Estimating Building Costs

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Preface

This book presents the state-of-the-art principles, practices, and techniques related to estimating building costs in metric. It is primarily designed as a textbook for graduate and upper-division undergraduate students in civil engineering, architectural engineering, construction engineering and management, and related programs. Instructors should find the book very useful and suitable for various teaching styles. Inasmuch as the book contains much more material than can be covered in one semester or quarter, selected chapters can be used to meet various academic objectives.

Practitioners or organizations involved in the building industry, such as owners, architects, project managers, general contractors, and subcontractors for building projects all over the world can use this book as a handy reference. Since this is possibly the first US textbook on building cost estimation in metric units, construction practitioners should find it invaluable when dealing with international and governmental projects. Although the text was not designed to provide answers to all estimating problems, it does provide a practical sequence and thorough knowledge of cost estimating.

Most financial costs in this book are representative of US national average costs in 1999. The costs are given for the purposes of problem solving and discussion in estimating procedures, and, of course, they will vary with time and the location of the building project. However, the principles, practices, and techniques described here for estimating building costs will continue to apply regardless of changes in the costs of materials, equipment, and labor.

The emphasis here is placed on several perspectives of building cost estimation, ranging from an overview of estimating building costs such as types of estimating and bidding procedures to a more detailed point of view such as quantity take-off and pricing for various Construction Specification Institute (CSI) divisions, and discussions on overhead costs, taxes, and insurance. To serve as a useful and effective reference, the contents of this book include 19 chapters as follows.

Chapter 1 discusses the US construction industry, and presents various cost indexes in use, one approach to preparing a detailed estimate, and an in-depth description of the organization and function of the estimating group. Chapter 2 describes various types of building estimates encountered during the lifecycle of a building project, along with the role and accuracy of each. Chapters 3 to 5 deal with the major components of the direct cost: estimating procedures and cost trends related to materials, construction equipment, and skilled and unskilled labor. The bidding process as recommended by AGC, which when properly implemented can enhance the success of the bidding effort, is described in Chapter 6. Chapters 7 to 16 are oriented to various categories of construction work organized in sequence and following the approach recommended by CSI. There are a few very specialized topics not covered in this book, not because they are unnecessary but for considerations of the book size and its intended use in an academic environment. Jobsite overhead costs, which are often estimated too generally, leading to significant loss for contractors, are covered in Chapter 17. Chapter 18 exposes the reader to additional contractor costs encountered during construction, especially bonds, taxes, and various types of insurance required by owners for protection. These costs represent a large sum of money and should not be neglected during bid preparation. The calculation of general overhead costs to be allocated to the project under consideration is discussed in Chapter 19.

Appendices are provided as useful tools, supplying a wealth of ready-to-use information for students and practitioners in daily practice. They include CSI Master Format and UniFormat codes, estimating forms, a list of available estimating software packages, a detailed construction site and investigation report, and a list of references related to cost estimating and pricing in a matrix format related to the book chapters.

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Nuntapong Ovararin
Kan Phaobunjong

Acknowledgments

This book is the result of a three-year effort in research and writing. It represents a compilation of many years of first-hand construction work experience, many years of teaching experience, and several field trips and interviews with a number of construction practitioners, academic personnel, and workshops. This is probably the first attempt in the US to present the state-of-the-art techniques and sciences of estimating building costs in true metric.

However, this successful accomplishment could not have been achieved without the continued support and encouragement of several groups of individuals and organizations. We would like to express our appreciation to the first supporting group, the faculty of the College of Engineering at the University of Texas at Austin. Our special thanks are extended to Professor and Dean of the College of Engineering, Dr. Ben G. Steetman, for building a creative and motivational environment for writing this book. We would also like to thank Professor and former chair of the Civil Engineering Department, Dr. James O. Jirsa, for teaching relief for the first author, financial support, and continuous encouragement. We are very grateful for their support and personal concern for this project.

We would also like to express our thanks to the second group, which includes several professionals from the construction industry, for providing guidance and many hours of their time during interviews with the authors in Austin, Texas. This group includes Dr. Doug Worrel, Vice President of Faulkner Construction Company; Mr. William Heine, President of American Contractors, Inc.; Mr. Marty Burger, Vice President of American Constructors, Inc.; Mr. Kenneth Painter, Former Executive Director of Associated General Contractors of America, Austin Chapter; and Mr. Gary Frazer, Chief Estimator of Encompass Electrical. Their willingness to share their time and profound insights regarding building cost estimation contributed to making this project a positive learning experience.

Additionally, we would like to acknowledge the third supporting group, which includes a number of graduate students enrolled in the Project Cost Management class at the University of Texas at Austin in the Spring of 2001, for their contribution regarding data collection and productivity loss surveys related to Finishing Operations. Our special thanks go to Mr. Unsuk Jung, a graduate student who voluntarily helped with the preparation of Appendix 2, Estimating Forms, and Appendix 5, Construction Site and Investigation Report.

Appreciation is also extended to the group of individuals from leading construction organizations in the field of cost estimating and implementation of metrication in the US, whose advice and information allowed us to incorporate their data in this text as guidance for estimators, construction practitioners, and students. These individuals include Mr. Gerald C. Ianelli, Director of Metric Programs at the National Institute of Standards; Mr. Gertraud Breitkopf, R.A., GSA Public Buildings Service of the National Institute of Building Sciences (NIBS); and Mr. William A. Brenner, AIA, Construction Metrication Council of NIBS.

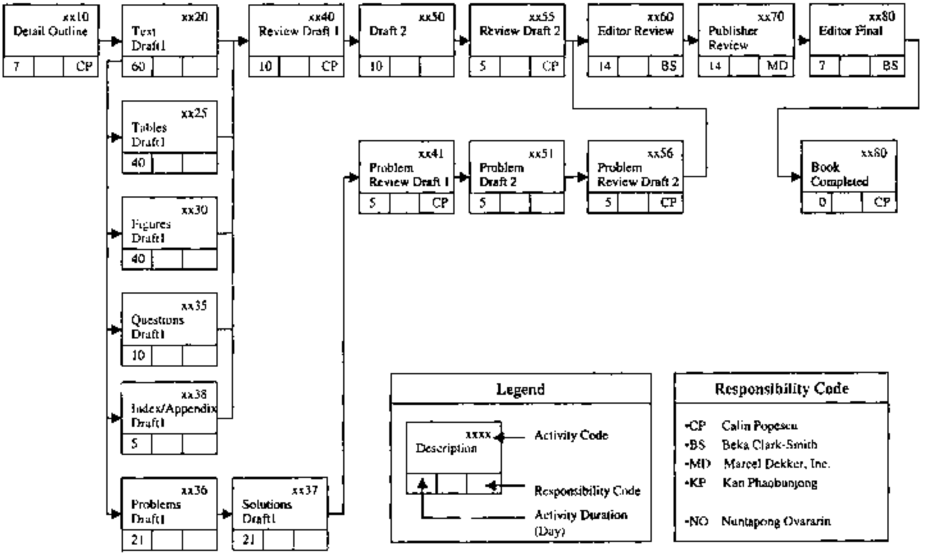
We owe our deepest gratitude to our families for their caring support and encouragement throughout our project. Their continued support and concern played an important role in the success of this work. Finally, we would also like to thank numerous individuals and organizations who are not mentioned here. Without their support and assistance in writing this book, this project could not have been successfully accomplished.

Contents

Introductory Remarks

As a young engineer, during the late 1950s, I was in charge of the construction of several-thousand-room hotels and restaurants at Mamaia, a Roumanian beach resort on the Black Sea. After forty years, I visited the same beach in the summer of 1999, and drafted on scratch paper the original outline of the present book. The outline initially motivated me to pursue the book project after my return to the University of Texas at Austin for my teaching duties. I assembled a project team composed of myself and two enthusiastic PhD candidates in Construction Engineering and Project Management. The team proceeded with the development of a standard network for the book chapters, including book-writing activities, duration of activities, relationship among activities, and responsible team members. The standard network is shown on the following page.

The team combined the standard network of all chapters, and developed a master schedule for the project with the use of the Primavera Project Planner. Consequently, the team coordinated and controlled the project by updating the project status monthly. Based on the critical path methods, the team paid special attention to critical and near-critical activities. Even though it was a somewhat challenging project, by use of such modern techniques in project management, the book was completed within three years. This represents approximately nine man-years of effort.



A successful builder is one who has the ability to obtain construction contracts that can be executed for a modest profit in an intensely competitive market. Moving toward this goal, general contractors and subcontractors of building construction projects require an efficient and practical cost estimating tool in developing contracts or controlling project costs. This book presents comprehensive knowledge in the area of building costs estimation, which can help contractors to better estimate and control construction costs. In addition, the metric measurement system is used throughout the world, and the US government and many agencies are making substantial advances toward the system in their construction projects. Many governmental construction projects in the US nowadays proceed with metric measurements. This book therefore can offer competitive advantages to building construction practitioners dealing with governmental and international projects. Also, I believe that the US construction industry will fully implement metric measurements in the near future. (See Tables A to E.) As a result, this book can provide substantial knowledge in estimating building costs to students and practitioners in the building construction industry.

Calin M. Popescu

Units Conversion

TABLE A S.I. Metric—English Systems

	Metric unit		English unit		
Length	1 mm		0.0394 in.	0.0033 ft	0.0011 yd
	1 cm	10 mm	0.3937 in.	0.0328 ft	0.0109 yd
	1 m	100 cm	39.3697 in.	3.2808 ft	1.0936 yd
	1 km	1000 m	3280.9920 ft	1093.6640 yd	0.6214 mi
Area	1 mm^2		0.0016 sq in.		
	1 cm^2	100 mm^2	0.1550 sq in.	0.0011 sq ft	
	1 m^2	10000 cm^2	1550.0160 sq in.	10.7640 sq ft	1.1960 sq yd
	1 ha	10000 m^2	11960.1240 sq yd	2.4711 A	
	1 km^2	100 ha	247.1100 A.	0.3861 sq mi	
Volume	1 cm^3		0.0610 cu in.		
	1 m^3	1000 L	35.3160 cu ft.	1.30764 cu yd	264.2 gal, U.S.
	1 mL	1 cm^3	1.308 cu yd.	0.0015 quarts	0.0003 gal
	1 L	1000 mL	61.022 cu in.	1.0567 quarts	0.2642 gal
Weight	1 g	1000 mg	0.0022 lb		
	1 kg	1000 g	2.2046 lb	0.0010 t	
	1 t, metric	1000 kg	2204.60 lb	0.98421 t, English	
Temperature	n °C		$(n \times 9)/5 + 32$ °F		

Table B English—S.I. Metric Systems

	English unit		Metric unit		
Length	1 in		25.4001 mm	2.5400 cm	0.0254 m
	1 ft	12 in.	304.8000 mm	30.4800 cm	0.3048 m
	1 yd	3 ft	91.4400 cm	0.9144 m	0.0009 km
	1 mi	1760 yd	1609.3000 m	1.6093 km	
Area	1 sq. in.		645.1630 mm^2	6.4516 cm^2	0.0006 m^2
	1 sq. ft	144 sq in.	92900 mm^2	929.0000 cm^2	0.0929 m^2
	1 sq. yd	9 sq ft	0.0001 cm^2	0.8361 m^2	8361.0000 ha
	1 A	4840 sq yd	4046.9000 m^2	0.4047 ha	0.0040 km^2
	1 sq. mi	640 A	258.9940 ha	2.5900 km^2	
Volume	1 cu. in.		16.3870 cm^3		
	1 cu. ft	1728 cu in.	28316.7360 cm^3	0.0283 m^3	28.3170 L
	1 cu. yd	27 cu ft	0.7646 m^3	763.3600 L	
	1 quart	0.2500 gal	0.9461 L		
	1 gal	4 quarts	0.003785 m^3	3.7843 L	
Weight	1 oz		28.3495 g	0.0283 kg	29.57 mL
	1 lb	16 oz	453.5924 g	0.4536 kg	
	1 t, English	2204 lb	1.0160 t, metric		
Temperature	n °F		$(n - 32) \times 5/9$ °C		

ABBREVIATIONS AND PREFIXES

Table C Abbreviations in SI Metric System

Length	Area	Volume	Weight	Temperature
millimeters (mm)	square millimeters (mm^2, sq m)	cubic centimeters (cm^3, cu, cm)	milligrams (mg)	degree Celsius (°C)
centimeters (cm)	square centimeters (cm^2, sq cm)	cubic meters (m^3, cu m)	grams (g)	
meters (m)	square meters (m^2, sq m)	milliliters (mL)	kilograms (kg)	
kilometers (km)	hectares (ha) square kilometers (km^2, sq km)	liters (L)	metric tons (t)	

Table D Abbreviations in English System

Length	Area	Volume	Weight	Temperature
inches (in.)	square inches (sq in.)	cubic inches (cu in.)	ounces (oz)	degree Fahrenheit (°F)
feet (ft.)	square feet (sq ft)	cubic feet (cu ft)	pounds (lb)	
yards (yd.)	square yards (sq yd)	cubic yards (cu yd)	English tons (t)	
miles (mi.)	square rods (sq rd)	quarts		
	acres (A)	gallons (gal)		
	square miles (sq mi)			

Table E Prefixes in SI Metric System

Prefix	Meaning
kilo (k)	1000
hecto (h)	100
centi (c)	1/100
milli (m)	1/1000

1

Introduction

1.1 THE CONSTRUCTION INDUSTRY

The *Standard Industrial Classification Manual* (1987) (SIC) divides construction into three broad types: building construction done by general contractors or operative builders, heavy construction done by general contractors and selected specialty trade contractors (highways, power plants, etc.), and construction done by specialty trade contractors such as electricians, plumbers, and painters. According to the 1992 census of the construction industry, there were nearly 2 million businesses in the United States operating in the construction industries. Although most of those construction establishments were small, they equaled $582 billion in total value; 1.3 million were nonemployers, and over half of the employer businesses had less than 5 employees. Yet those with 5 employees or more accounted for more than 80% of the total value of business done. They numbered 214,207 and represented 11% of all business. Those with paid employees accounted for $539 billion of business, of which $528 billion was for the value of construction work. Their payments for construction work subcontracted to other businesses amounted to $137 billion, leaving a net value of construction work of $391 billion and a value added of $235 billion.

1.1.1 General Contractors

Today, leading general contractors are US-based firms with operations in the domestic and international general building markets. These firms are included in the *Engineering News-Record* (*ENR*) annual listings of the 400 largest contractors, which ranks general contractors according to construction revenue (or contract value) from both domestic and international work. Revenue includes the value of prime construction contracts, shares of joint ventures, subcontracts, construction portion of design-construct contracts, construction management "at risk" contracts when the firm's risks are similar to those of a general contractor, and the value of installed equipment.

General contractors usually assume responsibility for an entire construction project, but may subcontract to others all of the actual construction work or those portions requiring special skills or equipment. The value of new contracts and revenue for the 20-year period from 1980 to 1999 for the *ENR* Top 400 general contractors are listed in Table 1.1. The total dollar value of total contracts from both domestic and international work for the top construction firms over this period ranged from a low of $98.4 billion in 1980 to a high of $230.4 billion in 1993. The total value of contracts for domestic and international work increased during 14 of these years. The largest percentage increase in total contract value occurred in 1982 (+44.1%), mainly as a result of a record increase in contracts in the domestic construction market (+64.75%). The value of contracts declined six times during those 20 years. The largest decline occurred

Table 1.1 New Contracts 1983–1999

Rank year	Domestic $Bil	Domestic %Chg	International $Bil	International %Chg	Total $Bil	Total %Chg
1999	144.3	16.9	27.9	−24.6	172.2	7.4
1998	123.4	0.1	37	11.2	160.3	2.5
1997	123.2	10	33.3	8.1	156.4	9.6
1996	112	−0.9	30.8	−8.7	142.8	−2.7
1995	113	−25	33.7	−49	146.6	−33
1994	152.4	−2	65.5	−12	217.8	−5
1993	155.6	−0.8	74.8	2.4	230.4	0.2
1992	156.8	−0.3	73.08	54.5	229.9	12.4
1991	157.2	6.4	47.3	20.4	204.5	9.3
1990	147.7	15.2	39.3	50.6	187.1	21.3
1989	128.2	17.1	26.1	42.6	154.3	20.7
1988	109.5	6.7	18.3	−19.7	127.8	1.9
1987	102.6	−4.2	22.8	−21.4	125.4	−7.9
1986	107.1	6.8	29	−7.0	136.1	3.7
1985	100.3	13.6	30.9	3.7	131.2	11.2
1984	88.3	6.1	29.8	−34.2	118	−8.2
1983	83.2	−36.0	45.3	38.5	128.5	−21.1

Source: *ENR* Top 400 Contractors.

in 1995 (−33%) following a 5-year period of general growth from 1989 to 1993.

The profitability of the *ENR* Top 400 general contractors from 1980 to 1999 based on revenue generated from domestic and international work is shown in Table 1.2. The average profit in 1999 was 4.42% in domestic markets and 5.94% in international ones. The highest percentage of profit for domestic work was reported in 1998 at 8.36%.

The top 30 general contractors in 1999, based on the *ENR*'s annual lists of the 400 leading contractors, are shown in Table 1.3. An analysis of the *ENR*'s top 400 firms from 1980 to 1999 identified 5 contractors that have topped the construction market for the last 20 years: Fluor Daniel, Inc. (10 times as number one), Bechtel Group, Inc. (5 times as number one), Kellogg, Brown & Root, Inc. (4 times as number one), and Parsons Corp. (once as number one).

1.1.2 Specialty Contractors

The next largest market sector is petroleum-related work, which accounted for approximately 14% of total revenues earned in the 1990s. The petroleum market includes the construction of refineries, petrochemical plants, offshore facilities,

TABLE 1.2 Profitability 1993–1999

Rank year	Domestic			International		
	No. firms reporting			No. firms reporting		
	Profit	Loss	Avg. % of Profit	Profit	Loss	Avg. % of Profit
1999	362	20	4.42	64	17	5.94
1998	214	16	8.36	61	13	4.01
1997	203	20	5.2	56	19	13.6
1996	192	32	6.24	59	21	5.36
1995	338	43	2.9	56	12	1.4
1994	326	48	6.8	54	10	3.7
1993	337	36	6.5	59	5	3.4

Source: *ENR* Top 400 Contractors.

pipelines, and so on. From 1990 to 1999 the value of petroleum construction as a percentage of total revenue ranged from a high of 30% in 1997 to a low of 4.1% in 1996. Other construction market sectors, listed in order of decreasing percentage of total annual revenue, include transportation, industrial process, manufacturing, power, hazardous waste, sewer and solid waste, and water supply.

The leading specialty contractors perform mainly in the domestic building markets. These firms are included in the *ENR*'s annual list of the 600 largest specialty contractors. The types of companies designated as specialty contractors include those involved in asbestos abatement, concrete, demolition/wrecking, electrical, glazing/curtain wall, mechanical, masonry, painting, roofing, sheet metal, steel erection, utilities, walls and ceilings, and excavation and foundation work. Specialty trade contractors may work for general contractors or other subcontractors, or may work directly for the owner of the property.

The values of contracts and revenues from 1993 to 1999 for the *ENR* Top 600 specialty contractors are listed in Table 1.4. The dollar value of new contracts from 1994 to 1999 ranged from a low of $18,057 million in 1994 to a high of $31,875 million in 1999. The total value of contracts for subcontracted work increased each year from 1995 to 1999, with the largest percentage increase (+14.7%) occurring in 1995.

An analysis of the dollar value and the percentage of the total revenue earned by the construction market from 1993 to 1999 is listed in Table 1.5. As in the general contractor market, the largest percentage of total revenue was earned from work in the general building sector. General building construction

TABLE 1.3 General Contractors 1999[a]

Rank	Firm	Revenue($)		New contracts	Markets (% revenue)								1998 rank
		Total	International		Gen. bldg.	Mfg.	Power	Wtr./ swr.	Indus./ petro.	Transp.	Haz. waste	CM at risk[b]	
1	Bechtel Group Inc., San Francisco, CA	9771.0	6022.0	12513.0	1	0	14	4	54	13	11	2	2
2	Fluor Daniel Inc., Irvine, CA	9640.0	5343.0	6388.0	3	8	7	0	53	2	6	11	1
3	Kellogg Brown & Root, Houston, TX	6835.0	4772.0	5983.0	8	1	0	1	82	4	2	46	3
4	CENTEX Construction Group, Dallas, TX	3748.1	0.0	4294.6	98	1	0	0	0	0	0	20	4
5	The Turner Corp., New York, NY	3699.0	54.3	4302.0	100	0	0	0	0	0	0	71	5
6	Foster Wheeler Corp., Clinton, NJ	3072.1	2204.8	52690.0	0	0	15	0	79	0	6	38	6
7	Skanska (USA) Inc., Greenwich CT	3028.0	0.0	4755.0	74	0	0	4	6	16	0	46	9
8	Peter Kiewit Sons Inc., Omaha, NB	2996.2	173.2	NA	15	1	8	16	2	54	0	0	7
9	Gilbane Building Co., Providence, RI	2248.6	0.0	2342.1	65	5	0	0	24	5	0	51	10
10	Bouls Construction Corp., New York, NY	2213.8	0.0	2865.0	89	1	0	0	8	1	0	87	15
11	McDermmott International Inc., New Orleans, LA	2067.8	1219.1	1681.5	0	0	9	0	91	0	0	0	11
12	Raytheon Engineers & Constructors, Cambridge, MA	1914.0	902.0	2275.0	0	0	41	7	37	10	6	0	8
13	J.A. Jones Inc., Charlotte, NC	1792.0	116.0	1654.0	68	0	6	4	9	11	3	9	16
14	Jacobs Sverdrup, Pasadena, CA	1661.0	525.0	4776.0	0	4	0	2	78	0	17	6	[c]
15	Morrison Knudsen Corp., Boise, ID	1631.0	249.0	4021.0	0	20	12	0	22	21	24	34	14
16	Black & Veatch, Kansas City, MO	1573.0	819.0	25080.0	2	1	54	12	22	0	0	7	21

Table 1.3 Continued

Rank	Firm	Revenue($) Total	International	New contracts	Markets (% revenue) Gen. bldg.	Mfg.	Power	Wrtr./swr.	Indus./petro.	Transp.	Haz. waste	CM at risk[b]	1998 rank
17	PCL Enterprises Inc., Denver, CO	1508.0	825.0	16330.0	81	3	0	2	9	5	0	3	19
18	Structure Tone Inc., New York, NY	1492.3	204.7	1638.3	100	0	0	0	0	0	0	100	20
19	The Clark Construction Group Inc., Bethesda, MD	1475.0	0.0	20890.0	86	1	3	1	0	8	0	58	17
20	The Whiting-Turner Contracting Co., Baltimore, MD	1350.0	0.0	1509.0	86	7	0	0	5	1	0	57	23
21	Granite Construction Inc., Watsonville, CA	1226.0	0.0	1076.0	0	0	0	5	0	57	0	0	24
22	Dillingham Construction Holdings Inc., Pleasanton, CA	1190.0	89.0	955.0	44	0	2	8	15	16	0	35	25
23	Parsons Corp., Pasadena, CA	1182.2	525.1	583.0	8	1	8	3	75	2	2	49	29
24	DPR Construction Inc., Redwood City, CA	1175.0	0.0	1012.0	55	35	0	0	10	0	0	99	32
25	ABB Lummus Global Inc., Bloomfield, NJ	1079.6	695.1	1971.1	0	0	3	0	97	0	0	0	12
26	Hensel Phelps Construction Co., Greeley, CO	1049.2	0.0	1407.0	84	0	0	0	0	16	0	33	30
27	Huber, Hunt and Nichols Inc., Indianapolis, IN	1039.0	0.0	1142.0	71	21	0	0	0	9	0	67	26
28	Perini Corp., Framingham, MA	10110.0	29.0	934.0	65	0	1	4	0	30	0	50	18
29	Morse Diesel International Inc., New York, NY	1006.0	0.0	1100.0	83	0	0	0	0	16	0	89	27
30	The IT Group, Monroeville, PA	932.0	15.0	900.0	9	0	1	7	2	0	81	11	97

[a] Companies ranked according to revenue obtained in 1998 in $millions. Some markets may not add up to 100% of Top 30 figure accounted for by construction management contracts.

[b] Percent of Top 30 figure accounted for by construction management contracts.

[c] Firms not ranked last year.

Source: The Top 400 Contractors, *ENR* 242:21, May 31, 1999.

TABLE 1.4 New Contracts and Revenue 1993–1999

Rank year	Revenue Total $Mil	Revenue Total %Chg	Contracts total $Mil	Contracts total %Chg
1999	37880.0	22.4	31875	12.8
1998	30958.5	13.7	28269	15.7
1997	27236.9	14.2	24443.5	11.8
1996	23859.3	9.2	21865.6	5.5
1995	21844.5	8.76	20719.5	14.74
1994	20084.3	−0.08	18057.2	2.6
1993	20100.0	−0.50	17590	2

Source: *ENR* Top 600 Specialty Contractors.

accounted for approximately 46% of the total revenue earned in 1999, and has remained above 42% since 1993.

Manufacturing construction is the next largest market for specialty contractors. In 1999, manufacturing construction (assembly facilities and plants) accounted for 13% of the total revenue. From 1993 to 1999, the value of manufacturing construction as a percentage of total revenue ranged from a low of 11.5% in 1990 to a high of 15.3% in 1998. Other construction market sectors, listed in order of decreasing percentage of total annual revenue in 1999, include industrial process, telecommunications, transportation, power, petroleum, sewer and solid waste, hazardous waste, and water supply.

The percentage of total revenue earned by construction specialties from 1990 to 1999 is listed in Table 1.6. The *ENR* annually ranks the largest specialty contractors based on total annual revenue from specialty, prime, or subcontracting work. The largest share of annual revenue earned each year is from electrical work. Electrical contractors in the *ENR*'s top 600 specialty contractors accounted for 31.3% of the total revenue ($411,842 million) in 1999. Specialty contractors performing mechanical work earn the second largest percentage of the annual revenue. In 1999, mechanical work accounted for 26.8% of the total revenue ($101,418 million), and has ranged from a low of 26% in 1990 and 1991 to a high of 29.1% in 1993. Other construction specialties each account for less than 10% of total annual revenue in any year.

An estimate of the profitability of specialty contracting firms from 1973 to 1999 can be seen in Table 1.7. Based on a survey of 580 specialty contract firms, the average percentage of profit and loss from specialty contracting in all markets in 1999 was 6.6 and 5.7%, respectively. The highest percentage of profit was reported in 1998 (7.7%). The top thirty 1999 specialty contractors from *ENR*'s

TABLE 1.5 Market Analysis 1993–1999[a]

Rank Year	Bldg.		Haz. waste		Indst.		Manu.		Other		Petrol.	
	Rev. $Mil	% of Total	Rev. $Mil	% of Total	Rev. $Mil	% of Total	Rev. $Mil	% of Total	Rev. $Mil	% of Total	Rev. $Mil	% of Total
1999	17503.6	46.2	399.4	1.1	3856.4	10.2	4981.5	13.2	1349	3.6	1411.3	3.7
1998	14423.4	46.6	332.7	1.1	3520.4	11.4	4727	15.3	1426.2	4.6	1409.3	4.6
1997	12774.2	46.9	307.8	1.1	3356.5	12.3	4127.2	15.2	827.5	3	1172.9	4.3
1996	11030.1	46.23	330.1	1.38	2776.2	11.64	3474	14.56	714.2	2.99	1027	4.3
1995	10039.3	45.96	408.8	1.87	2196.2	10.05	3110.9	14.24	737	3.37	1009.6	4.62
1994	8820	44.1	260	1.3	2640[b]	13.2	2460	12.3	1680	8.4	NA	NA
1993	8562.6	42.6	402	2	2452.2[b]	12.2[c]	2311.5	11.5	2472.3	12.3	NA	NA

Rank year	Power		Sewer/waste		Telecom		Trans.		Water	
	Rev. $Mil	% of Total	Rev. $Mil	% of Total	Rev. $Mil	% of Total	Rev. $Mil	% of Total	Rev. $Mil	% of Total
1999	1886.5	5	1481.2	3.9	2312.8	6.1	2269.1	6	428.9	1.1
1998	1495.9	4.8	1333	4.3	NA	NA	1954.2	6.3	336.2	1.1
1997	1349.1	5	1297.9	4.8	NA	NA	1703.9	6.3	320	1.2
1996	1296.6	5.43	1189.9	4.99	NA	NA	1623	6.8	398.5	1.67
1995	1407.1	6.44	1116	5.11	NA	NA	1493.9	6.84	325.7	1.49
1994	1480	7.4	1340[c]	6.7	NA	NA	1320	6.6	NA	NA
1993	1507.5	7.5	1447.2[c]	7.2	NA	NA	1145.74	5.7	NA	NA

[a] Na = Not available.
[b] = Includes petroleum market share.
[c] = Includes water market share.
Source: *ENR* Top 600 Specialty Contractors.

TABLE 1.6 Construction Specialties 1993–1999

Rank year	Asbestos Rev. $Mil	Asbestos % of Total	Concrete Rev. $Mil	Concrete % of Total	Demo/wreck Rev. $Mil	Demo/wreck % of Total	Electrical Rev. $Mil	Electrical % of Total	Excv. Fond. Rev. $Mil	Excv. Fond. % of Total	Glazing/CW Rev. $Mil	Glazing/CW % of Total	Haz. waste Rev. $Mil	Haz. waste % of Total	Masonry Rev. $Mil	Masonry % of Total
1999	447.2	1.2	2017.7	5.3	642.2	1.7	11842.1	31.3	1573.5	4.2	466.2	1.2	NA	NA	502.6	1.3
1998	385.8	1.3	1236.8	4	598.4	1.9	10089.3	32.6	1173.9	3.8	387.1	1.3	494.6	1.6	437.6	1.4
1997	414.6	1.5	1121.8	4.1	575.6	2.1	8177.7	30	998.3	3.7	614.1	2.3	665.3	2.4	388.2	1.4
1996	467	2	991.5	4.2	564.1	2.4	7335.5	30.7	975.4	4.1	585.4	2.4	137.1	0.6	404.8	1.7
1995	465.9	2.1	871.5	4	450.1	2.1	6682.5	30.6	885.6	4.1	519.8	2.4	188.7	0.9	332.8	1.5
1994	360	1.8	760	3.8	440	2.2	6320	31.6	900	4.5	520	2.6	140	0.7	360	1.8
1993	310.5	1.5	723.6	3.6	402	2	6231	31	844.2	4.2	542.7	2.7	140.7	0.7	321.6	1.6

Rank year	Mech. Rev. $Mil	Mech. % of Total	Other Rev. $Mil	Other % of Total	Painting Rev. $Mil	Painting % of Total	Roofing Rev. $Mil	Roofing % of Total	Sheet metal Rev. $Mil	Sheet metal % of Total	Steel erect Rev. $Mil	Steel erect % of Total	Utility Rev. $Mil	Utility % of Total	Wall Rev. $Mil	Wall % of Total
1999	10148	26.8	2536.7	6.7	510.6	1.3	992.2	2.6	852.2	2.2	1052.2	2.8	2808	7.4	1494.8	3.9
1998	8215	26.5	2239.9	7.2	474.9	1.5	739.4	2.4	864.4	2.8	989.4	3.2	1326.3	4.3	1305.1	4.2
1997	7542.9	27.7	2117.4	7.8	305.9	1.1	779.5	2.9	781.5	2.9	829.8	3	680.6	2.5	1243.8	4.6
1996	6850.1	28.7	1576	6.6	319.6	1.3	678.1	2.8	731.1	3.1	642.1	2.7	567	2.4	1034.9	4.3
1995	6325.3	29	1467.4	6.7	250.6	1.1	729.5	3.3	769.5	3.5	545.4	2.5	522.9	2.4	837.2	3.8
1994	5800	29	1160	5.8	220	1.1	640	3.2	660	3.3	540	2.7	480	2.4	680	3.4
1993	5849.1	29.1	1507.5	7.5	221.1	1.1	663.5	3.3	582.9	2.9	562.8	2.8	502.5	2.5	703.5	3.5

Source: *ENR* Top 600 Specialty Contractors.

TABLE 1.7 Profitability 1993–1999[a]

Rank year	Number of firms reporting		Average % of	
	Profit	Loss	Profit	Loss
1999	566	14	6.6	5.7
1998	572	15	7.7	1.8
1997	569	15	6	5.6
1996	557	20	5.86	4.41
1995	545	42	5.25	5.67
1994	NA	NA	NA	NA
1993	NA	NA	NA	NA

[a] NA = Not available.
Source: *ENR* Top 600 Specialty Contractors.

1999 annual list of the 600 leading specialty contractors are included in Table 1.8.

1.2 CONSTRUCTION COST INDEXES

1.2.1 Introduction to Construction Cost Indexes

In the construction industry, a company's success can be directly related to its ability to estimate a project accurately and to control costs and complete the project within budget. For both of these functions, the use of construction cost indexes can provide valuable information. However, to effectively use the various indexes that are available, the contractor must understand what the index provides and how to apply it correctly to a particular situation.

This first section describes the sources and structure of several prominent construction indexes. Each description includes the historical data from 1980 to the present. The indexes used are:

1. The *Engineering News-Record*'s (*ENR*) Construction Cost Index and Building Cost Index,
2. The E. H. Boeckh Company's Building Cost Index,
3. The Lee Saylor Inc. Labor/Material Cost Index,
4. The Turner Building Cost Index, and
5. The Means' Historical Cost Index.

Each of the indexes used is available to the public through *ENR*'s quarterly cost reports. Additional cost indexes are also briefly described without their historical

TABLE 1.8 Specialty Contractors 1999[a]

					Markets (% revenue)								
Rank	Firm	Firm type[b]	Total revenue	New contracts[d]	Gen. bldg	Mfg.	Power	Wtr./swr.	Indus./petro.	Transp.	Haz. waste	Other	1998 rank
1	EMCOR Group Inc., Norwalk, CT	E/M	2,210.4	2,541.7	66	8	1	6	7	11	0	1	1
2	Building One Services Corp., Minnetonka, MN	E	1,117.2	1,257.4	33	17	4	9	26	0	0	11	3
3	Integrated Electrical Services Inc., Houston, TX	E	1,100.0	439.0	61	0	0	0	28	0	0	0	4
4	MasTec Inc., Miami, FL	U	1,048.9	NA	0	0	12	0	0	2	0	86	[c]
5	Philip Services Corp., Hamilton, Ontario	M/O	988.0	NA	0	17	15	3	48	3	5	0	2
6	Comfort Systems USA Inc., Houston, TX	M	854.0	650.0	75	25	0	0	0	0	0	0	12
7	Group Maintenance America Corp., Houston, TX	M	761.5	NA	40	8	0	0	9	0	0	5	[c]
8	Quanta Services Inc., Houston, TX	E	714.1	650.0	0	0	49	0	5	9	0	37	14
9	Henkels & McCoy Inc., Blue Bell, PA	U	510.0	NA	0	0	0	0	5	0	0	75	7
10	The Kinetics Group, Santa Clara, CA	M	465.0	545.0	0	0	0	0	100	0	0	0	6
11	MYR Group, Henderson, CO	E	459.3	463.0	30	5	49	0	5	4	0	7	5
12	SASCO Group, Cerritos, CA	E	401.0	200.0	38	25	0	0	10	15	0	12	8
13	Performance Contracting Group Inc., Lenexa, KS	W/O	389.2	384.2	48	23	10	0	6	8	0	0	10
14	The Poole and Kent Co., Baltimore, MD	M	376.0	325.0	56	0	0	35	7	2	0	0	9
15	Mass. Electric Construction Co., Boston, MA	E	375.9	241.6	16	17	5	0	0	59	0	3	13

TABLE 1.8 Continued

Rank	Firm	Firm type[b]	Total revenue	New contracts[d]	Markets (% revenue) Gen. bldg	Mfg.	Power	Wtr./swr.	Indus./petro.	Transp.	Haz. waste	Other	1998 rank
16	MMC Corp., Leawood, KS	M	347.6	370.0	30	20	0	10	30	10	0	0	15
17	Limbach Facility Services, Houston, TX	M	332.0	372.0	65	35	0	0	0	0	0	0	16
18	Insituform Technologies Inc., Chesterfield, MO	U	301.0	316.8	0	0	0	81	19	0	0	0	11
19	Cupertino Electric Inc., Sunnyvale, CA	E	249.6	301.0	60	40	0	0	0	0	0	0	25
20	Baker Concrete Construction Inc., Monroe, OH	C	247.0	270.0	50	30	0	0	10	10	0	0	19
21	Centimark Corp., Canonsburg, PA	R	227.2	232.7	40	60	0	0	0	0	0	0	18
22	Air Conditioning Co., Inc., Glendale, CA	M	210.0	218.0	58	22	0	0	0	0	0	0	22
23	Rosendin Electric Inc., San Jose, CA	E	208.0	100.0	45	20	5	10	10	8	0	2	23
24	Scott Co. of California, San Leandro, CA	M	196.0	110.0	30	20	15	10	15	10	0	0	17
25	Fisk Electric Co., Houston, TX	E	190.8	203.5	73	5	0	0	5	0	0	17	34
26	General Roofing Services, Ft. Lauderdale, FL	R	190.0	NA	79	0	0	0	20	0	0	0	301
27	Schuff Steel Inc., Phoenix, AZ	ST	189.9	202.0	85	0	0	2	13	0	0	0	31
28	Shambaugh & Son Lp, Fort Wayne, IN	M	187.5	184.4	33	49	0	1	9	0	0	2	24
29	Motor City Electric Co., Detroit, MI	E	187.2	107.6	20	50	0	17	0	2	1	10	21
30	Southland Industries, Long Beach, CA	M	179.0	210.0	55	45	0	0	0	0	0	0	26

[a] Companies ranked according to revenue obtained in 1998 in $ millions from specialty, prime, or subcontracting work.
[b] Company type: A = asbestos abatement; C = concrete; D = demolition/wrecking; E = electrical; G = glazing and curtain wall; H = hazardous waste; M = mechanical; MA = masonry; O = other; P = painting; R = roofing; SH = sheetmetal; ST = steel erection; U = utility; W = wall/ceiling; X = excavation/foundation.
[c] Firms not ranked last year.
[d] NA = Not available.
Source: The Top 600 Specialty Contractors, *ENR* 243:15, October 11, 1999.

data, and finally, the Consumer Price Index (CPI) is described for comparison purposes.

In addition to comparing the construction indexes with each other, the next section examines the CPI compared with construction indexes and any noted correlations are discussed.

Finally, in the third section, some application issues are covered. First, the application of various cost indexes to particular classes of construction is explored. Then several of the indexes explained in detail in the first section are further broken down into applications for specific locations versus using a national average. These two issues provide a foundation for construction contractors to utilize the cost indexes in their estimating and cost control systems, bettering their chances for success in the marketplace.

1.2.2 Index Sources and Structures

1.2.2.1 *Engineering News-Record* (*ENR*) Construction Cost Index

The CCI is one of several indexes published monthly by the *ENR*. It can be found in the second weekly issue each month along with the *ENR*'s Building Cost Index (BCI) and materials index, skilled labor index, and common labor index. The indexes are listed for each of 20 major US cities and 2 Canadian cities, as well as a national average for the US. The 20 US cities used for the national average are Atlanta, Baltimore, Birmingham, Boston, Chicago, Cincinnati, Cleveland, Dallas, Denver, Detroit, Kansas City, Los Angeles, Minneapolis, New Orleans, New York, Philadelphia, Pittsburgh, St. Louis, San Francisco, and Seattle.

The CCI is composed of common labor and material portions. An average common labor rate (wage and fringes) is calculated for the 20 US cities and applied to 200 man-hours common labor to arrive at the labor portion. For materials, the *ENR* adds the average costs for 1.128 tons of Portland cement, 1088 board-feet of 2×4 lumber, and 25 cwt of standard structural steel shapes. Prior to 1996 the mill price was used, but due to the *ENR*'s pricing source leaving the market, the index was adjusted to reflect the 20-city average price for fabricated structural steel. The base year against which these costs are compared is 1913 ($1913 = 100$). Table 1.9 shows the historical performance of the CCI from 1980 to 1999.

1.2.2.2 *Engineering News-Record* (*ENR*) Building Cost Index

The *ENR*'s Building Cost Index (BCI) differs from the CCI only in the labor component which uses skilled labor instead of common. For the skilled labor component, the *ENR* computes the 20-city average of wages plus fringe benefits for three trades (bricklayers, carpenters, and structural ironworkers) and applies

Table 1.9 *ENR* Construction Cost Index (CCI)[a]

Year	ENR CCI	Increase from previous year (%)
1980	3,237	0.0
1981	3,535	9.2
1982	3,825	8.2
1983	4,066	6.3
1984	4,146	2.0
1985	4,195	1.2
1986	4,295	2.4
1987	4,406	2.6
1988	4,519	2.6
1989	4,615	2.1
1990	4,732	2.5
1991	4,835	2.2
1992	4,985	3.1
1993	5,210	4.5
1994	5,408	3.8
1995	5,471	1.2
1996	5,620	2.7
1997	5,826	3.6
1998	5,920	1.6
1999	6,059	2.3

[a] 1913 = 100.
Source: *ENR*.

this average to 66.38 hours of skilled labor. The material portion of the BCI is the same as the CCI as are the 20 cities used as well as the base period of 1913. Historical information on the BCI can be seen in Table 1.10.

1.2.2.3 Boeckh Building Cost Index

Boeckh's Commercial and Industrial Building Cost Index is one of several different construction cost indexes the company produces. To compute their indexes, Boeckh collects cost data from 205 cities in the United States. There are three general categories the data fall under: material, labor, and tax and insurance. The material portion consists of 89 separate elements divided into local, regional, and national levels. There are three local elements (face brick, concrete block, and ready-mix concrete) and 13 regional elements (lumber, sheet metal, reinforcing steel, and structural steel). The remaining 73 material components are divided at the national level between commercial construction items (46 material components) and residential materials (27 material components). For labor costs,

Table 1.10 *ENR* Building Cost Index (BCI)[a]

Year	ENR BCI	Increase from previous year (%)
1980	1,941	0.0
1981	2,097	8.0
1982	2,234	6.5
1983	2,384	6.7
1984	2,417	1.4
1985	2,428	0.5
1986	2,483	2.3
1987	2,541	2.3
1988	2,598	2.2
1989	2,634	1.4
1990	2,702	2.6
1991	2,751	1.8
1992	2,834	3.0
1993	2,996	5.7
1994	3,111	3.8
1995	3,111	0.0
1996	3,203	3.0
1997	3,364	5.0
1998	3,391	0.8
1999	3,456	1.8

[a] 1913 = 100.
Source: *ENR*.

Boeckh researches both union wages and open shop (merit shop) wages and uses the prevailing wage rates for each locality. Often the wages are union in the larger cities, but in some rural areas the merit shop wages prevail. Finally, Boeckh includes seven other elements under tax and insurance costs. They are: sales tax, workmen's compensation, bodily injury insurance, personal property insurance, local taxes, social security, and unemployment compensation. Table 1.11 shows the performance of the index since 1980. These data were collected through the *ENR* using a 20-city average for a composite index of several types of commercial and light industrial buildings.

1.2.2.4 Lee Saylor Material and Labor Index

Lee Saylor produces two construction cost indexes: the Material/Labor Index discussed here, and a subcontract index. The two portions of the Material/Labor Index are weighted 54% for labor and 46% for materials. In addition, this construction index provides subcategories for concrete, steel, or wood frame struc-

TABLE 1.11 Boeckh Building Cost Index[a]

Year	Boeckh	Increase from previous year (%)
1980	283	0.0
1981	311	9.9
1982	337	8.4
1983	354	5.0
1984	368	4.0
1985	374	1.6
1986	380	1.6
1987	388	2.1
1988	402	3.7
1989	420	4.4
1990	431	2.5
1991	444	3.2
1992	456	2.6
1993	470	3.0
1994	483	2.9
1995	494	2.1
1996	507	2.7
1997	523	3.2
1998	531	1.4
1999	534	0.6

[a] 1913 = 100.
Source: Boeckh.

tures. Numbers shown in Table 1.12 are for all construction types. The materials component consists of 23 different materials averaged from 20 US cities. The English unit of measure is maintained because the index is used only in the US. For the labor component, Saylor researches the wages and fringe benefits for nine selected trades in 16 US cities. The trades used are: carpenters, bricklayers, iron workers, laborers, operating engineers (average), plasterers, plumbers, electricians, and teamsters. The prevailing wages for these trades are then factored in with the materials component to provide the Material/Labor Index. The base period for this index is 1967. Historical data are shown in Table 1.12.

1.2.2.5 Turner Building Cost Index

The Turner Construction Company develops its cost index using several factors including labor rates and productivity, material prices, management and plant efficiency, and the competitive condition of the marketplace. 1967 is used as a base period for this index. Historical data are shown from 1980 in Table 1.13.

TABLE 1.12 Lee Saylor Cost Index[a]

Year	Lee Saylor	Increase from previous year (%)
1980	310	0.0
1981	335	8.1
1982	339	1.2
1983	371	9.4
1984	381	2.7
1985	391	2.6
1986	398	1.8
1987	406	2.0
1988	419	3.2
1989	430	2.6
1990	436	1.5
1991	441	1.2
1992	448	1.5
1993	462	3.1
1994	482	4.3
1995	498	3.3
1996	509	2.2
1997	520	2.3
1998	530	1.9
1999	533	0.6

[a] 1967 = 100.
Source: Lee Saylor.

1.2.2.6 Means Historical Cost Index

The R. S. Means Company develops a cost index based on a hypothetical composite building. Nine different types of structures are considered in developing this model. The composite building includes 66 material elements, 21 trades, and 6 different construction equipment rentals. Each of the elements is weighted based on the quantity needed to construct the hypothetical building. Means uses an extensive research network that includes contractors, manufacturers, wholesalers, distributors, labor experts, and individual estimators throughout 305 cities in the US and Canada. Means provides individual indexes for each of the cities whereas the *ENR* publishes an average of the 30 largest US cities. Data included here are the national average for the US as published in Means' estimating manuals. January 1, 1993 is used as the base period by this index, but Means includes instructions for converting costs from any given year to another year. The formula uses a ratio of the two-year indexes multiplied by the cost in one of the years as follows.

Table 1.13 Turner Building Cost Index[a]

Year	Turner	Increase from previous year (%)
1980	273	0.0
1981	301	10.3
1982	325	8.0
1983	342	5.2
1984	360	5.3
1985	374	3.9
1986	384	2.7
1987	397	3.4
1988	412	3.8
1989	426	3.4
1990	441	3.5
1991	448	1.6
1992	450	0.4
1993	460	2.2
1994	467	1.5
1995	474	1.5
1996	505	6.5
1997	525	4.0
1998	549	4.6
1999	567	3.3
2000	592	4.4

[a] 1967 = 100.
Source: Turner.

$$\frac{\text{Index for Year A (Future)}}{\text{Index for Year B (Past)}} X \text{ Cost in Year B} \\ = \text{Cost in Year A (Future Cost).} \tag{1.1}$$

For example, a building that costs $50 million to build in 1990 could be estimated in today's market with Index 1998 at 115.1 divided by Index 1990 at 94.3 multiplied by the Cost in 1999 at $50 million (115.1/94.3) to equal $61.02 million. Historical data for the Means' Historical Cost Index is shown in Table 1.14.

1.2.2.7 Other Construction Cost Indexes

There are numerous cost indexes used in the construction industry beyond the six discussed above. They range in diversity in both the type of construction they measure and in the region of application. Sources include construction and consulting companies, insurance firms, government agencies, and more. The *ENR*

TABLE 1.14 R.S. Means' Building Cost Index[a]

Year	R.S. Means	Increase from previous year (%)
1980	62.9	0.0
1981	70.0	11.3
1982	76.1	8.7
1983	80.2	5.4
1984	82.0	2.2
1985	82.6	0.7
1986	84.2	1.9
1987	87.7	4.2
1988	89.9	2.5
1989	92.1	2.4
1990	94.3	2.4
1991	96.8	2.7
1992	99.4	2.7
1993	101.7	2.3
1994	104.4	2.7
1995	107.6	3.1
1996	110.2	2.4
1997	112.8	2.4
1998	115.1	2.0
1999	118.1	2.6

[a] Base = 01 Jan., 1993.
Source: Means.

lists 14 indexes as "Construction's Most Important Cost Indexes" including the Boeckh, Saylor, Turner, and Means indexes discussed in detail above. The other 10 are listed below and are included later in this chapter when applicability issues are explored.

1. The Austin Company. This index includes cost data from major industrial areas for the construction of a 10,847 M^2 steel-framed industrial structure and a 774 M^2 office building. Labor and material portions include site work, electrical, mechanical, HVAC, and process services.

2. Bureau of Reclamation. BuRec's indexes cover 34 different types of dam and water projects that fall under its jurisdiction. They also provide a general property index that measures costs for office and maintenance buildings associated with the water projects.

3. *Chemical Engineering*. McGraw-Hill provides this index that is published each month in *Chemical Engineering* magazine. It applies specifically to chemical process plants and includes weightings of 61% for equipment and ma-

chinery; 7% for buildings, materials, and labor; and 10% for engineering and supervision.

4. Factory Mutual Engineering. This index considers costs of five typical industrial buildings ranging from a single-story, steel-framed warehouse to a multistoried building constructed of reinforced concrete. The differing construction types provide a weighting system that is applied to eight separate trades and seven different materials.

5. Fru-Con Corporation. This is a local index for the St. Louis area developed using the Fru-Con's current material and labor costs. The index is weighted using different percentages of labor, concrete, mortar, clay products, lumber, plastics, metals, paint, and glass.

6. Handy Whitman. Whitman, Requardt and Associates publishes this index based on an average of six different regions for a reinforced concrete building. Materials included are ready-mix concrete, lumber, steel bars, brick, and concrete block. Wages include six trades plus common labor. Indexes are provided for electric, gas, and water utilities.

7. Marshall and Swift. In this system of indexes, selected materials, labor rates, taxes, business factors, and the cost of financing are weighted together. Marshall and Swift then provides indexes for the nation as well as regions and districts. In addition to the general cost index, each level can be broken down into five different building types.

8. Nelson-Farrar Refinery Cost Index. As the name implies, this index pertains to the construction of refineries. A 1946 refinery is used as the estimated structure including 20% iron and steel, 8% nonmetallic building materials, 12% equipment, 39% skilled labor, and 21% unskilled labor. Changes in methods of design and construction are not considered.

9. Smith, Hinchman & Grylls, Inc. This index uses building material costs, freight rates, and labor (both skilled and unskilled) rates to measure in-place project costs, with 60% weighted to labor and 40% to materials.

10. US Department of Commerce. Two indexes are published by the Commerce Department: a Composite Fixed-Weight Index and an Implicit Price Deflator. The first is a ratio of annual new construction in current dollars to comparable values in 1992. The second is similar but also considers differences in market conditions.

1.2.2.8 USA Consumer Price Index

In general, consumer price indexes measure the cost of a specific basket of goods and services over time. For this chapter, data presented are for the United States Bureau of Labor Statistics "Consumer Price Index for All Urban Consumers," or the US CPI. According to the Bureau, the items included in the pricing survey are: food, clothing, shelter, transportation costs, medical and dental care charges, and other goods that people buy for day-to-day living. All of the taxes directly

Table 1.15 USA Consumer Price Index[a]

Year	CPI
1980	82
1981	91
1982	97
1983	100
1984	104
1985	108
1986	110
1987	114
1988	118
1989	124
1990	131
1991	136
1992	140
1993	145
1994	148
1995	152
1996	157
1997	161
1998	163
1999	—

[a] 1983 = 100.

associated with the purchase and use of items are included in the index. Items in this market basket are weighted for importance in the base year, as determined by a survey of consumer expenditures; relative weights change over time as the price of items rises more or less rapidly than the overall index. Prices are collected in 85 geographic areas around the country, utilizing more than 57,000 housing units and 19,000 retail businesses. The US CPI is based on monthly pricing of the market basket and this pricing occurs throughout the entire month. Table 1.15 contains the historical performance of the CPI since 1980. 1983 is the base period for the US CPI.

1.2.3 Industry Cost Trends (1980 to Present)

1.2.3.1 Index Growth in the Construction Industry

Table 1.16 charts the trends of the six construction cost indexes discussed earlier. The cumulative percentage of growth is calculated using 1980 as the base. Each year's cumulative growth is determined by dividing the annual average for a

TABLE 1.16 Construction Indexes Trend Cumulative Growth[a]

Year	ENR CCI (%)	ENR BCI (%)	Boeckh (%)	Lee Saylor (%)	Turner (%)	R.S. Means (%)
1980	0.0	0.0	0.0	0.0	0.0	0.0
1981	9.2	8.0	9.9	8.1	10.3	11.3
1982	18.2	15.1	19.1	9.4	19.0	21.0
1983	25.6	22.8	25.1	19.7	25.3	27.5
1984	28.1	24.5	30.0	22.9	31.9	30.4
1985	29.6	25.1	32.2	26.1	37.0	31.3
1986	32.7	27.9	34.3	28.4	40.7	33.9
1987	36.1	30.9	37.1	31.0	45.4	39.4
1988	39.6	33.8	42.1	35.2	50.9	42.9
1989	42.6	35.7	48.4	38.6	56.0	46.4
1990	46.2	39.2	52.1	40.7	61.5	49.9
1991	49.4	41.7	57.0	42.3	64.1	53.9
1992	54.0	46.0	61.1	44.5	64.8	58.0
1993	61.0	54.4	66.0	49.0	68.5	61.7
1994	67.1	60.3	70.8	55.4	71.1	66.0
1995	69.0	60.3	74.4	60.5	73.6	71.1
1996	73.6	65.0	79.1	64.1	85.0	75.2
1997	80.0	73.3	84.8	67.8	92.3	79.3
1998	82.9	74.7	87.5	71.0	101.1	83.0
1999	87.0	77.8	88.7	71.9	107.7	—

[a] 1980 = 100.

particular index by the 1980 value of the same index. In general, all of the indexes follow a similar pattern with the steepest growth in the early 1980s followed by a decade of slower inflation. In the mid 1990s, some indexes show another increasing trend. However, most indexes have already returned to the same general rate as was experienced from 1984 to 1993.

In addition to the cumulative growth, each year's annual increase over the previous year's indexes is shown in Table 1.17. The same trends discussed above can be seen more clearly. Sharp variations can also be seen from year to year with three of the indexes appearing more volatile than the others: the *ENR*'s BCI, the Saylor Material/Labor Index, and Turner's Building Cost Index. Turner's formula is protected property, which limits the ability to analyze trends in its performance. However, the BCI's greater volatility (when compared to the similar CCI) is a direct result of using skilled labor rates versus the common labor rates used in the CCI. Similarly, the Saylor Index weights common laborers with eight different skilled trades making 87% of its labor component, or 47% of the

Table 1.17 Construction Indexes Annual Growth[a]

Year	ENR CCI (%)	ENR BCI (%)	Boeckh (%)	Lee Saylor (%)	Turner (%)	R.S. Means (%)
1981	9.2	8.0	9.9	8.1	10.3	11.3
1982	8.2	6.5	8.4	1.2	8.0	8.7
1983	6.3	6.7	5.0	9.4	5.2	5.4
1984	2.0	1.4	4.0	2.7	5.3	2.2
1985	1.2	0.5	1.6	2.6	3.9	0.7
1986	2.4	2.3	1.6	1.8	2.7	1.9
1987	2.6	2.3	2.1	2.0	3.4	4.2
1988	2.6	2.2	3.7	3.2	3.8	2.5
1989	2.1	1.4	4.4	2.6	3.4	2.4
1990	2.5	2.6	2.5	1.5	3.5	2.4
1991	2.2	1.8	3.2	1.2	1.6	2.7
1992	3.1	3.0	2.6	1.5	0.4	2.7
1993	4.5	5.7	3.0	3.1	2.2	2.3
1994	3.8	3.8	2.9	4.3	1.5	2.7
1995	1.2	0.0	2.1	3.3	1.5	3.1
1996	2.7	3.0	2.7	2.2	6.5	2.4
1997	3.6	5.0	3.2	2.3	4.0	2.4
1998	1.6	0.8	1.4	1.9	4.6	2.0
1999	2.3	1.8	0.6	0.6	3.3	—

[a] 1980 = 100.

total index, dependent on the skilled rates, whereas laborers determine only 7% of the total index.

Another factor to consider when analyzing the differences in the indexes is the number of datapoints used in collecting cost information. The two most stable indexes, Boeckh and Means, use 205 and 305 cities, respectively. This helps balance regional trends and prevent domination of the indexes by sharp increases in cost within a particular region.

1.2.3.2 Forecasting of Future Costs

Many companies use the published databases to predict future cost increases in addition to reporting past performance. When using the indexes in this manner, it is recommended that contractors consult with the individual index source. However, there are several items to consider when predicting future inflation based on cost indexes.

Primarily, most of the indexes discussed devote a high proportion of their index to labor elements. Therefore, factors that influence the stability of wage rates should be considered when attempting to forecast. Collective bargaining agreements that are in place with various trade unions should be used. Specifically, any upcoming changes or stalled negotiations that may cause earlier agreements to remain in force longer should be reviewed. In addition, for federal government projects differences between the prevailing union rates and the required Davis–Bacon wage rates should be factored into the estimating process. Trends in the marketplace outside the construction industry should also be studied as indicators of overall economic growth or recession.

1.2.4 Utilization of Cost Indexes in Construction

Whether an index is used in estimating or in a contract's scope to allow economic price adjustments (such as allowed in the Federal Acquisition Guidelines), two important factors must be considered in selecting a particular index: type of construction and locality.

1.2.4.1 Applicability to Construction Types

Construction projects vary widely in materials, skills, and methods used depending on the desired end product. As such, the estimator must become familiar with the formulas used in the varying indexes to determine which index is most suited to the particulars of a chosen project. Table 1.18 provides a chart that can be used to separate the top 16 construction cost indexes into general project types as the first step in selecting an appropriate index. For this chart, nine different construction classes are used. Each of these is considered a separate type by the *ENR* when ranking construction companies annually. The classes used are described by the *ENR* as follows.

1. General Building: commercial buildings, offices, stores, educational facilities, government buildings, hospitals, medical facilities, hotels, apartments, housing, etc.
2. Manufacturing: auto assembly, electronic assembly, textile plants, etc.
3. Power: thermal and hydroelectric power plants, waste-to-energy plants, transmission lines, substations, cogeneration plants, etc.
4. Water Supply: dams, reservoirs, transmission pipelines, distribution mains, irrigation canals, desalination and portability treatment plants, pumping stations, etc.
5. Sewerage/Solid Waste: sanitary and storm sewers, treatment plants, pumping plants, incinerators, industrial waste facilities, etc.
6. Industrial Process: pulp and paper mills, steel mills, nonferrous metal refineries, pharmaceutical plants, chemical plants, food and other processing plants, etc.
7. Petroleum: refineries, petrochemical plants, offshore facilities, pipelines, etc.

TABLE 1.18 Construction Cost Indexes Utilization versus Construction Type

Cost index	Construction types								
	General building	Manufacturing	Power	Water supply	Sewerage/ solid waste	Industrial process	Petroleum	Transportation	Hazardous waste
ENR Construction Cost Index	X	X							
ENR Building Cost Index	X	X							
Boeckh Building Cost Index	X								
Saylor Material/Labor Index	X	X							
Turner Building Cost Index	X								
Means Historical Cost Index	X								
Austin Company Index	X								
BuRec Cost Index			X	X				X	
Chemical Engineering Index	X	X				X	X		
Factory Mutual Index	X	X				X			
Fru-Con Corp Index	X	X				X			
Handy Whitman Index	X	X	X						
Marshall and Swift Index	X	X							
Nelson Farrar Refinery Cost Index						X	X		
Smith, Hinchman, & Grylls Index	X	X							
Federal Highway Admin. Bid Price Index								X	

8. Transportation: airports, bridges, roads, canals, locks, dredging, marine facilities, piers, railroads, tunnels, etc.
9. Hazardous Waste: chemical and nuclear waste treatment, asbestos and lead abatement, etc.

Once a class is chosen, each of the applicable indexes must be studied to find which one best suits the particular project. Certain indexes such as the Saylor Material/Labor Index also provide breakdowns based on the type of structure (steel, reinforced concrete, or wood-frame).

1.2.4.2 Applicability to Local Use

A perfect match for the project's scope and type of construction still may not be a useful tool if its data do not reflect the market where the project is to be built. Therefore, once an index appropriate for a particular project is selected, consideration must be given to differences between the local market and national or regional averages. The first step in applying an index to a locality is to determine what is available from the source of the index. For most large cities, many of the indexes provide cost data for particular locations in addition to regional or national averages. Examples of such indexes are the *ENR* CCI and BCI (20 major US cities), Boeckh (205 US cities), Saylor (16 to 20 cities), and Means (305 US and Canadian cities). In addition, Turner can provide local historical data and interpretation from each of its 40 offices throughout the country.

If such a breakdown is unavailable for the index chosen for a particular project, another more involved process may be used by employing a reference such as the Means City Cost Indexes. These indexes provide a percentage ratio for 689 US and Canadian cities covering 930 three-digit zipcodes compared to a 30-city national average. As such, these city indexes can be used to convert any given cost index to local conditions. Most common applications would use the ratio to convert a national index to a locality, but an index such as Fru-Con's St. Louis Index can also be converted using the chosen locality's index along with the Means City Index for St. Louis.

Each city index is structured over the 16 CSI divisions and provides ratios for material and installation as well as a total-in-place ratio. Division 3 Concrete and Division 9 Finishes also include subdivisions for particular construction items, whereas Divisions 10 to 14 are combined. Finally, Means provides a weighted total for all 16 divisions, again broken into material and installation components as well as the combined total.

In converting the selected index to a particular city, one should follow these steps.

1. Thoroughly understand the structure of your chosen index.
2. Decide what level of detail is to be used when converting to the locality. This ranges from using the total ratio for all 16 divisions to using

the total material and installation ratios to using detailed line item ratios. Often the level of detail will be limited by the knowledge of the chosen index's structure.

3. Use the ratio(s) to convert the index's historical data to the local market. This requires both the historical data from the construction cost index as well as the historical city cost indexes from Means.

The following example converts the 1999 third-quarter Saylor Material/ Labor Cost Index to the Austin, Texas area.
the following:

1. The Saylor Index uses a 54% labor and 46% material weight and provides values for each component.
2. The total (16 division) ratios for Austin are used and applied to the overall Saylor Index using the individual material and labor components of the Saylor Index.
3. Third-quarter Saylor Index: Material at 148.13, Labor at 32.48, Index Value at 548.4. Austin City Cost Index: Material at 95.3, Labor at 68.8, Index Value at 82.5.

$$\text{City Cost Index}/100 * \text{National Index}$$
$$= \text{Local Index or } 82.5/100 * 548.4 = 452.4.$$

Similar calculations can be done for any period desired to provide historic trends for the local area. In any application, the greater the level of detail used to compute the local index, the greater the accuracy will be.

1.3 PREPARING THE DETAILED ESTIMATE

If a contractor chooses a project he or she can professionally and financially handle, it is worthwhile to expend all efforts to win the bid. Never forget that most public owners are obliged to select the lowest bidder. In addition, the contractor must successfully pass a qualification screening. For private work there is room for negotiation and in this situation the contractor must be prepared to lower the bid cost, reduce the project completion date, or accept additional owner requirements, but not to lose money.

After the decision to bid, arrangements need to be made to pick up the contract document, often at a special price. Most of the time after the bid opening, if the contractor is not successful then documents can be returned and costs recovered. The steps listed below, in logical order, are the road map for developing a detailed estimate.

Step one. Establish a notebook designated for this project, number the pages, and record everything related to the project.

Step two. Scan the bidding documents. Check for general conditions, specifications, addenda, and all the drawings. If any discrepancies exist, record them in the notebook and check with the architect or engineer as soon as possible. The bound volume of general conditions and specifications is generally organized into the following sections: the bid, the owner/contractor agreement, bonds, alternates, general conditions, specifications, and addenda.

a. The bid section includes the invitation to bid, instructions to bidders, and bid forms. The invitation to bid (see Fig. 1.1) must contain a description of the nature, extent, and location of the project as well as contact information for the owner or owner representative. The documents should also contain date, time, manner, and place that bids will be received; general contractor and subcontractors' prequalification requirements; date, time, and location of any prebid conference; availability of bidding documents with their dates, locations, and procurement costs; and bond requirements.

b. The owner/contractor agreement section is most often a "standard" (AIA, AGC) document that formalizes the construction contract sum (lump sum cost) and construction duration in time units or gives start and completion dates. It should also list progress payments retained, percentage of completed work value, schedule of values, acceptance conditions, and final payment constraints.

c. The bond section should include bid bond and performance bond forms and requirements. Bonds are written documents that describe the conditions and obligations related to the owner/contractor agreement (see Chapter 18, Surety Bond section for more information). A bid bond certifies that if a contractor is awarded the bid within the time specified in the invitation to bid, the contractor will enter into the contract and will provide all other required bonds in a timely manner. A performance bond guarantees the owner that within agreement limits the contractor will perform all work in accordance with the contracting document. Labor and material bonds guarantee to the owner that the contractor will pay in a timely fashion for supplied materials used by all the subcontractors related to the project.

Step three. Review the drawings to visualize the building size, height, shape, function, basements, and so on. Start with floor plans, cross-sections, exterior finish system, and the roof. Note all unusual construction procedures, building systems, and materials that have been specified.

Step four. Review structural drawings to get acquainted with specified systems: reinforced concrete, structural steel, masonry, wood, or combinations. Find out which pieces of heavy construction equipment will be needed for erection and for how long.

Step five. Pay attention to various wall sections (exterior, interior, fire walls, etc.). Note materials and prefabricated assemblies.

Step six. Review mechanical, electrical, fire extinguisher, and security drawings. Record any possible interference with substructure and superstructure erection.

OFFICIAL PROPOSALS

State of New York Office of General Services Advertisement for Bids

Sealed bids for Project Nos. 43107-C, 43107-H, 43107-P and 43107-E, separate contracts for Construction Work, HVAC Work, Plumbing Work and Electrical Work, Data Command & Control Center, Swan Street Building, Core 4, Floor 1B (Albany County), Albany, NY 12242, will be received by the Office of General Services (OGS), Design & Construction Group (D&C), Contract Administration, 35th Fl., Corning Tower, Empire State Plaza, Albany, NY 12242, on behalf of the State of New York, Office for Technology until 2:00 p.m. on Wednesday, November 7, 2001, when they will be publicly opened and read. Each bid must be prepared and submitted in accordance with the Instructions to Bidders and must be accompanied by a certified check, bank check, or bid bond in the amount of $56,200 for C, $8,000 for H, $6,500 for P, and $21,500 for E.

All successful bidders with bids over $50,000 on a multiple trade project or the successful bidder with a bid over $200,000 on a single trade project, will be required to furnish a Performance Bond and a Labor and Material Bond in the statutory form of public bonds required by Sections 136 and 137 of the State Finance Law, each for 100% of the amount of the Contract estimated to be between $1,000,000 and $2,000,000 for C, between $50,000 and $100,000 for H, between $50,000 and $100,000 for P, and between $250,000 and $500,000 for E. The requirement for Labor and Material and Performance Bonds may be waived on a bid under $200,000 on a single trade project.

The completion date for this project is 300 days after the Agreement is approved by the Comptroller.

It is the policy of the State and the Office of General Services to encourage minority business enterprise participation in this project by contractors, subcontractors and suppliers, and all bidders are expected to cooperate in implementing this policy.

The Office of General Services reserves the right to reject any or all bids.

Phone the office of John Barberis, Director, Utilities Management, Concourse Rm 114-1, Empire State Plaza, Albany, NY 12242, (518) 473-3249 for an appointment a minimum of 24 hours in advance of site visit.

The Bidding and Contract Documents may be obtained for $49.00 deposit per set, plus $6.00 per set shipping and handling fee, by calling the following toll free number (877) OGS-PLAN (647-7526) or by mail from the Plan Sales Unit, 35th Fl., Corning Tower, Empire State Plaza, Albany, NY 12242. Make check payable to the Office of General Services and write Fed. ID# and phone # on check.

William F. O'Connor, AIA
Deputy Commissioner

Procurement Dept., City of Philadelphia

Sealed bids will be received in Room 170A, Municipal Services Building on Tuesday, November 6, 2001 at 2:30 PM for Water Department proposal(s) listed below.

No bids will be accepted unless a Questionnaire and Financial Statement for Qualified Bidders with all questions fully answered is filed with the Water Department, 2nd Floor, ARAMARK Tower, 1101 Market Street, Phila., PA 19107 on or before Tuesday, October 23, 2001.

Specifications and Questionnaires and Financial Statements for Qualified Bidders may be obtained from the Water Department (address above) upon payment of a non-refundable charge of $30.00 for Bid Nos. 2421 and 2422. (N.B. Check or Money Order Only, made payable to the City of Philadelphia.)

Blueprints may be purchased at the bidders own expense from A-C Reproductions, 1510 Sansom Street, Philadelphia, PA 19102, Telephone No. (215) 563-5594, Fax No. (215) 563-5270.

A mandatory pre-bid meeting will be held at the site at 10:00 AM on Wednesday, October 24, 2001 for Bid Nos. 2421 and 2422. In addition to the pre-bid meeting, a mandatory two-day walkthrough tour of the project will be held at the site between 9:00 AM to 4:00 PM on Thursday, October 25, 2001 and Friday, October 26, 2001 for Bid Nos. 2421 and 2422. Attendance is required for both days of the walkthrough tour as well as the pre-bid meeting as a pre-requisite for pre-qualification for the bids.

Bid No. 2421; Work No. 73030; Description: Mechanical Work for HVAC System for the North Side of the Southwest Water Pollution Control Plant at 8200 Enterprise Avenue (Estimate is $10,000,000.00 to $15,000,000.00). Mandatory pre-bid meeting and mandatory two-day walkthrough tour of the project.

Bid No. 2422; Work No. 73031; Description: Electrical Work for HVAC System for the North Side of the Southwest Water Pollution Control Plant at 8200 Enterprise Avenue (Estimate is $1,500,000.00 to $3,000,000.00). Mandatory pre-bid meeting and mandatory two-day walkthrough tour of the project.

These bids require compliance with Minority Business Council Participation.

Louis Applebaum
Procurement Commissioner

Silverite Construction Co., Inc.

Silverite Construction Co., Inc. is seeking participation from all certified M/W/LBE contractors to bid all trades for the following contract: Bronx School For Law, Government & Justice. For further info or to submit your quotation contract:

Silverite Construction Co., Inc. 520 Old Country Rd., Hicksville, NY 11801 Atten: John Simenson. 516-681-0562, Fax 516-681-0571.

VISIT OFFICIAL PROPOSALS ONLINE AT WWW.ENR.COM

52 ENR/October 15, 2001

FIGURE 1.1 Invitation to bid.

Step seven. Start identifying work to be done by general contractor and work to be done by subcontractors.

Step eight. Read and study thoroughly the specifications for the work to be done by the general contractor and get acquainted with those related to any subcontracted work.

Step nine. Review general conditions and note the items that will affect project costs.

Step ten. Visit the project site and have with you the project manager or field engineer (see Appendix 5, Construction Site and Investigation Report).

Step eleven. Call a meeting with the personnel who will most likely hold the key supervisory positions. Establish with them the general guidelines for quantities take off and pricing.

Step twelve. Develop a list of subcontractors. Notify subcontractors and suppliers that the company is preparing a proposal and ask if they intend to submit bids.

Step thirteen. Following the site visit and staff consultation, develop a list of items to be considered for jobsite overhead and general overhead that need to be priced later (bonds, insurance, special owner requirements, etc.).

Company Logo

Quantity Take Off

Date 20 / OCT / 2004 Sheet No. 1 Of 1

Project Title 25 m SWIMMIN POOL Project No. C-28

Take Off By John D. Approved By CPP.

Code*	Description	No.	Dimensions			Unit		Unit		Unit		Unit	
	DIVISION 2 – SITE CONSTRUCTION												
	EXCAVATION BULK		30 m	18 m	3 m	m³	1620						
	HAULING EXCAVATED SOIL – EXCESS					m³	1100						
	CRUSHED STONE 15–20 mm / 300 mm deep		28	16	0.3	m³	135						
	COMPACTED BACKFILL with DOZER		25	15	1.0	m³	375						

* Masterformat, Uniformat, WBS, other, etc.

FIGURE 1.2 Quantity take off (metric).

Step fourteen. Start the quantities take off for the category of construction work selected to be done inhouse (most often site work, foundations, and concrete work). See Figure 1.2 for an example. Each item must be accounted for with no omissions or errors in interpreting the specifications. This work is done on workup sheets, with notes and sketches recorded in the notebook. When taking off quantities, make it a habit to start from the lowest level and break each item down by size, type of material, and workmanship specified. Also list the type of heavy construction equipment needed for each phase. Items should be listed using standard Uniformat coding in the same way in which the specifications are organized.

Step fifteen. Condense quantities from the workup sheet by work category and transfer them to a summary sheet for pricing (see Fig. 1.3). Pricing means the cost of materials, labor, and construction equipment. The prices used are from company files or generally available cost files adjusted to a particular location, or from quotes from suppliers and subcontractors. An example estimate summary is shown in Figure 1.4. During the process of quantity take off and pricing, many errors and omissions can occur. Keeping them to a minimum means survival in a very competitive market.

Company Logo **Pricing** Date 28 / OCT / 2001 Sheet No. 1 Of 1

Project Title 25 m SWIMMING POOL (EXCAVATION ONLY) Project No. C-28

Take Off By John D Approved By GAP.

Code*	Description	Quantity	Unit	Material U.P.	Material Total	Labor U.P.	Labor Total	Equipment U.P.	Equipment Total	Subcontract U.P.	Subcontract Total	Total U.P.	Total
	DIVISION 2 – SITE CONSTRUCTION												
02315400500	BULK EXCAVATION	1620	m³			1.16	1880.85		1377			2.01	3257
02320200200	HAULING EXCAVATED SOIL, 6 Km	1100	m³			3.51	37516.85		7535			10.26	11286
02721000304	BASE COURSE, CRUSHED STONE 300 mm	448	m²	5.25	2352.25		112.44		197			5.94	2661
02320000140	HAULING CRUSHED STONE 3 Km	135	m³			2.39	3224.78		645			7.17	967
02315100600	DOZER BACKFILL, COMPACTED 150 mm lift	375	m³			.52	1961.80		563			2.02	758
02320200200	HAULING BACKFILL 6 Km Round trip	490	m³			3.41	16706.85		3356			10.36	5026
	NOTE: UNIT PRICES FROM R.S. Means Building Construction Cost Data – Metric 2000												
	SHEET TOTAL				2352		7930		13673				23955
					MATERIAL		LABOR		EQUIPMENT		SUBCONTRACT		TOTAL

* Masterformat, Uniformat, WBS, other, etc.

FIGURE 1.3 Pricing form.

Company Logo | **Estimate Summary** | Date 31 / OCT / 2001 | Sheet No. 1 Of 4

Project Title: 10 STORY CONDOMINIUM (100 UNITS – 150 m²/UNIT) — Project No. C-29

Take Off By: John Doe — Approved By: C.P

CSI Division	Description	Material	Labor	Equipment	Subcontract	Total US $
2	**Site Work**				615000	615000
	Site Preparation, Demolition					
	Earth Work					
	Caissons & Piling					
	Drainage & Utilities					
	Paving & Surfacing					
	Site Improvements, Landscaping					
3	**Concrete**	750000	750000	300000		1800000
	Formwork					
	Reinforcing Steel & Mesh					
	Cast-in-Place Concrete					
	Precast Concrete					
	Cementitious Decks					
4	**Masonry**				1080000	1080000
	Mortar & Reinforcing					
	Clay Masonry					
	Concrete Masonry Units					
	Stone Masonry					
	Page Total	750000	750000	300000	1080000	3495000
		Material	Labor	Equipment	Subcontract	Total

Company Logo | **Estimate Summary** | Date 31 / OCT / 2001 | Sheet No. 2 Of 4

	Description	Material	Labor	Equipment	Subcontract	Total
5	**Metals**					
	Structural Metal Framing				300000	300000
	Metal Joists				150000	150000
	Metal Decking				150000	150000
	Light Gauge Framing				225000	225000
	Misc. & Ornamental Metals				75000	75000
6	**Wood and Plastic**					
	Rough Carpentry					
	Finish Carpentry				150000	150000
	Architectural Woodwork				150000	150000
7	**Thermal & Moisture Protection**					
	Water & Damp Proofing				225000	225000
	Insulation & Fireproofing				150000	150000
	Vapor Barriers				75000	75000
	Shingles & Tiles				75000	75000
	Roofing & Sheet Metal				900000	900000
8	**Doors & Windows**					
	Door & Window Frames				750000	750000
	Finish Hardware				150000	150000
	Glass & Glazing				525000	525000
	Curtain Walling					
	Page Total				4350000	4350000
		Material	Labor	Equipment	Subcontract	Total

FIGURE 1.4 Summary estimate.

Company Logo **Estimate Summary** Date 31 / OCT / 2001 Sheet No. 3 Of 4

	Description	Material	Labor	Equipment	Subcontract	Total
9	**Finishes**					
	Lath & Plaster Work				300000	300000
	Gypsum Plasterboard Systems				300000	300000
	Tile, Terrazo Work				225000	225000
	Acoustical Treatment				225000	225000
	Flooring & Carpets				300000	300000
	Painting, Wall Covering & Decorating				105000	105000
10	**Specialties**					
	Bathroom Accessories				225000	225000
	Lockers				105000	105000
	Partitions					
	Signs & Bulletin Boards					
11	**Equipment**					
	Appliances				225000	225000
	Dock					
	Kitchen				195000	195000
12	**Furnishings**					
	Blinds				75000	75000
	Seating					
	Page Total				2280000	2280000
		Material	Labor	Equipment	Subcontract	Total

Company Logo **Estimate Summary** Date 31 / OCT / 2001 Sheet No. 4 Of 4

	Description	Material	Labor	Equipment	Subcontract	Total
13	**Special Construction**					
	Integrated Ceilings				360000	360000
	Pedestal Floors					
	Pre Fabricated Rooms & Bldgs.					
14	**Conveying Systems**					
	Elevators, Escalators				360000	360000
	Pneumatic Tube Systems					
15	**Mechanical**					
	Plumbing & Sewerage				150000	150000
	Plumbing Fixture & Appliances				375000	375000
	Heating & Air Conditioning				225000	225000
	Fire Protection				165000	165000
16	**Electrical**					
	Rough Electrical Work				375000	375000
	Finish Electrical work				540000	540000
	Page Total				2250000	2250000

	Material	Labor	Equipment	Subcontract	Total
Total Direct Cost: Page 1 to 4	750000	750000	300000	10575000	12375000
Sales Tax 8 % (Materials)					60000
Project Site Overhead 20% of 12,375,000.					2475000
General Overhead 10% of 12375000					1237500
SubTotal					16147500
Profit 5 **% (Subtotal)**					807375
Contingency 3 **% (Subtotal or $)**					484425
Total Bid					17439300

or $ 1162/m²

1.4 SOURCES FOR NEW PROJECTS

It is of great importance for a general contractor or subcontractor to maintain a stream of new incoming projects. The value of the new work is an important indicator of company health. To bid on new projects or to negotiate them should be not only the responsibility of the owner or executive, but also of many of the employees, especially the very highly ranked chief estimator and his or her subordinates. Sources regarding new projects in a contractor's area can be found in local newspapers, local trade organization newsletters, national professional magazines, various Internet sites, leisure clubs, and friends. The earlier an organization finds out about a new project, the sooner a decision to bid or negotiate a contract can be made.

In most areas, the Associated General Contractors of America (AGC) publishes weekly newsletters regarding new projects. The Texas Construction Bulletin also offers a wealth of data regarding contracts awarded. This bulletin provides the bid tabulations of awarded contracts, which is valuable information for estimators and the construction community for a specific location. Figure 1.5 is a sample page from the Invitation to Bid for Austin, HEB Grocery Store #25. The blue prints, project specifications, and related bidding information can be found by interested contractors in Bin #54 at the local AGC. Bid tabulations are shown in Figure 1.6. The most recent contract awards list provided in the AGC local bulletin is also a good source of information for subcontractors to direct their efforts to new opportunities (Fig. 1.7).

In addition to AGC weekly bulletins, a huge computerized online database (AGC CONNECT) is available to interested contractors and contains all the general conditions, specifications, and blueprints of a project. A summary of available project documents, bid dates, locations, architects, bin numbers, and a location of the drawings for inspection are provided weekly. An example is shown in Figure 1.8.

Among many national professional magazines, McGraw-Hill has published the construction-oriented *Engineering News-Record* for more than 125 years. In their weekly PULSE section, interested readers can discover new projects in their design stages and find sources for possible bid dates. Figure 1.9 shows a new projects sample found on an *ENR* page that has additional references to their Internet sites www.enr.com and www.fwdodge.com. From the same weekly PULSE section, national and foreign contractors also have access to project bid dates, a source for bidding documents, and the costs for such documents. See Figure 1.10. The Internet is an important resource for a contractor to find out early about projects in his or her area of interest. Figure 1.11 is a sample printout page from www.enr.com:FWDODGE database with a narrow selection for Texas.

Austin, HEB Grocery Store #25 **2/14/01 2:00 pm**

Location: HEB Grocery Store #25,
500 Canyon Ridge Drive (Parmer & IH35)
Austin, TX

Addenda: **No Addenda**

Bin #: **54**

Trades: **General Docs.:** BIDDING/CONTRACT REQUIREMENTS; **General Req.:** GENERAL REQUIREMENTS; **Site Work:** SITEWORK, Termite Control, Drilled Concrete Piers, Site/Street Furnishings; **Concrete:** CONCRETE, Concrete Formwork, Reinforcing Steel, Cast-In-Place Concrete, Structural Concrete, Concrete Finishes, Architectural Precast Conc-Plant Cast; **Masonry:** MASONRY, Unit Masonry; **Metals:** METALS, Misc. Metals, Structural Steel, Steel Joist Girders, Steel Joists, Metal Decking; **Wood & Plastics:** WOOD & PLASTIC, Rough Carpentry, Finish Carpentry, Millwork; **Ther./Moist. Pro.:** THERMAL/MOISTURE PROTECTION, Waterproofing, Elastomeric Surface Waterproofing, Dampproofing, Water Repellents, Insulation, Roof/Deck Insulation, Prepared Roll Roofing, Elastomeric Traffic Coating, Roof Accessories, Joint Sealers, Sealants/Caulking; **Doors & Windows:** Steel Doors/Frames, Access Doors, Coiling Doors/Grilles, Sectional Overhead Doors, Traffic Doors, Aluminum Entrances/Storefronts, Automatic Entrance Doors, Hardware, Weatherstripping/Seals, Glazing, Glass, Glazed Aluminum Curtain Walls; **Finishes:** FINISHES, Lath/Plaster, Plaster Fabrications, Gypsum Board, Ceramic Tile, Acoustical Ceilings, Resilient Flooring, Carpet, Special Coatings, Painting, Wall Coverings; **Specialties:** SPECIALTIES, Compartments/Cubicles, Identifying Devices, Storage Shelving, Toilet/Bath Accessories; **Equipment:** EQUIPMENT, Refrigerated Display Cases, Audio-Visual Equipment, Loading Dock Equipment, Food Service Equipment, Food Storage Equipment; **Conveyors:** CONVEYING SYSTEMS, Hydraulic Passenger Elevators; **Mechanical:** MECHANICAL, Basic Mechanical Materials/Methods, Various Mechanical, Supports/Anchors, Motors, Mechanical Sound/Vibration/Seismic Control, Mechanical Insulation, Piping Insulation, Ductwork Insulation, Fire Sprinkler Systems, Plumbing, Various Plumbing, Plumbing Piping, Plumbing Specialties, Plumbing Fixtures, Domestic Water Heat Exchangers, Plumbing Equipment, Storage Tanks, Heating/Ventilating/Air Conditioning, Boilers, Gas Fired Unit Heaters, Heat Transfer, Air Handling Unit with Coils, Centrifugal Fans, Air Curtain Units, Air Distribution, Filters, Ductwork, Control Systems, Electric Control Systems, Testing/Adjusting/Balancing; **Electrical:** ELECTRICAL, Basic Electrical Materials/Methods, Various Electrical, Communications, Data Systems, Telephone Systems, Public Address/Music Systems, Controls; **Miscellaneous:** DIVISION 17: 17000 - Refrigeration Installation General Conditions, 17100 - Refrigeration Installation, 17960 - Refrigeration Equipment - Parallel Compressor System (Mechanical Enclosed With Parallel Compressor System and Remote Air Cooled Condensers)

Arch/Engr: Artisan Group, Inc., 826 Water St., Kerrville, TX 78028, Phone: 830-896-4220; Fax: 830-896-4226

Owner: HEB Construction, 946 Quintana Rd, San Antonio, TX 78204; Phone: 210-938-7911

Bids To: Owner

Plans From: Owner

Bonds: 10% Bid, 100% Payment, 100% Performance

Prebid: 9:00 am on 2/1/01 at HEB Construction Offices, 946 Quintana Road, San Antonio, TX 78211

Design: **Architect:** Artisan Group, Inc.
Structural Engr.: Bill Reiffert & Associates, Inc.
MEP Engineer: GPM Engineering
Architect: _HEB Construction

Status: Bidding

Bidders:		
	(AGC) EMERSON CONSTRUCTION CO., INC.	Ph.: 254-939-1863 Fax: 254-939-2094
	(AGC) EWING CONSTRUCTION CO	Ph.: 361-882-6525 Fax: 361-882-8424
	(AGC) WILLIAMS DEVELOPMENT AND CONST	Ph.: 713-683-8444 Fax: 713-680-0204
	(AGC) WORKMAN CORPORATION	Ph.: 512-326-9293 Fax: 512-326-3219
	Jordan Construction Co.	Ph.: 210-375-1260 Fax: 210-375-1261
	Thomas S. Byrne, Inc	Ph.: 817-335-3394 Fax: 817-877-5507

February 2, 2001

FIGURE 1.5 Austin HEB Grocery Store #25. (From: AGC, Austin Chapter, *Texas Construction Bulletin* 11:5.)

BID TABULATIONS

1/25/01 BRISCOE COUNTY, CAPROCK CANYONS SP REMOVE/REPL LIFT STATION

B-5 Construction, Inc
Phone: 903-545-2161
Amount: $40,773

Plains Utility Co
Phone: 806-744-6105
Amount: $41,498

Morton Irrigation, Inc
Phone: 806-239-4466
Amount: $45,200

1/25/01 BROWN COUNTY, LK BROWNWOOD SP WW IRRIGATION & DETENTION POND

Morton Irrigation, Inc
Phone: 806-239-4466
Amount: $153,479

Randall & Blake Inc
Phone: 817-481-6668
Amount: $211,500

Carter Construction
Phone: 817-244-3622
Amount: $212,666

1/25/01 AUSTIN, ARCADIA AVENUE DRAINAGE IMPROVEMENTS

***Cactus Concrete**
Phone: 512-288-3773
Amount: $52,225

*A & R Demolition
Phone: 800-756-7912
Amount: $57,297

J & M Construction Co
Phone: 512-845-7876
Amount: $61,460

1/24/01 FREDERICKSBURG, FREDERICKSBURG HIGH SCHOOL ADDN & RENOVATION

Hutchinson Construction
Phone: 512-832-9824
Amount: $2,760,000

STR Constructors, Inc
Phone: 512-515-0254
Amount: $2,949,000

Artisan Group, Inc.
Phone: 830-896-4220
Amount: $2,999,000

1/24/01 AUSTIN, CAMP MABRY STARC ARMORY BLDG 8 WTR HEATER REPLACEMNT

***Harkins Mechanical**
Phone: 512-281-5577
Amount: $35,700

Raintree Construction, Inc
Phone: 512-719-5754
Amount: $49,058

J H Mechanical
Phone: 512-837-4352
Amount: $59,285

1/23/01 CRYSTAL CITY, NEW ZAVALA COUNTY BANK BUILDING

Droemer Construction
Phone: 409-773-4852
Amount: $2,139,500

C. A. Landry
Phone: 210-651-4276
Amount: $2,365,500

Don Krueger Construction Company
Phone: 361-573-5291
Amount: $2,385,000

1/23/01 DAYTON, 1999 TCDP SANITARY SEWER IMPROVE

Kenneth Sterling Construction
Phone: 318-238-2674
Amount: $405,553

Mercer Construction Co.
Phone: 361-782-7163
Amount: $427,931

Triple B Services
Phone: 281-324-3264
Amount: $560,853

1/23/01 TEMPLE, TEMPLE CENTRAL SERVICE CENTER

(AGC) WACO CONSTRUCTION
Phone: 254-772-3660
Amount: $5,129,000

EBCO Development, Inc
Phone: 254-697-8156
Amount: $5,240,000

CSS, Inc
Phone: 254-865-8441
Amount: $5,295,782

TEXAS CONSTRUCTION BULLETIN February 2, 2001

FIGURE 1.6 Bid tabulation results. (From: AGC, Austin Chapter, *Texas Construction Bulletin* 11:5.)

CONTRACT AWARDS

AGC Connect
Virtual Plan Room

11/15/00 CORPUS CHRISTI, NEW PRIMARY SCHOOL, TULOSO-MIDWAY ISD

(AGC) MOORHOUSE CONSTRUCTION
Phone: 800-728-6040
Amount: $8,748,000

11/9/00 LEAGUE CITY, CLEAR CREEK ISD NEW ELEM. SCH @ FALCON PASS DR.

Brae Burn Construction Co.
Phone: 713-777-0063
Amount: $9,757,000

11/9/00 DAYTON, TDCJ CONSTRUCT MULTI PURPOSE BLDG, PLANE STATE JAIL

DT Construction
Phone: 281-540-2411
Amount: $654,700

11/7/00 COLLEGE STATION, TAMU POWER PLANT ROOF REPLACEMENT

Brazos Urethane, Inc.
Phone: 409-776-8081
Amount: $115,800

11/2/00 AUSTIN, ABIA PARKING LOT F EXPANSION

***Smith Contracting Co.**
Phone: 512-990-7640
Amount: $1,347,840

FIGURE 1.7 Austin contract awards since last bulletin. (From: AGC, Austin Chapter, *Texas Construction Bulletin* 11:5.)

In conclusion, there are unlimited sources regarding future projects of interest to general contractors or subcontractors for a specific location. Subscriptions to the major trade magazines and a scanning of Internet sites can be the key to survival in a very competitive construction market.

1.5 BUILDING COST INFORMATION STANDARDS

There are two systems that establish standards for the building design/construction estimating process. One system, Master Format, is oriented to materials and installation. The other system, Uniformat, analyzes and compares various costs.

1.5.1 The Master Format System

The Construction Specification Institute (CSI) publishes a manual of building work classification entitled Master Format. This is a list of titles, subtitles, and

			PLANS & SPECS				
			ON FILE IN THE AGC PLAN CENTER				
BID DATE & TIME		LOCATION	PROJECT	# OF ADDENDA	ARCHITECT	BIN #	SCAN
2/5/01	3pm	New Braunfels	Municipal Airport Improvements Projects	1	TXDOT	36	Y
2/6/01	1pm	Austin	Camp Mabry Renovations Bldg 41	1	Croslin	85	Y
2/6/01	2pm	Austin	UT Concrete Demolition Phase I (ENS) Suite 32N	1	UT Austin	83	Y
2/6/01	2pm	Georgetown	Williamson County Juvenile Justice Facility	memo	FT Woods, GC	65	Y
2/6/01	2pm	College Station	Lick Crk WWTP Expansion & Carters Crk WWTP Improv	1,2	COCS	49	Y
2/7/01	1pm	Austin	TXDOT Truck Wash Bay & Sewer Modif (Rebid)		TXDOT	12	Y
2/7/01	1pm	San Antonio	San Antonio District HVAC Campus Upgrade	1	TXDOT	82	Y
2/7/01	1pm	Hemphill	Lufkin Dist. Maintenance Facility Construction		TXDOT	55	Y
2/7/01	1pm	Hardeman County	Safety Rest Area Construction	1	TXDOT	50	Y
2/7/01	1pm	Anahuac	TXDOT New Maintenance Shop Facility Finish Out	1	TXDOT	24	Y
2/7/01	2pm	Burnet	New Junior HS & Shady Grove Elem Sch Gym Addn	1	Baird/Williams,GC	19	Y
2/7/01	2pm	Corpus Christi	Texas State Aquarium Sea Lab Renovation	1	COCC	7	Y
2/7/01	2pm	San Angelo	2000 RWM Replacement Projects	1	San Angelo	20	Y
2/8/01	11am	Austin	Dick Nichols Dist. Park Playscape Addn.	1	COA Parks/Rec	39	Y
2/8/01	12pm	Austin	City Hall Bid Pkg-Pedestrian Tunnel & Excavation	1,2,3	Cotera/K/N/R	77	Y
2/8/01	1pm	Austin	Metz Recreation Center Playscape Renov.	1	COA Parks/Rec	41	Y
2/8/01	1pm	San Antonio	Nelson Elementary School Addn & Renovations	1, 2,3	SAISD	66	Y
2/8/01	1pm	San Antonio	Nelson Elementary School New PE Facility	1,2,3	SAISD	66	Y
2/8/01	1:30pm	Austin	Neighborhood Traffic Calming Ph. 4, Zilker (Rebid)		COA	43	Y
2/8/01	2pm	Austin	UT Building Toilet & Lab Renov (PAT) & (WEL)		UT Austin	33	Y
2/8/01	2pm	Kerrville-Schreiner	Kerrville-Schreiner SP Waste Water Collection Facilities		TPWD	4	Y
2/8/01	2pm	Various	Grinder Pump & Lift Station Replace @ Various SP	1	TPWD	34	Y
2/8/01	2pm	Gregory	Gregory Portland ISD New High School		Pfluger	78	Y
2/9/01	2:30pm	Seminole	Gaines County Airport Improvement Project		TXDOT	1	Y
2/9/01	3pm	Austin	McNeil - San Felipe Crossing		Gary Shaw	38	Y
2/13/01	10am	Austin	Bedichek MS Band & Science Classroom Upgrade		Moellendorf	14	Y
2/13/01	2pm	College Station	TAMU Veterinary Med Ctr Vivarium Addn		TAMU	9	Y
2/13/01	2pm	Houston	TSU Spurgeon E Gray Hall Expansion & Renovations	1,2	PGAL	73	Y
2/13/01	2pm	Harlingen	Su Clinica Familiar Multi-Specialty Clinic	1	McCarthy, CM	53	Y
2/13/01	4pm	Schertz	Clemens HS Athletic Facility Expansion		Kencon, GC	67	Y
2/14/01	2pm	Austin	Austin Seafood and Steakhouse		Koeninger	63	Y

FIGURE 1.8 Plans and specs on file in the AGC Plan Center.

subsubtitles associated with a numeric code used to organize construction information into a standard. It is used extensively in the US building industry by designers, materials and product suppliers, and contractors for standardizing design specifications. It is also used by contractors to retrieve information during the bidding and pricing phases. The concept of broad scope (Division), medium scope (Subdivision), and several levels of details are used in practice. For example, the Means Building Cost data file is an illustration of the application of Master Formats for the standardization of unit prices in Building Construction. Regardless of the level of detail used in establishing a cost, the classification system, and the division and subdivision numbers can be used to provide a common base for organizing the specifications, for estimating and considering costs, and for materials and building component literature.

The CSI Master Format system consists of 16 divisions broken down into further subdivisions and subsubdivisions (see Table 1.19). Most computer estimating software programs today (see Appendix 3, Cost Estimating Software) incorporate the 16 divisions of the Master Format numbering system.

PULSE

PLANNING

CALIFORNIA Ignacio Gonzalez Architects is in early design stage for a 60,000-sq-ft **parking garage and Japanese restaurant** at Ninth Ave. and Van Ness in San Francisco. The project consists of a four-story robotic parking structure with a 6,000-sq-ft Japanese restaurant on bottom level of the garage. Further action possible in three to four months, pending needed approvals. *Ignacio Gonzalez Architects, 2516 Oceanfront Dr., Las Vegas, Nev. 89128. DR #99-829709.*

FLORIDA The Board of County Commissioners, Orange County, has selected Parsons Brinckerhoff as owner's representative-program manager for all phases of the development and construction administration for the **expansion** of the Orange County Convention Center. The $748-million project, located on a 207-acre site, includes development of a 2.8-million-sq-ft facility. The preliminary building program encompasses a 975,000-sq-ft exhibition hall on one floor, 169,400 sq ft of meeting rooms, up to 5,000 parking spaces and ancillary and support space totaling more than 1.7 million sq ft. It also will include an enhanced streetscape and utilities relocation. Construction on this project is slated for completion in 2002. *Parsons Brinckerhoff, 1408 N. West Shore Blvd., Tampa 33607.*

FLORIDA BNG Partners Inc. has chosen Kaufman & Broad as architect for the Port St. Lucie **senior citizens apartment complex** located on Lennard Rd. in Fort Pierce. The 248-unit complex is estimated to cost $18 million. Further progress pending funding and local approval. *Kaufman & Broad, 320 Golden Shore St., Suite 200, Long Beach 90802-4243; BNG Partners Inc., 1006 Beckstrom Dr., Oviedo 32765-5913. DR #99-829547.*

GEORGIA Dimery Associates and CWB Design have been selected to provide architectural and design services for **alterations** to the 112-unit Healey Building Condominiums at 57 Forsyth St. N.W. in Atlanta. The alterations involve hardwood floors, 10-ft finished ceilings and eight-ft windows. Ultima Holdings is owner-builder/developer for this project, estimated to cost $16 million. Preparation of construction documents are in progress. General contract to be negotiated. Construction scheduled to start in first quarter 2000. *Dimery Associates, 1300 Cook Rd., P.O. Box 310, Oxford 30267; CWB Design, 1950 Century Blvd. N.E., Suite 18, Atlanta 30345; Ultima Holdings, 555 Marietta St. N.W., Suite 1555, Atlanta 30303. DR #99-851358.*

ILLINOIS Prisco Serena Sturm Architects Ltd. is preparing working drawings and McShane Construction Corp. is construction manager for the **renovation** of the Union Station Multiplex at 444 W. Jackson Blvd. in Chicago. The project consists of the renovation of 70,000 sq ft of existing space at Union Station Multiplex into a health club with swimming pool, basketball courts, aerobic studios, offices, and shower and locker rooms. Construction manager to release for sub-trade bidding in January 2000. Construction scheduled to start in spring 2000. *Prisco Serena Sturm Architects Ltd., 3351 Commercial Ave., Northbrook 60062-1908; McShane Construction Corp., 6400 Shafer Court, Suite 400, Rosemont 60018. DR #99-848389.*

LOUISIANA First Baptist Church of Lafayette has selected the architectural firm of Louis E. Reames Jr. to design a new **church sanctuary** located at 1117 Lafayette St. in Lafayette. The project, estimated at $10 million, will replace a fire-destroyed sanctuary. Demolition of existing facility is in progress. *First Baptist Church of Lafayette, 1117 Lafayette St., Lafayette 70501-6837; Louis E. Reames Jr., 8156 Highland Rd., P.O. Box 14601, Baton Rouge 70808. DR #99-849709.*

NEW JERSEY Frank Mileto has been selected to provide architectural services for a new Holiday Inn **hotel** to be located on Rte. 1 & 9 in Elizabeth. The eight-story, 160,000-sq-ft hotel, owned by East Coast Hospitality Group LLC, is estimated to cost between $16 million and $24 million. Preparation of construction documents is under way. Bidding slated for March 2000 and construction targeted for April 2000. *Frank Mileto, 14 Beaver Brook Dr., Long Valley 07853; East Coast Hospitality Group LLC, c/o Econolodge, 853 U.S. Highway 1 & 9, Elizabeth 07201. DR #99-850696.*

NORTH CAROLINA National Park Service has selected Moser Mayer Phoenix Associates to design the **Wright Brothers National Memorial Visitors Center** at 1809 Virginia Ave. in Kill Devil Hills. The single-story, 24,000-sq-ft center is estimated to cost $17 million. Bidding tentatively expected in February. *Moser Mayer Phoenix Associates, Renaissance Plaza, 230 N. Elm St., Suite 1200, Greensboro 27401; National Park Services, 1809 Virginia Ave., Kill Devil Hills 27948-7639. DR #99-851182.*

NORTH CAROLINA ColeJenest & Stone has been selected as landscape architect by Heritage Communities Inc. for the Mallard Creek Golf Club **residential development** at Interstate 85 and Mallard Creek Church Rd. in Charlotte. *ColeJenest & Stone, 112 S. Tryon St., Charlotte 28284; Heritage Communities Inc., 9009 J.M. Keynes Blvd., Charlotte 28262. DR #99-829849.*

TEXAS The Wieser Group is designing an American Suites **hotel** with an outdoor swimming pool located in Austin. The five-story hotel is owned by Prime Hospitality Corp. General contract bidding and construction start possible within five to six months. *The Wieser Group, 3330 S. 700 East, Suite 202, Salt Lake City 84106; Prime Hospitality Corp., 700 Rte. 46 E., P.O. Box 2700, Fairfield, N.J. 07007-2700. DR #99-829983.*

UTAH MHTN Architects Inc. was selected by American Fork City to provide architectural services for the American Fork **fire and ambulance station** at 400 North and Center St. Early schematic design is under way on this estimated $15-million project. Further action pending funding. *MHTN Architects Inc., 420 E. South Temple, Suite 100, Salt Lake City 84111-1300; American Fork City, 31 Church St., American Fork 84003-1636. DR #99-829555.*

CONTRACTS/BIDS/PROPOSALS

DISTRICT OF COLUMBIA Blackstone Real Estate Advisors and its developer/partner, The Kaempfer Co. of Washington, D.C., have chosen The Clark Construction Group Inc. as the general contractor for **The Investment Building**, a Washington, D.C., landmark that was redesigned by Cesar Pelli. Located at the corner of 15th and K Sts., the building's historic limestone and terra-cotta facade will be preserved, bracing it with a structural steel frame while the remainder of the existing structure is razed. The new 512,000-sq-ft building will include 12 levels above-grade, 20,000 sq ft of retail space on the ground floor, three levels of underground parking and a lower lobby, as well as a rooftop terrace. Completion is scheduled for June 2001. *The Clark Construction Group Inc., 7500 Old Georgetown Rd., Bethesda, Md. 20814-6196.*

Much information for Pulse is derived from F.W. Dodge, a Division of the McGraw-Hill Companies. For more information on a project in Pulse which denotes a DR#, please call 1-800-FW DODGE (1-800-393-6343). For general information about Dodge products and services, call 1-800-FW DODGE or visit our Website at www.fwdodge.com.

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FIGURE 1.9 Planning. (From: *ENR*, Pulse Section, 01/17/2000.)

UTAH 1/24 (design-build management plans and schedules due)—Administrative Services of Utah, Division of Facilities and Construction Management, 4110 State Office Building, Salt Lake City 84114, a new three-story **Board of Pardons and Administration building** with total floor area of 53,000 sq ft, located east of Draper Prison and I-15 in Draper. $5.4 million. *AJC Architects, 1776 S. Main St., Salt Lake City 84115. DR #99-742356.*

CALIFORNIA 1/25 State of California Dept. of Transportation, 1120 N St., Room 0200, Mail Station #26, Sacramento 95814, **seismic retrofitting** of Novo River Bridge at Fort Bragg. $24.3 million. *For additional information call (916) 654-4490. DR #99-641449.*

ILLINOIS 1/25 Southern Illinois University at Edwardsville, Purchasing Office, P.O. Box 1012, Edwardsville 62026, 500-bed **student residence hall** with total floor area of 120,000 sq ft located at the corner of Whiteside and Circle in Edwardsville. *Solomon Cordwell Buenz & Associates Inc., architect, 625 N. Michigan Ave., Suite 800, Chicago 60611-3198. DR #99-619852.*

KENTUCKY 1/25 (extension)—University of Kentucky, Capital Construction and Property Management Division, Room 222, Peterson Service Building, Lexington 40506-0005, **plant science building**, Proj. #1745.0, located on the campus of the College of Agriculture, south of Cooper and Nicholasville Rd., in Lexington. The project, estimated to cost between $15 million and $16 million, consists of a two-wing, L-shaped research building. One wing will house faculty offices and support spaces of structural steel frame and the other wing will house laboratories and lab support spaces. *Luan & Henry Group, architect, 101 S. Eighth St., Louisville 40202. DR #98-854321.*

KENTUCKY 1/25 Commonwealth of Kentucky, Finance and Administration, Dept. of Facilities Management, Division of Contracting and Administration, Room 158, New Capitol Annex Building, Frankfort 40601, central regional **post secondary education center** located on Elizabethtown Community College campus for Kentucky Community & Technical College System. $9 million. *Ross Tarrant Architects Inc., architect, 206 W. Main St., Lexington 40507. DR #98-816801.*

NEW MEXICO 1/25 (tentative)—County of Bernalillo, One Civic Plaza N.W., 10th Floor, Albuquerque 87102, phase 2 of the three-building Metro County **detention center** with total floor area of 250,000 sq ft, located 20 miles west of downtown Albuquerque. $30 million. *Joint venture architects are: Custer Basarich Ltd./DCSW Architects, 1400 Central Ave. S.E., Albuquerque 87106-4811. DR #99-662275.*

CALIFORNIA 1/26 City of Santa Monica, 1685 Main St., Room 102, Santa Monica 90407, four-story, 118,000-sq-ft **public safety building**. The new police, fire and emergency services headquarters building, estimated to cost between $30 million and $33 million, is to be constructed northeast and adjacent to the existing police department building at 333 Olympic Dr. in Santa Monica. *Daworsky & Associates, architect, 3400 Wilshire Blvd., Suite 1000, Los Angeles 90010; JCM Group, 10866 Wilshire Blvd., Suite 600, Los Angeles 90024, is construction manager. DR #95-384594.*

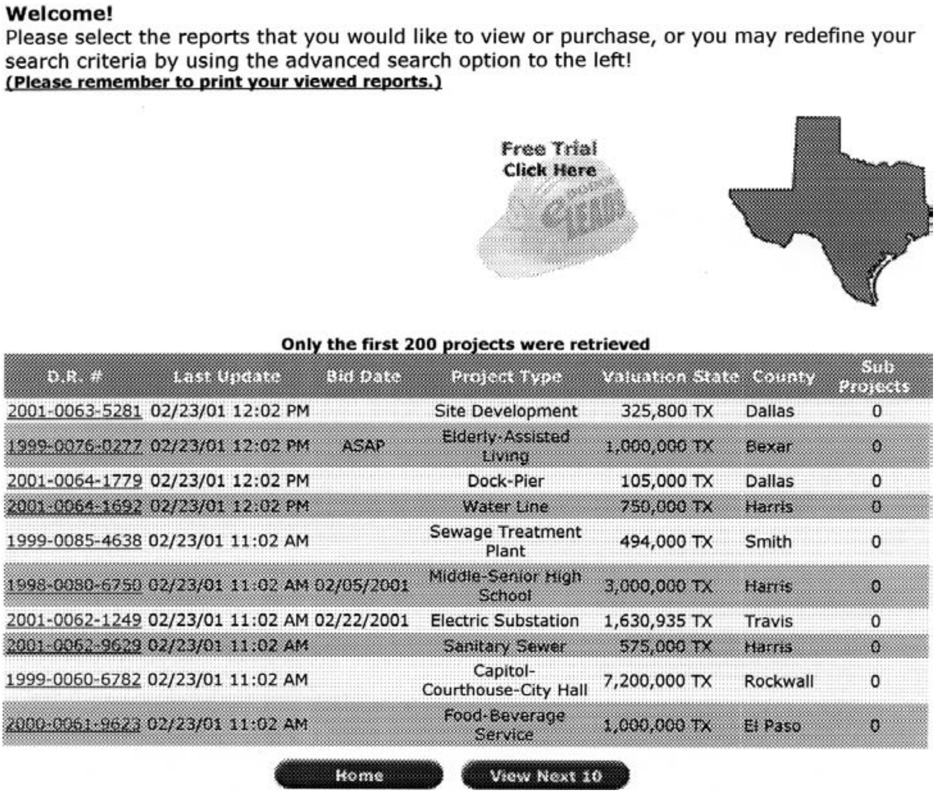
FLORIDA 1/26 Florida Dept. of Transportation, Contracts Division, 605 Suwannee St., Mail Station, 55 Haydon Burns Building, Tallahassee 32399, **widening and reconstruction of highway** on State Rte. 93 (I-275) south of Fletcher and north of U.S. 41 overpass in Hillsborough County. $15.4 million. The project consists of widening roadway from four to six lanes, including noise walls construction. *Point of contact: Paul Newell or Dennis Direns, assistant director, (850) 414-4000. DR #99-829580.*

MASSACHUSETTS 1/27 Freetown-Lakeville Regional School District, 98 Howland Rd., Lakeville 02347, **renovation and addition** to Apponequet Regional High School at 100 Howland Rd. in Lakeville. The project, estimated to cost $10.2 million, consists of the renovation of an existing 152,000-sq-ft facility and construction of a 12,000-sq-ft kitchen, a new art room, two new general classrooms, a 2,300-sq-ft multipurpose lecture/demonstration room, new lobby entrance and main office. *Kaestle Boos Associates Inc., architect, 124 Grove St., Suite 215, Franklin 02038-3156. DR #98-643346.*

NEW YORK 1/27 New York State University Construction Fund, 353 Broadway, P.O. Box 1946, Albany 12201-1946, three-story, 140,000-sq-ft **field house** at SUNY at Binghamton on Vestal Parkway E. $23.1 million. *Einhorn Yaffee Prescott, architect, 440 Park Ave. S., 16th Floor, New York City 10016-8012. DR #98-752916.*

Much information for Pulse is derived from F.W. Dodge, a Division of the McGraw-Hill Companies. For more information on a project in Pulse which denotes a DR#, please call 1-800-FW DODGE (1-800-393-6343). For general information about Dodge products and services, call 1-800-FW DODGE or visit our Website at www.fwdodge.com.

FIGURE 1.10 Bid Dates. (From *ENR*, Pulse Section, 01/17/2000.)



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D.R. #	Last Update	Bid Date	Project Type	Valuation	State	County	Sub Projects
2001-0063-5281	02/23/01 12:02 PM		Site Development	325,800	TX	Dallas	0
1999-0076-0277	02/23/01 12:02 PM	ASAP	Elderly-Assisted Living	1,000,000	TX	Bexar	0
2001-0064-1779	02/23/01 12:02 PM		Dock-Pier	105,000	TX	Dallas	0
2001-0064-1692	02/23/01 12:02 PM		Water Line	750,000	TX	Harris	0
1999-0085-4638	02/23/01 11:02 AM		Sewage Treatment Plant	494,000	TX	Smith	0
1998-0080-6750	02/23/01 11:02 AM	02/05/2001	Middle-Senior High School	3,000,000	TX	Harris	0
2001-0062-1249	02/23/01 11:02 AM	02/22/2001	Electric Substation	1,630,935	TX	Travis	0
2001-0062-9629	02/23/01 11:02 AM		Sanitary Sewer	575,000	TX	Harris	0
1999-0060-6782	02/23/01 11:02 AM		Capitol-Courthouse-City Hall	7,200,000	TX	Rockwall	0
2000-0061-9623	02/23/01 11:02 AM		Food-Beverage Service	1,000,000	TX	El Paso	0

Home   View Next 10

FIGURE 1.11 Dodge/Texas Selection home page. (From: www.enr.com.)

An example of the Master Format breakdown and its usage in a Means Building Cost file is shown in Table 1.20. The Master Format cost-breakdown system is one way to organize cost information when designing and procuring construction services. But the Master Format is not very useful in comparative cost analysis because it is a functionally oriented system. For an accurate project cost control to evaluate a project by building type and not by equipment or materials installed, a systems coding approach is mandatory.

1.5.2 The Uniformat System

Presently, the most widely used standardized system oriented to building construction is called Uniformat and was developed by the General Services Admin-

TABLE 1.19 Master Format Divisions

Division number	Division title
01	General requirements
02	Site construction
03	Concrete
04	Masonry
05	Metals
06	Wood and plastics
07	Thermal and moisture protection
08	Doors and windows
09	Finishes
10	Specialities
11	Equipment
12	Furnishings
13	Special construction
14	Conveying systems
15	Mechanical
16	Electrical

TABLE 1.20 R.S. Means Building Construction Cost Data[a]

Div. 9—Finishes

CSI—MASTER FORMAT LEVEL 1—01-16

CSI—MASTER FORMAT LEVEL 2

CSI—MASTER FORMAT LEVEL 3

R.S. Means 12 Digit Line Code

09100	METAL	Support Accessories
09100	N.L.B.	Wall Framing
09100–100–0010		Metal Studs, Partitions, 3000 mm high, with numbers
091130		Acoustical Suspension
09200		PLASTER & GYPSUM BOARD
09205		Furring & Lathing
09210		Gypsum Plaster
09220		Portland Cement Plaster
09250		Gypsum Board
09260		Gypsum Board Systems
09270		Drywall Accessories

TABLE 1.20 Continued

Div. 9—Finishes	
09300	TILE
09310	Ceramic Tile
09330	Quarry Tile
09350	Colass Mosaics
09370	Metal Tile
09400	TERRAZZO
09420	Precast Terrazzo
09450	Cast-In-Place Terrazzo
09500	CEILING
09510	Acoustical Ceilings
09600	FLOORING
09631	Brick Flooring
09635	Marble Flooring
09637	Stone Flooring
09643	Wood Block Flooring
09644	Wood Coup Flooring
09648	Wood Strip Flooring
09651	Resilient Base & Acc.
09658	Resilient Tile Flooring
09673	Composition Flooring
09680	Carpet
09700	WALL FINISHES
09710	Acoustical Wall Treatment
09770	Special Surfaces
09800	ACOUSTICAL TREATMENT
09820	Acoustical Insul./Sealants
09830	Acoustical Barriers
09840	Acoustical Wall Treatment
09000	PAINTS & COATINGS
09910	Paints & Coatings
09930	Stains/Transp. Finishes
09963	Glazed Coatings
09990	Paint Restoration

[a] CSI Master Format classification/line numbers.
Source: Means.

TABLE 1.21 UNIFORMAT System Level/Sublevel

Level	Sublevel	Level/sublevel title
A	—	Substructure
A	10	Foundations
A	20	Basement construction
B	—	Shell
B	10	Superstructure
B	20	Exterior enclosure
B	30	Roofing
C	—	Interiors
C	10	Interior construction
C	20	Stair finishes
C	30	Interior finishes
D	—	Services
D	10	Conveying systems
D	20	Plumbing
D	30	Heating, ventilating, and air conditioning
D	40	Fire protection systems
D	50	Electrical systems
E	—	Equipment and furnishing
E	10	Equipment
E	20	Furnishing
F	—	Special construction and demolition
F	10	Special construction
F	20	Selective demolition
G	—	Building sitework
G	10	Site preparation
G	20	Site improvements
G	30	Site civil/mechanical utilities
G	40	Site electrical utilities
G	90	Other site construction
Z	—	General
Z	10	General requirements
Z	20	Bidding requirements
Z	90	Project cost estimate

istration (GSA). It is composed of 12 cost-breakdown categories (see Appendix 3) and four levels of subcategories. Some levels are shown in Table 1.21.

Uniformat gives visibility to costs and identifies areas affected by change, making it a more effective comparison basis than the functionality oriented Master Format. Each major Uniformat category can be related to one or more divisions or subdivisions of Master Format (Table 1.22).

TABLE 1.22 Uniformat–Master Format Relationships

Uniformat	Master Format
C Interiors	
C 30 Interior finishes	DIV9. Finishes
C 3010 Wall finishes	9200 Plaster, gypsum board
	9300 Tile
	9700 Wall finishes
	9800 Acoustical treatment
	9900 Painting, coating
C 3020 Floor finishes	9300 Tile
	9600 Flooring
	9900 Painting, coating
C 3030 Ceiling finishes	9500 Ceiling
	9800 Acoustical treatment
	9900 Painting, coating

Most professional organizations concerned with building design construction and maintenance recognize Master Format as a standard for design manuals (specifications) and construction estimating while using Uniformat for construction cost comparisons and analysis.

1.6 ERRORS AND OMISSIONS MANAGEMENT

During the detail estimating process, errors occur. The magnitude of these errors in an estimating department can spell disaster. The worst possible reaction to errors and omissions is to cover up or attempt to recover the missing cost with fake change orders. Attempting to recover estimating mistakes with future contractor-initiated project changes could lead to costly project disputes, loss of reputation, or loss of client(s). Table 1.23 is an attempt to organize the causes of possible estimating errors and omissions while at the same time associating these with possible procedures for minimizing their chances of occurrence during detail estimating and bid proposal preparation.

1.7 THE ESTIMATING DEPARTMENT

1.7.1 The Estimator

The most important person in a general contractor's or subcontractor's organization is the estimator. The best contractor in the area cannot make a profit or stay in business for long if taken contracts are below the real cost. It is not difficult

TABLE 1.23 Errors and Omissions

	Possible estimating errors	Procedures for reducing errors
Ordinary	• Arithmetic, location of decimal point • Unit of measure, unit price relation • Errors in data input in estimating software • Errors in transferring data from quantity take off to cost summary	• Standardization of estimating forms • Quiet environment and adequate work station for estimators
Short cuts/rush/ short time to prepare the estimate	• Estimating quantities • Failure to check the estimate • Guessing the site overhead cost • Filling in for missing subcontractor costs	• Use of preliminary and conceptual estimates to check final numbers • Use of known average ratios to check relationship between quantities • Review finished pricing sheets and computer printouts
Carelessness	• Omitting work items • Omitting subcontractor quotes • Using obsolete productivity data files • No allowance for waste of materials • No allowance for possible major construction equipment breakdown • Omitting profit	• Use summary checklist for each type of building • List of subcontractor speciality for the project
Poor estimating management	• Not attending the prebid conference • Missing addenda • Missing the time/date of the bid • Incomplete proposal • Not visiting the project site • Not reviewing historical weather data • Not considering the time faster for pricing labor and materials • Not having a summary schedule • Not comparing unit prices used with nationally published adjusted by location and time	• Selection of the best estimators • New estimators inhouse training • Acquire state-of-the-art estimating software • Updating internal files related to labor productivity • Update subcontractor files • Last call to A/E office to check number of addenda issued • Develop bid day checklist

to obtain new contracts below your competitors' bids, but it is a sure path to bankruptcy. The following knowledge, managerial talents, and degree of construction experience make a good estimator.

1. Ability to read and understand contract documents, with special skills in reading construction drawings for all specialties and related specifications.
2. Ability to accurately take off the quantities of construction work for which he or she is preparing the detail estimate.
3. Ability to visualize the future building from drawings, which usually requires some years of construction site experience.
4. Knowledge of arithmetic, basic geometry, and statistics.
5. Familiarity with estimating software in depth and with available building cost databases.
6. Knowledge of building construction methods.
7. Knowledge of labor productivity, crew composition, and impacts of various forecasted site conditions on crew output.
8. Possession of office managerial skills in organizing project-related cost information.
9. Ability to work under pressure and to meet all bid requirements and deadlines.

The American Association of Cost Engineering, International (AACE) conducted a US survey oriented to Cost Engineering Function: The Estimator. The results were published in the *Cost Engineering Journal*, 42:9, September 2000. Table 1.24 is an adaptation of those published data. The more interested reader is encouraged to obtain the original source document.

Summarizing this 2000 survey, the male estimators with work-related experience of 20 years had an average salary of $67,632/year out of 278 respondents, and the female estimators with work-related experience of 13.5 years reported an average income of $53,348/year out of 24 respondents. The average entry-level salary in US dollars was reported at $36,940 for male and $33,836 for female. 70% of all respondents had an undergraduate or graduate degree.

1.7.2 The Estimating Group

The major function of the estimating group or department in a contractor or subcontractor organization is to price a future project to see if it can be obtained by either the bid procedures or by negotiation. During the quantities take-off phase for a selected portion of a project, a continuously successful bidder will have speed, accuracy, standardization, and completeness. Another important function

TABLE 1.24 Cost Estimating Function

Survey/Analysis	Rel. freq. (%)	Age (years)	Work related experience ave. (yrs.)	2000 Base salary (US$) Ave. ($)	2000 Base salary (US$) Std. dev. ($)	2000 Base salary (US$) #	Entry level salary (US$)
Gender							
Male	92.4	44.6	20.2	67,632	26,650	278	36,940
Female	7.6	38.9	13.5	53,348	17,470	24	33,836
Job satisfaction							
Very dissatisfied (1)	4.5	44.9	21.7	73,171	26,631	14	32,311
Somewhat dissatisfied (2)	12.3	45.1	19.2	64,000	25,632	36	34,615
Somewhat satisfied (3)	47.2	43.3	18.8	61,388	25,569	142	36,350
Very satisfied (4)	35.9	44.6	20.6	73,595	26,385	105	38,258
Level of education							
High school (1)	7.1	46.5	21	64,446	28,225	22	35,644
Associate degree (2)	15.2	44.5	19.7	54,364	20,459	47	32,209
Undergraduate/bachelor's degree (3)	55.8	43.1	18.8	69,157	29,018	164	37,117
Graduate/master's degree (4)	21.3	46.5	21.9	70,809	19,516	63	39,143
Graduate/doctoral degree (5)	0.6	40.5	15.5	61,386	16,425	2	40,294
Type of education							
Eng only	56.1	44.1	19.8	67,891	26,943	169	36,326
Bus only	11.5	45.6	18.9	64,637	24,888	33	39,064
Eng and bus	14.6	40.7	18.3	66,639	29,864	45	37,099
Neither	17.8	46.3	20.9	63,211	22,030	55	36,339
Professional certification							
PE only	9.2	44.4	20.1	66,927	31,395	29	35,852
CCE/CCC only	11.1	47.1	22.8	80,576	24,325	31	39,728
PE and CCE/CCC	4.8	52.7	29.7	81,423	18,559	15	38,810
None	74.8	43.2	18.5	63,533	25,470	227	36,370
Years of job-related experience							
1–5	9.9	29.4	3.3	40,982	12,299	29	29,528

6–10	12.7	33.6	8.4	50,163	23,392	39	34,402
11–15	16.9	39.4	13.8	58,642	18,339	51	35,995
16–20	17.8	43.7	19.1	68,581	23,196	55	37,105
21–25	13.4	49	24.1	73,059	21,713	41	35,191
26–30	17.5	52.6	28.3	77,629	20,977	51	39,927
31–35	6.4	53.8	34	81,847	23,714	20	43,327
36–40	3.5	59.6	38.5	110,000	42,119	10	46,276
>40	1.9	66	44.5	80,505	29,267	6	31,918
Number of people managed							
0 (no managerial duties	46.5	42.8	17.5	58,239	20,129	140	34,875
1–5	35.4	44.8	20.9	68,360	25,823	107	36,245
6–10	12.1	47.6	23.8	82,910	30,120	36	42,227
11–50	5.4	43.8	21.2	89,690	30,820	17	40,049
51–100	0.6	50	19.5	52,274	71,737	2	40,039
>100	0.0					0	
Number of employees in company							
1–5	3.0	48	23	76,250	44,307	8	41,857
6–10	3.6	45.1	20.1	65,436	23,411	11	31,930
11–50	14.5	39.6	15.6	59,247	26,558	43	34,724
51–100	6.3	40.4	16.1	62,935	21,748	17	36,499
101–500	26.3	43.7	19.8	67,590	30,159	78	38,329
501–1000	6.9	43.7	18.6	65,583	23,556	21	36,735
1001–5000	19.4	44.5	19.4	67,692	22,389	57	37,608
5001–10,000	7.9	45.3	20.4	68,267	24,484	24	36,201
10,001–50,000	10.5	51.3	26.9	72,562	25,356	29	36,290
>50,000	1.6	38.8	15.6	59,400	18,913	5	31,618
Employment status							
Employed full-time				66,497	26,304	302	36,741
All information below refers to full-time employment only							
Industry							
Chemical process	9.2			70,811	26,435	27	36,738
Construction—heavy	8.6			65,889	28,793	25	36,115

Table 1.24 Continued

Survey/Analysis	Rel. freq. (%)	Age (years)	Work related experience ave. (yrs.)	2000 Base salary (US$)			Entry level salary (US$)
				Ave. ($)	Std. dev. ($)	#	
Construction—other	31.5			66,441	29,626	97	35,848
Consulting	10.5			70,326	29,606	33	36,843
Environmental	4.1			74,131	20,668	13	41,273
Facilities management	1.6			62,139	12,759	5	36,591
Government	6.4			62,502	20,427	19	34,703
Manufacturing	8.6			56,831	22,423	25	34,564
Mining/minerals	1.3			59,250	7,871	4	48,895
Oil/gas production	4.1			66,970	28,025	12	29,361
Power generation/utilities	6.4			72,858	21,700	20	39,013
Transportation	2.2			83,833	13,924	6	43,643
Project type(s)							
Architecture	10.2			65,962	28,905	71	35,196
Construction	33.1			67,751	27,398	237	36,426
Engineering	20.7			67,281	28,151	150	35,113
Environmental	6.4			70,928	23,589	47	36,450
Facility management	5.8			74,579	32,311	40	37,795
Maintenance/service	5.4			62,312	31,298	38	30,763
Media production	0.4			61,833	65,350	3	23,880
Operations/research	2.8			63,298	28,758	18	35,949
Procurement	3.2			63,653	31,257	23	35,360
Product development	5.2			61,346	28,982	37	34,009
Research and development	4.1			71,884	31,615	27	38,498
Software development	0.8			60,476	57,556	6	28,402
Telecommunications/IT	0.8			55,903	20,497	6	29,166
Other	1.1			67,833	14,407	8	37,714

Source: *Cost Engineering* 42:9, September, 2000.

is to survive in the competitive building construction market. This can be achieved by following these guidelines.

1. Study the market opportunity and find out about upcoming projects of interest to the company.
2. Develop a project breakdown associated with estimated quantities and costs.
3. Assist the purchasing department with information for placing orders and needed delivery dates.
4. Assist in pricing and negotiation of project changes.
5. Develop a timely payment schedule.
6. Maintain cost reporting and control.
7. Brief the company executives and project managers about job cost status, outlook, and possible deviations.
8. Actively participate in recording the final quantities of work, project close-outs, and project disputes.

There is no substitute for on the job training for new or entry-level estimators. This is a continuous function for large and diversified contractors. Estimators-in-training should have workstations near more experienced estimators and short courses related to estimating software utilization. They should also accompany supervisors on field trips to projects, close-outs, and the like. From an educational point of view, contractors prefer engineering graduates (see Table 1.24), but high school graduates may be trained by an experienced estimator for a limited scope of work or narrowly specialized field. For site construction experience, it is most often mandatory to have a few years experience with building projects and up to 10 years for heavy construction. No contractors report selecting estimators directly from college who have no practical training or construction experience.

Estimators need more space than most office employees in a contractor organization. Most often they need two distinct workstations: one for quantity take off and one for pricing and telephone communication. For quantity take off they need one or two drafting size tables (one could be a digitizer), two or three storage filing cabinets for past and new project files, tackboards on walls, and shelves for project documentation, cost files, estimating software materials, reference books, and so on. For pricing and telephone communication with vendors and subcontractors, they need a large desk with a computer station to fulfill their basic needs.

As a whole, the estimating group needs a conference room for briefing or negotiating with subcontractors, suppliers, and the architect/engineer, or staff coordination meetings should be located close to the chief estimator's office. The area where the estimators work should be quiet, out of traffic from other employees, and above all secure during and after work.

1.7.3 The Cost of Estimating

Preparing estimates and bidding for new jobs is not a cheap operation. The cost of preparing estimates and bidding is accounted for under general overhead or the cost of doing business. If a contractor is unsuccessful in too many bids, then the cumulative cost of estimating is high and the volume of work on hand will curtail business growth and threaten corporate survival. On average, a general contractor expects the following cost estimating expenses in percentages of the bid value: new buildings 5%, sewage/water treatment plants 7.5%, and roads and bridges 1.25%. The effectiveness of an average-to-large estimating group should be evaluated once a year, considering the following cost-benefit ratio (more research is needed in this direction):

1. The number of jobs under contract versus the number of jobs bid in a year;
2. The amount of profit produced by projects successfully bid;
3. The degree of competition in the market where the contractor is operating, or the average number of bidders per project;
4. The cost of estimators and staff preparing the bid (timesheets should be kept to trace the man-hours spent for preparing each bid); and
5. The total cost of preparing the bids.

Implementing these procedures will, first, monitor fairly the performance of the estimating group, and will, second, lead to a reduction of the general overhead portion related to getting new work or business promotions.

1.8 REVIEW QUESTIONS

1. How many construction firms were operating in 1992 in the United States?
2. How many construction firms were reported as nonemployers?
3. What was the average profit for the domestic market reported by general contractors in 1999?
4. Name the five general contractors who have topped the market since 1980.
5. What was the percentage of total revenue for the general building industry in 1999?
6. Name a few types of specialty contractors surveyed by the *Engineering News Record*.
7. What was the business revenue for the largest specialty contractor in 1999?
8. Describe the composition of the Construction Cost Index (CCI).
9. Describe the composition of the Building Cost Index (BCI).

10. Give an example for figuring the future project cost (today) using CCI published indexes if the 1980 project cost $10 million.
11. What agency is in charge of monitoring the changes in the Consumer Price Index for the entire US?
12. What are the conceptual differences between Master Format and Uniformat systems promoted by the Construction Specification Institute (CSI)?
13. Describe the most frequent estimating errors that occur during construction estimate preparation and submittal.
14. What is the most common level of education for estimators as recorded by the AACE-I 2000 survey?
15. Enumerate the secondary functions of the estimating department in a contractor organization.

Chapter 2

Types of Estimates

2.1 BUILDING COST ESTIMATES CLASSIFICATION

There are many ways of classifying building cost estimates. The most significant of these are the degree of project definition, the end usage of the estimate, and the estimate generating methodology. The first classification, the degree of project definition, is based upon the percentage of completed architectural and engineering designs. It defines available input information to the estimator. The second classification, the end usage of the estimate, is based on available data progress and covers conceptual estimates for investment feasibility, and studies funding authorization, budgets, and contractor detail estimates for lump-sum bidding. The third classification, the estimate generating methodology, is based on processes employed to forecast building costs that are stochastic and deterministic.

In the stochastic approach, the base for cost estimating is the quantity of work units being installed (m^2 of tiles, number and type of windows, etc.). The base for estimating the cost is usually m^2 of the constructed building or the number of units (number of cars in a parking garage, number of beds in a hospital, number of students in a high school, etc.). The cost estimating techniques used in the stochastic approach are influenced by many variables that are considered by experienced estimators, variables which most of the time are not well defined.

In the deterministic approach, the project is well defined and estimators consider two variables, namely, the quantity of a specific category of work and the estimated unit price to complete one unit. The unit price is a variable function dependent upon location, time, and contractor experience and management skills.

Related to various types of building cost estimates, a prudent owner or contractor must associate the "expected accuracy range." The estimate accuracy is an indication of the degree to which the future final (true) cost of a building varies from the estimate prepared earlier. Accuracy is usually expressed as a positive or negative percentage range surrounding an estimated future cost. Table 2.1 provides a general overview of construction estimates in use at the time of this writing and are shown in relationship with a building lifecycle in Figure 2.1.

The project total cost is greater than engineering and construction costs because items such as land acquisition, market study, environmental studies, and financing costs are also included. A critical element for controlling the cost, schedule, and scope of a project is gaining and maintaining control of the design process. Failure to control and manage this process will result in delays and increased construction costs.

Design review submittals or status drawings should be issued at prescribed intervals during the design phase. At the beginning of the project, the manager needs to determine the frequency of submittals to be prepared and the purpose of these submittals. Typical frequencies for these submittals are at the 30, 60,

TABLE 2.1 Building Cost Estimates Classification

Estimate class 1	Scope 2	Project definition % A/E complete 3	Beneficiary 4	Expected accuracy range[a] (%) 5	Methodology 6
Conceptual estimate	Feasibility study	<10	Owner(s) Financier	−25, +50	Historical information, m^2 or m^3 or units
Engineering estimate (1)	Reevaluate feasibility for financing	30	Owner(s) Financier	−20, +40	m^2 or m^3 or units
Engineering estimate (2)	Reevaluate for construction financing	60	Owner(s) Financier	−15, +25	m^2 or m^3 or units finishing and systems well defined
Engineering estimate (3) budget estimate	Budgeting for construction evaluate the bids	90	Owner(s) Financier Construction Manager	−10, +15	m^2 or m^3 or units, systems, components
Contractor detail estimate	Bidding contractor(s) construction budget	100	Financier Const. Mgr. Owner(s) Contractor Subcontrators	−5, +10	Detail quantity take off Detail unit price estimate

[a] Degree of project final cost may vary from the "estimated" cost.

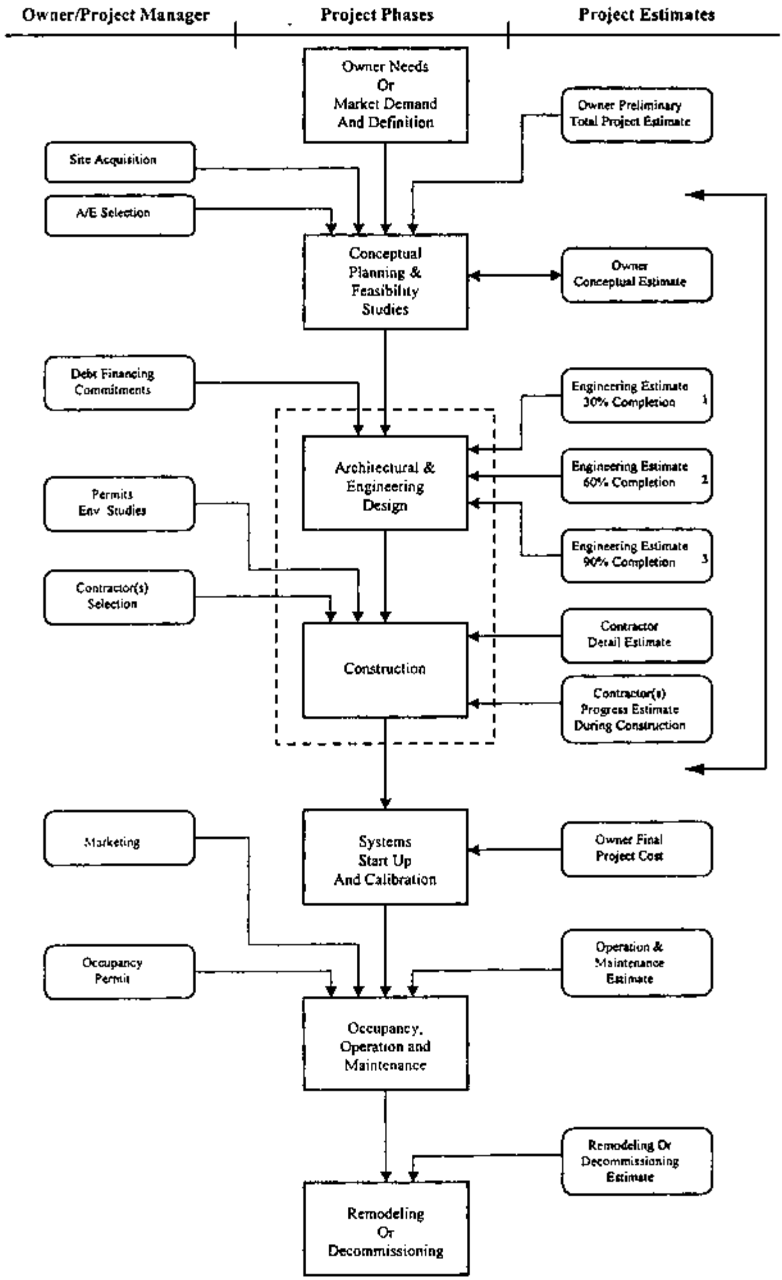


FIGURE 2.1 Project lifecycle estimates.

and 90% phases of design (commonly referred to as design development). Some managers prefer just two submittals at 50 and 90%. The more complex a project, the more frequently the manager may need to review the design. In most instances, the 90% design submittal should reflect a completed set of design documents. The last 10% incorporates any final review comments or permitting authority requirements into the bid set documents.

Between the 30 to 40% phase of the design cycle is a good time for the project team to review the design. By this point in the process, many of the critical design decisions, such as building footprint, major equipment types, processes, and so on, have been made and will be reflected in the documents. The 30% design submittal is the foundation for producing the first engineering estimate based on drawings, "as it exists on paper." In this design stage the estimator can develop quantities of work and apply actual unit prices.

Depending on the complexity of the building, a 60% submittal is the foundation for the second engineering estimate which will serve for:

1. Verifying that proposed systems and subsystems meet project needs;
2. Comparing the original proposed budget with more precise quantities and finishes' quality requirements;
3. Identifying unresolved problems that will greatly influence the final building cost; and
4. Reviewing the drawings and specifications for construction capabilities by a team of construction professionals (especially in a design-build or turnkey contractual agreement).

The 90% design submittal should be the completed set of bid documents. Since this is a "last chance review," the owner should be sure that the goals of the project are totally achieved. However, if changes are needed, such as the finishing date being delayed, it is less expensive to make the changes now before the contract is let than during construction. In this design phase, a set of documents will be sent to the permitting authorities for their review.

During the design process, either the designer or the project manager should prepare cost estimates based on known information at the data date to determine the project cost status. For a complex building, a comparison estimate is also recommended. If discrepancies greater than 10% exist between two estimates prepared by different estimators, then it is in the interest of the project for the two estimators to identify and resolve the differences. If the construction estimate is greatly different from the previous conceptual estimate, the following actions need to be taken by the project manager.

1. Make a detailed review of the estimate, unit prices, and magnitude of contingencies and/or markup, to determine if there really is a problem.

2. Recommend modifications (as necessary) to the scope of the project, along with the related reductions in project cost.
3. Increase the project budget, if possible, in order to maintain the original scope of the project.
4. Restructure the construction procurement contract to lead to a cost reduction during construction and startup phase.

Part of the general scope of work for an estimator is the development of a detailed cost breakdown structure, usually based on CSI format or Uniformat. The estimator should also identify during design development those items with high cost increase and reduction in order to balance the budget within the authority of the project manager. If the costs of the project continue to exceed the budget cost reduction as listed, then the above actions must promptly be taken to avoid delaying the project.

2.2 CONCEPTUAL ESTIMATES (ENGINEER'S ESTIMATE)

One method often employed in preparing early engineering estimates is to apply published standard average costs per unit area, unit volume of a building, or occupancy unit (cars in a parking garage, beds in a hospital, students in a high school, etc.). Several difficulties may be encountered using this technique of estimating the cost of a building based on available data summaries.

1. Published cost standards seldom represent 100% of the project under consideration.
2. The location factor of adjusting a city or community is not accounted for in the published standard.
3. The time factor involved in extrapolating future construction cost variations may differ.

The common procedure of applying standard cost by area, volume, or unit of occupancy requires that the estimator complete the following steps.

1. Determine the usable area of the building, volume, or number of occupant units.
2. Select from the most recently published standards for the type of building that most closely matches the project, the unit area, unit volume, or occupancy unit standard cost. See Figure 2.2 and Table 2.2.
3. Adjust selected standard costs to a project's location using regional adjustments factors (see Figure 2.3).
4. Fine-tune the time-adjusted costs by site differences or unusual characteristics, special requirements for interior and exterior finishes, scale

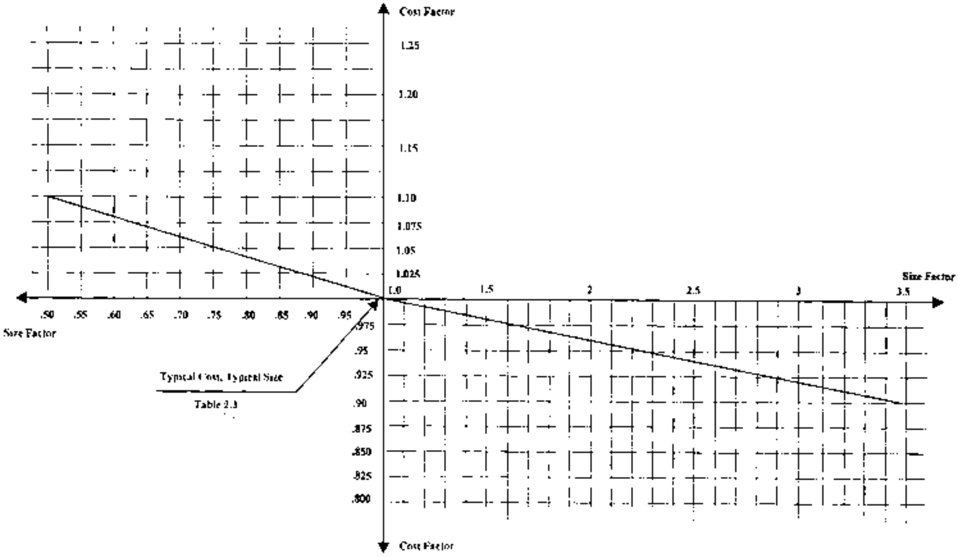


FIGURE 2.2 Building size factor (cost/m^2), orientative only. (From Means, *Building Cost Data*, 58th ed., 2000.)

adjustments, and specialized fixed equipment or systems not accounted for in the "standard."

5. Correct adjusted unit cost with the time factor (usually inflation) considering the midpoint of the construction phase (months from the date of estimate). See Table 2.3.

This elementary procedure can provide a quick and relatively easy method of obtaining a preliminary project estimate. A primary weakness of this approach, however, is that the available standard costs seldom match unique features of the project of interest. Even when the type of building or structure generally agrees with the standard, it is unlikely that every feature or proportion will be the same.

Example 2.1

An owner's intention is to build a small department store complex of good quality with an area of 3000 m^2 in Austin, Texas. Planned construction is to start in the early Spring of 2002. For a feasibility study, the owner needs the probable cost of construction. The estimator plans to use available data published by the R.S. Means Company for performing the estimate. From Table 2.2 he selects the cost/m^2 listed for department stores as \$544/m^2. The average US cost of \$544/m^2

Table 2.2 Building $/m² and Average Gross Area (2000) and Quality Class Cost/m² Modifier Factor

Building type	Avg. cost/unit		Avg. gross area m²	Avg. quality m²	Quality class modifier factor avg. = 1		
	Unit	Cost (2000)			Low	Good	Best
Apartment 1–3 levels	Ap.	60500	2000	582	0.80	1.34	1.86
Apartment 4–7 levels	Ap.	76500	4600	735	0.82	1.22	1.44
Apartment 8–24 levels	Ap.	73000	28800	843	0.83	1.21	1.42
Auditoriums	N/A		2300	972	0.74	1.35	1.70
Banks	N/A		400	1302	0.84	1.12	1.40
Churches	N/A		800	878	0.79	1.30	1.5
Clubs, country	N/A		600	878	0.85	1.31	1.5
Colleges classrooms, admin(?)			4600	1152	0.76	1.35	1.6
Colleges laboratories			4200	1679	0.82	1.20	1.4
Community centers			900	916	0.74	1.34	1.56
Court houses			3000	1249	0.86	1.15	1.38
Department stgores			8400	544	0.74	1.24	1.54
Dormitories 1–3 story	Bed	33300	2300	939	0.70	1.20	1.37
Dormitories 4–8 story	Bed	28300	5200	1216	0.76	1.22	1.45
Fire stations			500	920	0.74	1.24	1.55
Funeral homes			700	1012	0.80	1.15	1.30
Garages, parking	Car	11800	15100	337	0.7	1.80	2.46
Garages, service			900	643	0.90	1.08	1.16
Gymnasiums			1800	850	0.78	1.27	1.53
Hospitals	Bed	97500	5100	1604	0.85	1.48	1.94
Housing for the elderly	Unit	63500	3400	795	0.80	1.23	1.48
Housing public (low rise)			3300	737	0.75	1.30	1.61

TABLE 2.2 Continued

Building type	Avg. cost/unit		Avg. gross area m²	Avg. quality m²	Quality class modifier factor avg. = 1		
	Unit	Cost (2000)			Low	Good	Best
Jails			1300	1776	0.78	1.30	1.64
Libraries			1100	1047	0.78	1.25	1.42
Medical clinics			700	1003	0.81	1.25	1.50
Motels	Unit	43800	2500	721	0.82	1.17	1.37
Nursing homes	Bed	36200	2100	969	0.75	1.21	1.40
Offices 1–4 story			800	785	0.8	1.11	1.38
Offices 1–4 story			4800	825	0.80	1.19	1.36
Offices 1–4 story			24200	1055	0.80	1.20	1.37
Police station			1000	1313	0.74	1.25	1.50
Post offices			1200	973	0.79	1.26	1.60
Research laboratories			1800	1367	0.7	1.45	2.00
Restaurants	Seat	4200	400	1180	0.75	1.31	1.73
Retail stores (small)			700	578	0.83	1.13	1.30
Schools, elementary	Pupil	10500	3800	842	0.74	1.36	1.85
Schools, junior high	Pupil	11300	8500	857	0.68	1.50	2.20
Sports arenas			1400	715	0.72	1.47	2.0
Supermarket			1900	580	0.8	1.14	1.32
Swimming pools			1200	1345	0.89	1.08	1.20
Movie theaters			1000	858	0.87	1.14	1.28
Town halls			1000	943	—	—	—
Warehouses			2300	389	—	—	—

Source: Means, *Building Construction Cost Data*, 58th Edition *National Building Cost Manual*, 1999.

		TENNESSEE						TEXAS											
DIVISION		MEMPHIS			NASHVILLE			ABILENE			AMARILLO			AUSTIN			BEAUMONT		
		375, 380 - 381			370 - 372			795 - 796			790 - 791			786 - 787			776 - 777		
		MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL
02	SITE CONSTRUCTION	100.6	92.5	94.4	96.1	100.7	99.7	103.1	84.4	88.8	103.2	85.5	89.6	90.3	86.5	87.4	98.5	82.8	86.4
03100	CONCRETE FORMS & ACCESSORIES	96.3	61.3	66.2	96.0	68.6	72.4	96.6	54.3	60.3	100.3	60.8	66.4	99.0	65.5	70.2	106.0	71.6	76.5
03200	CONCRETE REINFORCEMENT	93.6	61.0	75.1	93.4	61.7	75.4	95.7	63.3	77.3	95.7	56.9	73.7	93.6	64.9	77.3	93.8	59.3	74.2
03300	CAST-IN-PLACE CONCRETE	97.4	67.7	85.0	91.0	66.7	80.9	99.1	50.9	79.0	102.8	60.2	85.0	89.2	62.5	78.1	92.8	68.5	82.7
03	CONCRETE	90.8	65.4	78.0	87.7	68.3	77.9	90.7	55.8	73.1	92.7	60.6	76.6	81.2	64.9	73.0	88.7	68.6	78.6
04	MASONRY	82.5	64.3	71.2	84.6	62.6	70.9	99.8	54.4	71.5	103.5	52.6	71.8	100.0	59.3	74.7	103.0	71.3	83.2
05	METALS	97.2	93.0	95.7	99.8	91.2	96.7	96.8	73.7	88.5	96.8	70.9	87.5	96.9	74.3	88.9	97.1	73.2	88.5
06	WOOD & PLASTICS	94.6	62.4	77.9	91.2	70.9	80.7	96.4	56.6	75.3	99.7	63.3	80.9	97.1	68.4	82.3	107.2	74.2	90.1
07	THERMAL & MOISTURE PROTECTION	99.9	66.0	84.0	97.2	64.8	82.0	96.6	60.1	79.5	98.7	56.6	78.5	94.9	64.3	80.6	96.6	71.0	84.6
08	DOORS & WINDOWS	99.8	66.1	91.6	93.8	69.3	87.8	93.6	58.4	85.0	93.6	58.0	84.9	96.2	67.6	89.2	98.1	67.5	90.7
09200	PLASTER & GYPSUM BOARD	101.2	61.5	76.6	100.1	70.5	81.8	94.8	55.1	70.2	94.8	63.2	75.2	95.9	68.3	78.8	96.9	74.4	83.0
09500	CEILINGS	90.4	61.5	71.4	91.8	70.5	77.8	107.5	55.1	71.4	102.5	63.2	76.7	90.3	68.3	75.8	106.9	74.4	85.6
09600	FLOORING	93.4	55.5	84.2	99.5	68.1	91.8	118.9	60.7	104.7	118.7	54.3	103.0	98.7	62.4	89.8	116.3	78.1	108.5
09900	PAINTS & COATINGS	98.0	67.0	79.9	107.3	62.2	81.0	94.7	70.7	80.7	94.7	50.5	68.9	99.3	56.7	74.4	90.5	68.1	77.4
09	FINISHES	94.9	60.4	77.3	101.7	68.1	84.6	102.6	57.1	79.4	102.6	58.6	80.2	94.1	64.1	78.8	99.0	72.8	85.6
10 - 14	TOTAL DIV. 10000 - 14000	100.0	73.2	94.3	100.0	73.3	94.4	100.0	70.9	93.8	100.0	64.3	92.4	100.0	67.7	93.2	100.0	75.7	94.9
15	MECHANICAL	100.0	66.2	84.7	100.0	65.1	84.2	100.0	46.7	75.9	100.0	56.3	80.2	99.9	61.9	82.7	99.9	64.9	84.0
16	ELECTRICAL	98.6	77.5	84.2	100.8	59.5	72.6	97.6	49.4	64.8	98.5	59.9	72.2	97.4	67.5	77.0	94.5	75.0	81.2
01 - 16	WEIGHTED AVERAGE	96.8	72.3	84.9	96.9	71.0	84.4	97.7	58.1	78.5	98.3	62.0	80.7	95.5	67.3	81.9	97.5	71.8	85.1

		TEXAS																	
DIVISION		BROWNWOOD			BRYAN			CHILDRESS			CORPUS CHRISTI			DALLAS			DEL RIO		
		768			778			792			783 - 784			752 - 753			788		
		MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL
02	SITE CONSTRUCTION	110.7	83.4	89.8	88.3	83.1	84.3	116.3	84.1	91.6	125.9	81.6	92.0	129.2	83.1	93.9	111.5	85.2	91.3
03100	CONCRETE FORMS & ACCESSORIES	93.9	39.1	46.9	79.6	53.0	56.8	94.2	59.7	64.5	102.5	52.1	59.2	96.3	68.6	72.5	90.7	34.4	42.4
03200	CONCRETE REINFORCEMENT	97.6	34.7	62.0	98.0	65.1	79.4	96.4	55.2	73.1	91.8	54.6	70.7	95.1	65.3	78.2	93.6	24.1	54.2
03300	CAST-IN-PLACE CONCRETE	106.8	46.7	81.7	74.4	71.6	73.2	101.6	58.5	83.6	105.8	57.5	85.6	103.9	67.2	88.5	113.9	40.5	83.3
03	CONCRETE	97.7	42.1	69.8	73.9	62.7	68.3	98.3	59.1	78.6	91.2	56.6	73.8	91.4	69.1	80.2	105.8	35.9	70.7
04	MASONRY	125.0	45.7	75.6	139.7	64.9	93.1	103.5	51.5	71.1	90.7	53.6	67.6	94.2	67.8	77.8	105.9	39.8	64.7
05	METALS	94.9	58.1	81.7	97.4	75.9	89.7	94.7	68.8	85.4	96.4	87.6	93.2	97.7	91.1	95.3	95.6	52.5	80.1
06	WOOD & PLASTICS	93.7	38.0	64.9	73.9	49.2	61.1	94.6	63.3	78.4	107.2	52.9	79.1	101.3	70.4	85.3	86.0	35.4	59.9
07	THERMAL & MOISTURE PROTECTION	96.8	48.4	74.1	91.0	66.9	79.7	97.4	54.6	77.3	97.5	57.9	79.0	93.5	70.0	82.5	95.1	39.0	68.8
08	DOORS & WINDOWS	89.7	38.7	77.3	100.5	56.2	90.2	90.7	58.5	82.9	103.4	52.9	91.1	107.3	66.7	97.5	97.1	29.9	80.7
09200	PLASTER & GYPSUM BOARD	93.5	37.0	58.5	88.7	48.6	63.9	93.1	63.2	74.5	97.0	52.0	69.2	98.2	70.4	81.0	93.1	34.2	56.6
09500	CEILINGS	98.3	37.0	58.1	102.8	48.6	67.2	98.3	63.2	75.2	95.8	52.0	67.1	105.1	70.4	82.3	87.5	34.2	52.5
09600	FLOORING	117.5	51.8	101.5	88.3	67.8	83.7	116.3	54.3	101.2	110.7	59.0	98.1	111.2	72.0	101.6	95.7	24.8	70.4
09900	PAINTS & COATINGS	94.7	40.6	63.1	85.9	75.7	80.0	94.7	53.7	70.7	114.1	50.6	77.0	100.5	66.1	80.4	99.3	35.7	62.1
09	FINISHES	101.7	41.3	70.8	87.0	56.8	71.6	101.8	58.5	79.6	100.6	53.0	76.3	104.0	69.1	86.2	93.4	33.5	62.8
10 - 14	TOTAL DIV. 10000 - 14000	100.0	57.9	91.1	100.0	65.9	92.8	100.0	63.3	92.2	100.0	71.3	93.9	100.0	75.5	94.8	100.0	54.6	90.4
15	MECHANICAL	96.8	39.8	71.0	96.7	74.6	86.7	96.8	54.6	77.7	99.9	47.1	76.0	99.9	67.7	85.3	96.6	25.0	64.6
16	ELECTRICAL	91.0	37.6	54.6	90.5	72.8	78.4	97.6	51.3	66.1	94.3	62.0	72.3	99.1	71.3	80.2	97.4	26.7	49.3
01 - 16	WEIGHTED AVERAGE	98.1	47.1	73.4	94.9	68.3	82.5	97.7	39.5	79.2	98.6	60.5	80.1	[illegible]	72.6	86.8	99.4	39.3	69.7

FIGURE 2.3 City cost indexes. (From Means, *Building Cost Data*, 58th ed., 2000.)

needs to be adjusted to its location in Austin, Texas using the weighted average factor of 81.9/100 from Figure 2.3. This is only one of many pages related to city cost indexes published annually in the US by the R. S. Means Company. To arrive at the probable cost of this store to be built in 2002, several additional factors need to be considered for this conceptual estimate: quality desired, size adjustment compared with typical stores, project location, and certainly inflation/deflation. Considering all these factors, the computation example follows (Year 2000 = 100, assuming a 2% increase/year).

Desired Department Store Size = 3000 m^2.
Cost \$/m^2 Average US (2000 = 544\$/m^2 (Table 2.2).
Quality Factor = 1.24 (Table 2.2).
Size Adjusting Factor (3000/8400 = 0.36) = 1.1 (Fig. 2.2).

TABLE 2.3 Historical Cost Indexes[a]

Year	Historical cost index Jan. 1, 1993 = 100	Year	Historical cost index Jan. 1, 1993 = 100	Year	Historical cost index Jan. 1, 1993 = 100
		1983	80.2	1966	22.7
1999	117.6	1982	76.1	1965	21.7
1998	115.1	1981	70.0	1964	21.2
1997	112.8	1980	62.9	1963	20.7
1996	110.2	1979	57.8	1962	20.2
1995	107.6	1978	53.5	1961	19.8
1994	104.4	1977	49.5	1960	19.7
1993	101.7	1976	56.9	1959	19.3
1992	99.4	1975	44.8	1958	18.8
1991	96.8	1974	41.4	1957	18.4
1990	94.3	1973	37.7	1956	17.6
1989	92.1	1972	34.8	1955	16.6
1988	89.9	1971	32.1	1954	16.0
1987	87.7	1970	28.7	1953	15.8
1986	84.2	1969	26.9	1952	15.4
1985	82.6	1968	24.9	1951	15.0
1984	82.0	1967	23.5	1950	13.7

[a] Adjustments to costs: this index can be used to convert national average building costs at a particular time to the approximate building costs for some other time. Time Adjustment using the Historical Cost Indexes: Index for Year A/Index for Year B × Cost in Year B = Cost in Year A.

Location Factor (city cost index) = .819 (Fig. 2.3).
Time Factor = 1.04 (Table 2.3).

Thus, $3000\ m^2 \times 544\$/m^2 \times 1.24 \times 1.1 \times .819 \times 1.04 = \$1{,}896{,}000$. Considering ±10% estimate accuracy, the owner figures a maximum budget for the 2002 project to be around 1,896,000 times 1.1, or $2 million.

Many times the contractor invited for a building project negotiation still in the design phase is asked by the owner to provide a preliminary conceptual estimate. An actual estimate for a building complex (office building and a detached parking garage) in the year 2002 and located in Austin, Texas is shown in Figure 2.4.

2.3 FIRM PRICE CONTRACTING ESTIMATE

When the design is completed (including contracting documents), a client may advertise for competitive bids, request proposals for competitive bids, or request proposals for a negotiation leading to a negotiated contract. Most often when project

	Quantity	Unit	Unit Cost	Subtotal	Total
Garage					
	2880	m^2	$173.6	500,000	500,000
Structure 70 Stalls			$7,142		
Building					
Demolition				N/A	N/A
Sitework	-		-	500,000	500,000
Structure					2,088,000
Floor Structure	7,200	m^2	$150	1,080,000	
Roof Structure	7,200	m^2	$120	864,000	
Balcony Premium		m^2		w/skin	
Roof	1,440	m^2	$100	144,000	
Penthouse				w/struct&roof	
Skin	2,640	m^2	$300	792,000	792,000
Finishes					1,410,000
Flooring	7,200	m^2	30	216,000	
Cabinets	50	unit	8,000	400,000	
Drywall and Ceilings	7,200	m^2	50	360,000	
Paint and Wallcovering	7,200	m^2	20	144,000	
Appliances	50	unit	4,000	200,000	
Lobbies	6	ea	15,000	90,000	
Stairs	14	flt	10,000	140,000	140,000
Elevators	15	st	20,000	300,000	300,000
Fire Sprinkler	7,200	m^2	20	144,000	144,000
Plumbing	7,200	m^2	80	576,000	576,000
HVAC	7,200	m^2	120	864,000	864,000
Electrical	7,200	m^2	90	648,000	648,000
Subtotal Building	7,200		$1,036		$7,462,000
Subtotal Building and Garage					7,962,000
Gen. Cond/Fee/Ins/Bonds	12.5% of Subtotal				1,000,000
Contingency	10% of Subtotal + Gen. Cond.				900,000
Total Estimated Cost					**$9,862,000**

FIGURE 2.4 Contractor preliminary conceptual estimate.

financing is based on public funds (city, county, state, federal), then competitive bids are required. Both approaches require the interested constructor to estimate the probable cost of completing project requirements in the time specified.

2.3.1 Estimate Types, Frequencies, and Usages

In the competitive bids scenario, several options regarding future project cost are available to finalize a price contract.

If the contractor or subcontractor is called to provide only the labor for installation and the client is providing the materials and needed construction equipment, then a "unit crew hours" estimate is appropriate. The final quantity of work may vary between the same limits known at the invitation to bid. The contractor will submit in her proposal the estimated number of specialized crews, hours required, and an estimated labor cost per unit installed assuming normal site conditions.

If the contractor has to provide a total direct cost for each unit of work installed in addition to labor cost, then she must figure the cost of materials and equipment needed for installation. In this situation, a cost line item for jobsite overhead and profit should be incorporated in the response to the invitation to bid as a separate general cost line item. This approach will reduce the chance for disputed costs close to project completion.

Another approach often used by subcontractors supplying cost data to the general contractor, who is preparing a response to an invitation to bid, is to provide a unit bid estimate. This is similar to the previous scenario, but the estimated job cost overhead and profit are reflected in the cost of installing one unit of bid work. The estimated unit cost of work is based on engineering estimated total quantity of work with an accepted variation of $\pm 10\%$. Most often, larger quantities of work will be reflected in a lower unit price and the opposite situation is also valid.

A lump-sum estimate is applicable when the design contract documents are 90 to 100% completed. The burden of figuring the total quantity of work and related unit prices falls entirely on the general contractor and subcontractors participating in the bid proposal. Any change in quantities, installation methods, or required quality will be reflected in a project change order which may lead to an increase or decrease of the original contract amount. The response to the invitation to bid also reflects the direct costs of all construction divisions, jobsite overhead, general overhead, and estimated profit.

2.3.2 Unit Price Estimating

2.3.2.1 One Unit Crew-Hour Estimate

Usually, construction work is not performed by a single worker. Instead, there is a labor force organized into crews of various sizes for maximum productivity.

Crew composition may represent multiple trades and include skilled and unskilled workers. As a base for estimating labor costs, R.S. Means in their *Building Construction Cost Data*, 58th edition, 2000, recognizes more than 300 construction crews to cover all possible construction items identified by the Construction Specification Institute and organizes them into 16 specification divisions. Figure 2.5 is a sample page of masonry-related crews from *Building Construction Cost Data,* 2000. For example, crew D-8 is made up of 3 bricklayers and 2 bricklayers' helpers. On a normal workday (8 h day) the crew will record 5×8 h/day = 40 crew-hours. For the estimator, field engineer, and construction manager, it is important to know the expected production of this crew associated with the work specified for the building. Crew D-8 is associated with many types of masonry work. Based on past performance and assuming normal site condition, the production rate per day is known. Table 2.4 provides average production data recorded in the US. Similar information recording crew productivity can be found in other published building cost files.

The number of crew-hours perceived to be required per unit of a line item of work is applied by the estimator to the total quantity taken off to obtain the total crew-hours of labor. The total crew-hours estimated are then converted into cost by applying the weighted local average hourly skill in the crew. The total labor cost for a category of work, divided by the estimated quantity provides the labor cost/unit of work. Specialty trade contractors (such as mechanical, piping, or electrical) extensively utilize unit labor-hour estimating. Compiled by the Mechanical Contractors Association of America, Figure 2.6 illustrates a unit labor-hour estimate for "Toilet Room Accessories" as a guide for mechanical contractors.

The main advantage of unit crew-hour estimating is that it identifies the influence of weighted crew average hourly rates to the total estimated labor cost.

2.3.2.2 Unit Direct Cost

Unit direct cost analysis is a procedure employed by building subcontractors when the total quantity of work is not well defined (± 20%) at the bid phase and figures the cost of materials, labor, and equipment for each unit of work to be completed or installed. The cost of subcontractor jobsite and general overhead, including the profit, is shown as a separate cost line item in response to the invitation to bid. This unit cost is the base for lump-sum estimates when the final quantities of work are defined with a little margin of error. The unit direct cost analysis can be illustrated by the following building project example. Assuming that a masonry subcontractor is preparing a direct cost estimate for exterior concrete block masonry (200 mm × 400 mm × 150 mm), not including the scaffolding, of regular weight for a large two-story building in Dallas, Texas, to be started and completed in the year 2000. The crew composition for this type of work is made up of 3 bricklayers and 2 bricklayer's helpers (Crew D-8) with a daily output as indicated in Table 2.4, line 220 250 0100 of 36.23 m^2 or 1.104 crew-

Crews

Crew No.	Bare Costs		Incl. Subs O & P		Cost Per Labor-Hour	
Crew D-1	**Hr.**	**Daily**	**Hr.**	**Daily**	**Bare Costs**	**Incl. O&P**
1 Bricklayer	$28.55	$228.40	$44.35	$354.80	$25.48	$39.58
1 Bricklayer Helper	22.40	179.20	34.80	278.40		
16 L.H., Daily Totals		$407.60		$633.20	$25.48	$39.58
Crew D-2	**Hr.**	**Daily**	**Hr.**	**Daily**	**Bare Costs**	**Incl. O&P**
3 Bricklayers	$28.55	$685.20	$44.35	$1064.40	$26.28	$40.87
2 Bricklayer Helpers	22.40	358.40	34.80	556.80		
.5 Carpenter	28.15	112.60	44.30	177.20		
44 L.H., Daily Totals		$1156.20		$1798.40	$26.28	$40.87
Crew D-3	**Hr.**	**Daily**	**Hr.**	**Daily**	**Bare Costs**	**Incl. O&P**
3 Bricklayers	$28.55	$685.20	$44.35	$1064.40	$26.19	$40.71
2 Bricklayer Helpers	22.40	358.40	34.80	556.80		
.25 Carpenter	28.15	56.30	44.30	88.60		
42 L.H., Daily Totals		$1099.90		$1709.80	$26.19	$40.71
Crew D-4	**Hr.**	**Daily**	**Hr.**	**Daily**	**Bare Costs**	**Incl. O&P**
1 Bricklayer	$28.55	$228.40	$44.35	$354.80	$25.25	$38.99
2 Bricklayer Helpers	22.40	358.40	34.80	556.80		
1 Equip. Oper. (light)	27.65	221.20	42.00	336.00		
1 Grout Pump, 1.5 m^3/hr		67.20		73.90		
1 Hoses & Hopper		31.60		34.75		
1 Accessories		10.55		11.60	3.42	3.76
32 L.H., Daily Totals		$917.35		$1367.85	$28.67	$42.75
Crew D-5	**Hr.**	**Daily**	**Hr.**	**Daily**	**Bare Costs**	**Incl. O&P**
1 Bricklayer	$28.55	$228.40	$44.35	$354.80	$28.55	$44.35
8 L.H., Daily Totals		$228.40		$354.80	$28.55	$44.35
Crew D-6	**Hr.**	**Daily**	**Hr.**	**Daily**	**Bare Costs**	**Incl. O&P**
3 Bricklayers	$28.55	$685.20	$44.35	$1064.40	$25.58	$39.76
3 Bricklayer Helpers	22.40	537.60	34.80	835.20		
.25 Carpenter	28.15	56.30	44.30	88.60		
50 L.H., Daily Totals		$1279.10		$1988.20	$25.58	$39.76
Crew D-7	**Hr.**	**Daily**	**Hr.**	**Daily**	**Bare Costs**	**Incl. O&P**
1 Tile Layer	$27.45	$219.60	$40.65	$325.20	$24.78	$36.68
1 Tile Layer Helper	22.10	176.80	32.70	261.60		
16 L.H., Daily Totals		$396.40		$586.80	$24.78	$36.68
Crew D-8	**Hr.**	**Daily**	**Hr.**	**Daily**	**Bare Costs**	**Incl. O&P**
3 Bricklayers	$28.55	$685.20	$44.35	$1064.40	$26.09	$40.53
2 Bricklayer Helpers	22.40	358.40	34.80	556.80		
40 L.H., Daily Totals		$1043.60		$1621.20	$26.09	$40.53
Crew D-9	**Hr.**	**Daily**	**Hr.**	**Daily**	**Bare Costs**	**Incl. O&P**
3 Bricklayers	$28.55	$685.20	$44.35	$1064.40	$25.48	$39.58
3 Bricklayer Helpers	22.40	537.60	34.80	835.20		
48 L.H., Daily Totals		$1222.80		$1899.60	$25.48	$39.58
Crew D-10	**Hr.**	**Daily**	**Hr.**	**Daily**	**Bare Costs**	**Incl. O&P**
1 Bricklayer Foreman	$30.55	$244.40	$47.45	$379.60	$26.76	$41.36
1 Bricklayer	28.55	228.40	44.35	354.80		
2 Bricklayer Helpers	22.40	358.40	34.80	556.80		
1 Equip. Oper. (crane)	29.90	239.20	45.40	363.20		
1 Truck Crane, 11 metric ton		401.35		441.50	10.03	11.04
40 L.H., Daily Totals		$1471.75		$2095.90	$36.79	$52.40
Crew D-11	**Hr.**	**Daily**	**Hr.**	**Daily**	**Bare Costs**	**Incl. O&P**
1 Bricklayer Foreman	$30.55	$244.40	$47.45	$379.60	$27.17	$42.20
1 Bricklayer	28.55	228.40	44.35	354.80		
1 Bricklayer Helper	22.40	179.20	34.80	278.40		
24 L.H., Daily Totals		$652.00		$1012.80	$27.17	$42.20
Crew D-12	**Hr.**	**Daily**	**Hr.**	**Daily**	**Bare Costs**	**Incl. O&P**
1 Bricklayer Foreman	$30.55	$244.40	$47.45	$379.60	$25.98	$40.35
1 Bricklayer	28.55	228.40	44.35	354.80		
2 Bricklayer Helpers	22.40	358.40	34.80	556.80		
32 L.H., Daily Totals		$831.20		$1291.20	$25.98	$40.35
Crew D-13	**Hr.**	**Daily**	**Hr.**	**Daily**	**Bare Costs**	**Incl. O&P**
1 Bricklayer Foreman	$30.55	$244.40	$47.45	$379.60	$26.99	$41.85
1 Bricklayer	28.55	228.40	44.35	354.80		
2 Bricklayer Helpers	22.40	358.40	34.80	556.80		
1 Carpenter	28.15	225.20	44.30	354.40		
1 Equip. Oper. (crane)	29.90	239.20	45.40	363.20		
1 Truck Crane, 11 metric ton		401.35		441.50	8.36	9.20
48 L.H., Daily Totals		$1696.95		$2450.30	$35.35	$51.05

FIGURE 2.5 Masonry crews. (From Means, *Building Construction Cost Data*, 58th ed., 2000.)

TABLE 2.4 Masonry Crew D-8 Daily Output

Means line number			Masonry work description	Unit	Daily output	Unit crew (hrs)
070	420	0200	Concrete block grouting by hand	m^2	102	0.392
210	120	2020	Brick veneer standard, running bond	m^2	20.44	1.957
210	350	0100	Structural facing tile, no scaffolding, 100 mm	m^2	20.44	1.957
210	220	1000	Concrete block, bark-up, no scaffolding, reinforced, alternate courses	m^2	40.41	0.990
220	250	0100	Concrete block exterior not including scaffolding, reinforced, alternate courses, tooled joints 2 sides	m^2	36.23	1.104
220	260	0200	Concrete block foundation wall, no scaffolding, normal weight, cut joints, parged 13-mm thick	m^2	41.81	0.957
220	320	0200	Concrete screen block, 203 mm × 406 mm; 102-mm thick	m^2	16.72	2.392
220	700	0100	Glazed concrete block, single face, 200 × 400 × 50 mm	m^2	33.45	1.196
270	200	0100	Glass masonry units, plain, 150 mm × 150 mm × 100 mm	m^2	10.63	3.744
414	500	0040	Marble ashlar, split face, 100-mm+ thick, random length	m^2	16.26	2.460
430	100	0011	Quarried stone, ashlar veneer 100 mm+, random, sawn face, low-priced stone	m^2	13.01	3.075

Source: Means, *Building Construction Cost Data*, 2000.

hours for each m^2. For this category of masonry work the direct cost (or 2000 bare cost) to be found in R.S. Means' *Building Construction Cost Data*, 2000 for each m^2 of completed work is:

1. Materials (regular weight concrete blocks size 200 × 400 × 150 mm) including some waste and the needed masonry mortar = \$12.60/m^2.
2. Labor (cost/day of indicated Crew D-8, 3 bricklayers and 2 helpers) assuming an average production rate of 36.23 m^2/day = \$29/m^2.
3. Total materials and labor cost at average US rates, \$12.60 Materials/m^2 + \$29 labor/m^2 = \$41.60/m^2.
4. Total direct cost (2000 bare cost) adjusted to Dallas, Texas calculated assuming average US direct costs adjusted by a factor to project location (City Cost Index). See Figure 2.3.

MECHANICAL CONTRACTORS ASSOCIATION OF AMERICA, INC.
5530 Wisconsin Ave., Washington, D C. 20015, Suite 750

PLUMBING FIXTURES & ACCESSORIES

TOILET ROOM ACCESSORIES

	Size	Manhours Recessed or Semi-Recessed	Manhours Surface Mount
Washroom Cabinet with Paper Towel & Soap Dispenser, Mirror & Shelf	30" x 17" x 4"	2 62	1 50
Paper Towel Disposal	48" x 14" x 7"	2 62	1 50
Paper Towel Dispenser/Disposal	30" x 15" x 8"	2 62	1 50
Paper Towel Dispenser	17" x 12" x 4"	2 62	1 50
Paper Towel Dispenser	15" x 11" x 4"	—	1 12
Duplex Feminine Napkin/Tampon Dispenser	32" x 14" x 6"	2 62	1 50
Partition Mounted Dual Napkin Disposal	17" x 13" x 4"	--	1 50
Toilet Paper Dispenser	15" x 7" x 3"	2 62	1 50
Surface Mtd Extra Roll Toilet Tissue Dispenser	13" x 5" x 6"	—	1 50
Toilet Seat Cover Dispenser	13" x 12" x 2"	2 62	1 50
Toilet Seat Cover Dispenser/Napkin Disposal	28" x 12" x 4"	2 62	1 50
Partition Mtd Dual Toilet Seat Cover Dispenser/Napkin Disposal	38" x 16" x 12"	—	1 50
Facial Tissue Holder	12" x 6" x 3"	1 88	1 12
Bedpan & Urinal Cabinet	60" x 17" x 6"	2 62	1 50
Soap Tank	16" x 13" x 6"	2 62	1 50
Soap Valve		—	1 12
Foot Operated Liquid Soap Dispenser	12" x 6" x 6"	—	1 50
Single Soap Dispenser with Shelf & Reservoir	16" x 12" x 4"	1 12	—
without Shelf	6" x 4" x 4"	—	1 12
Basin Mtd Counter Top Soap Dispenser	12" x 4" x 4"	—	1 12
Single Roll Toilet Paper Holder		1 12	1 12
Double Roll Toilet Paper Holder		—	1 12
Robe Hook		—	75
Towel Bar	24"	—	1 50
Recessed Soap Dish & Grab Bar		1 12	—
Mirror w/Shelf	16" x 24"	—	1 88
Mop & Broom Holder Strip		—	1 12
Ash Tray		—	1 12
Shower Rod w/Fasteners	5'	—	1 50
Sanitary Napkin Dispenser	26" x 10" x 7"	—	1 50
Bottle Opener		—	75

FIGURE 2.6 Plumbing fixtures and accessories. (Courtesy of Mechanical Contractors Association of America, Inc., Washington, DC.)

The adjusted unit price for Dallas can be obtained in one of the following ways.

1. By adjusting materials cost and installation cost individually for masonry work; thus $\$12.60/m^2 \times 0.942 + \$29/m^2 \times 0.678 = \$31.53/m^2$.
2. By adjusting the total direct (base) cost average US with the Dallas masonry factor; thus $\$41.60/m^2 \times 0.778 = \$32.36/m^2$.

As can be seen in these examples, both computations follow correct methodology yet lead to different results. The estimator's judgment as well as using the same sources (cost files) for cost information and location adjusting factors are important for estimate consistency.

2.3.2.3 Unit Bid Price Estimate

Unit direct cost and unit bid price estimates are acceptable only when the estimator uses a reliable database of known crew production rates and unit prices for various kinds of construction work. Contractors and subcontractors who use this method for preparing a bid typically maintain accurate updated records of similar work performed. The difference between direct cost unit price and unit bid price is the cost of jobsite overhead, general overhead, and contractor profit prorated for each unit of work. The disadvantage of unit bid price estimating is that big differences will result between estimated and actual cost in unit prices obtained for given work. One set of labor wages and materials cost prevailing in a particular location are often inapplicable in other geographical areas. In addition to a new project location and building configuration, a unit bid price estimate is also affected by jobsite conditions, organization, environment, subcontractor general organization, and the amount of desired profit. Considering the same source for unit cost information as in the previous subsections, the quoted unit weight including contractor overhead and profit is shown as $\$58.50/m^2$ average US. See Figure 2.7.

The adjusting cost computation to Dallas, Texas (which, based on Fig. 2.3, is $\$58.5/m^2 \times 0.0778 - \$45.51/m^2$), represents an increase of 40 to 50% compared to the direct cost for each unit of work. Each individual contractor and subcontractor has the responsibility to figure the appropriate markup factor for a particular job and location. A wrong assumption could lead to a lost bid or to financial loss at project completion.

2.3.3 Lump-Sum Estimate

Once the design has been completed, the owner will call for either competitive bids or proposals leading to a negotiated agreement. The highly competitive nature of this contracting practice creates a difficult business environment in which

250	0010	**CONCRETE BLOCK, EXTERIOR** Not including scaffolding										250
	0020	Reinforced alt courses, tooled joints 2 sides, foam inserts										
	0100	Regular, 200 mm x 400 mm x 150 mm thick	D-8	36.23	1.104	m²	12.60	29		41.60	58.50	
	0200	200 mm thick		33.91	1.180		14.65	31		45.65	64	
	0250	250 mm thick		32.98	1.213		17.20	31.50		48.70	68	
	0300	300 mm thick	D-9	30.66	1.566		26.50	40		66.50	91.50	
	0500	Lightweight, 200 mm x 400 mm x 150 mm thick	D-8	38.09	1.050		23	27.50		50.50	67.50	
	0600	200 mm thick		35.77	1.118		33.50	29		62.50	82	
	0650	250 mm thick		34.37	1.164		29	30.50		59.50	79	
	0700	300 mm thick	D-9	32.52	1.476		36.50	37.50		74	98.50	
260	0010	**CONCRETE BLOCK FOUNDATION WALL** Scaffolding not included										260
	0050	Normal-weight, trowel cut joints, parged 13 mm thick, no reinforcing										
	0200	Hollow, 200 mm x 400 mm x 150 mm thick	D-8	41.81	.957	m²	14	25		39	54.50	
	0250	200 mm thick		39.95	1.001		16.15	26		42.15	58.50	
	0300	250 mm thick		39.02	1.025		22	27		49	65.50	
	0350	300 mm thick	D-9	36.70	1.308		23.50	33.50		57	78	
	0500	Solid, 200 mm x 400 mm block, 150 mm thick	D-8	40.88	.979		17.75	25.50		43.25	59	
	0550	200 mm thick		38.55	1.037		22.50	27		49.50	66.50	
	0600	300 mm thick	D-9	35.30	1.360		35	34.50		69.50	92.50	
270	0010	**CONCRETE BLOCK, HIGH STRENGTH** Scaffolding not included										270
	0050	Hollow, reinforced alternate courses, 200 mm x 400 mm units										
	0200	21 MPa, 100 mm thick	D-8	39.95	1.001	m²	10.35	26		36.35	52	
	0250	150 mm thick		37.16	1.076		12.15	28		40.15	57	
	0300	200 mm thick		34.84	1.148		14.30	30		44.30	62.50	
	0350	300 mm thick	D-9	31.59	1.520		26	38.50		64.50	89	
	0500	34 MPa, 100 mm thick	D-8	39.95	1.001		16.70	26		42.70	59	
	0550	150 mm thick		37.16	1.076		21.50	28		49.50	67.50	
	0600	200 mm thick		34.84	1.148		32	30		62	81.50	
	0650	300 mm thick	D-9	31.59	1.520		35	38.50		73.50	98.50	
	1000	For 75% solid block, add					30%					
	1050	For 100% solid block, add					50%					

FIGURE 2.7 Concrete block masonry for exterior walls. (From Means, *Building Cost Data*, 58th ed., 2000.)

the construction contractor's profit depends on the ability to accurately take off the quantities of proposed work and to price adequately. The competing contractors have access to future project drawings, specifications that precisely define the project requirements. During the preparation of the contractor's estimate, the estimator measures quantities of various types of work to be completed (excavation, volumes of various types of concrete, masonry, etc.), obtains price quotations from interested subcontractors to work with the general contractor, and finally prices the work not subcontracted out, including estimated expenses related to the project site (jobsite overhead), general expenses, and expected profit or fee. The contractor provides only a lump-sum (total) cost to do the work as required by contract documents made available at and during the bidding period. The contractor is not obliged to provide a detailed estimate nor a cost estimation for all construction work categories. An example of a detailed estimate prepared by a contractor for bidding on a retail center expansion in Austin, Texas with a lump-sum amount of $5,495,760 is shown in Figure 2.8.

Retail Center Expansion - Austin, TX
Bid Day Cut Sheet
EXAMPLE ONLY

Project name	Retail Bid Day Cut Sheet
Client	Retail Stores, Inc. 701 S. Walton Louisville KY
Estimator	FCC
Labor rate table	Austin
Equipment rate table	Austin
Job size	97445 sqft · Sm
Duration	29 wks
Bid date	1/6/00 2:00 PM
Audit	Standard
Other bids	*CSI* Dal-Mac
Report format	Sorted by 'Group phase/Phase' 'Detail' summary

FIGURE 2.8 Retail center expansion.

Description	Labor Amount	Material Amount	Sub Amount	Total Amount	Notes
BID DAY SUMMARY					
DIVISION 1					
Jobsite Personnel	95,250	57,050	-	152,300	FCC
Field Office	1,000	29,950	-	30,950	FCC
Temporary Utilities		19,600	-	19,600	FCC
Safety	2,380	6,280	-	8,660	FCC
Equipment & Small Tools		4,300	3,000	7,300	FCC
Miscellaneous	100	22,145	-	22,245	FCC
Cleanup	19,300	30,925	8,750	58,975	FCC
Testing & Quality Control					***BY OWNER***
DIVISION 2					
Erosion Control	-	-			***IN SITE***
Site Demolition	-	-			***IN SITE***
Termite Control	-	-	10,795	10,785	HILL AND HILL
Building Demolition	0	0	172,893	172,993	SAFECO
Temp Partitions	-	1,000	23,475	24,475	FCC
Temp Entrance	-	-	5,000	5,000	FCC
Sitework - Sub	-	-	796,000	796,000	TEX-STAR
Sitework - Bond	-	-			***NONE***
Asphalt Paving & Base	-	-			***IN SITE***
Asphalt Overlay	-	-			***IN SITE***
Concrete Paving	-	-	86,613	86,613	NATIONAL
Splash Blocks	-	250		250	FCC
Curb & Gutter	-	-	0	0	***IN CONCRETE PAVING***
Site Signage			0		***IN PAVEMENT MARKINGS***
Pavement Markings	-	-	29,085	29,085	STRIPES AND STOPS
Storm Drainage	-	-	233,000	233,000	D & J PLUMBING
Drainage Structures	-	-			***IN STORM***
Sanitary Sewer	-	-			***IN STORM***
Demo/Cap Existing Utilities	-	-			-
Domestic Water	-	-			-
Fire Water	-	-			-
Gas Service	-	-			***IN STORM***
Pole Base - Turnkey	-	-	0	0	***IN BUILDING CONCRETE***
Chainlink Fence - New	-	-	16,435	16,435	FOSTER
Remove/Relocate C.L. Fence	-	-			***IN FENCE***
Hydromulch	-	-	10,000	10,000	FCC ESTIMATE 100,000 SF MAX
Landscape	-	-			***NONE SHOWN***
Irrigation	-	-			***NONE SHOWN***
Irrigation Sleeves					***NONE SHOWN***
Install/Relocate Cart Corrals	500	-		500	FCC
Pressure Wash Sidewalks			2,500	2,500	FCC
DIVISION 3					
Reinforcing - Material	-		-		***IN BLDG CONCRETE***
Masonry Reinforcing - Material	-	7,500	-	7,500	FCC ESTIMATE
Reinforcing - Place		-			***IN BLDG CONCRETE***
Building Concrete - Turnkey	-	-	550,000	550,000	LISTO CONCRETE
DIVISION 4					
Masonry	-	-	243,800	243,800	TEXAS MASONRY
DIVISION 5					
Class A Structural - Material	-	91,885	-	91,885	CARLSON WELDING
Steel Joist & Metal Deck - Mat	-		-		***BY OWNER***
Metal Fab & Misc. Metal - Matl	-		-		***IN STEEL***
Struct/Deck - Erect	-	-	103,900	103,900	SONY
Misc. Metal - Erect					***IN STEEL***
DIVISION 6					
Finish Carpentry	-	-	59,090	59,090	CHALLENGE
Roof Blocking	-	-	0	0	***IN FINISH CARPENTRY***
Interior Rough Carpentry	-	-			***IN ROOF BLOCKING***
Temporary Pharmacy			0		***IN DRYWALL***
DIVISION 7					
Sealants - Building	-	-	16,288	16,288	VERICLEAN
Sealants - Site	-	-			***IN ABOVE***
Building Insulation - Batt	-	-			***IN DRYWALL***
Freezer Insulation	1,084	6,430		7,514	FCC
E.I.F.S.	-	-	25,989	25,989	CRYER
Roofing & Sheetmetal	-	-	204,128	204,128	D & O ROOFING
Roofing Sub - Bond	-	-	5,000	5,000	FCC
Skylights - Material	-	8,060	-	8,060	MIKE ALLEN

FIGURE 2.8 Continued

Description	Labor Amount	Material Amount	Sub Amount	Total Amount	Notes
DIVISION 7					
Skylights - Install	2,600			2,600	IN ROOFING
Roof Curb - Material	-	16,815	-	16,815	AES
Roof Curb - Install		-			***IN STEEL ERECTION***
Decorative Metal Wall Panels			0		***IN ROOF***
Metal Soffit Panels			0		***IN ROOF***
DIVISION 8					
HMtl Drs/Frames/Windows - Matl	-	11,465		11,465	AMERICAN
HMtl Door Leafs - Install		-	9,290	9,290	CHALLENGE
HMtl Frames @ CMU	275	-		275	FCC
HMtl Frames in Gyp Partitions	-	-			***IN DRYWALL***
Overhead Coiling Grilles	-	-			***BY OWNER***
Coiling Counter Doors	1,500			1,500	OFCI
Chain Closures	0		2,220	2,220	CHALLENGE INSTALL
Sectional Overhead Doors					***BY OWNER***
Glass & Glazing	-	-	16,662	16,662	SPRING GLASS
Auto Door Operators					***BY OWNER***
Aluminum Store Fronts	-	-			***IN GLASS***
Translucent Wall/Skylight Pnls	-	-	9,448	9,448	ROB PELLETIER
Access Doors - Material	-	2,000	-	2,000	FCC
Access Doors - Install		-			***IN TRADES***
Flex Traffic Dr.-Mat'l AND STRIP	-		10,943	10,943	ZANES
Flex Traffic Dr.-Install	0		2,080	2,080	CHALLENGE INSTALL
Finish Hardware - Mat'l	-	15,249	-	15,249	AMERICAN
Finish Hardware - Install			0		***IN DOOR INSTALLATION***
DIVISION 9					
Drywall	-	-	419,220	419,220	CHALLENGE
Acoustical Ceiling	-	-			***IN DRYWALL***
Resilient Floor	-	-	65,360	66,360	FLOOR SERVICE
Carpet	-	-			***BY OWNER***
Floor Treatment (clean&wax)	-	-	0	0	***IN RESILENT***
Painting	-	-	99,025	99,025	SYSTEMS PAINTERS
Special Coatings	-	-			***IN PAINT***
Vinyl Wall Covering	-	-			***IN PAINT***
Ceramic Tile	-	-	35,500	38,500	G-MAN
Quarry Tile	-	-			***IN CERAMIC***
F. R. P. PANEL - MAT'L	-		-		***BY OWNER***
F. R. P. PANEL - Install			0		***IN DRYWALL***
DIVISION 10					
Toilet Partitions - Mat'l		0	13,114	13,114	ZANES
Toilet Partitions - Install	0				***IN PARTITIONS***
Toilet Accessories - Mat'l					***IN PARTITIONS***
Toilet Accessories - Install	0				***IN PARTITIONS***
Install O.F. Toilet Access	650			650	FCC
Corner Guards - Mat'l		360		360	ZANES
Corner Guards - Install	0		310	310	CHALLENGE
Install O.F. Equipment	2,500	1,500		4,000	FCC
DIVISION 11					
Loading Dock Equip			12,820	12,820	BCI
Food Service Equipment					***BY OWNER***
DIVISION 13					
Energy Monitoring & Control					***BY OWNER***
Glazed Structures			120,642	120,642	LUDY
DIVISION 15					
Plumbing	-	-	220,000	220,000	BUCKLEY
Plumbing - BOND	-	-			***NO BOND***
Fire Sprinkler System	-	-	124,800	124,800	FEDERAL
Fire Sprinkler Sys. - BOND	-	-			***NO BOND***
H V A C	-	-	142,782	142,782	BATES
H. V. A. C. - BOND	-	-			***NO BOND***
DIVISION 16					
Electrical	-	-	508,000	508,000	A & H ELECTRIC
Electrical - BOND	-	-	25,000	25,000	BOND PLUS DOUG

FIGURE 2.8 Continued

Faulkner Construction Co. Retail Center Expansion - Austin, TX Page 4A 2/17/00 8:54 AM

Estimate Totals

Labor	127,139			
Material	332,764			
Subcontract	4,444,057			
	4,903,960	4,903,960		
Total Payroll Tax/w Workers Cm	48,949		38.500 %	C
AUSTIN Sales Tax	27,453		8.250 %	C
	76,402	4,980,362		
Base Bldr Risk 1-Mo Inland SFR	797		0.016 %	T
Builders Risk*Duration - 1Mo.	5,676			L
Owner's Protective Liability	2,493		0.050 %	T
AGC Fees - Aust./S.Ant./Valley	6,122			B
	15,088	4,995,450		
Overhead & Profit	449,590		9.000 %	T
	449,590	5,445,040		
Bond (Over 500,000)<12 Mo.	50,720			B
	50,720	5,495,760		
	Total	***5,495,760***	***56.399 /sqft***	

FIGURE 2.8 Continued

2.4 NONFIRM-PRICE CONTRACTING

2.4.1 Introduction

Proposals other than the firm-price type generally are applied to construction projects not fully described by advance plans and specifications or perhaps only envisioned as a preliminary concept of what is required by the owner/client. Incomplete tender documents, however, are only one reason why an owner would award the work without competitive bids on a conditional basis. Some owners, for reasons of their own that might include the desire to avoid publicity for their project, prefer to negotiate in confidence with known constructors, sometimes on a variable-price basis. There are circumstances where industrial organizations make a practice of negotiating their proposed construction with given contractors to obtain the superior technical advantages and talents of the contractor's organization. The urgency of saving time is possibly the strongest reason for not following the time-proven method of competitive bidding.

Proposals other than firm-price expose the owner/client to some risks not common to fixed-price bids. Such transactions should not be entered into except between highly reputable firms and where there is a substantial amount of mutual confidence. However, history shows many variations other than firm-price contracts. During the last decade, more and more owners preferred new approaches in

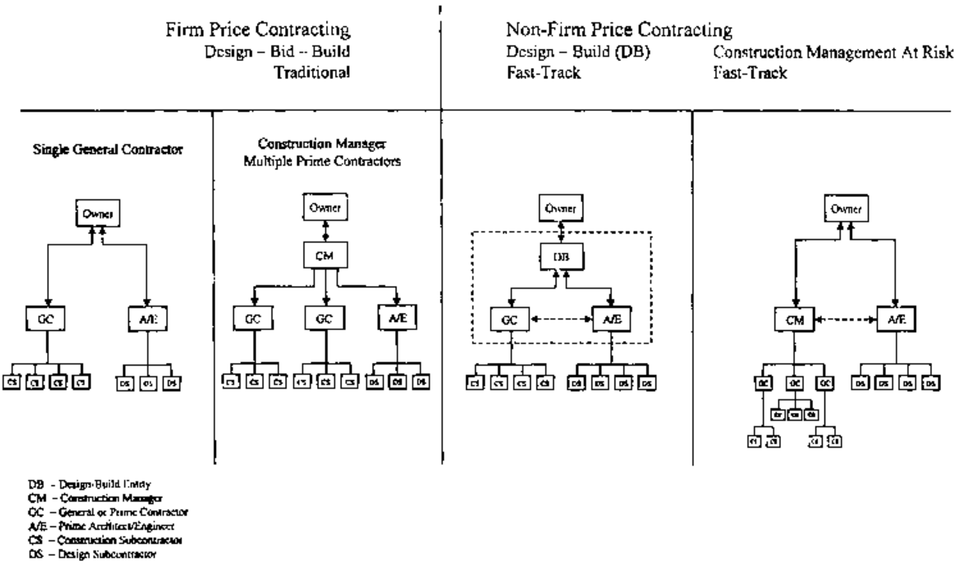


FIGURE 2.9 Project delivery systems. DB: design-build entity; CM: construction manager; GC: general or prime contractor; A/E: prime architect/engineer; CS: construction subcontractor; DS: design subcontractor.

project delivery organization. The most common patterns are shown in Figure 2.9.

Basically, nonfirm-price contracts fall into these general categories, each of which is discussed in greater detail below:

Cost plus a percentage fee,
Cost plus a fixed fee,
Cost plus a fixed fee with guaranteed maximum price,
Target price with incentive fee and penalty fee, and
Turnkey projects (not discussed below).

2.4.2 Cost Plus a Percentage Fee Contracts

A cost plus a percentage fee contract is usually applied to a situation where advance construction details are minimal. Sometimes only sketch plans and tentative specifications are available at the time of signing the contract for construction. Economic feasibility is usually involved and the parties to the contract, plus the third-party engineer/designer for the owner (unless it is a turnkey arrangement), jointly summarize the known facts, conditions, and technical requirements to be part of the contractual considerations. Thus the concept of the work is developed for the benefit of all concerned. The owner almost invariably must know some bracket of probable cost and the contractor is obliged to make the best estimate of what the contract work would cost on the basis of the available information. At this stage, little detailed estimating is done or is possible. But more care should be taken with respect to specialty items of large proportions, such as machinery to be furnished and installed. Some preliminary outside quotations should be solicited for unknown items. The entire matter is then coordinated and assembled and a substantial contingency factor added.

The conceptual methods of estimating are used if the contract is awarded and the construction designs, details, and specifications are advanced by the engineer. As more details become known, the contractor has the responsibility of re-estimating the various parts of the work in accordance with the detailed refined methods employed for fixed-price contracts. Since a cost plus a percentage fee arrangement contemplates complete reimbursement of all necessary costs incurred, plus a fee entirely commensurate with the amount of such cost, it is not necessary to consider the complications of adjusting the compensation to the contractor that are involved in other types of contracts. Usually the percentage fee represents the general cost overhead and contractor(s) profit. It is sometimes possible that the fee includes jobsite overhead costs.

2.4.3 Cost Plus a Fixed Fee Contracts

This type of contractual arrangement normally operates about the same as a cost plus a percentage fee agreement. However, the amount of the contractor's fee is stated as a fixed sum instead of varying with the amount of cost incurred. Reimbursement of all necessary costs for the work is a condition (jobsite overhead expenses included). To apply the principles of this type of contract, there must be available beforehand sufficient preliminary designs (60% completion) and information of record for the contractor to prepare an approximate cost estimate for all the work to be done under the contract. The construction details at this stage are rarely complete. But they should be sufficient to indicate proportion, size, and character of construction that would permit preliminary pricing of the items enumerated by the owner for inclusion in the contract. The contractor then proceeds to prepare an estimate using the principles described for the conceptual estimate in which pricing is based on cost factors known to the contractor for similar types of work. This process might also be classed as conceptual estimating, but it is recognized as possibly the best appraisal of the contract amount that can be made at the time. After the estimate is reviewed by the owner, it is either approved by the parties or modified by mutual agreement. Once approved, the estimate then becomes the basis for figuring the contractor's fee which is determined by the application of a percentage agreeable to the parties. Regardless of how much the actual cost of the work might overrun or underrun the preliminary estimate, the contractor receives only the fixed fee agreed upon by the parties. But the overall scope of the work cannot be changed by the owner.

2.4.4 Cost Plus a Fee with Guaranteed Maximum Fee Contracts

This variation of a cost-plus contract, assures the owner that the proposed venture can cost him no more than a given agreed total amount. It also assures the owner that if the costs exceed that amount, any overruns of cost would reduce or nullify the contractor's fee. In other words, the contract payment conditions decidedly favor the owner. He can, under the condition of the underrun of cost, derive the benefit of such underrun (or whatever proportionate part the contract might provide) and is protected against the cost exceeding an amount to which he might agree. The contractor, on the other hand, assumes the entire risk of a cost overrun and may be in a position to participate in underruns of cost. For this type of contract, the contractor should make a very detailed estimate and justify it to the owner. The amount of the total estimated cost plus the total amount of the fee generally is used as the guaranteed maximum cost to be written into the contract, except for any contingent amounts agreed to by the parties. The estimating and pricing of the contract work should be as refined and complete as possible, with the procedures described on pricing lump-sum and firm-price contracts.

2.4.5 Target Price with Incentive and Penalty Fee Contracts

This type of contract is particularly suited to projects for which only preliminary plans and specifications are available when they are offered for bids or negotiation, but because of the urgency of early completion or for other causes it is desired to get the work underway promptly. Mutual respect and understanding between the parties, again, is the first essential with respect to the success of this type of contract. Although all details of the construction cannot be stated, the description should be sufficient to bear a definite relation to the approximations made in the target estimate (30% design completion is expected). As part of the target estimate, the equivalent of a bid schedule should be prepared, listing the items of work, the approximate quantities for each, and the unit prices forming the basis of the target estimate. The methods of conceptual estimate are used for figuring the target price. The contractor would be required to keep books of account and cost accounts to fit a system and pattern agreeable to the owner, with periodic statements of the accounts and cost accounts. This should be in such form as to permit direct comparison to the target estimate. As time goes on and more things become known or apparent, re-estimates of cost should be made periodically by the contractor on a more refined basis (when design is 60% and

90% completed). These should provide forecasts of ultimate cost to the owner/client, regardless of whether matters are involved that would ultimately constitute a basis for changing the target estimate, which is the base for an incentive or penalty fee. Large overruns in quantities or materially different subsurface conditions that result in substantially greater costs than originally envisioned during early project development are usually considered to be occasions for modifying the target estimate.

For services, the contractor is to be paid a fee. It usually is stated in terms of a percentage of the total target estimate cost. This, in turn, would be stated in terms of a basic fee, which might be 8% of the target final approved estimate. However, if at the time of final settlement of the contract it is found that the actual costs exceed the target estimate costs, then the contractor is penalized at a given rate, say 1%, of the target estimate costs, for a stated amount that the actual cost overruns the target estimate cost. Should savings be realized and the actual necessary costs less than the target estimate costs, the contractor would be rewarded for such underrun of cost by being paid a supplemental fee. It would be measured in terms of a given rate, say 1% of the target estimate costs, for a stated amount that the actual cost underruns the target estimate cost. In lieu of this fee arrangement, provisions are sometimes made for a lower basic fee. There are no penalties for overrunning the target estimate costs, but a bonus for underrunning the target estimate costs by a division of the savings at a rate of, say 25% for the contractor and 75% for the owner, of any amounts by which the actual costs are less than the target estimate costs.

2.5 ACCURACY OF COST ESTIMATES

All building estimates at the engineering (conceptual) or construction (detail estimate) stages are probably either higher or lower than the true cost. If the client requests that the conceptual estimate (90% design completed) be within 5% accuracy of the true cost completion, what techniques or what effort would be needed to achieve the stated accuracy? What is the standard norm for acceptable accuracy for conceptual or detailed estimates? The word "accuracy" as defined in *Webster's College Dictionary* (1999) is "1) the condition or quality of being true, correct, or exact; precision; exactness. 2) The extent to which a given measurement agrees with the standard value for that measurement." For the purpose of this book, *construction cost accuracy* is defined as a percentage difference between the engineering estimate (conceptual 90% design completed) compared to the price of the contract award, or the *conceptual estimate accuracy*. *Bid detail estimate accuracy* is defined as the difference between a contractor's detailed bid estimate (base estimate) and the final construction costs at 100% completion assuming no project scope changes occur during the construction phase. An example of construction industry encounters with engineering estimate accuracy is shown in Table 2.5, which exhibits data collected from AGC–Austin, Texas for building projects of various sizes and types for the period January, 1998 to June, 2000.

Although Table 2.3 is based on various sizes and types of building projects in the Austin, Texas area and vicinity, similar statistics can be developed for other types of projects and geographical locations. Certainly these results cannot be viewed as a building construction industry "standard" for a class of projects in a specified location. There are many factors that have an impact on the direct cost of a building, such as materials to be incorporated, erection labor, and fixed equipment. In addition, a large category of factors is presented below for understanding the magnitude of possible deviation of the estimate from the true price.

2.5.1 Factors Affecting the Accuracy of a Detailed Estimate (Direct Cost)

2.5.1.1 Construction Materials

Materials have two components: quantity and cost. Quantity take off from drawings can vary from the true quantity due to estimator errors, not considering or using a wrong waste factor, or omitting the required average specified in contracting documents. Material quantities are now becoming more frequently available through computer-generated design and analytical programs, which reduce greatly the source of take-off errors. Changing from the English to the metric measurement system will also reduce the error in quantity take off. Material costs can be obtained from contracted unit prices, those costs prevailing at the site area, or from telephone quotes from suppliers. Many published price lists are available today, however, these require sound judgment on the estimator's part as to applicability to the project. The estimator's historical cost data references along with current cost data are likewise used quite commonly.

2.5.1.2 Erection Labor

Craft rates are those prevailing at the site and/or those based on union agreements for projects under or about to begin construction. For early prepared estimates, craft labor rates can be obtained from published reference data such as R.S. Means, Walker, *ENR*, DOL, and many other available sources. Also, similar project information can be referred to and adjusted or estimated by the estimator, as she desires. Estimating the craft or crew needed man-hours is perhaps one of the more difficult tasks facing an estimator. There are many factors that influence labor productivity on a project. The most accurate source is that which is actually being experienced on the project. Quite often experience on similar projects or areas can be utilized. Historical data, with company standards, commercially pub-

Table 2.5 AGC Connect (Austin Data File), New Building Projects Awarded Between 01/01/1998–08/02/2000[2]

Gov. entity 1	Project name 2	Value ($1000) 3	Awarded ($1000) 4	Awarded/ Value (%) 5	Bid date MM/YY 6
State	TxDOT Travel Information Center	2900	3600	124.1	01/98
City	Airport/reception	1500	1333	88.9	02/98
State	Parking garage	5500	5766	104.8	03/98
	Housing	2650	2948	111.2	05/98
	Austin Airport	5000	5974	119.5	06/98
Fed	County Jail	4200	3988	95.0	06/98
City	Emergency Service Building	3500	3880	110.9	07/98
	Convention Center	6000	6095	101.6	07/98
County	County annex	1500	1730	115.3	07/98
State	High security facility	25000	25105	100.4	08/98
Military	General Instruction Building	25000	12142	48.6	09/98
State	TxDOT E&M Facility	1350	1500	111.1	09/98
Military	Launch complex	10000	4475	44.8	09/98
	Aerospace engineering facility	5000	1100	22.0	09/98
	Corrosion control facility	5000	4300	86.0	09/98
	Crash/fire rescue station	5000	4479	89.6	09/98
County	Juvenile facility	2100	2624	125.0	10/98
Military	Communication squadron operation facility	5000	3882	77.6	10/98

State	Safety rest area	4300	4070	94.7	11/98
	TxDOT District HQ	6100	6805	111.6	11/98
Military	Operation facility	10000	5661	56.6	06/99
	Munitions management facility	5000	3200	64.0	06/99
State	Research and technology center	11000	11020	100.2	07/99
	Maintenance facility	1437	1262	87.8	07/99
	Maintenance facility	1250	1203	96.2	07/99
	Lab. maintenance, hazardous mat. facility	1340	1397	104.3	07/99
	Maintenance facility	1230	1140	92.7	07/99
	Maintenance facility	1180	1323	112.1	07.99
	Research and technology center	11000	11000	100.0	07/99
City	Aquatic center	3500	3989	114.0	08/99
	Service center	5600	4400	78.6	11/99
Military	Conforming storage facility	5000	2715	54.3	12/99
	Soldier development center	25000	13313	53.3	12/99
City	Justice center	6300	6715	106.6	02/00
	New law enforcement center	3600	4075	113.2	05/00
Fed	Experimental range HQ	10000	6020	60.2	06/00
Military	Child development center	5000	5623	112.5	06/00
City	Water treatment plant	7500	8660	115.5	06/00
State	McDonald Visitor Center	3400	3458	101.7	07/00
Fed	ASMP Air Deployment Facility Complex	10000	12444	124.4	07/00
Military	Fort Hood soldier service center	25000	11956	47.8	07/00

[a] Public/government buildings.
Source: AGC Connect.

lished data, and the judgment of the estimator, round out the typical sources of pricing information. Chapter 4 addresses in more detail the labor-pricing dilemma. Erecting labor probably leads to the greatest variation among the bidders and between the detail estimate and the true building cost.

2.5.1.3 Fixed Equipment Costs

Equipment quantities are available from the specific equipment procurement specification document, the project equipment list provided by the project engineer, the project descriptive "scope of work," and memos from the project engineer. Also, the estimator may use quantities developed from similar projects, and standard reference cost models. Consideration must be made by the estimator relative to a firm price or one subject to escalation. Equipment costs are also available from vendor's letters, telephone quotes, or again by the estimator using data from a similar project or previous experience. Most of the time the fixed or installed equipment for buildings does not play a major factor in the bidder spread (low, high) or estimate accuracy if the specifications are complete when the detail estimate is prepared. For the organization in charge of building cost estimating, the question is what level of design and engineering information must be provided to the estimator? And how much time is allowed to make an estimate within 5, 10, or 30% accuracy? For better accuracy, more time and higher costs for an estimate will be expected.

2.5.2 Factors Affecting the Accuracy of Conceptual Estimates

Building Types. Various studies related to building projects indicate that the ratio of the bid cost/engineering estimate indicate a mean and standard deviation to be 1.052 and 0.138 (McCoffer, 1976). Public building contracts were underestimated on an average of −5.2%. Another study indicates that for public schools the mean errors of detail estimate (bid) were found to be 6.5% (Morrison and Stevens, 1980).

Size of Contracts. Various studies (McCoffer, 1976; Wilson, 1987; Morrison and Stevens, 1980) including many types and sizes of building and non-building projects indicate that there is no consistent pattern of detail estimate accuracy bias with the project size.

Geographical Location. Very few studies are available to draw a final conclusion. Harvey's (1979) studies indicate significant differences in estimating accuracy (bias) across six Canadian regions.

Number of Bidders. Various studies in several countries revealed a significant negative correlation between low bid/engineering estimate ratios and the number of bids received for each contract. This pattern is true for the periods of "good years" and "bad years" for building construction. That means on building projects where many contractors submit bids, there is a greater probability that the lower bidder will be 5 to 8% under the engineer's estimate.

Ability of Estimators. The accuracy of the estimate is higher if estimators are involved with repetitive type projects, if they have a significant number of years in the field, and if there is a change in the state of the market as economic circumstances occur; unexpected materials' price trend variations and construction labor availability are minimal or considered normal.

Available Levels of Information. There is a direct relation between the levels of design information available to estimate the future cost (10, 30, 60, or 90% design complete) and the accuracy range. Various studies indicate a 15 to 20% standard deviation range; that is, the conceptual estimate reduces to 8 to 15% for detail estimates (design 90% completed).

State of the Construction Market. The cost estimates for buildings in a booming construction market are generally lower than those made in the years or geographical locations with a depressed economy. The accuracy of the estimates, in general, is higher when only few projects are available for bidding in a specific area. A general trend has been recorded of increased estimate accuracy with increased project size and increased bids directly related to the number of bidders.

2.6 REVIEW QUESTIONS

1. What is the expected accuracy range of the engineering estimate prior to bidding?
2. What are the major cost categories to be addressed in the owner's final project cost estimate?
3. What are the difficulties encountered by the estimator during the preparation of a project's conceptual estimate?
4. What is the composition of crew D-6? Explain the carpenters' role in the crew.
5. Explain the differences between "unit direct cost" and "unit bid price."
6. Describe the items included in Division 9 Finishes shown in Figure 2.8. Calculate the total amount subcontracted out by the general contractor.
7. What are common nonfirm construction contracting practices?
8. Describe factors affecting the accuracy of detail cost estimating (refer to direct cost components only).
9. Explain why the number of bidders for a project might affect the accuracy of an engineering estimate?

3

Estimating the Cost of Materials

3.1 DETERMINING MATERIAL QUANTITIES

The first part of an estimating task is to determine the amount of materials that will be required. Material quantities are the fundamental data forming the foundation on which all estimating processes build. This first step in determining the necessary amount of materials is called *quantity take off*.

3.1.1 Quantity Take Off

Quantity take off or quantity survey is a tedious process in determining required construction quantities. In its simplest form, construction cost estimating can be broken down into two major components: the determination of the quantities of work and the computation of the prices associated with those quantities. A quantity surveyor must have a thorough understanding of the construction drawings and the corresponding specifications in order to produce a good cost estimate for the project.

It is often thought that quantity take off is a simple process of reading the dimensions from drawings and performing simple computations to arrive at quantities. However, the quantity take off problem is much broader than that. Apart from determining the quantities of materials that will remain in place as indicated in the drawings, the quantity surveyor must also determine the quantities of materials that are not shown directly in the drawing, such as site modification works and support works. Site modification works include items such as grading, bulk excavation, and dewatering. Support works include items such as concrete formwork and shoring. It is these less prominent components of the construction project that make cost estimating a challenging and complex undertaking.

Quantity take off is an extremely important task with direct implications for the many estimating tasks that follow it. The unit prices and the total prices of materials to procure, labor and equipment requirements, and the scheduling of each activity are all based on the quantity take off. Therefore, it is clear that quantity take off is the foundation and the basis for all other estimating work and ultimately affects the total cost estimate of a project. Therefore, a quantity surveyor must be careful and thorough in her work in order to produce the most accurate calculations for the quantities of all the materials in the project.

3.1.2 Quanity Take Off Procedures

The quantity surveyor performs quantity take off from drawings and specifications. Drawings provide a graphical representation of the details of the project, including dimensions, type of materials, and location information of a component. Specifications complement the drawings by providing additional vital information that is difficult to show on the drawings, such as a specific type of paint to be used and the number of coatings for interior finishes.

1. Linear Calculation: Perimeter of a Concrete Slab

   $60\text{ m} + 50\text{ m} + 60\text{m} + 50\text{ m} = 220\text{ m}$

2. Area Calculation: Surface Area of Slab

   $60\text{ m} \times 50\text{ m} = 300\text{ m}^2$

3. Volume Calculation: Volume of Slab

   $60\text{ m} \times 50\text{ m}\ \ 0.10\text{ m} = 30\text{ m}^3$

4. Unit Measures Calculation: Number of Type "A" Windows on 1st Floor

   2 (North Wall) + 6 (East Wall) + 4 (South Wall) + 5 (West Wall) = 17 units

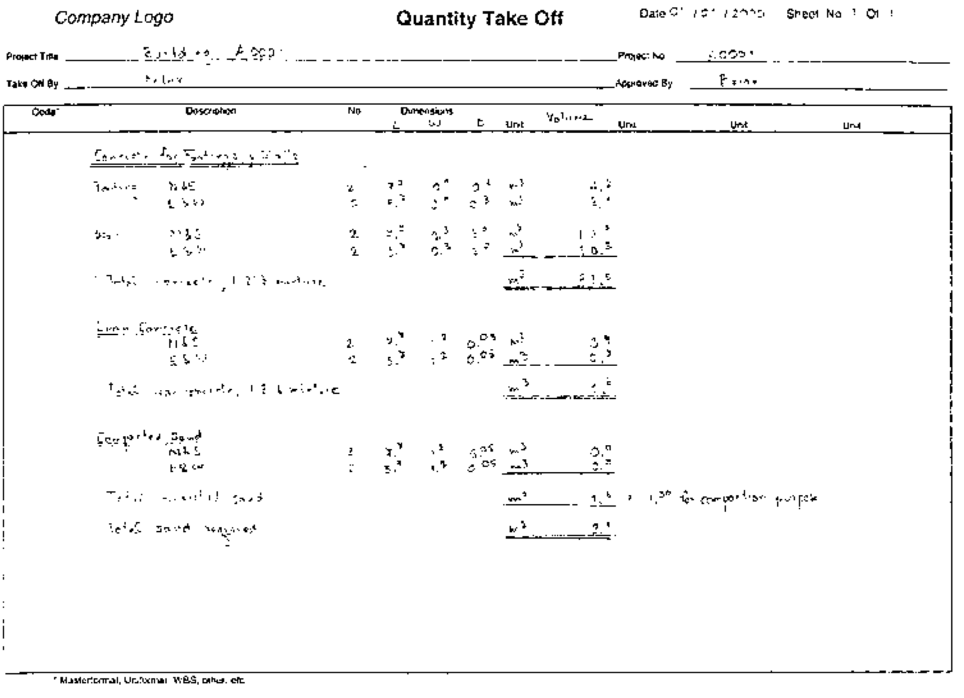
FIGURE 3.1 Examples of the four categories of calculations involved in estimating.

Quantity take off starts with the identification of the work item, such as a brick wall section or a concrete footing. The calculations involved in quantity take off can be categorized into four basic components: linear, area, volume, and unit measures. Linear calculations are used in determining perimeter, length, width, and height, and are the most basic type of construction calculation. Area calculations are obtained by multiplying two linear measurements. Volume calculations are obtained by multiplying three linear measurements. Unit measures are applied to construction items, such as the number of bricks, CMU blocks, windows, and doors. Figure 3.1 provides examples of the four categories.

When performing quantity take off, a quantity surveyor should visualize the entire project, thinking in terms of actual field procedures that will take place during construction. The actual field procedures can then serve as a guide, organizing the estimate in such a way that all interested parties can easily understand it. For example, in concrete take off, the quantity surveyor starts by calculating the volume of the concrete footings, followed by the grade beams, and the slabs on the ground for the basement before proceeding upward to the first and second floors.

Quantity take off is also facilitated by the use of forms associated with each construction division. The purpose of using forms is to standardize the worksheets by providing properly assigned areas where specific information is to be written, thus organizing information in such a way that followup and checking can be easily performed. Information can be more clearly presented by using forms, thus facilitating information retrieval and minimizing the likelihood of committing an error due to "picking out the wrong number." Examples of a quantity take off and a pricing form can be seen in Figures 3.2 and 3.3, respectively.

Another highly useful device enabling effective and efficient quantity take off is the use of checklists. Generally, checklists can be developed and used internally by contractors who have been working with similar kinds of projects. However, many technical books also provide templates of checklists that can be


Company Logo

Quantity Take Off

Project Title

Take Off By

Project No

Approved By

* Masterformat, Uniformat, WBS, other, etc.

FIGURE 3.2 Quantity take-off form.

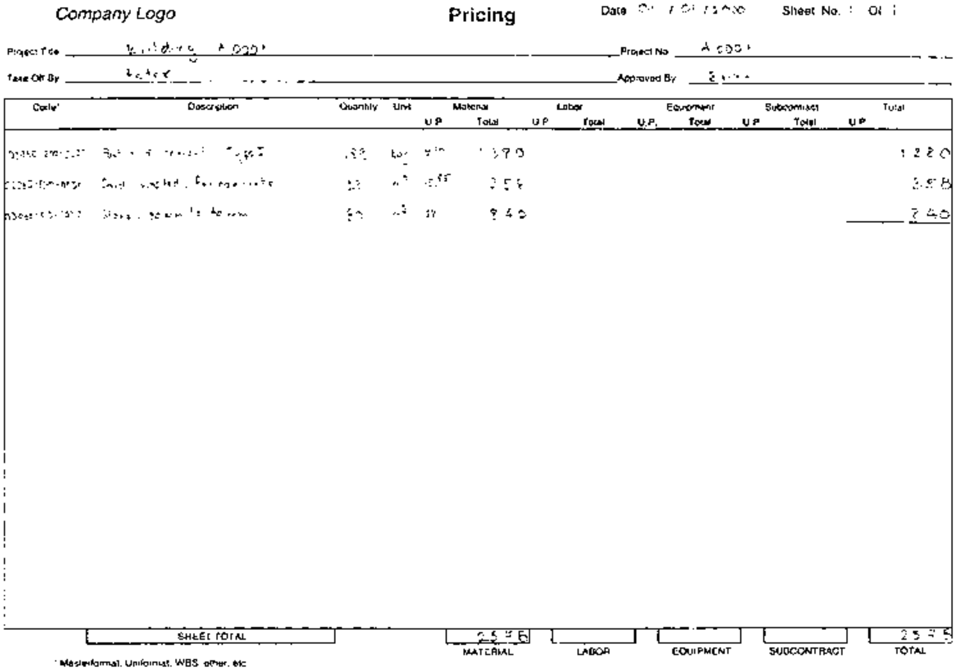
modified to suit the work requirements encountered by a contractor. A checklist can be used to effectively plan quantity take off work by providing a list of work that must be performed. It also serves as the final check on the work, making sure that all work has been completed and nothing omitted. An example of a checklist can be seen in Figure 3.4.

3.2 WASTE FACTORS

In addition to the calculated quantities obtained from quantity take off, the actual material quantities required for a work may be higher due to waste. Waste factor is used to increase material quantity, so as to ensure that enough material is procured to realistically complete the work.

3.2.1 Nature of Waste

Waste refers to the spoilage of materials that results as part of the construction process. Basically, waste in construction is due to two main factors: industrial standards and materials handling and installation.



Company Logo

Pricing

Date | Sheet No. | Of

Project Title | Project No

Take Off By | Approved By

Code*	Description	Quantity	Unit	Material U.P.	Material Total	Labor U.P.	Labor Total	Equipment U.P.	Equipment Total	Subcontract U.P.	Subcontract Total	Total U.P.	Total

SHEET TOTAL | MATERIAL | LABOR | EQUIPMENT | SUBCONTRACT | TOTAL

* Masterformat, Uniformat, WBS, other, etc.

FIGURE 3.3 Pricing form.

3.2.1.1 Industrial Standards

Construction materials are manufactured in standardized sizes that the contractor can procure. Some examples of materials with industrial standards are:

Plywood—for example, 1200 mm × 2400 mm × 16 mm;
Lumber—for example, 50 mm × 100 mm × 2400 mm;
Drywall—for example, 1200 mm × 2400 mm × 16 mm; and
Masonry unit—for example, 90 mm × 57 mm × 190 mm (standard brick).

Materials delivered in standard sizes would then be cut and fabricated to fit specific parts of a construction project. For example, in constructing a brick wall, some bricks will be cut to fit as end pieces. In this manner, waste allowance is a natural part of the construction process.

Quantifying the amount of waste due to the use of industrial standards is relatively easy compared to that which is due to handling and installation. This is because there are fewer variables involved when determining the quantity of

Materials	SP	Sub	Forms & Shoring	SP	Sub	Reinforcement	SP	Sub
1. Cement- types			1. Forms- types, # of uses			1. Bars- grades, # of bars		
2. Aggregate- sizes			2. Erection			2. Wire mesh- sizes		
3. Water			3. Removal			3. Cutting		
4. Color- oxide			4. Repair			4. Bends		
5. Ready-mix- strength			5. Ties			5. Hooks		
6.			6. Clamps			6. Ties		
7.			7. Braces			7. Stirrups		
8.			8. Cleaning			8. Chairs		
9.			9. Oiling			9.		
10.			10. Repairs			10.		
11.			11. Liners			11.		
12.			12.			12.		

Concrete	SP	Sub	Finishes	SP	Sub	Curing & Placement	SP	Sub
1. Footings			1. Hand trowel			1. Admixtures		
2. Walls			2. Machine trowel			2. Ponding		
3. Piers			3. Bush hammer			3. Spraying		
4. Columns			4. Wood float			4. Canvas		
5. Slabs			5. Broom			5. Vapor barrier		
6. Topping			6. Sand- sizes			6. Heating		
7. Beams			7. Rubbed			7. Cooling		
8. Girders			8. Grouted			8.		
9. Stairs			9. Fins- removal			9.		
10. Platforms			10.			10.		
11. Ramps			11.			11.		
12. Miscellaneous*			12.			12.		

*The miscellaneous item in the concrete section includes curbing, coping, walks, driveways, architectural, and testing.

SP: Self-performed items, Sub: Subcontracted items

FIGURE 3.4 Estimating checklist.

waste due to industrial standards since standardized material sizes and desired construction sizes are both known. With good recordkeeping on similar types of work, it is possible to determine the most probable waste factors for an associated work item. Furthermore, waste due to industrial standards is more a function of design factors rather than a given project. Thus, this type of waste factor can be applied to similar work items.

3.2.1.2 Material Handling and Installation

Quantifying waste due to material handling and installation is more difficult and more subjective. This component of waste is influenced by these following project-specific factors:

Pace of work: a rush job usually means more waste;
Site organization factors: degree of site congestion, orderliness, and general site management;
Availability and suitability of equipment and tools to handle and install the materials;
Workers' skills and attitudes;

Types and packaging of materials; and
Storage facilities: protection from the environment as well as theft.

As seen in the above list of factors that can influence the amount of waste, it is clear that the amount of waste due to material handling and installation will vary widely from project to project. To determine the appropriate waste factors involved due to material handling and installation will mean reading through the above list and evaluating project/site-specific factors. This can be a very subjective process. With good recordkeeping on previous work performance and by systematically comparing the current situation with similar performance in the past, a probable outcome can be predicted.

3.2.2 Waste Factors for Building Construction

Waste factors are usually listed by a percentage of the actual quantity of material left in place. That is, if the actual quantity of concrete required is 100 m^3 and the waste factor is 5%, the amount of concrete to be procured should be 105 m^3. Table 3.1 lists some of the waste factors associated with the materials in a building construction project.

3.2.3 Maintenance Stock

Another consideration for quantity take off is maintenance stock or attic stock. Maintenance stock is the additional amount of materials retained by the contractor and passed to the owner when the building is turned over. These materials are often requested by the owner's maintenance personnel and are specified in the contract with the architect. Material items associated with the maintenance stock are usually finishing items, such as sealing tiles, carpets, stone tiles, ceramic tiles, and paint. During the life of a building, it is expected that minor maintenance will affect some of the inplace finishes. For example, a tile wall or a painted wall may be broken to correct a problem or to install additional piping. This maintenance work could essentially destroy some of the inplace materials. In order to ensure continuity, batches of the same finishing materials will be required since different batches may have minor variations from the original materials. For example, red paint with identical specifications produced by the same manufacturer at two different times will not be perfectly identical. The same can be said for the color of the tiles and carpets. Natural products such as stone tiles will be even harder to match. Consequently, the owner will sometimes request maintenance stocks, thus the estimator should be aware of the items and account for them when estimating.

In general, the architect will specify that 2 to 3% maintenance stock of specific materials be provided to the owner at project completion. On a rare occasion, the amount may be as high as 5%.

TABLE 3.1 Typical Waste Factors for Building Project

Material type	Waste factor (%)
Precast concrete piles	5
Steel piles	2.5
Wood piles	20
Cast iron pipes	10
Reinforced concrete pipes	6
Corrugated metal pipes	7.5
PVC pipes	6
Vitrified clay pipes	10
Chain link fencing	2.5
Wood fencing	5.5
Ready-mix concrete	7.3
Reinforcing steel bars, light weight, bar #10 and 15	5.7
Reinforcing Steel bars, medium weight, bar # 20 and 25	4
Reinforcing Steel bars, heavy weight, bar # 30 and up	3.3
Formwork	25
Bricks	6
Concrete masonry units	5
Mortar	13
Metal studs	10
Wood	17.9
Plywood	16.7
Fiberboard	16.7
Asphalt roofing shingles	10
Clay roofing tiles	12
Concrete Roofing tiles	15
Roofing felt	10
Built-up roofing	5
Metal roofing	15
Sheet metal—coping, gutter, downspout, flashing	15
Acoustical tile	8
Acoustical board	4
Acoustical panels	4
Acoustical ceiling grid, suspension system	3
Wood flooring—parquet	5
Resilient flooring—tile (vinyl and asphalt)	5
Resilient flooring—sheet (vinyl and linoleum)	10
Carpeting	8
Paint	10

3.3 PRICING MATERIALS

After making a list of materials and their proposed quantities, the next step in determining the cost of materials is to price each and every item.

3.3.1 What is Pricing?

Pricing is a process of assigning a dollar value to a work item based on given specifications and the predetermined quantity required. The pricing of each work item should include the cost of each of these subcomponents:

Permanent and temporary materials to be procured,
Labor required for installing the materials,
Equipment required for moving and installing materials, and
Other consumables, such as fuel and tools.

This chapter focuses on the first component, the cost of materials. The following chapters discuss the remaining components. During the pricing process, specifications have to be scrutinized carefully to ensure that materials are priced correctly.

3.3.2 Material Costs

Material costs are obtained by getting quotations from suppliers, generally in a unit price of dollars per unit of measure of a specified material. Many unit prices may be provided for the same material depending on the volume of purchase at a given time. Generally, the more the amount of purchase, the lower the unit price is. This is called quantity discount. When using the unit price, the contractor has the responsibility of determining the quantities of materials to be purchased. The cost of materials includes not only the direct cost of the material items, but any other costs that may be acquired except labor or equipment for installation. Additional items of cost to be considered are sales taxes and freight costs.

The sales tax rate to be applied to the materials will vary depending on the location of the project. Chapter 18, Section 18.3 provides the prevailing sales tax rate for all states. Additional sales taxes may be levied at county or city levels, depending on local jurisdictions. Some projects may also be exempt from sales taxes, specifically when it is a publicly funded project. It is the responsibility of the estimator to include any sales taxes in the estimated direct costs of the materials.

Freight costs must also be considered and added to the direct cost of the materials. This cost can be a big portion of the total cost of materials when the jobsite is isolated and very far away from the nearest supplier. However, generally the freight cost per unit quantity of material can be reduced as the order quantity is increased.

3.3.3 Other Considerations for Material Procurement

In making material procurement decisions, the following interrelated factors need to be considered: quantity discount, interest rate, escalation, and holding cost. Quantity discounts provide incentives to the buyer to purchase more at one time, due to a lower unit purchase cost as well as shipping costs. However, this usually entails paying more up front due to the higher volume of purchase. This can also lead to higher material handling and storage costs due to a greater or excess volume of material.

Interest rate is the rate of return on capital. When the interest rate is low, the return on capital is low, therefore the cost of capital is low. During periods of low interest rates, it is more feasible to use capital for advanced purchasing since the cost of capital is low. Escalation refers to the continual rise in the price of goods, in this case the cost of materials. To guard against escalation, sometimes materials need to be procured early and stocked for later use at the expense of other costs.

Holding cost is associated with the storage of excess materials onsite. This can be in the forms of rental cost for a laydown area, of storage facilities (e.g., renting or constructing fencing, shed, warehouse, storage container, etc.), of rehandling cost, of theft or misplacement, of providing security, of insurance, and of financial loss in terms of interest on funds invested in inventory. Storage costs can be extremely high for a project located in prime commercial real estate. An offsite warehouse is another expensive alternative, as it requires staffing, security, and utilities. These costs can sometimes exceed any savings acquired through the advance purchasing of large quantities of materials before they are needed.

In an ideal situation, materials should be ordered and shipped to arrive when they are ready to be used. In this way, materials can be unloaded directly where they are needed. However, by ordering large quantities of materials before they can be used means that excess materials will have to be unloaded and placed in storage areas generally away from the work areas. Without proper site management, large quantities of materials on hand may lead to congested storage areas and increased material rehandling as items may need to be moved in order to get to more needed materials. Rehandling is an unnecessary cost item that should be avoided as it consumes the productive time of high-priced labor and equipment. On the average, construction materials are rehandled at least three times before they are finally installed or used.

3.4 MATERIAL PRICING SOURCES

The pricing of materials is generally much easier than the pricing of labor and equipment costs. Material pricing sources are: published sources, company cost records, and vendor catalogues and quotations.

3.4.1 Published Sources

Published prices of materials can be found in Means *Building Construction Cost Data*, which is published annually and is one of the most used cost references. Means produces cost files in two versions, metric as well as English. Figure 3.5 shows a sample page from the metric version where unit material costs are found under the "MAT." column of the "2000 BARE COSTS" section. For example, with reference to Mean's line number 03310-220-0150, the bare material cost of 21 MPa ready-mix concrete is \$82.50/m^3.

Current material prices can also be found in the *Engineering News-Record* (*ENR*). This weekly magazine publishes current material costs that are reported on a monthly basis in their "Construction Economics" section. *ENR*'s price reporters update the material prices monthly by calling a single source for each product in 20 US cities. The price represents that paid by a contractor for a specified large order. The national average prices and prices for individual cities are both reported in the "Construction Economics" section. In addition, *ENR*'s quarterly cost reports analyze these price trends in detail. Monthly prices appear on a weekly rotating cycle, as shown in Table 3.2.

Figure 3.6 shows a sample page from *ENR*. At the time of this publication, *ENR* is still reporting material prices based only in English units.

3.4.2 Company Cost Records

An inhouse cost database can be used to determine the costs of materials. Company cost databases are built on the proper documenting and compiling of company cost records from previous jobs. These cost records must be factored to account for different time periods, locations, and sizes of projects before being integrated into a cost database. To apply data to a new project, the cost for an item is chosen from the database and adjusted for the time, location, and size of the new project.

3.4.3 Vendor Catalogues and Quotations

Material prices may also be obtained directly from vendors through catalogues or direct inquiries. Figure 3.7 is a sample page from a Home Depot catalogue.

03200 | Concrete Reinforcement

	03230 | Stressing Tendons		Crew	Daily Output	Labor-Hours	Unit	2000 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P	
2250	16 metric ton	R03410-090	C-4	659	.048	kg	4.30	1.53	.12	5.95	7.50	600

	03240 | Fibrous Reinforcing	Unit	2000 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P	
0010	FIBROUS REINFORCING							300
0100	Synthetic fibers	kg	8.35			8.35	9.20	
0110	0.89 kg/m^3, add to concrete	m^3	7.65			7.65	8.40	
0150	Steel fibers	kg	1.06			1.06	1.16	
0155	15 kg. per m^3, add to concrete	m^3	15.70			15.70	17.25	
0160	30 kg/m^3 add to concrete		31.50			31.50	34.50	
0170	45 kg/m^3 add to concrete		48.50			48.50	53	
0180	59 kg/m^3 add to concrete		63			63	69	

3 CONCRETE

03300 | Cast-In-Place Concrete

	03310 | Structural Concrete		Crew	Daily Output	Labor-Hours	Unit	2000 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P	
0010	CONCRETE, FIELD MIX FOB forms 15.5 MPa	R03310-080				m^3	83.50			83.50	92	200
0020	21 MPa					"	87.50			87.50	96.50	
0010	CONCRETE, READY MIX Regular weight	R03310-040										220
0020	13 MPa					m^3	79			79	87	
0100	17 MPa	R03310-050					80			80	88	
0150	21 MPa						82.50			82.50	90.50	
0200	24 MPa	R03310-070					84.50			84.50	93	
0300	28 MPa						87.50			87.50	96.50	
0350	31 MPa						90.50			90.50	99.50	
0400	34 MPa						93.50			93.50	103	
0411	41 MPa						107			107	117	
0412	55 MPa						174			174	191	
0413	69 MPa						247			247	272	
0414	83 MPa						298			298	330	
1000	For high early strength cement, add						10%					
1010	For structural lightweight with regular sand, add						25%					
2000	For all lightweight aggregate, add						45%					
3000	For integral colors, 17 MPa, 5 bag mix											
3100	Red, yellow or brown, 0.82 kg/bag, add					m^3	17.60			17.60	19.35	
3200	4.26 kg/bag, add						95			95	104	
3400	Black, 0.82 kg/bag, add						21			21	23	
3500	3.40 kg/bag, add						87.50			87.50	96.50	
3700	Green, 0.82 kg/bag, add						42			42	46	
3800	3.40 kg/bag, add						200			200	220	
0010	CONCRETE IN PLACE including forms (4 uses), reinforcing	R03310-010										240
0050	steel, including finishing unless otherwise indicated											
0300	Beams, 7.441 kg/mm, 3 m span	R03310-100	C-14A	11.94	16.747	m^3	279	475	58	812	1,125	
0350	7.6 m span		"	14.18	14.102		252	400	49	701	965	
0500	Chimney foundations, industrial, minimum	R03360-130	C-14C	24.63	4.547		170	123	1.55	294.55	385	
0510	Maximum		"	18.13	6.178		198	167	2.10	367.10	485	
0700	Columns, square, 300 mm x 300 mm, minimum reinforcing	R04210-065	C-14A	9.14	21.872		300	620	76	996	1,400	
0720	Average reinforcing			7.74	25.823		420	730	89.50	1,239.50	1,725	
0740	Maximum reinforcing			6.90	28.969		525	820	101	1,446	1,975	
0800	400 mm x 400 mm, minimum reinforcing			12.40	16.128		242	455	56	753	1,050	

FIGURE 3.5 Sample page from Means' *Building Construction Cost Data, Metric Version,* 2000.

Table 3.2 Weekly Rotation of *Engineering News-Record* (*ENR*) Material Prices Report

Engineeering News-Record (*ENR*)—Construction Economics Reports	
Week 1	Asphalt, cement, aggregate, concrete, brick, block, lime
Week 2	Sewer, water, drain pipe
Week 3	Lumber, plywood, plyform
Week 4	Structural steel, rebar, building sheet piling

Sometimes, however, catalogues do not list prices and vendors will have to be contacted directly. When contacting a vendor for a quotation, it is a good idea to have a quotation form which can help facilitate the recording of information. A sample telephone quotation form can be seen in Figure 3.8.

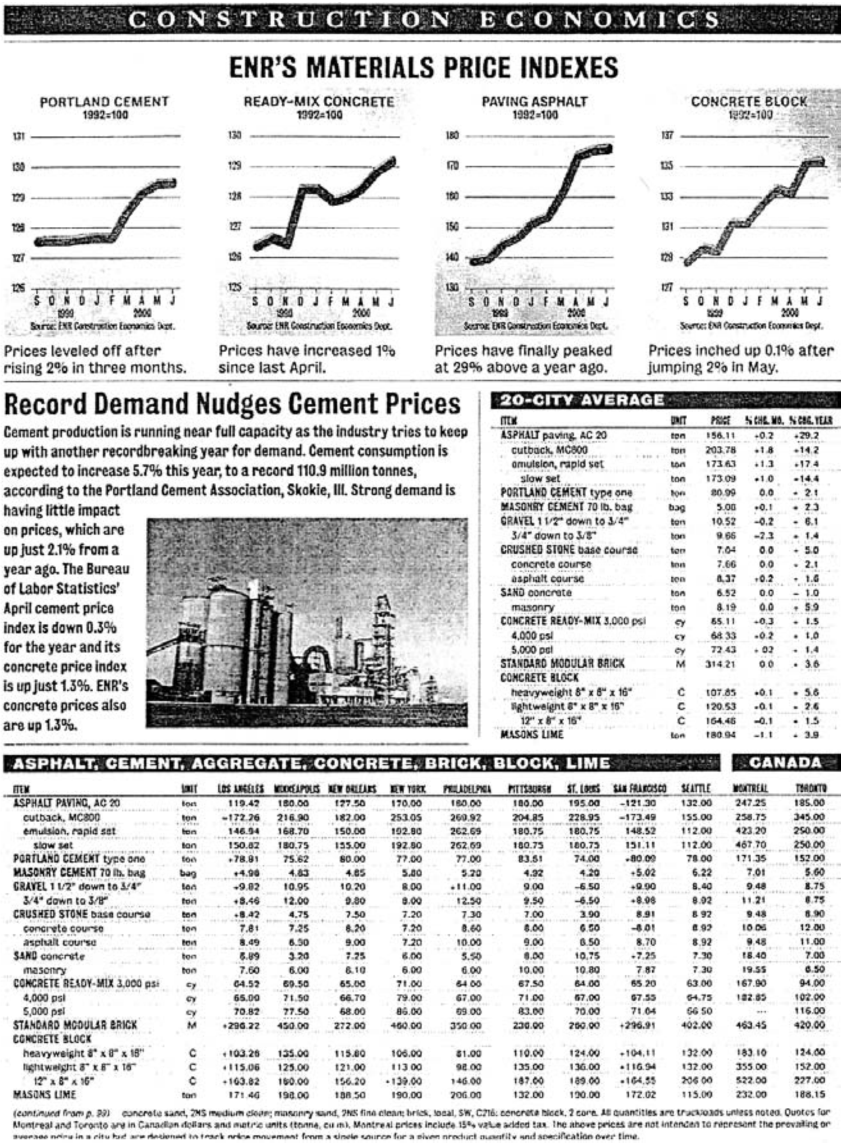
Compiling prices from vendors for a list of materials may be simple. However, to ensure complete and reliable cost information, several factors must be considered while analyzing material quotations:

Payment requirements,
Delivery charges,
Taxes,
Lead time/product availability,
Price guarantee,
Quantity discount information, and
Price Escalation clause.

3.5 TRENDS IN MATERIAL PRICES

Apart from the knowledge of prevailing prices of materials, it is also important to be aware of trends in the cost of materials. This is especially important for big projects where construction duration is long or for those projects where there is a long lead time between bidding and actual construction. In these situations, the knowledge of prevailing prices may not be enough since the contractor will have to estimate the future cost of materials when they will actually be needed.

Material price trends are developed by collecting and compiling price data of materials at similar time intervals from many time periods. Figures 3.9 to 3.15 provide examples of material price trends based on *ENR*'s "Construction Economic Reports."



CONSTRUCTION ECONOMICS

ENR'S MATERIALS PRICE INDEXES

Prices leveled off after rising 2% in three months.

Prices have increased 1% since last April.

Prices have finally peaked at 29% above a year ago.

Prices inched up 0.1% after jumping 2% in May.

Record Demand Nudges Cement Prices

Cement production is running near full capacity as the industry tries to keep up with another recordbreaking year for demand. Cement consumption is expected to increase 5.7% this year, to a record 110.9 million tonnes, according to the Portland Cement Association, Skokie, Ill. Strong demand is having little impact on prices, which are up just 2.1% from a year ago. The Bureau of Labor Statistics' April cement price index is down 0.3% for the year and its concrete price index is up just 1.3%. ENR's concrete prices also are up 1.3%.

20-CITY AVERAGE

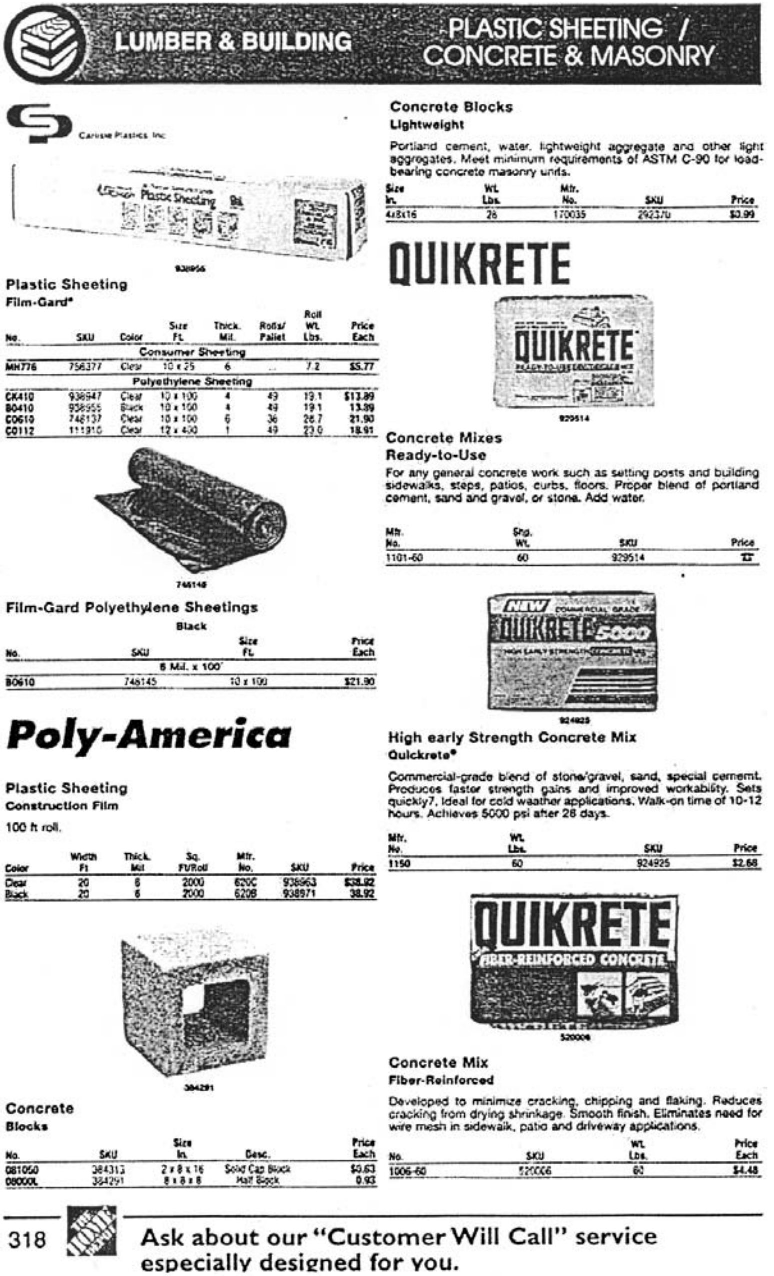
ITEM	UNIT	PRICE	% CHG. MO.	% CHG. YEAR
ASPHALT paving, AC 20	ton	156.11	+0.2	+29.2
cutback, MC800	ton	203.78	+1.8	+14.2
emulsion, rapid set	ton	173.63	+1.3	+17.4
slow set	ton	173.09	+1.0	+14.4
PORTLAND CEMENT type one	ton	80.99	0.0	+ 2.1
MASONRY CEMENT 70 lb. bag	bag	5.00	+0.1	+ 2.3
GRAVEL 1 1/2" down to 3/4"	ton	10.52	−0.2	- 6.1
3/4" down to 3/8"	ton	9.66	−2.3	+ 1.4
CRUSHED STONE base course	ton	7.04	0.0	+ 5.0
concrete course	ton	7.66	0.0	+ 2.1
asphalt course	ton	8.37	+0.2	+ 1.6
SAND concrete	ton	6.52	0.0	− 1.0
masonry	ton	8.19	0.0	+ 5.9
CONCRETE READY-MIX 3,000 psi	cy	65.11	+0.3	+ 1.5
4,000 psi	cy	68.33	+0.2	+ 1.0
5,000 psi	cy	72.43	+.02	+ 1.4
STANDARD MODULAR BRICK	M	314.21	0.0	+ 3.6
CONCRETE BLOCK				
heavyweight 8" x 8" x 16"	C	107.85	+0.1	+ 5.6
lightweight 8" x 8" x 16"	C	120.53	+0.1	+ 2.6
12" x 8" x 16"	C	164.46	−0.1	+ 1.5
MASONS LIME	ton	180.94	−1.1	+ 3.9

ASPHALT, CEMENT, AGGREGATE, CONCRETE, BRICK, BLOCK, LIME — **CANADA**

ITEM	UNIT	LOS ANGELES	MINNEAPOLIS	NEW ORLEANS	NEW YORK	PHILADELPHIA	PITTSBURGH	ST. LOUIS	SAN FRANCISCO	SEATTLE	MONTREAL	TORONTO
ASPHALT PAVING, AC 20	ton	119.42	180.00	127.50	170.00	180.00	180.00	195.00	−121.30	132.00	247.25	185.00
cutback, MC800	ton	−172.26	216.90	182.00	253.05	260.92	204.85	228.95	−173.49	155.00	258.75	345.00
emulsion, rapid set	ton	146.94	168.70	150.00	192.80	262.69	180.75	180.75	148.52	112.00	423.20	250.00
slow set	ton	150.82	180.75	155.00	192.80	262.69	180.75	180.75	151.11	112.00	467.70	250.00
PORTLAND CEMENT type one	ton	+78.91	75.62	80.00	77.00	77.00	83.51	74.00	+80.09	78.00	171.35	152.00
MASONRY CEMENT 70 lb. bag	bag	+4.98	4.83	4.85	5.80	5.20	4.92	4.20	+5.02	6.22	7.01	5.60
GRAVEL 1 1/2" down to 3/4"	ton	+9.82	10.95	10.20	8.00	+11.00	9.00	−6.50	+9.90	8.40	9.48	8.75
3/4" down to 3/8"	ton	+8.46	12.00	9.80	8.00	12.50	9.50	−6.50	+8.08	8.92	11.21	8.75
CRUSHED STONE base course	ton	+8.42	4.75	7.50	7.20	7.30	7.00	3.90	8.91	8.92	9.48	8.90
concrete course	ton	7.81	7.25	8.20	7.20	8.60	8.00	6.50	−8.01	8.92	10.06	12.00
asphalt course	ton	8.49	6.30	9.00	7.20	10.00	9.00	8.50	8.70	8.92	9.48	11.00
SAND concrete	ton	6.89	3.20	7.25	6.00	5.50	8.00	10.75	+7.25	7.30	18.40	7.00
masonry	ton	7.60	6.00	8.10	6.00	6.00	10.00	10.80	7.87	7.30	19.55	8.50
CONCRETE READY-MIX 3,000 psi	cy	64.52	69.50	65.00	71.00	64.00	67.50	64.00	65.20	63.00	167.90	94.00
4,000 psi	cy	65.00	71.50	66.70	79.00	67.00	71.00	67.00	67.55	64.75	182.85	102.00
5,000 psi	cy	70.82	77.50	68.00	86.00	69.00	83.00	70.00	71.04	66.50	---	116.00
STANDARD MODULAR BRICK	M	+296.22	450.00	272.00	460.00	350.00	230.00	260.00	+296.91	402.00	463.45	420.00
CONCRETE BLOCK												
heavyweight 8" x 8" x 16"	C	+103.26	135.00	115.80	106.00	81.00	110.00	124.00	+104.11	132.00	183.10	124.00
lightweight 8" x 8" x 16"	C	+115.06	125.00	121.00	113.00	98.00	135.00	136.00	+116.94	132.00	355.00	152.00
12" x 8" x 16"	C	+163.82	180.00	156.20	+139.00	146.00	187.00	189.00	+164.55	206.00	522.00	227.00
MASONS LIME	ton	171.46	198.00	188.50	190.00	206.00	132.00	190.00	172.02	115.00	232.00	186.15

(continued from p. 39) concrete sand, 2NS medium clean; masonry sand, 2NS fine clean; brick, local, SW, C216; concrete block, 2 core. All quantities are truckloads unless noted. Quotes for Montreal and Toronto are in Canadian dollars and metric units (tonne, cu m). Montreal prices include 15% value added tax. The above prices are not intended to represent the prevailing or average price in a city but are designed to track price movement from a single source for a given product quantity and specification over time.

FIGURE 3.6 Sample page from *Engineering News Record* (*ENR*) magazine.



LUMBER & BUILDING

PLASTIC SHEETING / CONCRETE & MASONRY

Carlisle Plastics Inc

938956

Plastic Sheeting

Film-Gard*

No.	SKU	Color	Size Ft.	Thick. Mil.	Rolls/ Pallet	Roll Wt. Lbs.	Price Each
			Consumer Sheeting				
MH776	756377	Clear	10 x 25	6	...	7.2	$5.77
			Polyethylene Sheeting				
CK410	938947	Clear	10 x 100	4	49	19.1	$13.89
B0410	938955	Black	10 x 100	4	49	19.1	13.89
C0610	746137	Clear	10 x 100	6	36	26.7	21.90
C0112	111910	Clear	12 x 400	1	49	23.0	18.91

746145

Film-Gard Polyethylene Sheetings

Black

No.	SKU	Size Ft.	Price Each
	6 Mil. x 100'		
B0610	746145	10 x 100	$21.90

Poly-America

Plastic Sheeting

Construction Film

100 ft roll.

Color	Width Ft	Thick. Mil	Sq. Ft/Roll	Mfr. No.	SKU	Price
Clear	20	6	2000	620C	938963	$38.92
Black	20	6	2000	620B	938971	38.92

384291

Concrete

Blocks

No.	SKU	Size In.	Desc.	Price Each
081050	384313	2 x 8 x 16	Solid Cap Block	$0.63
08000L	384291	8 x 8 x 8	Half Block	0.93

Concrete Blocks

Lightweight

Portland cement, water, lightweight aggregate and other light aggregates. Meet minimum requirements of ASTM C-90 for load-bearing concrete masonry units.

Size In.	Wt. Lbs.	Mfr. No.	SKU	Price
4x8x16	26	170035	292370	$0.99

QUIKRETE

929514

Concrete Mixes

Ready-to-Use

For any general concrete work such as setting posts and building sidewalks, steps, patios, curbs, floors. Proper blend of portland cement, sand and gravel, or stone. Add water.

Mfr. No.	Shp. Wt.	SKU	Price
1101-60	60	929514	[illegible]

924925

High early Strength Concrete Mix

Quickrete*

Commercial-grade blend of stone/gravel, sand, special cememt. Produces faster strength gains and improved workability. Sets quickly7. Ideal for cold weather applications. Walk-on time of 10-12 hours. Achieves 5000 psi after 28 days.

Mfr. No.	Wt. Lbs.	SKU	Price
1150	60	924925	$2.68

520006

Concrete Mix

Fiber-Reinforced

Developed to minimize cracking, chipping and flaking. Reduces cracking from drying shrinkage. Smooth finish. Eliminates need for wire mesh in sidewalk, patio and driveway applications.

No.	SKU	Wt. Lbs.	Price Each
1006-60	520006	60	$4.48

318 Ask about our "Customer Will Call" service especially designed for you.

FIGURE 3.7 Sample page from a vendor's catalogue. (Courtesy of Home Depot.)

Company Logo   Telephone Sub-Bid Quotation

TIME: __________ AM / PM   DATE: ______________   RECEIVED BY: ______________

PROJECT TITLE ____

DIVISION OF WORK ____

CONTRACTOR ____

BY: ______________   PHONE:( ) ______________   CITY: ______________

BID ITEM	BID AMOUNT

Furnished and Installed: Yes No	Taxes Incl.: Yes No
Furnish Only FOB Jotsite	Bond Inc.: Yes No Rate:
Addenda Nos.	MBE WBE

ALTERNATIVES:

______	$______	______	$______	______	$______	______	$______
______	$______	______	$______	______	$______	______	$______
______	$______	______	$______	______	$______	______	$______
______	$______	______	$______	______	$______	______	$______

INCLUDES: ____

EXCLUDES: ____

FIGURE 3.8 Telephone quotation form.

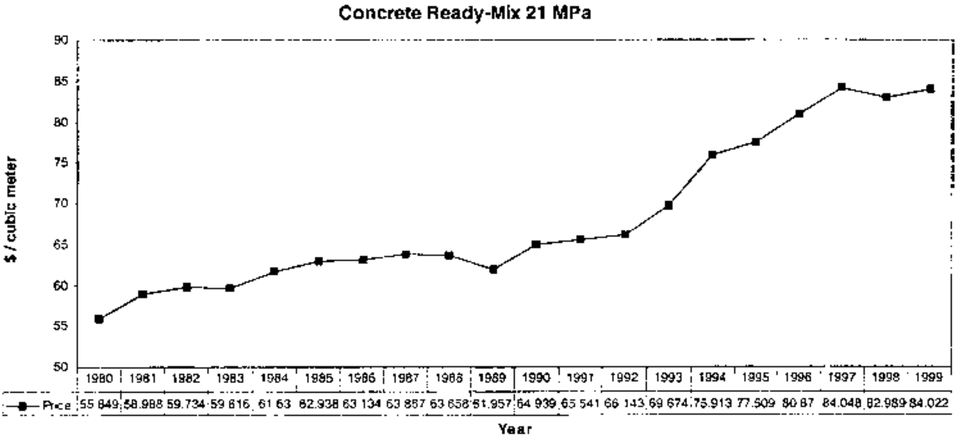


FIGURE 3.9 Price trend in ready-mix concrete, 21 MPa.

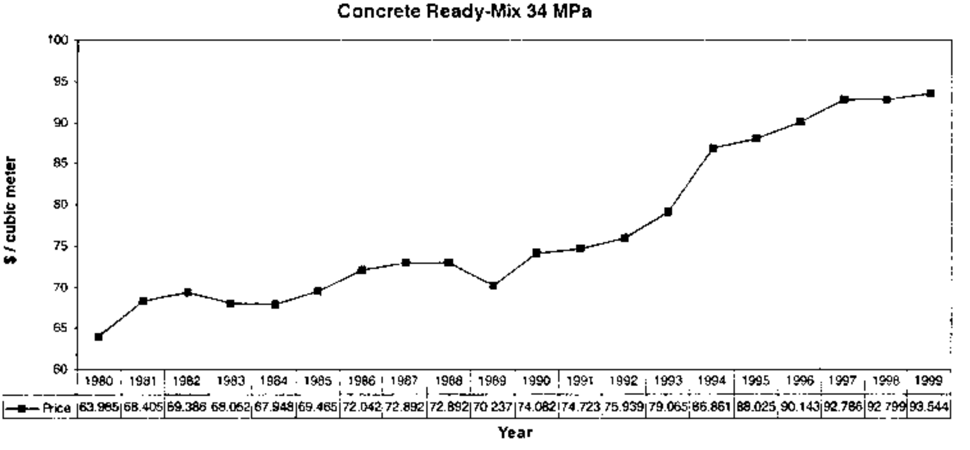


FIGURE 3.10 Price trend in ready-mix concrete, 34 MPa.

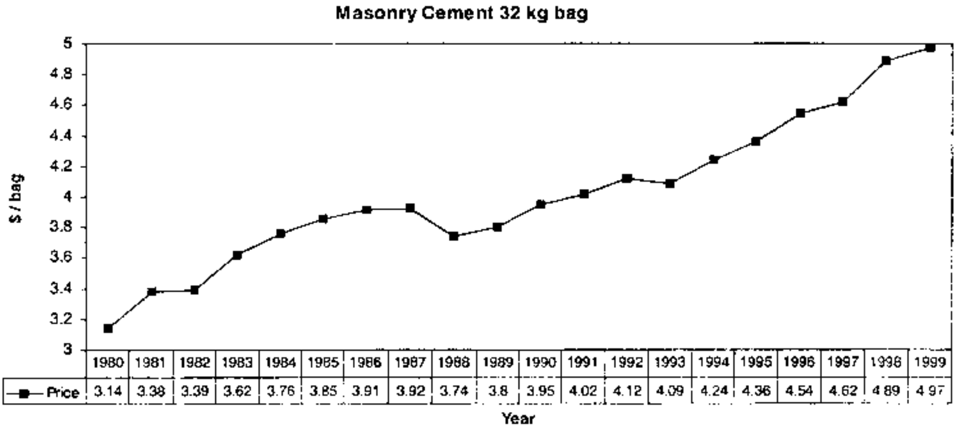


FIGURE 3.11 Price trend in masonry cement, 32 kg bag.

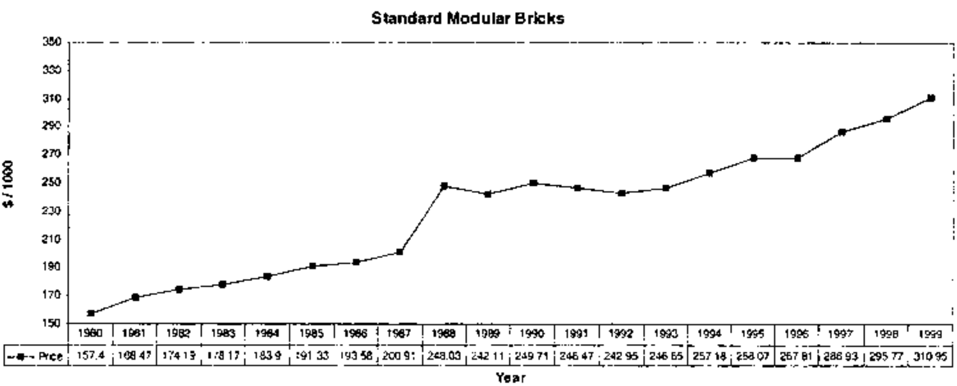


FIGURE 3.12 Price trend in standard modular bricks.

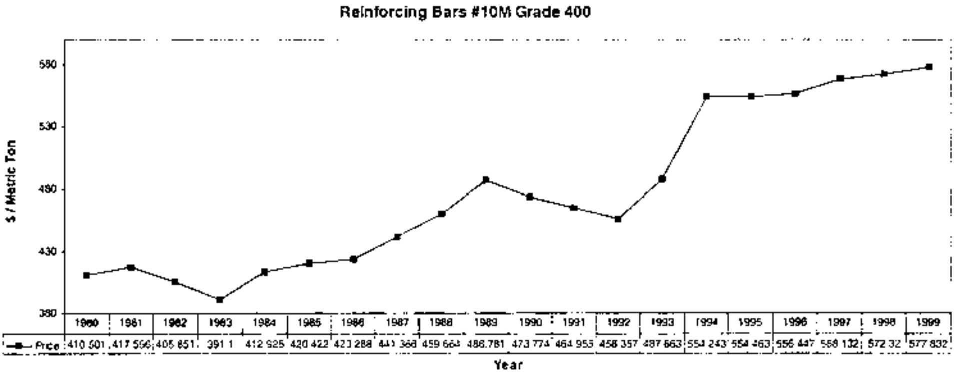


FIGURE 3.13 Price trend in reinforcing bars, #10M Grade 400.

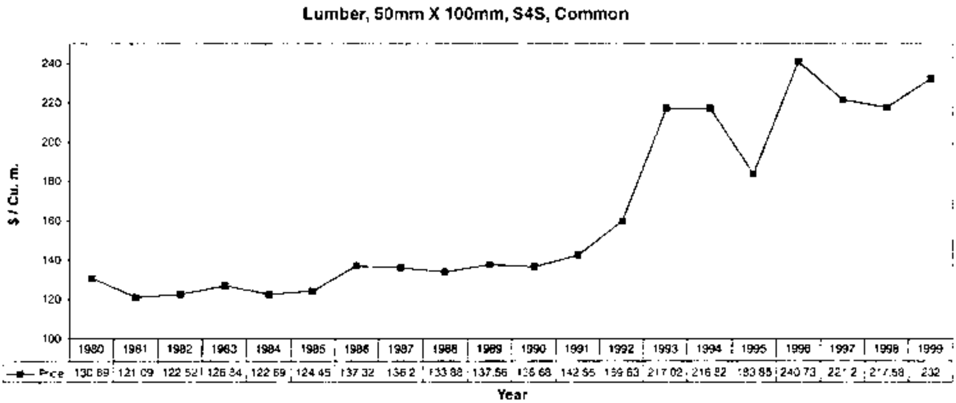


FIGURE 3.14 Price trend in lumber, 50 mm × 100 mm, S4S, Common.

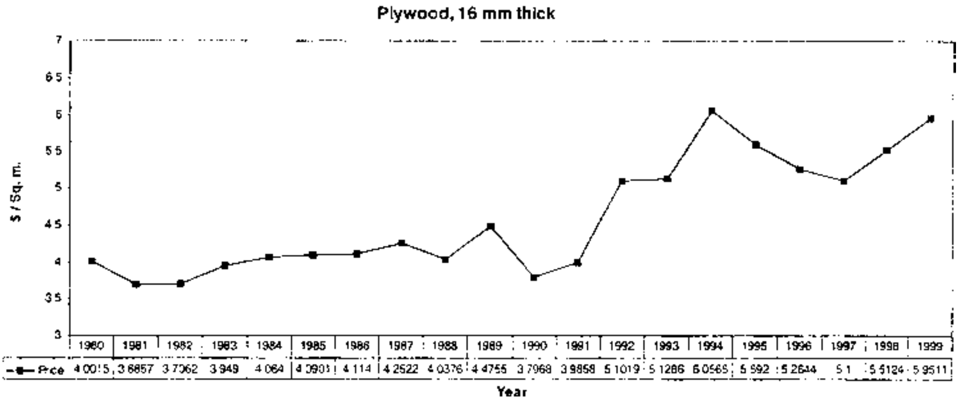


FIGURE 3.15 Price trend in plywood, 16 mm thick.

3.6 REVIEW QUESTIONS

1. What are the two main components of the construction cost estimating process?
2. What is material quantity take off?
3. Provide two advantages of using take off forms and checklists.
4. What are the two main factors causing waste in construction?
5. Explain how industrial standards are related to waste.
6. Give five conditions of a jobsite that tend to have a lot of waste.
7. What are material maintenance stocks? Why are they needed?
8. What is pricing?
8. Explain the interrelationship between quantity discount and holding cost.
9. Name three sources for determining material prices.
10. Apart from the current prices of materials, what other aspect of material prices must an estimator be aware? Explain.
11. What are some of the items that should be considered when analyzing material quotations?

4

Estimating the Cost of Labor

4.1 CONSTRUCTION LABOR

In today's fast-paced industrialized age, where many of the products we see are increasingly being mass produced in factories by machines, a building still remains as one of the few handcrafted products put together piece by piece by craftsmen. The construction industry, to which these craftsmen belong, is one of the most labor-intensive industries in the US. The labor cost component of a building project often ranges from 30 to 50%, and can be as high as 60% of the overall project cost. Therefore, it is clear that construction labor is a vital component of a construction project.

4.1.1 Types of Construction Labor

A building is a very complex product, made up of many different systems, such as the structural system, exterior enclosure system, and HVAC system. These systems can be broken down into many more subsystems and subsubsystems. In this way, a building construction project is divided into numerous work packages. These work packages can then be assigned to and completed by an individual worker or a crew. A crew is a team of workers, which can be of the same trade or a composite of many different trades. Due to the diverse nature of the different tasks associated with all the building systems, many types of craftsmen from many different trades are required in a building construction project. Table 4.1 provides a list of types of workers that can be involved in a building construction project, along with their description.

4.1.2 Components of Labor Costs

Labor costs in construction are determined by two factors: monetary and productivity. The monetary factor is related to hourly wage rates, wage premiums, insurance, fringe benefits, and taxes. Estimating the components of the monetary factor are more difficult in construction than in any other US industry. This is due to the variety of work involved in construction, as well as the many types of trades involved. The problem is further complicated by the presence of the unions with their craft structures and collective bargaining processes. Although the computational process of this component seems complex and tedious, it is only a matter of accounting as the needed numbers (such as wage rates, fringe benefits, and insurance) are readily available. The monetary factor is discussed further in Section 4.3.

The second factor, which is much more difficult to deal with, is productivity. In the most general sense, productivity is the ratio of input versus the respective output. In construction, the input is often the work hours of a worker or a crew, such as the 8 hours of a bricklayer. The output is the amount of work produced, such as laying 500 bricks. Thus construction productivity is defined

Table 4-1 Worker Classification Definition Sheet

Worker	Classification definition sheet
Asbestos worker	Worker who removes and disposes of asbestos materials
Carpenter	Worker who builds wood structures, or structures of any material that has replaced wood. Includes rough and finish carpentry, hardware, and trim
Carpet layer/flooring installer	Worker who installs carpet and/or floor coverings, vinyl tile
Concrete finisher	Worker who floats, trowels, and finishes concrete
Data communication/telecom installer	Worker who installs metal framed walls and ceilings, drywall coverings, ceilings, grids and ceilings
Electrician	Skilled craftsman who installs or repairs electrical wiring and devices. Includes fire alarm systems, and HVAC electrical controls
Elevator mechanic	Craftsman skilled in the installation and maintenance of elevators
Fireproofing installer	Worker who sprays or applies fireproofing materials
Glazier	Worker who installs glass, glazing and glass framing
Heavy equipment operator	Includes but not limited to all Cat tractors, all derrick-powered, all power-operated cranes, back hoe, back filter, power-operated shovel, winch truck, all trenching machines
Insulator	Worker who applies, sprays, or installs insulation
Ironworker	Skilled craftsman who erects structural steel framing and installs structural concrete Rebar
Laborer/helper	Worker qualified for only unskilled or semiskilled work. Lifting, carrying materials and tools, hauling, digging, cleanup
Lather/plasterer	Worker qualified for only unskilled or semiskilled work. Lifting, carrying materials and tools, hauling, digging, cleanup
Light equipment operator	Includes but not limited to air compressors, truck crane driver, flex plane, building, elevator, form grader, concrete mixer (less than 14 cf), conveyer
Mason	Craftsman who works with masonry products, stone, brick, block, or any material substituting for those materials and accessories
Metal building assembler	Worker who assembles premade metal buildings
Millwright	Mechanic specializing in the installation of heavy machines, wrenches, dock levelers, hydraulic lifts, and align pumps
Painter/wall covering installer	Worker who prepares wall surfaces and applies paint and/or wall coverings, tape, and bedding

TABLE 4-1 Continued

Worker	Classification definition sheet
Pipefitter	Trained worker who installs piping systems, chilled water piping, and hot water (boiler) piping, pneumatic tubing controls, chillers, boilers, and associated mechanical equipment
Plumber	Skilled craftsman who installs domestic hot and cold water piping, waste piping, storm system piping, water closets; sinks, urinals, and related work
Roofer	Worker who installs roofing materials, bitumen (asphalt and cold tar), felts, flashings, all types roofing membranes, and associated products
Sheet metal worker	Worker who installs sheet metal products: roof metal, flashings, and curbs, ductwork, mechanical equipment, and associated metals
Sprinkler fitter	Worker who installs fire sprinkler systems and fire protection equipment
Terrazzo worker	Craftsman who places and finishes terrazzo
Tile setter	Worker who prepares wall and/or floor surfaces and applies ceramic tiles to these surfaces
Waterproofer/caulker	Worker who applies waterproofing material to buildings. Products include sealant, caulk, sheet membrane, liquid membranes, sprayed, rolled, or brushed on

as the quantity of work produced in a given amount of time by a worker or a specific crew, that is, the quantity of construction output units produced in a given amount of time or a unit time. The formula for productivity is shown in Eq. (4.1).

$$\textit{Construction productivity} = \textit{quantity of work produced} \div \textit{time duration.} \tag{4.1}$$

For example, if a bricklayer can lay 500 bricks in 8 hours, the associated construction productivity is thus 500 bricks divided by 8 hours, which is 62 bricks per bricklayer hour.

Although most items associated with the monetary factor remain relatively constant over a short period of time, such as during the construction phase, productivity, on the other hand, can fluctuate wildly. To accurately estimate productivity, an estimator not only needs a good historical record, but a lot of experience. Section 4.4 addresses the issue of labor productivity in greater detail.

4.1.3 Basic Principle for Estimating Labor

The formula for computing the total cost of labor is quite simple. It requires the knowledge of the total work hours or labor hours needed to perform all the tasks and then applying the corresponding wage rates. The formula for calculating the total cost of labor is shown in Eq. (4.2).

$$\textit{Total cost of labor} = \sum_{i=1}^{n} \textit{total work hour}\ (i) \times \textit{wage rate}\ (i). \tag{4.2}$$

For example, assume that a crew for a work item includes three bricklayers and two helpers. The crew works for three days under straight time (8-hr day) to complete the work package. The wage rate for each bricklayer is $28.55 and each helper is $22.40. In this instance, the total cost of labor is $ 3131 as determined by computations shown in Figure 4.1.

Determining the total work hours for a task involves a knowledge of the quantity of work required for the task and the productivity rate for the specific crew that will be performing the work. The quantity of work associated with the material quantity is determined by the quantity take off discussed in Chapter 3. For example, the quantity of work for placing concrete would be associated with the amount of concrete to be placed. The formula for calculating the total work hours is shown in Eq. (4.3).

$$\textit{Total work hours} = \sum_{i=1}^{n} \textit{quantity of work}\ (i) \div \textit{productivity rate}\ (i). \tag{4.3}$$

An example of this calculation used to determine the work hours for a painting job can be seen in Figure 4.2.

	Hours	Straight Time Rate ($/hr)	Total Cost
Bricklayers	3 bricklayers X 3 days X 8 hr/day = 72 hr	$ 28.55	$ 2,055.60
Helpers	2 helpers X 3 days X 8 hr/day = 48 hr	$ 22.40	$ 1,075.20
			$ 3,130.80

FIGURE 4-1 Cost of labor computation example.

Work Description	Quantity	Productivity per Hour	Unit	Total Men-Hours
Exterior Painting	440	11	m^2	40
Interior Painting	378	14	m^2	27
				67

FIGURE 4-2 Work hours computation example.

4.2 CONSTRUCTION LABOR ENVIRONMENT IN THE UNITED STATES

Construction firms in the United States have the right to decide whether they will operate as an open or a union shop. An open shop contractor does not have agreements with labor unions and can hire any employees or subcontractors regardless of their union membership. A union contractor has an agreement with the local union and will hire only union members. Today, the line between union and nonunion for the contractor is not always clear. Nonunion firms may sign formal project agreements or informal agreements with the unions that effectively make them union firms on a particular project. Many nonunion contractors use union subcontractors, particularly in the mechanical and electrical trades.

Construction labor in the United States can also be categorized into union and open shop. An estimator must be aware of the local labor situation so as to make correct assessments of the monetary as well as the productivity factors affecting the labor component of the project. The local labor situation must be surveyed carefully in advance before the execution of the estimating process.

4.2.1 Unions

While surveying the unions, particular attention must be given to union work rules and whether the union can supply the needed amount of skilled work force. A contractor hiring union workers will have to sign a contract, a collective bargaining agreement, with the union. The contractor must be aware of the union work rules that may be incorporated in the agreement. The union work rules and the level of skill prevalent among the workers will be needed to determine the appropriate productivity for the job. The union agreements will also typically define the wage rates, fringe benefits, working conditions, grievance procedures, and other provisions. The estimator will also need this information in order to accurately price the labor cost. The existence of the union has both advantages and disadvantages to the individual employee as well as the construction firm hiring the employees. The advantages and disadvantages of unions for workers and contractors are summarized in Table 4.2.

TABLE 4-2 Advantages and Disadvantages of Unions for Workers and Contractors

Union membership for worker	
Advantages	**Disadvantages**
Hiring hall for job referral	Payment for initiation fees, dues, or assessments
Apprenticeship training	No choice of employer, lack merit promotions
Right to strike, wages, job conditions, benefits, and job security	Restrictive work assignment
Power to act collectively as a group to enforce demands	
Organization affiliation	
Union membership for construction company	
Advantages	**Disadvantages**
Available pool of skilled labor from union	Restrictive work rules
Fixed wages and uniform conditions prescribed by union	Inhibit innovation
	Workers have no loyalty to contractor
	Jurisdictional dispute can affect contractor

4.2.2 Open Shops

Over the past decades, there has been a tremendous decline in construction union memberships. The open shop model has enjoyed a steady growth in construction market share as well as geographic penetration. The spread began in the south where the open shop is stronger and from there has spread all over the United States.

Open shop contractors have less limitation placed upon them. They do not have to deal with restrictive union work rules, thus allowing for greater logistic flexibility. For example, without the union work rule of craftperson work assignments, a craftperson with multiple skills can perform multiple tasks on the same project, thus staying on a project longer and performing greater portions of the work. However, under open shop conditions, the contractor cannot go to a union hall looking for workers. Instead, the contractor must hire all craft personnel directly. This can be a problem since the quality of the worker would not be known, which can lead to high turnover and training if labor is in short supply.

Under open shop, a contractor has no legal precedence regarding worker compensation as with union workers. Here the contractor is free to negotiate the terms and conditions for each individual worker. However, the terms and conditions must comply with numerous labor laws. Table 4.3 list the important labor laws in the United States.

Table 4-3 Important US Labor Laws

Davis–Bacon Act	Requires payment of the prevailing wage rate and fringe benefits on federal and federally assisted construction projects
Walsh–Healey Public Contract Act	Requires payment of minimum wage rate and overtime pay on contracts to provide goods to the federal government
Federal and State laws	Regulate wages and salaries paid by employers
Contract Work Hours and Safety Standards Act	Sets overtime standards for service and construction contract
Family and Medical Leave Act	Entitles eligible employees of covered employers to take up to 12 weeks of unpaid job-protected leave each year

4.3 MONETARY FACTORS

Pricing labor is one of the most difficult components of a cost estimate. One of the problems is that unlike pricing materials and equipment where pricing guides and quotations are readily available, pricing labor involves many more variables. It is also the most subjective of cost estimating. This section addresses the monetary factors that affect the pricing of labor.

4.3.1 Base Wage Rates

The first step to pricing labor is to determine the base wage or base wage rate. Base wage rate is dollars per hour paid to an employee for each straight-time hour worked. Straight-time hours or normal hours refer to the regular working hours of 8 hours per day from Monday to Friday, therefore 40 hours per week. Base wage rates vary by location, craft, and type of work within a craft.

In the union environment, a contractor can contact the local union to determine current local agreements. Union workers are classified into three established labor classifications, each with its own base rate: journeyman, apprentice, and supervisor. The craft journeyman base rate serves as the benchmark. Apprentices receive a percentage of the journeyman rate. This percentage depends on the period of training. Supervisors receive a percentage or a fixed-dollar amount on top of the base journeyman rate. Other additions to the base wage rate are sometimes provided for special skills, such as operating certain equipment or for working in remote locations. Union agreements may also mandate special premiums on top of the base rate for dangerous work conditions, such as working on high ground, underground, and close to high voltage. Union base wage rates for various crafts can be seen in Tables 4.5 and 4.6.

Open-shop contractors on the other hand must develop their own company classifications and wage rates or pay scale that recognizes the workers' level of skills. They must be attractive enough to draw workers to the project.

4.3.2 Fringe Benefits, Payroll Insurance, and Taxes

In addition to the base wage rate, the contractor must also pay for various fringe benefits for the workers. These benefits may include contributions to funds for health and welfare, vacations, pensions, training, and many other items. The types and extent of fringe benefits provided vary from employer to employer and are also affected by labor market conditions, local practices, and management's attitudes toward employees. When working with union workers, the local union can be contacted for current agreements and details on fringe benefits to be provided for union workers. Open shop contractors are not restricted by the union agreements, but must also provide fringe benefits that are comparable to those of the union's in order to attract workers to the job. Open shop contractors can also pay the equivalent of union fringes as part of the base pay rate, but directly to the employee. Table 4.4 illustrates an example of a base wage and fringe benefits schedule for a carpenter journeyman under a union contract.

Like many of the fringe benefits, payroll insurance and payroll taxes can be based directly on payroll or they can be based on the total contract price. There are several different kinds of insurance with the most prominent being workers' compensation insurance, public liability insurance, and property damage insurance. Workers' compensation rate is different for various crafts and is related to the degree of risk and the nature of the work associated with that craft. Table 4.5 illustrates the percentages for workmen's compensation associated with each craft. Workers' compensation ranges between a low of 7% for electricians, to a high of 42.6% for structural steel workers. In the table, payroll taxes such as Federal and State Unemployment costs and Social Security taxes or FICA

TABLE 4-4 Wage and Fringe Benefits Schedule for Carpenter Journeyman Under Union Contract

Cost element	Rate ($)/hr[a]
Base wage	17.50
Union health and welfare	1.71
Union pension	1.00
Apprentice training	0.08

[a]October 2000.

Table 4.5 Labor Wage Rates and Burdens for Construction Crafts

Trade	Hourly base rate ($)[a]	Workers' comp. ins. (%)[b]	Average fixed overhead (%)[c]
Skilled workers average (35 trades)	28.75	18.1	16.5
Helpers average (5 trades)	21.50	19.7	16.5
Foremen average, inside ($0.50 over trade)	29.25	18.1	16.5
Foremen average, outside ($2.00 over trade)	30.75	18.1	16.5
Common building laborers	22.25	19.9	16.5
Asbestos/insulation workers/pipe coverers	31.05	18.5	16.5
Bricklayers	28.55	17.8	16.5
Bricklayer helpers	22.40	17.8	16.5
Carpenters	28.15	19.9	16.5
Cement finishers	27.00	11.5	16.5
Electricians	33.00	7.0	16.5
Elevator constructors	34.15	8.5	16.5
Equipment operators, crane or shovel	29.90	11.4	16.5
Equipment operators, medium equipment	28.85	11.4	16.5
Equipment operators, light equipment	27.65	11.4	16.5
Glazier	27.25	14.4	16.5
Millwrights	29.40	11.7	16.5
Painters	25.25	15.3	16.5
Plasterers	26.65	15.7	16.5
Plasterer helpers	22.35	15.7	16.5
Plumbers	33.25	8.8	16.5
Rodmen (reinforcing)	31.50	31.6	16.5
Roofers, composition	24.70	34.6	16.5
Roofers, tile, slate	24.80	34.6	16.5
Roofers, helpers (composition)	18.45	34.6	16.5
Sheet metal workers	32.55	12.3	16.5
Steamfitters or pipefitters	33.50	8.8	16.5
Structural steelworkers	31.70	42.6	16.5
Truck drivers, light	22.35	15.6	16.5
Truck drivers, heavy	22.80	15.6	16.5

[a] Labor rates are based on union wages, include fringe benefits, and averaged for 30 major US cities.
[b] Workers' Compensation rates are the national average of state rates established for each trade.
[c] Average fixed overhead includes Federal and State Unemployment costs set a 7.0%; Social Security taxes (FICA) set at 7.65%.
Source: Means' *Building Construction Cost Data* 2000 *Metric Edition*.

Cost Element	$ / Hour
Base Wage	17.50
Union Health and Welfare	1.71
Union Pension	1.00
Apprentice Training	0.08
Workers' Compensation (28.10% of straight time pay)	4.92
FICA (6.2% of annual wages up to $68,400)	1.08
Medicare Tax (1.45%)	0.25
Unemployment Insurance (5% of straight time pay)	0.88
Gross Hourly Wage Rate	$ 27.41
Percent Increase Over Base Rate	57%

FIGURE 4-3 Sample calculations for a loaded labor cost per hour.

(Federal Income Contribution Act) are summed into an average fixed overhead of 16.5%. The discussions on insurance and taxes are presented in greater detail in Chapter 18. Figure 4.3 shows a sample computation in calculating the fully loaded labor cost per hour.

4.3.3 Wage Premiums

A wage premium is extra money paid to workers for overtime work, shift work, hazardous work conditions, or unusually strenuous work. Premiums for overtime are paid at a minimum of time and a half or 150% over the base rate. For open shop contractors, time and a half is the norm for all overtime payments. However, when working with unions, overtime premiums of 200% or double time may be required for overtime work on Sunday or public holidays.

Oftentimes, hourly paid workers receive additional payment when working on shifts other than the normal day shift. Typically, the day shift extends from 8:00 AM to 4:30 PM with a half hour off for lunch. The swing shift extends from 4:30 PM to 12:30 AM the following day, with half an hour lunch break. The graveyard shift (so-called because it is in the middle of the night) extends from 12:30 AM to 8:00 AM with half an hour lunch break. The total elapsed time for three shifts is thus 24 hours, with starting and stopping times varying according to local area practices. In this way, the work hours associated with each shift equal 8 hours of actual work being performed on the day shift, 7.5 hours on the swing shift, and 7 hours on the graveyard shift. However, workers on each of the three shifts receive the same pay for 8 hours of work at the straight-time rate.

Wage premiums for hazardous work conditions or unusually strenuous work are typically paid as a fixed increase over the base wage rate. For example, a bricklayer working on a scaffold more than 25 feet above grade may receive an extra $0.90 per hour.

4.3.4 Sources of Labor Rate and Trends

Besides getting the prevailing labor wage rates from the local unions, there are also numerous sources of published wage rates. Table 4.5 shows an excerpt from Means' *Building Construction Cost Data*, reference R011-070: Contractor's Overhead & Profit, where the labor base wage rates and burdens are presented.

The *Engineering News-Record* (*ENR*) also collects and publishes labor wage rates on a quarterly basis. Table 4.6 is a compilation of *ENR* labor rate data from 1990 to 2000. In addition, Figure 4.4 shows a plot of wage rates over time for selected crafts.

4.4 LABOR PRODUCTIVITY

Labor productivity rates in the construction industry are characterized by their tendency to vary from individual to individual, day to day, and project to project. As a result, the labor cost, which is one of the largest and most important components of the estimate, has also been historically one of the most inaccurate aspects of estimating. Therefore, to improve the accuracy of the overall cost estimate of a building project, an estimator must have a thorough knowledge of labor productivity and be able to determine the appropriate productivity rate for the estimated project.

4.4.1 Factors Affecting Labor Productivity

Factors affecting labor productivity can be broken down into external and internal factors. External factors have, to a certain extent, a global effect on the productivity rates regionally or nationally. These factors are beyond the control of the contractors. Two important external factors are market conditions and climatic conditions. The internal factors affecting labor productivity are work conditions and management conditions.

4.4.1.1 Market Conditions

When the economy is booming with lots of construction work, workers can be scarce. This can lead to an influx of less trained or unskilled workers into the market who will require more time to perform the work. However, when construction work is scarce, there are fewer unskilled workers in the market due to higher competition for jobs and a limited amount of work. Then the contractor can be more selective and hire only the most qualified workers, resulting in higher productivity. Also, during scarce times, workers are more motivated to work and to remain on the job.

TABLE 4-6 *Engineering News-Record*: Wage Rate History ($) for Construction Crafts (1990–2000)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Bricklayers	24.09	24.49	25.20	25.85	26.36	27.07	27.88	28.49	29.44	30.25	30.89
Carpenters	23.01	23.91	24.68	25.21	25.85	26.44	27.17	28.00	28.94	29.65	30.64
Cement masons	22.43	23.38	24.08	24.78	25.39	25.84	26.51	27.43	28.22	28.97	29.58
Electricians	27.10	28.03	28.63	29.78	30.64	31.43	32.23	33.08	34.77	35.64	36.94
Elevator constructors	26.72	27.18	27.99	29.40	29.98	30.98	31.58	32.42	34.78	35.55	36.21
Glaziers	23.89	24.15	24.75	25.55	26.13	26.56	27.07	27.61	28.67	29.85	30.95
Insulation workers	25.86	27.24	28.65	29.48	30.16	30.78	31.40	31.92	33.46	34.01	34.61
Ironworkers—reinforcing	25.31	25.99	26.66	27.36	28.04	28.83	29.70	30.56	31.69	32.46	33.19
Ironworkers—structural	25.60	26.60	27.37	28.14	28.79	29.64	30.54	31.43	32.57	33.16	33.96
Laborers	18.46	19.19	19.80	20.27	20.83	21.31	21.80	22.26	23.03	23.65	24.28
Millwrights	23.90	24.81	25.63	26.37	27.14	27.94	28.64	29.28	30.59	31.26	31.95
Operating engineers—crane operators	24.78	25.77	26.48	27.15	26.99	27.89	28.84	29.74	30.99	31.58	32.17
Operating engineers—heavy equipment	24.38	25.77	26.25	26.95	26.87	27.53	28.79	29.60	30.77	31.42	31.89
Operating engineers—small equipment	22.67	23.68	24.16	24.56	24.60	25.67	26.26	27.13	28.04	28.53	28.95
Painters	22.21	22.76	23.42	23.83	24.38	24.95	25.73	26.47	27.36	28.21	29.04
Pipefitters	27.00	27.88	29.26	30.26	30.12	31.37	32.09	32.77	33.68	34.41	35.43
Plasterers	22.95	23.44	23.91	24.66	25.52	25.68	26.18	27.06	27.78	29.07	29.26
Plumbers	27.05	27.69	28.67	29.57	30.19	31.03	31.96	32.77	33.90	34.77	35.81
Roofers	21.62	22.45	23.53	23.79	24.28	24.32	24.86	25.75	26.68	27.46	28.08
Sheet metal workers	26.06	26.79	27.62	28.49	29.34	30.17	31.20	31.87	33.42	34.21	35.22
Teamsters—truck drivers	21.03	21.29	21.76	21.81	22.74	23.17	24.35	24.28	25.16	25.37	26.22

Source: *Engineering News-Record*, Third Annual Cost Reports (1990–2000).

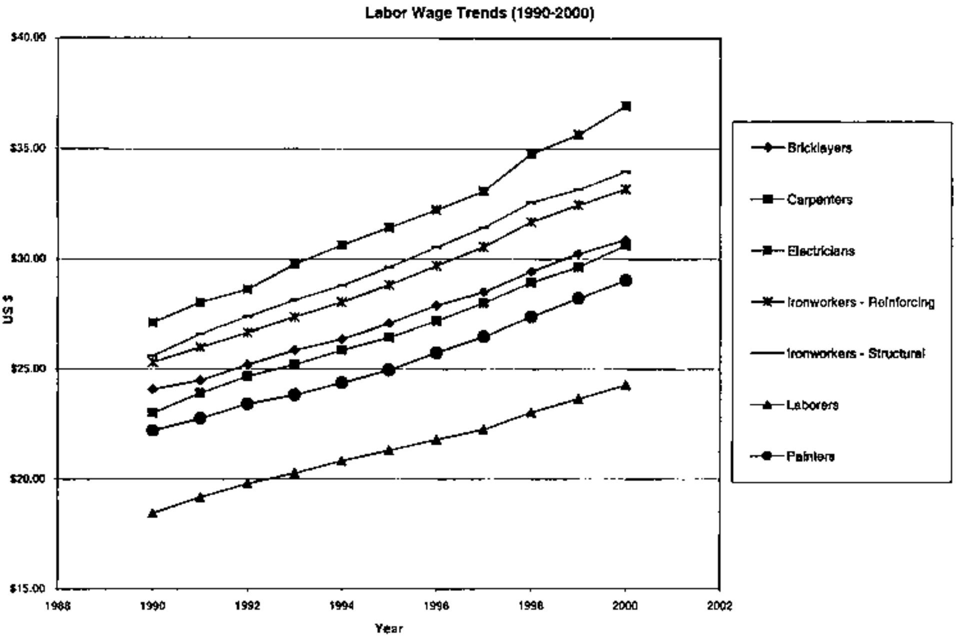


FIGURE 4-4 Growth in wages for selected crafts.

4.4.1.2 Climatic Conditions

Climatic conditions refer to temperature, wind, and rainfall. Typically, any weather extremes will affect the productivity of labor. Too hot can lead to exhaustion. Too cold can impair motor skills. Rain and strong wind are nuisances since they affect workers' physical comfort, ability to see, and the handling of materials. Apart from the effect of slowing down or stopping the project, working in some weather conditions also can give rise to additional work, such as the need to construct temporary shelters.

4.4.1.3 Work Conditions

Work conditions are related to workspace, site layout and organization, and lighting and noise levels. Workers working in ample space will work faster than those who are put in a confined space with limited workroom. This can happen on a jobsite that has limited space, such as those in downtown areas. This may also be due to accelerated work, which puts more men on the job, each performing lots of work that can lead to site congestion. In this situation, each worker or each craft is allocated a small amount of work area with limited storage space. The problem is worsened when the storage areas are located away from the work area, resulting in workers spending more time moving back and forth to get materials and therefore less time spent on productive work. This issue is closely related to the next factor, site layout and organization. With proper material storage and good site layout planning, the retrieval of construction material and the movement of workers and materials can be facilitated, resulting in better productivity as more of the workers' time can be dedicated to productive work. Lighting and noise levels on the site can also affect productivity as they affect the workers' perceptions of their environment as well as the ability to efficiently communicate among themselves.

4.4.1.4 Management Conditions

Management conditions are those involved with construction supports such as scheduling, procurement, and information support. Scheduling of work activities onsite affects workflow and the amount of activities on the site. Proper scheduling of activities can minimize disruptions and facilitate workflow, thus improving productivity. Scheduling prescribes the activities that will take place at any given time. Proper scheduling can improve productivity by having just the right amount of activities going on at any one time. Too many activities scheduled concurrently can lead to site congestion, while too few activities can be an inefficient use of resources. Management can also improve productivity by making sure that all materials, tools, equipment, and labor are adequately provided to carry out the work in an efficient manner. Resource shortages can have a serious effect on productivity, often resulting in bottlenecks or idle crew and equipment. Proper procurement and planning ensures that just the right amount of resources is available when needed. Having too much material that is not needed until a future date onsite can also lead to a lot of wasted time on material rehandling. Otherwise, productive time is spent preparing storage areas, moving materials to storage, and possibly rearranging materials as other materials are delivered and need storage. Having too much material stored onsite also means that the crew will certainly be spending more time looking for it. Another vital input to efficient production is information. Proper management support ensures availability of information and clear understanding of instructions. Information provided clearly and in a timely manner can promote work planning at the craft levels, thus enhancing labor productivity.

Labor productivity is difficult to estimate due to the fact that numerous factors can affect it and that their relationships are complex and have not been fully explored. Although it may be clear that what and how some factors affect labor productivity, quantifying the effects of the factors on labor productivity is a difficult issue. For example, we know that the amount of available workspace affects labor productivity, and that given the same conditions restricted workspace can impede workflow, whereas ample workspace allows for higher productivity. However, quantifying and generalizing the amount of workspace and establishing relationships between workspace and labor productivity can be very difficult.

4.4.2 Productivity Sources

Productivity rates can be determined from published sources such as Means' *Building Construction Cost Data* and Walker's *Building Estimator's Reference Book*. Figure 4.5 illustrates an excerpt from Means. For a line item, Means provides the crew types associated with that line as well as two forms of productivity rate: the daily output (unit/day) and labor hours (hr/unit). For example, referring to Figure 4.5, for line 09210-100-0900, the daily output is 72.74 m^2 and the labor hours required for 1 m^2 is 0.550 hours. The bare labor cost for the line item is \$13.70/m^2. Also, the crew type for this work is Crew J-1. With reference to Figure 4.6, the excerpt from Means' crew listing shows Crew J-1 as consisting of 3 plasterers, 2 plasterer helpers, and 1 mixing machine. The labor hours per unit production are determined by dividing the total labor hours of the crew by the daily output. Figure 4.7 shows the computation involved in determining the weighted weight rate for the crew and bare unit labor cost for the line item.

It is important to note the presentation of productivity in labor hours. By keeping the productivity record in labor hours, the record is essentially normalized and is not subjected to the variability in project locations and prevailing wage rates. In this way, unit labor costs for the contractor's own operating region can be easily developed by multiplying local wage rates including burden and fringe benefits by the productivity rate. For example, a contractor determines that the unit productivity for painting a wall is 0.55 hour per m^2. If the local wage rate including burden and fringe benefits is \$30 per hour, the unit labor cost becomes \$16.50 per m^2. If the wage rate is \$20 per hour, the unit labor cost becomes \$11 per m^2. In addition, productivity performance between projects can also be easily compared if contractors keep cost accounting records in man-hours.

09200 Plaster & Gypsum Board

	09210	Gypsum Plaster	CREW	DAILY OUTPUT	LABOR-HOURS	UNIT	2000 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P
100	0010	GYPSUM PLASTER 36 kg bag, less than 0.9 metric ton				Bag	14.20			14.20	15.65
	0100	Over 0.9 metric ton				"	12.90			12.90	14.20
	0300	2 coats, no lath included, on walls	J-1	87.79	0.456	m^2	4.09	11.35	0.62	16.06	22.50
	0400	On ceilings	"	76.92	0.520		4.09	12.95	0.71	17.75	25.00
	0600	2 coats on and incl. 10 mm gypsum lath on steel, on walls	J-2	81.10	0.592		8.20	15.00	0.67	23.87	32.50
	0700	On ceilings	"	69.40	0.692		8.20	17.55	0.79	26.54	37.00
	0900	3 coats, no lath included, on walls	J-1	72.74	0.550		5.70	13.70	0.75	20.15	28.00
	1000	On ceilings	"	65.22	0.613	▼	5.70	15.30	0.83	21.83	30.50

Source: Means Building Construction Cost Data 2000 Metric Edition

FIGURE 4-5 Excerpt from Means *Building Construction Cost Data*: line items. (From Means' *Building Construction Cost Data* 2000 *Metric Edition*.)

Crew No.	Bare Costs		Incl. Subs O & P		Cost Per Labor-Hour	
Crew J-1	**Hr.**	**Daily**	**Hr.**	**Daily**	**Bare Costs**	**Incl. O&P**
3 Plasterers	$26.65	$639.60	$40.85	$980.40	$24.93	$38.21
2 Plasterer Helpers	22.35	357.60	34.25	548.00		
1 Mixing Machine, 0.17 m³		54.50		59.95	1.36	1.50
40 L.H., Daily Totals		$1051.70		$1588.35	$26.29	$39.71

Source: Means Building Construction Cost Data 2000 Metric Edition

FIGURE 4-6 Excerpt from Means *Building Construction Cost Data*: crew listing. (From Means' *Building Construction Cost Data* 2000 *Metric Edition*.)

As can be seen above, productivity rates can come from many sources. However, the most reliable productivity records are the contractor's own historical data based on actual experiences performing similar work. The advantage of historical information is that it reflects how a company's workforce performs the work.

4.4.3 Adjusting Productivity

The productivity rates that are derived from historical data are often for average or standard projects. On most occasions, however, the project that is being considered deviates from standard conditions. Therefore, the productivity rates need to be modified to take into consideration how the new project deviates from the standard condition. In the simplest form, standard productivity rates can be adjusted to better suit a specific project by using productivity factors. Equation (4.4) shows how to derive adjusted productivity rates by applying the productivity factor.

With Reference to Line 09210-100-0900 in Figure 4.5 and Crew J-1in Figure 4.6
Crew J-1 consists of 3 plasterer and 2 plasterer helper

$$\text{Weighted Wage Rate (Bare Cost)} = \frac{3(\$26.65) \times 2(\$22.35)}{3+2}$$

$$= \$\,24.93\ /\text{hr}$$

$$\text{Bare Labor Unit Cost} = \$\,24.93\ /\text{hr} \times 40\ \text{hr} \div 72.74\ \text{m}^2$$

$$= \$\,13.70\ /\ \text{m}^2$$

FIGURE 4-7 Computing the weighted wage rate and the bare unit labor cost.

$$Adjusted\ productivity\ rate = standard\ productivity\ rate \times productivity\ factor. \quad (4.4)$$

The productivity factor can be determined for a single variable, such as weather, or it may be a composite factor accounting for many variables. For example, a site engineer may determine that the productivity factor for a particular crew is 0.9 on a very hot day. If the standard productivity for the crew is 100 m^2 per hour, then on a very hot day, the adjusted productivity can be estimated to be 90 m^2 per hour. In this way, the productivity factor adjusted the standard productivity to better estimate the actual productivity base on the actual site condition. Determining the productivity factor is one of the most complicated tasks with no hard and fast rules. Lots of experience and good recordkeeping are the only assured ways of determining the most probable and reliable productivity factors.

Another important issue relating to productivity is productivity loss due to changed conditions. Changed conditions occur when the nature of the work encountered is significantly different from that described in the contract document. Changed conditions can arise due to an unforeseen event, such as an unexpected discovery of rocks underground. Changed conditions can also be the result of change orders requested by the owner, such as extending the length of the building. Apart from the direct effects on the resources and time required for the project, an estimator must also consider the less subtle impact of changed conditions on productivity. Changed conditions lead to productivity loss that can be costly and must be accounted for by the contractor. However, determining the true cost due to loss in productivity can be very difficult as many of the variables are difficult to quantify. Tables 4.7 and 4.8 show tables developed by Dr. Calin M. Popescu for the Texas Masonry Council to address the issue of changed conditions on productivity loss. An example application of the table can be seen in Figure 4.8.

4.4.4 Productivity Impact and the Cost of Overtime

Overtime is one of the methods used to accelerate work. Hourly paid workers normally work five 8-hour days, or 40 hours per week, which is considered normal time. Any work time beyond that time is considered overtime. Short-term overtime can be used effectively to accomplish more work in a day. However, scheduling overtime for more than several weeks can result in huge productivity losses. Table 4.9 provides production efficiency with respect to the different overtime schemes. As can be seen from the table, productivity loss can be as high as 45% when work is scheduled to run a 12-hr day, 7 days per week, for 4 weeks. An example of a productivity calculation when overtime is applied is shown in Figure 4.9.

Table 4.7 Hypothetical Example for Rating Changed Conditions[a]

No.	Changed condition	Condition examples: Minor	Moderate	Severe
1	Congestion: Change prohibits use of optimum crew size including physically limited working space and material storage.	An additional crew/contractor working in the same area 1 day/week	Additional crews/contractors working in the same area 2–3 days/week	Additional crews/contractors working in the same area every day
2	Morale and attitude: Change involves excessive inspection, multiple change orders and rework, schedule disruption, or poor site conditions.	Less than 3 inspections/week, average 1 hour each	Daily inspection, 1–2 hours each	Fulltime inspection
3	Labor reassignment: Change demands rescheduling or expediting, and results in lost time to move out/in.	Crews move once a week between job areas	Crews move 2–3 times/week between job areas	Crews move almost daily between jobs
4	Crew size change: Change increases or decreases in optimum crew size results in inefficiency or workflow disruption.	Crew size changes once/week	Crew size changes 2–3 times/week	Crew size changes almost daily
5	Added operations: Change disrupts ongoing work due to concurrent operations.	Work disrupted once/week	Work disrupted 2–3 times/week	Work disrupted almost daily
6	Diverted supervision: Change causes distraction of supervision to analyze and plan changed work, stop and replan ongoing work, or reschedule work.	2 times/week, 1–2 hours	Daily, 1–2 hours	Daily, 4 hours or more
7	Learning curve: Change causes workers to lose time while becoming familiar with and adjusting to new work or a new environment.	Once a week	2–3 times/week	Daily
8	Errors and omissions: Change causes time lost due to mistakes engendered by changed circumstances.	Every 2 weeks or more	Every week	Every 1 or 2 day(s)

TABLE 4.7 Continued

No.	Changed condition	Condition examples: Minor	Moderate	Severe
9	Beneficial occupancy: Change requires the use of premises by owner prior to work completion, restricted work access, or working in close proximity to owner's personnel or equipment.	Punch list work	Punch list and new work one week prior to original completion date	Many crews and overtime a few days prior to original completion date
10	Joint occupancy: Change requires work to be done while other trades not anticipated in the bid occupy the same area.	Facility partly occupied, one trade working	Minor changes, 2–3 crews working in the same area	Facility in operation, work on limited shifts
11	Site access: Change requires inconvenient access to work area, inadequate workspace, remote materials storage, or congested worksite.	4 days/week, <25 yards to material storage	2–3 days/week, 25–50 yards to material storage	Only weekend material, >50 yards to material storage
12	Logistics: Change involves unsatisfactory supply of materials by owner or general contractor, causing inability to control material procurement and delivery and rehandling of substituted materials.	1 rehandling lifting, 4 days/week material availability	2 rehandling lifting, 2–3 days/week material availability	>3 rehandling lifting, limited time
13	Fatigue: Change involves unusual physical exertion causing lost time when original plan resumes.	Once/week	2–3 times/week	Every day for more than 1 week
14	Work sequence: Change causes lost time due to changes in other contractors' work.	One trade/ one change/week	2 trades/ 2–3 changes/week	Multiple trades, many changes
15	Overtime: Change requires overtime causing physical fatigue and poor mental attitude.	<5 hours/week, 1–2 consecutive weeks	5–10 hours/week, 3–5 consecutive weeks	>10 hours/week, >5 consecutive weeks
16	Weather or environment: Change involves work in very cold or hot weather, during high humidity, or in dusty or noisy environment.	Expected temp. +5°F in summer or −5°F in winter	Expected temp. +10°F in summer or −10°F in winter	Expected temp. +15°F in summer or −15°F in winter

[a] Hypothetical examples for rating as minor/moderate/severe beyond contract agreement prepared by C.M. Popescu (UT–Austin).

Table 4.8 Productivity Loss Due to Changed Conditions[a]

No.	Changed condition	Estimated productivity loss (%) if change is . . .[b] Minor	Moderate	Severe
1	Congestion: Change prohibits use of optimum crew size including physically limited working space and material storage.	5–20 10	14–25 19	20–45 32
2	Morale and attitude: Change involves excessive inspection, multiple change orders and rework, schedule disruption, or poor site conditions.	4–28 13	12–35 22	20–50 30
3	Labor reassignment: Change demands rescheduling or expediting, and results in lost time to move out/in.	5–10 8	12–35 21	20–50 34
4	Crew size change: Change increases or decreases in optimum crew size results in inefficiency or workflow disruption.	5–15 10	12–30 22	20–60 36
5	Added operations: Change disrupts ongoing work due to concurrent operations.	5–20 9	10–24 20	15–70 32
6	Diverted supervision: Change causes distraction of supervision to analyze and plan changed work, stop and replan ongoing work, or reschedule work.	5–10 7	11–30 18	18–50 31
7	Learning curve: Change causes workers to lose time while becoming familiar with and adjusting to new work or a new environment.	8–20 12	18–35 25	32–55 42
8	Errors and omissions: Change causes time lost due to mistakes engendered by changed circumstances.	5–15 7	10–30 17	18–45 30
9	Beneficial occupancy: Change requires the use of premises by owner prior to work completion, restricted work access, or working in close proximity to owner's personnel or equipment.	3–20 12	9–40 23	15–60 37

TABLE 4.8 Continued

No.	Changed condition	Estimated productivity loss (%) if change is . . .[b]		
		Minor	Moderate	Severe
10	Joint occupancy: Change requires work to be done while other trades not anticipated in the bid occupy the same area.	6–15 11	15–30 20	22–40 32
11	Site access: Change requires physically inconvenient access to work area, inadequate workspace, remote materials storage, or poor man-lift management.	5–25 13	15–35 23	20–50 35
12	Logistics: Change involves unsatisfactory supply of materials by owner or general contractor, causing inability to control material procurement and delivery and rehandling of substituted materials.	6–10 9	16–25 20	24–45 34
13	Fatigue: Change involves unusual physical exertion causing lost time when original plan resumes.	7–15 10	14–25 21	22–40 32
14	Work sequence: Change causes lost time due to changes in other contractors' work.	5–15 10	15–35 22	30–45 35
15	Overtime: Change requires overtime causing physical fatigue and poor mental attitude.	8–15 12	20–30 26	30–50 41
16	Weather or environment: Change involves work in very cold or hot weather, during high humidity, or in dusty or noisy environment.	5–15 9	15–30 19	25–45 31

[a]Survey result June 2000: minimum, maximum, and average percentages.
[b]Zero to 100% in each column.
Source: From Appendix B published in *Management Methods Bulletin No. CO1, File Change Orders*, Mechanical Contractors Association of America, Inc., Rockville, MD.

Part 1	Estimated masonry hours	20000 *(Item 1)*	
	Actual masonry hours	24000 *(Item 2)*	
	Total Work Hours Lost	4000 *(Item 3 = Item 2 - Item 1)*	
Part 2	Site Factors Causing Masonry Hours Lost		
	No. 3 Labor Reassignment, Minor Change	8%	
	No. 6 Diverted Supervision, Minor Change	8%	
Part 3	Work Hours Lost Due to Changed Conditions:		
	20,000 X (0.08 + 0.08) =	3200 *(Item 4)*	
	Total Work Hours Lost	4000 *(Item 3)*	
	Work Hours Lost Due to Subcontractor	800 *(Item 5 = Item 3 - Item 4)*	

FIGURE 4-8 Example computation of productivity loss due to changed conditions.

TABLE 4.9 Various Overtime Schemes and Production Efficiency

		Production efficiency				
Days per week	Hours per day	Week 1 (%)	Week 2 (%)	Week 3 (%)	Week 4 (%)	Average 4 weeks (%)
	8	100	100	100	100	100.00
5	10	100	95	90	85	92.50
	12	90	85	70	60	76.25
	8	100	100	95	90	96.25
6	10	95	90	85	80	87.50
	12	90	80	65	60	73.75
	8	100	95	85	75	88.75
7	10	90	85	75	65	78.75
	12	85	75	60	55	68.75

Source: Means' *Building Construction Cost Data* 2000 *Metric Edition.*

With Reference to Line 09210-100-0900 in Figure 4.5

Normal Daily Output $= 72.74\ m^2$

Productivity per labor hour $= 72.74\ m^2 \div 40\ hr$

$= 1.82\ m^2/hr$

Under 6-10 overtime scheme:

Average Production Efficiency = 87.50% (Table 4.10)

Adjusted Daily Output $= 1.82\ m^2/hr \times 50\ hr \times 0.875$

$= 79.56\ m^2$

FIGURE 4-9 Productivity calculations with overtime.

4.5 REVIEW QUESTIONS

1. What is a construction crew?
2. What is productivity?
3. What is overtime? Give a few examples of overtime patterns used in construction.
4. Explain why using overtime is not recommended for most construction projects.
5. Under what conditions are wage premiums applied?
6. List the factors affecting labor productivity. Briefly explain how the factors affect labor productivity.
7. Explain why it is a good idea to express construction productivity in work hours per unit of work.
8. What is the best source for productivity data? Explain why.
9. What are fringe benefits? List some of the items that can be included under fringe benefits.
10. Why is it necessary to adjust productivity rate data before applying them to a new project?

5

Estimating the Cost of Construction Equipment

5.1 INTRODUCTION

Modern construction is characterized by the increasing utilization of equipment to accomplish numerous construction activities. According to Means' *Illustrated Construction Dictionary*, equipment refers to all the equipment, tools, and apparatus necessary for the proper construction and acceptable completion of a project. In a construction project, equipment costs are typically divided into portions. The first and bigger portion covers the cost of equipment and is often referred to as equipment cost. The cost of equipment is one of the major cost categories in a construction project. It represents the cost of acquiring the equipment and the cost of operating that equipment during the construction processes. The second and smaller portion covers the cost of hand tools. This represents a smaller portion of the project cost and is often calculated as a percentage of payroll costs. It is added to the indirect cost under the jobsite overhead.

5.2 CONSTRUCTION EQUIPMENT

Equipment can be classified as specific use or general use.

5.2.1 Specific Use Equipment

Specific use equipment, as the name implies, is for a specific work item or items on the job. Units are assignable to jobs and are not shared by other subcontractors. This equipment is only for specific construction operations and is removed from the jobsite soon after the task is completed. Its usage is shorter term when compared to general use equipment. The most equipment-intensive operations are encountered in CSI-Division 2 Site Work, Division 3 Concrete, and Division 5 Metals. These works are voluminous, repetitive, and are ideal for equipment utilization. Some typical equipment used for site work includes:

Tractors,
Scrapers,
Front shovels,
Hoes,
Loaders and backhoe loaders,
Hauling units, and
Compactors.

Tractors are self-contained units designed to provide tractive power for heavy pushing and pulling work. Tractors can be crawler or wheel type. Crawler or track type units are designed for work requiring high tractive forces, whereas wheel type units sacrifice some of the tractive power while being designed for greater mobility and an ability to travel up to an excess of 50 km/hr. Tractors are one of the most versatile pieces of equipment since they can be modified for different uses by changing the blades and attachments of the units. Typical applications of tractors are land clearing, bulldozing, and ripping earth. In addition, tractors are also often used together with other construction equipment, such as in pushing a scraper during excavation or in pulling a roller compactor during compacting operations.

Scrapers are units designed to load, haul, and dump loose material. Scrapers represent an alternative to using two different pieces of equipment, one for loading and another for hauling. Scrapers are ideal for short hauls of less than a mile and for off-highway work conditions. In addition, the ability to deposit their loads in layers of uniform thickness also facilitates subsequent compaction operations.

Front shovels are excavation units used for digging above the surface of the ground on which the piece of equipment rests. The digging and loading motion of a shovel is an outward and upward thrust. A shovel is especially suited for hard digging conditions.

On the other hand, hoes, backhoes, or back shovels are excavation units used for digging below the surface of the ground on which the piece of equipment rests. Hoes develop excavation force by pulling the bucket downward and inward towards the unit, and curling the bucket. Apart from pit excavation, hoes are also used for excavating trenches and for the handling and laying of pipes.

Loaders are one of the most common pieces of construction equipment and are used extensively to handle and transport materials, excavate earth, backfill, and as a loading or hauling unit. Similar to tractors, loaders can be tractive for maximum tractive power or wheeled for greater mobility. Backhoe loader units are loaders that have a backhoe attachment on the back of the unit. These units are popular as they can do the work often performed by two specialized pieces of equipment.

Hauling units or trucks serve only one purpose, which is to efficiently transport material from one point to another. The longer the distance, the more the justification and advantage is in using trucks rather than other pieces of equipment. This is because trucks are the fastest moving construction unit and they generally cost the least to operate for the moving of material.

Compactors are pieces of equipment used to perform soil compaction. There are many types of compactors available to suit the varieties of soil that can be encountered on a construction site, as well as a required compaction methodology and the desired specified compaction.

The above list is not exhaustive and new equipment is continually being developed to handle other specialized tasks in construction. Table 5.1 presents a sample list of earthwork equipment and associated operating and rental costs.

5.2.2 General Use Equipment

General use equipment has shared utilization by all subcontractors on the construction site and is not associated with any particular work item or items. These

TABLE 5.1 Sample List of Earthwork Equipment with Operating Cost and Rental Rate

Equipment type	Hourly operating cost ($)	Rent/ day ($)	Rent/ week ($)	Rent/ month ($)
Excavator, diesel hydraulic, crawler mounted				
0.382 m^3 capacity	11.65	415	1,248	3,750
0.573 m^3 capacity	17.40	530	1,583	4,750
1.146 m^3 capacity	26.65	835	2,500	7,500
2.674 m^3 capacity	78.25	2,500	7,500	22,500
Backhoe-loader				
30 kW to 34 kW, 0.478 m^3 capacity	7.15	217	650	1,950
34 kW to 45 kW, 0.573 m^3 capacity	8.50	225	675	2,025
60 kW, 0.955 m^3 capacity	12.22	292	877	2,625
84 kW, 1.146 m^3 capacity	15.50	395	1,185	3,550
Tractor, crawler, with bulldozer				
56 kW	9.95	335	1,000	3,000
104 kW	17.55	650	1,950	5,850
224 kW	34.70	1,375	4,150	12,500
522 kW	94.00	3,325	10,000	30,000
Tractor loader, crawler, diesel				
60 kW, 1.1 m^3 capacity	9.87	420	1,255	3,775
71 kW, 1.1 to 1.3 m^3 capacity	10.23	475	1,425	4,275
142 kW, 1.9 to 2.5 m^3 capacity	19.25	1,050	3,150	9,450
205 kW, 2.7 to 3.8 m^3 capacity	26.90	1,375	4,100	12,300
Tractor loader, wheel, diesel				
48 kW, 0.8 to 1.0 m^3 capacity	8.45	277	830	2,500
75 kW, 1.3 to 1.5 m^3 capacity	11.35	405	1,215	3,650
127 kW, 2.3 to 3.4 m^3 capacity	15.30	700	2,100	6,300
280 kW, 5.4 to 6.0 m^3 capacity	45.65	1,425	4,300	12,900

Source: Means' *Building Construction Cost Data, Metric Edition,* 2000.

pieces of equipment are kept on the site over a longer period of time, throughout almost the entire construction phase. Some examples of general use equipment include:

Cranes,
Air compressors,
Floodlights and light towers,
Forklifts, and
Pumps.

Cranes are a must on any building construction project. Many types of cranes have been developed to better accommodate the variety of construction needs. Cranes can be static units, like the tower crane, or they can be movable units, as in a wheel- or track-mounted mobile unit. Tower cranes are normally general use equipment, whereas the mobile type may be specific task equipment. Cranes are used for lifting and moving loads, as well as assisting in the construction installation processes, such as the erecting of precast concrete panels.

Air compressors generate pressurized air that is used to power hand tools used in construction, such as pneumatic nailers, concrete vibrators, hand tempers, and jackhammers.

Floodlights and light towers provide illumination for a work area that lacks sufficient light or when work is carried out beyond daylight or in low lighting conditions.

Forklifts are used extensively to handle the loading and unloading of heavy bulk loads from trucks, the movement of materials to a storage area, and the subsequent distribution of the materials to work areas onsite.

Pumps are necessary for moving water from a source to a needed area on the construction site. Pumps can also supply the water pressure needed in some construction activities. Submersible pumps may also be required in the dewatering or draining of water collected in the work area.

Table 5.2 provides a sample list of general use equipment used in a building construction project and the associated operating and rental costs.

5.3 EQUIPMENT PLANNING

Construction requires large quantities of materials handling, horizontally and vertically. In its simplest form, a construction operation is the moving of material from one location to another. The primary function of equipment is to handle and move varieties of materials around the construction site. For example, a construction site may need to be leveled, thus involving the excavation of soil material from one area and the transporting of the excavated material to fill in another location onsite. The complexity of an operation increases as the requirement for final placing or installation increases. An example is the erection of structural steel members in a structural steel frame building. The members are hoisted from the hauling unit or storage location onsite and are moved and placed at the desired final location on the building structure. Structural steel workers then bolt and weld the members in place. These examples illustrate how the primary function of equipment is to handle and move materials on a construction site.

In general, equipment is designed to perform certain mechanical operations. Each piece of equipment has different operational characteristics and it may not be obvious which piece is best for a particular job. It is the responsibility of management to match the right unit or combination of units for executing the

TABLE 5.2 Sample List of General Use Equipment with Operating Cost and Rental Rate

Equipment type	Hourly operating cost ($)	Rent/ day ($)	Rent/ week ($)	Rent/ month ($)
Aerial lift, scissor type, to 7.6 m high, 900 kg capacity	1.80	125	375	1,125
Aerial lift, telescoping boom, to 18 m high, 340 kg capacity	8.47	500	1,500	4,500
Air compressor, portable, gas engine, 0.076 m^3/s	6.80	74	220	660
Floodlight on tripod 2000 W	0.13	42	125	375
Forklift, wheeled, for brick, 5.5 m, 1360 kg, 2-wheel drive	9.28	167	500	1,500
Generator, electric, gas engine, 5 kW	1.49	59	175	525
Light tower, towable, with diesel generator, 4000 W	1.95	142	425	1,275
Self-propelled crane, telescoping boom, 23 tons capacity	20.99	660	1,980	5,950
Submersible electric pump, 50 mm, 7.6 L/s	0.42	47	140	420
Tower crane, 40 m high, 30 m jib, 2800 kg capacity, 2 m/s	53.48	1,425	4,260	12,800

Source: Means' *Building Construction Cost Data, Metric Edition*, 2000.

work at hand. The understanding of equipment characteristics, their methods of movement, and their manner of material handling are vital for the planning of equipment operations. Equipment planning is required for production achievement, cost control, communication, and the coordination of the project and parties.

Equipment planning involves the gathering and analysis of relevant information on a project, the establishment of a project's scope, and the specification of limits on a project. Factors relating to time, money, location, competitive resources, and coordination requirements must be identified and established. Any assumption in planning must be written down. The planning of equipment usage begins with a site investigation report. The site condition is very important as it can affect the type of equipment selected for a project and subsequent construction methods. Refer to Appendix 5 for a sample of a site investigation checklist. With information from the site visit and details of the necessary work based on the contract, an estimator must visualize the construction process as well as future site conditions as construction work progresses. Equipment planning must identify the work to be done and establish:

1. Equipment lists and procurement schedules,
2. Equipment productivity and a desired construction schedule, and
3. Realistic cost estimates of equipment.

5.3.1 Shared Utilization Consideration

Equipment is generally specified under the general and special conditions in the contract. Shared equipment procurement and operation is the responsibility of the general contractor. Subcontractors traditionally furnish additional or specialized equipment as needed. Sharing equipment allows the elimination of duplicate equipment on a site and unnecessary mobilization and demobilization operations. In addition, equipment rental rates (per unit time period) can also be reduced due to longer usage. The shared use of equipment also provides more control for general contractors in coordinating work onsite, improving safety, and increasing productivity.

A general contractor must consult with subcontractors to determine what their needs will be and what will be furnished by each party. This is done before the submission of bids and the selections of subcontractors for the job. This is necessary so as to deduct duplicate equipment costs from subcontractor bids and to backcharge the subcontractors an agreed amount for equipment usage.

5.3.2 Factors Influencing Equipment Selection

Many factors can influence the expected performance of equipment on a construction site. These factors can be group into three categories: site conditions, the nature of the work, and equipment characteristics.

5.3.2.1 Site Conditions

Primary site condition factors are: types of material to be handled, physical constraints onsite, and hauling distances. An example of a type of material handled could be the number of trees and their sizes. In the clearing of a site, if there are only shrubs, then a dozer with a traditional dozer blade may work fine. However, if big trees are present and need to be cleared, then a more powerful dozer with the specialized V-tree cutter blade may be needed. Another example that can influence equipment selection is the type of soil encountered. For example, the compaction of clayey soil is done best with a sheep's foot roller, whereas more sandy soil is best compacted with a vibratory roller.

Physical constraints onsite refer to site area and layout, surface condition, topography, and adjacent neighborhood. The smaller the site area, the more constraints it has on the mobility of equipment, which in turn can have a serious impact on equipment productivity. Smaller equipment may be needed to maintain mobility or bigger units may be required to minimize equipment traffic and site congestion. Selection of cranes is also affected by the shape and layout of the site. Static cranes must have access to all the area around a site to be efficient as they have high mobilization cost. On the other hand, mobile cranes can be more easily relocated but require more workspace and have higher operating costs. The primary surface condition of concern is the bearing capacity of the soil. Low bearing capacity soil may dictate the selection of track-type instead of wheel-type running gear on the piece of equipment. Higher grade surfaces may call for a track-type piece of equipment due to the higher tractive force of the unit. The neighborhood of the construction site must be considered, such as other buildings and traffic in the area, as it can also offer obstacles to equipment movement or certain construction operations.

Hauling distances can affect the selection of equipment. For short hauls, a loader can pick up the load and move it to a dump area by itself. However, for longer hauling distances it would be best to divide the operation into two specialized operations with two specialized pieces of equipment performing the tasks. In this case, the loader can be just the loading unit and a dump truck can be just the hauling and dumping unit. The longer the hauling distance, the more advantage there is in using higher capacity hauling units since they can be more cost effective.

5.3.2.2 The Nature of the Work

Some factors relating to the nature of the work include payload, the total quantity of work, and the construction schedule. Payload has a direct relation to the capacity of the equipment selected. For example, the particular crane selected must be able to lift the maximum load the work may require.

A higher quantity of work can influence and justify the selection of higher capacity equipment. Although higher capacity equipment has higher mobilization and rental costs, the per-unit production costs are lower. Therefore, given a higher quantity of work, the savings in unit production costs could be high enough to offset higher mobilization and rental costs, and thus result in lower total costs. On some projects, costs may not be the governing constraint; instead, the construction schedule might be. A tighter schedule often requires higher productivity units, such as those with higher power, bigger capacity, more mobility, and faster deployment.

5.3.2.3 Equipment Characteristics

Equipment characteristics are related to equipment capabilities and costs. Equipment capabilities are their capacities and versatility. Capacity can be in the form of maximum allowable payload and maximum volume that can be handled. It can also relate to the power, mobility, or maneuverability of a piece of equipment. Versatility refers to the degree of applicability of a unit to perform many different operations. For example, a dozer can be adapted to perform many tasks by simply changing a blade or adding additional attachments. Versatility can make a piece of equipment more useful on a site, thus replacing the need for more specialized units. Equipment selection must also consider the possibility of shared utilization of selected equipment. Cost is certainly an important consideration in equipment selection. Costs associated with equipment are further discussed in the next section.

All the above factors can be related and they all must be considered together in equipment planning. Equipment planning can yield many solutions. Many decisions involve trade-offs that must be properly analyzed to identify the best solution. For example, choosing two smaller pieces of equipment instead of one larger unit may mean higher unit production costs, but there is a redundancy in the system that can be good insurance if one unit should break down and work can be kept moving.

Considering the above factors that can influence equipment selection, the outcome of equipment planning should yield a solution that satisfies the following three underlying objectives in equipment selection: feasibility, efficiency, and economy. The feasibility of an equipment plan refers to the selection of equipment that can carry out the tasks in a satisfactory manner. This is determined by the nature of the work that the equipment will perform and the condition in which the equipment will do the work. Efficiency refers to the equipment and the selection methods that maximize efficiency of the construction operation such as those decisions that can reduce the number of equipment pieces through selecting higher capacity units. Efficiency in operation may not have a direct effect on the direct cost of the project but may have an indirect effect on other aspects of the construction project, such as minimizing site congestion leading to higher productivity, while decreasing the likelihood of accidents and promoting communication and coordination. Finally, the selected pieces of equipment and methods that produce the lowest cost are ideal for the project as they directly contribute to lower construction costs, which is one of the goals of every construction project.

5.4 EQUIPMENT PROCUREMENT SOURCES AND ASSOCIATED COSTS

Equipment costs rank second behind labor costs in terms of uncertainty and their effects on the outcome of any anticipated profits from a job. This is again due to the unpredictable nature of production on a construction project. The understanding and knowledge of the components of equipment costs are necessary for a good cost estimate. It is also important to note that for any decision made in the acquisition of equipment, all costs should be considered and accounted. A contractor does not pay for equipment but the equipment should pay for itself. Costs incurred in the procurement of equipment must be recovered somehow in the profit or savings in other areas. Equipment can be acquired through three methods: purchasing, renting, or leasing.

5.4.1 Purchasing Equipment

Purchasing equipment used to be the most common and only way for a contractor to acquire equipment. Then came the business of renting and leasing, which has seen continual growth since its introduction. Currently, contractors may purchase equipment when factors pertaining to ownership and economics make this alternative more favorable to renting or leasing. A contractor may purchase new or used equipment from manufacturers, equipment dealers, or other contractors. One of the most popular and best sources for equipment shopping is the *Contractors Hot Line Magazine*, which can also be found on the Internet at www.contractors-hotline.com. This weekly magazine and Web site publish advertisements relating to the sales, rental, leasing, and servicing of equipment and related parts and accessories. The advertisements are submitted by equipment manufacturers, renters, and contractors.

The advantage of purchasing equipment is that it allows a contractor to have absolute control on the use and disposition of equipment. He can use the equipment in any manner he sees fit. He can make decisions on maintenance and servicing, thus ensuring the desired operational performance. After the job, the contractor can sell or trade the equipment according to his own choosing. There is also an element of pride in the ownership of equipment.

Costs associated with this option of acquisition are sometimes called the ownership costs. Such costs can be broken down into the following six cost categories: initial cost, depreciation, investment cost, insurance cost, tax, and storage cost.

5.4.1.1 Initial Cost

The initial cost is the total cost a contractor pays to purchase a piece of equipment and have it shipped to a jobsite or equipment yard. This initial cost is the basis for determining other costs related to ownership as well as operating costs. Generally, initial cost is made up of:

Price at the factory or used equipment price,
Extra options and accessories,
Sales tax,
Freight, and
Assembly or setup charges.

The initial cost is very straightforward, whereas the following costs require more analysis and computation.

5.4.1.2 Depreciation

Depreciation in cost estimating has two aspects: a tax-deferred expense, and the decline in market value of a piece of equipment due to age, wear, deterioration, and obsolescence.

The first aspect of depreciation is as a tax-deferred expense. This depreciation is a cost against income that reduces the income taxes of a corporation, such that the greater the depreciation, the smaller the corporation taxes for an equal-valued income. Depreciation is not an actual negative cash flow. The actual negative cash flow occurs when the asset is acquired. Depreciation is an accounting charge that allows for the recuperation of capital that was used to procure equipment or other physical assets.

There are three common methods for calculating depreciation expense for financial accounting purposes: straight-line, sum of years, and the Internal Revenue Service's modified accelerated cost recovery system (MACRS). Each involves the spreading of the amount to be depreciated over the recovery life of an asset in a systematic manner as prescribed by government tax laws. Each depreciation method selected produces different patterns of depreciation expense per fiscal period. To illustrate each method, the following example is used to compute the annual depreciation amount using each technique.

Example. Longhorns, Inc. purchases a bulldozer at a cost of $312,500. The piece of equipment is estimated to have a useful life of 10 years to the company and has an estimated salvage value of $40,000. It is also estimated that the unit will provide a service of 18,000 hours during the 10-year period.

Straight-Line Method. One of the most common and simplest depreciation methods is the straight-line method in which depreciation is spread uniformly over the expected useful life of the equipment. Figure 5.1 illustrates the sample depreciation computation and the associated depreciation schedule.

Sum of the Years Digit Method. This depreciation method determines the amount of depreciation in the same manner as that of the straight-line method. However, the difference between the two methods is in the distribution of the depreciation over a given time period. The sum of the years method is considered an accelerated method which recognizes that the stream of benefits provided by equipment may not be uniform, and consequently allows for greater depreciation of equipment during the earlier years. The computation of depreciation by this method can be seen in Figure 5.2.

Internal Revenue Service's Modified Accelerated Cost Recovery System (MACRS). This is another accelerated method of depreciation. MACRS provides two fixed rates on declining balance methods, at 200% (double-declining

$$\text{Annual Depreciation Expense} = \frac{\text{Original Cost} - \text{Salvage Value}}{\text{Useful Life}}$$

$$\text{Annual Depreciation Expense} = \frac{\$312{,}500 - \$40{,}000}{10} = \$\,27,250$$

Year	Book Value at Beginning	Depreciation Expense	Accumulated Depreciation	Book Value at End
1	$ 312,500	$ 27,250	$ 27,250	$ 285,250
2	$ 285,250	$ 27,250	$ 54,500	$ 258,000
3	$ 258,000	$ 27,250	$ 81,750	$ 230,750
4	$ 230,750	$ 27,250	$ 109,000	$ 203,500
5	$ 203,500	$ 27,250	$ 136,250	$ 176,250
6	$ 176,250	$ 27,250	$ 163,500	$ 149,000
7	$ 149,000	$ 27,250	$ 190,750	$ 121,750
8	$ 121,750	$ 27,250	$ 218,000	$ 94,500
9	$ 94,500	$ 27,250	$ 245,250	$ 67,250
10	$ 67,250	$ 27,250	$ 272,500	$ 40,000

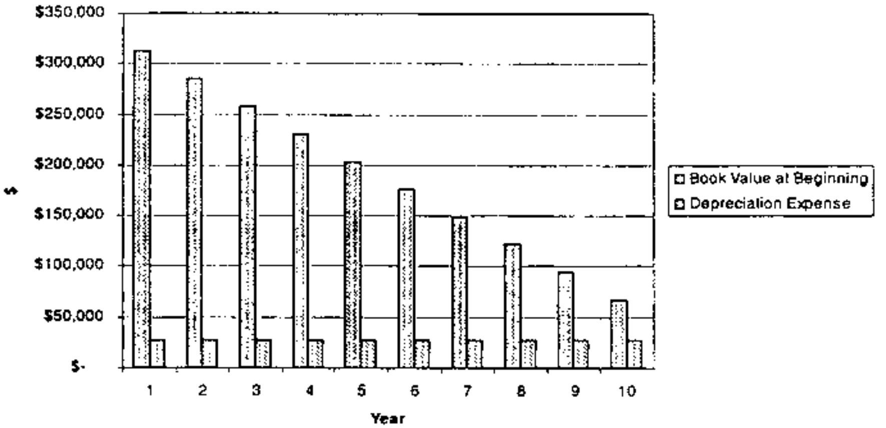


FIGURE 5.1 Depreciation computation: straight-line method.

balance method) and 150%. As does the sum of the years digit method, this method also allows for greater depreciation in the earlier years of a piece of equipment's recovery period. However, in the MACRS method, equipment is classified by a unit's life into appropriate classes of recovery periods. Each recovery period has a depreciation schedule from which the amount of depreciation for any given year in the recovery period can be calculated. A piece of equipment is assumed to have no salvage value with this depreciation method. Table 5.3 illustrates the IRS depreciation schedule for the 200% declining balance method,

$$\text{Annual Depreciation Expense} = (\text{Original Cost} - \text{Salvage Value}) \times \frac{\text{Remaining Life}}{\text{Sum of Digits of Years of Life}}$$

$$\text{Annual Depreciation Expense (Year 1)} = (\$312{,}500 - \$40{,}000) \times \frac{10}{1+2+\ldots+9+10} = \$\,49{,}545$$

$$\text{Annual Depreciation Expense (Year 2)} = (\$312{,}500 - \$40{,}000) \times \frac{9}{1+2+\ldots+9+10} = \$\,44{,}591$$

Year	Book Value at Beginning	Depreciation Expense	Accumulated Depreciation Expense	Book Value at End
1	$ 312,500	$ 49,545	$ 49,545	$ 262,955
2	$ 262,955	$ 44,591	$ 94,136	$ 218,364
3	$ 218,364	$ 39,636	$ 133,773	$ 178,727
4	$ 178,727	$ 34,682	$ 168,455	$ 144,045
5	$ 144,045	$ 29,727	$ 198,182	$ 114,318
6	$ 114,318	$ 24,773	$ 222,955	$ 89,545
7	$ 89,545	$ 19,818	$ 242,773	$ 69,727
8	$ 69,727	$ 14,864	$ 257,636	$ 54,864
9	$ 54,864	$ 9,909	$ 267,545	$ 44,955
10	$ 44,955	$ 4,955	$ 272,500	$ 40,000

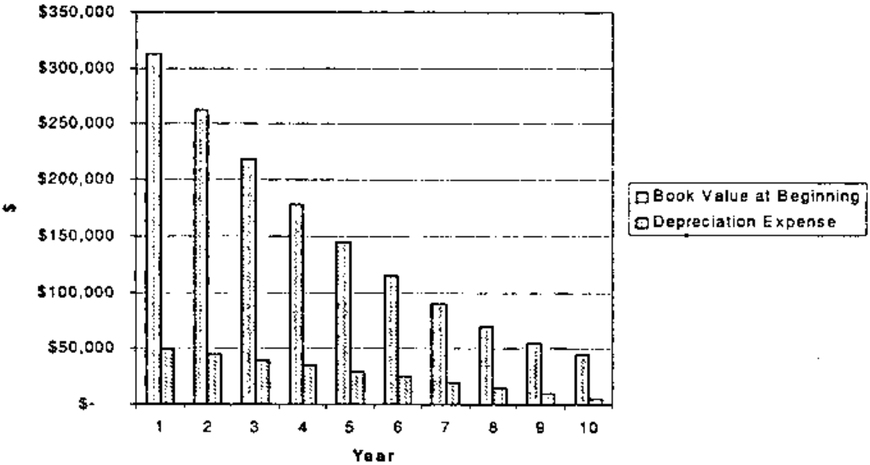


FIGURE 5.2 Depreciation computation: sum of years digit method.

TABLE 5.3 IRS Depreciation Schedule for 200% Declining Balance Method[a]

Year	3 years (%)	5 years (%)	7 years (%)	10 years (%)
1	33.33	20.00	14.29	10.00
2	44.45	32.00	24.49	18.00
3	14.81	19.20	17.49	14.40
4	7.41	11.52	12.49	11.52
5		11.52	8.93	9.22
6		5.76	8.92	7.37
7			8.93	6.55
8			4.46	6.55
9				6.56
10				6.55
11				3.28

[a]200% Declining balance switching to straight-line.
Source: Instructions for Form 4562: Depreciation and Amortization, 1999.

and Figure 5.3 shows the depreciation computation and associated depreciation schedule for this method.

Salvage value may be defined as the market value of a piece of equipment at the end of a period of usage. For accounting purposes and depreciation methods that consider salvage value, this value should be as close as possible to the value that the unit will yield at the end of the depreciation period. This estimate may be made based on historical data or used equipment auction prices.

The second aspect of depreciation is the estimated actual decline in market value of a piece of equipment due to age, wear, and deterioration. This depreciation is calculated so as to determine the actual costs associated with usage of a piece of equipment for any given time period. This depreciation amount is based on the actual unit's useful life rather than its tax write-off life, and should be the basis for other equipment cost computations. A unit's useful life can be obtained from company historical data or equipment manufacturer manuals. Table 5.4 shows the useful life of sample equipment on a page from the *Caterpillar Performance Handbook*.

It must be noted that maintenance practices are not considered in the table, but they play an important part in determining economic machine life. For example, operating conditions may suggest a 12,000-hour depreciation period for a piece of equipment, but poor maintenance could make it uneconomical to retain the unit beyond 10,000 hours. Lack of or improper maintenance can decrease the useful life of a unit, whereas good regular maintenance can often extend its useful life. This aspect of depreciation cost computation is necessary for assigning costs to work items, which facilitates a unit's cost recovery through usage billing

Annual Depreciation Expense = Original Cost × Depreciation Rate for that Year

Annual Depreciation Expense (Year 1) = $312,500 × 10.00% = $ 31,250

Annual Depreciation Expense (Year 2) = $312,500 × 18.00% = $ 56,250

Year	Book Value at Beginning	Depreciation Expense	Accumulated Depreciation Expense	Book Value at End
1	$ 312,500	$ 31,250	$ 31,250	$ 281,250
2	$ 281,250	$ 56,250	$ 87,500	$ 225,000
3	$ 225,000	$ 45,000	$ 132,500	$ 180,000
4	$ 180,000	$ 36,000	$ 168,500	$ 144,000
5	$ 144,000	$ 28,813	$ 197,313	$ 115,188
6	$ 115,188	$ 23,031	$ 220,344	$ 92,156
7	$ 92,156	$ 20,469	$ 240,813	$ 71,688
8	$ 71,688	$ 20,469	$ 261,281	$ 51,219
9	$ 51,219	$ 20,500	$ 281,781	$ 30,719
10	$ 30,719	$ 20,469	$ 302,250	$ 10,250
11	$ 10,250	$ 10,250	$ 312,500	$ -

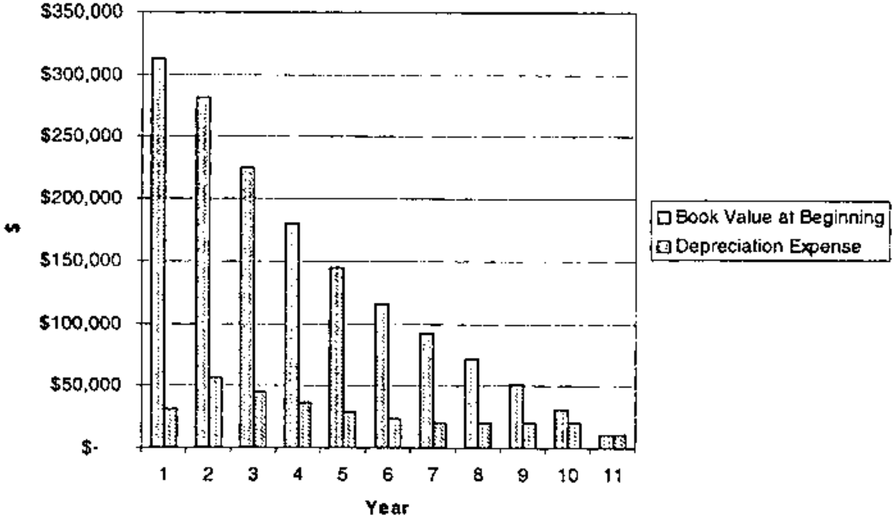


FIGURE 5.3 Depreciation computation: 200% declining balance method.

TABLE 5.4 Sample Manufacturer Suggested Equipment Useful Life[a]

	Moderate	Average	Severe
Track-type tractors	Pulling scrapers, most agricultural draw-bar, stockpile, coal-pile. No impact. Intermittent full throttle operation.	Production dozing in clays, sands, grav-els. Pushloading scrapers, borrow pit ripping, most land-clearing applica-tions. Medium im-pact conditions. Production landfill work.	Heavy rock ripping. Tandem ripping. Pushloading and dozing in hard rock. Work on rock sur-faces. Continuous high impact condi-tions.
Less than 200 kW	12,000 hr	10,000 hr	8,000 hr
More than 200 kW	22,000 hr	18,000 hr	15,000 hr

[a]Guide for Selecting Ownership Period Based on Application and Operating Conditions.
Source: Caterpillar *Performance Handbook Edition* 26.

as part of the cost of doing work. A sample computation for this depreciation charge can be seen in Figure 5.4.

5.4.1.3 Investment Cost

Investment cost represents the cost of investment, or the tying up of a company's capital in equipment. If the capital used to purchase equipment is borrowed, the investment cost is the cost of the interest paid on that borrowed amount. However, if the equipment is purchased with company assets, an interest rate equal to the company rate of return on the company investment should be charged as the investment cost. Investment cost is computed as the product of an interest rate multiplied by the value of the equipment. The value of the equipment may be

$$\text{Depreciation Expense per Hour of Operation} = \frac{\text{Original Cost}}{\text{Total Operating Hour}}$$

$$\text{Depreciation Expense per Hour of Operation} = \frac{\$\ 312{,}500}{18{,}000\ \text{Hours}} = \$\ 17.36 \text{ per operating hours}$$

Assuming 2000 hours of operation per year:

$$\text{Depreciation Expense} = \$\ 17.36 \text{ per hr.} \times 2000 \text{ hrs} = \$\ 34{,}722$$

FIGURE 5.4 Computation for depreciation charges based on operating hours.

taken as the average value over the equipment's life or, more realistically, as the depreciated value of the equipment at any given time.

5.4.1.4 Insurance Cost, Tax, and Storage Cost

Insurance cost represents the cost of fire, theft, accident, and liability insurance for equipment. The tax amount covers licensing fees or any applicable taxes associated with the equipment. Storage cost includes all the costs directly associated with equipment storage, such as the storage yard rental and maintenance, utilities, and wages for the guards. Generally, insurance cost and taxes for equipment are annual costs, as a percentage of the initial cost. In the US, insurance is about 3%, taxes are about 3%, and storage cost is about 1%.

Total ownership cost should be expressed as an hourly cost so as to facilitate the computation of equipment cost assigned to a work item. Although this cost may be used for estimating and for charging equipment costs to a project, it must be noted that ownership costs do not include equipment operating costs, job overhead, or profit. The next section presents equipment operating costs, and issues of job overhead and profit are assessed later in Chapter 17.

5.4.1.5 Equipment Operating Costs

Equipment operating costs are the direct costs associated with equipment operations. Unlike ownership cost, an operating cost is not a fixed cost but a variable one, directly proportional to the amount of work performed or operating hours. An operating cost is incurred only when the equipment is actually being used. Equipment operating costs include fuel, grease, oil, electricity, tires, and repairs. Operating costs vary from the type of equipment used, the nature of the work, and the working conditions of the equipment. Mobilization and demobilization charges and operator wages are not included in equipment operating costs. Like the ownership cost, the cost of operating equipment should be calculated on the basis of the work hour.

Fuel consumption can be closely monitored on the construction site. However, if this is not possible and no historical data exist, information from equipment manufacturers can be used for estimating. Fuel consumption depends on the application of the equipment. The application determines the engine load factor, which in turn controls engine fuel consumption. Figure 5.5 presents an hourly fuel consumption table and load factor guides for a Caterpillar track-type tractor. Sample fuel cost computation is shown in Figure 5.6.

The amount of lube oil, filter, and grease required by any equipment varies with the type of equipment and job conditions. The severity of conditions can affect the frequency of service a piece of equipment will need. Table 5.5 shows a table from Caterpillar that can be used for estimating the cost of lube oil, filter, and grease.

The cost of tires is one of the highest cost items under operating costs

TRACK-TYPE TRACTORS						
	Low		Medium		High	
Model	liter	US gallon	liter	US gallon	liter	US gallon
D5C (67 kW)	5.5-9.5	1.5-2.5	9.5-13	2.5-3.5	13-17	3.5-4.5
D6D (104 kW)	11-19	3-5	15-21	4-5.5	21-26	5.5-7
D8N (212 kW)	23-28	6-7.5	28-38	7.5-10	38-51	10-13.5
D11N (574 kW)	62-87	16.5-23	87-112	23-29.5	112-134	29.5-35.5

Load Factor Guide

High: Steady ripping, shuttle pushloading and downhill dozing. Drawbar work at full throttle, engine lugged to max. power most of the time; Little or no idling or travel in reverse.

Medium: Production dozing, pulling scrapers, most pushloading. Drawbar work at full throttle but not always lugging engine. Some idling and some travel with no load.

Low: Considerable idling or travel with no load.

FIGURE 5.5 Manufacturer-suggested hourly fuel consumption table with load factor guides. (From Caterpillar *Performance Handbook Edition* 26.)

Assumptions:

Fuel Cost = $0.33 per liter

Equipment = D8N
Load Factor = Medium } **From Fuel Consumption Table (Figure 5.5)**
Estimated Hourly Fuel Consumption = 33 liter per hour

Fuel Cost per Hour = 33 liter per hour × $0.33 per liter = $ 10.89 per hour

FIGURE 5.6 Sample fuel cost computation.

TABLE 5.5 Manufacturer Suggested Costs for Lube Oil, Filter, and Grease

Model: track-type tractors	Approx. Cost/Hr. ($) Material	Labor
D5C (67 kW)	0.20	0.08
D6D (104 kW)	0.45	0.26
D8N (212 kW)	0.53	0.10
D11N (574 kW)	1.15	0.28

Source: Caterpillar *Performance Handbook Edition* 26.

Table 5.6 Factors for Estimating Tire Service Life

No.	Condition	Factor
1	Maintenance	
	Excellent	1.090
	Average	0.981
	Poor	0.763
2	Speeds (maximum)	
	16 km/h (10 mph)	1.090
	32 km/h (20 mph)	0.872
	48 km/h (30 mph)	0.763
3	Surface conditions	
	Soft earth—no rock	1.090
	Soft earth—some rock	0.981
	Well maintained—gravel road	0.981
	Poorly maintained—gravel road	0.763
	Blasted—sharp rock	0.654
4	Wheel Positions	
	Trailing	1.090
	Front	0.981
	Driver (rear dump)	0.872
	Driver (bottom dump)	0.763
	Driver (self-propelled scraper)	0.654
5	Load	
	Recommended load	1.090
	20% overload	0.872
	40% overload	0.545
6	Curves	
	None	1.090
	Medium	0.981
	Severe	0.872
7	Grades	
	Level	1.090
	5% max	0.981
	15% max	0.763

Source: Caterpillar *Performance Handbook Edition* 26.

for construction equipment with pneumatic tires. Estimating tire costs requires estimating the service life of the tires, which depends on many factors relating to their application and the job conditions of the equipment. Table 5.6 lists job conditions that can affect tire service life and the associated factors that are used in estimated tire life computations. Figure 5.7 shows a sample tire cost computation.

Example:
An off-highway truck equipped with four tires, rated at 3500 hours, running on a well maintained haul road having easy curves and minimum grades and receiving "average" tire maintenance attention but being 20% overloaded
Assume: Cost of Tires = $5000
Estimated cost of tire repair = 15% of depreciation

Estimated Tire Service Life
Condition: 1 2 3 4 5 6 7
Factors: .981×.872 ×.981 ×1.03×.872×.981×.981 = .725
Estimated Tire Service Life = 3500 × .725 = 2540 hours

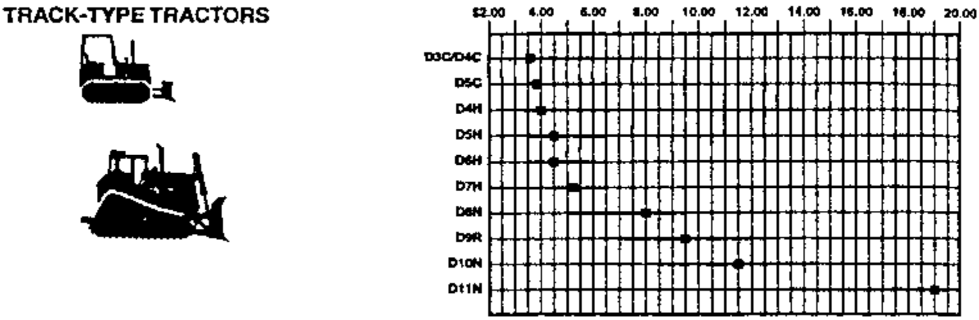
Tire Depreciation = $5000 ÷ 2540 hours = $ 1.97 per hour
Tire Repair = .15 × $ 1.97 per hour = $ 0.30 per hour
Tire Cost = $ 1.97 per hour + $ 0.30 per hour = $2.27 per hour per truck

FIGURE 5.7 Sample tire cost computation.

The cost of maintenance and repair is the largest item of the operating expense for construction equipment. Construction operations can subject equipment to considerable wear and tear, which in turn can have a tremendous impact on the usable life of equipment. The extent of wear varies for different types of equipment and manufacturers. In addition, the nature of the work, job conditions, and maintenance attention can also have an impact on the severity of wear and tear and ultimately repair costs. Generally, maintenance and repair costs increase as equipment gets older. The cost of maintenance and repair can be estimated based on actual cost experience on similar work or based on equipment manufacturer data. Figure 5.8 illustrates the computation of equipment repair costs using the *Caterpillar Performance Handbook*. The Caterpillar method uses an average cost method. Since the repair costs tend to be low in the beginning periods and rise gradually, averaging them produces extra funds at first which are reserved to cover future higher repair costs. Total estimated operating costs for selected pieces of equipment can also be seen in Tables 5.1 and 5.2.

5.4.2 Cost of Renting Equipment

Renting construction equipment is an increasingly popular procurement method. The primary advantage in renting equipment is the ability to procure the right piece of equipment for the job when the unit is needed. Renting allows for more specific equipment selection as more choices are usually available from renters than the contractor's presently owned fleet. Using owned equipment also encourages inefficiency through use of the wrong size or type of unit for a given job. Renting can eliminate that problem. In addition, pieces of equipment can be selectively acquired so as to be available only during the time they are needed and



Cost distribution
D3 to D7 — 60% Parts
40% Labor
D8 to D11 — 70% Parts
30% Labor

Extended-life Multipliers	
0-10,000 hours	1.0
0-15,000	1.1
0-20,000	1.3

Includes basic tractor equipped with ROPS canopy, straight bulldozer and hydraulic control.

Note: Repair time may be less on Elevated Sprocket Tractors due to modular design of power train components.

Legend:

A — B — C

Conditions (see Table 5.4)
A - Moderate
B - Average
C - Severe

Example:
D8N used for land clearing operation – 1600 hours per year for eight years
⇒Land clearing operation = Average condition (Table 5.4)
⇒Total use = 1600 hr/yr × 8 yr = 12,800 hr
∴ Extended-life Multiplier = 1.1

From Chart:

Estimated repair cost = $8.00 × Extended-life Multiplier
= $8.00 × 1.1
= $8.80 /hr

FIGURE 5.8 Sample repair cost computation. (From Caterpillar *Performance Handbook*.

removed soon after work is completed. In this way, costs associated with idle equipment can be eliminated.

Equipment rental rates vary throughout the country with larger cities normally having lower rates. Most rental companies calculate their rates on a monthly basis. Monthly rental rates vary from 2 to 5% of the cost of equipment. Monthly rates usually run about three times weekly rates, and weekly rates usually run about three times daily rates. Estimated equipment rental rates (US average) for selected construction equipment can be seen in Tables 5.1 and 5.2. These rates are based on late-model, high-quality equipment in excellent condition rented from equipment dealers. In addition, the rental rates are based on single shift operation, 8 hours per day, 40 hours per week. Premium rates are charged if usage exceeds a single-shift operation basis. Apart from renting from equipment dealers, a contractor may choose to rent needed equipment from other contractors. It is also important to note that rental rates from other contractors may be substantially lower than rental rates from equipment dealers. Equipment rental rates do not include transportation costs, erecting and dismantling costs, insurance, or taxes. These costs must be determined and added to the rental costs in order to determine the total cost of acquiring equipment. Figure 5.9 shows a sample rental agreement.

5.4.3 Cost of Leasing Equipment

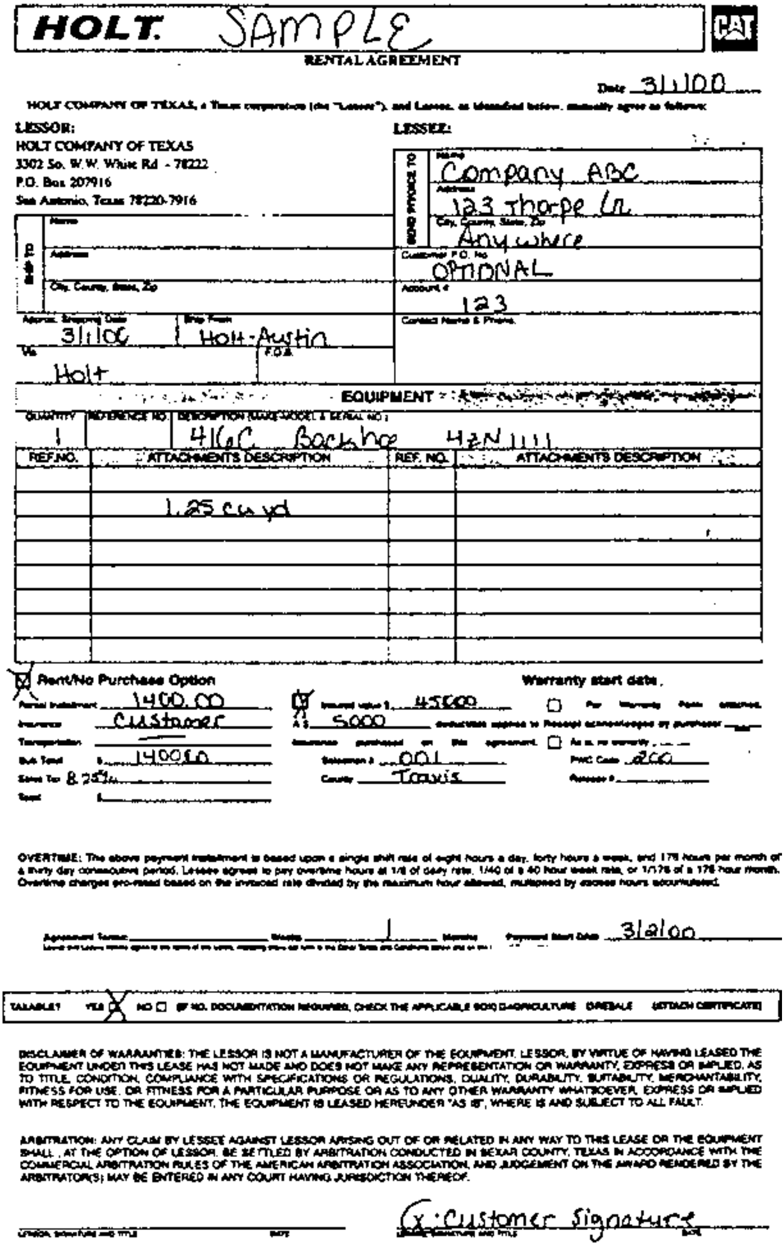
The distinguishing factor between leasing and renting is the duration of time. Leasing equipment is often considered when a piece of equipment is needed for more than six months. A lease is a contract conveying to a business (the lessee) the right to use, for a stated period of time, specified property, plant, or equipment owned by another party (the lessor) in exchange for periodic rental payment. Although the lessor owns the piece of equipment, the lessee can fully use it without any restrictions as if he or she were the owner. At the end of the contract term, usually more than one year, the lessee may choose an option from different alternatives, such as to buy, renew the lease, or turn over the asset to the lessor. Leasing is a substitution for debt. Unlike purchasing a piece of equipment with large upfront capital, a company pays for the acquired piece through small periodic payments. Figure 5.10 shows a sample lease agreement.

5.4.4 Cost of Equipment Mobilization and Demobilization

Equipment moving and setup costs or mobilization costs, and dismantling or demobilization costs can be substantial and must be considered. For example, a large tower crane may take two days to erect and two days to dismantle the structure. The total cost for erecting and dismantling could range between $12,500 and $80,000. Mobilization, demobilization, and downtime costs can be added to equipment procurement cost in order to determine the adjusted procurement cost for a piece of equipment. In this way, costs associated with the mobilization and demobilization of equipment can be accounted for and distributed.

5.4.5 Equipment Operator and Oiler

The cost for an equipment operator and oiler are not included under equipment costs but should be included under direct labor costs associated with the work. As with equipment operating costs, the cost for an equipment operator and oiler are variable costs that can be determined simply by multiplying the associated



HOLT. SAMPLE

RENTAL AGREEMENT

Date 3/1/00

HOLT COMPANY OF TEXAS, a Texas corporation (the "Lessor"), and Lessee, as identified below, mutually agree as follows:

LESSOR:
HOLT COMPANY OF TEXAS
3302 So. W.W. White Rd - 78222
P.O. Box 207916
San Antonio, Texas 78220-7916

LESSEE:
SEND INVOICE TO — Name: Company ABC
Address: 123 Thorpe Ln
City, County, State, Zip: Anywhere
Customer P.O. No: OPTIONAL
Account #: 123
Contact Name & Phone:

Ship to — Name / Address / City, County, State, Zip

Approx. Shipping Date: 3/1/00 — Ship From: Holt-Austin
Via: Holt — F.O.B.

EQUIPMENT

QUANTITY	REFERENCE NO.	DESCRIPTION (MAKE-MODEL & SERIAL NO.)
1		416C Backhoe 4ZN1111

REF. NO.	ATTACHMENTS DESCRIPTION	REF. NO.	ATTACHMENTS DESCRIPTION
	1.25 cu yd		

☒ Rent/No Purchase Option — Warranty start date

Rental Installment: 1400.00
Insurance: Customer
Transportation: —
Sub Total: $ 1400.00
Sales Tax: 8.25%
Total: $

☒ Insured value $ 45000
A $ 5000 deductible applies to [illegible]
Salesman # 001
County: Travis

☐ Per Warranty Form attached. ☐ As is, no warranty
PWC Code 200
Release #

OVERTIME: The above payment installment is based upon a single shift rate of eight hours a day, forty hours a week, and 176 hours per month of a thirty day consecutive period. Lessee agrees to pay overtime hours at 1/8 of daily rate, 1/40 of a 40 hour week rate, or 1/176 of a 176 hour month. Overtime charges pro-rated based on the invoiced rate divided by the maximum hour allowed, multiplied by excess hours accumulated.

Agreement Terms: ______ Weeks ______ 1 Months — Payment Start Date 3/2/00

TAXABLE? YES ☒ NO ☐ (IF NO, DOCUMENTATION REQUIRED, CHECK THE APPLICABLE BOX) AGRICULTURE RESALE (ATTACH CERTIFICATE)

DISCLAIMER OF WARRANTIES: THE LESSOR IS NOT A MANUFACTURER OF THE EQUIPMENT. LESSOR, BY VIRTUE OF HAVING LEASED THE EQUIPMENT UNDER THIS LEASE HAS NOT MADE AND DOES NOT MAKE ANY REPRESENTATION OR WARRANTY, EXPRESS OR IMPLIED, AS TO TITLE, CONDITION, COMPLIANCE WITH SPECIFICATIONS OR REGULATIONS, QUALITY, DURABILITY, SUITABILITY, MERCHANTABILITY, FITNESS FOR USE, OR FITNESS FOR A PARTICULAR PURPOSE OR AS TO ANY OTHER WARRANTY WHATSOEVER, EXPRESS OR IMPLIED WITH RESPECT TO THE EQUIPMENT. THE EQUIPMENT IS LEASED HEREUNDER "AS IS", WHERE IS AND SUBJECT TO ALL FAULT.

ARBITRATION: ANY CLAIM BY LESSEE AGAINST LESSOR ARISING OUT OF OR RELATED IN ANY WAY TO THIS LEASE OR THE EQUIPMENT SHALL, AT THE OPTION OF LESSOR, BE SETTLED BY ARBITRATION CONDUCTED IN BEXAR COUNTY, TEXAS IN ACCORDANCE WITH THE COMMERCIAL ARBITRATION RULES OF THE AMERICAN ARBITRATION ASSOCIATION, AND JUDGEMENT ON THE AWARD RENDERED BY THE ARBITRATOR(S) MAY BE ENTERED IN ANY COURT HAVING JURISDICTION THEREOF.

LESSOR SIGNATURE AND TITLE — DATE
X: Customer Signature
LESSEE SIGNATURE AND TITLE — DATE

FIGURE 5.9 Sample rental agreement.

HOLT. SAMPLE **CAT**

LEASE AGREEMENT ORDER DATE: 3/1/00

HOLT COMPANY OF TEXAS, a Texas corporation (the "Lessor"), and Lessee, as identified below, mutually agree as follows:

Lessor:
Holt Company of Texas
3302 So. W. W. White Rd. - 78222
P.O. Box 207916
San Antonio, TX 78220-7916

LESSEE: NAME	Company ABC
ADDRESS	123 Thorpe Ln
CITY, COUNTY, STATE, ZIP	Anywhere
CUSTOMER ACCT NO.	123
CUSTOMER P.O. NO.	
CUSTOMER CONTACT	
CUSTOMER PH. NO.	

NAME	ADDRESS	CITY, COUNTY, STATE, ZIP

APPROXIMATE SHIPPING DATE	SHIP FROM		
3/1/00	Holt-Austin		
VIA	FOB	CONTACT NAME AND PHONE NO.	
Holt			

EQUIPMENT

QUANTITY	REFERENCE NO.	DESCRIPTION (MAKE/MODEL & SERIAL NO.)
1		416C Backhoe 4ZN1111 (New)

REF. NO.	ATTACHMENTS DESCRIPTION	REF. NO.	ATTACHMENTS DESCRIPTION
	1.25 cu yd		

☒ Lease With Purchase Option — Warranty start date 3/2/00

Rental installment 1200.00
Insurance Customer
Transportation —
Sub Total $ ~~[illegible]~~ 1200.00
Sales Tax 8.25%
Total $

☐ Insured Value $ 45000
A $ 5000 deductible applies to insurance purchased on this agreement.
Salesman # 001
County Code Travis

☒ Per Warranty Form attached. Receipt acknowledged by purchaser
☐ As is, no warranty
PWC Code 200
Release #

OVERTIME: The above payment installment is based upon a single shift rate of eight hours a day, forty hours a week, and 176 hours per month of a thirty day consecutive period. Lessee agrees to pay overtime hours at 1/8 of daily rate, 1/40 of a 40 hour week rate, or 1/176 of a 176 hour month. Overtime charges pro-rated based on the invoiced rate divided by the maximum hour allowed, multiplied by excess hours accumulated.

Agreement Terms: 6 Months Payment Start Date 3/2/00

Lessor and Lessee hereby agree to the terms of the Lease, including those set forth in the Other Terms and Conditions below and on the back of this Lease.

Complete for Lease Purchase Option Only

PURCHASE OPTION: OPTION PRICE: $ 39000

a) Lessee is hereby granted an option, which option shall not be assignable, to purchase AS IS WHERE IS the Equipment covered by the Lease, for its then "Adjusted Option Price" (as hereafter defined). This option is conditioned upon the occurrence of the following conditions precedent:

i Lessee shall have performed all of the terms and conditions of the Lease, at the time and in the manner required and neither an event of default, nor an event which with due notice and/or lapse of time would constitute an event of default under the Lease shall have occurred and be continuing and

ii Lessee shall have paid to Lessor the Adjusted Option Price of the Equipment together with all taxes on or measured by such purchase price. The term "Adjusted Option Price" shall mean the Option set forth above less any Lease installments paid by Lessee hereunder plus non-warranty repairs, plus interest thereon from the starting date to the date of payment at a rate equal to the lesser the Maximum Rate or the Prime Rate plus ______ percent.

The purchase option will expire on ______. All other terms and conditions remain in effect.

TAXABLE? YES ☒ NO ☐ (IF NO, DOCUMENTATION REQUIRED, CHECK THE APPLICABLE BOX) ☐ AGRICULTURE ☐ RESALE (ATTACH CERTIFICATE)

DISCLAIMER OF WARRANTIES: LESSOR IS NOT A MANUFACTURER OF THE EQUIPMENT. LESSOR, BY VIRTUE OF HAVING LEASED THE EQUIPMENT UNDER THIS LEASE HAS NOT MADE AND DOES NOT MAKE ANY REPRESENTATION OR WARRANTY, EXPRESS OR IMPLIED, AS TO TITLE, CONDITION, COMPLIANCE WITH SPECIFICATIONS OR REGULATIONS, QUALITY, DURABILITY, SUITABILITY, MERCHANTABILITY, FITNESS FOR USE, OR FITNESS FOR A PARTICULAR PURPOSE OR AS TO ANY OTHER WARRANTY WHATSOEVER, EXPRESS OR IMPLIED WITH RESPECT TO THE EQUIPMENT. THE EQUIPMENT IS LEASED HEREUNDER "AS IS", WHERE IS AND SUBJECT TO ALL FAULT

ARBITRATION: ANY CLAIM BY LESSEE AGAINST LESSOR ARISING OUT OF OR RELATED IN ANY WAY TO THIS LEASE OR THE EQUIPMENT SHALL, AT THE OPTION OF LESSOR, BE SETTLED BY ARBITRATION CONDUCTED IN BEXAR COUNTY, TEXAS IN ACCORDANCE WITH THE COMMERCIAL ARBITRATION RULES OF THE AMERICAN ARBITRATION ASSOCIATION, AND JUDGEMENT ON THE AWARD RENDERED BY THE ARBITRATOR(S) MAY BE ENTERED IN ANY COURT HAVING JURISDICTION THEREOF.

(X)

LESSOR: SIGNATURE AND TITLE ______ DATE ______ LESSEE: SIGNATURE AND TITLE ______ DATE ______

PRINTING COMMUNICATIONS ASSOC. REV.

FIGURE 5.10 Sample lease agreement.

wage rates of the required craft with the operating hours of a specific piece of equipment.

5.5 CONSTRUCTION TOOLS

Construction tools are vital components of the construction processes. The development of tools has tremendously increased the productivity of construction work. For example, cutting through a wooden plank with a hand saw can take 10 to 12 minutes, whereas using an electric saw one can do the same work in less then a minute. Therefore, the use of proper tools can lead not only to greater work efficiency, but also to reducing labor costs. Although it can be assumed that each subcontractor would furnish the necessary additional tools, especially specialized tools, the contractor will still need to supply other miscellaneous tools. For example, a concrete firm may supply its own mixers and vibrators and a masonry firm supply its own saws and grinder. But in either instance, the general contractor supplies other general tools such as wheelbarrows, buckets, rope, hoses, hammers, and picks. Table 5.7 provides a list of miscellaneous tools that are commonly used on a building construction project along with their associated costs.

Tools are high wear items. Their costs are usually loaded on one job with no consideration for resale or reuse on other jobs. The cost of tools is typically considered as part of jobsite overhead and is computed as a percentage of payroll. As a markup on payroll, the cost of tools and minor equipment is about 3 to 6%.

TABLE 5.7 Miscellaneous Tools for Their Costs

Type of tool	Cost ($)
Circular saw	129
Power drive/drill kit—cordless	98
Power cord—2.5 m	17
Nailer—cordless	399
Finish nailer—cordless	499
Folding steel sawhorse	13
Hand saw	12
Sledge hammer	21
Nail hammer	8
Chain saw	239
Shovel	17
Wheelbarrow	75
Hose—25 m	38

Source: Home Depot *Pro Book* 1999.

The life of miscellaneous hand tools is generally taken as an average of one year. The loss of miscellaneous hand tools due to disappearance or theft is common on a construction site. Therefore, all attempts must be made to manage tool distribution and storage in order to keep tool losses under control.

5.6 REVIEW QUESTIONS

1. Describe and provide examples of specific use equipment and general use equipment.
2. What are the outputs of the equipment planning process?
3. What are some of the benefits in sharing equipment usage on the jobsite?
4. Why is it important for general contractors to discuss equipment requirements for the job with the subcontractors?
5. What are some factors that can influence equipment selection?
6. Describe how site conditions affect equipment selection.
7. Describe how the nature of the work affects equipment selection.
8. What are the important characteristics of equipment that must be considered in equipment selection?
9. What are the underlying objectives in equipment selection?
10. Name three common methods of procuring equipment.
11. What are the benefits of purchasing equipment?
12. What is depreciation?
13. What is salvage value?
14. What are some of the costs that must be included in equipment operating costs?
15. What are the benefits of renting equipment?
16. What is equipment leasing?
17. How can tool usage influence construction costs?

6

The Bidding Process

6.1 GETTING A CONSTRUCTION CONTRACT: A CONTRACTOR'S PERSPECTIVE

For a contractor to remain in business in the construction industry and be profitable, he or she will first need to get work. There are two common methods by which a contractor can get a construction contract: through direct negotiation with the client, or through competitive bidding, which is a more widely practiced method, especially for publicly funded projects.

Negotiated works are more common in private projects. This method of contracting provides the owner with greater control over the selection of his general contractor. Negotiated works are typically applied to complex construction projects, such as remodeling jobs. Negotiated works are also one of the best contracting methods for fast track projects. Because works and prices are negotiated, it is possible to contract out the work before design completion, allowing construction work to proceed at a faster pace. More discussion on negotiated work is presented in Chapter 2, Section 2.4.

Construction contracts are usually awarded through competitive bidding. Construction projects that are competitively bid constitute the largest segment of the construction industry in the United States (ASPE, 1996). In competitive bidding, contractors submit their bids based on the given sets of plans and specifications. A construction contract is then awarded to the lowest bidder. In this manner, competitive bidding requires complete working drawings and specifications for this method to be effective. Only with completed working drawings and specifications can the submitted bids be realistically compared.

The importance of screening for a contractor is vital for the success of the bidding process and ultimately the project. The contractors must also be screened to ensure that they are of the same caliber. In private work, the owner with the help of the architect can select and limit the number of bidders. The selection can be based on the owner's and architect's past experiences working with the contractor or on the contractor's reputation. In public work, the bidding is open to any "qualified" bidders. However, the qualifications here are based more on financial status of a contractor, rather than on a reputation for quality. More discussion on competitive bidding is presented in Chapter 2, Section 2.3.

Bidding is one of the most important processes in a contractor's operations. To get work, a contractor must be successful at bidding for the work. In addition to getting work, successful bidding must ensure that the contractor can perform the work and achieve the desired profit. Although bidding high can mean more profit, the likelihood of getting the contract may be low. This is especially true when competition is high, such as in a period of limited construction opportunities. Bidding too low, on the other hand, may mean working for little or no profit or, worst of all, working at a loss. In this way, bidding for work may literally make or break a company. The ultimate aim of bidding is to get the construction contract. Bidding is a costly process for the contractor. A contractor must commit her personnel to planning and to tedious cost estimating work in order to come up with the bid. There is no return for submitting a nonwinning bid.

6.2 SUBCONTRACTED WORK

A building construction project is a complex undertaking. It usually requires the participation of many parties. According to surveys conducted by The Associated General Contractors of America, the average percentage of work performed by subcontractors is between 40 to 70% (Walker, 1999). The cost for subcontracted work can be as high as 60 to 80% of a bid (Ostwald, 2001). It is rare today to find a contractor that can perform all the work in a project. The specialization of construction work, together with the development and application of new construction materials and technologies, has led to a growing number of specialty contractors. These firms can be more efficient in performing the specialized components of construction work than the general contractor. The general contractor, or the prime contractor, is the firm that essentially puts everything together and gets the contract. When the general contractor cannot perform certain components of the work, she will turn to other contractors or specialty contractors, who then become her subcontractors on the project.

There is usually only one contract between the owner and the general contractor. The subcontractors enter into contracts with the general contractor and are responsible to her, not to the owner. In this way, the general contractor is responsible for the whole project. She is not only putting together the best price from all the subcontractors' bids, but in essence putting together the best team to perform the construction work. Another implication of this is that the general contractor is responsible financially to the owner and her subcontractors for the overall performance of the project.

Another important factor that may affect the contractor's selection of subcontractors is regulations imposed by the local authorities. This is especially true for public projects constructed in the US. The regulations may state that in order for the contractor to be qualified to perform the job he must have a certain percentage of the work subcontracted to local subcontracting firms or to firms owned by historically disadvantaged groups. These types of regulations are often imposed to protect local businesses or businesses owned by historically disadvantaged groups.

The competitiveness of the project depends on the cost effectiveness of the general contractor. Similarly, the cost effectiveness of the general contractor is dependent upon the cost effectiveness of the subcontractors. The general contractor engages a subcontractor in the same manner as the owner engages the general contractor. In addition, it is also possible for the subcontractor to engage other specialized subcontractors to help perform parts of the work.

6.3 PRE-BID CONFERENCE

Pre-bid conferences are a means for the owner and design team to meet with the contractors who are intending to bid for the project. Pre-bid conferences are usually held, if possible, at the project site, shortly after the invitation to bid or roughly towards the middle of the bidding period, but should be no later than 20 days prior to bid date. When a pre-bid conference can be held on the site, the owner and design team may conduct a site tour for all the contractors. A pre-bid conference allows the owner and design team to communicate last-minute information or new information about the project to the contractors. In addition, the meeting also allows the owner and design team to respond to any questions the contractors might have relating to the bidding document. All the new information presented, the responses to the questions, and any clarification of the bidding document should be confirmed in writing and issued to all bidders as an addendum.

6.4 BIDDING FLOWCHART

Figure 6.1 illustrates the typical bidding process in a building construction project. The following subsections discuss the steps in bid preparation.

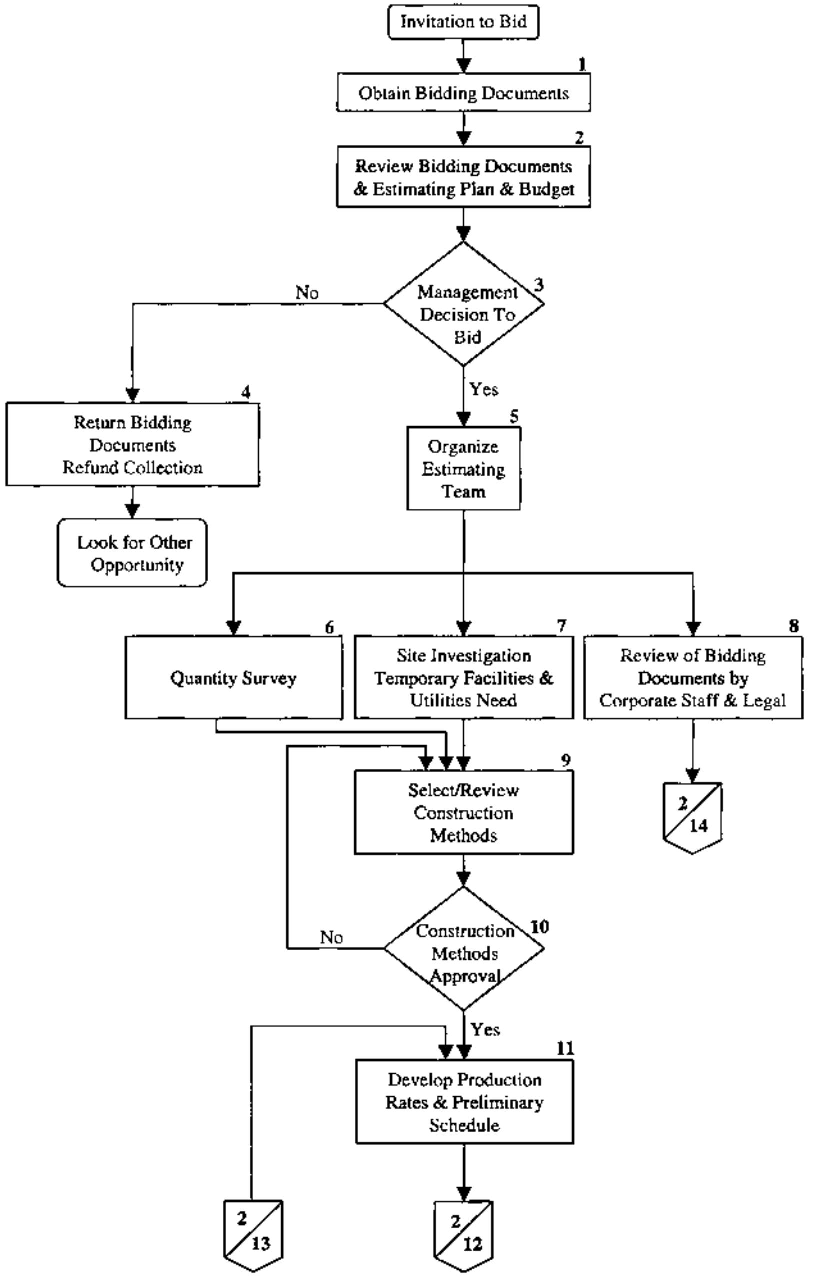


FIGURE 6.1 Bidding flowchart.

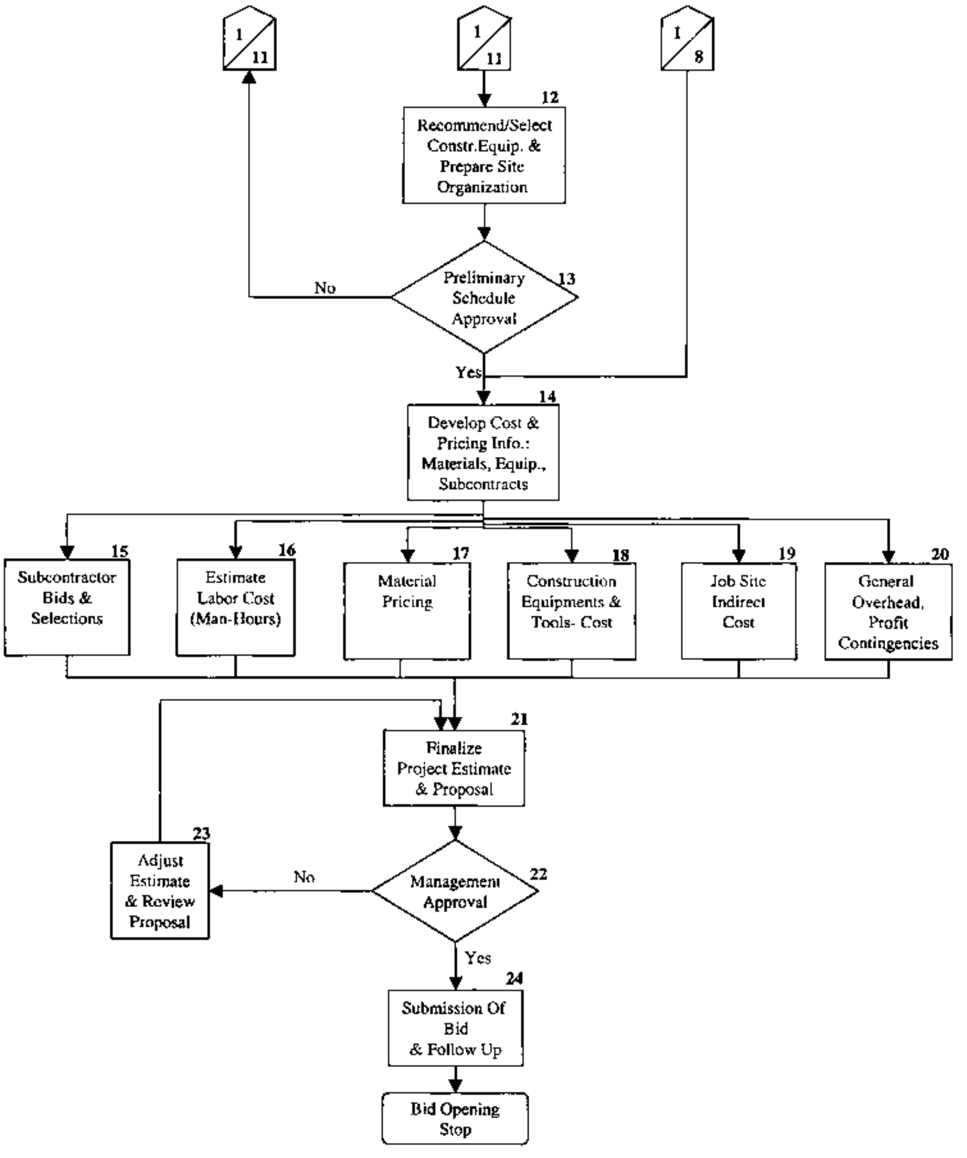


FIGURE 6.1 Continued

6.4.1 Invitation to Bid

The bidding process for the contractor begins with the invitation to bid. Other similar documents are the request for proposal and request for quotation. The invitation to bid can be in the form of a letter sent to a select group of contractors by the owner or by the architectural/engineering firm. Alternatively, it can be publicly announced or advertised. A bid advertisement should have a minimum advance notice of 30 days prior to bid document issue. Some of the sources where new projects can be advertised or make requests for bids include *F.W. Dodge Company Reports*, *Associated General Contractors Report*, local newspapers, trade magazines and journals, and local plan rooms.

The invitation to bid or bid advertisement will typically contain the general information:

Name of project and a short description,
Bidding document information: available date, time, location,
Pre-bid conference or details identification meeting information,
Bid proposal submission date,
Type of proposal,
Approximate contract amount,
Approximate size,
Project location,
Licensing requirements,
Bid, performance, and payment bond requirements,
Contractor prequalification requirements,
Name of owner,
Name of architect,
Name of engineers, and
Contact information.

The invitation to bid is often accompanied by the instruction to bidders. The instruction to bidders is an expanded document from the invitation to bid and provides more information about the project, such as a detailed description, possible restrictions, completion dates, jobsite visitation, and other special conditions. Finally, a bid proposal form may be attached. Only the blanks associated with the project prices need to be filled in by the contractor submitting the bid. This prescript method of submitting the bids allows the owner to efficiently evaluate the bids.

6.4.2 Obtaining Bidding Documents

The invitation to bid and instruction to bidders provide information regarding the acquisition of the bidding document. Elements typically included in the bidding document are:

Invitation to bid,
Instruction to bidders,
Proposal form/bid form,
General conditions,
Special conditions,
Plans and drawings,
Specifications, and
Addenda.

A proposal form or bid form is a special document produced by the owner and design team. The bid form is to be completed and signed by the bidders and states the terms of any offers. It is often used to confirm that the bidders have examined the plans, specifications, and job location and have acknowledged receipt of all the addenda. The amount of compensation for the work to be performed by the bidder is also presented, along with costs for alternates (if applicable), and bonding requirements. In this way, the bid form is a sort of checklist of the agreement between the owner and the contractor. This preformatted bid form issued by the owner allows the owner to efficiently evaluate the submitted bids during bid opening.

General and special conditions are part of the specifications. The general conditions provide the general terms and conditions applicable to all contracts with the owner. Special conditions, on the other hand, set forth terms and conditions applicable specifically to the particular contract.

The most prominent parts of the bidding document are the drawings and specifications. These items provide the technical requirements of the contract. The drawings serve as the visual presentation of the project design and provide such critical information as the dimensions, locations, and how the building is to be constructed. The specifications complement the drawings by elaborating on the quality of construction materials and methods of installation to be used in the construction. The two documents essentially define the scope and quality of the project.

Addenda are written modifications or additions to the bid documents made prior to bidding. Addenda can present clarifications on terms and conditions as well as corrections to the bid document, drawings, and specification, including last minute changes to the bid documents. Addenda are issued after the bid documents have been distributed but prior to the bid submission date.

When reviewing the invitation to bid and instruction to bidders, the contractor should look for the date and time the bidding documents will be available for pickup. Another concern is the cost of acquiring the documents. On public projects, it is common practice for the contractor to purchase the bid documents. The cost for the document will be approximately the cost of reproduction plus handling. On private work, typically the document can be acquired by placing a deposit, the amount of which should closely approximate the cost to reproduce the bid document. The purpose of the deposit is to insure the safe return of the bid documents. In this way, if the contractor chooses not to pursue the work, he can return the documents and be refunded. Another alternative for acquiring information for proposal preparation is to visit the local Association of General Contractors (AGC) plan room, which may have the document available for review at no cost to members or associates.

6.4.3 Review of the Bidding Document and the Decision to Bid

After receiving a set of the bidding documents, the first step is to review the drawings and specifications and to make the critical decision of whether to bid for the project. Factors to be considered in reviewing the documents and in making a decision to bid can be categorized into three groups; internal factors, project-related factors, and external factors.

6.4.3.1 Internal Factors

Internal factors are concerned with the contractor's firm and include the following.

1. *Current Commitments*. The amount of on-going construction work must be considered in order to prevent the firm from work overload.

2. *Other Available Projects*. When many projects are available for bidding, priorities must be set for the project for which the firm has the best chance of winning.

3. *Bidding Time*. This is the amount of time available for the firm to prepare the bid or the time between the issue of the bidding document and bid submission. Bidding time varies depending on the size of the project, the complexity of the project, the completeness of the drawings, and the efficiency of communication and dispersion of information among all the parties involved. For a simple project, the minimum time allowance is three weeks. For larger and more complex projects, the bidding time can be four to six weeks or can be established after consultation with several potential bidders (ASPE, 1996).

4. *Bonding Requirements*. This refers to whether performance bonds or payment bonds are required. In addition, the firm's bonding capacity must be considered as it can influence its ability to bid for the current project as well as future projects.

5. *Business Plan*. The project type and requirements must be considered with the firm's business plans kept in mind as this can have an impact on the firm's future growth and other capital investments.

6. *Personnel and Equipment*. The available qualified staff and support staff are crucial to the decision to bid. The availability of the firm's already owned

equipment must also be considered so as to maximize equipment utilization and minimize idle time. Alternative sources for acquiring additional personnel and equipment must also be considered.

7. *Finances*. Financial resources are a significant factor that must be considered when making a decision to bid on a project. The firm must analyze its existing working capital, current and future cash flows, and the available credit line from financial institutions.

6.4.3.2 Project-Related Factors

Project-related factors to be considered by the general contractor include the following.

1. *Past Working Experience*. The past experiences of the parties in the contract can have a major influence on the firm's decision to bid.

2. *Quality of Drawings and Specifications*. Poor quality documents are those that are faulty, vague, and inconsistent. Future problems must also be anticipated and considered in the decision to bid on the project.

3. *Contract General Conditions*. For example, payment provisions and retainage clauses can have a significant impact on the construction work schedule and the firm's cash flow.

4. *Time Constraints*. Any time constraints in the contract, such as project completion date, must be properly evaluated for schedule adequacy and feasibility. This is especially important when liquidated damages are specified.

5. *Public Relations*. The community's perceptions and reactions to the project must be taken into consideration when the project is unpopular.

6. *Project Funding*. It is important to determine the source of funding for the project and whether the project is adequately financed. Consideration should not be given to projects that are not adequately financed or when the source of funding is unreliable or based on future arrangements.

7. *Award Time*. The waiting time between bidding and contract award, often long for public projects, must also be taken into consideration in preparing the bid.

8. *Project Special Requirements*. When special knowledge or skills are required for the completion of the project, the sources for such knowledge and skills must be determined and established.

6.4.3.3 External Factors

The following external factors should be considered.

1. *Competition*. The higher the number of bidders, the higher the risk is of not winning the bid. Although the number of bidders is important, it is equally important to know the companies that will be competing in the bidding. Previous encounters with known competitors must also be considered for bidding patterns as well as competitor specialties. Competing with companies the firm

never bid against before can create a sense of uncertainty and increase the risk of losing the bid.

2. *Economic Outlook*. The outlook of the local or national economy as well as within the company must be considered in making a decision to bid. During periods of economic downturn, a contractor may prefer to work with minimal or no profit, rather than suffer the losses that the company might face due to the lack of work and the burden of maintaining office overhead costs.

3. *Local Labor Condition*. The labor supply must be evaluated to determine availability and sufficiency. Other sources must also be considered if there is a potential for labor shortage. Alternatively, labor can be brought in from surrounding locations or work can be subcontracted out.

4. *Availability of Suppliers and Subcontractors*. This is especially important when bidding in new territories. Considerations regarding local suppliers and subcontractors must take into account their ability to adequately supply needed materials, special knowledge, and skills. Alternatively, remote suppliers can be established and the subcontractors brought in with the consideration that their prices remain competitive.

Should the firm choose not to proceed, the bidding process would terminate with the firm returning the document and getting back the refund when applicable. However, if the firm chooses to proceed, the major work in preparing the proposal begins.

6.4.4 Organizing the Estimating Team

With the decision to pursue the work, the firm can organize the estimating team for bid preparation. The size of the estimating team will be dependent upon the size of the project and the personnel the firm has available during that time. The team can be one or several persons. The firm may appoint a senior estimator to lead the estimating team. It is vital that only one individual be in charge of the overall estimating effort. This individual will be the lead or chief estimator. For small projects, she may be working alone or with minimal help when doing most of the estimating work. For bigger projects, the lead estimator will be in charge of breaking down the work and making detailed work assignments to the estimating team. The estimating team can be composed of a staff specializing in different work, such as quantity surveying or the pricing of different elements in the project.

6.4.5 Quantity Survey

The real work of estimating begins with the quantity survey or quantity take off. The quantity survey establishes the list of quantities of materials that are to be used in the project. This list of materials is documented in the project's bill of materials. More discussion on the quantity survey or quantity take off can be found in Chapter 3.

The quantity survey is the basis for all subsequent estimating tasks and directly affects how the contractor plans and executes the construction effort. A detailed and accurate quantity survey is vital for the success of the contractor performing the work. However, in situations where works are to be subcontracted, it is still essential for the general contractor to perform the quantity survey. The reasons include:

1. Better understanding of the work to be subcontracted,
2. Establishment of fair cost estimate for evaluating subcontractors' bids,
3. Checking of a subcontractor's scope of work, and
4. Determination of time duration that can be assigned to a subcontractor.

6.4.6 Project Site Investigation

The existing conditions of the project site, along with its surrounding areas can have a great impact on construction costs. All construction planning effort, including cost estimating, must take into account the site conditions in order to be realistic. Although some of the existing site information is usually available in the drawings and specifications, it is often limited and cannot be compared with the information that an estimator can gather by actually visiting the site and having a first-hand look around. Some of the critical items an estimator looks for include:

1. Site access;
2. Availability of utilities: water, electricity, and telephone;
3. Site drainage;
4. Proximity of adjacent structures;
5. Site layout; and
6. Vegetation, terrain, and soil conditions.

In addition to gathering specific physical information about the site, it is also important to gather information about the areas around the site, the locale, and city. Information regarding labor conditions and availability, local suppliers and subcontractors, weather, and local amenities are vital to the construction planning effort.

Typically, the information gathered is compiled and presented in the Construction Site Investigation Report (refer to Appendix 5). However, not all information must be collected if the general contractor is local or familiar with the area.

6.4.7 Review of Bidding Documents by the Corporate Staff and Legal Team

With the decision to bid, the bidding document must be scrutinized and thoroughly reviewed by the corporate staff and legal department in order to ensure that the firm is not entering into a contract in an unfavorable position. In addition, all critical contract clauses must be identified and considered in the preparation of the bid. Examples of such clauses are those relating to payment procedures, retainage clause, guarantees, imposed dates, and liquidated damages.

Retainage is a practice unique to the construction industry. It is the practice of withholding a percentage of the payment due to the contractor for the work performed and completed for that payment period. The purpose of the retainage is to give leverage to the owner in ensuring that the work is completed successfully. It is a form of guarantee. The period of retainage withholding varies according to the contract, which may be at 50% completion, or project substantial completion, or project final acceptance. A typical retainage amount is 5 to 10% of the periodic payment and is usually applied until 50% of the work is completed. Retainage can affect the cash flow of the contractor and must be considered in the preparation of the bid.

Liquidated damages are provisions in the contract that are designed to compensate the owner for economic consequences the owner might suffer if the contractor fails to complete the project on schedule. The inclusion of liquidated damages in the contract can result in higher bids due to increased risks faced by the contractor.

6.4.8 Construction Methods

The selection of the construction methods to be used on a project is one of the major factors affecting the final amount of a bid and consequently its competitiveness. Construction methods here encompass the way in which the project is to be executed; what, where, and how temporary facilities are to be built; what equipment is to be used and how much; labor needs; and which elements of the work are to be subcontracted out. The planning and selection of the construction methods must take into consideration information from the site visit report as well as from quantity surveys. Site conditions and any physical restrictions onsite can affect the choice of equipment and how work is to be accomplished. The types and volumes of work determined by the quantity surveys can also influence the choice of equipment and installation procedures. The selected construction methods must reflect contractor capability. It should also take advantage of the contractor's most competitive position, such as using the firm's own fleet of equipment and promoting the efficiency of his operations. Finally, the proposed construction methods must be reviewed and approved by the general contractor's management staff.

6.4.9 Schedule and Production Rates

A cost estimate is highly related to the construction schedule and production rates considered in the estimate development.

A construction schedule is the contractor's plan for the execution of the work and is an integral part of the estimate. The schedule not only dictates when work of one element starts, but also dictates the order in which the work is to be executed and when each phase should be completed. In developing a schedule, the estimator must review the bid document, which may require specific work items or work areas of the project to be completed by a specified time or in some order. The planned project completion date must be evaluated and considered during schedule development. Another crucial factor to be considered is weather. Inclement weather can affect the work by slowing down or stopping the operations. A construction schedule must, therefore, plan around poor weather and consider the lower construction productivity faced during periods of inclement weather. Finally, the schedules submitted by the subcontractors and vendors on the project must also be considered in the preparation of a project's preliminary schedule.

With the establishment of the construction schedule, the desired production rates for each work item can be determined based on the quantity of work to be done and the amount of time available for carrying it out. The production rate is the rate at which construction work is performed. For example, if through quantity survey it was determined that 6000 bricks need to be laid for the construction of a wall, and the schedule allows for 6 days, the desired production rate can be calculated to be approximately 1000 bricks per day. The desired production rates can be achieved by planning for and acquiring the necessary equipment and crafts that can satisfactorily perform the work. The required production rate can be considered as the main factor affecting the choice of equipment.

6.4.10 Finalizing the Project Estimate

Cost and pricing information must be determined and compiled for all the cost elements in the project. The contractor must determine the total cost of materials, labor, and equipment (rented or from his fleet). Then any subcontractor bids selected for the project are added along with a markup for managing the subcontractors. Finally, jobsite and general overhead costs together with anticipated profit are added to the estimate to produce a total bid amount.

6.5 ALTERNATES AND UNIT PRICES

Alternates are alternative construction features proposed by the owner/designer team. This can be in the form of alternative materials and methods to be used in the project. The inclusion of alternates in a bid requires the bidders to price and present the alternates and prices in the bid, along with the base bid for the project. The alternates and their pricing allow the owner to investigate options and make a decision based on submitted prices.

Itemized unit prices are sometimes requested by the owner and designer for reference and decision making purposes. Unit prices are usually requested for work associated with earthwork, concrete work, and masonry work, although it is sometimes possible to be requested for nearly all the trades. The inclusion of unit price information in the bid allows the owner to decide on any future additions and deletions to the work, as well as facilitating the calculations of any future cost changes.

6.6 CLOSING THE BID

The final process of putting the bid together is crucial and is usually done within a limited amount of time, often in the last 24 hours prior to the bid date deadline. To properly organize the information and minimize errors due to omission, a bid

Company Logo **Estimate Summary** Date Sept/ 5 /2000 Sheet No. 1 Of 1

Project Title: Research Building Project No.: 1122-71

Take Off By: John Smith Approved By: Richard Clements

CSI Division	Description	Material	Labor	Equipment	Subcontract	Total
02300	Earthwork	135828	60342	78440		274610
02900	Planting				29100	29100
03100	Formwork	114699	616257			730956
03200	Reinforcing Steel				32100	32100
03300	Cast-In-Place Concrete	247659	69384			317043
03400	Precast Concrete				271533	271533
04200	Masonry Units	119646	201003			320649
05300	Metal Decking				23400	23400
06100	Rough Carpentry	2586	19800			22386
06200	Finish Carpentry	1400	34689		48000	84089
07100	Dampproofing & Waterproofing				75000	75000
08100	Metal Doors & Frames	500	10896		30900	42296
08200	Wood & Plastic Doors		15276		23625	38901
08500	Windows				141000	141000
08800	Glazing				Include Above	
09200	Plaster & Gypsum Board				319200	319200
09300	Tile				59250	59250
09500	Ceilings				172200	172200
09600	Flooring				126600	126600
09900	Painting				53400	53400
10 000	Specialties				96000	96000
15 000	Mechanical				1050000	1050000
16 000	Electrical				559500	559500
	Page Total					4839213

	Material	Labor	Equipment	Subcontract	Total
Total Direct Cost: Page 1 to 1					4839213
Sales Tax 8.25 % (Materials)	51341				51341
Project Site Overhead					376881
General Overhead					250786
SubTotal					5518221
Profit 1 % (Subtotal)					55182
Contingency 3 % (Subtotal or $)					165546
Total Bid					5738949

FIGURE 6.2 Sample completed bid summary sheet.

closing checklist or bid summary sheet may be used. The bid closing checklist can serve as a reminder of key items to be included in the bid. It may be developed for a particular project based on the project's requirements, such as signatures, bonds, and permits. A bid summary sheet or recapitulation sheet (or just "recap") is often used to summarize and compile all the costs associated with the project. Only one person, usually the lead estimator, should be in charge of completing the form in order to minimize confusion and the possibility of missing an important item. A sample completed bid summary sheet can be seen in Figure 6.2.

6.7 REVIEW QUESTIONS

1. What are the two most common methods by which a contractor can acquire a construction contract?
2. Explain the roles of subcontractors in a construction project.
3. List some of the sources where an invitation to bid can be found.
4. What information can be found in an invitation to bid?
5. What is the content of a bidding document?
6. What is an addendum? What purpose does it serve?
7. What are some of the factors a contractor considers when making a decision to bid? Discuss.
8. Why is it a good idea for the general contractor to perform quantity surveys on work that is to be subcontracted out?
9. What is the purpose of a site visit? List some of the elements that must be examined during a site visit.
10. What is retainage? Why should a contractor be concerned with a retainage clause in a contract?
11. What is liquidated damage? How can the imposition of liquidated damage affect the bid amount?
12. Explain the relationship between production rate and construction schedule.
13. What is a pre-bid conference?

8

Concrete

8.1 INTRODUCTION TO CONCRETE WORK

Like other total direct costs, the total direct cost of concrete work is the summation of all costs including labor, equipment, material, and subcontractors required to complete the work. Concrete is currently one of the most common and extensively used materials in construction. Costs of labor, equipment, and materials in concrete construction are relatively high. To better explain quantity take off, the following sections introduce the components of concrete work, concrete construction crafts, take off needs, and take off methods for concrete cost estimating. In addition, a checklist table is introduced to enhance the quality of quantity take off. Later sections of this chapter discuss concrete materials and methods, concrete forms and accessories, reinforcement, cast-in-place concrete, and precast concrete as well as cementitious decks and underlayment.

8.1.1 Components of Concrete Work

Typically, concrete work consists of two major components, structural and non-structural. Structural elements are the major components in concrete building construction. They include footings, concrete pilings, foundation walls, slabs on grade, columns, beams, above-grade floor structures, wall structures, abutments, roof structures, and other special elements such as stairways. The structural elements can be made from lightweight, normal weight, and heavyweight concrete.

TABLE 8.1 Major Structural Building Components

Structural building components	Description
Footing	All types of footings of structures.
Abutment	End-bearing structure with beam seats, back walls, wing walls, etc.
Column	A supporting pillar of slabs. Columns normally have variety of shapes and sizes (square, rectangular, circle, polygonal or L-shape).
Beam and girder	A supporting member spanning between columns or walls and carrying loads from floor or roof slabs.
Slab	A slab on-grade and a floor or roof slab.
Wall	On-grade concrete walls, earth retaining walls, pier stems, barriers, etc.
Deck	Floor slabs on bridges, building, or other aboveground structures.
Arch	All types of structural curved members.
Special shaped element	Stairways, pipe end walls, etc.

The weight per volume of these concrete types is provided in Table 8.16 in Section 8.5.1. The nonstructural elements, on the other hand, are normally made from only lightweight concrete. They are composed of such decorative elements as exterior windows, door trims, railings, and specially formed and designed concrete items such as statuary, corbels, and cornices. The major structural building components to be taken off are listed in Table 8.1.

8.1.2 Concrete Construction Crafts

Concrete work requires a significant number of crafts and the cost of crafts is normally high. An estimator must therefore include the costs of desired concrete construction crafts in the cost estimation. Table 8.2 presents six major crafts usually involved in concrete construction work. Each craft performs different tasks. Carpenters primarily execute tasks in the area of concrete forms and accessories. Labor generally performs concrete placement operations including placing and vibrating the concrete, performing joint and concrete cleanup tasks, applying curing compound, and performing water curing. Ironworkers have the major responsibility for reinforcing bar installation and miscellaneous metalwork.

8.1.3 Take-Off Needs

The purpose of a quantities take off is to isolate the quantities of each building material and to group them into assigned categories. The take-off needs are then presented as units of concrete quantities to identify differences in construction and cost. Table 8.3 presents the take-off needs for concrete cost estimating.

TABLE 8.2 Concrete Construction Crafts

Concrete craft	Description
Carpenters	Erect forms, install embedded items in the forms, and remove the forms after concrete is hardened.
Labor	Place concrete in the forms and help carpenters.
Cement masons	Perform wet and dry finish treatments, plug tie holes, and repair misaligned joints and honeycomb.
Ironworkers	Tie reinforcing steel in the forms and perform miscellaneous metalwork.
Teamsters	Drive vehicles such as transit-mix and dumpcrete trucks for tools and materials delivery purposes.
Operating crews	Crane operators, concrete pumps operators, concrete batching and mixing plants engineers, and large compressor plants engineers.

Table 8.3 Take-Off Needs for Building Projects

Take-off needs	Description
Concrete volume (m^3)	Most concrete parts of the building structure including footings, columns, beams, floor, and roof slabs.
Contact area (m^2)	Surface areas of concrete to be formed.
Joints (m)	Lengths of special keyway, joint materials, and waterstops.
Shore area (m^2)	Surfaces of formwork requiring external supports such as shoring.
Finish area (m^2)	Surface areas of concrete to receive a special treatment.
Protective coating (m^2)	Surfaces requiring a special material to waterproof or protect the concrete.
Embedded items	Details of embedded items in concrete work such as pipe, hardware, and curbing.
Unusual items	This category may be found in costs of concrete work, but usually not treated as items in concrete work.

8.1.4 Take-Off Methods for Concrete Cost Estimating

One of the most common take-off needs for concrete work is concrete volume. As shown in Eq. (8.1), concrete volume is simply determined by the multiplication of the length, width, and height (or depth) of a structural unit.

$$\textit{Volume}\ (\mathrm{m}^3) = \textit{Length}\ (\mathrm{m}) \times \mathrm{Width}\ (\mathrm{m}) \times \textit{Height}\ (\mathrm{m}). \tag{8.1}$$

As shown in Equation (8.2), concrete area is the product of the length and width of a structural unit.

$$\textit{Section Area}\ (\mathrm{m}^2) = \textit{Length}\ (\mathrm{m}) \times \textit{Width}\ (\mathrm{m}). \tag{8.2}$$

Even though the multiplication seems to be a simple task, an estimator can make mistakes due to unfamiliarity with take-off methods. There are three methods used to perform the quantity take off for concrete work. They are differentiated by how the area of a structural component is determined, namely, the unit, perimeter, and centerline methods.

The first is the unit method. This requires a structural component to be totally separated into several single units. The total length applied in Eq. (8.2) is simply a summation of the length of all units that have the same width and height. For example, Figure 8.1(a) presents a structural wall with the dimension of 6 m $\times$ 8 m, outer to outer. The wall has a thickness of 0.20 m^2 and 0.30 m, and a height of 2.5 m. To determine the total section area of the wall, an estimator needs to separate the wall into four single units as shown in Figure 8.1(b). In this case, the total section area equals $[(2 \times 5.4 \times 0.2) + (2 \times 8 \times 0.3)] =$

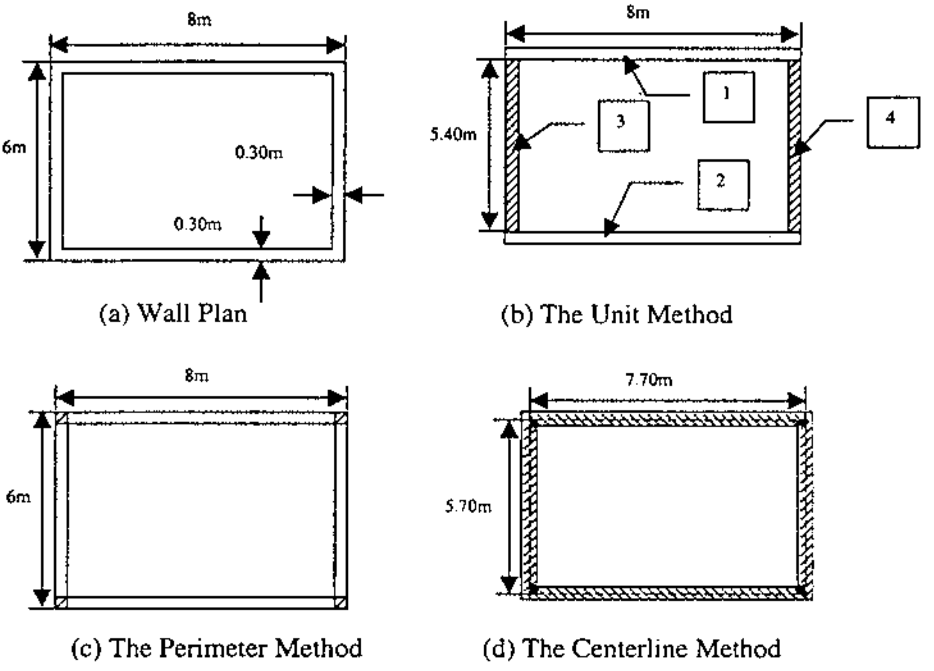


FIGURE 8.1 Three quantity take-off methods.

6.96 m^2 and the total volume is 17.4 m^3. Computation details are presented in Table 8.4.

Next is the perimeter method. In this instance, the total section area is the product of the perimeter thickness and the thickness of the structural component subtracted by the area widths at the corners. As shown in Figure 8.1(c), subtraction is a result of the double computation of four shaded areas at the corners. Table 8.4 presents the total section area of $[(2 \times 6 \times 0.2) + (2 \times 8 \times 0.3) - 4(0.3 \times 0.02)] = 6.96\ m^2$.

TABLE 8.4 Computation Details for the Take-Off Methods

Methods of quantity take off	Computation	Total volume
Unit	$[2 \times (8 + 5.4)] \times 0.3 \times 2.5$	20.1
Perimeter	$[2 \times (8 + 6) - (4 \times 0.3)] \times 0.3 \times 2.5$	20.1
Centerline	$[2 \times (7.7 + 5.7)] \times 0.3 \times 2.5$	20.1

The third is the centerline method. In this case, the total area is simply the product of the length and thickness of the centerlines. As shown in Figure 8.1(d), the dark area is computed twice for this method. However, the dark area is equal to the white area at the corners that are not included in the computation. Therefore, the centerline method does not require area subtraction. Table 8.4 presents the total area of $[(2 \times 5.7 \times 0.2) + (2 \times 7.8 \times 0.3)] = 6.96\ m^2$.

When using any of the methods described above, the total volume of the wall is 17.4 m^3. According to the sample illustration in Table 8.4, each wall unit has the same height of 2.5 m. However, if each wall unit has a different height, an estimator can separate all the units by height and then use any of the calculation methods to obtain the total volume. Some estimators may employ the average height in the calculation. No matter which method an estimator uses, it is important that the estimator choose a suitable one so errors and omissions can be minimized.

8.1.5 Checklist for Concrete Work

A checklist is a useful tool for cost estimation. It basically helps an estimator remember important cost items and can help prevent major mistakes during the quantity take-off process. Table 8.5 presents a checklist for concrete work. Self-performed (SP) or subcontracted (Sub) items can be marked to identify sources of an estimated cost. Costs of self-performed items are obtained by the estimator's estimation. Costs of subcontracted items are normally provided by tentative subcontractors. Additional items can be added to the table.

8.2 BASIC CONCRETE MATERIALS AND METHODS

Concrete is one of the major and most common materials used in current construction. It is widely used because of its strength, durability, water tightness, and resistance to scratching and freezing, thawing, and some chemicals. Additionally, concrete is the principal material for many other construction components such as masonry units, mortar, grout, and precast concrete units. Typically, concrete gains more strength as it gets older. Its strength also depends on its major ingredients. In this section, major concrete materials are first introduced and then concrete construction methods addressed. Equipment is presented along with the methods so an estimator can have a clear understanding of equipment usage.

8.2.1 Basic Concrete Materials

Concrete is basically a mixture of cement, water, and aggregates. Cement usually contains, by volume, from 10 to 15% of the total concrete mix. One cubic meter

TABLE 8.5 Checklist for Concrete Work

Materials	SP[a]	Sub[b]	Forms & shoring	SP[a]	Sub[b]	Reinforcement	SP[a]	Sub[b]
1. Cement—types			1. Forms—types, # of uses			1. Bars—grades, # of bars		
2. Aggregate—sizes			2. Erection			2. Wire mesh-sizes		
3. Water			3. Removal			3. Cutting		
4. Color-oxide			4. Repair			4. Bends		
5. Ready-mix-strength			5. Ties			5. Hooks		
6.			6. Clamps			6. Ties		
7.			7. Braces			7. Stirrups		
8.			8. Cleaning			8. Chairs		
9.			9. Oilings			9.		
10.			10. Repairs			10.		
11.			11. Liners			11.		
12.			12.			12.		
Concrete			**Finishes**			**Curing & placement**		
1. Footings			1. Hand trowel			1. Admixtures		
2. Walls			2. Machine trowel			2. Ponding		
3. Piers			3. Brush hammer			3. Spraying		
4. Columns			4. Wood float			4. Canvas		
5. Slabs			5. Broom			5. Vapor varrier		
6. Topping			6. Sand—sizes			6. Heating		
7. Beams			7. Rubbed			7. Cooling		
8. Girders			8. Grouted			8.		
9. Stairs			9. Fins—removal			9.		
10. Platforms			10.			10.		
11. Ramps			11.			11.		
12. Miscellaneous[c]			12.			12.		

[a] SP = self-performed items.
[b] Sub-subcontracted items.
[c] Includes curbing, coping, walks, driveways, architectural, and testing.

TABLE 8.6 Types of Portland Cement

Portland cement	Description
Type I	The normal Portland cement suitable for most uses.
Type II	For concrete structures in water or soil containing moderate amounts of sulfate, or when heat must be controlled.
Type III	The high early strength cement employed when high strength is required in a week or less.
Type IV	The low to moderate heat Portland cement used for massive concrete structures.
Type V	The sulfate-resistant Portland cement commonly used where the water or soil is high in sulfates.
Types IA, IIA, and IIIA	They normally have the same properties as types I, II, III except that they contain small quantities of air-entrained materials.

of cement is approximately 1510 kg. The most widely used cement for construction is Portland cement. It is usually made from limestone, clay, silica, iron ore, and other raw materials in a very high-temperature manufacturing process (1500°C). Portland cement can be purchased by numbers of bags or by tons. One bag usually contains 43 kg of cement. To improve cement characteristics, additives can be added to the concrete during the production process. These additives allow concrete to obtain high early strength, sulfate-resistance, low heat, or faster cure. According to the Portland Cement Association (2000), there are six types of cement commonly used in construction. These are shown in Table 8.6.

To produce concrete, aggregates are also significantly needed in the concrete mixture. Aggregates are sand (fine aggregate) and gravel or crushed stone (coarse aggregate) available in various sizes. One m^3 of loose damp sand and dry sand is approximately 1690 and 1407 kg, respectively. One m^3 of crushed stone is approximately 1525 kg. It is almost likely that a concrete mixture of these materials can indicate concrete strength. A concrete mixture is a proportion of volumes of cement, fine aggregate, and coarse aggregate, respectively. For example, a concrete mixture of 1:2:3 represents 1 volume unit of cement, 2 volume units of fine aggregate, and 3 volume units of coarse aggregate. In general, a concrete mixture of 1:2.5:3 presents concrete with a 28-day compressive strength of 21 MPa. A concrete mixture of 1:2.75:4 represents concrete with 28-day compressive strength of 16 MPa.

The last important mixture in concrete is water. It chemically reacts with the cement components in a process called hydration that hardens and binds the aggregates into a solid mass. The amount of water in the mixture compared with the amount of cement is called the water to cement ratio (water–cement ratio, w/c). The water–cement ratio ranges from 0.40 to 0.75 depending upon a needed concrete strength, a required slump, and desired concrete material properties. A low water–cement ratio produces a concrete that is difficult to place. However, it is likely that the lower the water–cement ratio, the stronger the concrete is.

8.2.2 Cast-In-Place Concrete Work

To minimize the errors of quantity take off and pricing, an estimator needs to know construction methods. Concrete construction methods are too broad for this text to cover in detail. This section presents only general, but major, operations for cast-in-place concrete work. There are five major operations for typical cast-in-place concrete work, namely, form preparation, embedded items placement, concrete placement, cure and protection, and form removal. Each operation needs different methods to perform its respective work.

The first operation is form preparation. Formwork is required to form and contain wet concrete before the concrete hardening process. This operation includes, but is not limited to, earth excavation for footings, shoring erection for proper elevation, surface grading for slab on grade, and form preparation for footings, walls, and other building parts. After form preparation, the second operation of embedded-items placement is performed. This operation includes both structural items (such as concrete reinforcement) and nonstructural items (such as anchor bolts, plates, corner protection angles, conduits, and ductwork). All embedded items must be promptly placed before the next operation.

Concrete placement is the third operation. This includes the delivery of concrete from the site plant or the ready-mix concrete supplier by a truck to the workplace. This operation also consists of the placement of concrete at the designated level or elevation in the concrete forms. After the concrete reaches the designated level in the forms, a proper finish is applied to the exposed surfaces to provide a smooth, hard, and consolidated surface without voids and roughness. A cure and protection operation is the fourth step. Cure serves the purpose of obtaining higher concrete strength and preventing concrete cracks due to a fast concrete-setting process. Protection from precipitation, freezing, or high temperature is also needed prior to the setting process of concrete in order to ensure quality of finish and the proper water–cement ratio.

The fifth and last operation for cast-in-place concrete work is form removal. Once the concrete has hardened and gained proper strength, the formwork is removed. This operation includes removing, cleaning, repairing, and storing the shoring and forms for future use. Proper cleaning and coating are significant because they can present a number of material reuses and high material costs. After form removal, concrete finishing or topping may take place to ensure the quality of the concrete surface and the designated level.

These five operations are major functions for cast-in-place concrete work. Section 8.5.2 presents more details regarding concrete operations that focus on only concrete items for cast-in-place concrete work. The details of cost estimating for cast-in-place concrete is discussed in Section 8.5.

8.2.3 Precast Concrete Work

Precast concrete work is a common construction practice in building construction. Precast concrete is normally formed, placed, and cured in a concrete manufacturing plant or at a job site prior to shipment to desired locations. It not only significantly increases productivity but also provides convenience, which leads to faster construction. The work does not involve as many operations as required for cast-in-place concrete work, however, there must be an accurate assessment of precast concrete items needed, a determination of their sizes and positions, and requisite installation skills. To serve different work areas, precast concrete is built in a variety of sizes and forms as required in drawings and specifications. The precast concrete is normally delivered to the jobsite at the time requested by a contractor. Details of cost estimating for precast concrete work and the types of the precast concrete are presented in Section 8.6.

8.2.4 Concrete Placement and Equipment

Concrete can be furnished by either a ready-mix concrete supplier or an onsite batching and mixing plant. Concrete is normally delivered in 1 to 5 m^3 to the jobsite by transit-mix or dumpcrete trucks. There are specific options for conveying concrete. The first option is to batch, mix, and discharge the concrete into the truck at the plant, and then deliver it to the jobsite. To prevent the wet concrete from segregation, the drum needs to continually rotate during transportation. The second option is to batch and discharge the concrete into the truck at the plant, and then add water during transportation or at the jobsite.

When the concrete arrives at the placement area, it must be placed into the concrete forms prior to its beginning to set. For on-grade work, the concrete can usually be discharged from a transit-mix truck or dumpcrete truck directly into the forms. At some height above grade or at some distance from the truck, hoisting or transporting equipment is needed. Typical hoisting equipment, such as a crane with a dump bucket, a concrete pump, or a conveyer belt, must be provided. A crane is required for concrete construction not only to place the concrete but also to transport material and equipment, such as forms and concrete reinforcement. A variety of crane types is available on the market, such as conventional and hydraulic truck cranes, conventional crawler cranes, hydraulic rough terrain cranes, and tower cranes. Crane sizes may vary from 15 to 300 tons serving different work purposes. Bucket sizes range from 0.38 to 3.06 m^3. A crane and bucket system may have capacities of 45 to 60 m^3/hr or more, depending on labor productivity. This system effectively transports the concrete both in vertical and horizontal directions. However, a concrete pump system is becoming increasingly prevalent because of its convenience in both transporting and placing the concrete. For horizontal transportation, a conveyer belt system works fine in building construction.

In addition to this major equipment, there is other important equipment required for concrete work. Air compressors are required to blow debris out of the formwork prior to concrete placement, to clean material and equipment, or to control air-operated vibrators. To transmit vibration to the concrete, either air-operated or electric-driven vibrators are needed in order to merge wet concrete after the concrete is placed in the forms. For surface work, immersion vibrators containing a high-speed rotating drive are required. Welding machines are primarily needed for concrete reinforcement. Miscellaneous equipment includes a chute, a wheelbarrow, and a buggy. It is likely that all equipment costs, along with maintenance and operating costs, are normally required for the cost estimation.

8.2.5 Quantity Take Off and Pricing for Basic Concrete Materials

In building construction, concrete can be obtained from a ready-mix concrete supplier or batching and mixing plants. However, if a project is relatively small or requires a limited amount of concrete, concrete mixing operations may be required at the project site. Quantities of concrete materials, including cement, sand, and gravel or crushed stone, must be taken off. To begin the quantity take off, an estimator needs to calculate the quantity of dry concrete materials from the concrete mixture. If a building project requires a concrete mixture of 1:2:3 with a water–cement ratio of 0.45, the total number of dry units equals 6. However, to obtain 1 m^3 of wet concrete, a total volume of 1.5 m^3 of dry materials is normally required. Therefore, this project requires dry materials:

$$\text{Cement} = 1/6 \times 1.5 = 0.25\ m^3;$$
$$\text{Sand} = 2/6 \times 1.5 = 0.50\ m^3;$$
$$\text{Stone} = 3/6 \times 1.5 = 0.75\ m^3.$$

However, the quantity of cement is normally taken off by its weight (kg) or numbers of bags, so an estimator needs to change its volume to its equivalent weight or number of cement bags. To obtain its weight, an estimator can multiply the obtained volume by its density, approximately 1510 kg/m^3. To obtain the number of bags, an estimator can divide the total weight by weight per one bag of cement. To hasten the quantity take-off procedure, Table 8.7 presents dry concrete materials (including cement, sand, and crushed stone) according to various concrete mixtures. A waste factor for each material is also required. A waste factor of 5 to 10% is typically required for cement. For sand and crushed stone,

TABLE 8.7 Quantities of Dry Materials for 1 m^3 of Concrete[a]

Concrete mixture	Cement kg	Cement m^3	Sand m^3	Stone m^3	Concrete mixture	Cement kg	Cement m^3	Sand m^3	Stone m^3
1:1:1	755	0.5	0.50	0.50	1:2:4	317	0.2	0.43	0.86
1:1:2	574	0.4	0.38	0.75	1:2.25:3	347	0.2	0.52	0.70
1:1:1.75	559	0.4	0.37	0.65	1:2.75:4	287	0.2	0.53	0.78
1:2:2	453	0.3	0.60	0.60	1:3:3	317	0.2	0.64	0.64
1:2:2.25	423	0.3	0.56	0.65	1:3:5	257	0.2	0.50	0.83
1:2:3	378	0.3	0.50	0.75	1:3:6	227	0.2	0.45	0.90

[a]Estimated numbers suitable for estimating, not design, purposes.

due to its loss during transportation, a waste factor of 10 to 30% is exercised. The more quantity a contractor needs, the less waste factor an estimator uses.

8.2.6 Computation Example for Basic Concrete Materials

According to the continuous footing and wall shown in Figure 8.2, the total cost of major concrete materials (including cement, sand, and crushed stone) will be determined (see Table 8.8). This project requires the use of Portland cement type I, washed sand for concrete, and 30 mm stone. The concrete mixture for the footing and wall is 1:2:3. The water–cement ratio is 0.60. A concrete mixture of 1:3:6 is employed for the lean concrete.

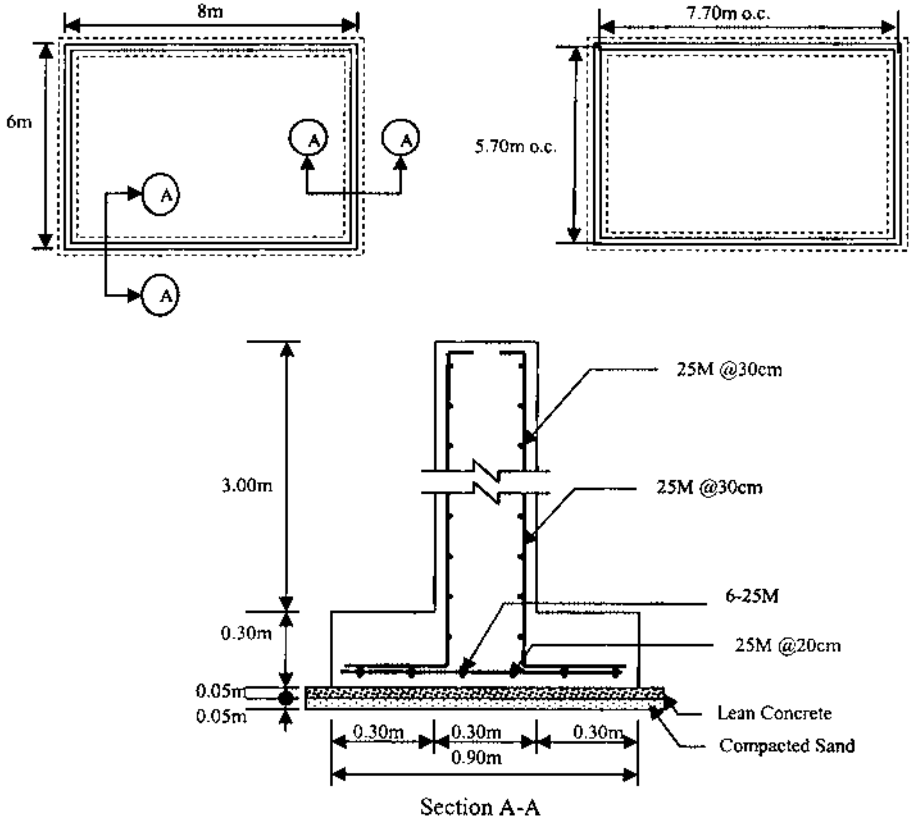


FIGURE 8.2 Footing and wall plan and Section A-A.

TABLE 8.8 Cost of Material for Major Basic Concrete Materials Concrete

Code 03060	Basic concrete materials	Crew	Daily output	Labor (hrs)	Unit	Mat.	Labor	Equip.	Total	Total[a]
110-0950	Sand, washed, for concrete				m^3	15.55			15.55	17.1
110-1050	Stone, 20 to 40 mm				m^3	28			28	31
200-0240	Portland, type I, plain/air entrained, TL lots, 68 kg bags				Bag	7.3			7.3	8.05

[a]Including O&P.
Source: *Means*, 1999.

Step 1. Perform the quantity take off for structural concrete, lean concrete, and sand. Details for the quantity take off are presented in Figure 8.3. According to Figure 8.3, the total volume of the footing and wall is 31.5 m^3, the total volume of lean concrete is 1.6 m^3, and the total volume of the compacted sand is 2.1 m^3.

Step 2. Determine the quantity of the concrete materials required for 1 m^3 of concrete. This project requires the concrete mixture of 1:2:3 for footing and wall elements, and the concrete mixture of 1:3:6 for the lean concrete purpose. According to Table 8.7, a total quantity of 378 kg of cement, 0.50 m^3 of sand, and 0.75 m^3 of crushed stone is required for 1 m^3 of concrete for footing and wall elements. For the lean concrete, a total quantity of 227 kg of cement, 0.45 m^3 of sand, and 0.90 m^3 of crushed stone is required for 1 m^3 of concrete.

Step 3. Determine the total quantity of the concrete materials for the footing and the wall. This project requires dry concrete materials:

Cement = (31.5 × 378 kg) + (1.6 × 227 kg) = 12,270 kg = (12,270 kg) / (68 kg/bag) = 180 bags;
Sand = (31.5 × 0.50 m^3) + (1.6 × 0.45 m^3) + 2.1 m^3 = 18.6 m^3;
Stone = (31.5 × 0.75 m^3) + (1.6 × 0.90 m^3) = 25.1 m^3.

Step 4. Consider a waste factor for each concrete material used, waste factors of 5, 20, and 20% are exercised for cement, sand, and stone, respectively. Therefore, the total estimated quantity of concrete materials is:

Cement = 180 bags × 1.05 = 189 bags;
Sand = 18.6 m^3 × 1.20 = 23 m^3;
Stone = 25.1 m^3 × 1.20 = 30 m^3.

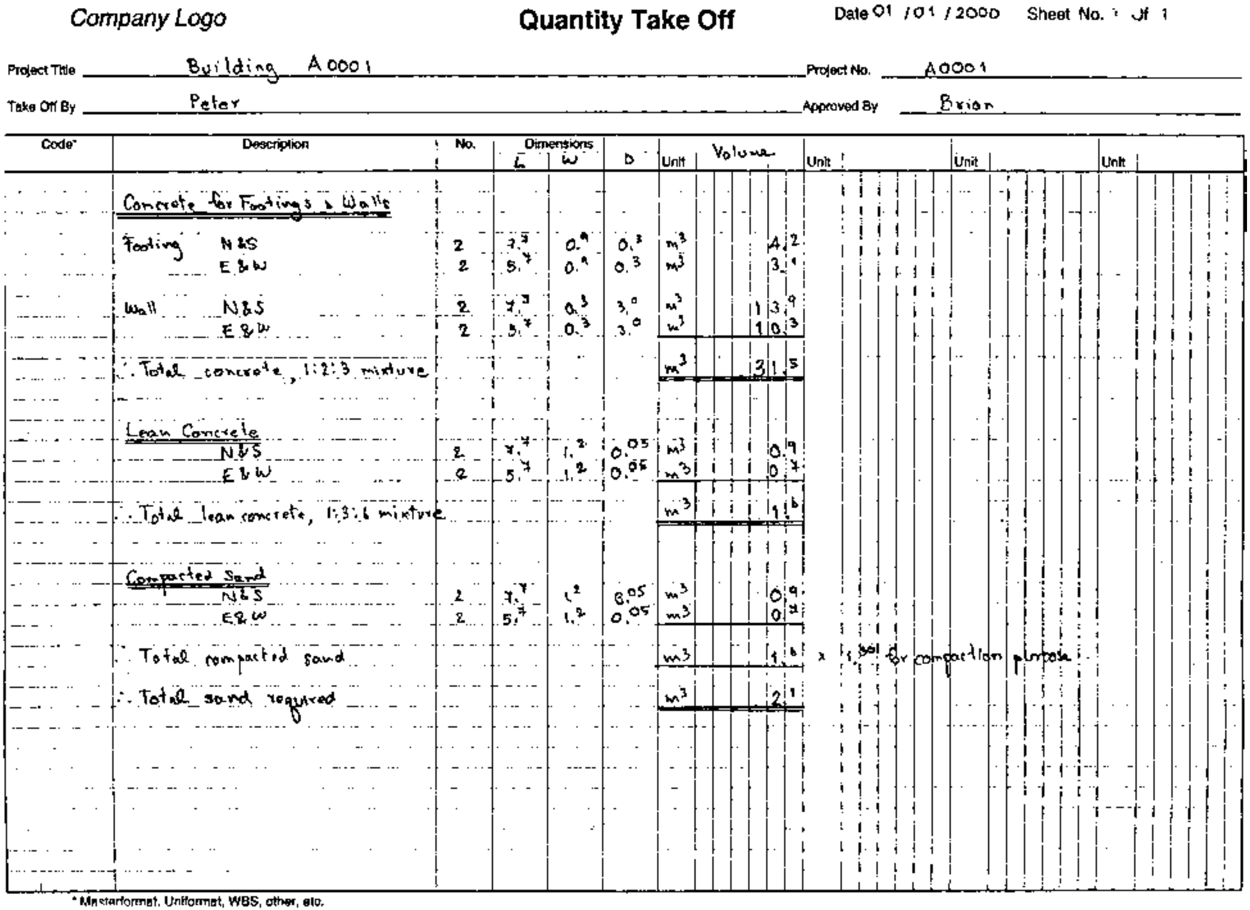
Step 5. Using Table 8.8, the total cost of major concrete materials is calculated and shown in Figure 8.4. The total cost for the basic concrete materials is $2578.

8.3 CONCRETE FORMS AND ACCESSORIES

In previous sections, an introduction to concrete work and basic concrete materials and methods were presented. They were provided to help understanding of concrete work including labor, materials, and equipment, as well as concrete operations. This section introduces topics related to concrete forms and accessories including types of forms, formwork systems, and shoring systems. This section also presents quantity take off and pricing for concrete forms and accessories. Finally, an example of cost estimation is presented.

8.3.1 Types of Concrete Forms

It is certain that the types of the concrete forms used must meet project and work requirements. In fact, project needs and the types of work can indicate the con-



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Quantity Take Off

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Project Title: Building A0001 — Project No.: A0001

Take Off By: Peter — Approved By: Brian

Code*	Description	No.	Dimensions L	Dimensions W	D	Unit	Volume	Unit		Unit		Unit	
	Concrete for Footings & Walls												
	Footing N&S	2	7.7	0.9	0.3	m³	4.2						
	E&W	2	5.7	0.9	0.3	m³	3.1						
	Wall N&S	2	7.7	0.3	3.0	m³	13.9						
	E&W	2	5.7	0.3	3.0	m³	10.3						
	∴ Total concrete, 1:2:3 mixture					m³	31.5						
	Lean Concrete												
	N&S	2	7.7	1.2	0.05	m³	0.9						
	E&W	2	5.7	1.2	0.05	m³	0.7						
	∴ Total lean concrete, 1:3:6 mixture					m³	1.6						
	Compacted Sand												
	N&S	2	7.7	1.2	0.05	m³	0.9						
	E&W	2	5.7	1.2	0.05	m³	0.7						
	∴ Total compacted sand					m³	1.6	× 1.30 for compaction purpose					
	∴ Total sand required					m³	2.1						

* Masterformat, Uniformat, WBS, other, etc.

FIGURE 8.3 Quantity take off for basic concrete materials.

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Pricing

Date 01 / 01 / 2000 Sheet No. Of 1

Project Title Building A 0001 Project No. A 0001

Take Off By Peter Approved By Brian

Code*	Description	Quantity	Unit	Material U.P.	Material Total	Labor U.P.	Labor Total	Equipment U.P.	Equipment Total	Subcontract U.P.	Subcontract Total	Total U.P.	Total
03060-200-0240	Portland cement, Type I	189	bag	7.30	1380								1380
03060-110-0950	Sand, washed, for concrete	23	m³	15.55	358								358
03060-110-1850	Stone, 20 mm to 40 mm	30	m³	28	840								840
	SHEET TOTAL				2578 (MATERIAL)		(LABOR)		(EQUIPMENT)		(SUBCONTRACT)		2578 (TOTAL)

* Masterformat, Uniformat, WBS, other, etc.

FIGURE 8.4 Pricing for basic concrete materials.

TABLE 8.9 Examples of Concrete Forms and Accessories

Forms	Accessories
Wood or plywood	Metal pans
Panels—wood, metal, plastic	Steel joists for supports—steel, aluminum
Fiber	Fiberglass pans
	Shores—wood, metal, fixed, adjustable
	Corrugated steel floor panels
	Form liners—plastic, rubber, steel

crete forms needed. Project needs may refer to the availability of materials, to tools and skilled crews, or to cost budgets. Types of work include below-grade, on-grade, wall, or high-rise concrete construction, therefore, types of concrete forms can generally be classified by their work types and materials. Types of forms based on work types are introduced in Section 8.3.2.

Based on material content, concrete forms can be classified into three groups, namely, wood, metal, and miscellaneous forms which could be a combination of those or other materials. Among these forms, wood forms are normally the least expensive and may be used up to four times depending upon their use or maintenance. The waste factor for wood forms may take a significant role. Hardware composed of the necessary metal parts is required to tie and hold the wood forms. Hardware includes nails, snap ties, tapered tie bolts, tie screws, deck hangers, and so on, the cost of which can vary from 1/4 to 3/4 of the forms. Metal forms, on the other hand, are usually much more expensive, but may last for many uses and can be repaired.

The sizes of concrete forms can be acquired from suppliers or construction material books. Most concrete forms can be rented or purchased depending upon their tentative numbers of uses and available cost. In most circumstances, a supporting system, such as a shoring system, is required to make the formwork system rigid. As a result, along with material, tools, and labor costs, the cost of a supporting system needs to be added into the total cost of concrete forms. Table 8.9 presents examples of major concrete forms and accessories.

8.3.2 Formwork Systems

In the construction industry, most cast-in-place concrete tasks significantly involve using a formwork system. Concrete work requires different formwork systems to serve different functions. Formwork systems can be categorized into five work types: below-grade, on-grade, wall, slab/beam/column/stair, and high-rise concrete construction. An estimator needs to know which formwork system suits certain concrete work types.

The first concrete work type is below-grade construction, the most common form of which is the gang form system, especially for basement walls. It may be made from wood planking, plywood, plyform, rolled steel boxes, or any combination of these materials.

The second concrete work type is on-grade construction. It includes curbs, gutters, sidewalks, and slabs on grade. Concrete forms for on-grade slab construction are referred to as flatwork forms, which are classified into three groups according to their material components: heavy-gauge steel for curb, gutter, and sidewalk construction, light-gauge steel for slab construction, or others, which includes all wood or combination of wood and light-gauge steel. The wood plank system is a supporting system for on-grade construction. It is constructed with single or double wales and braces. This system has the advantage of a maximum-height extension of 2.40 m and can be employed for mass excavation, trench excavation, or wall construction.

The third concrete work type is wall construction. This work normally requires the use of a plyform system (see Fig. 8.5). A plyform system is primarily

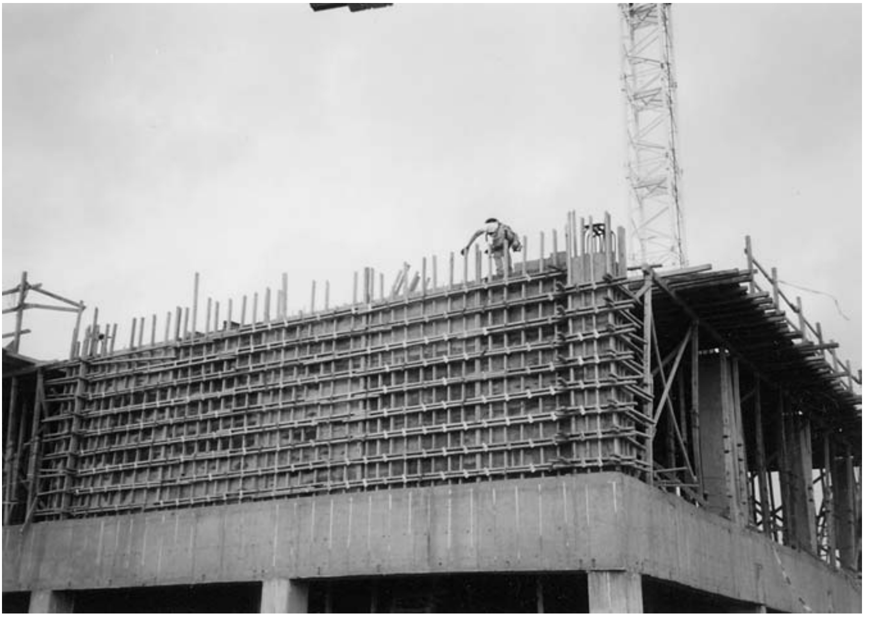

FIGURE 8.5 Plyform system for wall and column construction.

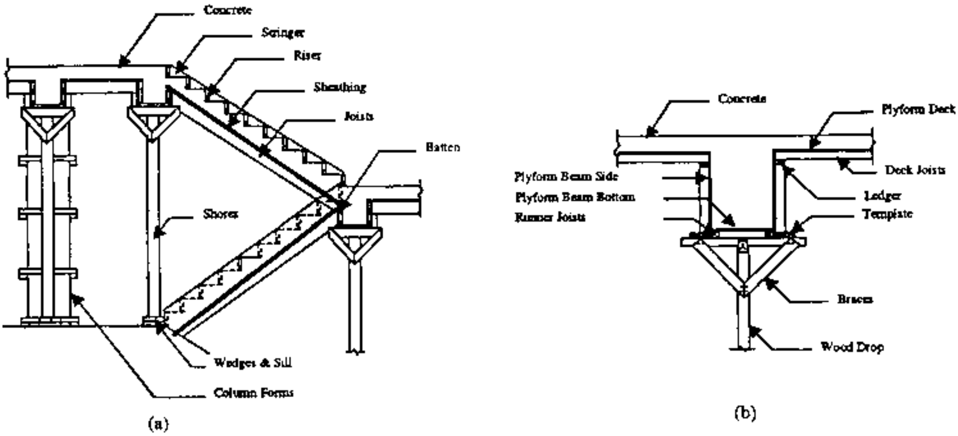

FIGURE 8.6 Typical methods of wood form construction for (a) concrete stairs and columns, and (b) concrete beams.

made from 1.20 m × 2.40 m sheets of treated plywood with the thickness of 19 or 25 mm. This system is supported by wales and braces and requires the use of formties or snap ties with nuts and washers. By using formties, this system can be installed through holes in the plyform and tightened to fit a wall thickness. The ties normally serve as a part of the concrete wall reinforcement.

The fourth concrete work type is slab, beam, column, and stair construction. Plywood forms with a shoring system are needed. There are many types of slab construction, such as flat slab, beam and girder type, and pan construction with concrete joists. For column construction, there are many forms, both in wood or metal, available on the market depending upon the sizes and shapes of the columns. The plywood system may be employed for rectangular columns. Figure 8.6 presents typical methods of wood form construction for concrete stairs, columns, and beams.

The fifth concrete work type is high-rise concrete construction. A slip gang form, also called a flying form, is primarily employed. It is usually made from wood or steel. This system supports the structure and can be raised to the next level by a crane after the concrete curing process.

8.3.3 Shoring System

Shoring, also called falsework, is a supporting system of forms carrying both the weights of building elements and the live loads on the elements during construction. Live loads include weights of crews, equipment, and materials. The shoring system is temporarily set to support concrete forms and is removed after the concrete gains enough strength. It may include steel or wood beams, stands, jacks, or a combination of these. For floor construction, there are two common shoring systems: adjustable shores and 1 m × 1 m wood shores. Adjustable shores are normally made from wood, steel, or a combination of these. Vertical steel shores are available in various sizes adjustable up to 5.0 m. Material costs of adjustable steel shores are considered expensive. On the other hand, the 1 m × 1 m wood shoring system offers lower material costs. This system has been a traditional shoring system for years. It requires wedging, cutting, and height adjusting. However, labor costs of this system are relatively high compared to the adjustable shores system.

In current construction, many contractors use sectional steel scaffolding units for shoring the formwork for slab and beam construction. Typical scaffolding consists of base plates, 0.50 m adjustable extension legs, 1.50 m frames with a height of 0.90 to 1.95 m, and diagonal braces, which give a distance between frames of 0.75 to 2.10 m. A combination of the sectional steel scaffolding and adjustable shores or sectional steel scaffolding and 1 m × 1 m wood shores can be seen in construction sites nowadays.

8.3.4 Quantity Take Off and Pricing for Concrete Forms and Accessories

According to the take-off needs previously described, units of measure for concrete forms can be classified as contact area (m^2), shore area (m^2), finish area (m^2), and embedded items (Ea). To perform the quantity take off, concrete forms for each building component must be separately kept, since they are not only formed differently, but also have different units, concrete types, and finishes. To perform quantity take off, concrete forms can be categorized into specific groups as shown in Table 8.10.

TABLE 8.10 Categories of Concrete Forms for Quantity Take Off

Categories
Ribbon footing forms: meter (m)
Slab edge forms (by height): meter (m)
Foundation edge forms: square meter (m^2)
Wall forms: square meter (m^2)
Pier forms: square meter (m^2)
Column forms: square meter (m^2)
Beam bottom forms: square meter (m^2)
Beam side forms: square meter (m^2)
Supported slab forms: square meter (m^2)

After quantity take off has been completed, the costs of concrete forms and accessories are computed from the combination of cost for labor, equipment, and material. Labor and equipment costs include all crews and equipment needed to erect and remove forms, clean forms, and install shores and supports. Material costs contain all forms, shores, wood, hardware, and other accessories. Examples of the costs for labor, material, and equipment for major structural cast-in-place forms are presented in Tables 8.11 and 8.12. The major impact on the total cost of concrete forms is normally the cost of labor and equipment. The cost of each building component can vary because of differences in shapes and sizes. A waste factor of 5 to 10% of the total material cost is generally required.

8.3.5 Computation Example for Concrete Forms and Accessories

Referring to Figure 8.2, we perform cost estimating for concrete forms and accessories. According to Tables 8.11 and 8.12, we determine the total cost for the major materials used and the labor required to conduct the footing and wall construction. This project requires the use of plywood forms as shown in Figure 8.7. The forms are anticipated to be used twice, but dowel supports for the footings are anticipated to be used only once. The wall forms require the use of snap ties and flat washers with plastic cones. The footing forms require 19 mm diameter nail stakes.

Step 1. Perform the quantity take off for structural concrete forms and accessories. Details for the quantity take off are presented in Figure 8.8. A waste factor of 8% is employed for each item. According to Figure 8.8, the total estimated quantity for major concrete forms and accessories is as follows.

Footing Forms = 17.5 m^2CA.
Dowel Supports = 32.8 m.
Nail Stakes = 69 Ea.
Liners = 173.7 m^2CA.
Wall Forms = 173.7 m^2CA.
Snap Ties = 4.1 hundreds.

Step 2. According to Table 8.11 and Figure 8.8, the total cost of the major materials used and labor for constructing the concrete forms is calculated as shown in Figure 8.9. The total estimated cost for the forms and accessories is $16,811.

8.4 CONCRETE REINFORCEMENT

The previous section addressed cost estimating for concrete reinforcement. This section presents topics related to concrete reinforcement, including types of the

TABLE 8.11 Costs of Labor and Material for Structural Cast-in-Place Forms Concrete (USA $)

Code 03110	Structural C.I.P. forms	Crew	Daily output	labor (hrs)	Unit	Mat.	Labor	Equip.	Total	Total[a]
430-0050	Forms in place, footings, continuous wall, plywood, 2 use	C-1	40.88	0.783	m2CA	12.8	21		33.8	47
430-0500	Dowel supports for footings or beams, 1 use	C-1	152	0.211	m	2.92	5.6		8.52	12.05
455-2450	Forms in place, walls, job-built plywood wall forms, over 2400 to 4800 mm high, 2 use	C-2	32.05	1.498	m2CA	12.6	41		53.6	79
455-5820	Liners for forms (add to wall forms), aged wood, 100 mm wide, 2 use	1 Carp	37.16	0.215	m2CA	29	6.05		35.05	41.5

[a]Including O&P.
Source: Means, 1999.

TABLE 8.12 Cost of Material for Concrete Accessories Concrete

Code 03150	Concrete accessories	Crew	Daily output	Labor (hrs)	Unit	Mat.	Labor	Equip.	Total	Total[a]
640-0600	Accessories, snap ties, flat washer, 1400 kg, with plastic cone, 275 & 300 mm				h	85.5			85.5	94
850-4050	Nail stakes, 19 mm diameter, 600 mm long				Ea	2.75			2.75	3.03

[a]Including O&P.
Source: Means, 1999.

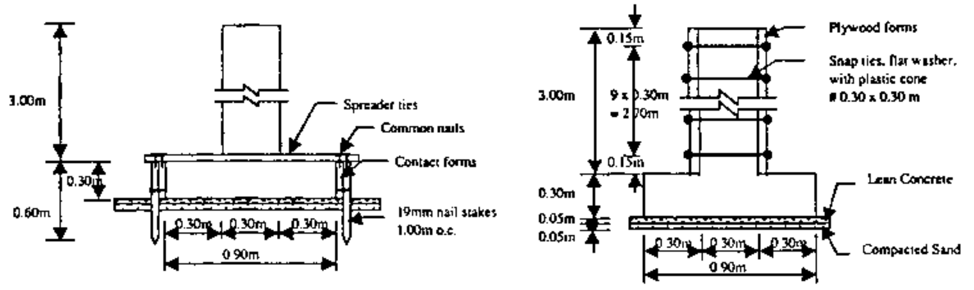

FIGURE 8.7 Plywood forms for continuous footing and wall.

reinforcement and its major characteristics, quantity take off, and pricing. Finally, an example of cost estimation is presented.

8.4.1 Types of Concrete Reinforcement

There are three major types of concrete reinforcement on the market today, each with different advantages based on usage. These are reinforcing bars, welded-wire fabric, and a combination of the two. The first type of concrete reinforcement is reinforcing bars, also called rebar or steel bars. They can be coated or uncoated. Rebar is available in various sizes and shapes as shown in Tables 8.13 and 8.14. In the US some reinforcing manufacturers, warehouses, and construction companies employ English units. Since the US government supports the metric unit, a soft English–metric conversion was developed and bar sizes in metric units in soft English–metric conversion were determined based on existing bar sizes in English units. Table 8.13 presents bar sizes in soft English–metric conversion. However, Table 8.14 presents bar sizes in pure metric units; thus no conversion is required. In Table 8.13, the #10 (in metric size) is available in a smooth finish; the rest are furnished in irregular shapes. Other sizes are available for special orders. Reinforcing bars are purchased on the market in 6 meter lengths and cut or bent at the jobsite. On the other hand, for big projects bars can be ordered from mills or main warehouses where they are completely cut, bundled, and tied. This method offers less waste and probably less cost, however, it takes more time.

The second type of concrete reinforcement is welded-wire fabric (WWF), also called welded-wire mesh, welded-steel fabric, or welded-steel mesh. WWF is primarily used with on-grade concrete slabs and is furnished in flat sheets or rolls depending on sizes, spacing, and required quantities. The typical WWF roll is 1.5 m wide by 45 m long. Compared to bars, WWF is cheaper and easier to install because of less weight. The third type of concrete reinforcement is a combination of the reinforcing bars and WWF. Sometimes a combination of rebar

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Quantity Take Off

Date 01 / 01 / 2000 Sheet No. 1/2

Project Title: Building A0001 Project No.: A0001

Take Off By: Peter Approved By: Brian

Code*	Description	No.	Dimensions L	Dimensions W	Dimensions D	Unit	Area	Unit		Unit		Unit	
	Forms in place for Footings												
	N&S exterior	2	8.5	0.3		m²CA	5.2						
	interior	2	6.8	0.3		m²CA	4.1						
	E&W exterior	2	6.6	0.3		m²CA	4.0						
	interior	2	4.8	0.3		m²CA	2.9						
	∴ Total footing forms					m²CA	16.2	× 1.08 =		17.5 m²CA			
	Dowel supports for Footings												
	N&S	2	8.6			m	17.2						
	E&W	2	6.6			m	13.2						
	∴ Total dowel supports					m	30.4	× 1.08 =		32.8 m			
	Nail stakes, 19 mm, 600 mm long												
	N&S (8.6 m × 1.0 m o.c. × 2 sides)	2	18.0			Ea	36.0						
	E&W (6.6 m × 1.0 m o.c. × 2 sides)	2	14.0			Ea	28.0						
	∴ Total nail stakes					Ea	64.0	× 1.08 =		69.1 Ea			

* Masterformat, Uniformat, WBS, other, etc.

FIGURE 8.8(a) Quantity take off for concrete forms and accessories.

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Quantity Take Off

Date 01/01/2000 Sheet No. Of 2

Project Title Building A0001 Project No. A0001

Take Off By Peter Approved By Brian

Code*	Description	No.	Dimensions L	Dimensions W	Dimensions D	Unit	Area		Unit		Unit		Unit
	Forms in place for walls												
	N&S exterior	2	8.0	3.0		m²CA	48.0						
	interior	2	7.4	3.0		m²CA	44.4						
	E&W exterior	2	6.0	3.0		m²CA	36.0						
	interior	2	5.4	3.0		m²CA	32.4						
	∴ Total wall forms					m²CA	160.8	× 1.08	=	173.7 m²CA			
	Liners for forms (add to wall forms)												
	areas as wall forms					m²CA	160.8	× 1.08	=	173.7 m²CA			
	Snap ties with plastic cone, 300mm												
	N&S (9 Ea × 4.4 m long/0.3 m O.C.)	1				h	2.2						
	E&W (9 Ea × 5.4 m long/0.3 m O.C.)	1				h	1.6						
	∴ Total snap ties					h	3.8	× 1.08	=	4.1 h			

* Masterformat, Uniformat, WBS, other, etc.

FIGURE 8.8(b) Quantity take off for concrete forms and accessories.

Company Logo

Pricing

Date 01/01/2000 Sheet No. 1 of 1

Project Title: Building A0001 Project No.: A0001

Take Off By: Peter Approved By: Brian

Code*	Description	Quantity	Unit	Material U.P.	Material Total	Labor U.P.	Labor Total	Equipment U.P.	Equipment Total	Subcontract U.P.	Subcontract Total	Total U.P.	Total
03110-430-0050	Forms in place, footings, plywood, 2 use	17.5	m² CA	12.80	224	21.0	368						592
03110-430-1500	Dowel supports for footings, 1 use	32.3	m	2.93	96	5.69	184						280
03150-850-4050	Nail stakes, 19 mm, 600 mm long	69.7	Ea	2.75	190								190
03110-455-2450	Forms in place, walls, plywood, 2 use	173.7	m² CA	12.64	2,189	41.0	7,122						9,311
03110-455-5820	Liners for forms, walls, 100 mm wide, 2 use	173.7	m² CA	29.0	5,034	6.05	1,051						6,088
03150-640-0600	Snap ties, flat washers, w/plastic cone, 300 mm, 1400 kg	4.7	h	85.54	350								350
	SHEET TOTAL			MATERIAL	8086	LABOR	8775	EQUIPMENT		SUBCONTRACT		TOTAL	16,811

* Masterformat, Uniformat, WBS, other, etc.

FIGURE 8.9 Pricing for concrete forms and accessories.

TABLE 8.13 ASTM Standard Metric Reinforcing Bars

Bars size[b]		Nominal dimensions[a]			
			Cross-sectional area		
Metric	[English]	Diameter mm [in.]	mm²	[in.²]	Weight kg/m [lbs/ft]
#10	[#3]	9.5	71	[0.11]	0.560
#13	[#4]	12.5	129	[0.20]	0.994
#16	[#5]	15.9	199	[0.31]	1.552
#19	[#6]	19.1	284	[0.44]	2.235
#22	[#7]	22.2	387	[0.60]	3.042
#25	[#8]	25.4	510	[0.79]	3.973
#29	[#9]	28.7	645	[1.00]	5.060
#32	[#10]	32.3	819	[1.27]	6.404
#36	[#11]	35.8	1006	[1.56]	7.907
#43	[#14]	43.0	1452	[2.25]	11.38
#57	[#18]	57.3	2581	[4.00]	20.27

[a]Equivalent inch-pound bar sizes are shown in brackets.
[b]Equivalent nominal dimensions of inch-pound bars are shown in brackets.

TABLE 8.14 Metric Rebar Specification—ASTM A615M

Grade 300 (300 MPa[a] = 43,560 psi; +8.7% vs. Grade 40)
Grade 400 (400 MPa[a] = 58,000 psi; −3.4% vs. Grade 60)

Bar no.	Diameter	Area	Equivalent (in.²)	Comparison with US customary bars
10M	11.3	100	0.16	Between #3 & #4
15M	16	200	0.31	#5 (.31 in.²)
20M	19.5	300	0.47	#6 (.44 in.²)
25M	25.2	500	0.78	#8 (.79 in.²)
30M	29.9	700	1.09	#9 (1.00 in.²)
35M	35.7	1000	1.55	#11 (1.56 in.²)
45M	43.7	1500	2.33	#14 (2.25 in.²)
55M	56.4	2500	3.88	#18 (4.00 in.²)

[a]MPa = megapascals.

and WWF may serve best for specific areas. However, an estimator needs to be aware of lapping and waste for quantity take off.

8.4.2 Concrete Reinforcement Characteristics

To conduct quantify take off and pricing for concrete reinforcement, an estimator should know some important characteristics of concrete reinforcement, including specifications and tensile strength. There are four major specifications for concrete reinforcement: ASTM A615M (grade 40 or 60 steel), ASTM A616M (rail steel), ASTM A617M (axle steel), and ASTM A706M (low-alloy steel). In building construction, ASTM A615 for grade 40 or 60 steels is extensively used. Tensile strength refers to how much stress the rebar can resist per one unit area of the bar before breaking. A unit of tensile strength is kg/cm^2. The maximum tensile strength for grade 40 rebar is approximately 2770 kg/cm^2.

8.4.3 Quantity Take Off and Pricing for Concrete Reinforcement

Concrete reinforcement work today is normally a subcontracted operation. A subcontractor prefabricates and delivers the concrete reinforcement to the jobsite. Therefore, costs of concrete reinforcement work can be obtained from the subcontractor. However, an estimator can perform a quantity take off without obtaining cost information from the subcontractor. To conduct the take off, reinforcing bars are normally taken off by lengths (m) and then priced by weight (ton). An estimator needs to include the numbers of bars, including their sizes and lengths. Costs for the waste when splicing or lapping the bars may range from 5 to 15%. Waste may be less than 1% when the bars are precut and formed at mills or warehouses. In general, however, waste is approximately 10% when the bars are cut and bent at a jobsite, especially for slabs and footings on grade. Unlike bars, WWF is usually purchased in units of square meters (m^2). To conduct a quantity take off, an estimator needs to identify the numbers of WWF in length and lapping. The lapping of one square must be included.

Along with waste, the estimator needs to consider concrete reinforcement supports, embedded items, and rust prevention requirements. In the construction process, concrete reinforcement is installed at a certain level in forms prior to placing concrete. This can be accomplished by using supports such as concrete bricks, bar chairs, spacers, bolsters, or wires. These supports may be produced from plastic, galvanized steel, or zinc-coated steel. Embedded items basically include anchor bolts, framing hold-downs, anchor straps, and any other items placed in the concrete. These items are mostly furnished and installed by other trades, but sometimes they can be installed by the concrete contractor, thereby incurring additional labor cost. Finally, rust prevention may be required by the specifications, thus contributing additional costs.

8.4.4 Computation Example for Concrete Reinforcement

Referring to Figure 8.2, we perform cost estimating for concrete reinforcement. Following Table 8.15, we determine the total cost of the major materials and labor required to conduct the footing and wall construction. This project requires the use of reinforcement A615M, grade 400. In addition, dowels #15M with the length of 60 cm are required for every 0.50 m of the footing.

Step 1. Perform the quantity take off for concrete reinforcement. Details for this quantity take off are presented in Figure 8.10. A waste factor of 10% is employed. In Figure 8.10, the total estimated quantity for concrete reinforcement is presented as follows.

Reinforcing for footings = 1.3 Met. Ton.
Reinforcing for walls = 5.9 Met. Ton.
Dowels = 62 Ea.

Step 2. According to Table 8.15 and Figure 8.10, the total cost of materials and labor for concrete reinforcement is calculated and shown in Figure 8.11. The total estimated cost for concrete reinforcement is $7196.

8.5 CAST-IN-PLACE CONCRETE

Two major concrete work types were presented in the preceding sections, namely, concrete forms and concrete reinforcement. This section presents another major concrete work type: cast-in-place concrete. This concrete is usually supplied by either a batch plant located on the jobsite or a ready-mix concrete company. This section covers types of cast-in-place concrete, operations focusing on cast-in-place concrete, and quantity take off and pricing for cast-in-place concrete. Costs of labor, material, and equipment for cast-in-place concrete are also furnished.

8.5.1 Types of Concrete

Typically, there are two ways to classify concrete: by usage and weight. Based on usage, concrete is composed of two major classifications, structural and non-structural. Due to its high strength, structural concrete is installed for structural building components including footings and foundation walls, slabs on grade, columns, above-grade slabs, walls, and roof structures. Such an installation must strictly follow codes and regulations. Concrete inspections and testing for strength, quality, and its content are normally required. On the other hand, non-structural concrete is installed for building components that do not require high concrete strength. The components may include finishing areas, exterior window

TABLE 8.15 Costs of Labor and Material for Reinforcing

Code 03210	Reinforcing steel	Crew	Daily output	Labor (hrs)	Unit	Mat.	Labor	Equip.	Total	Total[a]
600-0010	Reinforcing in place A615M Grade 400									
600-0500	Footings, 10 to 25M	4Rodm	1.91	16.797	Met. Ton	585	530		1115	1550
600-0700	Walls, 10 to 25M	4Rodm	2.72	11.758	Met. Ton	585	370		955	1275
600-2420	Dowels, 600 mm long, deformed, 15M	2Rdmn	435	0.037	Ea	0.65	1.16		1.81	2.7

[a] Including 0&P.

Source: *Means*, 1999.

Company Logo

Quantity Take Off

Date 01 / 01 / 2000 Sheet No. Of 1

Project Title: Building A001 Project No.: A001

Take Off By: Peter Approved By: Brian

Code*	Description	No.	Dimensions L	W	D	Unit	Length	Unit		Unit		Unit
	Reinforcement for footings, #25m											
	N&S											
	6 for each (longitudinal)	12	8.0			m	96.0					
	8 m long/0.2m +1 = 41 for each	82	0.9			m	73.8					
	E&W											
	6 for each (longitudinal)	12	6.0			m	72.0					
	6 m long/0.2m+1 = 31 for each	62	0.9			m	55.8					
	∴ Total #25m for footings					m	297.6	× 1.10	=	327.4 m × 3.973 kg/m		
	Reinforcement for walls, #25m								=	1.3 tons		
	N&S											
	(3.2m long/0.3m +1)×2 sides for each	47	8.0			m	376.0					
	(8.0m long/0.3m+1)×2 sides for each	111	3.6			m	399.6					
	E&W											
	(3.2m long/0.3m+1)×2 sides for each	47	6.0			m	282.0					
	(6.0m long/0.3m+1)×2 sides for each	84	3.6			m	302.4					
	∴ Total #25m for walls					m	1360.0	× 1.10	=	1496.0 m × 3.973 kg/m		
	Dowels, 600mm long, #15M								=	5.9 tons		
	N&S											
	7.6m long/0.5m+1 = 16 for each	32				Ea	32.0					
	E&W											
	5.4m long/0.5m+1 = 12 for each	24				Ea	24.0					
	∴ Total #15m dowels					Ea	56.0	× 1.10	=	62 Ea.		

* Masterformat, Uniformat, WBS, other, etc.

FIGURE 8.10 Quantity take off for concrete reinforcement.

Company Logo	Pricing	Date 01 / 01 / 2000	Sheet No. 1

Project Title: Building A0001 — Project No.: A0001

Take Off By: Peter — Approved By: Brian

Code*	Description	Quantity	Unit	Material U.P.	Material Total	Labor U.P.	Labor Total	Equipment U.P.	Equipment Total	Subcontract U.P.	Subcontract Total	Total U.P.	Total
03210-600-0500	Reinforcing in place, footings, #15 M A 615 M, Grade 400	1.3	Met. ton	585	760	530	689						1,449
03210-600-0700	Reinforcing in place, walls, #25 M A 615 M, Grade 400	5.9	Met. ton	585	3452	370	2183						5,635
03210-600-2420	Dowels, 600 mm long, deformed, #15 M	62	Ea.	0.65	40	1.16	72						112
	SHEET TOTAL				4252		2944						7196
					MATERIAL		LABOR		EQUIPMENT		SUBCONTRACT		TOTAL

* Masterformat, Uniformat, WBS, other, etc.

FIGURE 8.11 Pricing for concrete reinforcement.

TABLE 8.16 Weight per Volume of Different Concrete Types[a]

Types of Concrete	Weight/volume (Kg/m^3)
Insulating lightweight	315–1110
Structural lightweight	1820
Semi-lightweight	1820–2060
Normal weight	2400
Heavy weight	2850–4590

[a]Estimated numbers suitable for estimating, not design, purposes.

and door decorations, lightweight slabs, stairwells, and special design components. Nonstructural concrete is normally lightweight.

Based on weight, concrete is classified by weight per volume. Table 8.16 provides the weights of different types of concrete. Different concrete types also mean different concrete strengths. The cost of concrete is priced by concrete strength. An estimator, therefore, needs to know not only the types of concrete but also the minimum compressive strengths for different types of buildings. Compressive strength represents how much weight or impact concrete can resist before cracking or breaking. Minimum compressive strengths for different types of building construction are provided in Table 8.17.

8.5.2 Concrete Operations

Section 8.2.2 presented the major operation for cast-in-place concrete work. This section presents five major concrete operations focusing only on concrete material, namely, concrete fabrication, transportation, placement, finish, and curing. The first operation is concrete fabrication. For this operation, concrete is normally supplied by either the onsite batching and mixing plant or an offsite concrete supplier such as a ready-mix concrete company. A contractor may have batching and mixing operations onsite if a project is relatively small, requires a limited amount of concrete, or there is difficulty in concrete transportation. On the other

TABLE 8.17 Minimum Compressive Strength of Different Types of Buildings[a]

Types of buildings	Minimum compressive strength (MPa)
Residential	14
Light commercial	17–21
Major commercial, high-rise, or industrial	24–69

[a]Estimated numbers suitable for estimating, not design, purposes.

hand, a contractor can order ready-mix concrete to speed up the operations or to ensure concrete quality.

The second operation is concrete transportation. If concrete is mixed at the jobsite, labor, equipment, and tools (such as a chute, wheelbarrow, buggy, or conveyer belt) are needed to perform the work. Costs associated with these will need to be taken into account. If ready-mix concrete is required, the ready-mix concrete supplier normally transports the concrete to the jobsite by a truck. Transporting equipment was previously presented. In general, concrete costs will include only the transportation costs incurred for a certain distance between the jobsite and the plant. An additional cost for the truck waiting at the jobsite may be added if the truck is there longer than the agreement period. A contractor may contact the supplier for more details of the concrete cost.

The third operation is concrete placement. Equipment and labor are extensively required to place the concrete. Equipment such as a concrete pump or crane is needed to convey concrete to the forms. Since there are many ways to place the concrete, an estimator needs to consider available labor and equipment in addition to any physical restrictions of a jobsite such as site access and site layout. Details of the placing methods were presented earlier in this chapter.

The fourth operation is concrete finish. As mentioned earlier, the concrete finish is applied after concrete placement. Costs of concrete finishes vary with structural components and project specifications. Sometimes the costs of concrete finishes are incorporated into the cost of concrete placement.

The fifth operation is concrete curing. Concrete cure is a significant process since it prevents concrete cracks and gives concrete higher strength due to a slower setting process. To slow the setting process and to seal moisture in, concrete is normally covered with a wet burlap blanket or polyethylene sheets, chemical curing compounds, or given direct water application in hot weather. To prevent concrete freezing before the setting process completes, concrete is covered by straw or other insulating material, or supplied a heat source in cold weather. Therefore, in cost estimating, an estimator needs to consider the method of curing, requirements of material and labor, and the time frame.

8.5.3 Quantity Take Off and Pricing for Cast-in-Place Concrete

The cost of cast-in-place concrete is significantly high in concrete building construction due to use of extensive labor, equipment, and materials. In addition, it is subject to variations due to such factors as construction methods and physical restrictions of a jobsite. For example, in concrete placement, the cost of the conveyer method is normally cheaper than the cost of the crane and bucket method. In general, to perform cost estimating, concrete quantity is normally taken off by volume in units of cubic meters (m^3). For cure, finish, and protection work, concrete surfaces are taken off in square meters (m^2). The costs of concrete fabrication, transportation, placement, finish, cure, and protection in terms of labor, material, and equipment must be carefully identified. To perform concrete cost estimating, the estimator also needs to pay attention to special requirements such as the water–cement ratio, concrete strength, concrete additives, cement types, sizes of aggregate, placement methods, curing methods, and finishing methods. Special considerations such as concrete quantity, waste factor, and delivery time, as well as weather conditions are also required. As a rule of thumb, a waste factor of 5 to 15% is applied.

8.5.4 Computation Example for Cast-in-Place Concrete

Referring to Figure 8.2, we perform cost estimating for cast-in-place concrete. Following Tables 8.18 through 8.20, we determine the total cost of major labor needs, material, and equipment required to perform footing and wall construction. This project requires the use of 21 MPa ready-mix concrete. A crane and bucket system is furnished to perform the placing work. Spray membrane curing compound is employed to cure the concrete. The interior wall requires a sandblast finish with a light penetration.

Step 1. We perform the quantity take off for cast-in-place concrete. Details for the quantity take off are presented in Figure 8.12. A waste factor of 10% is employed. Following Figure 8.12, the total estimated quantity for cast-in-place concrete is presented as follows.

Placing concrete and vibrating for footings = 8.0 m^3.
Placing concrete and vibrating for walls = 26.6 m^3.
Concrete ready mix = 34.6 m^3.
Sandblast = 84.5 m^2.
Curing, sprayed membrane curing compound = 212.3 m^2.

Step 2. Using Tables 8.18 through 8.20 and Figure 8.12, the total cost of our sample cast-in-place concrete is presented in Figure 8.13 as $5032.

8.6 PRECAST CONCRETE

Precast concrete is formed, placed, and cured in separate forms elsewhere, and then set into a specified location after gaining enough strength. Precast concrete can be made in a concrete manufacturing plant or at a job precasting yard. Precast concrete is popular because it provides a faster construction method. However, certain skills in placing and storing precast concrete are required. In addition, an order to the manufacturer and a delivery schedule must be made in advance. In

Table 8.18 Costs of Labor, Material, and Equipment for Structural Concrete (USA $)

Code 03310	Structural concrete	Crew	Daily output	Labor (hrs)	Unit	Mat.	Labor	Equip.	Total	Total[a]
220-0150	Concrete, ready mix, regular weight, 21 MPa				m^3	82.5			82.5	90.5
700-2000	Placing concrete and vibrating, including labor, equipment, continuous footings, shallow, with crane and bucket	C-7	68.81	1.046	m^3		25	13.25	38.25	53.5
700-5200	Placing concrete and vibrating, including labor, equipment, walls, 300 mm thick, with crane and bucket	C-7	68.81	1.046	m^3		25	13.25	38.25	53.5

[a]Including O&P.
Source: Means, 1999.

Table 8.19 Costs of Labor and Material for Concrete Finishing (USA $)

Code 03350	Concrete finishing	Crew	Daily output	Labor (hrs)	Unit	Mat.	Labor	Equip.	Total	Total[a]
350-0700	Sandblast, light penetration	1 Cefi C-10	102	0.235	m2	2.15	6		8.15	11.4

[a]Including O&P.
Source: Means, 1999.

this section, types of precast concrete, prestressed concrete, and a checklist for the precast concrete are presented. The section also addresses quantity take off and pricing for precast concrete work.

8.6.1 Types of Precast Concrete

There are many ways to classify precast concrete. Like regular concrete, precast concrete can be classified into structural or nonstructural concrete. Structural precast concrete is typically made from normal weight concrete. Examples of structural precast concrete are single or double tees, floor and roof hollow-core slabs, columns, beams, wall panels, and so on. Nonstructural precast concrete is lightweight and usually used for decorative building components.

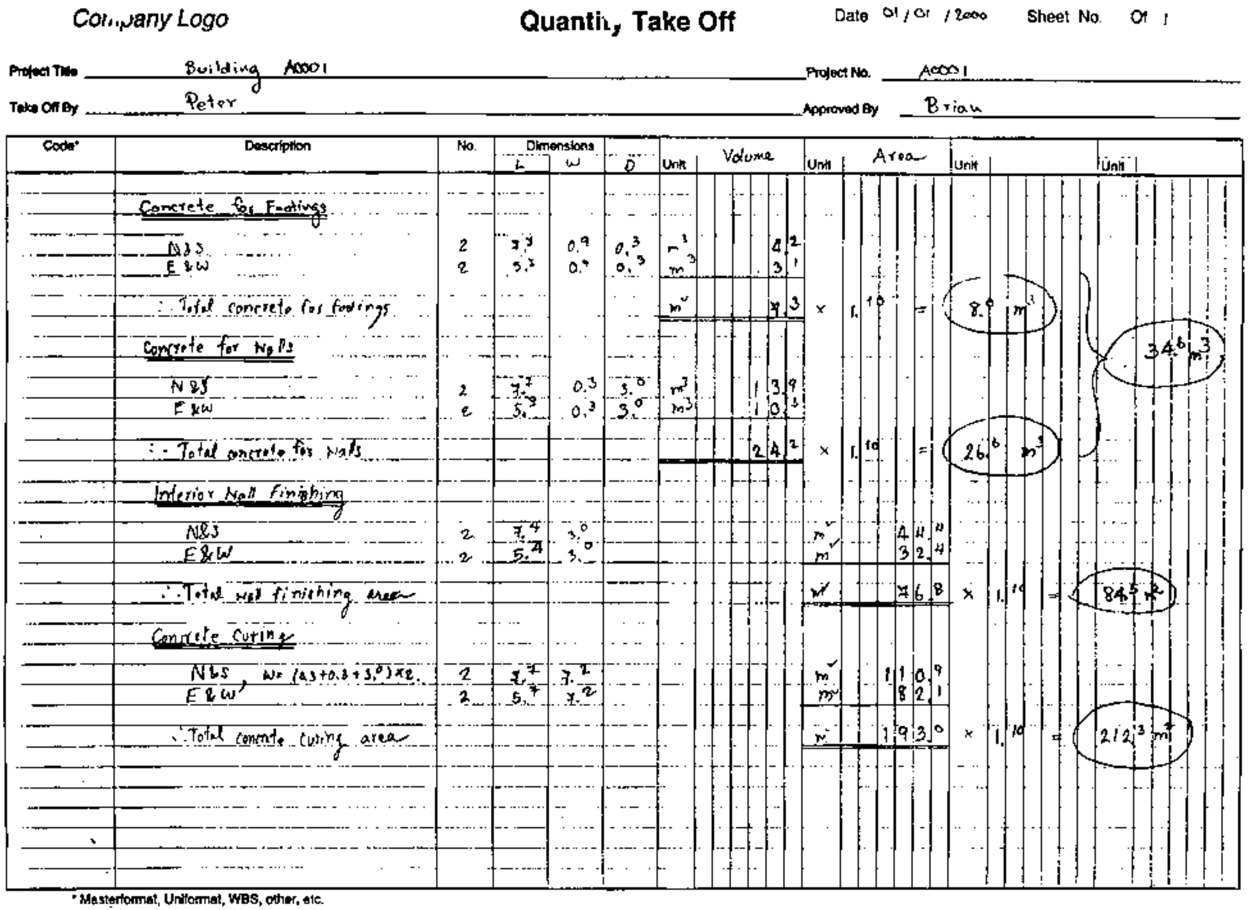
Another common way to categorize precast concrete is based on its type of reinforcement and is categorized into reinforced or prestressed concrete. Reinforced precast concrete basically consists of regular reinforcing bars, whereas prestressed concrete is composed of high-strength cables called strands. Prestressed concrete is presented in detail in the next section. Typical prestressed concrete products are shown in Figure 8.14.

Another way to classify precast concrete is based on its types of structural members of which there are four major types, namely, slabs, joists, beams and columns, and tilt-up panels. The first precast concrete type includes precast slabs

Table 8.20 Costs of Labor and Material for Concrete Curing (USA $)

Code 03390	Concrete Curing	Crew	Daily output	Labor (hrs)	Unit	Mat.	Labor	Equip.	Total	Total[a]
200-0300	Curing, sprayed membrane curing compound	2 Clab	833	0.018	m2	0.38	0.4		0.78	1.05

[a]Including O&P.
Source: Means, 1999.


Company Logo

Quantity Take Off

Date 01/01/2000 Sheet No. 01 1

Project Title: Building A0001 Project No.: A0001

Take Off By: Peter Approved By: Brian

Code*	Description	No.	L	W	D	Unit	Volume	Unit	Area			Unit		Unit	
	Concrete for Footings														
	N&S	2	7.3	0.9	0.3	m3	4.2								
	E&W	2	5.3	0.9	0.3	m3	3.1								
	∴ Total concrete for footings					m3	7.3	×	1.10	=	8.0 m3		34.6 m3		
	Concrete for walls														
	N&S	2	7.7	0.3	3.0	m3	13.9								
	E&W	2	5.9	0.3	3.0	m3	10.3								
	∴ Total concrete for walls						24.2	×	1.10	=	26.6 m3				
	Interior Wall finishing														
	N&S	2	7.4	3.0				m2	44.4						
	E&W	2	5.4	3.0				m2	32.4						
	∴ Total wall finishing area							m2	76.8	×	1.10	=	84.5 m2		
	Concrete Curing														
	N&S, W=(4.3+0.3+3.0)×2	2	7.7	7.2				m2	110.9						
	E&W	2	5.7	7.2				m2	82.1						
	∴ Total concrete curing area							m2	193.0	×	1.10	=	212.3 m2		

* Masterformat, Uniformat, WBS, other, etc.

FIGURE 8.12 Quantity take off for cast-in-place concrete.

Company Logo

Pricing

Date 01 / 01 / 2000 Sheet No. 01 of 1

Project Title: Building A0001 Project No.: A0001

Take Off By: Peter Approved By: Brian

Code*	Description	Quantity	Unit	Material U.P.	Material Total	Labor U.P.	Labor Total	Equipment U.P.	Equipment Total	Subcontract U.P.	Subcontract Total	Total U.P.	Total
03310-220-0150	Concrete ready mix, regular weight, 21 MPa	34.6	m3	82.50	2,854								2,854
03310-700-2210	Placing concrete and vibrating, including equipment & labor, shallow continuous footings, with crane and bucket	8.0	m3			25.0	200	13.25	106				306
03310-700-5200	Placing concrete and vibrating, including equipment & labor, walls, 200 mm thick, with crane and bucket	26.6	m3			25.0	665	13.25	352				1,017
03350-350-0100	Sandblast, light penetration	84.5	m2	2.15	182	6	507						689
03390-200-0200	Curing, sprayed membrane curing compound	212.9	m2	0.38	81	0.40	85						166
	SHEET TOTAL				3117		1457		458				5032
					MATERIAL		LABOR		EQUIPMENT		SUBCONTRACT		TOTAL

* Masterformat, Uniformat, WBS, other, etc.

FIGURE 8.13 Pricing for cast-in-place concrete.

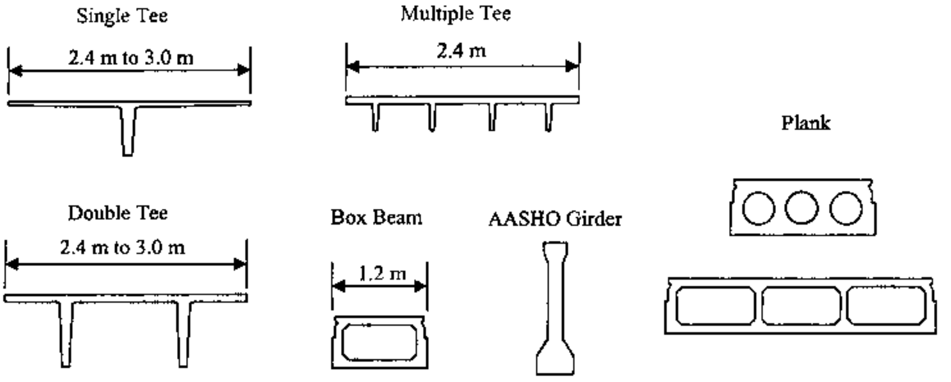


FIGURE 8.14 Typical precast concrete products.

for floors, roofs, and walls. These are commonly available in normal weight and lightweight concrete, regular or high-strength concrete. In general, precast slabs are available in various forms including hollow-core, solid, and channel. Hollow-core slabs with strands (high-tensile strong cables) are normally used for floors and roofs spanning 4 to 13 m. In building construction, the thickness of hollow-core slabs ranges from 10 to 31 cm. There are various widths of hollow-core slabs but the common ones are 88.0 and 105.6 cm. The lightweight solid and channel slabs may be cut, nailed, drilled, or sawed. Side edges of these slabs are generally tongued and grooved. They are often put in place with special fasteners, such as a clip. The maximum span for the solid and channel slabs is approximately 3 m. For longer spans and heavier loads, most precast slabs are used with reinforcing bars or WWF to increase the strength of the slabs. Slabs are generally transported by a truck from the concrete manufacturing plant. Once at the jobsite, they are hoisted by a crane to the floor location, then erected directly into the designated position. Slabs need to be aligned, leveled, and their sides filled with grout. Joints underneath are normally caulked after the building has been enclosed. A concrete topping with 5 cm depth is sometimes applied on top of the slabs.

The second precast concrete type is joists. Precast joists are typically employed to support floor or roof slabs spanning up to 7.3 m. They are normally available in I-shaped sections in various sizes. The depth of the joists can range from 15 to 30 cm. Joists can be produced at the jobsite, or at the concrete manufacturing plant and then delivered to the jobsite. To construct cast-in-place concrete slabs, some sort of form and wood sleepers are normally required. Wood sleepers are employed to brace the joists. Wood forms or plywood are set on top of the joist and/or the sleepers. The cost of precast concrete joists is based on the size of the amount of reinforcing steel required and the size and locality of the job. Additional cost must be included, especially if extra reinforcing bars are required.

The third precast concrete type is beams and columns. Precast concrete beams and columns are normally formed, placed, and cured at the concrete manufacturing plant and then delivered to the jobsite. At the jobsite, beams and columns are hoisted by a crane and set into the proper position. In general, beams and columns are available in square, rectangular, box-shaped, T-shaped, and I-shaped sections. They can be made from reinforced or prestressed concrete. Sizes and spans or lengths generally depend on engineering requirements.

The fourth precast concrete type is the tilt-up wall panel. These can be produced at the jobsite. All embedded items are installed prior to the concrete placement. When the panels are set into the designated position, they are normally braced by temporary adjustable steel braces until the main roof or slab structure is fastened. Caulking and sealing is performed last. Generally, the construction of precast tilt-up wall panels has advantages not only in speeding up the construction period, but also in reducing project costs by reducing forms and accessories. However, this construction also has some disadvantages regarding the control of quality and safety, and the storage of the panels and panel beds. In addition, changes in design and approvals from the owner and architects/engineers would also be required. These disadvantages may contribute to project delay.

8.6.2 Prestressed Concrete

Prestressed concrete is concrete that has compressive stresses contributed by tensile forces in the internal high strength strands. Prestressed concrete is normally used in various forms, including single and double tees, channel section, I joists, T joists, hollow-core slabs, and solid flat slabs. Costs of these concrete products vary based on size, section, delivery distance, and purchase locality. Generally, there are two fundamental methods of retraining the strands: pretensioning and posttensionning. Pretensioning is the process of applying tensile forces into the strands before casting the concrete. On the other hand, posttensionning is the process of applying tensile forces into the strands after casting the concrete. For large structural members, strands are tensioned at the jobsite. After reaching the desired forces, strands are secured with end-bearing devices.

8.6.3 Quantity Take Off and Pricing for Precast Concrete

Most precast concrete quantity is normally taken off by area (m^2) and length (m). Costs of precast concrete products may be quoted by a manufacturer on a

TABLE 8.21 Checklist for Precast Concrete

Materials & requirements	Sp[a]	Sub[b]
1. Walls		
2. Floors		
3. Ceilings		
4. Beams		
5. Girders		
6. Joists		
7. Lintels		
8. Bearing		
9. Inserts		
10. Finishes		
11. Accessories		
12. Strength requirements		
13. Attachment requirements		
14. Special requirements		
15. Color and shapes		
16.		
17.		
18.		
19.		
20.		

[a] SP = Self-performed items.
[b] Sub = Subcontracted items.

delivery-only basis or on a delivery-and-installation basis. Grouting and caulking costs may already be included in the basic installation cost. Costs of the products generally vary according to size, section, span, delivery distance, and purchase locality. The availability of specific types and sizes of required products should be checked in advance. The estimator usually needs to check drawings and specifications for how precast members will be fastened in place and for special anchorage details, inserts, and other accessories. Mechanical and electrical requirements should also be checked by the estimator. A bracing system and 5 cm concrete topping may also be required. For small construction projects, estimating precast concrete may not require a waste factor. However, for bigger projects, a waste factor of 5 to 10% should be added for errors and omissions. Table 8.21 presents a checklist for precast concrete work. Additional precast concrete items can be added into the table for convenience.

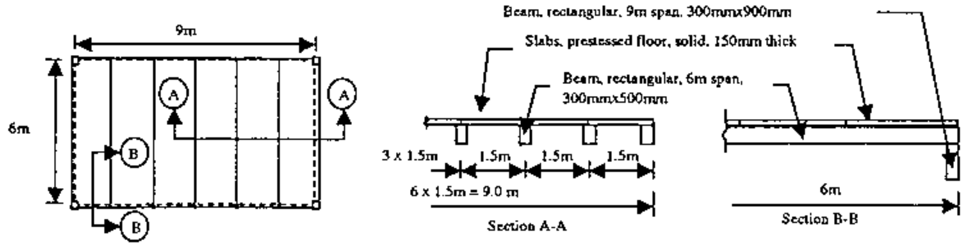


FIGURE 8.15 Concrete floor plan and sections.

8.6.4 Computation Example for Precast Concrete

Referring to Figure 8.15, we perform cost estimating for precast concrete work. Using Table 8.22, we determine the total cost of labor, material, and equipment required to conduct a floor slab construction. This project requires the use of a solid prestressed concrete slab with a thickness of 150 mm. Rectangular beams are required to support the floor slab. Costs of the products are provided in Table 8.22. For illustration purpose, product costs include the costs of transportation, grouting, and caulking. A concrete topping and bracing system are not required in this particular project.

Step 1. We perform the quantity take off for precast concrete. Details for quantity take off are presented in Figure 8.16. The total estimated quantity for precast concrete is presented as follows.

Beam, rectangular, 300 mm × 500 mm = 6 Ea.
Beam, rectangular, 300 mm × 900 mm = 2 Ea.
Slabs, prestressed floor, 150 mm = 54 m^2.

Step 2. Using Table 8.22 and Figure 8.15, the total cost of precast concrete is shown in Figure 8.17 as $14,010.

8.7 CEMENTITIOUS DECKS AND UNDERLAYMENT

Cementitious decks are normally lightweight and nonflammable concrete or gypsum. They are employed for roofs and floors mostly in steel framing construction. The use of cementitious decks is widespread because it increases the rigidity of the building structure. Cost of the decks varies with the size and type of the structure, availability of materials, material delivery cost, and labor cost. In gen-

TABLE 8.22 Costs of Labor, Materials, and Equipment for Precast Concrete (USA $)

Code 03410	Precast concrete	Crew	Daily output	Labor (hrs)	Unit	Mat.	Labor	Equip.	Total	Total[a]
100-1200	Beam, rectangular, 6 m span, 300 mm × 500 mm	C-11	32	2.25	Ea.	925	69.5	49	1043.5	1200
100-1400	Beam, rectangular, 9 m span, 300 mm ± 900 mm	C-11	24	3	Ea.	2175	93	65	2333	2600
620-0050	Slabs, prestressed roof/floor, solid, grouted, 150 mm thick	C-11	418	0.172	m2	48	5.35	3.74	57.09	66.5

[a]Including O&P.
Source: *Means*, 1999.

Company Logo

Quanti.y Take Off

Date 01/01/2000 Sheet No Of 1

Project Title: Building A001 Project No.: A0001

Take Off By: Peter Approved By: Bylon

Code*	Description	No.	Dimensions L	W	D	Unit	Quantity	Unit	Unit	Unit
	Beam, rectangular, 6 m span, 300 mm × 500 mm	6	6			Ea	6			
	Beam, rectangular, 9 m span, 300 mm × 900 mm	2	9			Ea	2			
	Slabs, prestressed floor, solid, grouted, 150 mm thick	1	9	6		m²	54			

* Masterformat, Uniformat, WBS, other, etc.

FIGURE 8.16 Quantity take off for precast concrete.

Company Logo

Pricing

Date 01/01/2000 Sheet No. 1 Of 1

Project Title: Building A0001 Project No.: A0001

Take Off By: Peter Approved By: Brian

Code*	Description	Quantity	Unit	Material U.P.	Material Total	Labor U.P.	Labor Total	Equipment U.P.	Equipment Total	Subcontract U.P.	Subcontract Total	Total U.P.	Total
03410-100-1200	Beam, rectangular, 6 m span, 300 mm × 500 mm	6	Ea.	925	5,550	69.5	417	49	294				6,261
03410-100-1400	Beam, rectangular, 9 m span, 300 mm × 900 mm	2	Ea.	2175	4,350	93	186	65	130				4,666
03410-520-0050	Slabs, prestressed floor, solid, grouted 150 mm thick	54	m²	48	2,592	5.35	289	3.75	202				3,083
	SHEET TOTAL			MATERIAL	12,492	LABOR	892	EQUIPMENT	626	SUBCONTRACT		TOTAL	14,010

* Masterformat, Uniformat, WBS, other, etc.

FIGURE 8.17 Pricing for precast concrete.

eral, however, the total cost of cementitious construction is very economical because of the ease of design and the finished undersurface. Examples of items in cementitious decks and underlayment work include wood fiber, concrete channel slabs, concrete and wood plank, form board, and insulation.

8.8 REVIEW QUESTIONS

1. What are the take-off needs for concrete cost estimation?
2. What are the major crafts involved in concrete construction?
3. What are the take-off methods for concrete quantity take off?
4. What are the major operations for cast-in-place concrete work?
5. Why does an estimator need to understand construction methods and operations in order to perform a good estimation?
6. What are the major factors affecting the cost of concrete formwork?
7. What are the types of concrete reinforcing bars?
8. What are the reasons for high costs in cast-in-place concrete work?
9. What are the differences between precast concrete, reinforced precast concrete, prestressed concrete, pretensioned concrete, and posttensioned concrete?
10. What are the advantages and disadvantages of precast concrete in building construction?

9

Masonry

9.1 INTRODUCTION TO MASONRY

It is certain that being a good estimator requires knowledge and skills acquired through practice and experience. Particularly in masonry estimation, a good estimator needs to be well organized and a proficient information collector. The major reason is that masonry contains a variety of products, unit types, unit sizes, specifications, and properties. This variety causes a difference not only in masonry costs but also in masonry productivity. In this chapter the authors cover in detail all possible aspects of masonry cost estimation including masonry materials, crews, tools, equipment, and procedures in masonry cost estimation. The concepts furnished in this chapter will enable an estimator to successfully perform a masonry cost estimation. Means' *Building Construction Cost* (1999) is the primary source of cost information for this chapter.

9.1.1 Masonry Components

Masonry building elements, such as masonry walls, normally contain many components, namely, masonry units, mortar, grout, and accessory materials. Masonry units include clay masonry units, concrete masonry units, clay tiles, ceramic veneer, glass masonry units, adobe masonry units, masonry stones, and special nonconventional masonry units. The most common products are clay masonry units and concrete masonry units.

The next basic component of masonry is mortar. Mortar is used to bed masonry units and to bond individual units into a combined component. In other words, mortar separates masonry units and, at the same time, holds masonry units together. Mortar also provides an architecturally aesthetic appearance and allows size variations in masonry units. Further details of mortar types and usage are presented later in this chapter. A third masonry component called masonry grout is a fluid concrete with pea-gravel aggregate. It is used to fill some or all cells in hollow units or between wythes to increase wall strength. The last basic masonry component is accessory materials. This category includes reinforcement, connectors, sealants, flashing, coating, and vapor barriers.

9.1.2 Masonry Materials and Specifications

One important task of an estimator is to obtain the correct and updated cost data for materials and equipment. Generally, the cost of materials is approximately 20 to 40% of the total masonry work. To obtain the most up-to-date and accurate materials costs, an estimator can request a materials quotation and special discounts from a manufacturer or supplier. In most circumstances, a supplier provides a specified lump sum price for materials, including how to deliver, who will unload, damage responsibility, applicable taxes, delivery sequence, and samples. The supplier can also provide estimated quantities, and an estimator can use the obtained quantities to compare with his or her own estimate. Along with the masonry materials, masonry accessories must be included in the total masonry costs. For illustration purposes, tables containing cost information in this chapter were generated according to Means (1999), using national average costs for masonry.

To be able to precisely estimate masonry materials, an estimator needs to understand not only the materials cost but also materials quality specifications. Unlike the steel or concrete industries, no single segment of the masonry industry produces a finished masonry product. Due to the fact that a masonry product contains many components or materials, it is difficult to assign clear responsibility for the final masonry product. In the US masonry industry, the American Society for Testing and Materials (ASTM) has established specifications for masonry materials to ensure their quality. Examples of major masonry materials that comply with the ASTM specifications are listed in Table 9.1. Much information regarding masonry materials in this chapter is taken from the ASTM specifications.

9.1.3 Masonry Tools and Equipment

The total cost of masonry tools and equipment is approximately 10% of the total masonry work for a small job and 5% of the total masonry work for a bigger job. If more than a few hand tools are employed on a job, an estimator may include a contingency expense. The equipment and tools can be either rented or purchased. If the equipment and tools are rented, the estimated cost will be the rental expense as well as the cost of maintenance and supplies they consume, such as gas and oil. If the equipment and tools are purchased, the estimated cost will be an appropriate portion of its lifetime cost and the cost of maintenance and supplies.

It is challenging to estimate the appropriate portion of lifetime cost. It is likely that small tools may be disposable after the job completion, so there is no salvage value and they can be charged to the job for the value of the purchase price. Small tools include mortar hoes and boxes, buckets, extension cords, water hoses, and mortar boards. On the other hand, larger equipment may be reusable for future jobs, so it can be accounted for based on an appropriate portion of the lifetime cost during the job timeframe. Larger equipment consists of mortar mixers, forklifts, masonry saws, ladders, and wheelbarrows.

9.1.4 Masonry Construction Crafts

Masonry construction is labor-intensive work that results in a significant cost in labor, which comes to approximately 50 to 60% of the total masonry work. Labor cost varies primarily dependent upon crew size and labor productivity. In general, bricklayers and helpers or hod carriers are primary crews in masonry construction. Some jobs may require additional trades such as operating engineers, weld-

TABLE 9.1 ASTM Masonry Specification Standards

ASTM Specifications	Clay masonry units
C32	Sewer and manhole brick
C43	Structural clay products
C62	Building brick
C73	Calcium silicate face brick
C216	Facing brick
C410	Industrial floor brick
C652	Hollow brick
C896	Clay products
C902	Pedestrian and light traffic paving brick
	Clay tiles
C34	Clay load-bearing wall tile, structural
C56	Clay nonload-bearing tile, structural
C57	Clay floor tile, structural
C126	Facing tile, facing brick, and solid masonry units, ceramic glazed structural clay
C212	Structural clay facing tile
C530	Structural clay nonload-bearing screen tile
	Concrete masonry units
C55	Concrete building brick
C90	Hollow load-bearing concrete masonry units
C129	Hollow nonload-bearing concrete masonry units
C139	Concrete masonry units for construction of catch basins and manholes
C145	Solid load-bearing concrete masonry units
C279	Chemical-resistant masonry units
C744	Prefaced concrete and calcium silicate masonry units
C936	Solid concrete interlocking paving units
	Masonry mortar
C91	Masonry cement
C105	Ground fire clay or refractory mortar for laying up fireclay brickwork
C144	Aggregate for masonry mortar
C207	Hydrated lime for masonry purposes
C270	Mortar for unit masonry
C287	Chemical-resistant sulphur mortar
C476	Grout for reinforced and nonreinforced masonry
C1329	Masonry cement
	Other materials
C33	Concrete aggregates
C150	Portland cement
C331	Lightweight aggregates for concrete masonry units
C595	Blended hydraulic cements

ers, ironworkers, and carpenters. A medium-size job with good working conditions generally requires two bricklayers and one helper. If improper working conditions occur, more support personnel may be needed to carry out the tasks, resulting in an additional labor cost. Improper working conditions include difficult scaffolding conditions, hoisting problems, lack of working or storage space, or crowded areas. It is certain that most jobs are normally most efficient with small crews because working space is significantly important to masonry labor productivity.

Due to the fact that productivity varies based on many factors, it is difficult to predict actual productivity exactly. The best way to estimate productivity is to consider the productivity of the same crew on previous similar jobs. To begin collecting productivity data, it is wise to first examine normal masonry conditions, including common masonry units (modular bricks or modular CMU), a running bond, and type S mortar with no grout. An estimator may need to separate types of masonry components, such as single wythe-barrier wall, composite wall-filled collar joint, cavity wall-brick veneer over CMU backup, or cavity wall-brick veneer over steel studs. It is also clear that the weight of masonry units is important to masonry labor productivity; an estimator can make an educated guess about the productivity based on the weight of materials.

Table 9.2 provides labor production for laying building bricks and Table 9.3 presents labor production for laying face bricks in common bond. Chapter 4 provides a discussion of the details of labor productivity and cost estimation for changes due to field factors affecting masonry labor productivity. Factors affecting masonry labor productivity are discussed in the next section.

9.1.5 Factors Affecting Masonry Productivity

Factors affecting masonry productivity include the types of buildings being constructed, materials, workmanship, management, construction techniques, weather, and others. "Types of buildings" refers to low-rise or high-rise, commercial, residential, or industrial. For instance, factory and warehouse buildings have long straight walls resulting in high masonry productivity. On the other hand, school and office buildings have many openings, so they require the field cutting of units, resulting in lower productivity.

The second major factor affecting productivity involves the materials being used on a job. Types, sizes, and textures of masonry units have a major influence. The use of modular bricks can eliminate the field cutting of units and definitely increase productivity. Bigger masonry units can provide higher productivity than small masonry units. For instance, for brick construction, economy bricks (100 × 100 × 300 mm) have approximately 50% more productivity than standard modular bricks (100 × 67 × 200 mm) due to their size. Compared to smooth surfaces, rough surfaces of masonry units normally require more attention when

TABLE 9.2 Labor Production for Laying Building Bricks

Class of work	Mortar types	Average no. bricks laid/ 8 hr day	Average hours per 1000 bricks: Mason hours	Labor hours	Hoist engineer (hrs)
200 mm walls, one-story buildings, residences, and garages	Lime	700–800	10.8	9.0	0.36
300 mm walls, ordinary construction, garages, factories, schools, stores,	Lime	900–1050	8.3	8.0	0.36
houses, apartment buildings, etc.	Cement	750–900	9.6	8.0	0.36
400 mm walls, heavy warehouse, factory, and industrial work with straight	Lime	1000–1250	7.3	8.0	0.36
walls	Cement	900–1050	8.2	8.0	0.36
Backing-up face brick for 200 to 400 mm walls, first-grade workmanship	Lime	750–900	9.6	9.0	0.36
Cut stone, terra cotta on steel, or concrete skeleton frame buildings	Cement	700–800	10.6	9.0	0.36

TABLE 9.3 Labor Production for Laying Face Bricks in Common Bond

Mortar joints	Laying 1000 standard or modular size face bricks in common bond							
	2:1:9 Lime-cement mortar				Cement mortar			
	Mason hours	Labor hours	Hoist engineer	No. laid/ 8 hr day	Mason hours	Labor hours	Hoist engineer	No. laid/ 8 hr day
Flush cut	16–19	12–13	0.5	400–525	18–20	13–20	0.5	375–475
V-tooled, concave, or ranked out	18–20	12–13	0.5	375–475	19–21	13–14	0.5	350–450
Struck or weathered	18–21	12–13	0.5	360–450	20–22	13–14	0.5	350–435
Rodded	19–23	12–13	0.5	325–450	20–25	13–14	0.5	300–425
Stripped	27–32	15–16	0.5	225–325	28–37	16–18	0.5	200–300

laying; consequently, they lead to lower productivity. Regular-shaped masonry units are familiar to masons, whereas special-shaped masonry units require additional awareness when laying, and thus result in lower productivity. Types of mortar, bond patterns, and wall thickness also have an effect on labor productivity. Types M and S mortar offer compressive strength more quickly when they are hardened, but low workability and flow when they are liquid. In contrast, types N and O mortar offer a low compressive strength, but high workability and flow. Types M and S therefore gain sufficient strength earlier, resulting in fewer dates necessary to rent a wall bracing system or a lower cost in accessory materials. However, they require more time to be laid, resulting in lower productivity.

The next two factors affecting masonry productivity are workmanship and management. Well-trained masons and higher grades of workmanship involve not only productivity but also work quality. It is almost certain that experienced masons maintain higher productivity and better quality. Management has a significant impact on labor productivity in many respects. For instance, establishing good labor–management relationships certainly increases productivity. Management can also motivate workers resulting in significantly higher productivity. For example, management may let workers participate in construction decision making, encourage competition among masons by dividing them into teams, maintain the masons' awareness of their performance, reward craftsmanship, eliminate unproductive time such as waiting for mortar, supply proper and on-time materials and equipment, and provide efficient work access and work areas. There is no doubt that working in a congested area among other trades or pipes significantly reduces labor productivity. The ability of the foreman with regard to planning, scheduling, and the laying out of the work also extensively affects masonry productivity.

Another factor significantly influencing labor productivity is construction technique. In masonry construction, using concave-tooled joints rather than raked joints can increase productivity. It is also recognized that using corner poles when laying masonry units can increase masonry productivity. For cavity walls, simultaneously laying inner and outer withers can increase productivity because scaffolding is moved only once.

The next factor affecting labor productivity is weather. Masonry labor productivity on a clear and dry day is notably higher than on a cold, hot, or wet day. The primary reasons include requirements to heat materials during freezing weather and to wet masonry units during hot weather, and the need for complete protection during rainy or windy weather. Additional factors that may affect labor productivity include the labor market and materials availability.

9.2 CLAY MASONRY UNITS (BRICKS)

The first and most common type of masonry unit is a clay masonry unit usually called a brick. Bricks are extensively used due to their availability, durability,

minimum maintenance, and aesthetically pleasing appearance. Based on their use, bricks can be classified into three general categories: glazed, paving, and fire bricks. Glazed bricks are used where a durable and sanitary surface is required. Paving bricks are used on a flat base in applications such as walkways, driveways, and patios. The most common bricks, fire bricks, are used elsewhere including high-temperature areas such as chimneys and incinerators.

Fire bricks are normally made out of fire clay or shale that is fired and exposed to the peak temperature of 1320°C in a modern plant with a total manufacturing process of 60 to 80 hours. Fire bricks are usually solid and have a rectangular box shape with core holes created for manufacturing purposes. They are available in a variety of sizes, shapes, colors, and textures. On the current market, there are many types of fire bricks including building bricks, brick veneer, cast ceramic flooring, face bricks, and structural face tile. The most prevalent bricks are common building bricks and face bricks. Common building bricks are employed where quality and appearance are not as important, and face bricks are normally utilized in exterior walls.

This section introduces many aspects of brick types, their major characteristics, and associated costs. Much of the information in this section is based on documents published by the Brick Institute of America (BIA) and ASTM.

9.2.1 Characteristics of Bricks

It is clear that an estimator needs to be familiar not only with brick types but also their characteristics. Different brick characteristics can result in different levels of productivity and also the materials cost. Major brick characteristics include dimensions, shapes, colors, and textures. These characteristics are certainly significant because they help an estimator to better take off material quantities.

Masonry unit dimensions are typically described in terms of thickness × height × length (T × H × L). The length is the largest dimension, followed by the thickness, and then the height. There are three masonry unit dimensions: specified, nominal, and actual dimensions. The specified dimensions of the bricks are used to specify the manufacturing size of masonry units. The dimension of typical bricks is 90 × 57 × 190 mm. The nominal dimensions present the distances occupied by the unit plus one-half of the joint width on each side (or the unit plus the joint width). Typical joints are 10 mm thick, so typical bricks have a nominal dimension of 100 × 67 × 200 mm. The actual dimensions are the specified dimensions along with minor allowable manufacturing tolerance. All bricks vary slightly in their dimensions because of the shrinkage of the clays in burning.

Table 9.4 presents nominal sizes, number of bricks per m^2, quantity of mortar, and quantities and costs of face bricks and brick veneer. This table is based on a running bond; therefore an additional 10% of mortar is required for English, Dutch, and Flemish bonds. Among the bricks listed in Table 9.4, modular bricks are the most common in building construction because they are the standard for government agencies or major architectural offices. Table 9.5 presents the number of bricks per 1 m^2 based on the thickness of the wall and the width of the mortar joints. Figure 9.1 shows typical modular clay bricks. There are some nonmodular clay bricks available on the market including standard (90 × 57 × 200 mm), engineer standard (90 × 70 × 200 mm), closure standard (90 × 90 × 200 mm), king size (76 × 70 × 240 mm), and queen size (76 × 70 × 200 mm). These dimensions are specified.

This section introduces brick dimensions, so it is appropriate to consider how to compute required masonry bricks and mortar per 1 m^2 wall area. According to Figure 9.2, three modular clay bricks with a mortar joint thickness of 10 mm have a height of approximately 200 mm and the length of 200 mm. Therefore, 0.04 m^2 of a wall area requires 3 clay bricks. In other words, 1 m^2 of the wall area requires approximately 75 bricks with a joint thickness of 10 mm. An estimator can employ this approach, with slight changes, to other types of masonry units.

Besides brick dimensions, brick shapes and textures are important characteristics resulting in a variety of material and labor costs. Bricks are generally available in a variety of shapes and textures. Brick shapes include special corners,

TABLE 9.4 Brick Sizes, Costs, and Quantities[a]

Name	Nominal size (mm) T × H × L	Specified size (mm) T × H × L	No. bricks/m^2	m^3 of mortar/1000 bricks (waste included)		Cost/1000 bricks	
				10 mm joint	13 mm joint	Face brick ($)	Brick veneer ($)
Modular	100 × 67 × 200	90 × 57 × 190	73.66	0.29	0.37	315–350	350
Economy	100 × 100 × 200	90 × 90 × 190	48.43	0.32	0.41	420–525	475
Engineer	100 × 80 × 200	90 × 70 × 190	60.60	0.30	0.39	288–475	335
Jumbo	150 × 100 × 300	140 × 90 × 290	32.29	0.67	0.87	1100	1250
Norwegian	100 × 81 × 300	90 × 71 × 290	40.36	0.42	0.53	500–700	570
Norman	100 × 67 × 300	90 × 57 × 290	48.44	0.40	0.51	410	735
Roman	100 × 51 × 300	90 × 40 × 290	64.58	0.38	0.48	410	760
SCR	150 × 67 × 300	140 × 57 × 290	48.43	0.61	0.79	410	900
Utility	100 × 100 × 300	90 × 90 × 290	32.29	0.44	0.56	915	1000

[a] Mortar quantities based on 10 mm mortar joints and running bond patterns. Brick quantities based on single-wythe walls with 10 mm joints and running bond pattern.

Source: Means, 1999.

TABLE 9.5 Number of Standard Bricks per 1 m^2 Wall

Thickness of wall (mm)	Width of bed mortar joints					
	3.1 mm	6.3 mm	9.4 mm	12.5 mm	15.6 mm	18.8 mm
200 or 225	157.9	150.7	143.5	136.4	131.0	124.9
300 or 325	236.8	226.1	215.3	204.5	196.5	187.3
400 or 425	315.7	301.4	287.1	272.7	261.9	249.7
500 or 525	394.7	376.8	358.8	340.9	327.5	312.2
600 or 625	473.6	452.1	430.6	409.0	392.9	374.6

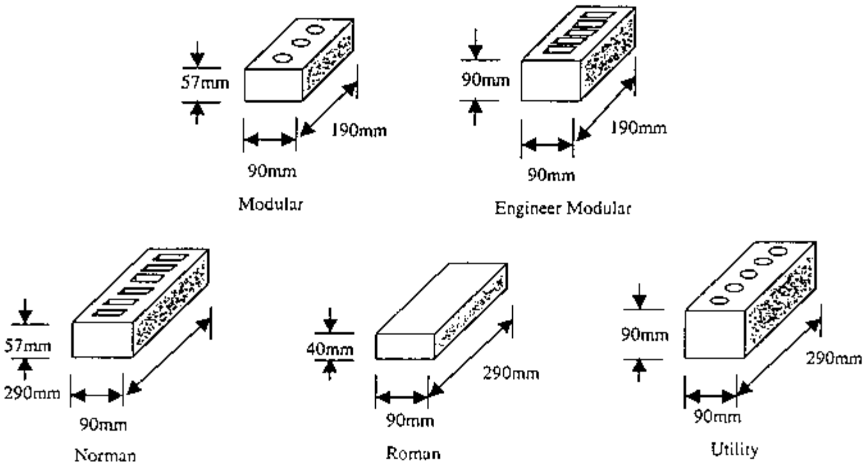


FIGURE 9.1 Masonry clay units.

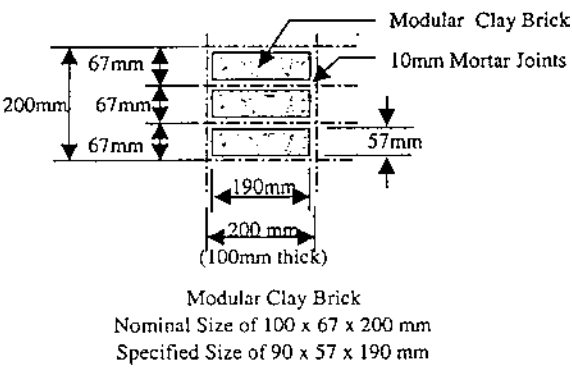


FIGURE 9.2 Modular clay bricks.

TABLE 9.6 Production Factor and Productivity Rate for Several Brick Textures

Special brick	Production factor	Bricks/ bricklayer/ day
Smooth finish	1	560
Matte finish	0.95	532
Rough finish	0.95	504

sills, lintel bricks, coping bricks, and radial bricks. Special shapes usually have lower productivity and higher cost compared to more normal rectangular shapes. In the market, brick textures fall into three classifications: smooth, matte, and rough finish. These textures affect bricklaying productivity because it is very easy to clean mortar from smooth-surface bricks, and difficult to clean mortar from rough-surface bricks. For rough-surface bricks, a mason needs to be careful not to dirty the exposed face, causing lower productivity. Table 9.6 presents a production factor and productivity rate for each texture. For example, if a mason can lay 100 smooth-finish bricks for a job, he or she will lay only 95 rough-finish bricks for a similar job. This table, however, provides only sample information that may not match a particular crew. An estimator, therefore, needs to develop a similar table suitable for his or her own crews from a similar past job.

9.2.2 Masonry Unit Orientations, Surfaces, and Mortar Joints

Masonry units are usually labeled differently based upon their orientations in a wall. Figure 9.3(a) presents a variety of unit orientations viewed as perpendicular to the plane of the wall. They include stretcher, header, soldier, shiner, rowlock, and finally sailor. Masonry unit surfaces are also labeled differently as shown in Figure 9.3(b). Bed, face, and head are designated as a side formed by thickness × length (T × L), height × length (H × L), and thickness × height (T × H), respectively. According to Figure 9.3(c), there are six mortar joint patterns: concave, flush, raked, struck, weathered, and V joints. Table 9.7 presents orientation factors for calculating the quantity of standard bricks based on Table 9.4 and using stretcher orientation.

9.2.3 Brick Bonds

Brick bonds can assist in strengthening brick walls and also provide various attractive patterns or designs on walls. For any bond pattern, a row of masonry

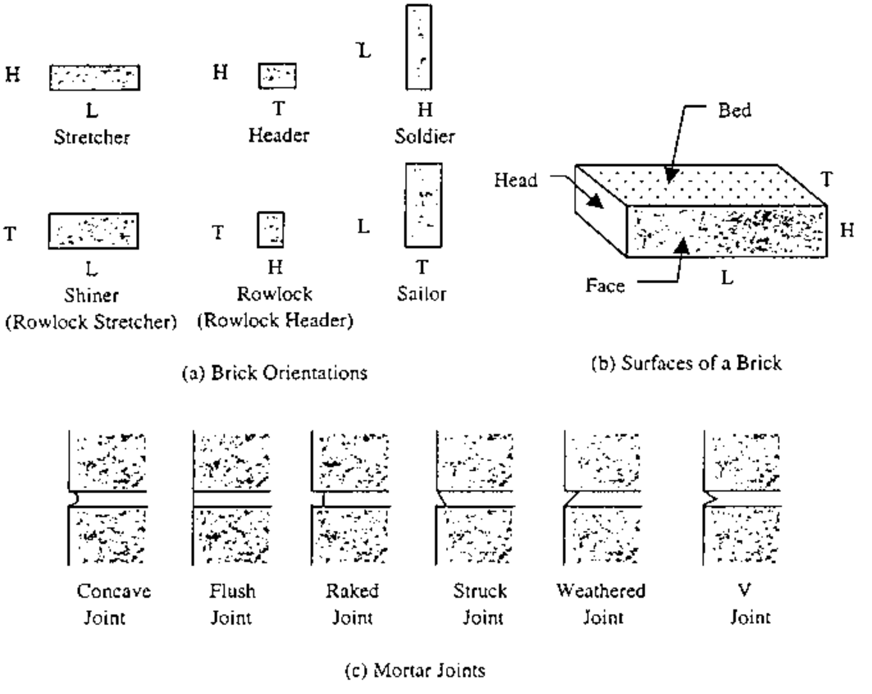


FIGURE 9.3 (a) Brick orientations; (b) surfaces; and (c) mortar joints.

TABLE 9.7 Orientation Factors for Calculating Standard Brick Quantities[a]

Orientation	Description	Factor added to quantities in Table 9.4 (%)
Header	W × H exposed	+100
Rowlock	H × W exposed	+100
Rowlock Stretcher	L × W exposed	+33.3
Soldier	H × L exposed	0
Sailor	W × L exposed	−33.3

[a] Based on Table 9.4 using stretcher orientations.
Source: Means, 1999.

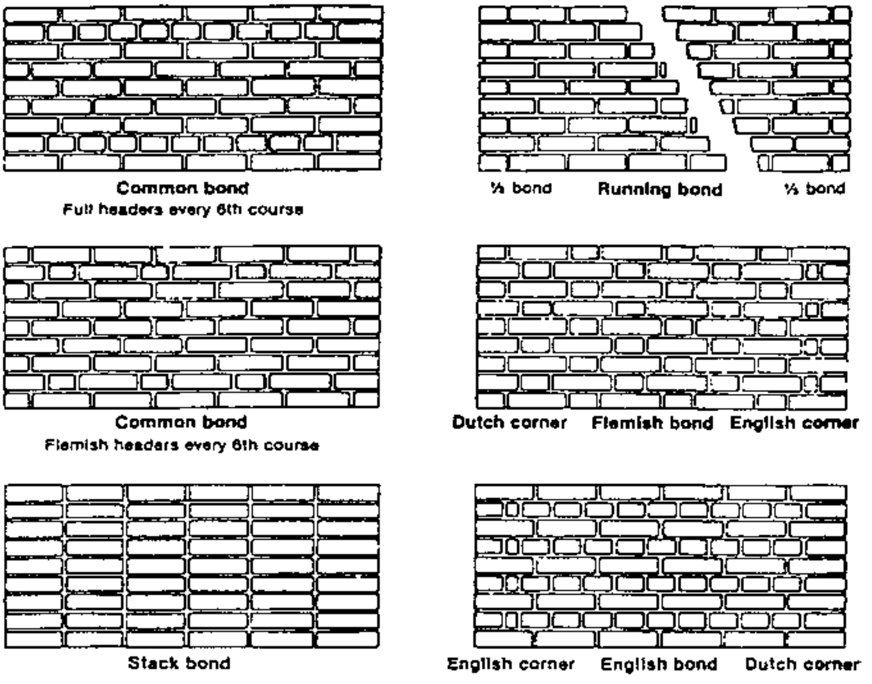


FIGURE 9.4 Typical bond patterns. (From Kolkoski, 1988.)

units in a horizontal alignment is called a course. In the common header bond, a header course is placed every fifth, sixth, or seventh course. The all-stretcher band is reinforced every sixth course with metal ties placed between the joints and the stacked bond has similar metal reinforcing every sixth course. Figure 9.4 shows typical bond patterns including running bond, 1/3 running bond, stack bond, Flemish bond, common or American bond, and English bond. Running bond is the most common bond pattern in contemporary buildings. It is certain that each bond type has an effect on labor productivity, resulting in a different number of bricks set in a day for different bond patterns. According to Table 9.8, an area of common bond bricks with a full header every fifth course requires 20% more bricks than the same area of the typical running bond bricks provided in Table 9.4. For instance, according to Table 9.4, an area of 1 m^2 of a running bond wall requires 73.66 modular bricks, but according to Table 9.8, an area of 1 m^2 of a common bond with full header every fifth course requires $73.66 \times 1.20 = 88.39$ modular bricks. A waste factor for each bond pattern is also provided in Table 9.8.

TABLE 9.8 Bond Factors for Calculating Standard Brick Quantities[a]

Bond type	Description	Factor added to quantities in Table 9.4 (%)	Waste factor (%)
Common	Full header every fifth course	20.00	4
	Full header every sixth course	16.70	
	Full header every seventh course	14.30	
English or English Cross	Full header every other course	50.00	8–15
	Full header every sixth course	16.70	
Dutch or Dutch Cross	Full header every other course	50.00	8
	Full header every sixth course	16.70	
Flemish	Full headers every course	33.30	3–5%
	Full headers every sixth course	5.60	

[a] Based on running bond given in Table 9.2. Add an extra 10–15% bricks for cutting waste unless masonry saw is used.
Source: Means, 1999.

9.2.4 Brick Grades and Types

For general building use, the most frequently used bricks are common building bricks and face bricks. Common building bricks are manufactured according to ASTM C62 and face bricks are manufactured according to ASTM C216. Common building bricks are typically classified into three grades based on resistance to weather conditions including SW (severe weather), MW (medium weather), and NW (normal weather). SW bricks are used for a very frequent occurrence of frost or for an area where bricks can be frozen when permeated with water. In building construction, for example, they are employed for foundation courses and retaining walls. MW bricks are used for an area where bricks are exposed to freezing temperatures but unlikely to be saturated with water. Normally they are used on the face of a wall above grade. NW bricks are employed for an area where bricks are not exposed to extreme temperature. They are typically employed for backup and interior walls, as well as exterior walls where no frost action occurs.

According to ASTM C216, based on their resistance to weather, face bricks are available in the two grades of SW and MW. Each grade is composed of three types based on the requirements for appearance and size: FBS (face brick standard), FBX (face brick extra), and FBA (face brick architectural). FBS bricks are for general use in building construction. FBX bricks are employed for areas where color and tolerance are significant and can be used either in interior or exterior walls. FBA bricks are nonuniform in size and texture, and are manufactured specifically for aesthetic architectural effects. In contract specifications, if no type of face brick is specified, FBS bricks are often employed.

9.2.5 Wall Types

There are two general types of walls, single wythe and multiple wythe. Figure 9.5 displays examples of single and multiple wythe walls. This figure can help

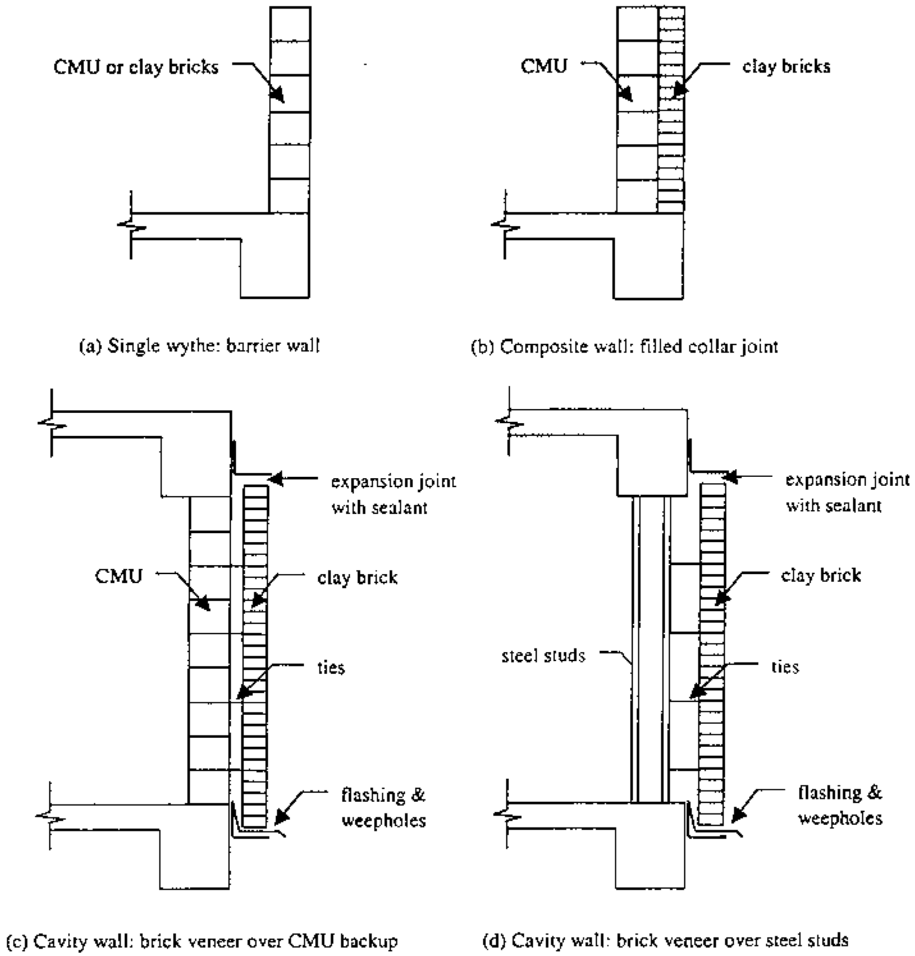


FIGURE 9.5 Typical wall types: (a) single wythe, barrier wall; (b) composite wall, filled collar joint; (c) cavity wall, brick veneer over CMU backup; (d) cavity wall, brick veneer over steel studs.

an estimator visualize how the wall will be constructed and what materials could be used for single- and multiple-wythe walls. Typical single-wythe walls consist of a barrier wall. Common multiple-wythe walls include a composite wall, cavity wall, brick veneer over concrete block backup, and brick veneer over steel studs.

9.2.6 Costs of Labor, Materials, and Equipment for Clay Masonry Units

Due to the fact that clay and shale are widely available, modular bricks have economic advantages over other masonry units. Table 9.9 was generated to present some costs of materials and/or labor for major brick types. Standard common building bricks have the average price of $305/1000 bricks. With 3% bricks and 25% mortar waste, standard brick veneers have the average materials price of $350 and the labor cost of $685/1000 bricks. For standard modular face bricks, the average materials cost is approximately $333/1000 bricks. Information furnished in Table 9.9 is bare costs; the total costs including 10% overhead and profit are presented in the final column.

9.3 CONCRETE MASONRY UNITS

Concrete masonry units, commonly known as CMU, are extensively used in building construction in many parts of the US because of their availability, strength, and fireproofing qualities. Concrete masonry units are utilized for both exterior walls and interior partitions where easy maintenance and stain resistance are required. Additionally, they are employed for foundations, backups, fireproofing, load-bearing, and non-load-bearing walls and partitions. The National Concrete Masonry Association is the primary source of information for this section.

9.3.1 Characteristics of Concrete Masonry Units

Concrete masonry units are mainly characterized by sizes, weights, and textures. Concrete masonry units on the market include concrete blocks, chimney blocks, concrete screen blocks, coping, concrete block-interlocking blocks, and glazed concrete blocks. These are all normally available in various sizes and surface textures including smooth, slump block, split-face blocks, ribbed block, various patterns, and polished face. The most common of all concrete masonry products are concrete blocks, including concrete back-ups, bond beams, decorative blocks, exterior blocks, foundation wall blocks, high-strength blocks, and concrete block

TABLE 9.9 Cost of Labor and Materials for Clay Masonry Units

						Bare cost			
Code 04210	Clay masonry units	Crew[c]	Daily output	Labor (hrs)	Unit[b]	Mat.	Labor	Total	Total[a]
100-0010	Common building brick, C 62, TL lots, material only								
100-0020	Standard, minimum				k	250		250	275
100-0050	Average (select)				k	305		305	335
120-0010	Brick veneer, scaffolding not included, truckload lots								
120-0015	Material cost incl. 3% brick and 25% mortar waste								
120-0020	Standard, sel. common, 100 × 68 × 200 mm (73/m2)	D-8	1.50	26.667	k	350	695	1045	1450
120-1150	Economy, 102 × 102 × 203 mm (48/m2)	D-8	1.40	28.571	k	475	745	1220	1675
120-1201	Engineer, 102 × 81 × 203 mm (61/m2)	D-8	1.45	27.586	k	335	720	1055	1500
300-0010	Face brick, C216, TL lots, material only								
300-0300	Standard modular, 100 × 68 × 200 mm, minimum				k	315		315	385
300-0350	Maximum				k	350		350	345
300-0450	Economy, 100 × 100 × 200 mm, minimum				k	420		420	460
300-0500	Maximum				k	525		525	580
300-0510	Economy, 100 × 100 × 300 mm, minimum				k	420		420	460

300-0520	Maximum				k	525		525	580
300-1260	Engineer, 100 × 81 × 200 mm, minimum				k	288		288	315
300-1270	Maximum				k	475		475	525
350-0010	Structural face tile, scaffolding not included, standard colors								
350-0020	6T series, 133 × 300 mm, 25 pieces/m^2, glazed 1 side, 50 mm T	D-8	20.90	1.914	m^2	53.5	50	103.5	137
350-0100	100 mm thick, glazed 1 side	D-8	20.44	1.957	m^2	59.5	51	110.5	145
350-0150	Glazed 2 sides	D-8	18.12	2.208	m^2	97	57.5	154.5	197
350-2000	8W series, 200 × 400 mm, 12.11 pieces/m^2								
350-2050	50 mm thick, glazed 1 side	D-8	33.45	1.196	m^2	56.5	31	87.5	111
350-2100	100 mm thick, glazed 1 side	D-8	32.05	1.248	m^2	65	32.5	97.5	122
350-2150	Glazed 2 sides	D-8	30.19	1.325	m^2	105	34.5	139.5	170
810-0010	Terra cotta, coping, split type, not glazed, 229 mm wide	D-1	27.43	0.583	m	15.7	14.85	30.55	40.5
810-0100	330 mm wide	D-1	24.38	0.656	m	25.5	16.7	42.2	54
810-0500	Partition or backup blocks, scored, in C.L. lots								
810-0700	Nonloading, 305 × 305 × 76 mm thick	D-8	51.10	0.783	m^2	48	20.5	68.5	84
810-1000	Load bearing, 305 × 305 × 102 mm thick	D-8	46.45	0.861	m^2	43.5	22.5	66	82.5

[a] Includes O&P, 10% of the total bare cost.
[b] k indicates 1,000.
[c] Crew D-1 includes 1 bricklayer and 1 bricklayer helper. Crew D-8 includes 3 bricklayers and 2 bricklayer helpers.
Source: Means, 1999.

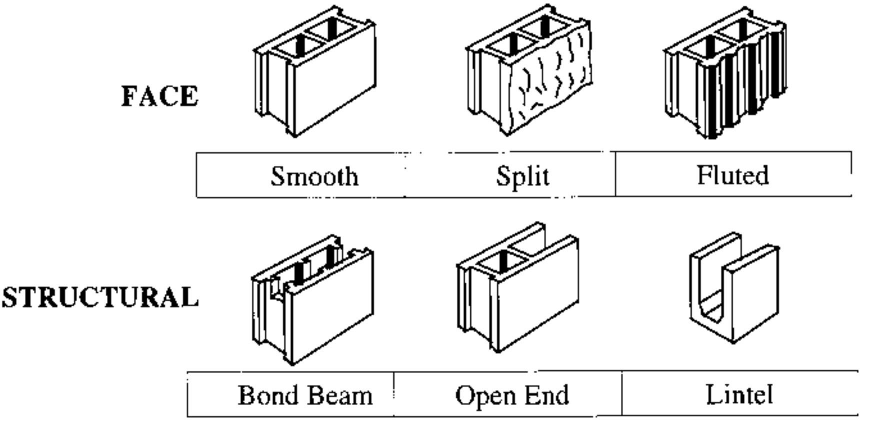


FIGURE 9.6 Typical concrete masonry units.

lintels. Special units are available with glaze in one or more size(s). Figure 9.6 shows typical concrete blocks available in various sizes. Table 9.10 presents sizes, weights, and quantities of load-bearing concrete blocks. Modular concrete blocks are the most frequently used blocks in building construction. According to Table 9.10, modular concrete blocks have the nominal size of 200 × 200 × 400 mm and the specified size of 190 × 190 × 390 mm when the mortar joint thickness is 10 mm. According to Figure 9.7(b), one modular concrete block with the mortar joint thickness of 10 mm has a nominal height of 200 mm and a nominal length of 400 mm. Therefore, 0.08 m^2 of a wall area requires 1 concrete block. In other words, 1 m^2 of a wall area requires approximately 12.5 bricks for a joint thickness of 10 mm. Table 9.11 presents the number of tiles and mortar required per 1 m^2 of wall.

Another common type of concrete masonry unit is concrete bricks with the nominal modular size of 100 × 67 × 200 mm and the specified modular size of 90 × 57 × 190 mm. According to Figure 9.7(a), similar to the modular clay bricks, three courses of modular concrete bricks with a mortar joint thickness of 10 mm has a height of 200 mm and a length of 200 mm. Therefore, 0.04 m^2 of a wall area requires 3 concrete bricks. In other words, 1 m^2 of a 100 mm wall area requires approximately 75 bricks for a joint thickness of 10 mm. In addition to the modular size, concrete bricks also have other sizes available on the market such as the nominal jumbo size of 100 × 100 × 300 mm and the nominal Roman size of 100 × 51 × 300 mm. Tables 9.12 and 9.13 show the number of bricks, blocks, and mortar required per 1 m^2 of wall.

TABLE 9.10 Sizes, Weights, and Quantities of Load-Bearing Concrete Blocks per m^3 and Required Mortar[a]

Concrete blocks nominal size (mm) T × H × L	Concrete blocks specified size (mm) T × H × L	Approximate weight (kg)		No. blocks/1 m^2 of wall (units)	Quantity of mortar/1 m^2 of wall (m^3)
		Heavyweight units	Lightweight units		
100 × 130 × 300	90 × 120 × 290	5–6	4–5	25.83	0.024
150 × 130 × 300	250 × 120 × 290	8–9	5–6	25.83	0.026
200 × 130 × 300	190 × 120 × 290	10–11	6–7	25.83	0.027
100 × 200 × 300	90 × 190 × 290	8–9	5–6	16.15	0.018
150 × 200 × 300	140 × 190 × 290	12–13	8–9	16.15	0.020
200 × 200 × 300	190 × 190 × 290	15–16	10–11	16.15	0.021
250 × 200 × 300	240 × 190 × 290	19–20	12–13	16.15	0.023
300 × 200 × 300	290 × 190 × 290	22–23	13–14	16.15	0.024
100 × 100 × 400	90 × 90 × 390	5–6	4–5	24.22	0.027
150 × 100 × 400	140 × 90 × 390	8–9	5–6	24.22	0.029
200 × 100 × 400	190 × 90 × 390	10–11	7–8	24.22	0.030
100 × 200 × 400	90 × 190 × 390	10–11	7–8	12.11	0.015
150 × 200 × 400	140 × 190 × 390	16–17	11–12	12.11	0.015
200 × 200 × 400	190 × 190 × 390	20–21	13–14	12.11	0.020
250 × 200 × 400	240 × 190 × 390	26–27	16–17	12.11	0.021
300 × 200 × 400	290 × 190 × 390	29–30	18–19	12.11	0.024

[a] Wall thickness = 1 block.

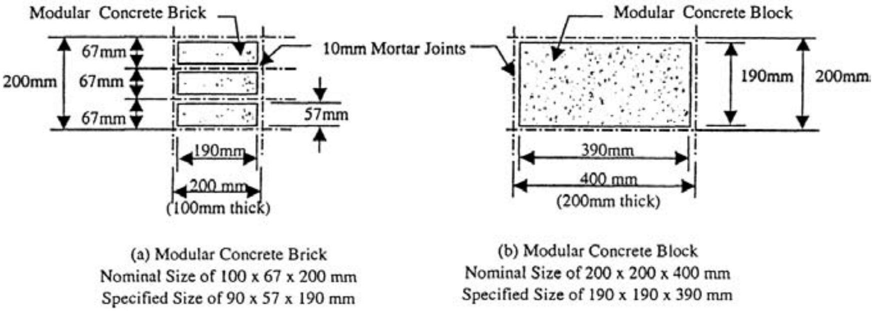


FIGURE 9.7 (a) Modular concrete brick and (b) block.

TABLE 9.11 Quantity of Concrete Partition Tiles and Mortar Required per 1 m² of Wall[a]

Concrete partition tiles nominal size (mm) T × H × L	No. tiles/ 1 m² of wall (units)	Quantity of mortar/ 1 m² of wall (m³)
100 × 200 × 300	16.15	0.018
150 × 200 × 300	16.15	0.020
200 × 200 × 300	16.15	0.021
50 × 200 × 400	12.11	0.009
100 × 200 × 400	12.11	0.015
150 × 200 × 400	12.11	0.015
200 × 200 × 400	12.11	0.018

[a] Thickness of wall = 1 tile.

TABLE 9.12 Quantity of Modular Concrete Bricks Based on Wall Thickness

Concrete brick nominal size (mm) T × H × L	No. modular concrete brick/1 m² of wall — Thickness of wall: 1-brick (100 mm)	2-brick (200 mm)	3-brick (300 mm)
100 × 67 × 200	72.66	145.32	217.98
100 × 100 × 200	48.44	96.88	145.32
130 × 100 × 200	36.60	73.20	109.80
100 × 51 × 300	64.59	129.17	193.76
100 × 51 × 400	48.44	96.88	145.32

Source: Means, 1999.

TABLE 9.13 Quantity of Mortar per 1000 Blocks for Partitions and Backup

Concrete blocks (nominal size)	Mortar/1000 blocks (m^3)	
	For partitions	For backup
50 × 200 × 400	0.45	1.02
100 × 200 × 400	0.88	1.44
150 × 200 × 400	1.30	1.87
200 × 200 × 400	1.76	2.32
250 × 200 × 400	2.18	2.75
300 × 200 × 400	2.61	3.17

Source: Means, 1999.

9.3.2 Costs of Labor, Materials, and Equipment for Concrete Masonry Units

The costs of materials and labor for most common masonry work are provided in Table 9.14. Backup concrete blocks with reinforcement alternative courses and 200 mm thickness have the average national unit costs of $14.85 and $28.50 per 1 m^2 wall area for materials and labor, respectively. Lightweight block bond beams have material and labor costs of $10.95 and $11.25 per 1 m^2 wall area. Hollow concrete blocks with the nominal size of 200 × 200 × 400 mm for foundation walls have material and labor costs of $16.15 and $26.00, respectively, per 1 m^2 wall area. Concrete lintels have material and labor costs of $19.50 and $89.65, respectively, per 1 m^2 wall area. The cost information in this chapter provides US national average costs, so it is necessary that an estimator check the local market for availability of materials within the project area.

9.4 OTHER TYPES OF MASONRY UNITS

Other types of masonry units include glass masonry units, adobe masonry units, masonry stone, and special nonconventional masonry units. These types of masonry units are made from a variety of materials and offer distinct advantages.

9.4.1 Glass Masonry Units

Glass masonry units are made from silica sand, limestone, soda ash, and other inner components that are melted in a furnace at a temperature over 1260°C. The most typical glass masonry unit is the glass block, commonly used for interior and exterior nonload-bearing walls. The glass block provides several advantages including an obvious visual impact, reduced ultraviolet transmission, lighting, solar reflection, fire resistance, and thermal insulation.

TABLE 9.14 Cost of Labor and Materials for Concrete Masonry Units

Code 04220	Concrete masonry units	Crew[b]	Daily output	Labor (hrs)	Unit	Bare cost Mat.	Bare cost Labor	Bare cost Equip.	Bare cost Total	Total[a]
220-0010	Concrete block, back-up, scaffolding not included									
220-0020	Sand aggregate, 200 × 400 mm units, tooled joint 1 side									
220-1000	Reinforced, alternate courses, 100 mm thick	D-8	40.41	0.99	m^2	9.45	26		35.45	50.5
220-1100	150 mm thick	D-8	38.55	1.037	m^2	12.7	27		39.7	56
220-1150	200 mm thick	D-8	36.70	1.09	m^2	14.85	28.5		43.35	60.50
220-1200	250 mm thick	D-8	35.77	1.118	m^2	20.5	29		49.5	68
220-1250	300 mm thick	D-9	33.91	1.416	m^2	22	36		58	80.5
230-0010	Concrete block, bond beam, scaffolding not included									
230-0020	Not including grout or reinforcing									
230-0100	Regular block, 200 mm high, 200 mm thick	D-8	172.00	0.233	m	5.3	6.05		11.35	15.3
230-0150	300 mm thick	D-9	155.00	0.31	m	8.35	7.9		16.25	21.5
230-0500	Lightweight, 200 mm high, 200 mm thick	D-8	175.00	0.229	m	5.2	5.95		11.15	14.95
230-0550	300 mm thick	D-9	158.00	0.304	m	9	7.75		16.75	22
230-2000	Including grout and 2-#20M bars									
230-2100	Regular block, 200 mm high, 200 mm thick	D-8	91.44	0.437	m	9.9	11.4		21.3	28.5
230-2150	300 mm thick	D-9	76.20	0.63	m	14.3	16.05		30.35	41
230-2500	Lightweight, 200 mm high, 200 mm thick	D-8	9.96	0.43	m	10.95	11.25		22.2	29.5
230-2550	300 mm thick	D-9	77.72	0.618	m	15	15.75		30.75	41
240-0010	Concrete block, decorative, scaffolding not included									
240-0020	Embossed, simulated brick face									

240-0100	200 × 400 mm units, 100 mm thick	D-8	37.16	1.076	m^2	23	28		51	69
240-0200	200 mm thick	D-8	61.59	1.266	m^2	31.5	33		64.5	86
240-0250	300 mm thick	D-8	27.87	1.435	m^2	40.5	37.5		78	103
240-0400	Embossed both sides									
240-0500	200 mm thick	D-8	27.87	1.435	m^2	35	37.5		72.5	96.5
240-0550	300 mm thick	D-8	25.55	1.566	m^2	46	41		87	114
250-0010	Concrete block, exterior, scaffolding not included									
250-0020	Reinforced alt courses, tooled joints 2 sides, foam inserts									
250-0100	Regular, 200 × 400 × 200 mm thick	D-8	33.91	1.18	m^2	14.65	31		45.65	64
250-0600	Lightweight, 200 × 400 × 200 mm thick	D-8	35.77	1.118	m^2	33.5	29		62.5	82
260-0010	Concrete block, foundation wall, scaffolding not included									
260-0050	Normal-weight, trowel cut joints, parged 13 mm thick, no reinforcing									
260-0250	Hollow, 200 × 400 × 200 mm thick	D-8	39.95	1.001	m^2	16.15	26		42.15	58.5
260-0550	Solid, 200 × 400 × 200 mm thick	D-8	38.55	1.037	m^2	22.5	27		49.5	66.5
270-0010	Concrete block, high strength, scaffolding not included									
270-0050	Hollow, reinforced alternate courses									
270-0300	21 MPa, 200 × 400 × 200 mm thick	D-8	34.84	1.148	m^2	14.3	30		44.3	62.5
270-0500	34 MPa, 200 × 400 × 200 mm thick	D-8	34.84	1.148	m^2	32	30		62	81.5
280-0010	Concrete block, lintels, scaffolding not included									
280-0100	Including grout and horizontal reinforcing									
280-0400	200 × 400 × 200 mm thick 1-#10bar	D-4	83.82	0.382	m	19.5	9.65	1.31	30.46	38
280-0450	200 × 400 × 200 mm thick 2-#10bar	D-4	82.30	0.389	m	19.85	9.8	1.33	30.98	38.5

[a] Includes O&P.

[b] Crew D-4 includes 1 bricklayer, 2 bricklayer helpers, 1 equipment operator, 1 grout pump, and 1 hose and hopper. Crew D-8 includes 3 bricklayers and 2 bricklayer helpers.

9.4.2 Adobe Masonry Units

Adobe masonry units are unfired clay. The most common adobe masonry units are adobe bricks normally used with adobe mortar. Adobe bricks are available in a range of sizes and prices. Some sizes of adobe bricks are similar to those of clay masonry bricks; however, their prices are slightly different.

9.4.3 Stone Masonry

Masonry stone includes both artificially shaped stone and naturally shaped rock. Stone has been used in masonry construction for thousands of years and nowadays it is mostly used for nonload-bearing exterior walls. In addition, masonry stone can be used as a veneer for both interior and exterior walls, walkways, and trim on buildings. Masonry stone can be employed with or without mortar and offers a distinctively pleasing appearance due to the variety of shapes and types of finish. Natural rock is random in size, whereas artificial stone is available in regular shapes. Sawed-bed and cut stones are also available in many areas. Types of stone finish are split, tooled, rubbed, and machine brushed. The most common masonry stone products are bluestone, granite, limestone, marble, sandstone, slate, and quarried stone.

9.4.4 Special Nonconventional Masonry Units

Special nonconventional masonry units are typically made from new materials and have particular shapes or textures for specific applications. Examples of these special nonconventional masonry units include (1) interlocking units for mortarless construction; (2) lightweight units made from lightweight manufactured aggregate, wood chips, sawdust, or waste paper; and (3) masonry units incorporating waste products such as glass.

9.4.5 Costs of Labor, Materials, and Equipment for Other Types of Masonry Units

The national average materials costs associated with labor and equipment costs for masonry units are provided by Means (1999). Table 9.15 highlights some of the costs to offer an estimator a big picture of masonry unit costs. Plain glass block with the size of 150 × 150 mm (100 mm thick), excluding scaffolding, has a materials cost of $132/m^2$ and a labor cost of $83/m^2$, when the average area ranges from 90 to 465 m^2. Adobe bricks with the size of 100 × 75 × 200 mm has a materials cost of $19.40/m^2$ and a labor cost of $33.50/m^2$.

9.5 MASONRY MORTAR

Mortar is used to bed masonry units and to bond individual units into a combined component. In other words, mortar separates masonry units while at the same

TABLE 9.15 Costs of Labor, Materials, and Equipment for Other Masonry Units

Code 04270	Glass masonry units	Crew[b]	Daily output	Labor (hrs)	Unit	Bare cost Mat.	Bare cost Labor	Bare cost Equip.	Bare cost Total	Total[a]
200-0010	Glass block, scaffolding not included									
200-0100	Plain, 100 mm thick, under 90 m², 150 × 150 mm block	D-8	10.68	3.744	m²	140	97.5		237.5	305
200-0300	90 to 465 m², 150 × 150 mm block	D-8	12.54	3.189	m²	132	83		215	275
200-0500	over 465 m², 150 × 150 mm block	D-8	13.47	2.969	m²	133	77.5		210.5	266
Code 04290	**Adobe masonry units**									
100-0010	Adobe brick, unstabilized, with adobe mortar									
100-0260	Brick per m², 100 × 75 × 200 mm (65/m²)	D-8	24.71	1.619	m²	19.4	42		61.4	87
100-0280	100 × 100 × 200 mm (48/m²)	D-8	30.94	1.293	m²	19.7	33.5		53.2	74
100-0300	100 × 100 × 350 mm (27/m²)	D-8	50.17	0.797	m²	12.15	21		33.15	46
Code 04413	**Granite**									
300-0010	Granite, cut to size									
300-0050	Veneer, polished face, 20 to 50 mm thick									
300-0150	Low price, gray, light gray, etc.	D-10	12.08	3.312	m²	202	88.5	33	323.5	395

TABLE 9.15 Continued

Code 04270	Glass masonry units	Crew[b]	Daily output	Labor (hrs)	Unit	Bare cost Mat.	Labor	Equip.	Total	Total[a]
300-0220	High price, red, black, etc.	D-10	12.08	3.312	m^2	345	88.5	33	466.5	555
Code 04414	**Limestone**									
400-0010	Limestone									
400-0020	Veneer facing panels									
400-0500	Texture finish, light stick, 114 mm thick, 1.5 m × 3.6 m	D-4	27.87	1.148	m^2	204	29	3.93	236.93	273
400-1000	Medium ribbed, textured finish, 114 mm thick, 1.5 m × 3.7 m	D-10	25.55	1.566	m^2	121	42	15.7	178.7	215
Code 04415	**Marble**									
500-0011	Marble ashlar, split face, ± 100 mm thick, random									
500-0100	Base, polished, 19 or 22 mm thick, polished, 150 mm high	D-10	19.81	2.019	m^2	40	54	20.54	114.5	150
500-1050	Facing, polished finish, cut to size, 20 to 25 mm thick, average	D-10	12.08	3.312	m^2	193	88.5	33	314.5	385

[a] Includes O&P.

[b] Crew D-4 includes 1 bricklayer, 2 bricklayer helpers, 1 equipment operator, 1 grout pump, and 1 hose and hopper. Crew D-8 includes 3 bricklayers and 2 bricklayer helpers. Crew D-10 includes 1 bricklayer foreman, 1 bricklayer, 2 bricklayer helpers, 1 equipment operator, and 1 truck crane.

Source: Means, 1999.

time it holds masonry units together. Additionally, mortar is employed to seal unit joints in order to prevent air and moisture from entering and to bond with steel reinforcements, ties, and anchor bolts. Mortar also provides an architecturally pleasing appearance and allows size variations in masonry units. Mortar is available ready-mixed (in bags), premixed (mixed at a plant and transported to the site), and job-mixed (ingredients are mixed by hand or in a cement mixer at the site). There are three general groups of mortar including Portland cement-lime, masonry cement mortar, and mortar-cement mortar. Each group can be classified into four types (M, S, N, O) based on compressive strength according to the ASTM C270. All mortar materials and mortar types must conform to ASTM specifications. This section introduces mortar materials, typical types of mortar, and costs of mortar materials.

9.5.1 Mortar Materials

Mortar is made from three major materials including Portland cement, lime, and masonry sand. These basic mortar materials are mixed with water and some admixtures according to ASTM specifications. Each material must meet ASTM specifications to ensure the mortar quality (see Table 9.1 for ASTM designations). Table 9.16 presents the mortar components: cement, lime, and aggregate.

According to Table 9.16, there are several types of mortar materials including Portland, air-entraining Portland, blended, masonry, and mortar cement. Portland cement for masonry usually has three types. Type I Portland cement is the most common cement utilized in mortar for general-purpose construction. Type II Portland cement is used in an area where moderate sulphate action occurs or heat must be controlled. Type III Portland cement is a high-early-strength cement. These cements can be mixed with a very small amount of an air-entraining additive, so the final products are called air-entraining cements (types IA, IIA, IIIA). An air-entraining additive offers not only more plasticity in fresh mortar but also

Table 9.16 Mortar Materials

Mortar materials	Types of mortar materials
1. Cement	1.1 Portland cement (Types I, II, III)
	1.2 Air-entraining Portland cement (Types IA, IIA, IIIA)
	1.3 Blended cement (Types IS, ISA, IP, IPA, S, SA)
	1.4 Masonry cement
	1.5 Mortar cement
2. Lime	2.1 Quicklime
	2.2 Hydrated lime
3. Aggregate	3.1 Masonry sand

more durability in hardened mortar. It also provides a better bond for hardened mortar and reduces the amount of waste. Portland cement is available on the market in bags of 32 kg or in bulk. Blended cement, a type of Portland cement, includes Portland blast furnace slag cement (Types IS, ISA), Portland pozzolan cement (IP, IPA), and slag cement (S, SA). Masonry cement, another Portland cement, consists of Portland cement and finely ground limestone or hydrated lime. There are three types of masonry cement: M, S, and N. Agents such as plasticizing admixtures, air-entraining admixtures, and water-retention additives can be added to the masonry cement to affect plasticity, water retention, and durability. For example, gypsum can be added to control the setting time of masonry cement. Mortar cement is composed of basic materials as in masonry cement, but in different proportions. Mortar cement differs from masonry cement in that it is formulated especially for higher tensile bond strength compared to that of Portland cement-lime mortar.

Another major mortar material is lime, including quicklime and hydrated lime. Quicklime for structural purposes and hydrated lime for masonry purposes must conform to ASTM C5 and ASTM C207, respectively. Quicklime is usually available in an unslaked form and, to secure the best result, should be slaked prior to use according to the manufacturer's suggestions. Quicklime may cause serious burns to skin and eyes due to its fast reaction with water. In addition, the aging period may vary ranging from a few hours to several days depending on its chemical properties and the skill of the person slaking the quicklime. Hydrated lime, on the other hand, is available in a slaked form, and thus it generally is faster, easier, and safer than quicklime. Hydrated lime can be classified into two types, S and N. Without oxide limits, type S (special) hydrated lime helps putties develop high plasticity and workability upon mixing. In contrast, with oxide limits, type N (normal) hydrated lime requires several hours or overnight to make putties develop plasticity and workability. In general, hydrated lime is available in bulk or in bags of 23 kg.

The last mortar component is aggregate in compliance with ASTM C144. Aggregate includes natural (bank-run) or manufactured sand. Manufactured sand is made by crushing stone, gravel, or air-cooled blast furnace slag. These mortar materials need to be mixed with fresh water in specific proportions to generate the best results. Fresh water refers to clean water without acids, alkalies, or organic materials. In short, the water should be drinkable. Specified proportions for different types of mortar, according to ASTM C270, are introduced in the next section.

9.5.2 Types of Mortar

There are four major classifications of mortar products on the current market: Portland cement-lime (PCL) mortar, masonry-cement (MC) mortar, and mortar-cement mortar. Each classification has different materials proportions. PCL mortar is made from a mixture of Portland cement, lime, and masonry sand. It can be batched by hand onsite using materials from bags, or batched automatically onsite using materials from silos. MC mortar is a mixture of masonry cement and sand, often with additional Portland cement. Mortar-cement mortar consists of different proportions of mortar cement and masonry sand, usually containing additional Portland cement. Each mortar classification can be further categorized into four types according to ASTM C270, namely, types M, S, N, and O.

All mortar types (M, S, N, O) must meet the ASTM requirements of property and proportion specifications. Property specifications mainly designate mortar compressive strength, water retention, and maximum air content, as presented in Table 9.17. Therefore to meet the requirements, property specifications of the mortar must be controlled by laboratory testing. Each mortar type offers different advantages and its use normally depends on work functions. Type M mortar has high compressive strength, and is normally used for both reinforced and unreinforced masonry, especially in contact-to-earth areas, such as foundations, retaining walls, walkways, sewers, and manholes. Type S mortar, with moderate compressive strength and high tensile bond strength, is used for reinforced masonry and where flexible strength is required, such as where cavity walls are exposed to strong winds. Type N mortar has medium compressive strength and tensile bond strength and is generally used in exposed masonry above grade, such as exterior walls, chimneys, and parapet walls. Type O mortar has low compressive strength and is normally used for nonsevere exposed walls and interior walls where compressive strength does not exceed 2.41 MPa. In short, types M and S mortar are usually employed for work requiring high compressive strength and high tensile bond strength; in contrast, types N and O mortar are utilized for work requiring low compressive strength and low tensile bond strength, but high workability and flow.

A second way to specify mortar is according to proportion specifications, by designating the volume of the mortar in order to control the requirements. Table 9.18 presents proportions of mortar by volume for PCL mortar, MC mortar, and mortar-cement mortar, respectively. Generally, the greater the amount of Portland cement, the higher the strength of the mortar. Types M and S mortar, therefore, contain a higher volume of Portland cement compared to types N and O mortar. In contrast, lime offers mortar higher workability and flow, so types N and O mortar contain more lime.

In a large construction project, mortar can be mixed by either property or proportion specifications. In a small construction project, mortar is usually mixed to proportion specifications using a small portable mixer. Tables 9.19 and 9.20 present quantities of mortar materials for different types of lime. If the use of a 1:1:6 mix (proportion specification) is required for a job, for instance, it means mortar must be mixed in volume proportions with 1 part Portland cement, 1 part lime, and 6 parts fine sand. According to Table 9.20, to lay 1000 bricks, the

TABLE 9.17 Common Mortar Types Conforming to ASTM C270[a]

Mortar type	Comprehensive strength (MPa)	Water retention (%)	Maximum air content		
			PCL mortar (%)	MC mortar (%)	Mortar-cement mortar (%)
M	17.24	75	12	18	12
S	12.41	75	12	18	12
N	5.17	75	14 (12 if reinforced)	20 (18 if reinforced)	14 (12 if reinforced)
O	2.41	75	14 (12 if reinforced)	20 (18 if reinforced)	14 (12 if reinforced)

[a] Information suitable for estimating, not design, purposes.
Source: ASTM Standards.

TABLE 9.18 Mortar Types Specified by Proportion[a]

Mortar type	Portland cement	Masonry cement type M	Masonry cement type S	Masonry cement type N	Hydrated lime	Masonry sand[b]
Portland cement-lime mortar						
M	1				≤¼	3
S	1				½	4½
N	1				1	6
O	1				2	9
Masonry-cement mortar						
M		1				3
S			1			3
N				1		3
O				1		3
M	1			1		6
S	½			1		4¼
Mortar-cement mortar						
		1				3
S			1			3
N				1		3
O				1		3
M	1			1		6
S	½			1		4½

[a] Information suitable for estimating, not design, purposes.
[b] Sand volume ranges from 2¼ to 3 times the volume of cementitious materials.
Source: ASTM Standards.

mortar can be a mixture of 3.9 sacks of Portland cement, 77 kg of dry unslaked hydrated lime, and 0.88 m^3 of fine sand. However, the lime proportion can also be determined in volumes of lime putty.

9.5.3 Costs of Labor, Materials, and Equipment for Masonry Mortar

Masonry mortar is priced by the number of mortar bags or cubic meters of mortar. According to Table 9.21, the price of a 32 kg bag of masonry cement is $5.90 per bag and the price of a 23 kg bag of hydrated lime is $5.60 per bag. Type M masonry cement mortar with the mixture of 1:1:6 has a materials cost of

TABLE 9.19 Quantities of Materials Needed for Masonry Using Quicklime[a]

Quicklime[b]								
			Quantity of material required					
			for 1 m³ of mortar			to lay 1000 bricks		
Proportion by volume								
Portland cement	Lime putty	Sand	Cement (sack)	Dry unslaked lime (kg)	Sand (m^3)	Cement (sack)	Dry unslaked lime (kg)	Sand (m^3)
0	1	3	0	133	1.3	0	89	0.9
1	3	12	2.9	100	1.3	2	67	0.9
1	2	9	3.9	89	1.3	2.6	59	0.9
1	1.5	7.5	4.7	80	1.3	3.1	53	0.9
1	1	6	5.9	67	1.3	3.9	45	0.9
1	0.5	4.5	7.8	44	1.3	5.2	30	0.9
1	0	3	11.8	0	1.3	7.8	0	0.9

[a] Information suitable for estimating, not design, purposes.
[b] Pebble or pulverized quicklime at 2.55 m^3 lime putty per metric ton.

TABLE 9.20 Quantities of Materials Required for Masonry Using Hydrated Lime[a]

Quicklime[b]								
			Quantity of material required					
			for 1 m³ of mortar			to lay 1000 bricks		
Proportion by volume								
Portland cement	Lime putty	Sand	Cement (sack)	Dry unslaked lime (kg)	Sand (m^3)	Cement (sack)	Dry unslaked lime (kg)	Sand (m^3)
0	1	3	0	232	1.3	0	96	0.9
1	3	12	2.9	174	1.3	2	116	0.9
1	2	9	3.9	155	1.3	2.6	103	0.9
1	1.5	7.5	4.7	139	1.3	3.1	93	0.9
1	1	6	5.9	116	1.3	3.9	77	0.9
1	0.5	4.5	7.8	77	1.3	5.2	52	0.9
1	0	3	11.8	0	1.3	7.8	0	0.9

[a] Information for estimating, not design, purposes.
[b] Hydrated lime at 1.3 m^3 lime putty per metric ton.

TABLE 9.21 Costs of Labor, Materials, and Equipment for Masonry Mortar

Code 04060	Masonry mortar	Crew[a]	Daily output	Labor (hrs)	Unit	Bare cost Mat.	Bare cost Labor	Bare cost Total	Total[b]
200-0010	Cement, gypsum 36 kg bag, T.L. lots				Bag	11.4		11.4	12.55
200-0100	Masonry, 32 kg bag, T.L. lots				Bag	5.9		5.9	6.5
400-0010	Lime, masons, hydrated, 23 kg bag, T.L. lots				Bag	5.6		5.6	6.15
500-0010	Mortar								
500-0020	With masonry cement								
500-0100	Type M, 1:1:6 mix	1 Brhe	4.05	1.976	m^3	109	44.5	153.5	189
500-0200	Type N, 1:3 mix	1 Brhe	4.05	1.976	m^3	100	44.5	144.5	179
500-2000	With Portland cement and lime								
500-2100	Type M, 1:1/4:3 mix	1 Brhe	4.05	1.976	m^3	133	44.5	177.5	215
500-2200	Type N, 1:1:6 mix, 5 MPa	1 Brhe	4.05	1.976	m^3	108	44.5	152.5	187
500-2300	Type O, 1:2:9 mix (pointing mortar)	1 Brhe	4.05	1.976	m^3	105	44.5	149.5	184
500-2900	Mortar for face brick, 36 kg bag, T.L. lots				Bag	12.5		12.5	13.75
540-0010	Colors, 23 kg bags (2 bags/k bricks)								
540-0050	Average				kg	5.5		5.5	6.05
750-0200	Sand for mortar, screened and washed, at the pit				m^3	20.5		20.5	23
750-0250	With 16 km haul				m^3	22.5		22.5	25

[a] Brhe = bricklayer helper.
[b] Includes O&P.
Source: Means, 1999.

\$109/m³ of mortar and a labor cost of \$44.50/m³ of mortar. Type M Portland cement-lime mortar with a mixture of 1 : ¼ : 3 has materials and labor costs of \$133 and \$44.50/m³ of mortar. Sand screened and washed at the pit has a cost of \$20.50/m³ of mortar. Once again, cost information proposed in this chapter is based on Means (1999) using US national average costs and requires an estimator to use a cost database acquired from one's own crews and similar jobs.

9.6 MASONRY GROUT, REINFORCEMENT, AND MASONRY ACCESSORIES

The previous sections introduced major components of masonry including masonry units and mortar. This section covers masonry grout, reinforcement, and masonry accessories related to both materials and their costs.

9.6.1 Masonry Grout and Reinforcement

Masonry grout is a fluid concrete with pea-gravel aggregate. It is used to fill some or all cells in hollow units or between wythes. Costs associated with masonry grout materials include grouting, anchor bolts, reinforcing, and wall ties. Masonry grout is taken off by total grouting area or total volume and then multiplied by unit cost to obtain the total cost of masonry grout. Reinforcement consists of steel deformed bars, deformed reinforcing wire, and wire fabric. Steel deformed bars named rebar can be classified into three categories, namely, billet, rail, and axle steel, which conform to ASTM A615, A616, and A617, respectively. Rebar is generally taken off by linear meters and then multiplied by unit weight for each size of reinforcement to obtain total weight. It is then multiplied by the unit cost per weight of rebar to obtain the total reinforcement cost. In addition, rebar can be multiplied by the unit cost per length of rebar, resulting in the total rebar cost. Masonry grout and rebar estimates are similar to concrete and reinforcement estimates, respectively, for concrete work. An estimator can refer to Chapter 8 (Concrete) for more details. Wire fabric is usually taken off by linear meters and then multiplied by the unit costs per linear meter. Examples of reinforcement for composite and cavity walls are presented in Figure 9.8.

9.6.2 Masonry Accessories

This category includes connectors, sealants, flashing, coating, vapor barriers, lintels, sills, coping, bracing systems, and scaffoldings (Fig. 9.9). Connectors are made from galvanized or stainless steel proving axial and shear strength, axial and shear stiffness, and corrosion resistance and protection. Connectors are com-

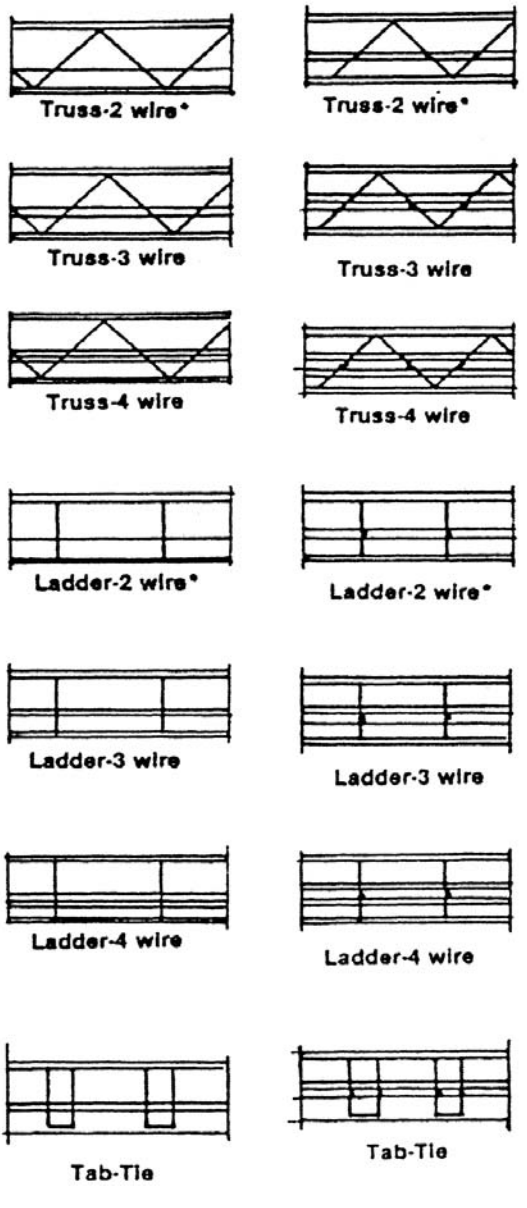


FIGURE 9.8 Reinforcement for composite and cavity walls. (From Kolkoski, 1988.)

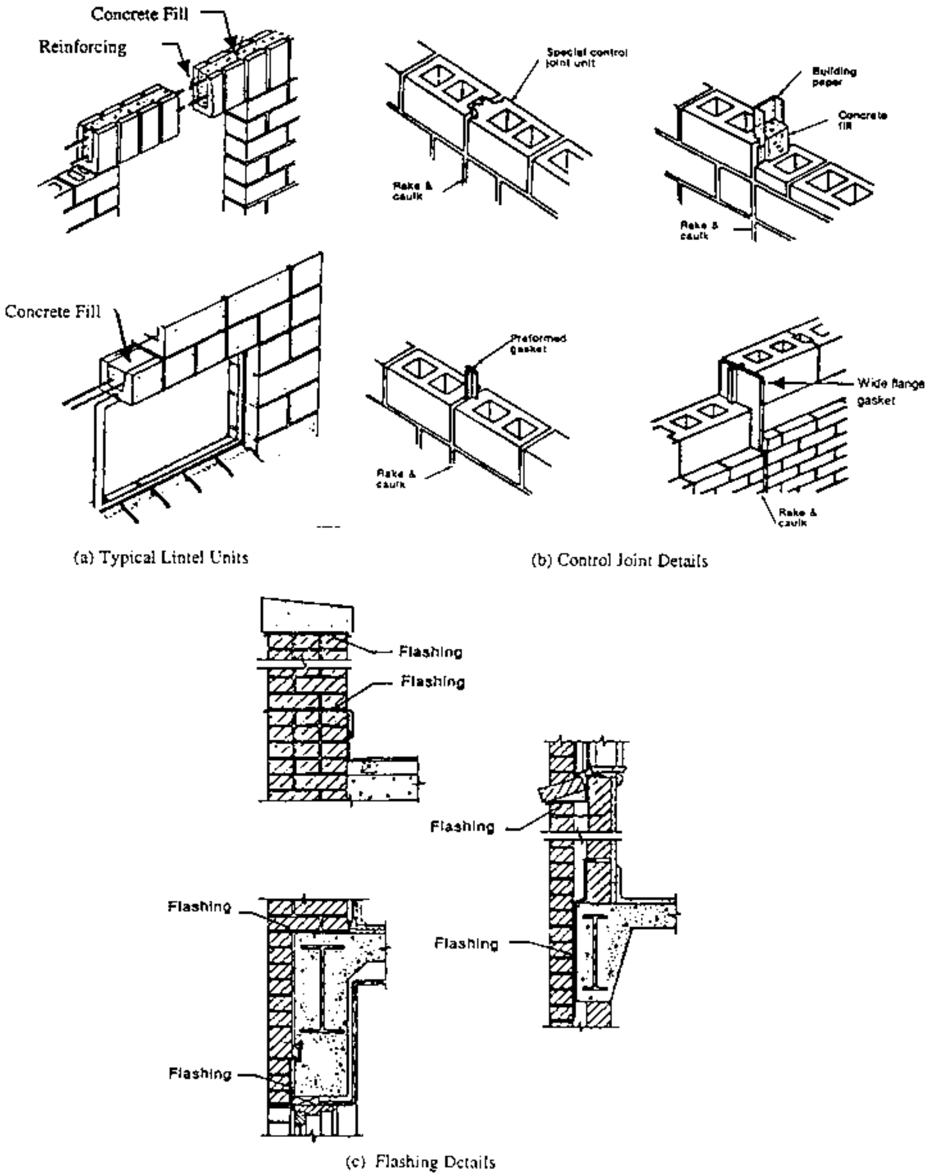


FIGURE 9.9 (a) Typical lintel units; (b) control joint details; (c) flashing details. (From Kolkoski 1988.)

posed of ties, anchors, and fasteners. Ties are used to connect a masonry wall to another wall, anchors are used to connect a masonry wall to a framer, and fasteners are used to connect other structures to a masonry wall. Sealants are utilized to prevent the passage of water through places where gaps are intentionally left in masonry walls. Flashing [see Fig. 9.9(c)] is a flexible waterproof barrier intended to permit water that has penetrated the outer wythe to exit the wall. It is placed at the bottom of each story level, over window or door lintels, and under windows or doors. Flashing is made of stainless steel, copper, plastic-coated aluminum, rubberized plastic (EPDM), and plastic. Coatings, including paint and water-repellent coatings, are generally unnecessary in masonry and are often harmful because paint is usually less durable than the masonry it covers and water-repellent coating cannot bridge wide cracks. In addition, coatings tend to trap water behind them resulting in freeze–thaw damage. Vapor barriers are waterproof membranes usually made from polyethylene or PVC. They are intended to prevent interstitial condensation within the cavity of a cavity wall. Lintels [Fig. 9.9(a)] are horizontal structural members installed above a wall opening, whereas sills are usually installed at the bottom of windows or doors, bricks, stones, tiles, and concrete precasts. Coping is employed to cover the top course of the wall to protect it from severe weather. Bracing systems and scaffolding are usually utilized during masonry wall construction.

Masonry accessories can easily be forgotten and neglected. For instance, most masonry walls, both interior and exterior, usually require a bracing system. An estimator needs to determine the costs of bracing walls needed during construction in terms of labor and materials. A bracing system must remain in place until a permanent bracing system is completed. A permanent bracing system includes wall columns or corners, and anchors that fasten to a structural frame. Other items that are sometimes overlooked by an estimator are anchor slots on beams and columns, which are generally supplied and installed by a steel fabricator. In contrast, the ties for masonry work are typically installed by a bricklayer.

9.6.3 Costs of Labor, Materials, and Equipment for Masonry Grout and Accessories

Table 9.22 presents some costs of masonry grout, reinforcement, and accessories. Masonry grout is priced by linear meters of bond beam and lintels, square meters of grouting area, and cubic meters of grout volume. The cost of masonry grout for bond beams, lintels, and CMU cores is $\$124/m^3$, with the associated labor and equipment costs of \$81.50 and \$11.05 per m^3. Anchor bolts with diameters of 13 mm and lengths of 300 mm have a material cost of \$1.22 each and labor cost of \$1.20 each. Reinforcement is usually priced by its weight and the average materials and labor costs of #10M bars placed vertically are \$0.62/kg and \$1.44/kg, respectively.

TABLE 9.22 Costs of Labor, Materials, and Equipment for Masonry Grout and Assessories

Code 04070	Masonry grout	Crew[a]	Daily output	Labor (hrs)	Unit	Bare cost Mat.	Bare cost Labor	Bare cost Equip.	Bare cost Total	Total[b]
420-0010	Grouting, bond beams, lintels, 200 mm deep, pumped, not incl. block									
420-0020	200 mm thick, 0.2 m^3/mm	D-4	427.00	0.075	m	2.3	1.89	0.26	4.45	5.75
420-0250	Concrete block cores, solid, 200 mm thick, pumped, 0078 m^3/m^2	D-4	63.17	0.507	m^2	9.8	12.8	1.73	24.33	32.5
420-0500	Cavity walls, 50 mm space, pumped, no shoring, 0.05 m^3/m^2	D-4	158.00	0.203	m^2	6.45	5.1	0.69	12.24	15.75
420-2000	Grout, C476, for bond beams, lintels, and CMU cores	D-4	9.91	3.229	m^3	124	81.5	11.05	216.55	274
Code 04080	**Masonry anchor, reinforcement**									
070-0010	Anchor bolt, hooked w/nut and washer, 13 mm dia., 200 mm long	1Bric	200.00	0.04	Ea	0.47	1.14		1.61	2.29
070-0030	300 mm long	1Bric	190.00	0.42	Ea	1.22	1.2		2.42	3.21
200-0010	Reinforcing steel bar, A615, placed horiz., #10M bars	1Bric	204.00	0.039	kg	0.62	1.12		1.74	2.42
200-0050	Placed vertical, #10M bars	1Bric	159.00	0.05	kg	0.62	1.44		2.06	2.91
650-0010	Wall ties, to brick veneer, galv., corrugated, 20 × 180 mm, 22 Ga.	1Bric	10.50	0.762	h	4.47	22		26.47	39
650-0600	Cavity wall, a type, galvanized, 150 mm long, 6 mm dia.	1Bric	10.50	0.762	h	20	22		42	56
650-1000	Rectangular type, galvanized, 6 mm dia, 50 × 150 mm	1Bric	10.50	0.762	h	25.5	22		47.5	62

Code 04090	Masonry accessories									
170-0140	Control joint, rubber, 200 mm and wider wall	1Bric	85.34	0.094	m	17.55	2.68		20.23	23.5
170-0160	PVC, 200 mm wall	1Bric	85.34	0.094	m	6.65	2.68		9.33	11.45
420-0100	Insulation, inert, styrofoam, plant installed, add to block price									
420-0200	200 × 400 mm units, 150 mm thick				m^2	8.05			8.05	8.9
420-0500	200 × 200 mm units, 200 mm thick				m^2	6.65			6.65	7.35
650-0010	Pargeting, regular Portland cement, 13 mm thick	D-1	23.23	0.689	m^2	1.37	17.55		18.92	29
860-0010	Vent box, extruded aluminum, 100 mm deep, 60 × 206 mm	1Bric	30.00	0.267	Ea	30.5	7.6		38.1	45.5
Code 04900	Masonry restoration, cleaning									
200-0010	Cleaning and point, smooth brick	1Bric	27.87	0.287	m^2	2.15	8.2		10.35	15.1
220-0010	Cleaning masonry, no staging included, unless noted									
220-0220	Chemical cleaning, brush and wash, average	D-1	37.16	0.431	m^2	0.54	10.95		11.49	17.65
220-0400	High pressure water only, average	B-9	139.00	0.288	m^2		6.5	1.3	7.8	11.7
750-0010	Steam clean, building, not incl. scaffolding, minimum	B-9	279.00	0.143	m^2		3.25	0.65	3.9	5.8
900-0010	Washing brick, acid wash, smooth brick	1Bric	52.03	0.154	m^2	2.48	4.39		6.87	9.5

[a] Crew B-9 includes 1 labor foreman, 4 laborers, air compressor, 2 air tools and accessories, and 3.5 cm diameter air hoses. Crew D-1 includes 1 bricklayer and 1 bricklayer helper. Crew D-4 includes 1 bricklayer, 2 bricklayer helpers, 1 equipment operator, 1 grout pump, and 1 hose and hopper. Bric and Ea refer to a bricklayer and each, respectively.

[b] Includes O&P.

9.7 MASONRY COST ESTIMATION

This chapter has presented many aspects of masonry including major masonry materials and their associated costs, their important characteristics, and factors affecting masonry costs. An understanding of these aspects supplies essential background knowledge for the next significant stage, masonry cost estimation. This section proposes masonry cost estimation by first introducing a general procedure for estimation, followed by a detailed estimate for each major masonry material. This approach gives an estimator an idea of how masonry cost estimation is accomplished from both general and more in-depth perspectives.

9.7.1 General Procedure for Masonry Units Cost Estimation

One of the major purposes of this chapter is to furnish a simple but effective procedure for masonry cost estimation. This significant procedure will help an estimator obtain a picture of how to estimate masonry costs. For illustration purposes, Table 9.23 was created to show the major steps of masonry cost estimation.

Step 1. Extensively study project specifications and plans to acquire an understanding of all the important aspects of masonry including types of materials, testing, construction methods, and other requirements. An estimator needs to consider all provisions related to masonry including masonry units, mortar, grout, and accessory materials.

Step 2. Determine take off quantities of masonry products, such as wall areas (m^2) or lengths of bond beams (m).

Step 3. Consider the quantities of masonry units needed, such as the number of bricks or CMUs (1000 units or unit). This can be achieved by multiplying wall areas with a number of units for 1 m^2 of wall area. Masonry walls are taken

TABLE 9.23 Major Steps for Masonry Cost Estimation

Step	Description
1	Specifications and drawings
2	Takeoff for masonry products such as wall areas, lengths of bond beams (m^2, m)
3	Takeoff, pricing for masonry units such as numbers of bricks or CMUs (1000 units, each)
4	Takeoff, pricing for masonry mortar (m^3)
5	Takeoff, pricing for masonry gout and accessories such as flashings, reinforcing, and weepholes
6	Total costs of masonry work

off separately by various types of walls, thickness, types of units, sizes of units, types of mortar, bond patterns, and mortar joints. Therefore, the obtained quantities of masonry units can be adjusted by multiplying by variable factors. A waste factor of 3 to 15% can be employed based upon types of units, quantities of units, and the quality of unit delivery.

Step 4. Determine the quantities of masonry mortar (m^3) by multiplying the wall area (m^2) by the amount needed in 1 m^2 of a wall area. Since the mortar joints may vary from one wall to another, the acquired quantities of mortar can be modified by multiplying by some factors, such as a waste factor ranging from 10 to 30%. All factors from the third and fourth steps can be obtained from Means (1999), Walker (1999), or a database gathered from an estimator's own experiences of similar jobs. To achieve the most precise factors, gathering data based upon specific crews on a similar job is the method an estimator should pursue.

Step 5. Discover the quantities of grout and accessory materials needed, such as flashings, reinforcing, weepholes, ties, bracing systems, and scaffolding.

Step 6. Determine the costs of materials, labor, and equipment for each material.

Step 7. Calculate the total cost of masonry. This can be accomplished by multiplying quantities of materials by unit costs in order to arrive at a sum for all costs. Unit costs also can be obtained from Means (1999) and Walker (1999), the estimator's database, materials suppliers, manufacturers, or masonry subcontractors. Cost of equipment is illustrated in Chapter 5. Overhead and profits are demonstrated in Chapters 17 to 19. However, in order to determine the total masonry cost, it is possible to omit Steps 3 through 5 if an estimator already has the material costs per unit of wall area or length, or if the detailed quantities of masonry materials are not required. For instance, if there is a structural-face-tiles wall area of 10 m^2 (6T series, 133 × 300 × 25 pieces/m^2, glazed 1 side, 50 mm thickness) and a unit materials cost of \$53.50/m^2, then the total materials cost is simply \$535. Although this computation can eliminate some computation time, it has the disadvantage of not taking into account the exact number of masonry units an estimator needs for a particular job. These steps are presented in detail in the next section.

9.7.2 Cost Estimation for Masonry Units

The previous section presented the general procedure for masonry cost estimation. This section introduces masonry cost estimation for masonry units or how to determine materials and associated labor costs. According to Table 9.23, there are six major steps to estimating the total cost of masonry, but the next two sections focus on take off and pricing (Steps 2 and 3).

***Example* 9.1**

Determine the total cost of modular face bricks for a wall area of 100 m^2. It is a single-wythe wall with 10 mm joints and common bond with full header every fifth course.

Step 1.

Total wall area = 100 m^2.

Step 2.

Total number of bricks (Table 9.4, based on a running bond) = 73.66 brick/m^2 of wall.
Multiplier for a common bond (Table 9.8) = 20% added or 1.20.
Number of modular face bricks = (73.66 bricks/m^2 of wall) × 1.20 = 88.39 bricks/m^2 of wall.
Number of bricks for 100 m^2 of wall = 8839 bricks.
Total number of bricks including a waste factor of 5% = 8839 bricks × 1.05 = 9280 ~ 9300 bricks.

Step 3.

Average materials cost of the modular face bricks (Table 9.4) = \$332.50/k brick.
Total materials cost = (\$332.50/k brick) × (9.3 k brick) = \$3092.

The first step is to determine the total area (m^2 for walls) or total length (m for bond beams, lintels, and others) separately by type of units, sizes and textures of units, wall thickness, width of mortar joints, and bond patterns. To determine wall areas, openings with less than 0.2 m^2 are generally ignored because the cost per unit of openings is counterbalanced with the approximate costs of cutting and trimming required. A wall corner should be taken only once, not twice (see quantity take off methods in Chapter 8).

The second step is to determine the total quantity of units required (1000 units each) by multiplying the total area or length by appropriate multipliers. Multipliers are presented in previous sections and result from differences in thicknesses of walls, thicknesses of mortar joints, types of units, sizes of units, orientations of units, and patterns of bonds. There is no doubt that the orientation of units and bond patterns affects the number of masonry units in walls because different orientations and bond patterns occupy areas in the wall differently. Table 9.4 presents the number of bricks required for a variety of brick sizes, based on single-wythe walls with 10 mm joints and running bond. Table 9.5 shows the number of standard clay bricks required per 1 m^2 for various thicknesses of walls and widths of bed mortar joints. Table 9.8 shows bond factors for calculating the quantity of standard bricks based on Table 9.4 for running bond walls.

In Example 9.1, if modular face bricks are used for single-wythe walls with 10 mm joints, and a common bond (not a running bond) with a full header is used every fifth course, the quantity of bricks can be determined by multiplying 73.66 (from Table 9.4) by 1.20 (from Table 9.8) resulting in a quantity of 88.39 bricks per 1 m^2. If the total wall area for the job is 100 m^2, then 8839 bricks are required. This calculation is based on smooth-finish standard bricks with common bond pattern. If the texture and orientation are different, an estimator can implement factors indicated in Tables 9.6 and 9.7 to better estimate the quantity of masonry units. Tables 9.10 through 9.12 present quantities of concrete blocks, tiles, and concrete bricks per 1 m^2 of wall, respectively. As a rule of thumb, a waste factor ranging from 3 to 15% can be implemented depending on the delivery system, the bond patterns, and workmanship. For masonry units with a fine handling method, a waste factor of 3% can be applied for unexposed backup work and a waste factor of 5% can be employed for exposed face work to account for broken units during transportation. If a 5% waste factor is applied to the 8839 bricks in this example, then the total number of bricks is 9280 (or approximately 9300 bricks). However, a waste factor for stone work is sometimes challenging to estimate. There is almost no waste for strong stone or cut and dressed stone; on the other hand, there is a high waste factor for breakable stone and complicated stone work, for instance, up to 10 to 15% for the ashlar pattern.

The third step is to price the masonry units by either multiplying the areas of masonry walls (m^2) by the unit costs ($/$m^2$), or multiplying the numbers of masonry units (1000 units) by unit costs ($/1000 units). For some units, such as bond beams, lintels, and stone trims, the quantities can be taken off in units of linear meters, so total costs can be determined by multiplying the lengths of the products (linear meters) by their unit costs ($/m). The unit costs ($/m^2, $/1000 units or $/m) can be obtained from either an estimator's database or local masonry units suppliers. The alternative costs database generated by Means (1999) is available on the market. For illustration purposes, Table 9.9 presents some costs of clay masonry units, Table 9.14 presents some costs of concrete masonry units, and Table 9.15 presents costs of other masonry units. For Example 9.1, the modular face bricks shown in Table 9.4 have the average materials cost of $332.50/1000 bricks; therefore the total quantity of 9300 face bricks would have a maximum materials cost of $3092.

9.7.3 Cost Estimate for Masonry Mortar

After take off and pricing for masonry units have been determined, the next action is to estimate mortar costs.

Example **9.2**

Determine the total cost of Type M mortar (1:1:6 mix with the use of masonry cement) required for a total wall area of 100 m^2. Similar to Example 9.1, this wall is a single-wythe wall with 10 mm joints and common bond with full header every fifth course.

Step 1.

Total wall area = 100 m^2.
Number of bricks for 100 m^2 of wall = 8839 bricks.

Step 2.

Quantity of mortar with waste included (Table 9.4, modular) = 0.29 m^3/1000 bricks.
Quantity of mortar for 1000 bricks = 0.29 m^3 × 8.839 = 2.56 m^3.

Step 3.

The total unit cost for Type M mortar (Table 9.21) = \$153.50/m^3 of mortar.
Total materials and labor cost = (\$153.50/m^3) × (2.56 m^3) = \$393.

The first step in mortar cost estimation is to determine the total wall area and the number of bricks needed.

The second step is to determine the total quantity of mortar (m^3) needed by multiplying the obtained total wall area (m^2) or total length (m) by quantity of mortar needed per area or length of masonry units. In addition, the total quantity of mortar (m^3) can be obtained by multiplying the total number of masonry units (1000 units) by quantity of mortar needed to lay 1000 units (m^3/1000 units). Table 9.4 presents quantity of mortar (m^3) per 1000 clay bricks, Tables 9.10 and 9.11, respectively, present concrete blocks and concrete partition tiles per 1 m^2 wall area, and Table 9.13 presents the quantity of mortar (m^3) required to lay 1000 partitions or backup blocks. For Example 9.2, the modular face bricks wall area of 100 m^2 with 10 mm joints and a common bond (not a running bond) requires mortar of 2.56 m^3.

In some circumstances, the quantity of mortar materials (such as Portland cement, lime, and sand) is required, so an estimator can use Tables 9.18 through 9.20 for Step 2. For instance, according to Table 9.20, the quantity of materials for 1 m^3 of type M hydrated mortar (1:1:6 mixture) requires 5.9 sacks of Portland cement, 116 kg of hydrated lime, and 1.31 m^3 of fine sand. For a total hydrated mortar of 2.56 m^3, the job requires 15 sacks of Portland cement, 297 kg hydrated lime, and 3.4 m^3 fine sand. In general, the obtained quantity of mortar or mortar materials can be multiplied by a waste factor ranging from 10 to 30% for work using clay and concrete masonry units. For stone work, the mortar waste factor can range from 2 to 30% depending on the types of stone and patterns. It is reasonable to assume a mortar waste factor of 2 to 4% for cut stone and 6 to 20% for ashlar masonry. In Example 9.2, the quantity of mortar was included in the quantity unit.

After obtaining the total mortar quantity, the third step is to price the mortar by multiplying the mortar quantity (m^3) by the unit cost ($/$m^3$). For instance, if the 2.56 m^3 of type M hydrated mortar (1 : 1 : 6 mix with the use of masonry cement) is used, the total materials and labor cost is approximately $393 resulting from the product of 2.56 m^3 mortar and $153.50 total unit cost (from Table 9.21). An estimator can also determine the total cost of mortar materials by multiplying the quantity of mortar materials by its unit cost.

9.7.4 Cost Estimate for Masonry Grout, Reinforcement, and Accessories

According to Table 9.23, the next action after obtaining the masonry unit and mortar costs is for the estimator to compute the total cost for masonry grout and accessories. The first step of this process is to perform quantity take off for these materials. However, this can be done when taking off the masonry units and mortar. Masonry grout is taken off by volume (m^3) and the reinforcement is taken off by length or weight (m or kg). Masonry accessories include anchor bolts (each), ties (100 ties), caulking, control joints (m), insulation (m^2), scaffolding (each), fasteners (each), waterproofing (m^2), and flashings (m^2). After the quantities of masonry grout, reinforcement, and accessories are determined, the total cost of these items can be obtained by multiplying the quantities needed for the job by their respective unit costs. Some of the unit costs for masonry grout, reinforcement, and accessories are provided in Table 9.22.

9.7.5 Computation Example for Masonry Cost Estimation

Computation examples in this section refer to Figures 9.10 and 9.11 for quantity take off and pricing. Figure 9.10 presents a plan for a one-story office building using composite walls of standard modular brick veneer and hollow concrete blocks, and Figure 9.11 provides the take off areas for the walls. The requirements for this job are listed below.

90 × 57 ×.190 mm brick veneer and 190 × 190 × 290 mm concrete blocks.
Grouting is required for bond beams and lintels.
No scaffolding is required.
1.80 m × 2.40 m doors and 2.00 m × 1.00 m windows.
Smooth-finish brick veneer with 10 mm concave joints and running bond patterns.

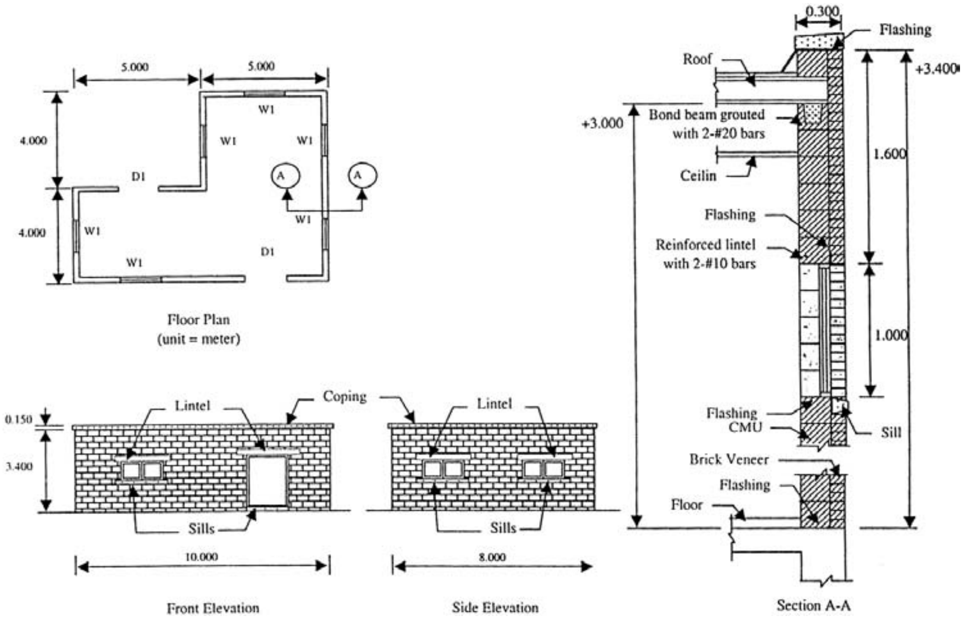


FIGURE 9.10 Floor plan, elevations, and cross-section of a one-story building.

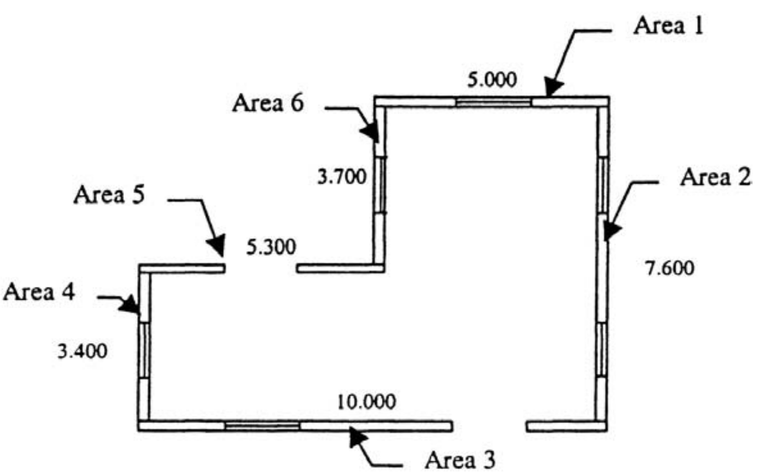


FIGURE 9.11 Take off areas of a wall.

Type M mortar with Portland cement and lime (1:1/4:3 mix).
Lightweight concrete block reinforced every other course.
Lightweight concrete block for bond beams reinforced by 2 #20 bars.
Lightweight concrete block for lintels reinforced by 2 #10 bars.

***Example* 9.3**

Determine the total quantity and the material and labor costs of modular brick veneer, concrete blocks, and mortar for this project. The quantity information for the materials is provided in Tables 9.4 and 9.10, and the cost information is provided in Tables 9.9, 9.14, and 9.21.

Step 1. Perform quantity take off for the modular brick veneer of the wall. Details for quantity take off are presented in Figure 9.12, and waste factors of 3 and 15% are employed for masonry units and motar, respectively. According to Figure 9.12, the total estimated quantity of modular brick veneer is 7500 bricks, and the total amount of 4.9 m^3 of mortar is needed for both bricks and concrete block work. The estimated quantities are 1638 blocks of concrete bond backup, 36 m of bond beams, and 20.4 m of lintels.

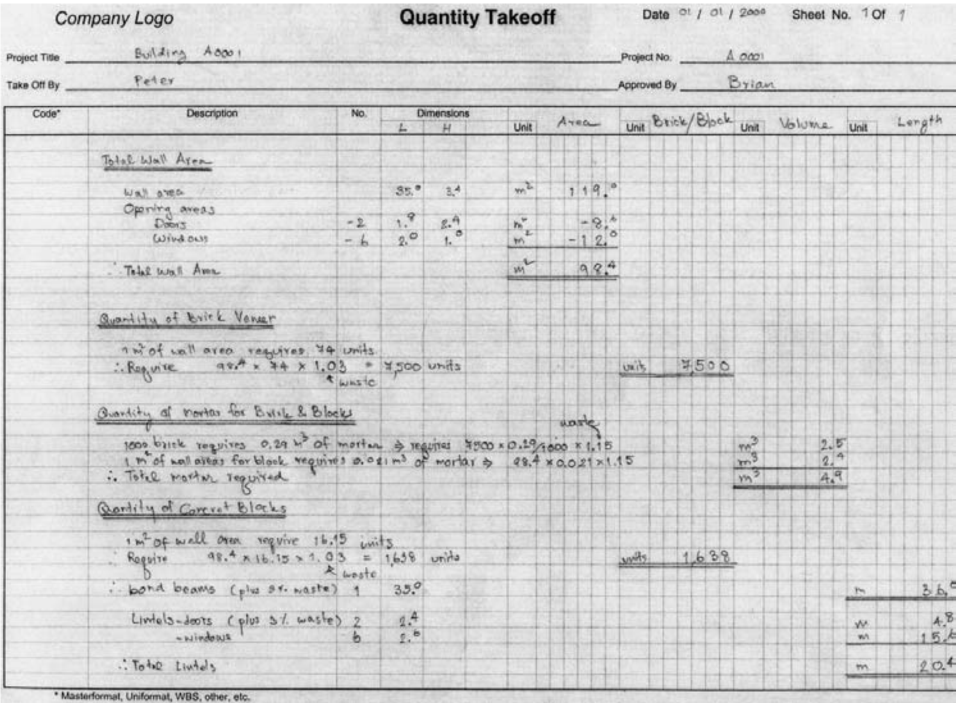


FIGURE 9.12 Quantity take off for brick veneer, concrete blocks, and mortar.

Company Logo **Pricing** Date 01 / 01 / 2000 Sheet No. Of

Project Title Building A0001 Project No. A0001

Take Off By Peter Approved By Brian

Code*	Description	Quantity	Unit	Material U.P.	Material Total	Labor U.P.	Labor Total	Equipment U.P.	Equipment Total	Subcontract U.P.	Subcontract Total	Total U.P.	Total
04210-120-0010	Brick Veneer, scaffolding not included Standard, 100mm × 68mm × 200 mm	7.5	k	350	2,625	695	5,212						7,837
04220-220-1150	Concrete Block, back-up, 200mm thick	98.4	m²	14.85	1,461	28.5	2,804						4,265
04220-230-2500	Concrete Block bond beam, lightweight, grouted 200 mm high, 200 mm thick	36.0	m	10.97	394	11.25	405						799
04220-230-4450	Concrete Block, lintels, grouted 200 mm × 200 mm × 200 mm th., 2-#6 bar	20.4	m	19.85	405	9.8	200						605
04060-500-2100	Mortar, with portland cement and lime, Type M	4.9	m³	133	652	44.5	218						870
SHEET TOTAL				MATERIAL	5537	LABOR	8839	EQUIPMENT		SUBCONTRACT		TOTAL	14,376

* Masterformat, Uniformat, WBS, other, etc.

FIGURE 9.13 Pricing for brick veneer, concrete blocks, and mortar.

Step 2. Determine materials and labor costs for the masonry units and mortar for the walls. According to Figure 9.13, the total estimated cost is $14,376 resulting from a materials cost of $5537 and labor cost of $8839.

9.8 REVIEW QUESTIONS

1. What are the four major masonry components?
2. What are available sources for masonry materials costs?
3. What are the methods for estimating equipment costs? Which is the best method and why?
4. What are the major crafts in masonry construction?
5. What are the factors affecting productivity in masonry?
6. What are the nominal and specified dimensions of modular face bricks and modular concrete block?
7. Why are masonry unit orientations, their surfaces, and mortar joints important to masonry cost estimation?

8. What are the types of brick bonds and what is their importance to masonry cost estimation?
9. What percentages are material, labor, and equipment costs compared to the total cost of masonry work?
10. What are the major mortar materials?
11. What are some masonry accessories?

10

Metals

10.1 INTRODUCTION TO METALS

Structural metal products are typically made of various materials including aluminum, brass, and bronze, but the most common one on the market is steel. Structural steel has been increasingly used recently in multistory buildings due to its better productivity and flexibility in shapes and styles. Structural steel is also commonly integrated into concrete and masonry construction to provide additional support to buildings and to increase the size of building structures. Steel is used for various building structures besides multistory buildings, such as theaters, auditoriums, gymnasiums, stadiums, and churches. This chapter mostly focuses on structural steel cost estimation based on the cost data provided in Means (1999) and Walker (1999). The following sections introduce several structural members and miscellaneous metals, a metal delivery system in building construction, and a materials checklist. This fundamental information will give the estimator a better understanding of the variety of metal costs that must be considered when performing an estimate.

10.1.1 Structural Metal Members and Miscellaneous Metals

According to Means (1999), the Metals category has six major subdivisions as shown in Table 10.1. This table also presents major structural members and other miscellaneous metals that fall under each subdivision. The first subdivision shown refers to basic materials and methods, which includes miscellaneous metals. Most miscellaneous metals are metal fastenings required to connect structural members to the structure. There are two types of fastenings commonly used in building construction: bolts and welds. Both types of connectors have different advantages in structural steel construction; these are discussed in a later section.

The next four subdivisions in Table 10.1 are primarily key components of building structures including framing, joists, and decking. Framing includes several structural components such as columns, beams, lintels, bracing, and trusses. A column is a vertical member of a building structure, usually carrying loads perpendicular to its cross-section. Common cross-sections of a column are wide-flange, circular, and box shapes. A beam is a horizontal structural element of a building structure that resists flexural shear stresses resulting from loads applied along the transverse axis of the member. Cross-sections of a beam are generally available in wide-flange, channel, angle, and T-shapes. A lintel is a horizontal element spanning and typically carrying the load above window and door openings. A classic example of lintels is a door header made from steel angles and used to support the bricks over the opening. A joist is a network of structural members arranged to form a truss acting as a beam to support a floor or ceiling. Common steel shapes for a joist are channel, angle, and pipe. Decking is a group of metal sheets laid over structural members of a building to strengthen a flooring

TABLE 10.1 Major Subdivisions in Steel Work

CSI code	Title	Structural member or miscellaneous	Sample
5050	Basic materials and methods	Metal fastenings	Anchor bolts, bolts and hex nuts, drilling, expansion anchors and shields, high-strength bolts, screws, rivets, vibration pads, weld shear connectors, studs, rods
5100	Structural metal framing	Structural steel and aluminum	Subpurlins, ceiling supports, columns, curb edging, lightweight framing, lintels, pipe support framing, plates, beams, girders
		Wire rope assemblies	Steel wire rope
		Metal framing systems	Space frame
5200	Metal joists	Steel joists	Open web joists
5300	Metal decking	Metal decking	Steel decking
5400	Cold-formed metal framing	Load-bearing metal studs	Bracing, bridging, load-bearing metal studs, framing
		Cold-formed metal joists	Bracing, bridging, framing/band joist, boxed headers/beams, joists, web stiffeners
5500	Metal fabrications	Ladders and metal stairs	Fire escape stairs, stairs
		Handrails and railings	Pipe, industrial
		Gratings	Floor gratings (aluminum, planks, steel)
		Other	Floor plates, stair treads and nosings, metal castings

system and to provide a built-in form. One of the most familiar types of metal decking is fluted cold-rolled steel decking. Generally, structural steel members are made either at the site or fabricated at the shop from standard steel shapes such as H-columns, I-beams, and C-channels. Details of standard shapes are presented in a later section.

In building construction, structural members made from standard rolled shapes are generally more economical than fabricated members. However, if standard shapes are not available in sufficient sizes to provide adequate strength, it is necessary to build up the members from several elements such as standard shapes and plates, and two different kinds of standard shapes. The last subdivision refers to metal fabrications including specialty items, other than structural members, done at a fabrication shop. This includes ladders, stairs, handrails and railings, and gratings. A grating refers to a partition, covering, or frame of parallel bars or crossbars, and steel reinforcing bars, when laid parallel to each other, such as welded wire fabric.

10.1.2 Structural Metal Delivery System

There are four major contributors involved in structural metal construction: a steel mill, a metal fabricator, a general contractor, and a subcontractor. Figure 10.1 shows the relationship among these four contributors. A steel rolling mill will make several sizes of structural steel shapes, which are stored in a warehouse. These shapes will be delivered to a metal fabricator upon request, and then the fabricated products will be delivered to the project site for erection. To better estimate cost, close communication and exchange of essential information be-

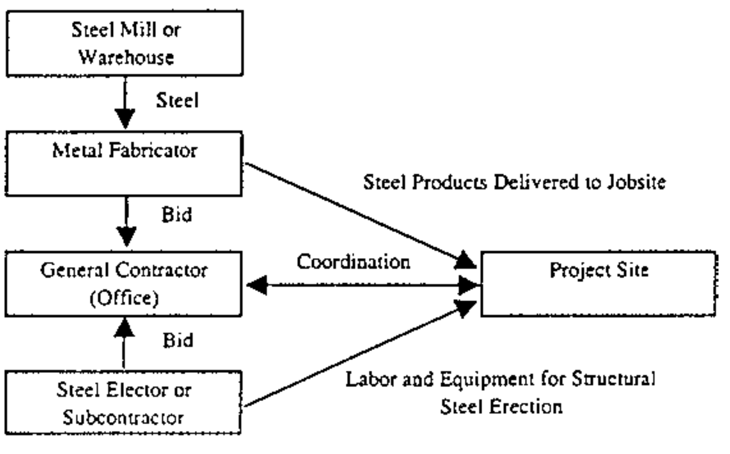


FIGURE 10.1 Information resources flow in structural metal construction.

tween the main office and the project site are required both before and during construction. The information needed includes all bid documents and any changes to the plan that may occur.

The general contractor will either purchase fabricated structural steel elements and erect them at the project site using his or her own construction crew, or purchase the prefabricated elements and use a selected subcontractor to oversee their erection. Typically, general contractors do not have a skilled crew, suitable equipment, or the expertise to erect structural metal, so the latter option produces a faster and more economical operation. The charge for the erection is typically based on an agreed price per ton of steel in place, including bolting or welding the connections. The required equipment for steel erection includes cranes, air tools, rivet busters, welders, and impact wrenches.

A metal fabricator is always required to fabricate structural steel and the preferred approach is for the fabricator to subcontract the erection work. The general contractor will submit plans and specifications of the work to the metal fabricator for quotations. The fabricator will supply structural steel shop drawings or detailing which include pictorial descriptions of how to install the steel members. Once approved by an engineer, the drawings become part of the construction drawings. The fabricator also figures a quantity take off for main steel members, details, and miscellaneous items, and determines the costs for fabricating, welding, priming, overhead, and profit. The structural metal includes columns, beams, trusses, joists, lintels, bearing plates, girders, purlins, decking, bracing, tension rods, and any other items required. The quotation submitted to the general contractor for inclusion into the bid will typically contain not only the fabricated products but also the cost of transporting the products to the project. However, some fabricators may not have the ability to produce all the required metal sections due to such common restrictions as overall size, length, and weight of a structural piece. The choice of metal might also prove restrictive. For instance, aluminum is generally difficult to weld and requires a trained and certified craftsperson. In addition, individual pieces may be unprofitable to build in some shops, so the fabricator may exclude these items during the bidding. Therefore, a general contractor must be sure to include any left-out items and add them into the estimate and, most important, find a fabricator to determine a price in a timely fashion.

10.1.3 Basic Materials

Basic erection materials and selected construction methods influence project costs. Basic materials include metal connectors or fastenings and other miscellaneous items excluded in structural metal framing, metal joists, metal decking, cold-formed metal framing, and metal fabrications. Metal fastenings include anchor bolts, bolts and hex nuts, drilling expansion anchors and shields, high-strength bolts, screws, rivets, vibration pads, weld shear connectors, studs, rods, and so on. Nuts, bolts, washers, connection angles, and plates can increase the total steel weight by a significant amount, and thus greatly affect the estimated costs. The estimator can apply a rule of thumb that the estimated weight of these accessories is up to 10% of the total estimated steel weight. Some costs of basic materials are provided in Table 10.13.

Miscellaneous metals are used to support other structural building components for connection, protection, and aesthetic purposes. Miscellaneous metals can be used to connect concrete or masonry to wood or steel, wood to steel, or steel to steel and include metal fabricated hangers, clips, connectors, and gussets. Typical connections for structural metal framing are welding, bolts, and rivets. Welding is a fusion process for establishing a chemical bond between two pieces of metal. The bond is created by melting the surfaces of the metal pieces, generally while filling melted metal from an electrode into a gap and allowing it to solidify. A bolt is a metal pin or rod used for fastening pieces together. It generally has a head at one end, a screw thread at the other end, and is secured by a nut. A rivet is a headed bolt or metal pin used for connecting objects by passing it through a hole in both pieces, and then beating and pressing down the plain end to form a second headed end. Some miscellaneous metals used to guard other components are corner guards, handrails, fences, and bollards. Miscellaneous metals used for aesthetic purposes include decorative tubular and malleable wrought-iron work.

10.1.4 Metals Checklist

The Metals division is one of the most complicated for an estimator regarding quantity take off and pricing. There are many different items within this division and each individual fabricator and subcontractor will provide only a part of the work specified for this division. This requires the estimator to know the complete scope of work within this division and make a detailed comparison among all the companies quoting for the work. Sometimes the general contractor will not receive any coverage on some items, so the estimator needs to determine the missing items and conduct the estimate based on individual pricing. In addition, unclear information regarding furnishes and installations can confuse the estimation process. The estimator needs to ensure whether the obtained quotes are for "furnish only," "install only," "furnish and install," or "not furnish and not install." Equally important, the estimator needs to price unfamiliar materials as well as determine labor costs excluded in the quotes. The estimator, therefore, should have a detailed checklist in order to perform a decent estimate for metals. A sample metal checklist is provided below:

1. *Contract*: self perform, subcontract;
2. *Shapes*: sections, lengths, quantities, weights, locations, fasteners;

3. *Engineering*: fabrications, shop drawings, shop painting, testing, inspection, unloading–loading, erection;
4. *Furnish and install*: furnish only, install only, furnish and install, not furnish and install;
5. *Connections*: riveting, welding, bolts, bracing (cross and wind);
6. *Fabrications*: metal stairs, ladders, handrails and railings (pipe and tube), gratings and floor plates, castings;
7. *Ornamental*: stairs, prefabricated spiral stairs, handrails and railings, sheet metal, metal castings;
8. *Expansion control*: expansion joint covers, slide bearings, assemblies;
9. *Miscellaneous*: plates, anchor bolts, hangers, clips, rods, ties, painting.

10.2 STRUCTURAL METAL FRAMING

10.2.1 Types of Structural Metal Framing

In building construction, structural metal framing is composed of several structural steel components, sometimes in combination with other materials such as structural aluminum and wire rope assemblies. Structural steels used for the framing of a building are generally standard pieces rolled in a variety of shapes. They are produced at large manufacturing plants and shipped to the shop for fabrication into columns, girders, beams, lintels, and other major structural components. The most common shapes of steel are wide-flange (W, WF) beams, I-beams, S-beams, H-columns, channels, bearing plates, and angles as shown in Figure 10.2. These shapes are standard mill pieces and are considerably cheaper than special shapes or composite members requiring extensive fabrication. Wide-flange shapes are most commonly used as floor beams and are coded. For instance, W 460 $\times$ 52

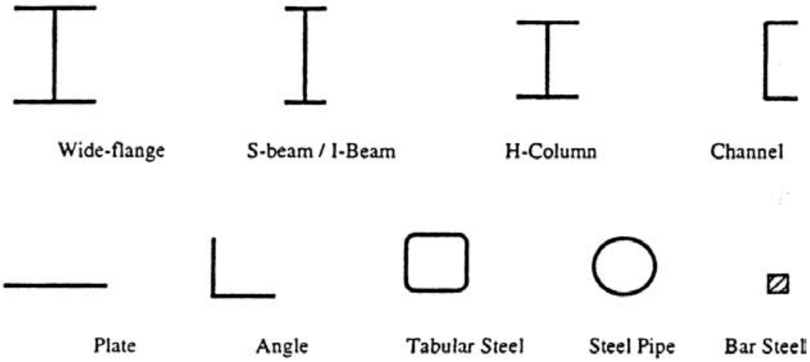


FIGURE 10.2 Common steel shapes.

refers to wide-flange steel with a nominal depth of 460 mm (actual depth 450 mm), and a nominal weight of 52 kilograms per linear meter. Figure 10.3 shows typical drawing designations of steel members. I-shaped or S-shaped steel is generally used for spandrel beams at an exterior wall and are similarly coded. For instance, the notation S 310 × 47.3 represents I-shaped steel with a nominal depth of 310 mm and a weight of 47.3 kilograms per meter. The major difference between the wide-flange beam and the I-beam is the width of the flange. The flange of a wide-flange beam is wider than the flange of an I-beam. Other common standard shapes are C channels and L angles. The notation C 200 × 9.7 means that the depth of the C-channel steel is 200 mm, and the weight is 9.7 kilograms per meter. The notation L 152 × 89 × 9.5 denotes L-angle steel with arm lengths of 152 and 89 mm, and a thickness of each arm as 9.5 mm.

Structural steel shapes, however, can be made from various steel types. Common structural steels can be classified into several types with the most common ones being ASTM A36, A585, and A242. As shown in Table 10.2, each type has one or more minimum yield stresses based on its production and raw materials used during its production. Among them, ASTM A36 steel, known as all-purpose carbon-grade steel, is the most common one. It is widely used in building construction due to its light weight and economic advantages. However, other types may have certain advantages over ASTM A36 steel depending on their applications. ASTM A242 steel with its fine qualities of corrosion resistance, high strength, and low alloy has increased atmospheric corrosion resistance more than twice that of ASTM A36 steel with copper. To provide the greatest protection from oxidation, ASTM A588 steel with its weathering resistance, high strength, and low alloy can be used in exposure conditions to allow a tightly adherent oxide to form on the steel surface. Nowadays, high-strength steels have become popular in building construction due to the overall savings they provide from reduced weight and proper use.

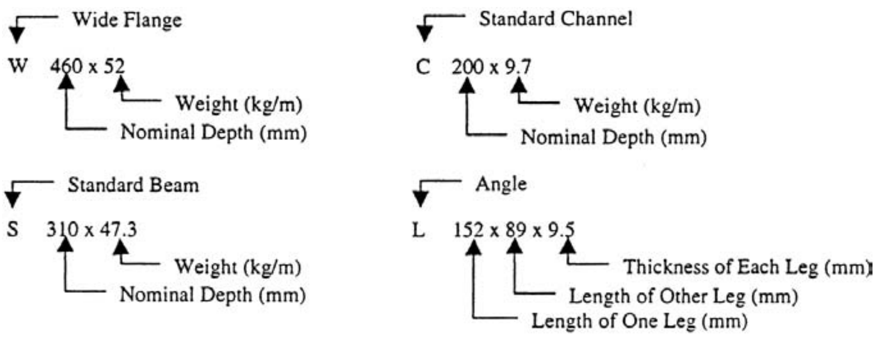


FIGURE 10.3 Typical drawing designations.

Table 10.2 Common Structural Steel Specifications for ASTM Types

Steel type	ASTM designation	Minimum yield stress (MPa)
Carbon	A36	250
	A529	290
		275
		290
		315
High-strength low-alloy manganese–vanadium	A441	345
		290
		345
		415
High-strength low-alloy columbium–vanadium	A572	450
High-strength low-alloy columbium–vanadium	A992	345
		290
		315
Corrosion-resistant high-strength low-alloy	A242	345
		290
		315
Weathering high-strength low-alloy	A588	345
Quenched and tempered low-alloy	A852	485
		620
Quenched and tempered alloy	A514	690

Source: Means, 1999.

Along with other essential information, steel shapes and types are usually provided in specifications that allow the estimator to determine their cost. Most specifications require shop drawings on the items to be made, along with their connection requirements, installation processes, and drawings of the fastening details. Specifications also provide information regarding coating and painting to be applied in the shop or field. The general contractor not only performs the cost estimate but also acquires quotes in pre-bid proposals from fabricators and subcontractors. The general contractor's estimate contains all cost items included in the scope of the work, whereas the subcontractor's quotes usually focus on just those items that will be provided by the fabricator. The general contractor's estimator can then prepare sheets for analyzing the different quotes, continue take off calculations, and finally price the work.

10.2.2 Structural Metal Framing Construction

Steel construction typically involves the use of field-bolted connections with lateral bracing supported by other elements of the buildings, such as x-bracing and masonry walls. Shop connections can be accomplished by welding or bolting. Some fabricators may have particular methods for fabrications and installations that can affect quotes. Table 10.3 shows a variety of productivity rates for erecting structural steel; however, this information does not include final bolting or welding costs. A typical crew of steel erectors or ironworkers varies from five to eight or more persons. Sometimes the crew has additional individuals who bolt or weld the connections. Table 10.4 shows typical crews arranged for structural metal construction as considered by Means (1999) for unit price calculations.

In structural steel building construction, the anchor bolts are installed in the concrete foundations and the bases for the columns are placed above the foundations by suitable means. These means generally involve steel shims and steel wedges used to permit the bases to be set at the required elevations and grouted to these elevations. The structural steel columns are then erected and the beams installed for the first tier of floors, which is usually two floors. If a power or tower crane is used to hoist the members, a typical crew size of eight is required. One ironworker will hook the lifting line to the structural members to be lifted while another four will make the temporary and permanent bolt connections. The connections between the columns and the beams are temporarily bolted through holes. After the tier of columns and beams is in place, the structure is

TABLE 10.3 Approximate Rates of Erecting Structural Steel[a]

Structure type	Equipment type	Crew size	Crew-hour/ton
Roof trusses			
Up to 1200 lb	Crane	5	1.6
1200–2400 lb	Crane	5	1.3
2400–3600 lb	Crane	5	1.0
3600–4800 lb	Crane	6	0.8
4800–6000 lb	Crane	6	0.7
Purlins and braces	Crane	5	1.2
Framed steel structures			
Up to 4 stories high	Crane	7	0.5
Up to 8 stories high	Tower crane	7	0.5
8 to 18 stories high	Tower crane	8	0.5
Mill buildings, factories, etc., columns and beams	Crane	6	0.8
Churches, theaters, etc.	Crane	5	1.2
Plate girders			
5–10 tons	Crane	6	0.4
10–20 tons	2 Cranes	8	0.3

[a] Excluding final bolting or welding.
Source: Peurifoy and Oberlender, 1989.

TABLE 10.4 Typical Crews for Structural Metal Construction

Crew no.	Bare costs ($) Hour	Bare costs ($) Daily	Including subs O&P ($) Hour	Including subs O&P ($) Daily	Bare cost/ Labor-hour ($)
Crew E-2					
1 Structural steel foreman	33.70	269.60	61.70	493.60	30.72
4 Structural steel workers	31.70	1014.40	58.05	1857.60	
1 Equipment operator (crane)	29.90	239.20	45.40	363.20	
1 Equipment oiler	24.65	197.20	37.45	299.60	
1 Crane, 82 metric ton		1022.00		1124.20	18.25
56 Labor hours, daily totals		########		4138.20	48.97
Crew E-4					
1 Structural steel foreman	33.70	269.60	61.70	493.60	32.20
3 Structural steel workers	31.70	1014.40	58.05	1393.20	
1 Gas welding machine		84.00		92.40	2.63
32 Labor hours, daily totals		########		6117.40	83.80
Crew E-7					
1 Structural steel foreman	33.70	269.60	61.70	493.60	31.22
4 Structural steel workers	31.70	1014.40	58.05	1857.60	
1 Equipment operator (crane)	29.90	239.20	45.40	363.20	
1 Equipment oiler	24.65	197.20	37.45	299.60	
1 Welder foreman	33.70	269.60	61.70	493.60	
2 Welders	31.70	507.20	58.05	928.80	
1 Crane, 82 metric ton		1022.00		1124.20	
2 Gas welding machines		168.00		184.80	14.88
80 Labor hours, daily totals		########		5745.40	46.10

Source: Means, 1999.

plumbed before installing the permanent bolts. This operation is repeated for succeeding tiers until the erection of the structure is completed.

After the structural members are completely installed, roof trusses can be erected. One or two workers are required at each end of the truss to secure it to the supporting structure with bolts. An additional one or two workers may be required to help move the ends of the trusses into the desired position before bolting. Some or all of the purlins should be attached to the trusses to provide rigidity as soon as possible. Temporary bolting and purlins are required to rigidly support the trusses. After the trusses are erected and plumbed, two or more ironworkers can permanently bolt the connections and one or more helpers may be required for assisting the crew with tools and connecting bolts. For bolted connections, the fabricating operations include cutting. purchasing, milling, planning, and marking each member. Similarly, for erecting steel structures with welded connections, the same general procedure is followed as for erecting structures with bolted connections. Some holes are punched at noncritical points of the structural members so temporary bolts can be installed prior to welding. Ironworkers can start welding the structural members after they are placed in the correct position. A definite pattern for welding is specified and strictly followed to eliminate distortion in the structure. For example, if beams are to be welded to opposite flanges of a column, the two welds should be conducted simultaneously to prevent unequal heating of the two sides of the column. For welded connections, the fabricating operations include cutting, some punching for temporary bolt connections, milling, beveling, planning, and shop welding. In many circumstances, coats of field painting are also applied with spray guns.

10.2.3 Cost Items in Structural Steel Estimation

Due to the fact that this division involves a number of project participants, construction methods, and equipment, several cost items must be determined in preparing a comprehensive detailed estimate for a steel structure. Some major cost items in structural steel estimation are listed below, followed by a longer explanation of each:

1. Purchasing structural steel shapes;
2. Transporting prefabricated metal;
3. Fabricating finished members;
4. Transporting finished members;
5. Erecting steel members;
6. Painting the steel structure; and
7. Paying overhead.

10.2.3.1 Purchasing Structural Steel Shapes

The initial purchasing of the steel shapes includes the basic cost of the metal at the mill or warehouse, plus possible extra charges for sizes and sections. There may also be charges for small quantities or quantity discounts for large orders. The basic price per ton of the structural shapes varies from one mill to another with the size and weight of the shape and the required quantity. A list of the extra charges can be obtained from mills that produce structural steel shapes. Extra charges for quantity are also added to the basic price and are generally determined by the theoretical cost of the individual size, total weight, grade, thickness of a structural section ordered of one grade on the same order, and quantity for one mode of shipment to one destination at one time. Structural steel prices typically change very often, so the estimator should always request an updated price list from mills and warehouses. According to Means (1999), in 1999, ASTM A36 carbon structural steel had a mill base price of $553 per ton

TABLE 10.5 Extra Charges for Sizes and Sections

Shapes	Size (mm)	Weight (kg/m)	Size extra/ton ($)
Wide flange	W 360	677–1192	$137
	W 360	216–634	22
	W 360	33–196	0
	W 250	167–180	0
Standard beams	S 610	119–180	154
	S 510	98–143	154
	S 460	81–104	88
	S 310	47–74	88
	S 250	38–52	88
	S 200	27–34	88
	S 150	19–26	88
Standard channels	C 380	50–74	66
	C 310	31–45	66
	C 250	17–28	66
	C 180	15–22	66

Source: Means, 1999.

with extra size charges ranging from $0 to $155. Table 10.5 shows samples of extra charges over the base price for major structural steel shapes. Table 10.6 presents extra charges for different quantities of structural steel.

10.2.3.2 Transporting Prefabricated Metal

One of major items added to the base price of metal is the cost of shipping from the rolling mill to a fabricating shop by truck, train, or ship. This item primarily depends on the location of the mill where the steel is purchased. In some circumstances, steel shapes are purchased from warehouse stocks that generally cost approximately $0.10 to $0.35 per kilogram more than those from mills. Referring to Walker (1999), the average cost of freight or trucking for steel from a rolling mill is $44 per ton.

10.2.3.3 Fabricating Finished Members

The cost of fabrications is generally composed of costs for preparing shop drawings and details for shop fabrication, fabricating the steel into finished members, shop painting, and shop overhead and profit. The cost of overhead and profit may range from 15 to 25% depending upon the quantity of the order. The sum of the costs for the steel, transportation, and fabrications produces the total cost of structural members from the fabricating shop. An additional cost for making shop drawings and details for shop fabrication is incurred when the engineer and architect do not furnish drawings in sufficient detail for the shop to fabricate the mem-

TABLE 10.6 Extra Charges for Quantity of Structural Steel

Quantity (ton)	Extra charge/ ton ($)
4.54 and over	None
2.72–4.53	7
1.81–2.71	12
0.91–1.80	18
0.45–0.90	61
under 0.45	110

Source: Means, 1999.

bers. This cost is based on the complexity of the detailing and the number of drawing sheets required. Also, the cost per unit weight varies significantly depending upon the type of building, weight of steel, quantity of steel members, and so on. The drawings show that the cost per ton for lightweight members (such as roof trusses) is generally high compared to heavy members (such as large beams). This is due to the fact that the construction of lightweight members requires extensive detailing without involving much tonnage. The unit cost also varies based on the quantity of fabricated members required. The smaller the amount, the higher the shop drawing cost is per ton. According to Walker (1999), shop drawings are usually prepared on 600×900 mm sheets, and the cost of preparing one drawing sheet may vary from $300 to $500.

Cost of assembling and fabricating steel shapes into finished products varies significantly with the operations performed, sizes of the members, quantity of members required, and extent to which the operations are duplicated or similar members are used. The finished members include structural members (such as columns, girders, beams, trusses), and all necessary items used in connection with these items. The unit cost of fabricating lightweight steel members is typically higher than for heavier members. The average cost is approximately $264 per ton.

Applying one or more coats of paint after the completion of fabricating is typically required in specifications, except when steel is to be embedded in concrete. The cost of applying a coat of shop paint to structural members is typically estimated as cost per ton of structural steel. The average surface per ton of structural members ranges from 16 to 21 m^2, and ordinary structural beams, plate girders, and trusses range from 20 to 26 m^2 per ton, 11 to 17 m^2 per ton, and 25 to 31 m^2 per ton of steel, respectively. A gallon of paint can cover about 35 to 45 m^2 of surface or 1.8 tons of steel when spray guns are used to apply the paint. One painter can use a spray gun to paint approximately 1 to 2 tons (18.5 to 37.0 m^2) per hour, depending on the size and complexity of sections. According to

Walker (1999), the estimated labor cost for one shop coat of spray paint to one ton of steel is $26.83 per hour, and it takes about 0.76 hours for one painter to spray one ton, thus resulting in the total labor rate of $20.40 per ton.

10.2.3.4 Transporting Finished Members

The cost of transporting structural steel from the fabricating shop to the job varies depending on the quantity of steel, weight of steel members, transportation method, and distance of delivery. A truck can haul about 20 tons per load. When transporting steel by a combination of railroads and trucks, an intermediate handling is considered. The estimator, therefore, should determine the freight or truck cost per ton for any particular job. According to Walker (1999), the average cost of hauling structural steel is $34 per ton.

10.2.3.5 Erecting Steel Members

Expenses for erecting structural members can be classified into three categories: equipment rental for erecting the steel, labor cost for erecting structural members, and labor cost for field connections. In building construction, estimating the field cost of handling and erecting structural steel is challenging for numerous reasons, such as weather conditions, delays in materials delivery, labor conditions, strikes, lack of storage facilities, and equipment availability. Equipment used for erecting steel structures depends on the type of structure, the size of the structure, the size of the structural members, and the location. Steel frames may be erected with cranes for buildings of up to four stories. For higher buildings, steel members may be placed with tower cranes or guy derricks. Roof trusses are typically delivered to the job partially or completely assembled. At the jobsite, it is recommended that they be hoisted into place directly from the delivery truck by power cranes. The cost of labor for erecting structural steel varies with the type of structure, the kind of equipment used, the sizes of the structural members, the types of connections, and the wage rates at the project location.

10.2.3.6 Painting the Steel Structure

Applying coats of paint to structural steel in the field is sometimes required. Two field coats are typically applied with a spray gun. A painter can paint 3/4 to 1-1/2 tons per hour depending upon the structural member types and sizes. Roof trusses generally require higher painting costs than structural steel frames because of a greater area of steel per ton and the difficulty in painting.

10.2.3.7 Paying Overhead

Subcontractor overhead, general overhead, insurance, taxes, and profit may vary considerably from one project to another, ranging from 15 to 60% of the direct cost of a project.

10.2.4 Costs of Labor, Materials, and Equipment for Metal Framing

The previous section discussed several cost items of metal framing and how these costs can vary based on numerous factors such as steel shapes, sizes, and quantities of materials required, operations performed, and the job location. Table 10.7 presents several cost items which are average numbers at a certain time frame, but for which different mills or fabricating shops can have different figures. However, this table provides a simple process for determining the costs to obtain the price of structural steel delivered at the jobsite. It includes cost items 1 to 4 as stated previously.

Based on Means (1999), Table 10.8 shows the general average costs of structural steel. This table indicates that the total bare installation cost is $385 per ton. Table 10.9 presents average costs of labor, material, and equipment for metal framing, also based on Means (1999).

TABLE 10.7 Fabrication (Shop) Cost for Metal Framing

Cost items	Price/ton ($)
1. Structural shapes	
Base price of steel, f.o.b. Pittsburgh or Chicago	553.40
Extras	63.80
2. Handling metals	
Freight or trucking on steel from rolling mill	44.00
Shop handling charge which includes unloading steel from cars or trucks upon arrival and loading cars or trucks after fabrication	27.60
3. Fabrications	
Shop drawings, cost varies $30–60 per ton	66.60
Shop labor and fabrication costs (varies according to operations required)	264.00
Tonnage charges	
Painting structural steel in shop	20.40
Handling structural steel in shop	16.60
Cutting structural shapes to lengths	24.40
Total direct shop cost	1080.80
Business administration, overhead, sales expense, 20%	216.16
Total direct shop cost and overhead	1296.96
Profit on total cost, including overhead, 10%	129.70
Total direct shop cost, overhead, profit	1426.66
4. Transportation from shop to job, varies	44.00
Price of structural steel, delivered at job	1,470.66

TABLE 10.8 General Average per Metric Ton in Place for A36M Steel[a]

Items	Cost items	Bare costs: Itemized ($)	Bare costs: Summary ($)
Material costs	Base price for A36M steel	365	1325
	Extras and delivery to shop (with common bolts)	155	
	Drafting	100	
	Shop fabrication and warehouse rehandling	540	
	Shop coat paint	65	
	Trucking to jobsite	100	
Instruction costs	Unload and shake-out, 1.3 hrs @31.70	39	385
	Erect and plumb, 6.2 hrs @31.70	197	
	Field bolt, 2.2 hrs @31.70	69	
	Crane and minor erection equipment (including operator and oiler) (18.2 tons/day)	80	
	Total per metric ton in place	1710	1710

[a] High-strength steel base price may be substituted.
Source: Means, 1999.

10.2.5 Cost Estimation for Metal Framing

The steps for estimating metal framing include taking off the quantities from the plans, computing the weights of various sections, making the shop drawings and detailing the steel, and estimating the cost of shop fabrication, freight, trucking, and erecting the steel on the job. Quantity take off may have a definite sequence composed of columns and details, beams and details, and bracing and flooring. A complete take off floor by floor is required. Using specifications and other contract documents, the estimator needs to have a complete list of all structural steels, ornamental metals, and miscellaneous metals for the project. Each class of work such as columns, girders, and trusses should be kept separate since each involves different labor operations in fabrication and erection. Special shapes and composite members require extensive fabrications, so they should be listed separately from the standard mill shapes. One of the most important aspects of an estimate is to know which work items are subcontracted. In some circumstances, the general contractor may subcontract the metal work with fabrications and installations to specialty contractors. The estimator must also create a list of all those items on the drawings not identified in the specifications. In addition, the estimator pays attention to numerous miscellaneous items such as bearing plates, loose lintels, and anchor bolts. All standard connections for detailing can

Table 10.9 Costs of Labor, Materials, and Equipment for Metal Framing

Code 05120	Structural steel	Crew	Daily output	Labor (hrs)	Unit	Bare cost ($) Mat.	Labor	Equip.	Total
300-0005	Curb edging								
300-0100	Steel angle w/anchors, on forms, 50 mm × 50 mm, 5.8 kg/m	E-4	101	0.317	m	11.4	10.2	0.83	22.43
300-0300	100 mm × 100 mm angles, 12.2 kg/m	E-4	83.82	0.382	m	23.5	12.3	1	36.80
300-1100	Steel channels with anchors, on forms, 100 mm, 8 kg/m	E-4	82.30	0.389	m	14.95	12.5	1.02	28.47
300-1300	200 mm channel, 17 kg/m	E-4	68.58	0.467	m	31	15	1.23	47.23
560-0010	Plates structural steel								
560-2300	1.2–1.5 m wide, 3–8 m long, 4.5–5 tons, mill pieces, 3/4 in. thick				ton	785			785
560-2400	2 in. thick				ton	785			805
640-0010	Structural steel members								
640-0740	Shop fabricated for 1–2 story bldg., bolted conn's., 91 tonnes, W250 × 49 [W10 × 33]	E-2	168	0.333	m	65	10.25	6.10	81.35
640-0900	W250 × 73 [W10 × 49]	E-2	168	0.333	m	97	10.25	6.10	113.35
640-1900	W360 × 39 [W14 × 26]	E-2	302	0.185	m	52	5.70	3.38	61.08
640-2700	W410 × 39 [W16 × 26]	E-2	305	0.184	m	52	5.65	3.35	61
640-2900	W410 × 46 [W16 × 31]	E-2	274	0.204	m	61	6.30	3.73	71.03
640-3100	W460 × 60 [W18 × 40]	E-2	293	0.273	m	78.5	8.50	3.78	90.78

Source: Means, 1999.

be referred to in the American Institute of Steel Construction (AISC) standards, with the exact lifting methods.

During the take off for metal framing, the estimator can use drawings, along with the specifications, to measure and record the quantity, shape, size, length, and details of the required items, and then determine the probable weight of various sections using steel manuals from manufacturers or warehouses. Structural metals are purchased by the ton, and the cost per ton varies depending upon the type and shape required. Several structural steel handbooks provide the nominal weights of steel sections, where weight variations of 2.5% above or below the nominal weights are permissible and may occur. However, the actual weight of the structural steel is what is measured and charged, rather than the nominal weight. The weight of the details for connections should be determined and priced separately. The list of steel prices obtained from the mill or warehouse is then used to determine the total cost of the structural steel before fabrication.

Based on her own estimated cost, the general contractor reviews the quotes from subcontractors or fabricators for subcontracted work. The estimator of the general contractor should have a list of all items in this division. This checklist is needed to ensure that the estimate is complete and that the estimator can compare different quotes from several subcontractors using the same list. The list not only contains all work to be done under this division, but also space that allows for the noting of any addendum requirements. Samples of noting are whether sales tax will be included or excluded, and whether materials are furnished and installed. The estimator needs to identify items not to be furnished or items outside the scope of the metal division. Also, the estimator needs to ensure that the prices are based on the installation, or furnished only, or both. On the bid day, the general contractor will, most of the time, receive multiple quotes from specialty contractors. All information is crucial for the comparison and analysis that the estimator will be doing on the various quotes.

The estimator needs to compare items that subcontractors have quoted. In most cases, the estimator will find that more than 80% of the work will be at the same cost. After making comparisons, the estimator should contact each subcontractor to clarify the individual quotes. Many estimators will have a checkmark placed next to the items that are obvious and do not need confirmation or clarification. Prior to bid submission, the estimator needs to call subcontractors or fabricators to clarify any unchecked items that are either in the original quote or are outside the scope of the project.

10.2.6 Computation Example for Metals Cost Estimation

Figure 10.4 shows a floor and roof framing plan for a two-story light-factory building and Figure 10.5 shows a column schedule for the same project. All

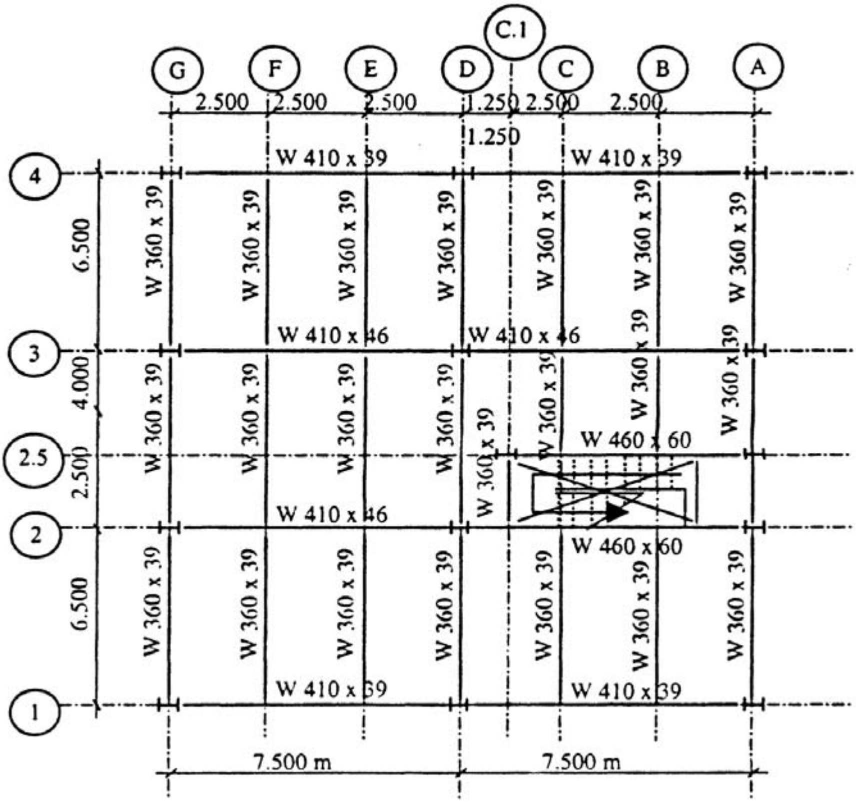


FIGURE 10.4 First and second floor and roof framing plan.

structural steel framing members are A36 wide flange shapes with bolted connections and their materials cost and associated costs, extra charges, and shop fabrication costs are provided in previous sections. The cost of transporting the steel from the rolling mill to the fabricating shop is $44 per ton and from the shop to the jobsite is $50 per ton. The shop handling charge is $28 and includes unloading the steel from the train cars or trucks upon arrival and loading the train cars or trucks after fabrication. The cost of preparing the shop drawing and details for shop fabrication is estimated at $40 per ton. The cost of shop painting is $22 per ton, shop overhead is 20%, and profit is 10%. According to Table 10.9, what are the costs of labor, material, and equipment for the structural steel shapes, including fabrication? What is the final price of the structural steel framing delivered to the jobsite?

COLUMN / LEVEL	A-1	A-2	A-2.5	A-3	A-4	C.1-2.5	D-1	D-2	D-3	D-4	G-1	G-2	G-3	G-4
ROOF														
SECOND FLOOR (3.000mm height)	W250 x 73	W250 x 73	W250 x 49	W250 x 73	W250 x 73	W250 x 49	W250 x 49	W250 x49	W250 x 49	W250 x 49	W250 x 49	W250 x 49	W250 x 49	W250 x49
FIRST FOOR (3.000mm height)														
BASE PLATE SIZE (3/4" thick)	350x350	350x350	300x300	350x350	350x350	300x300	300x300	300x300	300x300	300x300	300x300	300x300	300x300	300x300
BASE PLATE TYPE	A	A	B	A	A	B	B	B	B	B	B	B	B	B
FUTURE COLUMN EXTENTION	X	X		X	X									
ANCHOR BOLTS (300mm long)	6 - 25dia	6 - 25dia	4 - 19dia	6 - 25dia	6 - 25dia	4 - 19dia	4 - 19dia	4 - 19dia	4 - 19dia	4 - 19dia	4 - 19dia	4 - 19dia	4 - 19dia	4 - 19dia

Note: 6 - 25dia refers to 6 anchor bolts that have a 25mm diameter.

FIGURE 10.5 Column schedule.

Step One. Perform the quantity take off by determining the total length of the structural steel framing members including beams and columns. Then compute the weights of various sections and figure the total weight of the steel. Figure 10.6 shows sample calculations. The total weight of the structural steel is 31.94 tons.

Step Two. Determine the costs of labor, materials, and equipment for the structural steel framing members. Table 10.9 shows these costs by steel member length in meters based on Means (1999) data. Figure 10.7 presents the calculation for estimating steel and fabrication costs. The estimated total cost of materials, labor, and equipment (including fabrication) is $49,929.

Step Three. Determine the total final price of structural steel framing delivered to the jobsite. Based on the assumptions provided, the total final price is $71,554, as shown in Table 10.10.

10.3 METAL JOISTS

10.3.1 Types of Metal Joists

In many construction projects, standard and long-span metal joists have recently replaced wood and fire-resistant construction due to their strength and fire resistance. Steel joists are not fabricated by a traditional steel fabricator; instead they are manufactured by a supplier specializing in the production and design of steel joists. Steel joists are generally used for floor and roof construction. To obtain the required fire rating, steel joists are used with a combination of a 50 to 65 mm reinforced concrete slab on top of the joists and a fire-resistant suspended ceiling of gypsum board or plaster underneath the joists. When a concrete slab is not used, steel joists can be used in semifireproof construction by nailing the wood sheathing to nailers secured to the joists. For industrial construction, steel joists are used to replace structural steel roof purlins giving an economic advantage in materials savings. The most common metal joist is the open web joist, as shown in Figure 10.8, or the prefabricated lightweight truss that can be used in light-occupancy buildings construction. Newer types of steel joist construction are available, such as the modular steel joist system bolted and/or welded to other modular joists to make a solid exposed system to support the roof. These joists, however, are not commonly used in typical building structures. This section therefore focuses only on the open web joist.

Open web joists are also common in large flat-roof construction for industrial and some commercial applications. They are constructed from a combination of structural gauge angle iron for the top and bottom chords and from solid bent steel joist or tabular steel pieces welded and/or bolted to the chord members that are made from either hot-rolled structural sections or cold-formed sections. The chord members can be made using several steel shapes including angle, pipe,

Quantity Take Off

Date

Sheet No. 1 Of

Project Title ______________________ Project No. ______________________

Take Off By ______________________ Approved By ______________________

Code*	Description	No.	Dimensions L	Unit	Length	Unit	Unit	Weight	Unit
	COLUMNS								
05120-640-0700	W 250 × 49	10	6	m	60.0 × 49 kg/m =		ton	2.94	
05120-640-0900	W 250 × 73	4	6	m	24.0 × 73 kg/m =		ton	1.75	
	BEAMS								
05120-640-0600	W 360 × 39	19 × 3 levels	6.5	m	370.5				
		2 × 3 levels	4.0	m	24.0 } 402 m. total		ton	15.678	
		1 × 3 levels	2.5	m	7.5				
05120-640-0620	W 410 × 39	4 × 3 levels	7.5	m	90.0		ton	3.51	
05120-640-0740	W 410 × 46	3 × 3 levels	7.5	m	67.5		ton	3.105	
05120-640-1900	W 460 × 60	2 × 3 levels	13.75	m	82.5		ton	4.95	
							ton	31.94	

* Masterformat, Uniformat, WBS, other, etc.

FIGURE 10.6 Quantity take off for structural steel members.

Company Logo	Pricing	Date	Sheet No.	Of

Project Title ____________ Project No. ____________

Take Off By ____________ Approved By ____________

Code*	Description	Quantity	Unit	Material U.P.	Material Total	Labor U.P.	Labor Total	Equipment U.P.	Equipment Total	Subcontract U.P.	Subcontract Total	Total U.P.	Total
	COLUMNS												
05120-640-0740	W 250×49	60	m	65	3,900	10.25	615	6.1	366				4,881
05120-640-0900	W 250×73	24	m	97	2,328	10.25	246	6.1	146				2,720
	BEAMS												
05120-640-0600	W 360×39	402	m	52	20,904	5.7	2,291	3.38	1,359				24,554
05121-640-0620	W410×39	90	m	52	4,680	5.65	508	3.35	302				5,490
05120-640-0740	W 410×46	67.5	m	61	4,118	6.3	425	3.73	252				4,795
05120-640-1900	W 460×60	82.5	m	78.5	6,476	8.5	701	3.78	312				7,489
	SHEET TOTAL				42,406 (MATERIAL)		4,786 (LABOR)		2,737 (EQUIPMENT)		(SUBCONTRACT)		49,929 (TOTAL)

* Masterformat, Uniformat, WBS, other, etc.

FIGURE 10.7 Pricing of structural steel framing members.

Table 10.10 Pricing for Fabricated Structural Steel Delivered at Jobsite

Cost items	Price/ton ($)	Quantity (ton)	Cost ($)
1. Structural shapes			
Base price of steel (from detailed calculations)	1,563.70	31.93	49,929.00
Extra charge for size and section (included in 1.1)	0.00	31.93	0.00
Extra charge for quantity (included in 1.1)	0.00	31.93	0.00
2. Handling metals			
Freight or trucking on steel from rolling mill	44.00	31.93	1,404.92
Shop handling charge which includes unloading steel from cars or trucks upon arrival and loading cars or trucks after fabrication	28.00	31.93	894.04
3. Fabrications			
Shop drawings	40.00	31.93	1,277.20
Shop labor and fabrication costs (included in 1.1)	0.00	31.93	0.00
Painting structural steel in shop	22.00	31.93	702.46
Total direct shop cost	1,697.70		54,207.62
Business administration, overhead and sales expense, 20%	339.54		10,841.52
Total direct shop cost, overhead	2,037.24		65,049.14
Profit on total cost, including overhead, 10%	203.72		6,504.91
Total direct shop cost, overhead, profit	2,240.97		71,554.06
4. Transportation from shop to job			
Transporting structural steel	50.00	31.93	1,596.50
Price of structural steel, delivered at job	2,240.97		71,554.00

and channel. Due to their structural strength, open web steel joists are made to span as long as 60 m without additional support. They also facilitate the installation of plumbing, conduits, and other installations requiring a furred ceiling or heavy fills on top of the structural slab. There are five basic series of open web steel joists: K (horizontal bridging) spanning up to 15 m, CS (horizontal bridging) spanning up to 10 m, LH (bolted cross bridging) spanning up to 30 m, DLH

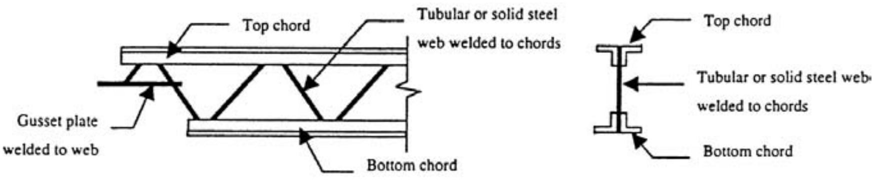


Figure 10.8 Open-web steel joists.

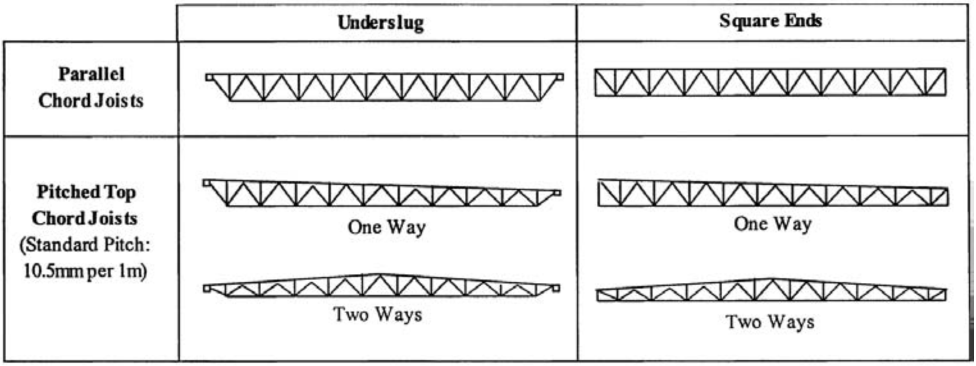


FIGURE 10.9 Typical steel joists in building construction.

(bolted cross bridging) spanning up to 45 m, and SLH (bolted cross bridging) spanning up to 60 m.

To find the weight per linear meter of steel joists, the estimator can refer to *Sweets Catalog* or a manufacturer's catalogue. To avoid obtaining the weight per meter, the estimator can directly find material, labor, and equipment costs of standard steel joists, not fabrication costs, from Means (1999). Specifications in building construction list the type of joists required, along with the type of attachments, finishes, and accessories. Accessories that may be specified are bridging, ceiling extensions, masonry wall anchors, bridging anchors, and header angles. Many specifications require industry standards to be met for strength, types of steel used in the joists, erection and attachment techniques, and finishes. There are various shapes of open web steel joists in building construction. Figure 10.9 shows typical shapes of steel joists for different applications. Several pitched top chord joists are used for roof applications, and parallel chord joists are used for floor and roof applications. Further information on the types of steel joists and how to bridge and connect joists is available from the Steel Joist Institute and joist manufacturers.

10.3.2 Costs of Labor, Materials, and Equipment for Metal Joists

The cost of standard steel joists varies depends upon several factors such as the quantity of joists ordered, size and length of the joists, and job location. According to Walker (1999), the cost of standard joists for an average job is approximately in the range of $650 to $800 per ton including nominal bridging members and other accessories, and the cost of long span steel joists ranges from $580 to $750 per ton including accessories. Similarly, labor cost for handling and setting steel joists varies significantly depending on several factors including the building type, size and length of joists, amount of handling and hoisting required, and equipment used. Generally, the labor cost for long span and large floor areas, such as garages, offices, and factory buildings, is considerably cheaper than that for small and irregular buildings. According to Walker (1999), the cost of joist erection, including the placement of accessories, varies from $150 to $250 per ton excluding materials costs. This cost is primarily based on labor conditions, location, and type of buildings. For an ordinary job, a crew of five ironworkers can handle and place about 4 to 4.5 tons of joists (including bridging) per eight-hour day. For an irregular job, a crew of five ironworkers should handle and place about 3 to 3.5 tons of joists (including bridging) per eight-hour day. Table 10.11 shows national average costs of labor, materials, and equipment for metal joists based on Means (1999).

10.3.3 Metal Joists Cost Estimation

Steel joists and related products are normally purchased by the general contractor directly from the manufacturer. The best method for preparing general contract estimates is to send plans and sketches to the manufacturer. This will ensure a sub-bid based on an economical layout, design, and necessary accessories. In the quote, the manufacturer will typically note the tonnage of joists and other information that enables the contractor to determine the required handling and labor costs for erection. General procedures for metal joists cost estimation are as follows.

1. Take off the linear meter of each different type of joist required;
2. Determine the total weight and cost of each separate type;
3. Estimate quantity and cost of the accessories required; and
4. Determine the total cost of the metal joists.

The estimator first needs to determine the number of each different type of joist required. Structural metal is sold by the ton and the number of tons required must be determined for each separate type. To do so, the estimator simply multiplies the linear meter by weight per meter of the required joist. The estimator can then determine the cost of the joists required by multiplying the weight by its cost per weight. If the general contractor is to erect the joists, the estimator needs to have a list of equipment, labor work hours, and costs. On small jobs, it is possible for the contractor to use the contractor's own crew to erect the joists. On bigger jobs, however, the subcontractor specializing in erecting joists commonly does the job because the subcontractor has all the necessary equipment and skilled crews. If the joist erection is to be subcontracted, the general contractor must define the responsibilities as to who will install the joists and accessories. The next cost estimation step for metal joists is to determine the accessories

TABLE 10.11 Costs of Labor, Materials, and Equipment for Metal Joists

Code 05210	Steel joists	Crew	Daily output	Labor (hrs)	Unit	Bare cost ($) Mat.	Labor	Equip.	Total
600-0010	Open web joists, truckload lots								
600-0020	K series, horizontal bridging, spans up to 10 m, minimum	E-7	13.61	5.879	ton	895	184	87.50	1166.50
600-0050	Average	E-7	10.89	7.349	ton	1050	229	109	1388
600-0080	Maximum	E-7	8.16	9.798	ton	1400	305	146	1851
600-0140	10K1	E-7	366	0.219	m	7.85	6.80	3.25	17.90
600-0200	16K3	E-7	549	0.146	m	9.90	4.55	2.17	16.20
600-1010	CS series, horizontal bridging								
600-1040	Average	E-7	10.89	7.349	ton	1225	229	109	1563
600-1240	20CS2	E-7	610	0.131	m	17.20	4.09	1.95	23.24
600-1260	20CS4	E-7	610	0.131	m	30	4.09	1.95	36.04
600-2000	LH series, bolted cross bridging								
600-2040	Average	E-7	11.79	6.783	ton	1250	212	101	1563
600-2300	24H10	E-7	427	0.187	m	42	5.85	2.79	50.64

Source: Means, 1999.

required. Since metal joists are purchased directly from the manufacturer, the estimator can request a list of accessories from the manufacturer. The cost of accessories added to the two previous costs will total the cost required for metal joists installation. For any given project, the total weight of steel joists is controlled by the loads to be supported and the architectural and engineering designs.

10.4 METAL DECKING

10.4.1 Types of Metal Decking

The most widely used metal decking is steel decking. It is usually installed by either ironworkers or sheet metal workers. Metal decking can be purchased directly from a decking manufacturer or supplied by the same fabricators who supply structural and miscellaneous metals. To suit the requirements of different jobs, metal decking comes in a variety of shapes, sizes, thicknesses, and accessories. Most decking is available unpainted, painted, primed, and galvanized. Accessories for decking include clips for fastening the decking to the purlins, flexible rubber closures to seal the flutes, acoustical finishes, and lighting. Allowable decking spans can range from approximately 1.20 to 10.0 m, depending on the decking type. Steel decking is used for both structural metal framing and light gauge framing. It is produced in prefabricated cold-rolled 22- to 16-gauge steel sheets and is available in several patterns and combinations. Figure 10.10 shows steel decking commonly used for building construction. Corrugated cold-rolled steel sheets are used for roofing or siding on nonresidential structures. Fluted cellular cold-rolled steel sheets and fluted cold-rolled steel sheets are commonly used as support for wood and concrete roof decks, lightweight concrete floor decks, and the installation of rigid roof insulation. The cellular-type fluted decking, sometimes called “Walker Duct,” is typically used as raceway for underfloor wiring in large commercial office buildings and retail store applications.

In building construction, decking is typically used for roof and floor applications. Roof applications include many decking systems such as simple decks

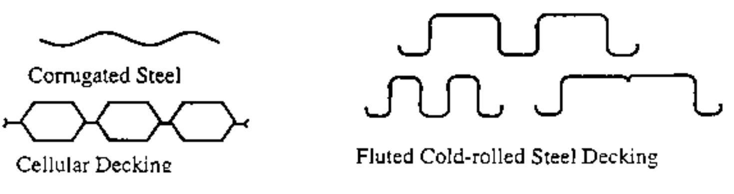


FIGURE 10.10 Common steel decking.

installed with insulation board and built-up roofing applied on top, forms with reinforcing and concrete, and decks with lighting and acoustical properties. Steel roof decking contains steel sheets available in 18-, 20-, or 22-gauge. For typical roof live loads, the 20-gauge and 18-gauge decks weighing 146 kg/m^2 to 195 kg/m^2 are generally used for spans ranging from 1.8 to 2.2 m, and 2.1 to 2.4 m, respectively, at the center of the purlins. Commercial decks generally have a standard cross-section with width/depth of 750 mm/37 mm and longitudinal ribs spaced 150 mm from the center. To suit various job conditions, decks are also available in other depths such as 44, 50, and 62 mm deep, as well as in various lengths ranging from 4 to 9 m. Greater depths and lengths can be special-ordered. Likewise, floor applications consist of several decking systems including simple decking forms with reinforcing and concrete on top, and more complicated systems that combine electrical and telephone outlets, electrical raceways, air ducts, acoustical finishes, and recessed lighting. A steel deck erected in an inverted position acts as a form to support concrete while permitting the ribs to act as reinforcement. Steel deck reinforcing forms generally provide all the reinforcement necessary to satisfy flexure requirements, but they need a reinforcing mesh to minimize cracking from shrinkage. The decking form allows concrete to be poured at any portion of the building without consideration for removing, cleaning, and resetting the temporary form.

To accommodate the concrete slab or lightweight insulation materials, the metal deck for both applications is placed on top of steel joists and is generally spot-welded to the joists. Two tack welds per 450 mm width of deck section at the end laps and one weld on the outside rib on the intermediate supports are recommended. A crew of two workers can place and weld approximately 18 m^2 of deck per hour.

10.4.2 Costs of Labor, Materials, and Equipment for Metal Decking

Costs of materials and erection are about the same for both roof and floor applications. These costs can be obtained from decking manufacturers or suppliers. Several crucial items of decking information are available in the specifications, including the type of decking, thickness, gauge of metal, accessories, method of attachment, and finish required on the decking. Other items that are required in specifications for the completion of the decking include painting of the decking underside, acoustical treatment, insulation, and openings. Specific information on allowable loads, costs of materials and erection, and other required information can be acquired from various decking manufacturers or suppliers. Table 10.12 shows samples of national average costs of labor, materials, and equipment for metal decking, according to Means (1999).

TABLE 10.12 Costs of Labor, Materials, and Equipment for metal Decking

Code 05310	Steel decking	Crew	Daily output	Labor (hrs)	Unit	Bare cost ($) Mat.	Labor	Equip.	Total
300-0010	Metal decking steel decking								
300-0250	Cellular units, galvanized, 51 mm deep, 18–20 gauge	E-4	132	0.242	m^2	35	7.80	0.64	43.44
300-0320	16–18 gauge	E-4	126	0.254	m^2	45	8.20	0.67	53.87
300-0400	75 mm deep, galvanized, 20–20 gauge	E-4	128	0.250	m^2	31.5	8.05	0.66	40.21
300-3300	Open type, galvanized, 38 mm deep, 20 gauge, under 45 m^2	E-4	359	0.089	m^2	10.1	2.87	0.23	13.20
300-6300	Slab form, steel, 24 gauge, 33 mm deep, uncoated	E-4	353	0.091	m^2	7	2.92	0.24	10.16

Source: Means, 1999.

10.4.3 Metal Decking Cost Estimation

The procedure for metal decking cost estimation, as follows, is relatively simple.

1. Determine how many square meters are required;
2. Determine materials and labor costs;
3. Determine transportation, unloading, and storage costs; and
4. Determine the total cost of the decks.

Quantity take off and pricing involve not only computing the areas of floors, roofs, and the types of decks shown on the drawings and in the specifications, but also more complicated issues that the estimator needs to take into account. Metal decking is priced by the square meter, so the estimator must determine how many square meters are required for each deck type. A systematic plan should be followed by starting on the lowest floor on which the decking is used and then working up through the building. Estimates for all floors should be maintained separately. For multistory buildings, it is important to correctly count the number of floors requiring the steel deck, and separately itemize the roof deck and any necessary poured concrete for the first floor. A complication in taking off quantities is that building construction generally involves many different sizes and types of openings. For example, small openings for pipes and conduits may be drilled after the floor or roof is installed, but larger openings may require special deck lengths and reinforcing or structural support. The estimator needs to identify who will supply this reinforcing or support. Moreover, some deck terminations are part of the deck package (such as screed angles and pour stops) whereas others are part of a steel contract (such as angles attached to structural members and cast-in-place angles and plates). It is up to the estimator to ensure that all pieces are included in the final estimate.

Decking is commonly installed by welding directly through the bottom of the ribs in intervals with a maximum of 30 cm, and side joists are mechanically fastened in intervals of not more than 1 m. The estimator should determine approximately how many weld washers are required and how long it takes for installation. One or two workers can easily position the decking and prepare for the welder to make the connections. When preparing the estimate, the estimator can consult local dealers and suppliers for materials prices. Besides the cost of materials and labor for performing the installation, the estimator may need to include the cost of transporting the materials to the jobsite, and unloading, storing, or placing the materials for use at the proper location. All costs are included in the total cost of the decks.

10.5 LIGHT-GAUGE FRAMING AND MISCELLANEOUS METALS

10.5.1 Light-Gauge Framing

Light-gauge framing refers to metal studs and joists made from 12- to 20-gauge cold-rolled steel. Studs or punched studs are used in areas where other electrical, plumbing, and materials such as tie rods and turnbuckles may be installed. Common types of studs include the double-nailable, channels, and C-type with knurled flanges. Studs are generally supported by lateral bridging at certain points of a wall, so stock V-bars, channels, or special clipping systems are required. On the other hand, due to their rigidity, joists or unpunched studs are used for structural floor, ceiling, and roof framing where no penetrations are required. Common types of joists include double nailable and C-joists. Joist webs are available in solid, selectively punched, or continuously punched; joist bridgings are available in solid channels or V-units.

Light-gauge framing systems can be used for the complete wall, floor, and roof construction of buildings up to four stories in height and also in combination with other framing systems for exterior curtain walls, load-bearing partitions, parapets, fire separation walls, and trusses. Interior bearing walls can be constructed with structural light-gauge framing to provide extra support for large open areas such as retail store spaces and hotel lobbies. Components of light-gauge framing can be completely detailed, cut, and assembled in the shop and delivered for erection at the jobsite. However, where on-the-job cutting and assembly is preferred, the materials can be cut with a radial saw.

Light-gauge framing sections are fabricated from structural cold-formed high tensile steel designed specifically for light weight and higher strength while having the advantage of conventional steel framing. At the plant, all sections are painted with a coat of oven-dried, rust-resistant red zinc chromate paint, and thus galvanized. A nailing groove for all double studs and joists is developed for easy and economical attachment of other materials. The advantages of using these systems include uniform fabrication, reduced dead load, less storage space needed at the jobsite, reduced shrinkage or swelling, punched slots for passage of other trades, noncombustibility, and secure nailing to eliminate nail popping. These advantages allow architects and engineers to have almost unlimited boundaries in design and provide cheaper alternatives compared to conventional wood or steel construction if properly designed and engineered. Equally important, the advantages of this system for workers in other trades can probably offer cost savings to the overall project.

The procedure for estimating the cost of light-gauge framing is the same as that outlined previously for structural metal framing. The estimator should take off the needed quantities and determine the weight of various light-gauge sections. In addition, the estimator should consider all possible cost items based on materials, material delivery, construction methods, equipment, fabrications, and labor factors. These cost items are referred to in the structural metal cost estimation described previously.

10.5.2 Miscellaneous Metals

Miscellaneous metals include metal fabrications and expansion controls. Metal fabrications are small-scale fabricated pieces generally made from rolled shapes and manufactured to standard details. Some literature refers to metal fabrications as "ornamental metals" generally made of steel, aluminum, brass, and bronze, and which are often specially ordered. The most common metal fabrications are metal stairs including both fire escape and regular stairs. Metal stairs generally refer to stairs and other associated items such as stringers, treads, nosings, and railings. Economical steel stairs are made from common materials and use standard details with a uniform and simple method of field assembly. The main stringers of the stairs, as well as the angles and tees for the carrier members, are made from steel channels and plates. Risers and treads are usually made by specialty shops. Stairs should be assembled and delivered directly to the site with simple and straightforward field connections. This can result in efficient installations and help minimize the cost of equipment and labor. Stair installation can be performed by the general contractor or by subcontractors where special installation or equipment is needed. A crew of four ironworkers in an eight-hour day can install approximately 40 to 50 risers of 0.9 m standard stairs or 14 m^2 of landing.

Other important types of metal fabrication include pipe railings, steel grating, steel stacks, steel ladders, and steel window guards. Pipe railings are generally made of steel and aluminum order from stock. Two ironworkers can install approximately 30 m of straight-run railing per day. Gratings can be made of steel, aluminum, or stainless steel. A typical crew of four ironworkers can lay about 9 m^2 of grating per hour. Steel stacks are generally fabricated by companies specializing in steel boiler and tank manufacturing. A crew of four ironworkers can install all necessary derricks and rigging in one day, and place and bolt one 6 m section of stack in four hours or approximately two sections of 10 m per day. To estimate metal fabrications, the estimator needs to carefully review the drawings and specifications and discuss pricing and installation with possible suppliers. Also before submitting a bid on the work, the estimator should obtain a second estimate from a steel fabricator to verify the estimator's own calculations.

Expansion controls are necessary where the various coefficients of expansion require more than the small neoprene control that is used in concrete. Due to its lower coefficient of expansion, metal is used because it withstands rapid temperature changes and prevents material failures. Expansion controls are made of metal plates, bars, and other special shapes that are used in heavy traffic areas

Table 10.13 Costs of Labor, Materials, and Equipment for Light-Gauge Framing and Miscellaneous Metals

Code 05420	Cold formed metal framing	Crew	Daily output	Labor (hrs)	Unit	Bare cost ($) Mat.	Labor	Equip.	Total
100-0130	Bracing, continuous, top, bottom, flat strap, 20 ga × 50 mm wide, joists at 400 mm O.C.	1 Carp	162	0.049	m	1.17	1.39		2.56
120-0010	Bridging, solid between joists w/31 mm leg track, per joist bay								
120-0340	Joists 300 mm O.C., 16 ga track × 200 mm wide	1 Carp	65	0.123	Ea	1.48	3.46		4.94
120-1240	Joists 400 mm O.C., 18 ga track × 200 mm wide	1 Carp	75	0.107	Ea	1.52	3		4.52
200-0330	Framing, band joist (track) fastened to bearing wall, 16 ga track × 200 mm deep	2 Carp	256	0.063	m	3.96	1.76		5.72
300-0300	Framing, boxed headers/beams, Double, 16 ga × 200 mm deep	2 Carp	54.86	0.292	m	13.50	8.20		21.70
410-0010	Framing, joists, no band joists (track), web stiffeners, headers, beams, bridging, or bracing								
410-0330	Joists (50 mm flange) and fasteners, materials only, 16 ga × 200 mm				m	4.86			4.86
500-0010	Framing, web stiffeners at joist bearing, fabricated from stud piece (41 mm flange) to stiffen joist								

500-2220	200 mm deep joist, with 63 mm stud (50 mm flange)	1 Carp	120	0.067	Ea	1.30	1.88		3.18
Code 05514	Ladders								
500-0010	Ladder, steel, 500 mm wide, bolted to concrete, with cage	E-4	15.24	2.100	m	174	67.50	5.50	247
Code 05517	Metal stairs								
700-0010	Stair steel, safety nosing, steel stringers								
700-0020	Grating tread and pipe railing, 1050 mm wide	E-4	35	0.914	Riser	100	29.50	2.40	131.90
700-0810	Custom steel stairs, 1050 mm wide, average	E-4	30	1.067	Riser	200	34.50	2.81	237.31
Code 05520	Handrails, railings								
700–0500	Railing, pipe, steel, 2 rail, on stairs, primed, 31 mm dia	E-4	48.77	0.656	m	30.50	21	1.73	53.23
Code 05530	Gratings								
340-2100	Floor grating, steel, Stainless steel gratings, up to 28 m^2, standard spacing, 19 × 3 mm bars	E4	46.45	0.689	m^2	720	22	1.81	743.81
Code 05090	Basic material: metal fastenings								
080-0140	Anchor bolts, 19 mm dia × 300 mm long	2 Carp	45	0.356	Ea	2.11	10		12.11
080-0160	25 mm dia × 300 mm long	2 Carp	35	0.457	Ea	3.20	12.85		16.05

Source: Means, 1999.

requiring structural stability. Connections at concrete floors and roof decks may also require such controls, especially where seismic control is necessary in large structures of steel, glass, and concrete. The control connections may be made using standard details or customized fabrications designed for a specific job. In building construction, expansion control covers are generally also required, but may be installed by other subcontractors. For example, an expansion joint cover used on an exterior block wall can be installed by the masonry contractor. Expansion control covers include metal expansion joint frames and covers, slide bearings, anchors, and related accessories. The estimator, therefore, needs to be certain that both the materials and the installation of expansion controls and their covers are included in the estimate.

10.5.3 Costs of Labor, Materials, and Equipment for Light-Gauge Framing and Miscellaneous Metals

The availability of various types of structural framing and miscellaneous metals results in a significant difference in their costs. The estimator should price them with the supplier indicated and design criteria shown. Means (1999) suggests that joists can be figured at $17.86 per 50 kilograms for general budget purposes. Also, the cost of punched galvanized C-joist varies from around $5.67 to $14.67 per meter. For miscellaneous metals, the cost of 90 mm of punched and galvanized stud is $1.67 in 20-gauge, $2.50 in 18-gauge, and $2.83 in 16-gauge. Table 10.13 shows the US national average costs for labor, materials, and equipment of light-gauge framing and miscellaneous metals according to Means (1999). One or two carpenters, designated as "carp," are generally sufficient for many metal framing operations.

10.6 REVIEW QUESTIONS

1. What are the six major subdivisions of the metals division?
2. Explain the structural metal delivery system.
3. What are the major common steel shapes in building construction?
4. To what do the "W530 × 66" and "L75 × 50 × 9" designations refer?
5. What are major steel connections? Explain their definitions, construction methods, and costs.
6. Explain the construction method for structural metal framing erection.
7. What are the cost items in structural steel estimation?
8. What does the estimator do to compare quotes from subcontractors or fabricators?

11

Wood

11.1 INTRODUCTION

Wood is one of the oldest and most used materials for construction work. It is used extensively for temporary work, such as formwork and scaffolding, as well as for permanent work, such as floors, walls, and roof framing. The use of wood as the basic construction material has been due to its availability, strength, durability, and workability. In addition, the aesthetic nature of wood also makes it a favorite finishing material used in most home and office projects.

Applications of wood framing have been more prevalent for light construction such as houses and small buildings. This chapter discusses wood as used in these light construction projects. Because the framing methodology discussed in this chapter is more widely practiced in the US and Canada, this chapter is the only chapter in the book that is presented in English instead of in metric units.

The work in this division is primarily divided into two main categories: rough carpentry and finish carpentry. Rough carpentry deals with such structural components of construction like floor, wall, and roof framing. Finish carpentry, on the other hand, adds finishing touches to a project. It deals with smaller construction items such as the exterior molding, fascia, and interior trim. Finish carpentry also includes the installation of prefabricated woodwork such as cabinets and stairs.

11.2 ROUGH CARPENTRY

Rough carpentry includes all the framing and sheathing in a project. In taking off for rough carpentry, it is important for the estimator to thoroughly understand how the work will be put together. Rough carpentry usually involves a more detailed understanding of how the construction will be executed in order to accurately take off for quantities of lumber. For example, to determine the amount of concrete required for a concrete slab, the estimator need only determine the floor dimensions in order to calculate the desired volume of concrete. However, for wood floor framing, the estimator needs to determine not only the floor dimensions, but also the types of sill, joist, header, and subfloor to be used. In addition, the estimator needs to know how each of these components will be put together, such as the spacing between the joists and where the joists are to be doubled. Therefore, the only sure way to estimate the quantity of lumber required for any particular job is to do a take off of each piece of lumber needed for the work.

11.2.1 Lumber

The main material used in rough carpentry is lumber. Lumber or dimension lumber refers to a processed wood member that is less then 5 in. in the smallest dimension. A member that is 5 in. or larger in its smallest dimension is sold as timber. The most common thickness for dimension lumber is 2 in., with 2 in. by 4 in. and 2 in. by 6 in. being the most commonly used sizes. Boards are usually 1 in. thick and come in various widths, typically ranging from 2 to 10 in.

Lumber is available in many grades and is produced from many species of trees. Commonly used species in the US are pine, fir, spruce, oak, maple, redwood, and cedar. Fir, pine, and spruce are used for general construction and framing work. Oak, maple, redwood, and white pine are used more for flooring, siding, and finishing work. The grading of lumber varies by the species of tree, seasoning method, and the degree of imperfections in the wood.

Lumber for general building purposes is called yard lumber and is usually produced from pine and fir. Yard lumber can generally be categorized into two major groups: common lumber or select lumber. Common lumber has defects and blemishes and is not suitable for finishing purposes, but is satisfactory for general construction purposes where appearance is not an issue. Common lumber can be further classified into grades 1, 2, 3, and 4, with 1 being the best grade and 4 being the worst. Grades 1 and 2 are used for framing where strength is required. Grade 3 and 4 have many defects and lend themselves to uses where strength is not critical. Select lumber has minimal defects and blemishes. This lumber is used where its surfaces will be exposed to view, such as for trim, facing, moldings, and other general finish carpentry. Select lumber is further classified into grades A, B, C, and D. Grades A and B are the best and are suitable for natural finish. Grades C and D have minor defects and blemishes that can be painted over.

In addition to the specifications of the various lumber grades, lumber can also be further specified by required preservation treatments that protect the wood against decay and insect attack. Wood can be given pressure treatments, which allows the preservative chemical to be applied under pressure, thus maximizing the chemical penetration and giving the wood maximum protection against decay and termite attack. Pressure-treated wood is required in these conditions:

1. Wood member in contact with masonry or concrete;
2. Wood member at grade or below grade, or less then 8 in. above ground; and
3. In crawl space, floor joists less then 18 in. above interior grade and wood beams less then 12 in. above interior grade.

The availability of the various grades of lumber for a project's location must be investigated as part of the estimate. This is also important for the pricing of the lumber. Lumber is a traded commodity and is thus sensitive to supply and demand in the marketplace. Prices of forest products fluctuate widely from location to location and from season to season depending upon economic conditions. Therefore, it is advisable to call local suppliers for the latest market price.

11.2.2 Lumber Sizes and Measurements

Lumber is produced in many shapes and sizes. The size of lumber is given in inches (thickness and width) and its length is always in feet. In specifying lumber, sizes are stated along with the wood type and the grade required, such as Southern Yellow Pine No. 2 & Better 2×4×10.

Lumber is designated based on its nominal dimension size. Nominal dimension is the full size of rough lumber, wood that has been sawed and trimmed, but has not been surfaced or dressed. Dressing is an operation that smoothes out the rough lumber surfaces, thus giving it a uniform size and smooth surfaces. Lumber can be surfaced on one or more sides. Some of the abbreviations for surface finishing are S1S2E for "smooth surface, one side, two ends" and S4S for "smooth surface, four sides." The dressing operation removes some lumber material in the process, resulting in a smaller dimension size for dressed lumber. The actual size of lumber is sometimes referred to as the dressed size. In addition to smoothing the surfaces, dressing can also prefabricate tongue-and-groove ends to planks or board, thus permitting better fitting of the members during installation. However, this process further reduces the surface of the board and the actual dressed surface must be considered in the take-off process. It is also important to state the number of dressed sides required and any other special requirements, such as predrilling, when ordering lumber.

Lumber can be produced and sold in green or dry conditions. Green refers to lumber fabricated at a moisture content of more then 19%. Lumber fabricated at a moisture content less than 19% is rated as dry. Green lumber must be dressed to a slightly larger dimension than dry lumber. This requirement ensures that the lumber achieves approximately the same actual dimensions after air drying in service. Table 11.1 shows the nominal dimensions of common lumber sizes as well as associated dressed or actual dimensions.

When needed in small quantities, lumber can be purchased by the piece, for example, 20 pieces of 2×4×12. However, commercially lumber is bought and sold in volume, which is computed from its nominal dimensions. Therefore, lumber should be taken off and tallied by volume. The unit volume of lumber is "board feet measure" or just "board feet" (B.F.). Prices of lumber are typically quoted per 1000 board feet or M.B.F. A board foot is the equivalent volume of a piece of lumber 12 in. by 12 in. and 1 in. thick. Therefore, 1 board foot of lumber is equal to 144 in^3. Board foot volume can be calculated by determining the size or cross-section of a member (in inches) and the length of the member (in feet). The three values are multiplied together and divided by 12 as shown in Eq. (11.1).

$$\textit{Number of B.F.} = \frac{\textit{Thickness}\ (\text{in.}) \times \textit{Width}\ (\text{in.}) \times \textit{Length}\ (\text{ft})}{12}. \qquad (11.1)$$

Table 11.1 Nominal and Dressed Sizes of Lumber

Nominal size (in.)	Dry S4S—actual size (in.)	Green S4S—actual size (in.)
2 × 4	1 1/2 × 3 1/2	1 9/16 × 3 9/16
2 × 6	1 1/2 × 5 1/2	1 9/16 × 5 5/8
2 × 8	1 1/2 × 7 1/4	1 9/16 × 7 1/2
2 × 10	1 1/2 × 9 1/4	1 9/16 × 9 1/2
2 × 12	1 1/2 × 11 1/4	1 9/16 × 11 1/2

Example 11.1. *Calculating the Board Feet Lumber*

To calculate the number of board feet for 20 pieces of 10 ft long 2×4s:

Total length of 2×4s = 20 pieces × 10 ft/piece = 200 ft.
Number of B.F. = 2 in. × 4 in. × 200 ft ÷ 12 = 133.33 B.F. or 0.133 M.B.F.

Alternatively, Table 11.2 provides the common sizes of lumber and the associated conversion factor for converting the length of a member to board feet. These adjustment factors are essentially the amount of board feet per linear foot of the specified member size.

Example 11.2. *Calculating Board Feet of Lumber—Alternate Method*

To calculate the number of board feet for 20 pieces of 10 ft long 2×4s using an alternate method:

Table 11.2 Typical Lumber Sizes and Associated Board Foot Measure per Linear Foot

Nominal size (in.)	B.F./L.F.
2×4	0.667
2×6	1.000
2×8	1.333
2×10	1.667
2×12	2.000
2×14	2.333
2×16	2.667

Total length of 2×4s = 20 pieces × 10 ft/piece = 200 ft.
From Table 11.2: for 2×4 member, the number of B.F./L.F. = 0.667.
Number of B.F. = 200 ft × 0.667 B.F./ft = 133.33 B.F. or 0.133 M.B.F.

The first step of lumber take off is to determine the length and quantity of the item under consideration. The second is to calculate the total length for each lumber size. The third and final step is to convert the take-off length to board foot measures of lumber. All lumber take-off items should be kept separate according to lumber dimensions, classification, grade, and any chemical treatments involved.

Lumber is cut and sold in multiples of 2 ft lengths. The typical lengths of lumber produced are 6, 8, 10, 14, 16, 18, and 20 ft. Lengths longer than 16 or 20 ft may require special ordering. This standardization of lumber lengths is one reason waste must be considered. This is because any length required that does not match these standard lengths must be cut from these standard lengths. Therefore, it is important to do a careful take off in order to accurately estimate the quantity of lumber required, as well as to determine the proper lengths of lumber to order so as to minimize the inevitable end waste due to cutting. An estimator essentially has to determine which lengths and quantities to order for each size, and how each length type can be most efficiently cut and used. The end waste for lumber is generally in the range of 5 to 15%. Poor management and failure to properly plan the cutting of lumber can significantly inflate this percentage. The amount of waste also depends on the lumber quality, desired quality of the construction, and the complexity of the framing work.

11.2.3 Plywood and Waferboard

Plywood and waferboard are used extensively for the subfloor, wall sheathing, and roof sheathing. Plywood panels consist of an odd number of veneers glued over each other at right angles. Waferboards are nonveneer panels, also commonly known as particleboard, flakeboard, or oriented strand board (OSB). Waferboard panels are manufactured from small fragments of wood bound together with adhesive. Plywood or waferboard are applied over framing to close in the floor, wall, and roof frameworks, thus forming a base for subsequent finishing materials, such as floor tiles and wall plastering. The standard sheet size for plywood and waferboard is 4 feet wide by 8 feet long with variable thicknesses. Most common thicknesses available are 1/4, 3/8, 1/2, 5/8, and 3/4 in. The selection of a thickness depends on the proposed application of the plywood, such as for wall sheathing or subflooring. The thickness also depends on the loading conditions and underlying framing. For example, the bigger the joist spacing or the heavier the floor load, the thicker the plywood needs to be for the subfloor.

Plywood is graded by the quality of the surface veneers as well as an exposure rating, whether for interior or exterior applications. Plywood grades are specified by the American Plywood Association (APA). Each surface veneer of the plywood sheet can be given a grade ranging from A to D, with A being the best grade. CDX grade is typically used for subflooring and roof sheathing. CDX rated plywood means that the grade of the veneer on one side is "C" grade, and the other is "D" grade. The "X" means that the plywood is rated as exterior grade.

Due to the typical application over large surfaces like floors, walls, and roofs, plywood and waferboard are generally taken off by the coverage area in square feet.

11.2.4 Types of Residential Framing

There are two types of residential framing commonly used in the US: western or platform framing and balloon framing. Platform framing is the more common framing system used today and can be seen as an evolution from the balloon framing system. The practice of balloon framing has generally decreased due to more stringent code regulations and the inherent structural weaknesses associated with this type of framing. Figure 11.1 illustrates section details of platform and balloon framing.

Platform frames are constructed by room-sized sections of framework. These sections, once fully built, are erected in rows along a long wall and are stacked atop one another on multistory buildings, typically no more than three stories high. Balloon framing, on the other hand, uses walls made up of studs that run from the foundation all the way up to the rafters. Due to the greater stud length, which can be as high as 24 feet, the wall will typically be strengthened by diagonal bracing. In balloon framing, the wall will run along the entire length of the building and usually not be segmented by room lengths, as in platform framing. Balloon framing is more of a stick-built kind of construction where most of the framing work takes place on the construction site. On the other hand, the modular nature of platform framing allows for a greater prefabrication of framing components, such as wall and roof segments. These components are then delivered to the site and simply erected in place, thus decreasing the amount of onsite construction and speeding up the entire construction process. The construction of modular sections also allows for higher construction productivity.

11.2.5 Floor Framing

The take off for wood framing starts with the floor. Figure 11.2 shows a plan view of a sample floor frame. The details of the floor section can be seen in Figure 11.3. The finished floor can be installed directly on the subfloor, or on an additional layer of underlayment which rests over the subfloor. The subfloor is supported by floor joists installed at regular intervals over the floor area. The joist ends rest on the sill plates, which are installed on top of the foundation wall. When the joists cannot span from wall to wall, a beam can be used to support

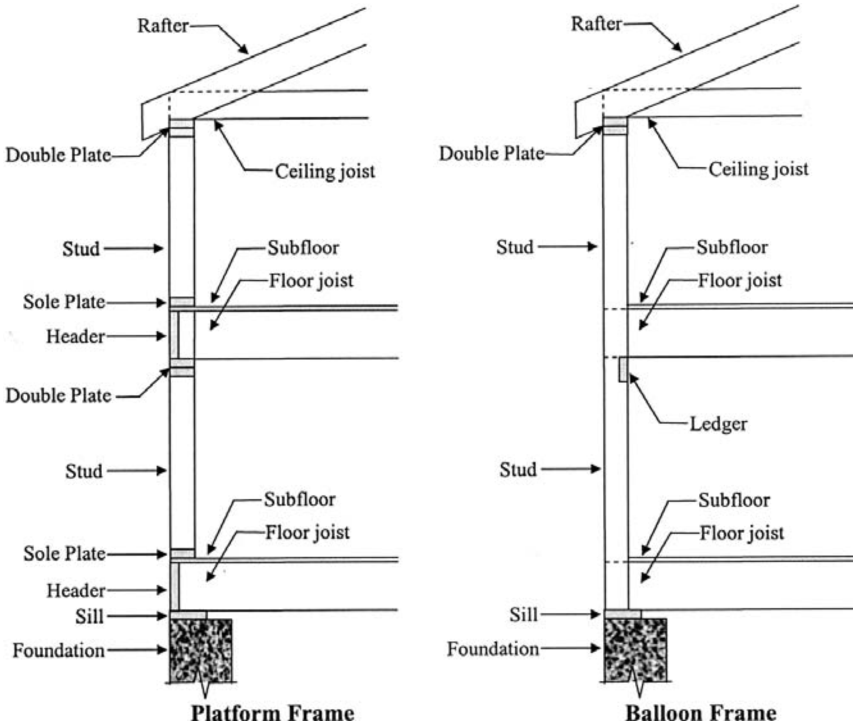


FIGURE 11.1 (a) Platform and (b) balloon framing systems.

one end of the joists, dividing the floor area into bays. The beam can be supported by the foundation walls, as well as by posts. The joist ends on the exterior sides are closed in by the same size lumber called headers.

In taking off for floor framing, the estimator needs to refer to the drawings of the wall sections in the plan. This take off involves the determination of floor dimensions (length, width, thickness, and area), the lumber types to be used, and the spacing and installation procedures for the floor components. It is also important to note where the joists will be doubled, such as under load-bearing walls and bathtubs. All items of the floor frame should be measured net in place and consideration given to basic construction requirements that may not be shown on drawings, such as allowances for bearings on supports, the overlapping of joining members, additional member requirements, and bridging.

11.2.5.1 Floor Beams or Girders

On a small project, floor beams or girders may not be necessary. However, on projects where the floor area is large, the foundation wall alone may not be able

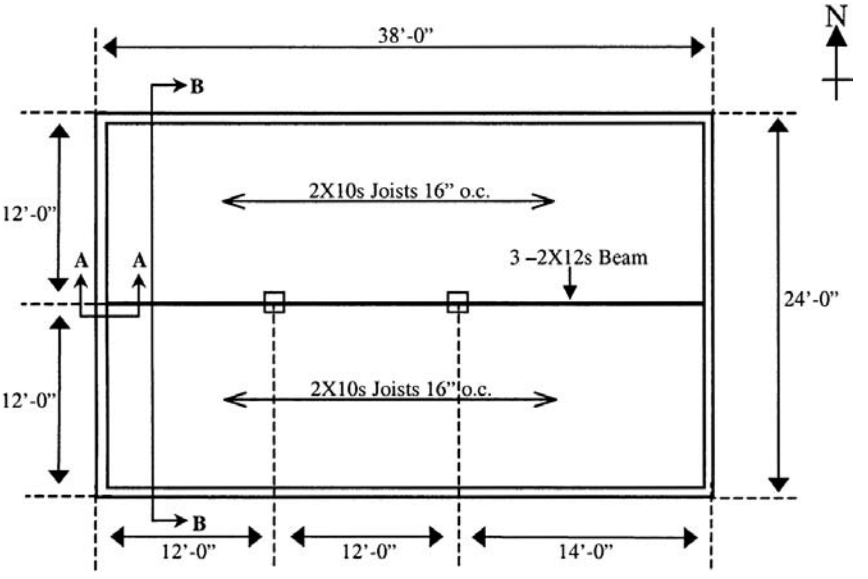


FIGURE 11.2 Plan view of floor framing detail.

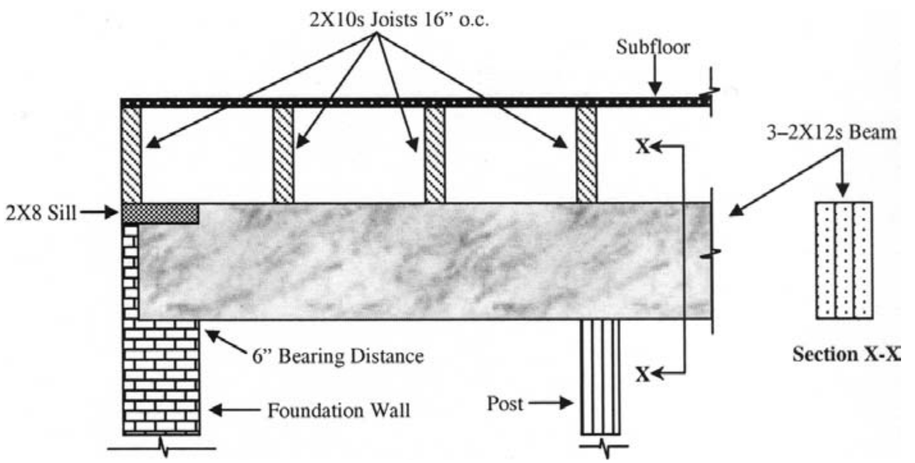


FIGURE 11.3 Floor framing detail (Section AA from Fig. 11.2).

to carry all the loads from the floors above. Beams and posts can be used to provide additional support for the joists, thus lessening the load on the foundation wall. Beams are also necessary when the width of the building is greater than the desired span of the joists. Beams can be metal, but if wood is used, they are usually made up of 2×10s or 2×12s ganged together as shown in Figure 11.3.

In taking off for beams, the lumber size and the number of pieces of lumber required to construct the beams must be determined. This can be done by examining in detail a wall section, as shown in Figure 11.3. The next step is then to determine the total length of the beams. Once the total length required is known, then the amount of B.F. can be calculated.

Example 11.3. *Floor Beam Take Off*

In Figures 11.2 and 11.3 the beams are made up of three pieces of 2×12s. The length of the beam required can be determined as follows.

Beam span (inner dimension) = exterior building dimension − 2(foundation wall thickness) = 38 ft 0 in. − 2(8 in.) = 36 ft 8 in.
Beam length = beam span + bearing distance on both ends = 36 ft 8 in. + 2(6 in.) = 37 ft 8 in.
Since the beam consists of three 2×12s, the total length of the 2×12s is = 37 ft 8 in. × 3 = 133 ft 0 in.
From Table 11.2, the board foot conversion factor for 2×12 = 2 B.F./L.F.
The total B.F. = 133 ft 0 in. × 2 B.F./ft = 226 B.F. or 0.226 M.B.F.

11.2.5.2 Foundation Sill Plate

Foundation sill plates are the first floor framing elements that are installed. Typical lumber sizes for sills are 2×4, 2×6, 2×8, 4×6, or 4×8, and they are usually surfaced on four sides (S4S). To prevent rotting, the sills should be made of treated lumber. The sills may be installed directly on the grade beam or a layer of mortar may be applied on the grade beam before the placement of the sills in order to be level. The sills are secured to the grade beams by anchor bolts installed at every 6 to 8 ft on center. Alternatively, concrete nails can also be used to fasten the sill plate to the top of a concrete foundation wall. The take off for the sill plate is first to determine the lumber type to be used; second, to measure and sum the total length of the sills required; and third, to calculate the total board feet of lumber for sills based on lumber size and the total length required.

Example 11.4. *Foundation Sill Plate Take Off*

In Figures 11.2 and 11.3, the dimensions of the building and placement of the sills can be seen along with the sill size, which is 2×8. The length of the sill can be determined by breaking up the sill into lengths: two full 38 ft length sections and two slightly less than 24 ft length sections. This is done to eliminate the double counting at the corners. The total sill length is calculated as seen below.

Total sill length = 2(38 ft) + 2[24 in. − 2(7-1/2 in.)] = 121 ft 4 in.
From Table 11.2, the board foot conversion factor for 2×8 = 1.333 B.F./L.F.
The total B.F. = 121 ft 4 in. × 1.333 B.F./ft = 162 B.F. or 0.162 M.B.F.

11.2.5.3 Floor Joists

Floor joists are installed on top of the sill plates as shown in Figures 11.3 and 11.4. Typical lumber sizes for joists are 2×6, 2×8, 2×10, or 2×12, and undressed or surfaced on four sides. The on-center spacing for joist installation is generally at 12, 16, or 24 in. The take off for floor joists involves the determination of the type of lumber to be used. Then the floor dimensions are determined along with specified joist placements, including their spacing, any extras, and doubling requirements. Joists are usually doubled when they will be subjected to heavier loads, such as under a partition wall, load-bearing wall running parallel to the joists, or under a bathtub. The number of joists for any given floor length is determined by dividing the floor length by the on-center joist spacing and adding one extra joist that is required at the end of the span. Alternatively, Table 11.3 lists the multiplication factors for many on-center spacings. These multiplication factors are used to multiply the floor length in order to determine the number of joists for the given floor length. One extra joist must also be added for the end of span. The number of joists and the length of each joist are then used to compute the board foot measure for joists.

The length of a joist is usually the span length plus the ends bearing on the walls or other supports. On a multibay application, the joist from one bay may be lapped with a joist from another bay, with this overlapped allowance considered during take off.

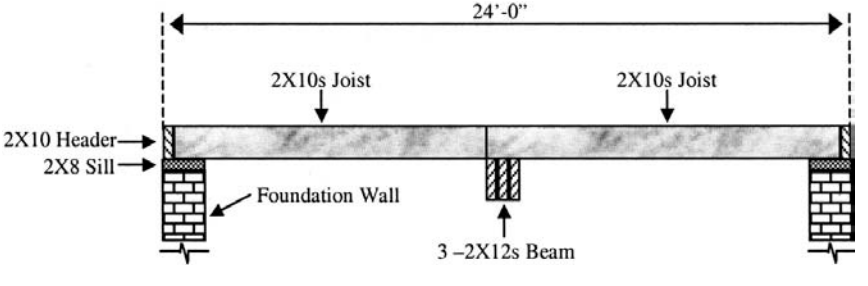


FIGURE 11.4 Joist framing detail (Section BB from Fig. 11.2).

TABLE 11.3 On-Center Spacing and Multiplication Factor for Calculating Members per Span Length

On-center spacing (in.)	Multiplication factor
12	1.00
16	0.75
20	0.60
24	0.50
30	0.40
36	0.33
42	0.29
48	0.25
54	0.22
60	0.20

Example 11.5. *Floor Joist Take Off*

Looking at Figure 11.2, the dimensions of the building and the placement of the joists can be seen along with joist size. The joists are 2×10s installed at 16 in. o.c. Figure 11.4 shows the section details of the joists. Using 12 foot lengths of 2×10s permits four inches of lap length for joists at the beam support. Figure 11.5 shows the floor plan of the building, indicating the number of partition walls present. There are four partition walls parallel to the joist placement. The number of joists can be determined as follows.

From Table 11.3, 16 in. o.c. corresponds to a multiplication factor of 0.75.
Number of joists = (38 ft × 0.75) = 28.5 which rounds up to 29 + 1 = 30 joists.
The total number of joists for the two bays = 30 × 2 = 60 joists.
Add one extra joist under each partition wall = 60 + 4 = 64 joists.
Total length of 2×10s for floor joists = 64 joists × 12 ft = 768 ft.
From Table 11.2, the board foot conversion factor for 2×10s = 1.667 B.F./L.F.
The total B.F. = 768 ft × 1.667 B.F./ft = 1280 B.F. or 1.280 M.B.F.

Large openings in the floor are sometimes required for ducts, chimneys, and stairs. To accommodate these openings some of the joists must be cut and additional elements added to strengthen floor framing. Figure 11.6 shows the details for floor framing with openings. As shown in Figure 11.6, trimmers are added to box in the sides of the opening. Headers are also added to support the cut end of the joists and form the remaining two sides of the opening. Generally, a single header and trimmer are used for openings with a header length less than

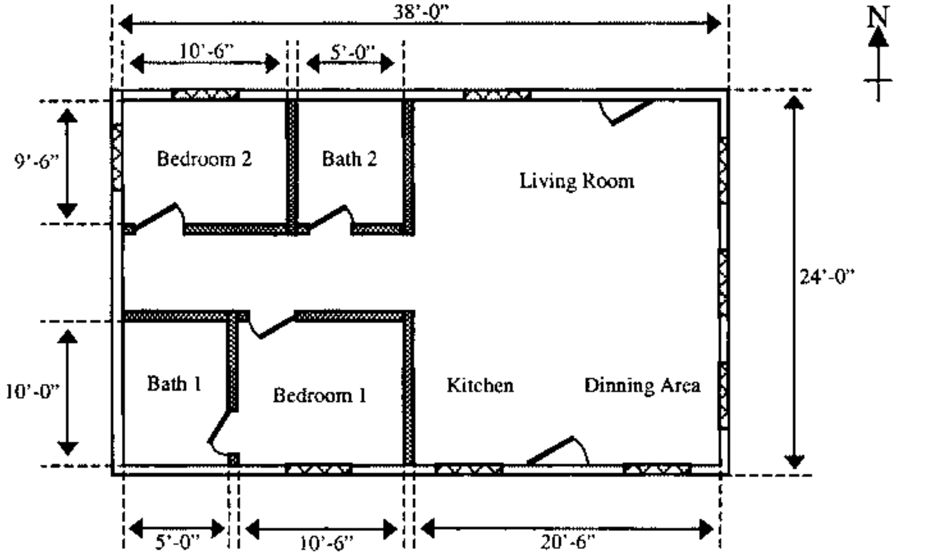


FIGURE 11.5 Floor plan of a building.

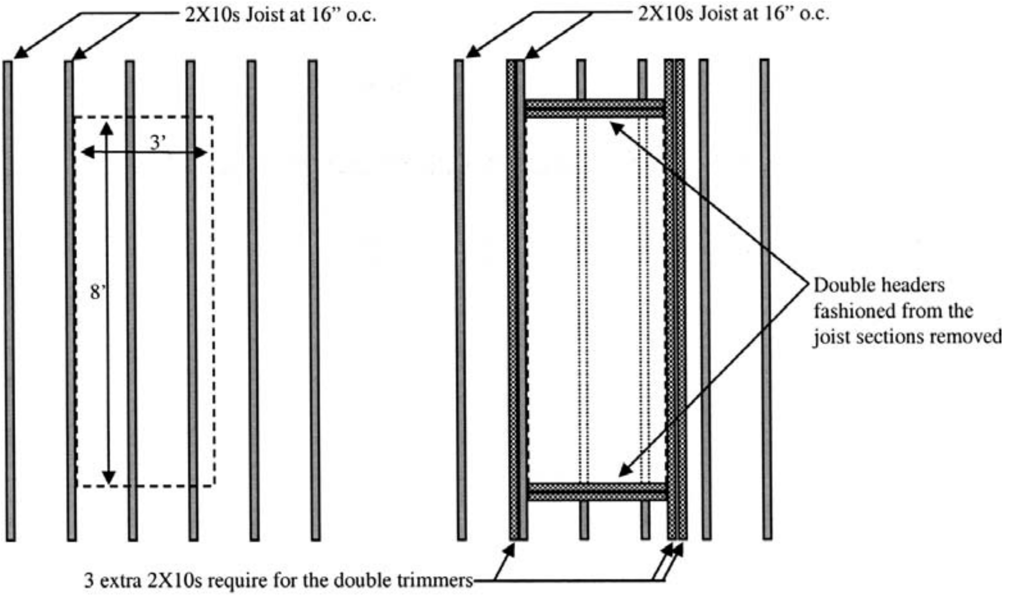


FIGURE 11.6 Framing detail for floor opening.

4 ft. For header lengths greater than 4 ft, the trimmer and header are usually doubled.

11.2.5.4 Joist Headers

A joist header is required to close in the two open ends of the joists as can be seen in Figure 11.4. They are usually the same lumber size as used for the joists. The calculation for the header follows.

Example 11.6. *Joist Headers Take Off*

From Figure 11.2, the dimensions of the building can be determined and Figure 11.4 shows the placement and the size of the header, which is the same as the joist size and uses 2×10s.

The total length of the header on both sides = 38 ft × 2 = 76 ft.
From Table 11.2, the board foot conversion factor for 2×10 = 1.667 B.F./L.F.
The total B.F. = 76 ft × 1.667 B.F./ft = 127 B.F. or 0.127 M.B.F.

11.2.5.5 Bridging

Figure 11.7 illustrates different types of bridging used in floor framing. Bridgings are members added between joists to stiffen the joists and to provide bracing for the floor. Bridging has been used for many years and some codes still require it, although studies have shown that bridging is virtually useless under most circumstances and that its use is not necessary unless dictated by the engineering design (Olin et al., 1995). Cross-bridging can be made of 1×3 or 1×4 lumber or alternatively metal bridging can be used. Metal bridging comes ready for installation whereas the lumber for wood bridging must be cut to proper sizes. Metal bridging also typically requires half as much nailing as wood bridging. Two cross-bridgings are required for each joist spacing. Another type of bridging used is the solid type, where the bridging members are typically the same size as the joist

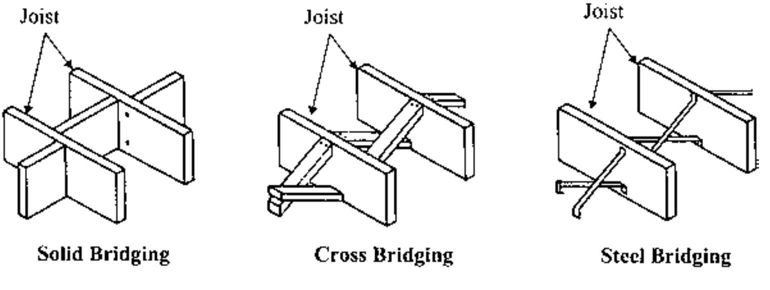


FIGURE 11.7 Bridging.

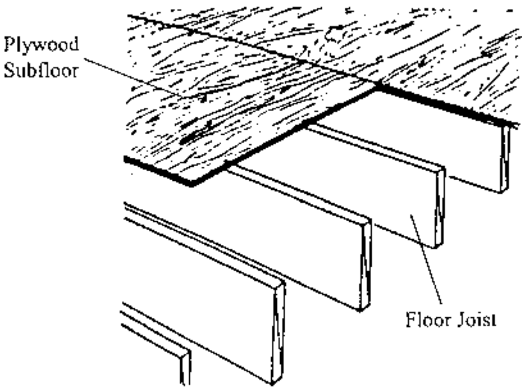


FIGURE 11.8 Plywood subfloor. (From Means, 1991.)

member and one piece is required for each joist spacing. The amount of bridging required varies by local codes and specifications, but typically at least one row is required between a joist span. Bridging is typically taken off by the number of pieces required. Additional bridgings are sometimes provided where joists will be subjected to heavy loads, such as under partition walls running parallel to the joist.

Example 11.7. *Bridging Take Off*

Referring to Example 11.4, assume that one row of bridging is required for each joist span and that the bridging is to be fabricated from 1×3 lumber. The number of pieces of 1×3 required for the bridging can be calculated as follows.

Number of spaces = 38 ft × 0.75 = 28.5 round up to 29 spaces.
Total number of spaces = 29 spaces per bay × 2 bays = 58 spaces.
Total number of bridgings = (2 pieces of 1×3 per space) × 58 spaces = 116 pieces.

11.2.5.6 Subfloors and Underlayment

Subfloors are installed over the joists, and thus complete the floor framing system. Subfloor not only serves as the working platform during construction, but is required as the base for many floor finishes. Subfloors can be constructed of plywood sheets or lumber planks.

Plywood comes in a standard sheet size of 4 ft × 8 ft but in a wide variety of thicknesses. The thickness of the sheet selected depends on the required floor load, floor finishing type, and the spacing of the floor joists. Plywood sheets are typically specified for certain joist spacings and loading applications. For subfloor use, 5/8 or 3/4 in. thickness is common for most installations. Plywood is secured to the floor with nails (8d common nail), at 6 in. spacing along the floor joists. Gluing is sometimes used in conjunction with nailing. Plywood sheets can be installed edge to edge or the plywood can be dressed with tongue and groove, thus permitting a better seal between the sheets.

Alternatively, lumber planks can also be used for subflooring. Typical plank sizes are 1×6 and 1×8. The planks can be laid straight across the joist or diagonally. It must be noted that laying planks diagonally is more labor-intensive and often results in more wastage of material (an additional 10 to 15% more waste) as there will be more cutting involved. Plank edges may be squared or dressed with shiplap or tongue-and-groove edges. Two 8d common wire nails should be used to secure each plank to the joists.

For certain floor finishes (such as thinset tile, thinset terrazzo, and resilient flooring), an additional layer of subfloor called underlayment is sometimes required. The underlayment is usually plywood sheets. The underlayment is laid directly over the subfloor and serves as the base for the floor finishes. Using underlayment is often desirable, although it may not be necessary for the type of floor finishing selected, as the subfloor which also serves as the working platform during construction can be subjected to considerable wear and may have some damage by the time it is ready to receive floor finishes. The installation of underlayment over the subfloor before the application of floor finishes ensures that the base of the finished floor is of good quality and ready to receive finishing applications.

Take off for subflooring and underlayment involves the determination of the type of material to be used and the total floor area to be covered. The take off for coverage area is in square feet of floor surfaces.

Example 11.8. *Subfloor Take Off*

Refer to Figure 11.2.

The floor area = 38 ft × 24 ft = 912 SF.
The area covered by one 4 ft × 8 ft plywood panel = 4 ft × 8 ft = 32 SF.
The number of plywood sheets required = 912 SF ÷ 32 = 28.5, rounded up to 29 sheets.

This method does not account for any complexity in the shape of the floor area. When the floor area is irregularly shaped, the best and most accurate method is to sketch out the floor area to be covered and determine the proposed layout of the plywood panels. In this way, the actual number of sheets of plywood can be more accurately estimated.

11.2.6 Wall Framing

Wall framing can be classified into exterior and interior wall framing, and consists of sole plates, studs, and top plates, as shown in Figure 11.9. A sole plate rests

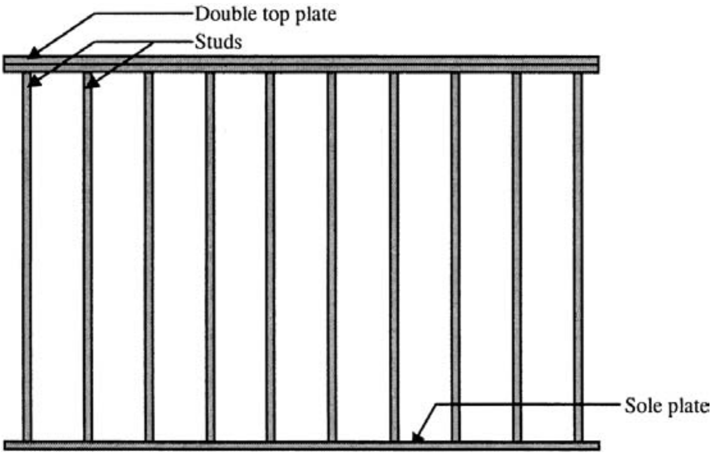


FIGURE 11.9 Wall framing detail.

on the floor and supports the bottom ends of the studs. Studs are the lumber placed vertically in a row at a certain spacing forming the wall framing. The top ends of the studs run into the top plate. The top plate and the sole plates act as headers for the studs, similar to the floor header for the joists in a floor framing system. Studs are usually 2×4 or 2×6 members and are installed with typical on-center spacing of 12, 16, 20, or 24 in. The most common spacings for studs are at 16 or 24 in. on-center. These spacings permit the use of standard widths and lengths of panel sheathing and lath for plaster finishing, and therefore remain the convention in use. In addition to the even foot length, studs are available in precut lengths of 92-1/2 in. This precut length is made ready for the framing of a standard 8 ft 1 in. high wall. The standard wall height is assembled with one sill plate (1-1/2 in.), stud (92-1/2 in.), and double top plate (3 in.), which adds up to the standard height of 97 in. or 8 ft 1 in. The sole plate and top plate are usually the same lumber size as the studs for exterior and interior load-bearing walls. Nonload-bearing walls may have studs with smaller lumber sizes than are used for the sole and top plates. These studs are typically installed in a staggered manner, as shown in Figure 11.10. Top plates can be single or double depending on the required strength of the wall.

11.2.6.1 Sole Plate and Top Plate

Take off for wall framing starts with the plates. The plates can be taken off by determining the length of the wall. Interior walls can be broken up into straight wall sections with the lengths from each section determined and totaled. The sole plate and the top plate of the exterior walls are taken off in the same manner as the foundation sill plate.

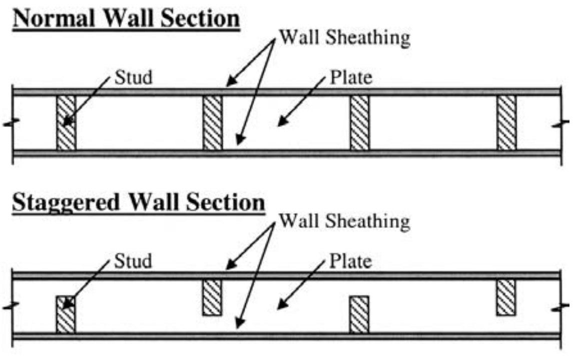


FIGURE 11.10 Studs framing detail.

Example 11.9. *Sole Plate and Top Plate Take Off for Exterior Walls*

Refer to Figures 11.5 and 11.9. The dimensions of the building and the placement of the plates can be seen along with the plate size. 2×6 Lumber is used for the single sole plate and double top plate.

The length of 2×6s for the sole plates = 2(38 ft) + 2[24 in. − 2(5-1/2 in.)] = 122 ft 2 in.
From Table 11.2, the boardfoot conversion factor for 2×6s = 1.0 B.F./L.F.
The total B.F. for sole plate = 122 ft 2 in. × 1.0 B.F./ft = 122 B.F. or 0.122 M.B.F.
The length of 2×6s for the top plates = double the length of the sole plate = 244 ft 4 in.
The total B.F. for top plate = 244 ft 4 in. × 1.0 B.F./ft = 244 B.F. or 0.244 M.B.F.

Example 11.10. *Sole Plate and Top Plate Take Off for Interior Walls*

Assume the same wall framing for the interior wall.

The total length of the interior wall = 2(9 ft − 6 in.) + 2(10 ft − 6 in. + 6 in. + 5 ft + 6 in.) + 2(10 ft) = 72 ft 0 in.
The length of 2×6s for the sole plates = 72 ft 0 in.
The total B.F. for sole plate = 72 ft 0 in. × 1.0 B.F./ft = 72 B.F. or 0.072 M.B.F.
The length of 2×6s for the top plates = double the length of the sole plate = 144 ft 0 in.

The total B.F. for top plate = 144 ft − 0 in. × 1.0 B.F./ft = 144 B.F. or 0.144 M.B.F.

11.2.6.2 Studs

Studs are taken off in a similar manner to joist take off. The wall length is first determined. The number of studs needed for the wall section can be determined by dividing the wall length by the on-center spacing of the studs. Alternatively, the multiplication factor for the given spacing can be determined from Table 11.3 and can be used to determine the number of studs. One more stud is always added to the result of the calculation to account for the end stud. Extra studs are generally required when two wall sections come together, such as at corners and at an abutting wall intersection. Figure 11.11 shows the placement of the extra studs at a wall corner and an abutting wall. These extra studs can be accounted for in the take off by counting the number of corners and abutting walls, and adding one extra stud for each corner and abutting wall encountered.

In taking off for wall framing, the estimator will inevitably run into a wall with an opening. Openings in the wall are necessary to accommodate doors and windows. As in floor framing, an opening requires the cutting of stud members and the placement of additional elements to transfer the load around the opening, thereby maintaining the strength of the wall. Figures 11.12 and 11.13 show a wall framing detail for doors and windows, respectively.

The partial wall section above or below an opening is called the cripple wall. The shorter studs in the cripple wall are called cripple studs. The cripple wall above the opening is supported by the header or lintel. The header takes the load from above and transfers it to two jack studs supporting the header. The jack stud on each side is flanked by the king stud or the full-size stud. The top ends of cripple studs on the cripple wall below a window opening are enclosed by the sill.

Generally, the construction of an opening will require additional studs for the jack studs, cripple studs, sill, and header. This header is often taken off sepa-

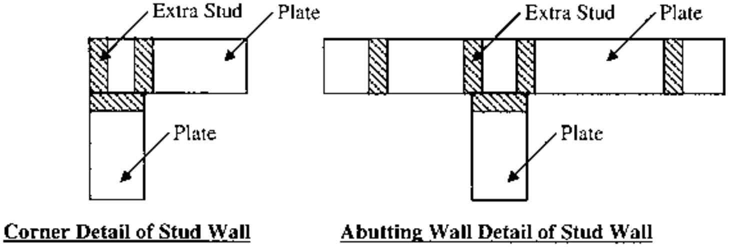


FIGURE 11.11 Extra studs placement at wall corner and abutting wall.

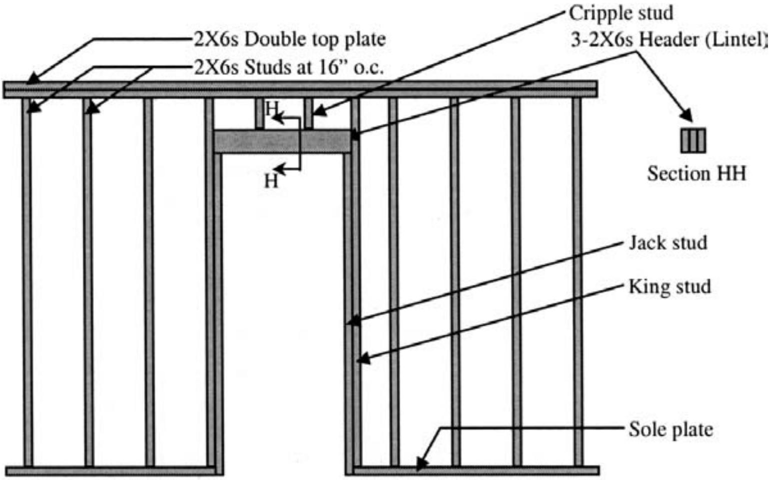


FIGURE 11.12 Framing detail for wall with door.

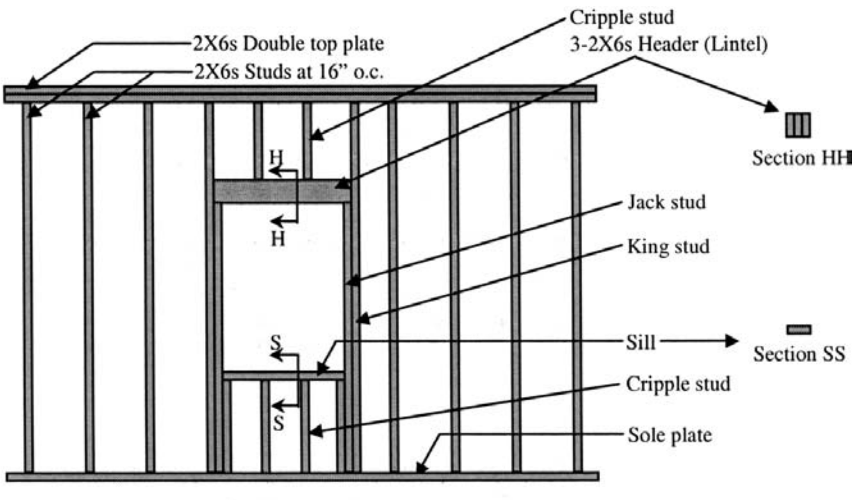


FIGURE 11.13 Framing detail for wall with window.

rately. The other elements can be fabricated from the full-size studs removed, with additional studs often being required to completely form the framing for the opening. For estimating purposes, one extra stud is required for every door opening and two extra studs are required for every window opening. For more accurate take off, it is necessary to take off all the pieces required for every opening.

Example 11.11. *Stud Take Off for Exterior Wall*

Referring to Figure 11.5, assume a standard wall height, 2×6 studs S4S, at 16 o.c.

North and south walls: wall length = 38 ft.
Number of studs = 38 ft × 0.75 = 28.5 rounded up to 29 and plus 1 = 30 studs.
East and west wall: wall length = 24 ft – 6 in. on each side = 24 ft – 1 ft = 23 ft.
Number of studs = 23 ft × 0.75 = 17.25 rounded up to 18 and plus 1 = 19 studs.
Add for corners: four corners = 4 studs.
Add for abutting walls: six abutting wall = 6 studs.
Add for door openings: two doors = 2 studs.
Add for window openings: nine windows = 9 × 2 per window = 18 studs.
Total number of studs = 2(30 + 19) + 4 + 6 + 2 + 18 = 128 studs.
Nominal size for studs = 2×6 × 8, therefore
Total B.F. for studs = 128 studs × 8 ft × 1 B.F./ft = 1024 B.F. or 1.024 M.B.F.

Example 11.12. *Stud Take Off for Interior Walls*

Assume the same wall framing for the interior wall.

Bedroom 2 and bath 2, east wall: wall length = 9 ft 6 in.
Number of studs = 9 ft 6 in. × 0.75 = 7.1 rounded up to 8 and plus 1 = 9 studs.
Bedroom 1 and bath 1, east wall: wall length = 10 ft 0 in. + 6 in. = 10 ft 6 in.
Number of studs = 10 ft 0 in. × 0.75 = 7.5 rounded up to 8 and plus 1 = 9 studs.
Corridor walls, north and south: wall length = 10 ft − 6 in. + 0 ft − 6 in. + 5 ft − 0 in. + 0 ft − 6 in. + 16 ft 6 in.
Number of studs = 16 ft 6 in. × 0.75 = 12.4 rounded up to 13 and plus 1 = 14 studs.
Add for corners: two corners = 2 studs.
Add for abutting walls: two abutting walls = 2 studs.

Add for door openings: four doors = 4 studs.

Total number of studs = 2(9 + 9 + 14) + 2 + 2 + 4 = 72 studs.

Nominal size for studs = 2 × 6 × 8, therefore

Total B.F. of studs = 72 studs × 8 ft × 1 B.F./ft = 576 B.F. or 0.576 M.B.F.

Example 11.13. *Headers Take Off*

Referring to Figures 11.5, 11.12, and 11.13, assume that the header is made up of three 2×6s as shown in the figures and that the door and window openings are 3 ft. The header length can be determined as follows.

Header length = opening length + bearing distance = 3 ft 0 in. + 2(1.5 in.) = 3 ft 3 in.

Total length of 2×6s for each header = 3 × 3 ft 3 in. = 9 ft 9 in.

Total number of headers = number of openings = 15.

Total B.F. of 2×6s for headers = 15 headers × 9 ft 9 in. per header × 1 B.F./ft = 146 B.F. or 0.146 M.B.F.

11.2.6.3 Wall Sheathing

Wall sheathing can be lumber, plywood, waferboard, fiberboard, or gypsum board. The specifications must be checked to determine the type of sheathing to be used and the precise specifications required. The installation of sheathing on a wall provides bracing for the wall and improves wall rigidity and strength. In addition, the sheathing serves as one of the barriers protecting the building from external elements, such as wind and moisture. Sheathing also contributes to the insulation property of the wall. However, the primary function of the sheathing is typically to provide a base on which the finishing material can be applied. Most finishes generally applied over wood-framed construction require some kind of wall sheathing.

When plywood or waferboard are used for wall sheathing, they are applied horizontally across the wood studs and fastened with nails. The typical thickness used is 1/2 in. and 5/8 in. Alternatively, lumber planks can be used for wall sheathing, although they are more common for exterior walls. Their typical size is 1×6 or 1×8 S4S with shiplap or tongue-and-groove ends. The planks can be installed horizontally over the studs or diagonally. Diagonal sheathing will require more labor and will result in more material wastage (an additional 10 to 15% more waste) as there will be more cutting and fabrication involved.

The take off for wall sheathing is similar to the take off for the subfloor. The steps in the take off are to determine the type of material to be used and the total floor area to be covered. The take off for coverage area is in square feet of wall surfaces. Openings in the walls are generally ignored unless they are significantly large. The most accurate take off can be performed by planning out the exact details of the work, determining how the sheets or planks are actually to be installed over the desired area, and determining the actual cut pieces and where they can be reused.

Example 11.14. *Wall Sheathing Take Off for Exterior Wall*

Refer to Figure 11.5.

Exterior perimeter of building = 2(38 ft + 24 ft) = 124 ft.
Given a wall height of 8 ft.
Total S.F. of exterior wall = 124 ft × 8 ft = 992 S.F.
Using plywood, the number of sheets required = 992 S.F. ÷ 32 S.F./Sheet = 31 sheets.

11.2.7 Roof Framing

Roof framing can be stick-built onsite with rafters fashioned from dimension lumber or more commonly built with prefabricated trusses which tend to be cheaper and faster to assemble. For a simple gable roof as seen in Figure 11.14, the basic elements of the roof shown are ceiling joists, rafters, and ridge board.

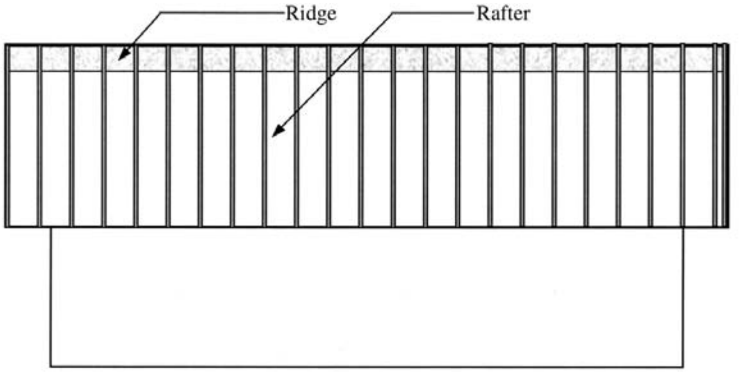
11.2.7.1 Ceiling Joist

Ceiling joists are horizontal framing members similar to floor joists. When rafters are used, the ceiling joists form the bottom of the roof and secure the rafters from pushing beyond the walls. In addition, ceiling joists also support the ceiling finish material and are usually not designed to support a floor load. If the attic is to be used extensively as a storage area, floor joists are required instead. Ceiling joists are taken off in an identical manner to that of floor joists.

11.2.7.2 Rafters

Rafters provide the main support for the roof sheathing, in the same way as the floor joists support the subfloor. Rafters are like the floor joists in that they take the load from the roof sheathing and transfer the weight to the walls. Rafters are typically constructed using 2×6 or 2×8 lumber, but 2×8s and 2×10s are also used. The building plan and specifications must be examined to determine the rafter lumber type and size along with the required spacing. The spacing for rafters can be 12, 16, 20, 24, 32, and 36 inches; however, the most commonly used spacings for rafters are 16 and 24 inches on-center. The number of rafters for the roof can be determined in the same manner as the determination of the number of floor joists.

Estimating the lumber quantity for rafters is a little more complicated than estimating for floor joists. This is because rafters are sloping members and not horizontal members like joists where the dimension can be readily determined. Figure 11.15 illustrates some of the terms used in describing a roof. As shown in the figure, span length is the distance between supporting members of the roof.



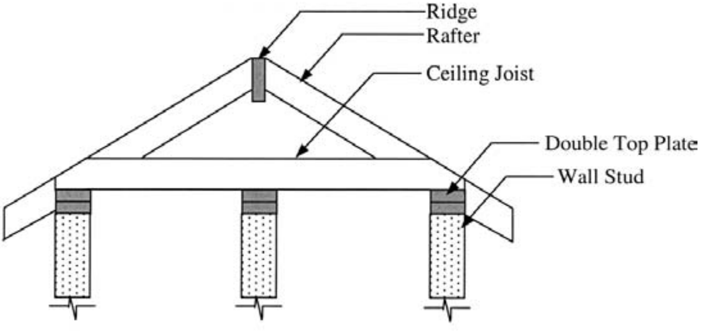


FIGURE 11.14 Gable roof.

Run length is one-half of the span length. For rafters with overhang, the run length includes the distance of the overhang. The rise is the vertical distance from the top plate elevation to the measuring line for the roof slope. Roof pitch is the ratio of the rise and the span. The roof slope is the ratio of the rise and the run.

The length of the rafters is determined as the hypotenuse of a right angle triangle whereby the horizontal distance is the run length and the vertical distance is the rise length. Alternatively, a table with multiplication factors for slope length adjustment can be developed and used, as shown in Table 11.4.

Example 11.15. *Slope Length Calculation*

A span length of 24 ft is given and a rise length of 5 ft.

Run length = 24 ft ÷ 2 = 12 ft.

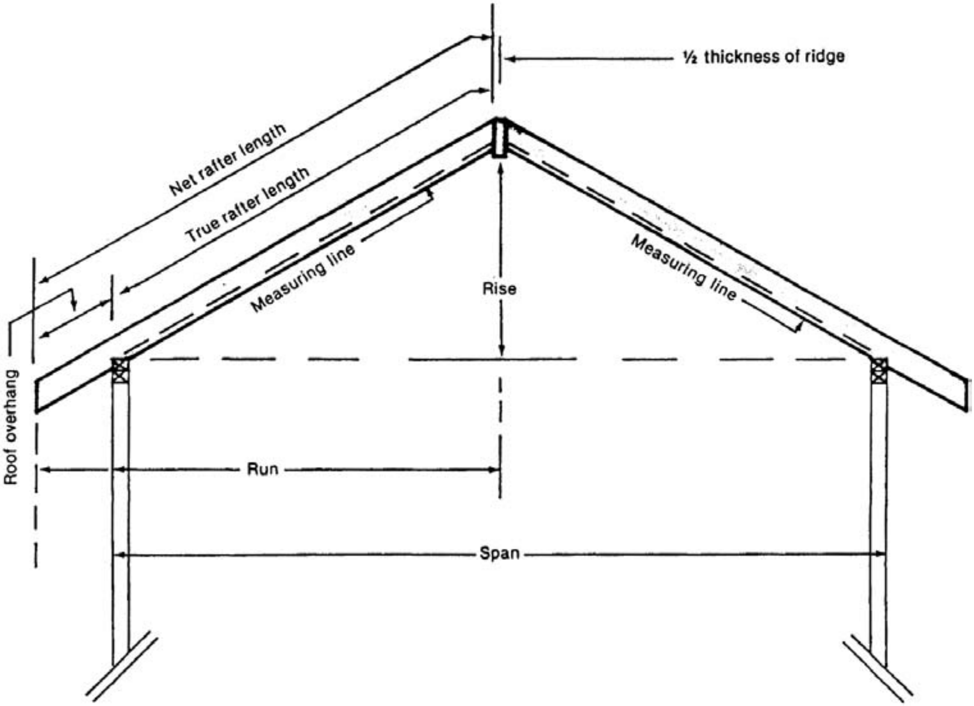


FIGURE 11.15 Roofing terms. (From Jackson, 1987.)

TABLE 11.4 Pitch/Slope Rafter Length Adjustment Factor

Pitch of roof	Slope of roof	Multiplication factor
1:12	2:12	1.015
1:08	3:12	1.030
1:06	4:12	1.055
5:24	5:12	1.083
1:04	6:12	1.120

By right angle triangle: slope length = hypotenuse length = square root ($run^2 + rise^2$) = $12^2 + 5^2$ = 13 ft.

Alternatively, the pitch of the roof is 5:24.

From Table 11.4, the length adjustment factor = 1.083.

Slope length = run length × 1.083 = 12 ft × 1.083 = 13 ft.

11.2.7.3 Ridge

The ridge board is the topmost part of the roof. The ridge board should be one size larger than the rafters. For example, if 2×6s are used for the rafters, 2×8s or larger member sizes should be used as the ridge. The ridge can be easily taken off by determining the total length of the ridge on the roof.

11.2.7.4 Roof Sheathing

Roof sheathing is the main support for the roofing materials, such as roof shingles and tiles. The take off for roof sheathing is identical to the take off for the subfloor. That is, the dimension of the roof is determined and the roof area is calculated and totaled in square feet of roofing surface. The plan and specifications must be consulted to determine the proper thickness and the type of sheathing required. Plywood is the material of choice for decking with asphalt shingles, roll roofing, and slate. The thickness used is usually at least 1/2 in. thick.

11.2.7.5 Truss Roof

Trusses are a roof framework consisting of many individual pieces of lumber that are prefabricated into one unit. Trusses are also fashioned out of 2 in. thick dimensional lumber, usually 2×4s, connected with metal plates or gusset plates. Figure 11.16 illustrates some common light wood truss configurations.

Trusses are an alternative to conventional roof framing. Like conventional roof framing, trusses extend from plate to plate on the exterior bearing walls. The top or upper chord is the equivalent of a rafter, and the bottom chord is the equivalent of the ceiling joist. The truss is connected with gang plates instead of nails. Trusses are prefabricated with a jig at a controlled manufacturing facility and are delivered to the jobsite ready for erection. The ridge is not present in the truss system. Instead, a precut blocking is used and is supplied as part of the truss system. If a truss system is selected as the roof system to be used, the estimating and pricing are often performed by the truss manufacturer who may be subcontracted by the general contractor. The truss subcontractor generally is required to estimate the amount of material, including all the accessories and the installation charges, and tender a bid to the general contractor.

11.2.8 Nails

All the lumber pieces are assembled and secured together using wire nails. Figure 11.17 shows the sizes of common wire nails. Table 11.5 gives the type of wire

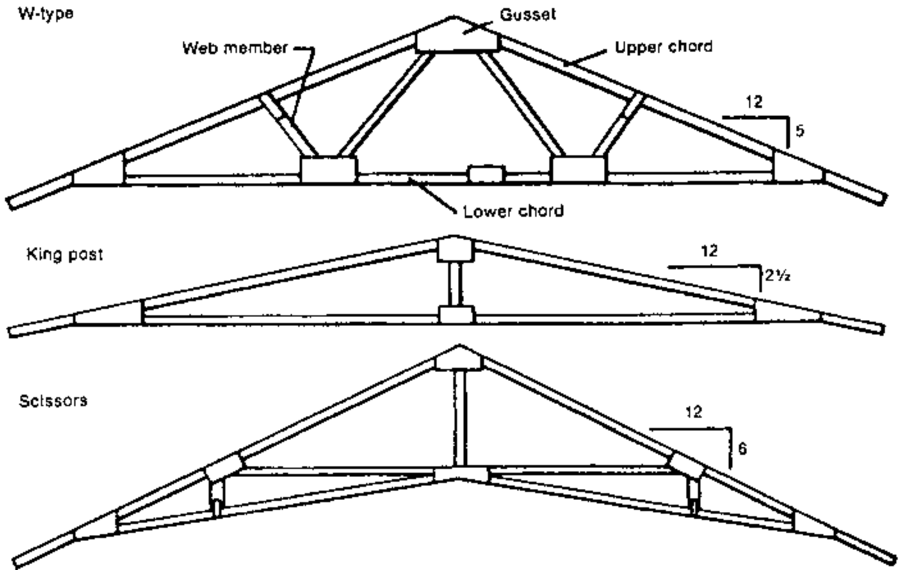


FIGURE 11.16 Light wood trusses. (From Jackson, 1987.)

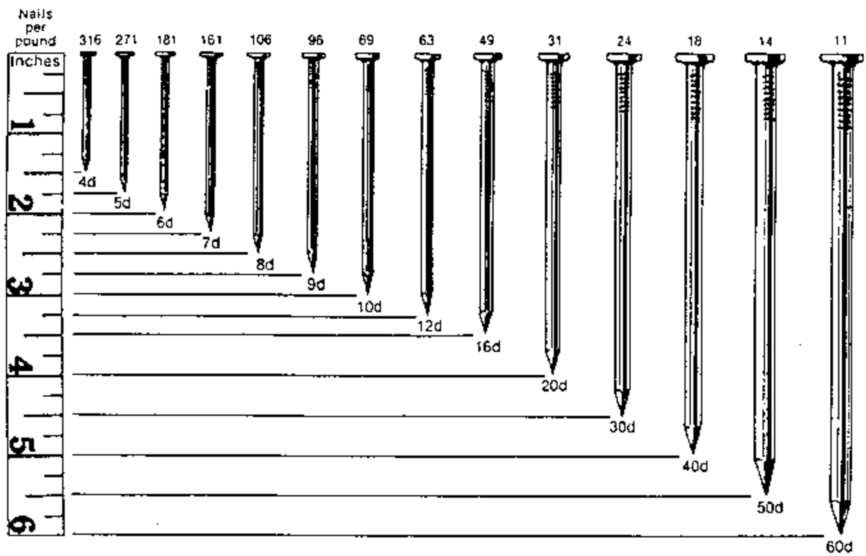


FIGURE 11.17 Sizes of common wire nails. (From Jackson, 1987.)

TABLE 11.5 Nail Types and Quantities Required for Selected Rough Carpentry Work

Material types	Size, kind of nail	Unit	Nails required (lbs)
Joist, 2×6	16d common	M.B.F.	7
Joist, 2×8	16d common	M.B.F.	5
Joist, 2×10	16d common	M.B.F.	4
Joist, 2×12	16d common	M.B.F.	3.5
Subfloor, plywood, 5/8 in.	8d common	1000 S.F.	8
Subfloor, board, 1×6	8d casing	M.B.F.	18
Stud, plate, header, 2×4	16d common	M.B.F.	22
Sheathing, board, 1×6	8d common	M.B.F.	25
Sheathing, board, 1×8	8d common	M.B.F.	20

Source: Jackson, *Carpentry Estimating*, 1987.

nails commonly used along with the number of nails in lbs. for selected rough carpentry work.

11.2.9 Estimating Labor in Wood Framing Work

Figure 11.18 shows a completed form summarizing rough carpentry take off.

Wood framing work is often performed by crews consisting of at least two carpenters and may also involve common laborers who usually function as helpers. The labor costs for framing work will vary with the class of work, whether ordinary or first-grade quality, the complexity of the type of work, and whether tools are available and used. Ordinary workmanship is typically encountered in rough carpentry work in most building projects where cost is the main consideration. On the other hand, first-grade workmanship is often specified when quality is also an important consideration, such as in high-class residences and office buildings, especially in finish carpentry work. The use of modern tools can significantly facilitate the construction process, leading to increased productivity. For example, an electric handsaw can cut a 2×12 plank in four or five seconds, whereas it takes about a minute to do it by hand. Generally the use of power tools can increase productivity by 10 to 20 times (Walker, 1999). It must also be remembered that carpentry is a craft, therefore, the ability and experience of the carpenter can affect the productivity of the framing work and ultimately the cost for performing the work. The productivity of selected rough carpentry works can be seen in Table 11.6. Figure 11.19 shows a sample pricing worksheet for rough carpentry.

Company Logo

Quantity Take Off

Date 10/19/99 Sheet No. 1 Of 1

Project Title: Jackson Residence | Project No. A 02 - 02

Take Off By: John Kelly | Extension By: John Kelly | Approved By: Adam Smith

Code*	Description	No.	Dimensions: length	width		Unit		Unit		Unit	Unit
06110 505 5060	Floor Beam → 2×12	3	37'8"			L.F.	113'0"	MBF	0.226		
06110 560 4640	Foundation sill plate → 2×8	1	121'4"			L.F.	121'4"	MBF	0.162		
06110 530 2720	Floor Joist → 2×10	64	12'			L.F.	768'0"	MBF	1.280		
	Joist Header → 2×10	1	76'			L.F.	76'0"	MBF	0.127		
	Total							M.B.F.	1.407		
06110 200 0010	Bridging → 1×3										
	38' × 0.75 = 28.5 → 29 spaces										
	29 spaces × 2 bays × 2 pcs/space =	116				C.Pc.*	1.16				
06160 850 0100	Subfloor	1	38'	24'		S.F.	912				
06110 590 6040	Exterior Wall – Sole plate & Top plate	1	244'4"			L.F.	244'4"	MBF	0.244		
	Interior Wall – Sole plate & Top plate	1	144'			L.F.	144'0"	MBF	0.144		
								MBF	0.388		
06110 590 6160	Exterior Wall – Studs (2×6×8)										
	North & South Wall (38') 2 walls	60									
	East & West wall (23') 2 walls	38									
	add for corners: 4 (1/corner)	4									
	add for abutting walls: 6 (1/each)	6									
	add for door opening: 2 (1/door)	2									
	add for window opening: 9 (2/window)	18									
	Total	128				L.F.	1024	MBF	1.024		
06110 590 6160	Interior Wall – Stud (2×6×8)										
	Bed & Bath 2, East wall (9'6") 2 walls	18									
	Bed & Bath 1, East wall (10'6") 2 walls	18									
	Corridor Wall North & South (12'6") 2 walls	28									
	Add for 2 corner, 2 abutting wall, 4 door	8									
	Total	72				L.F.	576	M.B.F.	0.576		

* Masterformat, Univormat, WBS, other, etc. * C.Pc. = 100 pieces

FIGURE 11.18 Sample rough carpentry take-off worksheet.

Table 11.6 Productivity and Costs for Selected Rough Carpentry Work

Line Item	Description	Daily output	Labor (hrs)	Unit	2000 Bare cost Mat.	Labor	Equip.	Total
06110 Wood Framing								
200 0010	Bridging, wood, for joists 16 in. O.C., 1×3 in.	1.30	6.154	100 pieces	26.50	173.00		199.50
200 0015	Using pneumatic nailed	1.70	4.706	100 pieces	26.50	132.00		158.50
505 5060	Framing, beams, girders, triple, 2×12 in.	2.85	5.614	M.B.F.	740.00	158.00		898.00
505 5065	Using pneumatic nailed	3.31	4.840	M.B.F.	740.00	136.00		876.00
530 2720	Framing, joists, 2×10 in.	1.49	10.738	M.B.F.	605.00	300.00		905.00
530 2725	Using pneumatic nailed	1.71	9.357	M.B.F.	605.00	263.00		868.00
550 0800	Partitions, wood stud with single bottom and double top plate, 2×6 in. stud, 8 ft high, 16 O.C.	90	0.178	L.F.	5.30	5.00		10.30
550 0805	Using pneumatic nailed	108	0.148	L.F.	5.30	4.17		9.47
590 5860	Framing, walls, headers over openings, 2×6 in.	0.36	44.444	M.B.F.	590.00	1250.00		1840.00
590 5865	Using pneumatic nailed	0.43	37.209	M.B.F.	590.00	1050.00		1640.00
06160 Sheathing								
800 0600	Sheathing, plywood on walls with exterior CDX, 1/2 in. thick	1125	0.014	S.F.	0.53	0.40		0.93
800 0605	Using pneumatic nailed	1395	0.011	S.F.	0.53	0.32		0.85
850 0100	Subfloor, plywood CDX, 5/8 in. thick	1350	0.012	S.F.	0.67	0.33		1.00
850 0105	Using pneumatic nailed	1674	0.010	S.F.	0.67	0.27		0.94

Source: Means' *Building Construction Cost Data*, 2000.

Company Logo | **Pricing** | Date 10/19/99 | Sheet No. 1 Of 1

Project Title: Jackson Residence | Project No. A02-02

Prices By: Janet Jones | Take Off By: John Kelly | Quantity By: John Kelly | Extension By: John Kelly | Approved By: Adam Smith

Code*	Description	Quantity	Unit	Material		Labor		Equipment		Subcontract		Total	
				U.P.	Total	U.P.	Total	U.P.	Total	U.P.	Total	U.P.	
06110505 5060	Floor Beam : 2×12 (triple)	0.226	M.B.F.	740	167.24	158	35.71					898	202.95
06110560 4840	Foundation Sill Plate : 2×8	0.162	M.B.F.	1100	178.20	750	121.50					1850	299.70
06110590 2720	Floor Joist and Header	1.407	M.B.F.	605	851.24	300	422.10					905	1273.34
06110200 0010	Bridging : 1×3	1.16	C.Pr.	26.50	30.74	173	200.68					199.50	231.42
06160650 0100	Subfloor, Plywood, CDX 5/8" thick	912	S.F.	0.67	611.04	0.33	300.96					1	912.00
06110590 6040	Exterior & Interior Wall: Plates 2×6	0.388	M.B.F.	590	228.92	600	232.80					1,190	461.72
06110590 6160	Exterior & Interior Wall: Studs 2×6×8	1.600	M.B.F	590	944.00	450	720.00					1,040	1664.00
06110590 5860	Header over opening : 2×6	0.146	M.B.F.	590	86.14	1250	182.50					1,840	268.64
06160800 0700	Exterior Wall sheathing : Plywood 5/8"	992	S.F.	0.67	664.64	0.43	426.56					1.10	1091.20

* Masterformat, Uniformat, WBS, other, etc.

FIGURE 11.19 Sample rough carpentry pricing worksheet.

11.3 FINISH CARPENTRY

Finish carpentry refers to the installation of finish material such as decorative trim, molding, and wood paneling on walls. In addition, finish carpentry may also include the installation of cabinets as well as the stairs and other miscellaneous wood ornaments. Generally, finish carpentry is further classified as exterior and interior finish carpentry.

Unlike rough carpentry, the materials and methods in finish carpentry are not localized to just the US and Canada, therefore, the finish carpentry section is presented in both English and metric systems.

11.3.1 Exterior Finish Carpentry

Exterior finish carpentry includes the installation of items such as fascia board, soffit, frieze board, and molding as shown in Figure 11.20. For these exterior works, the quality of the material is important. The lumber selected should be rated for exterior work, having good weather resistance and the ability to hold paint well. Due to the high visibility of the exterior trims, the number of joints for exterior finishing work should be kept to a minimum.

11.3.1.1 Fascia Board

Fascia board is the outermost part of the cornice. The cornice is the part of the roof that is projected beyond the building wall. Fascia board is the member that is attached vertically to the end of the rafters or trusses, thus closing that open

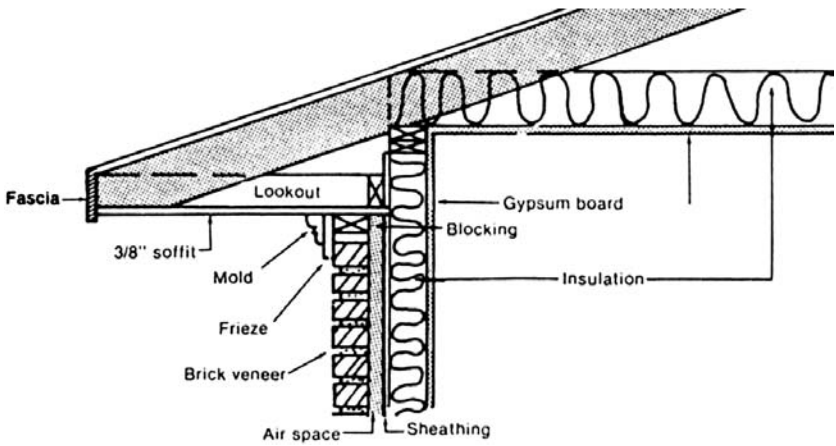


FIGURE 11.20 Cornice detail. (From Jackson, 1987.)

end of the rafters, just like the header member closing the open end of the floor joists. Fascia board is typically one inch thick with the width long enough to cover the ends of the rafters or trusses. Typical lumber sizes used are 1×6 (25 mm × 150 mm) and 1×8 (25 mm × 200 mm). The take off for fascia board is determined by the lumber size used and the total length in linear feet (L.F.) or meters of the fascia board required.

11.3.1.2 Soffit

Soffit is sometimes used to box in the roof overhang as shown in Figure 11.20. The soffit is usually made of exterior-grade plywood with typical thicknesses being 1/4 in. (7 mm), 3/8 in. (10 mm), 1/2 in. (13 mm), 5/8 in. (16 mm), and 3/4 in. (19 mm). Only one side of the plywood will be visible, so the hidden side can be of lower quality; usually an A grade is selected for the exposed surface and a C grade is selected for the hidden surface. In estimating for plywood soffit work, the type of plywood specified is first determined. The take off for the plywood soffit is in square feet (S.F.) or square meters (m^2), which can be calculated by taking the horizontal length of the overhang and multiplying by the length of the roof. In addition, the number of plywood sheets required can be easily computed by dividing the total square feet or square meters of soffit required by the area of a 4 ft × 8 ft (1200 mm × 2400 mm) plywood sheet.

11.3.1.3 Frieze Board

Frieze board is typically used as trimming around a building with concrete or masonry finishing. The frieze board also serves as the base for the exterior molding when it is used, as shown in Figure 11.20. On a building with wood siding as the exterior finished material, the frieze board may not be necessary and the molding can be installed directly onto the wood siding. Like the fascia, the frieze board is usually 1 in. or 25 mm thick lumber. Typical widths are 4 in. (100 mm), 6 in. (150 mm), and 8 in. (200 mm). Since the frieze board is typically installed around the building exterior, the quantity take off for the frieze board is determined by the total perimeter length of the building's exterior walls. The take off for the frieze board is in linear feet or meters.

11.3.1.4 Exterior Molding

Molding is another decorative item used on both exterior and interior finish carpentry. For exterior work, the wood molding used must be exterior grade. Figure 11.21 shows the shapes and sizes of selected common moldings used for exterior trims. For exterior molding, the take off involves determining the type of molding used and the total length of molding required. The total length is usually the perimeter of the building's exterior wall. The length is taken off in linear feet or meters, similar to the frieze board take off.

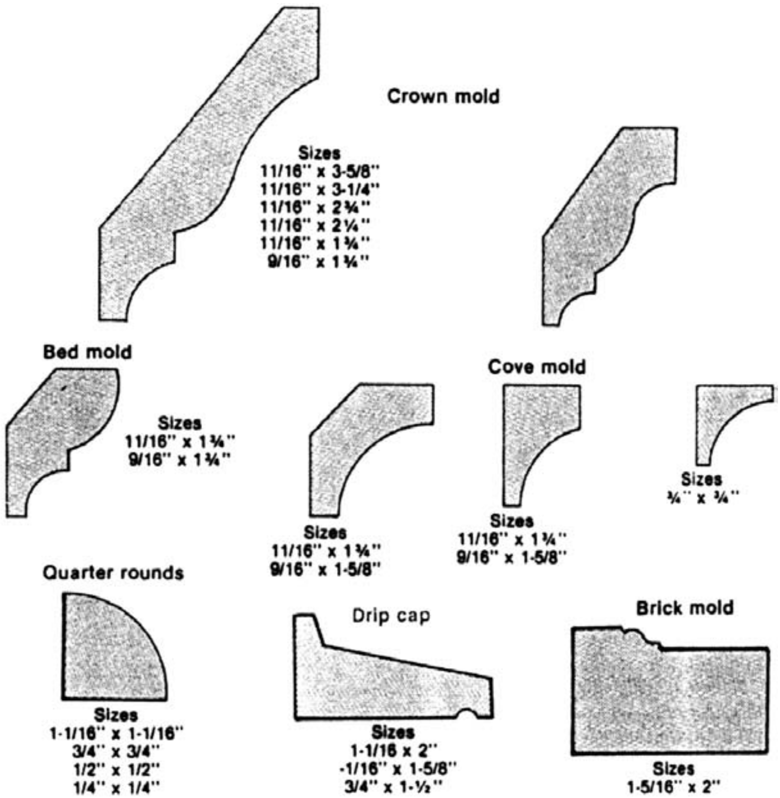


FIGURE 11.21 Molding. (From Jackson, 1987.)

11.3.2 Interior Finish Carpentry

Interior finish carpentry generally includes the installation of interior stairs and interior trims.

11.3.2.1 Stair

Apart from its functionality, a stair is one of the most important aesthetic elements in interior design. Final stair construction is often executed in the final stages of finish carpentry, so as to minimize wear and tear on the finish surfaces. A rough stair is often laid out during the rough carpentry stage so that workmen can move from level to level within the building. Rough lumber is used for the temporary tread until the building is ready to receive the finish interior trims. Then the stair carriage or stringer is installed.

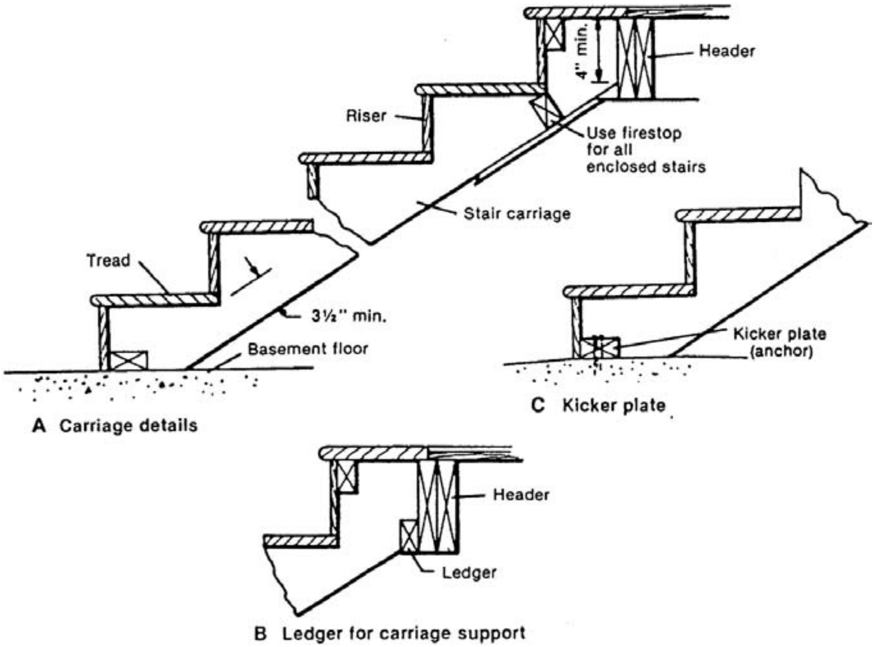


FIGURE 11.22 Stair detail. (From Jackson, 1987.)

The components of a stair are shown in Figure 11.22. The carriage or stringer is the main structural element of the stair, supporting the load of the stair. It is also the element to which other stair elements are attached. The treads and risers are, respectively, the horizontal and vertical elements installed on the carriages. The tops of the carriages are typically supported by a ledger which is nailed to the floor header. The bottoms of the carriages can rest on the floor or be secured by an anchored kicker plate.

The most accurate take off for a stair is done by performing a detailed take off for each element required in stair construction. Generally, stairs are estimated by their required width and height. Alternatively, the number of risers or flights can also be used for making the estimate. The number of risers can be computed by dividing the floor-to-floor rise with the rise for each tread. The number of flights is one less than the number of risers. For example, if the floor-to-floor rise is 8 ft 10 in. (106 in.) and the tread rise is 8 in., the result of the division is 13.25 risers. Therefore, the number of risers used can be either 13 or 14 risers. If 14 risers are used, the number of flights is 13. Table 11.7 presents the productivity and cost data for selected stair construction.

Table 11.7 Productivity and Costs for Selected Stair Construction

Line item	Description	Daily output	Labor (hrs)	Unit	2000 Bare cost Mat.	Labor	Equip.	Total
06430 Stairs & Railing								
620 0200	Stairs, prefabricated, box stairs, 3 ft wide, oak treads, no handrails, 4 ft high	4	4	Flight	430.00	113.00		543.00
620 0400	Stairs, prefabricated, box stairs, 3 ft wide, oak treads, no handrails, 8 ft high	3	5.333	Flight	775.00	150.00		925.00
620 0700	Stairs, prefabricated, box stairs, 3 ft wide, pine treads for carpet, no handrails, 4 ft high	4	4	Flight	164.00	113.00		277.00
620 0900	Stairs, prefabricated, box stairs, 3 ft wide, pine treads for carpet, no handrails, 8 ft high	3	5.333	Flight	274.00	150.00		424.00
620 1100	For 4 ft wide stair add			Flight	25%			
620 4000	Residential, wood, oak treads, prefabricated	1.50	10.667	Flight	930.00	300.00		1230.00
620 4200	Residential, wood, oak treads, built in place	0.44	36.364	Flight	1325.00	1025.00		2350.00

Source: Means' *Building Construction Cost Data*, 2000.

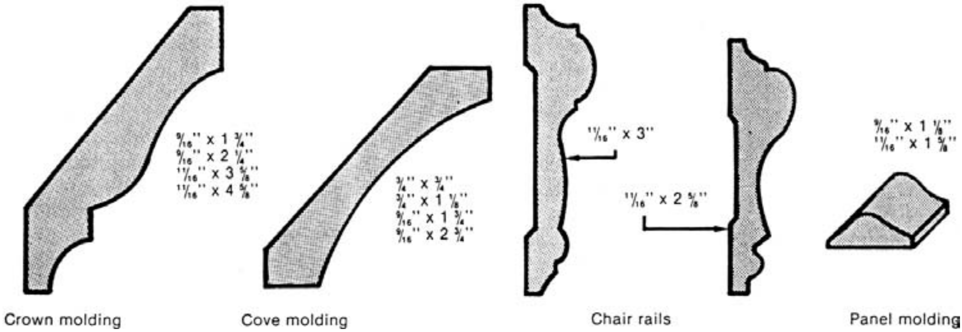


FIGURE 11.23 Wall molding. (From Jackson, 1987.)

11.3.2.2 Interior Trim

Interior trim consists of several types of molding, some of which are wood base, wood panel molding, wood chair rail, and crown molding. All moldings and chair rails are taken off by length, in linear feet or meters. Figure 11.23 shows common types of wall moldings. In addition, Figure 11.24 illustrates the placement of these wall moldings.

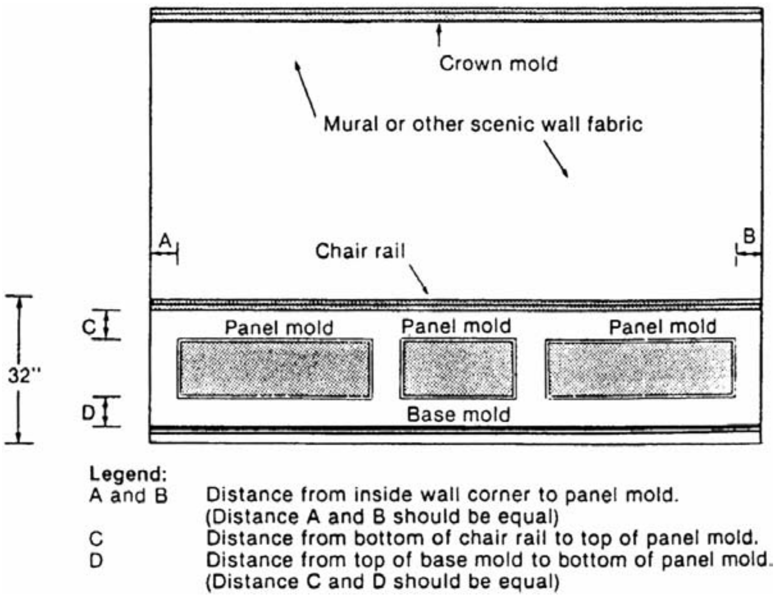


FIGURE 11.24 Wall molding placement. (From Jackson, 1987.)

TABLE 11.8 Productivity for Selected Finish Carpentry Work

Work category	Unit	Productivity	
		Daily output	Labor (hr)
English			
Exterior finish carpentry-molding, fascia	L.F.	238	0.034
Exterior finish carpentry-molding, cornice boards	L.F.	253	0.033
Interior finish carpentry-molding, base	L.F.	227	0.035
Interior finish carpentry-molding, ceiling	L.F.	267	0.031
Interior finish carpentry-trim, chair rail	L.F.	255	0.032
Interior finish carpentry-paneling, hardboard	S.F.	500	0.032
Interior finish carpentry-paneling, plywood	S.F.	420	0.038
Metric			
Exterior finish carpentry-molding, fascia	m	72.4	0.111
Exterior finish carpentry-molding, cornice boards	m	77.4	0.110
Interior finish carpentry-molding, base	m	69.1	0.116
Interior finish carpentry-molding, ceiling	m	81.4	0.100
Interior finish carpentry-trim, chair rail	m	77.2	0.206
Interior finish carpentry-paneling, hardboard	m^2	46.5	0.344
Interior finish carpentry-paneling, plywood	m^2	39.0	0.410

Source: Means' *Building Construction Cost Data*, 2000.

11.3.2.3 Interior Paneling

Wood paneling used today is generally prefinished and can be in the form of hardboard or plywood sheets. Quantity take off for wood paneling is in the number of square feet or square meters of wall coverage required.

11.3.2.4 Architectural Woodwork

Cabinets can be taken off by the type and number of units required. Cabinets are often supplied by millwork subcontractors and delivered to the jobsite prefabricated, generally requiring minimal handling and installation. Miscellaneous wood ornaments consist of various kinds of products, such as fireplace mantels, louvers, and grills, and can be taken off in a variety of ways.

The terms finish carpentry and architectural woodwork differ only by the quality of the workmanship. Architectural woodwork generally refers to work that is custom made and of high quality. Architectural woodwork is usually supplied and installed by specialty subcontractors.

Table 11.9 Productivity for Selected Finish Carpentry Work

		Carpenter hours		Labor hours	
		Workmanship		Workmanship	
Work category	Unit	Ordinary	First grade	Ordinary	First grade
English					
Exterior finish carpentry-fascia board	hr./100 L.F.	4.0	NA	NA	NA
Exterior finish carpentry-wood cornice	hr./100 L.F.	14.2	NA	NA	NA
Interior finish carpentry-wood base	hr./100 L.F.	5.8	7.4	1.0	1.0
Interior finish carpentry-wood picture molding	hr./100 L.F.	3.0	4.4	0.5	0.5
Interior finish carpentry-wood chair rail	hr./100 L.F.	2.8	0.5	3.8	0.5
Interior finish carpentry-sheet paneling	hr./100 S.F.	1.6	NA	NA	NA
Metric					
Exterior finish carpentry-fascia board	hr./100 m	13.3	NA	NA	NA
Exterior finish carpentry-wood cornice	hr./100 m	47.3	NA	NA	NA
Interior finish carpentry-wood base	hr./100 m	19.3	24.7	3.3	3.3
Interior finish carpentry-wood picture molding	hr./100 m	10.0	14.7	1.7	1.7
Interior finish carpentry-wood chair rail	hr./100 m	9.3	1.7	12.7	1.7
Interior finish carpentry-sheet paneling	hr./100 m^2	1.8	NA	NA	NA

Source: Walker's *Building Estimator's Reference Book, 26th Edition*, 1999.

11.3.3 Labor and Productivity for Interior Carpentry Work

Similar to rough carpentry, estimating the labor costs for finish carpentry must consider the desired construction quality or grade. In practice, there are three grades of workmanship for finish carpentry: economy, custom, and premium. Economy is the lowest grade and premium is the best grade. Custom grade is usual for most construction applications. Premium grade can decrease the work productivity from that of custom by 25 to 50% (Means, 1999). Custom grade can be referred to as "ordinary workmanship," whereas premium grade is referred to as "first-grade workmanship." The productivity of selected finish carpentry work can be seen in Tables 11.8 and 11.9.

11.4 REVIEW QUESTIONS

1. Give some of the reasons for the popularity of wood as a basic construction material.
2. What is rough carpentry?
3. List some of the works involved in rough carpentry.
4. What is finish carpentry?
5. List some of the works associated with finish carpentry?
6. What is dimension lumber?
7. Under what condition is chemically treated lumber used?
8. What is meant by green lumber?
9. What is nominal dimension?
10. What is meant by dressed lumber?
11. What are board feet?
12. What is the standard size of plywood?
13. What are the two types of residential framing and how are they different?
14. List and describe the elements of floor framing.
15. List and describe the elements of wall framing.
16. List and describe the elements of roof framing.
17. What is roof pitch?
18. What are some of the factors affecting rough carpentry productivity?
19. What are some of the benefits of using wood trusses for roof framing?

12

Thermal and Moisture Protection

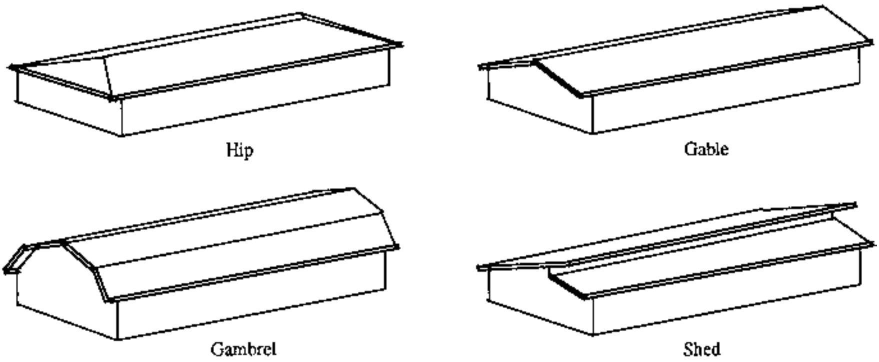


FIGURE 12.1 Types of sloped roofs.

12.1 INTRODUCTION TO THERMAL AND MOISTURE PROTECTION

Thermal and moisture protection work encompasses many products, types, specifications, and properties. For a better understanding of quantity take off, the following sections introduce roofing technology, codes, and regulations related to thermal and moisture protection work. Later sections of this chapter discuss four major types of materials: waterproofing, dampproofing, insulation, and roofing. Each section primarily deals with types of materials and take off and pricing issues.

12.1.1 Roofing Terminology

There are several common types of sloped roofs, as shown in Figure 12.1. These simple shapes are often complicated by intersecting walls or roofs and projections through the roofs. Projections include chimneys, plumbing vents, roof ventilators, and dormers. A composite diagram of sloped roof types, accompanied by roofing terminology is shown in Figure 12.2.

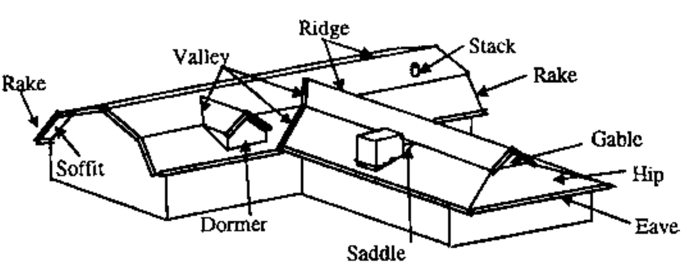


FIGURE 12.2 Roofing terminology.

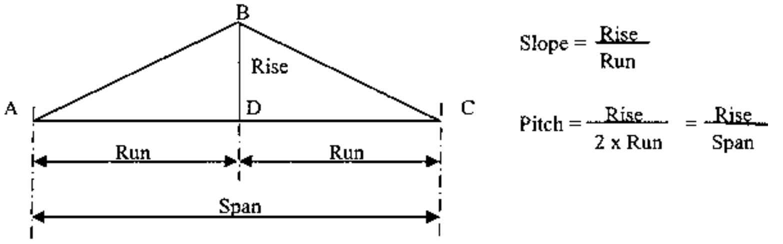


FIGURE 12.3 Slope and pitch.

Figure 12.3 shows the cross-section of a roof. The terms "slope" and "pitch" are sometimes confused when referring to the incline of a sloped roof. Both terms are defined and shown in Figure 12.3. Slope refers to the incline of a roof as a ratio of vertical rise and horizontal run. Pitch refers to the incline of a roof as a ratio of the vertical rise to the span, or twice the horizontal run. Figure 12.4 shows shingle roofing terminology.

12.1.2 Codes and Regulations in Thermal and Moisture Protection Work

Thermal and moisture protection work requires a number of materials which must conform to various standards, including those established by the American Society for Testing and Materials (ASTM) and those set by the General Services Administration and known as Federal Specifications. Table 12.1 lists several types of products for waterproofing and dampproofing, and for insulating, along with their respective standards. For instance, waterproofing and dampproofing

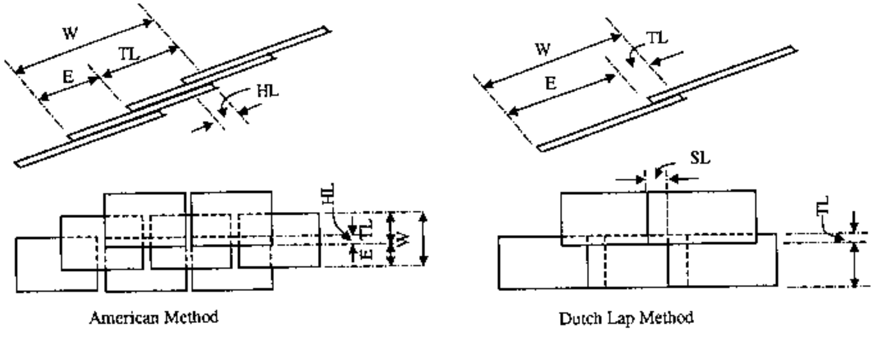


FIGURE 12.4 Shingle roofing terminology: E = exposure; TL = toplap; HL = headlap; SL = sidelap; W = width for strip shingles or length for individual shingles.

TABLE 12.1 Current Quality Standards

Waterproofing and dampproofing products		Insulating Products	
Material	Standard	Material	Standard
Coal-tar-based pimer	ASTM D43	Polystyrene	ASTM C578
Coal-tar bitumen	ASTM D450 Type II or III	Polyurethane	ASTM C591
Coal-tar felt (No.15)	ASTM 227	Polyisocyanurate	Fed. Spec. HH-I-1972/1
Asphalt primer (cut-back type)	ASTM D41	Phenolic	ASTM C1126
Waterproofing asphalt (vertical surfaces)	ASTM D449 Type I	Perlite loose fill/board	ASTM C549/C728
Waterproofing asphalt (unexposed horizontal surfaces)	ASTM D449 Type II	Vermiculite	ASTM C516
Waterproofing asphalt (exposed surfaces)	ASTM D449 Type C	Cellular glass	ASTM C552/E136
Asphalt-saturated organic felt (No.15)	ASTM D226	Organic fiber	ASTM C208/C209
Bituminous-saturated organic fabric	ASTM D173	Mineral fiber	ASTM C553/C612/C665/C687/C726/C764

asphalt should conform to ASTM D449 Types I, II, and C for vertical, unexposed horizontal, and exposed surfaces, respectively. Some insulation materials are manufactured from flammable materials or materials that produce toxic combustion discharges when they are heated or burned. Most building codes require that these materials are protected by fire-resistant finishes, such as gypsum wallboard.

12.2 WATERPROOFING

12.2.1 Moisture Problems and Controls

Moisture can be present in several states: as an invisible gas (water vapor), a liquid (water), and a solid (ice). Even though moisture in its vapor form does not damage buildings, it is very unstable and becomes dangerous as it condenses (liquefies) or freezes (solidifies). Eventually, condensation can cause the decaying of organic materials, corroding of metal products, and blistering of paint coatings. Moreover, freezing can cause the cracking or spalling of concrete and masonry. These moisture problems can exist in heated buildings in cold climates or in cooled buildings in warm humid climates, where there are temperature decreases or the passage of water vapor to areas with lower temperature.

There are two kinds of condensation: surface and concealed. Surface condensation occurs when the surface of a building structure loses heat fast enough to reach the dewpoint (condensation temperature). Visible surface condensation may occur in summer on both below-grade and slab-on-grade structures such as concrete basement walls and floors, tunnels, pits, horizontal decks below paving or earth, and exposed cold-water pipes. Due to their large mass, these structures tend to maintain a relatively cool and constant temperature. If the dewpoint temperature of the air within the space rises above the temperature of these structures, condensation can damage finish surfaces in below-grade spaces or finish flooring laid on a slab on grade.

Concealed condensation occurs when the persistent production of water vapor inside an occupied building raises the vapor pressure above the pressure outside the building, resulting in vapor diffusion into exterior walls, ceilings, and roofs. In winter, when water vapor is allowed to enter a structure and condensation occurs within its cold outer layers, frost or water may develop in siding and sheathing, causing paint failure; in wall cavities causing decay; and in concealed spaces of the roof and ceiling assembly causing a buildup of roof blisters and cracks. In building spaces with high relative humidity, such as laundries, saunas, and pool enclosures, special consideration must be given to the proper placement of vapor retarders and to sufficient insulation.

Moisture problems resulting from both surface and concealed condensations can be prevented or minimized by using waterproofing or dampproofing systems. The term "proof" can be misleading in construction, because technically there is no product that will completely waterproof or dampproof. Rather, products can only resist or retard the penetration of water or dampness. The extent of resistance to or retardation of water and dampness depends on the materials used, installation procedures, and level of maintenance.

12.2.2 Waterproofing Materials

Waterproofing is a membrane, coating, or sealant composed of one or several materials, and is used to prevent or resist the passage of water into building structures and to resist the hydrostatic pressure to which building structures might be subjected. There are three basic types of waterproofing materials: membrane, clay, and cementitious.

12.2.2.1 Membrane Waterproofing

Membrane waterproofing systems for vertical and horizontal surfaces consist of several similar materials, as shown in Figure 12.5. On vertical surfaces, the system is composed of a membrane, a protection course, a drainage medium, and

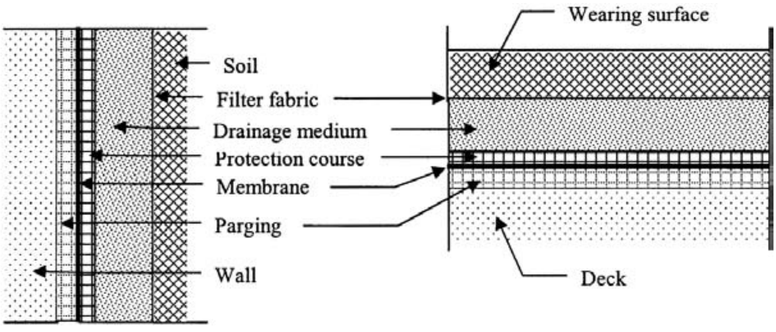


FIGURE 12.5 Vertical and horizontal membrane waterproofing systems.

a layer of filter fabric. Similarly, on horizontal surfaces, there is a membrane, a protection course, a drainage medium, a layer of filter fabric, and a wearing surface. There are three possible types of membranes: fluid-applied, sheet, and bituminous.

Fluid-applied membranes produce a continuous, flexible, and water impermeable film on a variety of surfaces such as concrete, masonry, stone, wood, and metal. Fluid-applied membranes are generally thicker than sheet membranes and leaks are easily located. Major advantages of fluid-applied membranes are that the materials are relatively less expensive than sheet membranes and they conform easily to irregular surfaces. On the other hand, the installation cost of fluid-applied membranes is usually higher than sheet membranes because of the difficulty of installation. Many concealed fluid-applied waterproofing membranes used nowadays are polyurethane or hot rubberized asphalt. Silicone and neoprene systems are also available on the market. Sheet membranes are made of several materials including butyl synthetic rubber sheet, ethylene propylene diene monomers (EDPM) sheet, premolded bituminous sheet, rubberized asphalt sheet, and self-adhesive butyl sheet.

Another type of membrane, bituminous membrane, is usually applied on vertical below-grade surfaces, but sometimes on horizontal surfaces. Bituminous membranes contain different numbers of plies with a variety of thickness and content. They include hot coal-tar pitch, hot asphalt, and self-adhering sheet or roll products. Hot coal-tar pitch is used when the melting point can be kept low and there is no incompatibility with adjacent materials. It is used directly or in combination with sheet or roll materials such as roofing felt, polyester, nylon, and fiberboard. Hot asphalt, however, is found in a natural state or is refined from petroleum. It is required when a higher melting point is needed. Another type of bituminous product is a self-adhering sheet or roll product that is a combination of rubber and asphalt or pitch, such as neoprene or butyl. These sheet and roll products are highly moisture resistant, and are currently widely used for below-grade, on-grade, and roofing systems.

12.2.2.2 Clay Waterproofing

Clay waterproofing is a layer of bentonite clay which, when wetted, can expand to between 10 to 15 times its dry volume. Bentonite is usually applied below grade to the exterior surfaces of building walls and tunnels. Bentonite is especially useful in restricted areas where access is not available to install membrane waterproofing. It is available both in loose form for mixing with water and spraying in place and in dry sheets placed between cardboard and adhered to a drainage board and a plastic sheet.

12.2.2.3 Cementitious Waterproofing

Cementitious waterproofing for nondecorative purposes is made of Portland cement, aggregate, and acrylic or plastic admixtures. Iron oxide waterproofing is composed of the previous materials, plus pulverized iron fillers. This type of cementitious waterproofing is used on the exterior or interior of below-grade walls, pits, and sumps. Another type of cementitious waterproofing is hydraulic cement composed of cement and rapid-setting hydraulic material. This type is used to seal holes, cracks, and open joints.

12.2.3 Take Off and Pricing for Waterproofing

The total cost of waterproofing work is influenced by several variables including use and type of materials, material prices, quantity or covering capacity, and cost of applying such materials. There are several kinds of waterproofing materials, as discussed in previous sections. Prices of these materials vary significantly in different locations, so the estimator should check with local distributors for current prices. Most moisture protection work is performed by cement masons, plasterers, bricklayers, or roofers. Thus the cost estimator needs to consider factors affecting labor productivity. Equally important, there are several methods for mixing and applying waterproofing materials that can influence the total cost of waterproofing work.

One of the most widely known methods of waterproofing is the integral method, which is used where the various liquids, pastes, or powders are mixed in with the concrete mass. While the concrete is being mixed, the water-repelling compounds are blended with the cement, sand, and gravel to fill the voids in the cement and sand mixture and produce a waterproof mixture. The quantity ratios are subject to the specifications of the manufacturers. The estimator should estimate additive admixtures in the concrete mass in gallon per cubic meter of the concrete. Prices of the additive materials are provided by manufacturers based on the locality.

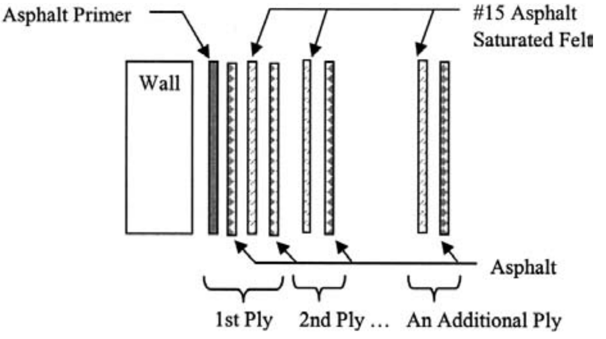


FIGURE 12.6 Applications of waterproofing on a wall surface.

When the integral method of waterproofing is not permitted, the membrane method may be required. A membrane waterproofing system consists of two to seven hot mappings of pitch or asphalt on one to six plies of saturated felt or fabric, as shown in Figure 12.6. Prior to applying the first hot bitumen mopping coat asphalt primer should be applied uniformly and completely. A layer of saturated felt or fabric and hot asphalt are applied next to complete the first ply of waterproofing. Thereafter, additional plies of waterproofing can be applied. After the last ply of saturated felt or fabric is applied, the entire surface is mopped with a heavy application of hot pitch or asphalt. At the jobsite, three or four workers are required to apply membrane waterproof to walls and floors. One worker is required to attend the fire and heat the bitumen, while two or three workers are mopping the walls and applying the felt or fabric.

Based on drawings and specifications, the number of plies, the lap, the type of felt, the number of felt rolls, and the amount of tar or asphalt of each structure surface can be determined. The quantities of various materials include the number of plies, rolls of felts, and gallons of asphalt primer. These quantities are used along with materials costs and labor rates to determine the total work cost. The estimator can estimate quantities of a variety of plaster coats, paints, and membrane waterproofing compounds by determining the entire surface area in square meters (m^2) of the materials applied.

12.2.3.1 Asphalt Primer

To determine the quantity of asphalt primer, the estimator must determine the entire surface area, multiplied by the amount of asphalt primer per m^2 of surfaces. About 4.1 liters of asphalt primer can cover 10 m^2 of surfaces. For one application of the primer to the surface, one worker can coat about 10 m^2 per 1.07 hours.

Table 12.2 Required Pitch or Asphalt Weights per 10 m^2 Surface

No. plies saturated fabric of tarred felt	Alternate moppings of pitch or asphalt required	Weight (kg) pitch or asphalt required/ 10 m^2/waterproofing
2	3	44–52
3	4	60–68
4	5	72–86
5	6	88–104
6	7	104–120

12.2.3.2 Pitch or Asphalt

To determine the quantity of pitch or asphalt, the estimator first determines the area of the waterproofing to be applied, multiplied by the quantity of pitch or asphalt per m^2 of surfaces. For one application of asphalt, two workers can heat and mop about 200 m^2 per 8-hour day, or a total of 0.80 hours per 10 m^2 for two workers. The workers use approximately 34.1 kg of asphalt for mopping 10 m^2 of surface on the first ply, and 15 to 17 kg per 10 m^2 of surface on each additional ply. Table 12.2 shows the weight of pitch or asphalt per 10 m^2 of surface, based on different numbers of layers of saturated felt. Prices of pitch or asphalt vary significantly due to market conditions, locations, and manufacturers, so the estimator should check with local distributors.

12.2.3.3 Felt or Fabric

To estimate the quantity of felt or fabric in rolls, the estimator must determine the entire surface area, divided by the area of felt or fabric in one roll. Tar or asphalt felt for waterproofing is furnished in rolls of 40 m^2 weighing 27 kg per roll, so tar or asphalt saturated fabric is usually sold by m^2 or by the roll. At the jobsite, two workers are required to cut the felt to lengths and place it on the wall, at a rate of about 200 m^2 of surface per 8-hour day, or a total rate of 0.8 hours per 10 m^2. For the first ply, 0.30 rolls of No.15 felt (0.30 rolls $\times$ 40 m^2/roll = 12 m^2) are required to coat a surface of 10 m^2 (plus 2 m^2 for waste). For any additional ply, 0.26 rolls of No.15 felt are required to coat 10 m^2 of surfaces.

The total estimated quantity of felt required for various building surfaces must include a percentage for overlap and waste. As shown in Table 12.3, if the felt is applied to walls or floors covered with a single layer of felt or membrane, each strip of 900 mm felt requires a 100 to 15 mm lap based on specifications, which is approximately 12 to 17% of the original surface. In the same manner, each strip of 400 mm felt requires a 100 to 150 mm lap, which is approximately 20 to 25% of the original wall or floor area. However, if more than one strip of

Table 12.3 Percentage of Lap and Waste of Felt or Fabric

Felt	Width of felt (mm)	Length of lap (mm)	Lap and waste (%)
Single	900	100	12
Single	900	150	17
Single	400	100	20
Single	400	150	25
Multiple	—	100	7
Multiple	—	150	10

felt is required, the estimator should allow 100 to 150 mm laps at the ends of the wall or floor, which is about 7 to 10% of the actual area.

12.3 DAMPPROOFING

12.3.1 Dampproofing Materials

Dampproofing usually consists of a bituminous coating applied to prevent building materials from absorbing moisture or to prevent moisture from penetrating further into an invaded system. However, bituminous dampproofing is not appropriate for resisting hydrostatic pressure. Dampproofing may be used on either interior or exterior surfaces, but in either case it is usually concealed. There are two types of bituminous dampproofing on the market: cold and hot forms.

12.3.1.1 Hot-Applied Bituminous Dampproofing

A hot-applied bituminous dampproofing system is composed of either an asphalt primer and dampproofing asphalt, or a coal-tar-based primer and coal-tar bitumen. Asphalt or pitch is heated into a semiliquid state and is applied to walls or slabs by mopping, spraying, or spreading over felt strips, cloth, or fiber mesh. Hot-applied bituminous dampproofing is used on the exterior of buildings, usually underground, and especially on large projects when the use of a hot system with solvents is permitted. It may be applied directly on smooth concrete walls or on a coat of parging over masonry.

12.3.1.2 Cold-Applied Dampproofing

A cold-applied dampproofing system can be either a coal-tar- or asphalt-based system. It is used on both the interior and exterior of buildings, and especially on small projects where the use of a hot product would be difficult or too costly. However, due to the fact that coal-tar products have a distinctively unpleasant odor, they are almost never used on the interior of buildings. Coal-tar-based cold-applied bituminous dampproofing systems are composed of a coal-tar bitumen compound including coal-tar pitch and solvent compound, inorganic fiber reinforcement, and a variety of fillers. On the other hand, asphalt-based cold-applied bituminous dampproofing systems are composed of cut-back asphalt or asphalt emulsion materials. Both materials are available as liquid, semifibrated, or heavily fibrated types. They are available in cans and drums, and can be cold-applied directly from the container by trowel, brush, or broom.

12.3.2 Take Off and Pricing for Dampproofing

Variables affecting costs of dampproofing include location, work space, condition, number of coats, type of materials, and method of application. As for materials, there are many waterproofing paints available on the market. Based on specifications, the application of one or more coats of paint can be required to make walls impermeable to dampness. Workers can use a roofer's brush or a mop to apply dampproofing paints for exterior walls below grade. For the first coat of this nature of work, a worker can apply about 55 to 65 m^2 per 8-hour day. For the second and third coats, the worker can slightly increase the productivity rate due to the fact that the working surface is smoother and the worker is familiar with the working area.

For the interior of exterior masonry walls, one or more coats of heavy black paint acting as a dampproofing and plaster bond are applied prior to applying the first coat of plaster. The labor productivity for applying plaster bond paints varies depending upon the consistency of the paint, the condition of the wall, and the method of applying the paint. Generally, when the paint is applied by hand, a worker can cover 65 to 75 m^2 per 8-hour day. However, when the paint is applied by an air spray, a worker can cover 220 to 260 m^2 per 8-hour day.

For the exterior walls above grade, colorless and transparent dampproofing is required. This kind of dampproofing is usually made from silicone and is available in a liquid form applied by brushing or spraying. This can be applied to several types of surfaces, such as brick, stone, stucco, and concrete. When applying dampproofing paints by hand, a roofer can apply 85 to 100 m^2 of surface per 8-hour day for the first coat. On later coats, a worker can cover 90 to 110 m^2 per 8-hour day. However, when applying by spray, a worker can cover 215 to 265 m^2 per 8-hour day.

12.4 INSULATION

12.4.1 Heat Transfer and Control

Insulation refers to any material that can retard the transmission of sound and heat through any part of a building structure. Both sound and heat transmissions are of interest to designers, but this chapter covers only heat transfer and control. Heat transfer through a building enclosure occurs by three means: convection, conduction, and radiation. Convection refers to a thermal movement concept where there are upward and downward movements of air due to a difference in air temperature: warm air rises, cold air falls. To prevent or minimize heat transfer, hollow walls, floors, and roofs should be continuously sealed by adding insulation.

Conduction is the transmission of heat through building materials. The rate of conductance of a material or combination of materials is known as the U-value, referring to hourly heat loss or gain through an exterior wall. In other words, the U-value is the amount of heat in British thermal units (Btu) transmitted in one hour per square foot of wall area, as a difference of temperature between the inside and outside air is 1°F. The reciprocal of the U-value is the R-value ($R = 1/U$). R-values are used for estimating the effect of the individual components of a building section on the total heat flow. Most common insulation products are rated at R-7, R-9, R-19, and R-30. The most recent energy requirements include R-19 in exterior walls and R-30 in the ceiling or the underside of the roof.

The last mean of heat transfer is radiation, the emission of energy from the surface of a building section. For example, bright surfaces are good reflectors and also have low emission coefficients. They are poor heat absorbers. On the other hand, heat will radiate from one dark surface to another constantly. By inserting a layer of reflective surface, the heat will be reflected back to the surface from which it escaped.

Structural and finished materials generally permit excessive heat flow, resulting in lower energy efficiency and, perhaps, an uncomfortable environment. This can result in a higher building maintenance cost. However, heat flow through building materials can be minimized or controlled by several major conventional techniques. The first technique is to use concrete, stone, solid masonry, or other dense materials that have the capacity to store heat and slow heat flow. The second technique is to use building materials that are inherently good insulators. The last technique is to add thermal insulation in the roof, walls, and floors. In most environments except areas of high humidity, insulation products should be placed near the inside of the building envelope.

12.4.2 Insulation Materials

For energy conservation purposes, insulation has become an important issue in building design and construction. To design a building nowadays, a designer creates not only an aesthetic, healthy, and comfortable indoor environment, but also a more energy-efficient building. To serve such purposes, several insulation materials are manufactured and classified into groups: rigid, mineral fiber, loose-fill, and foamed-in-place.

12.4.2.1 Rigid Insulation

Rigid insulation materials are usable in all parts of a building, including foundations, walls, roofs, and special-shaped areas. They are rigid boards made from polystyrene, polyurethane, polyisocyanurate, phenolic, cellular glass, organic fiber, perlite, and glass fiber. Polystyrene, polyurethane, and polyisocyanurate are preformed nonstructural plastic cellular products. Polystyrene boards are used over structural roof decks, beneath promenade walking surfaces, at foundation perimeters, and in masonry cavities, whereas polyurethane boards are made with asphalt-impregnated felt bonded to both sides, for use in roofing systems. Polyisocyanurate insulation products are lined with reflective foil, foil-kraft material, or glass fiber felt. They are used for wall sheathing and in roofing systems.

Phenolic insulation products are made with a foil-kraft liner or a glass fiber scrim, and are used in walls and in roofing systems. Cellular glass insulation products are noncombustible lightweight boards used on roof decks, exterior decks, and promenades and as perimeter insulation products for slabs and foundations. On the other hand, organic fiber insulation products are used in roofing systems and are made of wood fibers or other organic fibers and water-resistant binders. Perlite is used with mineral binders and waterproofing agents to make insulation boards. Lastly, glass fiber insulation products are made from inorganic glass fibers bonded together by a resinous binder. They are used primarily in roofing systems.

12.4.2.2 Mineral Fiber Insulation

Mineral fiber insulation materials are produced from slag, glass, or, in some countries, rock. Products made from slag are sometimes called rock wool or mineral wool. Mineral fiber insulation materials are manufactured in rigid and semirigid boards and in blankets or batts. Rigid and semirigid mineral fiber insulation materials are used mostly for roofing systems and curtain walls, respectively. Blankets and batts are similar in appearance and composition, but different in length. Blankets are generally produced in rolls that can be cut to size, but batts are made in 120 cm wide panels. Both are used generally in areas where loose-fill insulation materials are not permitted or where the attached foil or kraft paper facing is required as a vapor retardant. They are used as thermal insulation in walls and partitions, below floors in crawl spaces, and above ceilings in attics and the like, and sometimes as sound insulation.

12.4.2.3 Loose-Fill Insulation

Loose-fill insulation materials are generally used in attics and walls, and are made from fibers, granules, or chips including mineral wool, glass wool, and cellulosic fibers. Common types of loose-fill insulation materials include perlite and vermiculite, pouring and blowing wool, and cellulosic fiber. Loose perlite and vermiculite are used in areas where they can be readily poured or blown, such as the voids in concrete masonry units and the spaces between wythes in masonry walls. However, loose-fill insulation other than perlite and vermiculite should not be used in walls or closed cavities because the large fibers may catch on nails or other obstructions and leave unfilled voids. Pouring and blowing wool insulation materials including slag and glass wool can be used between ceiling joists in attics, where the wool can be poured from bags or blown by machine. Cellulosic fiber insulation materials are made of recycled newsprint, wood chips, and other organic fibers, and are installed by being blown or poured into the cavities and sometimes by being sprayed.

12.4.2.4 Foamed-in-Place Insulation

Foamed-in-place insulation materials include urethane-, polyisocyanurate-, and phenolic-based materials. With a high thermal resistance of 6.25 or above, urethane and polyisocyanurate foams can be used in various applications including floor and wall cavities, roofs, and structural sandwich panels. Also, phenolic-based forms can be installed in the same applications, but with a lower thermal resistance.

12.4.3 Take Off and Pricing for Insulation

The cost of insulation work includes the materials, labor, and equipment costs. Materials costs vary based on locality, so the estimator needs to contact local manufacturers or warehouses. Most insulation work is performed by cement masons, plasterers, bricklayers, or roofers, with little extra equipment required in most circumstances.

12.4.3.1 Rigid Insulation

The first category of insulation is rigid insulation, often called “beadboard.” Rigid insulation materials are rigid boards made from polystyrene, urethane, glass fibers, and glass foams. They are used for sheathing, lath, roof decks, perimeter insulation materials, and interior finish. Rigid insulation is light and easily cut; one worker can install about 135 m^2 per day.

12.4.3.2 Mineral Fiber Insulation

Among several types of mineral insulation, blankets and batts are very popular because of their light weight and ease in cutting and handling. The encasing material is usually furnished with flapped edges for easy attachment to studs and joists. Since they are light and sometimes precut to fit standard construction, one carpenter can handle the installation. The carpenter can install friction-fit insulation with no attachments at a rate of 185 m^2 per 8-hour day. On the other hand, the carpenter can install flanged type bound in kraft paper or foil at a rate of 165 m^2 per 8-hour day.

12.4.3.3 Loose-Fill Insulation

The next major category is loose-fill insulation. Among several types of loose-fill insulation, mineral wool and perlite or vermiculite insulation materials are the most widely used types in the industry. Loose insulating wool is appropriate for any purpose where insulation can be packed by hand between ceiling joists or side wall studs. Loose or bulk rock wool is usually furnished in 18 kg bags containing 0.11 m^3. A worker can place loose or bulk insulating wool between wood studs at a rate of 32 m^2 to 42 m^2 per 8-hour day. Perlite or vermiculite insulation materials are used to insulate attics, lofts, and side walls. A mason can pour about 50 bags of 5.7 m^3 per 8-hour day.

12.4.3.4 Foam-in-Place Insulation

The last category of insulation refers to foam-in-place insulation materials. Foam-in-place insulation materials adhere well to most building surfaces, conform to irregular forms, and set up quickly. The installation work requires specialized equipment, so it is usually subcontracted to an experienced applicator.

12.5 ROOFING

12.5.1 Roofing Materials

Roofing refers to all of the materials placed over a structural roof and used for moisture and/or thermal protection, whereas the roof is the supporting structure over which the roofing is applied. Roofing can be broadly classified into two types: steep and low-slope. Steep roofs are those whose slope equals or exceeds 5 cm/1 m, whereas those with a slope of less than 5 cm/1 m are called low-slope roofs. The primary functions of steep and low-slope roofing are to shed water and to provide a waterproof membrane, respectively.

12.5.1.1 Asphalt Shingle

Asphalt shingles are manufactured in several forms, colors, and sizes, but can be classified into three basic types: strip shingles such as the square-butt or hexagonal type, individual shingles such as the interlocking or staple-down type, and giant individual shingles. Square-butt strip shingles especially the three-tap type, are the most widely used nowadays. Most asphalt shingles carry an Underwritings Class C rating, whereas those incorporating a glass fiber layer are rated as Class A. Asphalt shingles are fastened to wood decking with galvanized roofing nails starting at the lower edge of the roof, as shown in Figure 12.7.

Shingles must be nailed properly with a sufficient quantity of nails. Nails

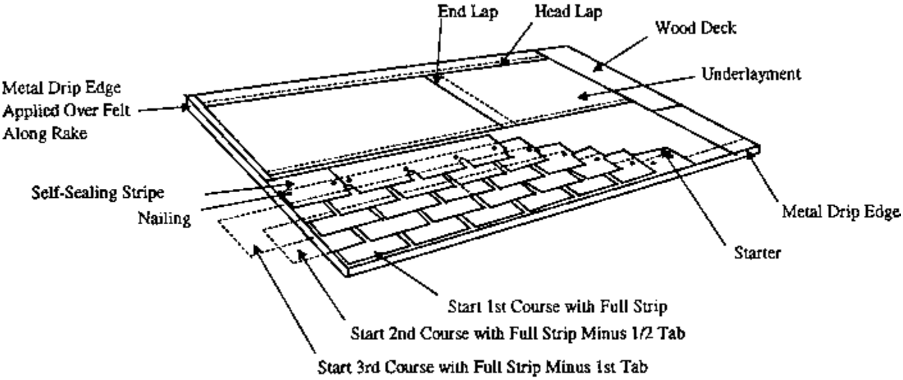


FIGURE 12.7 Application of square-butt strip shingles.

for applying asphalt roofing should be of corrosion-resistant metal with sharp points and large flat heads. Other than shingles and nails, a major material for shingle roofing is flashing, which is required at all intersections with vertical surfaces.

12.5.1.2 Wood Shingles and Shakes

Wood shingles are sawn, have smooth faces and backs, and are produced in three major grades and a variety of types. Shakes are split, have rough split faces and either sawn or split backs, and are produced in one grade and three types. Wood shingles and shakes are made from selected cedar logs cut to proper lengths. Cedar shingles are sold according to grade, thickness, and type. Their nominal lengths are 40, 45, and 60 cm with the length exposed to weather after installation of 12.5, 13.75, and 18.75 cm, respectively. Major grades of shingles include No.1 (Blue Label), No.2 (Red Label), and No.3 (Black Label), ranging from the highest quality to the more economical. On the other hand, wood shakes are manufactured in lengths of 45, 60, and 80 cm, and in random widths. They are classified into three types of units, hand-split-and-resawn, taper-split, and straight-split. Each type of shakes may be used for roof shingles. Hand-split-and-resawn shakes have the heaviest butt lines and give the most rugged textured appearance to the roof, whereas taper-split and straight-split shakes provide a more uniform texture and are preferable to hand-split-and-resawn shakes.

12.5.1.3 Built-Up Roofing

Built-up roofing (BUR) refers to the combination of bituminous materials such as asphalt or coal-tar, pitch, and roofing felts. In the application process, plies of saturated felt and moppings of pitch are alternated with tar-saturated felt, or asphalt with asphalt-saturated felt. This layer is covered by a poured layer of pitch or asphalt into which slag or gravel has been embedded. These materials are generally used on roofs where water may collect and stand, and thus BUR is required for most flat roofs.

12.5.2 Take Off and Pricing for Roofing

Roofing materials are estimated by the number of 10 m^2 of roof area (in English units, by square or 100 sq. ft). There are several tips the estimator should consider when determining flat roof area. For brick, stone, or tile buildings that have parapet walls above the roof level, the area should cover the outside of the walls on all four sides to allow for flashing up the side of each wall, about 200 to 300 mm high. For roofs projecting or overhanging beyond the walls of the building, the area should include the overhang as part of the net area. Openings less than 9 m^2 are not to be deducted from the net area, whereas openings of 9 to 45 m^2 are to be 50% deducted.

An accurate calculation of the roof area is the basis for an accurate estimate, so the estimator should persist in calculating the net area of the roof plus materials waste. To estimate material waste, the net area of a roof should be increased by about 10% for gable roofs, 15% for hip roofs, and 20% for roofs with valleys and dormers.

12.5.2.1 Asphalt Shingles

Asphalt shingles are one of the most common roofing materials in building construction. Major materials for asphalt shingles, including shingles, nails, fasteners, and flashing, should be correctly estimated. For asphalt shingles, the estimator needs to determine type of shingles, size, number of shingles per 10 m^2, nail length, and number of nails. Asphalt shingles are sold by square (9.3 m^2 or 100 sq. ft) of roof. When measuring roofs of any shape, the estimator should allow one course of shingle for the starters at the eaves, so the quantity of the first or starting course of shingles is double. Table 12.4 presents the net quantities of

TABLE 12.4 Quantity of Various Asphalt Shingle Products

Shingle style	Size (cm)	No./10 m^2	Length exposed (cm)	No. nails/ shingle	Nails/ 10 m^2 (kg)
Asphalt strip, 3 tab, 107 kg	30 × 90	86	12.5	4	0.48
Fiberglass asphalt, 155 kg	30 × 90	86	12.5	4	0.48
Hexagon strip, 77 kg	30 × 90	93	12.5	6	0.73

Source: Peurifoy and Oberlender, 1989.

asphalt shingles of various styles required to cover 10 m^2. In addition to the amount provided in the table, the average waste of materials falls in the range of 5 to 8%, and should be included in the estimate.

For each manufacturer, the cost of asphalt shingles varies with the style, materials, color, weight, and warranty. The estimator must check the cost from local manufacturers, although Means does provide national average cost data for asphalt shingles. At the jobsite, carpenters or experienced roofers are required to lay asphalt shingles. A roofer can lay 10 m^2 of asphalt shingles in 1.1 hours on double-pitched roofs with no hips, valleys, or ridges. For roofs with gables and dormers, a roofer can lay 10 m^2 of shingles in 1.3 hours. Labor productivity can vary based upon the experience of the workers, type of work, surfaces to be laid, and distance from the ground. The productivity for simple areas is better than that for irregular areas. Work that requires the cutting of shingles for correct fit, such as for skylights, hips, valleys, gables, and dormers, will reduce the labor productivity.

12.5.2.2 Wood Shingles and Shakes

Like asphalt shingles, wood shingles and shakes are sold by square (9.3 m^2) of roof but packed in bundles of 200 shingles each. The quantity of shingles and shakes can be determined per 10 m^2. For wood shingles and shakes, four to five bundles are typically required per 10 m^2. A total of 10% waste is required to cover the double row of shingles at the eaves, required cutting, and narrow shingles. Table 12.5 lists the number of shingles and quantity of nails required for 10 m^2 of roof area. It is important that nails are corrosion resistant. Each shingle should be fastened with two nails to shingle laths, which are installed perpendicular to the roof rafters.

A roofer can lay approximately 13 to 16 bundles per 8-hour day, although the number of shingles and shakes laid per hour will vary with the ability of the

TABLE 12.5 Number of Wood Shingles and Quantity of Nails Required per 10 m^2 of Surface

Distance laid to weather (mm)/area covered by one shingle (cm^2)	Actual no./10 m^2 without waste	Waste (%)	No./10 m^2 with waste	No. 4-square bundles	Kg. 3d nails
200.0 mm/100.0 cm^2	1066	10	1173	5.4	1.56
212.5 mm/112.5 cm^2	947	10	1042	4.7	1.22
125.0 mm/125.0 cm^2	853	10	938	4.3	0.97
135.5 mm/137.5 cm^2	775	10	852	3.9	0.78
150.0 mm/150.0 cm^2	710	10	781	3.5	0.73

workers and the class of work. Specialized carpenters in shingle laying can lay more shingles than ordinary carpenters, and in turn require a higher wage rate. The labor cost of laying wood shingles and shakes varies primarily with the type of roof such as a plain gable roof or a steep roof. Generally, simple plain roofs with no roof projections incur a lower cost for laying shingles and shakes.

12.5.2.3 Built-Up Roofing

The quantity of most built-up roofing materials is taken off by m^2 of roof area. The specifications regarding the type of roofing vary widely, depending on the surface to which the BUR is applied and the service required. Major materials include pitch or asphalt, asphalt or tarred felt, gravel or aggregate, and flashing. The quantity of BUR is determined by specifying the weight and number of applications of pitch or asphalt, the weight and number of plies of felt, and the weight of gravel or slag. About 12.2 kg of coal-tar pitch or 9.7 kg of asphalt should be used for each mopping per 10 m^2 of surface. For the last pouring in which the gravel or slag is embedded, about 32.9 kg of asphalt or 36.3 kg of pitch per 10 m^2 is required. Table 12.6 shows the quantity of asphalt required for 10 m^2 of roof. Pitch and asphalt weigh about 5.8 kg per liter, and are contained in 500 and 250 kg cartons, respectively.

Asphalt or tarred felt for BUR is furnished in four rolls containing 40 m^2, weighing from 25 to 28 kg per roll for No.15 felt. On the other hand, No.30 felt is furnished in two rolls containing 20 m^2, weighing 27 kg. The quantity of roofing felt required to cover 10 m^2 of surface in various thicknesses is shown in Table 12.7.

Roofing gravel or aggregate should be uniformly embedded into a heavy top pouring of asphalt or pitch. About 195 kg of gravel for BUR or 146 kg of slag is required for 10 m^2 of roof areas. Along with the quantity of gravel, type, size, and color of gravel should be determined in the estimation.

Another material used in BUR is flashing, which is taken off by linear meter.

The cost of BUR generally depends on roof size, roof complexity, the incline of the roof, and the distance of the roof above the ground. Bigger or more complex roofs, or roofs with a higher incline or higher distance increase labor costs because more time is required to hoist and lay materials. On one- to three-story buildings, a

TABLE 12.6 Quantity of Asphalt Required for 10 m^2 of Roof

Surface to which roof is applied	No. plies	Dry	Mopped	Kg./10 m^2
Wood, plywood, structural wood fiber	5	2	3	129
Poured gypsum, lightweight concrete	4	1	3	129
Concrete, precast concrete, or gypsum	4	0	4	150

TABLE 12.7 Quantity of Roofing Felt Required for 10 m^2 of Roof

No. plies	Waste (%)	m^2 felt/10 m^2 roof	Kg./m^2 roof (No.15 felt)
1	8	11	5.4
2	8	22	10.7
3	8	32	15.6
4	8	43	21.0
5	8	54	26.4

five-worker crew can lay 167 m^2 of 5 ply asphalt and gravel, or pitch and gravel, over a wood rock deck in one 8-hour day. For high buildings, the same crew can lay about 80 to 85% of the above amount within the same time. The five-worker crew includes one worker at the kettle, one worker carrying hot asphalt, one worker rolling felts, one worker nailing, and one worker mopping.

12.6 SAMPLE OF QUANTITY TAKE-OFF AND PRICING FOR MOISTURE PROTECTION

Referring to Figures 12.8 to 12.10, please answer the questions below.

1. Determine the quantity and cost of asphalt primer.
2. Determine the quantity and cost of asphalt.

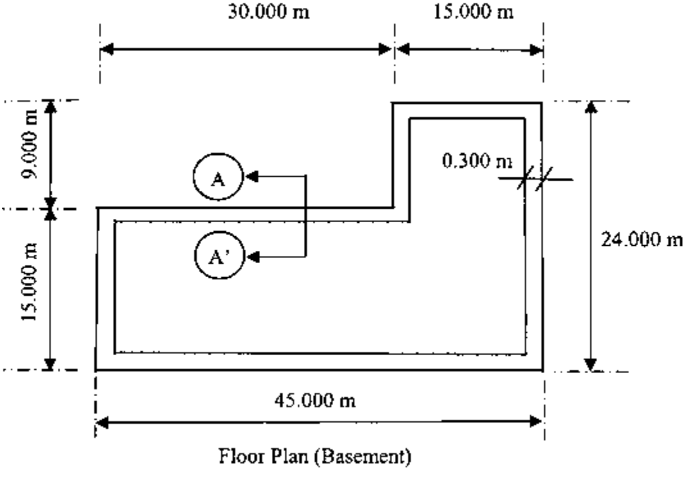


FIGURE 12.8 Basement floor plan.

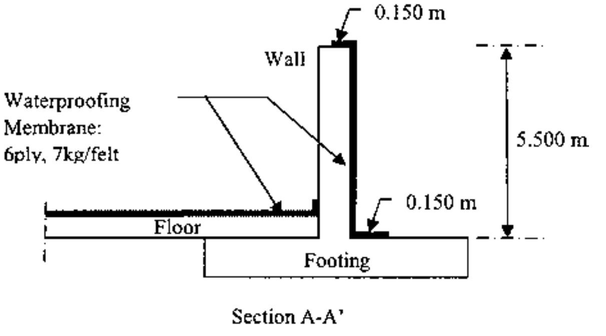


FIGURE 12.9 Detailed Section A-A′.

3. Determine the quantity and cost of asphalt felt, No.15.
4. Determine the total labor cost.

Supplementary information:

- Asphalt primer costs $0.59 per liter in 208-liter drums ($2.25 per gallon), $0.62 per liter in 114-liter drums ($2.35 per gallon), and $0.66 per liter in 19-liter cans ($2.50 per gallon).
- Waterproofing pitch or asphalt costs $270.00 per ton in carload lots, and $280.00 per ton for less than a carload.
- No.15 tar or asphalt saturated felt costs $12.00 per roll of 40 m^2 in carloads, and $12.50 per roll for less than a carload.
- Roofer wage rate is $22.50 per hour.

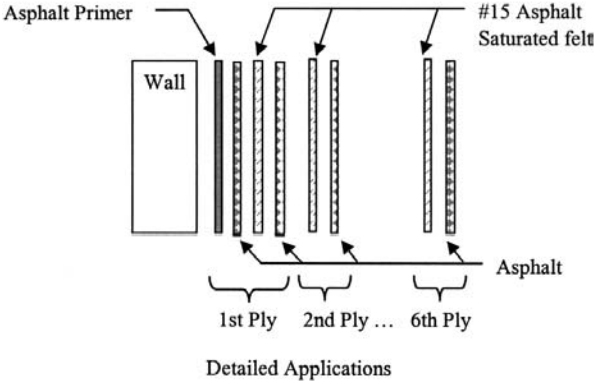


FIGURE 12.10 Detailed applications of moisture protection.

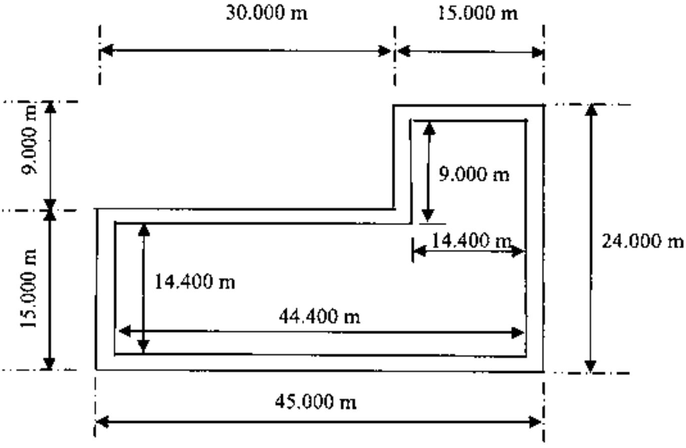


FIGURE 12.11 Basement floor plan for calculating floor area.

1. Determine the quantity and cost of asphalt primer. Based on Figure 12.11, one can determine the entire floor area.
   Floor area = (14.40 × 44.40) + (14.40 × 9.00) = 768.96 m^2.
   Wall area = (30.00 + 9.00 + 15.00 + 24.00 + 45.00 + 15.00) × 5.50 = 759.00 m^2.
   Total area = (768.96 + 759.00) × 1.10 for laps and wastes = 1681 m^2.
   Asphalt primer costs \$0.59 per liter in 208-liter drums.
   A total of four liters of primer is required for a 10 m^2 surface.
   The quantity of asphalt primer = (1681 m^2) × (4.1 liters/m^2) = 690 liters
   The cost of asphalt primer = \$0.59/liter × 690 liters = \$407
2. Determine the quantity and cost of asphalt. A total of six plies of #15 saturated felt requires seven layers of asphalt as shown in Figure 12.10. A total of 34.1 kg asphalt per 10 m^2 is required for the first ply, and a total of 17 kg asphalt per 10 m^2 is needed for the other plies.
   Quantity of asphalt = 1681 m^2 × [(34.1 kg) + (17 kg × 5 plies)]/ 10 m^2 = 20,021 kg.
   Waterproofing asphalt costs \$270.00 per ton in carload lots.
   Total cost of asphalt = 20.02 tons × \$270/ton = \$5405.
3. Determine the quantity and cost of asphalt felt, No.15. For the first ply, 0.30 rolls of No.15 felt are required to coat 10 m^2 of surfaces. For any additional ply, 0.26 rolls of No.15 felt are required to coat 10 m^2 of surfaces.

Quantity of asphalt felt = 1681 m^2 × [0.30 + (0.26 × 5 rolls of 40 m^2)]/10 m^2 = 269 rolls of 40 m^2.

Total cost of asphalt felt = $12.00/roll × 269 rolls = $3228.

4. Determine the total labor cost.

   For the first ply:

   Rate for applying asphalt primer = 1.07 hr/10 m^2.

   Rate for applying felt = 0.80 hr/10 m^2.

   Rate for applying two layers of hot bitumen =2 × 0.80 hr/10 m^2.

   Total rate for applying the first ply = 3.47 hr/10 m^2.

   For each additional ply:

   Rate for applying felt = 0.80 hr/10 m^2.

   Rate for applying one layer of hot bitumen = 0.80 hr/10 m^2.

   Total rate for applying each additional ply 1.6 hr/10 m^2.

   Total roofer hours per 10 m^2 = 3.47 + (5 × 1.6) = 11.47 hr/10 m^2.

   Total roofer hours = 1681 m^2 × 11.47 hr/10 m^2 = 1928 hours.

   Roofer wage rate = $22.50/hr.

   Total labor cost = 1928 hr × $22.50/hr = $433,800.

12.7 REVIEW QUESTIONS

1. What is the difference between "slope" and "pitch" for a roof?
2. Explain how moisture causes problems for buildings.
3. What are the three basic types of waterproofing materials?
4. What are the variables affecting the cost of waterproofing?
5. What are the two types of bituminous dampproofing?
6. What are the variables affecting the cost of dampproofing?
7. What is the difference between "roof" and "roofing"?
8. What are the tips an estimator should consider when determining roof areas?

13

Doors and Windows

13.1 INTRODUCTION TO DOORS AND WINDOWS

This chapter, in general, deals with doors, windows, glazing, hardware, and other accessories such as weather stripping and seals, screens, stops, panic devices, and handicap devices. It begins with a description of the components of door and window units, installation crafts, and a checklist for door and window estimates. This allows the estimator to become familiar with materials covered later in the chapter. No information regarding equipment is provided since all materials for doors and windows are freighted by the suppliers to the project and only personal hand tools are needed by the crew. The chapter concludes with general procedures for estimating the cost of doors and windows, which in this chapter are primarily based on Means' *Building Construction Cost* (1999) that presents average national cost data. The estimator, therefore, needs to make some modifications to a given project, crew, or company.

13.1.1 Components of Doors, Windows, and Frames

Doors and windows are used to provide easy access and security to the users, while keeping unpleasant weather conditions outside and maintaining comfortable conditions inside. For these reasons, doors and windows have several components that serve various functions. Figures 13.1 and 13.2 show the major parts of a typical door and window. Table 13.1 presents some terminology related to doors, windows, and accessories.

Major components of doors and windows basically include frames, glass, hardware, and other accessories. A frame, attached to the building structure, is used to provide support to a door or window. Hardware includes handles, hinges or butts, kickplates, locks, and bolts. Accessories are composed of weather stripping, thresholds, mullions, sills, stools, locks, handles, and so on. Weather stripping is used to prevent heat loss and the intrusion of insects, dust, noise, and moisture. A threshold and a door sweep are used to prevent heat loss around the edges of the door. Details regarding glass and accessories for doors and windows are presented later in the chapter.

13.1.2 Crafts for Door and Window Installation

Most doors and windows require only one or two carpenters to install each unit. However, large units such as metal sliding doors may require structural steel foremen, structural steel workers, an equipment operator, and a crane. There are many types of crafts associated with door and window installation based upon the types of work performed. Generally, carpenters are in charge of installing several types of doors, windows, and frames including commercial steel doors,

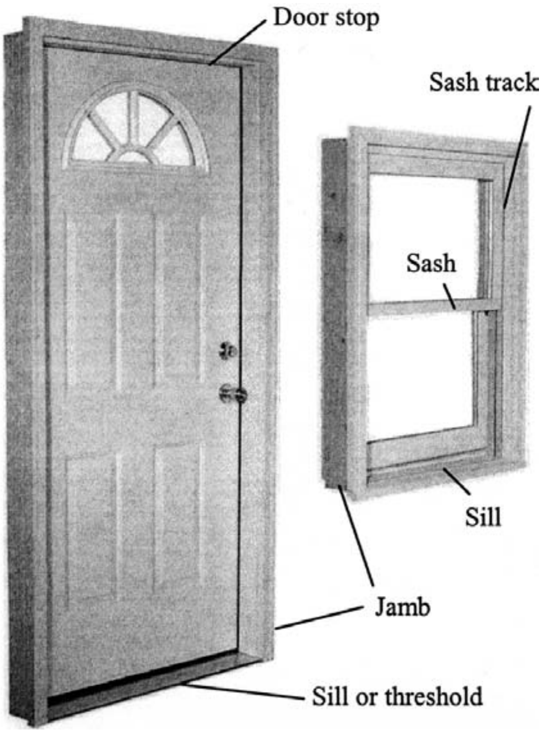


FIGURE 13.1 Major components of doors and windows. (From Hearst Communications and Cowles Creative Publishing, 1998.)

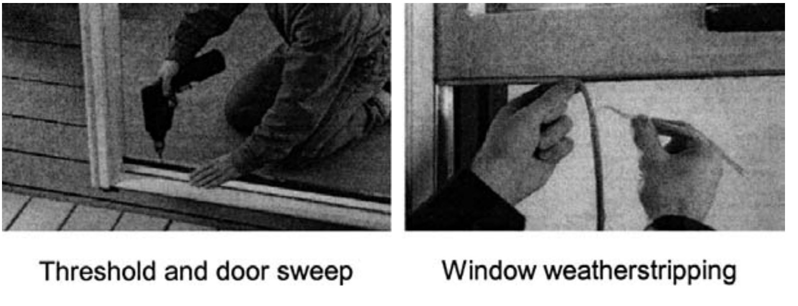


FIGURE 13.2 Installation of threshold, door sweep, and window weather stripping. (From Hearst Communications and Cowles Creative Publishing, 1998.)

Table 13.1 Door and Window Components

No.	Component	Description
1	Apron	Finished piece that covers the joint between a window sill and the wall finish below
2	Bite	Depth to which the edge of a piece of glass is held by its frame
3	Butt-joint glazing	Type of glass installation in which the vertical joints between edges of glass do not meet at a mullion, but are made weathertight with a sealant
4	Casing or trim	Wood finish pieces surrounding the frame of a window or door
5	Drip	Discontinuity formed into the underside of a window sill or wall component to force adhering drops of water to fall free of the face of the building rather than further toward the interior
6	Flashing	Flexible waterproof barrier intended to permit water that has penetrated the outer wythe to exit the wall
7	Glazier's points	Small pieces of metal driven into wood sash to hold glass in place
8	Jamb (head and side)	Vertical side of a door or window
9	Light or lite	Sheet of glass
10	Lintel	Beam or horizontal member of the openings required to support the above wall portion
11	Mullion	Vertical or horizontal bar between adjacent window or door units
12	Muntin	Small vertical or horizontal bar between small lights of glass in a sash
13	Sill or threshold	Member on the building exterior, which is just below the bottom member of the frame
14	Split jamb	Door frame fabricated into two interlocking halves, to be installed from opposite sides of an opening
15	Stile	Vertical framing member in a panel door
16	Stool	Interior horizontal member at the bottom of the frame
17	Weatherstripping	Ribbon of resilient material used to reduce air inflation through the crack around a sash or door

fire doors, residential steel doors, and both steel and wood frames. One carpenter can work on small items, such as access doors, bulkhead cellar doors, wood windows, sliding windows, and accessories. A crew of two carpenters is typically used to install most wood doors, sliding wood and plastic doors, coiling doors, sound-control doors, and overhead doors. In Means (1999), a crew called "E-4" includes one structural steel foreman, three structural steel workers, and one welding machine and is recommended for door frames with steel channels, anchors, and bar stops. A crew called "L-5" in Means (1999) includes one structural steel foreman, five structural steel workers, one equipment operator, and one hydraulic crane and is necessary for such large units as sliding metal doors and grilles. Means also suggests that a crew of two glaziers is suitable for a storefront system, an automatic entrance door, and most glass work. To illustrate the relationship between labor and productivity, these are presented along with materials in sections that refer to cost.

13.1.3 Checklist for Door and Window Estimating

There is a variety of door and window types, sizes, specialty requirements, and accessories. Therefore, the estimator needs to study specifications, plans, and other contract documents to identify all materials required for a project. To better estimate doors and windows, Table 13.2 presents a checklist to help identify necessary items needed for a project.

13.2 DOORS AND DOOR FRAMES

This section focuses on door and frame units, installation, cost, and labor productivity. It covers different types of doors and frames, namely, metal, wood, plastic, specialty, and entrances and storefronts. Major requirements for doors and frames, including premachining, prefinishing, and fire-rating requirements are also presented.

Table 13.2 Door and Window Checklist

Doors and windows
1. Sizes and number required
2. Frame and core types
3. Face veneer specified: wood/veneer doors
4. Prefinished or job finished: the finish
5. Prehung or job hung: the installer
6. Special requirements: fire rating, sound control, and louvers
7. Frame, hardware, and accessories
7.1 Frame: types, sizes, styles, number required (glass required, preassembled)
7.2 Method of attachment of frame to surrounding construction
7.3 Finish required on frame: who will apply it
7.4 Hardware: types required and installer
7.5 Accessories: types required and time to install them

13.2.1 Introduction to Doors and Frames

Generally, doors are classified as either interior or exterior with further classification according to materials and functions. However, it is possible that exterior doors are sometimes used in interior spaces. Doors can also be categorized as panel, flush, or slab, and combinations of panel and flush with glass called lights or lites. Doors are commonly made of wood, steel, stainless steel, aluminum, plastics, glass, bronze, copper, a combination of steel and wood, and a combination of wood and plastic. Doors can be identified by their method of opening, as shown in Figure 13.3, such as swing, sliding, swing-up, revolving, bypassing, overhead, and rolling. Figure 13.3 also shows types of swing doors further classified as single swing, double swing, and swing pair, or inside swing, and outside swing. The single swing type encompasses four major types that may confuse the estimator due to their names: left hand, right hand, left hand reverse bevel, and right hand reverse bevel. The sliding type can be identified as single sliding, double sliding, and vertical sliding.

The most prevalently used doors are the wood swing type which are available in 35 and 44 mm thicknesses, 2000, 2035, and 2135 mm heights, and 450 to 915 mm widths with 5 mm increments. Specialty doors are usually manufactured to serve particular needs with such requirements as fire-rating, sound reduction, and lead-lining. Based on their physical components, doors can also be classified as hollow-core, solid-core, flush, and French doors. Descriptions of these door types are provided in Table 13.3.

Like doors, frames can be made of various materials, the most common of which are wood, steel, and aluminum. Steel frames or door bucks can be made

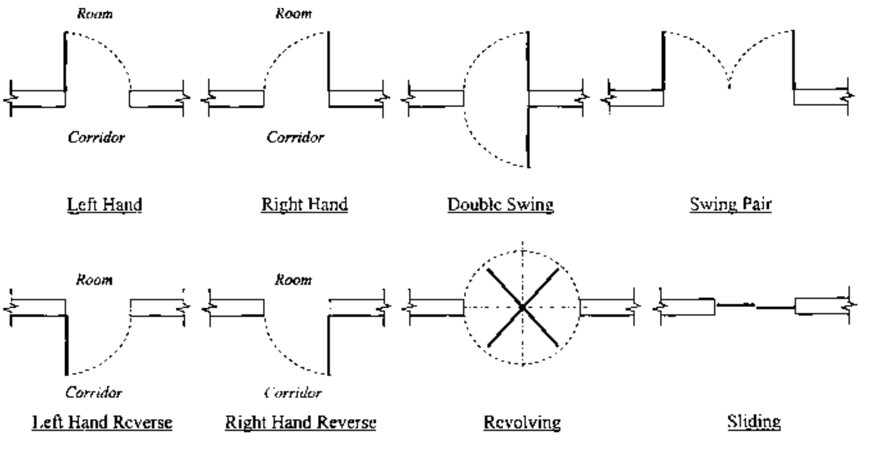


FIGURE 13.3 Types of doors.

TABLE 13.3 Door Types

No.	Door types	Description
1	Hollow-core	Door with two face veneers separated by an airspace, with solid wood spacers around the four edges
2	Flush	Door with smooth planar faces
3	French	Symmetrical pair of glazed doors hinged to the jambs of a single frame and meeting at the center of the opening
4	Solid-core	Door with a core of solid wood block or particleboard

of 14-, 16-, and 18-gauge steel, and usually are available in many styles, shapes, and sizes. Major components an estimator should consider include jambs, the sides of the frame, heads, the horizontal pieces at the top of the frame, and other required features such as weather stripping, anchors, base anchors, a sound-retardant strip, and a fire-rating requirement. Door frames must be installed and anchored during the construction process; therefore they should be ordered and delivered on time to prevent job delay. Door accessories include glazing, grilles, louvers, weather stripping, molding, trim, mullions, transoms, and so on. Doors are sometimes sold separately from the hardware and door accessories, but windows, glass, and window accessories are sold as single units.

An estimator can find information regarding doors, frames, and accessories on the door schedules. Beginning with mark designations (numbers or letters), door schedules display useful door information including door size, door materials, frame type and size, and louver or glass panels. In addition, designations for finish hardware sets, fire requirements, and special instructions are usually included.

13.2.2 Metal Doors and Frames

Metal doors, called hollow metal doors, are made of steel, stainless steel, aluminum, bronze, or copper. The doors may be constructed of metal frames to which are added large glazed areas, hollow metal, tin clad, or a variety of other designs. Steel doors in building construction are usually interior doors that require fire ratings or entrance and exit doors without fire ratings. Aluminum doors are typically entrance doors and interior swinging doors where no fire ratings are required. There are also sliding, bypassing, revolving, and overhead doors. Hollow metal (HM) doors are made of 16-, 18-, or 20-gauge cold-rolled steel with steel frame and casings, in various thicknesses and standard manufacturing sizes.

HM manufacturers produce both stock design doors and frames as well as special designs for architectural requirements. Among manufacturers, stock items vary in size, width, hardware, location of hinge or lockset, and installation; thus a door from one manufacturer may not be compatible with a frame from another manufacturer. A contractor is usually responsible for checking the compliance of a door and its accompanying frame. Many manufacturers produce frames with three hinge locations, each sized 87.5 or 112.5 mm in height, which fit a standard cylindrical lockset. However, if HM items require specific architectural designs that differ from manufacturing standards, these items are considered a specialty. Specialty items include custom-made units, structural aluminum or steel prefabricated units, and oversized units. Use of such items increases the cost and time required for delivery of the units to the project.

For both stock and custom doors, door manufacturers do not supply glass and other glazing, so in order to more accurately price the items, the estimator needs to check the price from the glass supplier and account for installation types and an installer. Finish for HM doors ranges from lacquered and anodized aluminum, to primed or prefinished steel, to natural and satin finished bronze. It is wise to study the specifications, drawings, and bid documents to gain a thorough knowledge of what is required.

Metal frames for doors are made of 18-, 16-, and 14-gauge metal and can accommodate 35 or 44 mm thick doors. Metal frames are typically welded together and installed during the rough framing or masonry installation phases, and the doors are installed later. For building construction, the frames are usually ordered according to frame width dimensions and door opening sizes, as well as the thickness of the walls to which they are mounted. Standard door opening sizes vary significantly, ranging from widths of 600 to 1200 mm for single swing and 1200 to 2400 mm for double swing, and standard heights of 200, 2100, 2150, and 2400 mm. Many manufacturers produce standard frame widths of 118.75, 143.75, 168.77, and 218.75 mm. Metal frames for doors can be classified as knocked down (KD), set-up-and-spot welded (SUS), or set-up-and-arc welded (SUA). The KD frames are installed after the rough framing and the wall are completed. They are used on drywall partitions by snapping together into a snug smooth fit to provide freedom from maintenance and protection from damage. Erected prior to the wall construction, SUS and SUA frames are weld-joint constructed and result in stronger units. Most metal doors and frames look alike but there may be significant differences among them. When estimating these items, be sure to choose the line item that most closely complies with the specification or door schedule requirements regarding type of metal, metal gauge, door core materials, fire rating, and finish.

13.2.3 Wood and Plastic Doors and Frames

For building construction, wood doors are the most common and are generally used as interior doors for offices, hotels, and other commercial buildings. Some types of wood and plastic doors, such as flush veneer slab doors and white pine entrance doors, are used as exterior doors because of a water- and weather-resistant finish applied to the doors. Doors with a combination of light-gauge metal and wood, or so-called metal-clad doors, are used as entry doors in residential and light commercial construction. Plastic doors or plastic-clad wood doors are used as double-swing doors for heavy traffic in warehouses and restaurants to ensure safety protection. Specialty wood and plastic doors do not conform to manufacturers' standard units and include prefabricated units, custom-made units, and oversize units.

Wood doors are typically classified as solid-core (SC) and hollow-core (HC), as previously shown in Table 13.3. SC doors have a core of solid wood block (stave) or particleboard, and HC doors have cores that are not solid. HC doors, however, are manufactured with face veneers of tempered hardboard or plywood, and the core has some materials to provide support to the face veneers, such as low-density fibers or wood stripping. Common veneer materials used for both types of wood doors include lauan, birch, and oak. Sizes of wood doors vary from one manufacturer to another. The common standard thicknesses of fiber-core and hollow-core doors range from 28 to 31.25 mm; those of wood-block doors range from 31.25 to 62.50 mm. Widths and heights of these doors also vary, therefore, the estimator must check the specifications for the stipulated sizes and types. Either type of wood door may require compliance with the Architectural Woodwork Institute (AWI) standards or acoustical standards, so the doors are premortised for hinges and predrilled for cylindrical locksets.

There are various wood and plastic door units on the market, but the most frequently used are prehung and closet doors. Prehung doors are used widely for houses and apartments ranging from economy to middle class. Available in a completely assembled package, the door is hung in place with hinges applied, stops nailed in place, and jambs already assembled. The other common unit is closet doors including sliding and bifolding doors. Both types of closet doors offer a variety of combinations in materials and sizes. Several types of doors are used in building construction, including entry doors, sliding doors, passage doors, and bifolding doors. These may be either prehung or closet doors. Figure 13.4 shows common types of wood doors used in residential and small commercial building construction.

Bifolding closet doors offer the advantage of full access to the closet, and the frames for bifolding closet doors can be obtained in kits containing hinges, pivots, knobs, guide assembly, and track, but excluding jambs and casings. Entry doors, as specified by the name, are used for the entrances of apartments, office buildings, and other small commercial buildings. The cost of an entry door is usually relatively high because of its appearance and resistance to unpleasant weather conditions, as well as assorted hardware pieces and accessories. Passage doors, offering an economic advantage, can be made of various materials including hardboard, lauan, birch, and louvered or paneled pine. Sliding doors are avail-

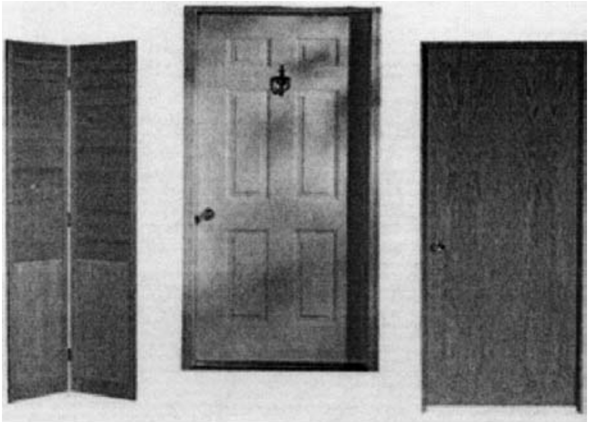


FIGURE 13.4 Common types of wood doors. (From Hearst Communications and Cowles Creative Publishing, 1998.)

able in various heights including those that can extend to the ceiling in order to provide access to upper storage shelves. Frames for sliding doors can be obtained in kits containing two side jambs, head assembly with track attached, and the necessary hardware for hanging the doors.

13.2.4 Specialty Doors

Specialty doors are usually manufactured to serve particular needs, such as sound control, fire-rated, and lead-lined requirements. Specialty items include custom-made units, structural aluminum or steel prefabricated units, and oversized units. The prices of these items are relatively high compared to standard manufactured units, and the delivery time and installation may take longer. There are many varieties of specialty doors, usually priced per unit, which include frame, hardware, or operations required for a complete installation. Specialty items include access doors, bulkhead cellar doors, security gates, coiling grille doors, rolling grille doors, cold storage doors, shock-absorbing doors, acoustical doors, overhead doors, tin-clad fire doors, and folding doors and partitions.

Coiling doors, called rolling shutters, are preassembled at the factory and are made of steel or aluminum according to fire-rating requirements. Due to door requirements, the installation must conform to Underwriters Laboratory specifications. Steel mounting jambs and heads are usually furnished by the metal fabrications contractor. Rolling grilles, which roll horizontally or vertically to provide protection or to control traffic, are used for protecting open-fronted store fronts in enclosed shopping areas, and for closing off counter areas.

Acoustical doors are specially designed and constructed for use where sound control is desired, including conference rooms, television rooms, radio studios, hospitals, and clinics. These are usually veneered doors made of metal or wood, with a variety of cores and a wide range of sound control. Custom finishing of the doors is available, including veneered finishes to match other doors in the building. To prevent the problem of noise transmission around the door, acoustical doors require an automatic drop seal for the bottom of the door and adjustable doorstops or other types of sound control devices at the doorjamb. These seals and devices are sometimes sold separately from the door, so the estimator may need to determine linear measurements and include them along with materials and labor costs in the estimate.

Like many other doors, overhead doors are available in steel and wood and are manufactured in several types, sizes, styles, and finishes. Based on the operation of the door, types of overhead doors include rolling, sectional, and canopy. In addition to types, sizes, styles, and finishes of the doors, the estimator also needs to know installation details, the types of door hangers needed, and the types of door operation (hand, electronic, or chain). The residential garage door is made of various materials including wood, fiberglass, hardboard, and metal and has a variety of styles including one-piece overhead, swing-up overhead, spring-balanced overhead, and self-balancing overhead. The typical size of a garage door is 2400×2100 mm or 2700×2100 mm. A garage door requires two carpenters for installation with a labor productivity of six to eight doors per day.

Tin-clad fire doors are either sliding or swing with fusible links and automatic closing devices. They are used for heavy traffic areas and where fire rating is an issue, such as in factories, mills, and hardware buildings. Based on its fire-rating index, these doors are classified with a Class A rating consisting of three plies of tongue-and-groove lumber clad with tin sheeting on all sides and a thickness of 65.6 mm, or with Class B or C ratings consisting of two plies of tongue-and-groove lumber with cladding and a thickness of 43.7 mm.

Finally, folding doors and partitions are designed to increase spatial flexibility and provide a more efficient use of floor space in a building. When an opening is greater than 14 m^2, the units are considered partitions rather than doors. These doors are made of fiberglass, vinyl, or wood, or a combination of these materials, and ordered completely finished and with all necessary hardware included. Based on the type of construction, the opening height ranges from 2.5 to 6.5 m and the width ranges from 2.5 to 9.0 m.

13.2.5 Entrances and Storefronts

Storefronts are designed for small, one-story structures such as commercial and retail frontages. They are typically made of a combination of aluminum, steel, or wood, and glazing. A single unit of storefront includes doors and windows separated by steel, aluminum, or wood mullions. Aluminum is extruded into many different shapes and sizes with various thicknesses. To prevent oxidation of the aluminum surfaces, the extrusions of aluminum are anodized in a number of colors as well as a clear finish. Paint coating is also available and usually results in a better appearance. Entrances are smaller storefront units with a single entry and sidelights, and are typically used for a single commercial structure such as a free-standing bank building or a hotel or motel. Many sizes and designs are available with various styles of applied panels and finishing hardware.

13.2.6 Premachining and Prefinishing

To minimize machining time at the jobsite, doors can be machined at the factory to accommodate various types of hardware including rim locks, finger pulls, door closers, flush catchers, hinges (butts), and any special requirements. Premachining for doors usually yields greater cost control with satisfactory products, and skilled door hangers are not required. Compatibility between the door and its hardware is important, and approved shop drawings, hardware and door schedules, and the hardware manufacturers' templates must be provided to the door manufacturer.

Along with premachining, the estimator needs to identify whether the doors are to be prefinished at the factory or job finished, as well as the type of finish required. Prefinishing for doors generally offers a savings in finishing time and a better quality than job finishing. A variety of coatings is available, such as varnish, lacquer, vinyl, polyester films for wood doors, pigments, and tints. The prefinished doors should be carefully stored, handled, and installed because a damaged finish is often difficult to repair. In general, prefinished doors are also premachined, and premachined ones are usually prefinished.

13.2.7 Fire Label Requirements

According to building codes, certain door locations within a building (such as stairwells, trash rooms, furnace rooms, garage entries, and storage rooms) require a fire rating for the door and frame. The rating is determined when the manufacturer subjects its product to actual fire testing by either an Underwriters Laboratory or a Factory Mutual testing laboratory. The ratings refer to how long it takes to reach a certain temperature set by the lab. The doors are given *A*, *B*, or *C* ratings and called "labeled doors." An *A* label refers to a 3-hour rating, a B label refers to a 1-1/2- to 2-hour rating, and a *C* label refers to a 3/4-hour rating. Fire doors can be made of hollow metal, sheet metal, composite wood with incombustible cores, and other composite constructions. When specialty hardware is required, the frame must also be labeled.

13.2.8 Costs of Labor and Materials for Doors and Frames

Regarding doors and frames, the national average materials costs associated with labor and equipment costs are provided by Means (1999), and many other cost files. Based on Means' (1999), Table 13.4 highlights some of these costs and offers an estimator a broad picture of door and window costs. Two carpenters should erect about 17 hollow-core doors (915 × 2035 mm) per 8-hour day at a labor cost of $26.50/door, with the total bare cost of $191.50/door (materials and labor costs). For wood and plastic doors, two carpenters should install about 19 interior prehung doors (35 × 2035 × 915 mm) per 8-hour day at a labor cost of $23.50/door, resulting in the total bare cost of $127.50/door (materials and labor costs). Table 13.4 also indicates that two carpenters can install about 4 sliding doors (1830 × 2085 mm) per 8-hour day at a labor cost of $113/opening and total bare cost of $863 per opening.

13.3 WINDOWS AND WINDOW FRAMES

Windows are classified as either stock or custom made. Stock windows are readily available and easily priced, whereas custom-made windows are usually priced based on the installation area, the type of window, and according to the estimate made by the manufacturer or local supplier. For such an estimate, a copy of the drawings and specifications should be forwarded to the manufacturer or supplier preparing the proposal. To prepare an estimate, the estimator must study the bid proposals, which usually contain all required accessories and specify whether the glass, other glazing, and installation are provided by the supplier, the general contractor, or a subcontractor. Similar to door schedules, window schedules included in the specifications consist of a list of windows and their requirements including mark designation, window size, window materials, frame type and size, glass, and special instructions.

Windows and window frames are made of several materials including steel, stainless steel, aluminum, bronze, plastic, wood, and a combination of steel and wood. Windows are designed in many types to serve various functions, such as awning, casement, fixed, hopper, single-hung, double-hung, sliding, projected, jalousie, and combinations of these. Figure 13.5 and Table 13.5 offer graphical and text presentations of some types of windows. For sliding windows, designation *O* refers to a fixed panel window, and designation *X* refers to a sliding panel window. For instance, 10020OXXO presents a 3.05 × 0.61 m window with fixed-open-open-fixed combination glass. Accessories for windows include screens, sills, mullions, hardware, and weather stripping. All materials being bid upon must conform to the specifications.

Table 13.4 Costs of Labor and Materials for Doors and Frames

Code 08110	Metal doors and frames	Crew[a]	Daily output	Labor (hrs)	Unit	Bare cost Mat.	Bare cost Labor	Bare cost Total	Total[b]
200-0010	Commercial steel doors								
200-0520	Hollow core, 44 mm thick, full panel, 20 ga., 915 × 2035 mm	2 Carp	17.00	0.941	Ea	165	26.50	191.50	224
200-1240	Half glass, 20 ga., 915 × 2035 mm	2 Carp	18.00	0.889	Ea	235	25	260	299
200-1720	Insulated, 45 mm thick, full panel, 18 ga., 915 × 2035 mm	2 Carp	15.00	1.067	Ea	245	30	275	315
250-0010	Door frames								
250-0100	Steel channels with anchors and bar stops, 150 mm channel 12 kg/m, 915 × 2135 mm door, 68 kg	E-4	13.00	2.462	Ea	108	79.50	193.95	271
600-0010	Residential steel door								
600-0020	Prehung, insulated, exterior								
600-0060	Embossed, full panel, 915 × 2135 mm	2 Carp	15.00	1.067	Ea	233	30	263	305
300-0010	Steel doors, sliding								
300-0020	Up to 15 240 × 5485 mm, electric, standard duty, minimum	L-5	33.45	1.674	m^2	194	53	263.75	325
300-0100	Maximum	L-5	31.59	1.773	m^2	325	56.50	399.20	475
Code 08210	Wood and plastic doors and frames								
720-0010	Prehung doors								
720-4640	Interior, passage door, 117 mm solid jamb, hollow core, 35 × 2035 × 915 mm wide	2 Carp	19.00	0.842	Ea	104	23.50	127.50	152

TABLE 13.4 Continued

Code 08110	Metal doors and frames	Crew[a]	Daily output	Labor (hrs)	Unit	Bare cost Mat.	Bare cost Labor	Bare cost Total	Total[b]
900-0280	Flush, int., 45 mm, 7 ply, hollow core, oak face, 915 × 2035 mm	2 Carp	17.00	0.941	Ea	70	26.50	96.50	119
900-0010	Wood door, architectural								
900-0380	Flush, int., 45 mm, 7 ply, hollow core, walnut face, 915 × 2035 mm	2 Carp	17.00	0.941	Ea	131	26.50	157.50	187
930-0010	Wood door, residential								
930-1000	Entrance door, colonial, 44 × 2035 × 926 mm wide	2 Carp	16.00	1	Ea	298	28	326	375
930-7720	Passage doors, flush, no frame included, birch, hollow core, 34 × 2000 × 600 mm wide	2 Carp	18.00	0.889	Ea	33.50	25	58.50	76.5
930-7760	Passage doors, flush, no frame included, birch, hollow core, 34 × 2000 × 800 mm wide	2 Carp	17.00	0.889	Ea	40.50	25	65.50	84.5
960-0010	Wood frames								
960-3220	Interior frame, oak, 17 × 116 mm deep	2 Carp	107.00	0.150	m	16.75	421	20.96	25
Code 08260	Sliding wood and plastic doors								
700-0020	Glass, sliding, vinyl clad, 25 mm insul. glass, 1830 × 2085 mm high	2 Carp	4.00	4	Opng.	750	113	863	995

[a] Crew 2 Carp indicates 2 carpenters. Crew E-4 includes 1 structural steel foreman, 3 structural steel workers, and 1 gas welding machine. Crew L-5 includes 1 structural steel foreman, 5 structural steel workers, 1 equipment operator (crane), and 1 hydraulic crane with the capacity of 23 metric tons.

[b] Includes OP. *Source*: Means, 1999.

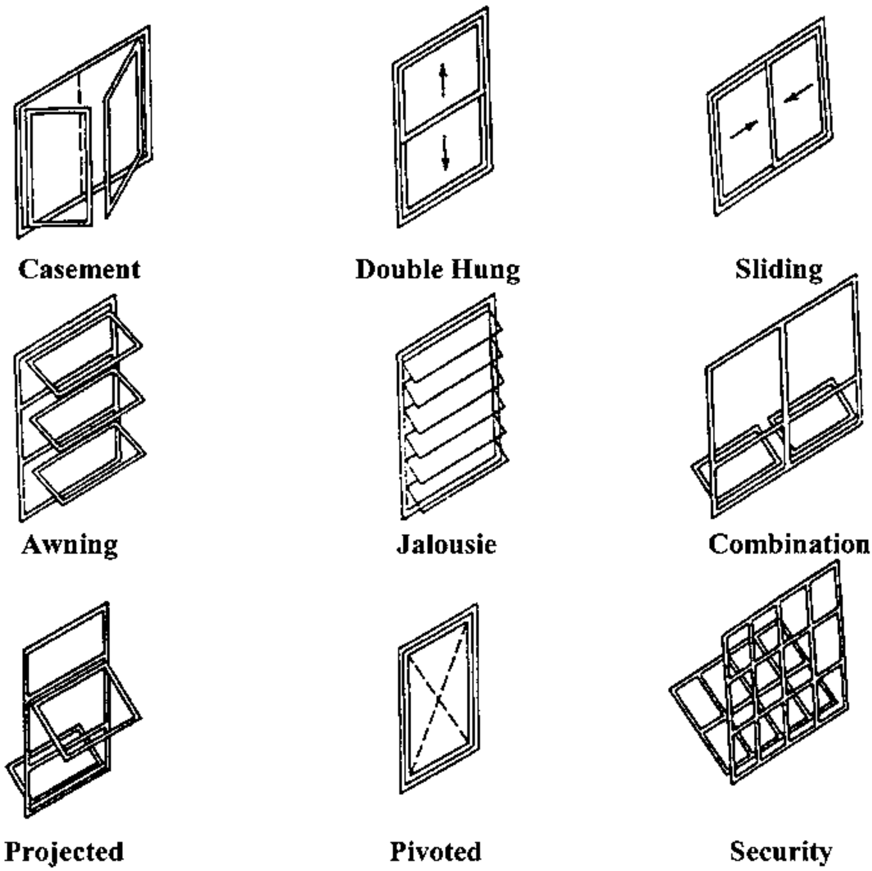


FIGURE 13.5 Types of windows based on their use in building construction.

13.3.1 Metal Windows and Frames

Metal windows and frames are made of steel and aluminum frames and casings, each with a variety of types and sizes. In general, metal window products are classified as standard, commodity, and specialty. The standard products are produced by the manufacturers to reduce costs and promote a faster delivery. Commodity products are standard products subject to high demand and are usually available at the manufacturer warehouse or from product dealers. Specialty products are not available from a manufacturer's stock and must be prefabricated and delivered by the factory. Two common metal windows on the market are steel and aluminum windows. A steel window is made of 18-gauge or heavier cold-

TABLE 13.5 Major Window Types

No.	Window types	Description
1	Awning	Window that pivots on an axis at or near the top edge of the sash and projects toward the outdoors
2	Casement	Window that pivots on an axis at or near a vertical edge of the sash
3	Fixed	Glass that is immovably mounted into a wall
4	Hopper	Window whose sash pivots on an axis along the sill, and opens by tilting toward the interior of the building
5	Single-hung	Window with two overlapping sashes, the lower of which can slide vertically in tracks, and the upper of which is fixed
6	Skylight	Fixed window installed in a roof
7	Sliding	Window with one fixed sash and another that moves horizontally in tracks

rolled steel and its frame is welded as a single unit. Most steel windows are delivered preglazed and the glazing is installed after the walls are finished. They are available in various types and sizes to meet building needs.

On the other hand, an aluminum window is only sometimes prefabricated with the glazing and may have an aluminum frame. This type of window is common where wood and metal stud frames are used. Like steel windows, aluminum windows are available in various types and sizes to meet building requirements. Standard products are produced to reduce costs while reducing delivery time. To protect aluminum surfaces, aluminum windows may require a certain type of finish including mill finish, anodizing, paint, and tint. A mill finish refers to a natural silvery sheen and anodizing refers to a protective film. Exposed aluminum surfaces may be subject to splashing with plaster, mortar, or masonry cleaning products, so exposed aluminum should be protected with either a clear lacquer or strippable coating, and care on the job is necessary. In addition to the finish, coating is also important because it can protect concealed aluminum that may be in contact with concrete and masonry or that absorbs moisture and gets wet. Common coatings are bituminous paint and zinc-chromate primer. The estimator needs to include finishes and coatings in the cost estimate for aluminum windows and frames.

13.3.2 Wood and Plastic Windows and Frames

Like wood and plastic doors, wood and plastic windows are offered in a variety of sizes and styles. Wood windows can be purchased as complete units with frame, sash, hardware, weather stripping, and glazing assembled at the factory.

The two usual glazing options are single-pane float glass and insulated glass 12.5 mm thick. Common window units include double-hung, gliding, casement, and roof windows, some of which are presented in Figure 13.5. The exterior of wood windows is typically finished with rigid vinyl (PVC), but the interior portion is unfinished and is expected to be finished by painters or others. Frames for the wood windows can be stock or custom products. Many stock frames are made from ponderosa pine, southern pine, and Douglas fir. Frame finishes include plain, primed, preservative-treated, and painted. Based on the window size, materials, and finish stated in the specifications, the estimator should check wood window prices from manufacturers or local suppliers. The estimator also needs to figure the cost of any required insect screens, light grilles, window blinds, and window treatments.

13.3.3 Costs of Labor and Materials for Windows and Frames

Based on Means (1999), Table 13.6 presents some of the average national costs of windows and frames. For average quality, 900 × 900 mm sliding wood windows with standard glazing have an average US national total cost of $150.50/unit, and the 1200 × 1050 mm sliding windows have a total cost of $177/unit. One carpenter is expected to install ten 900 × 900 mm units per 8-hour day or nine 1200 × 1050 mm units per 8-hour day.

13.4 GLAZING, HARDWARE, AND ACCESSORIES

Doors and windows have several components that serve a variety of functions, such as glazing, hardware, and various accessories including weather stripping, screens, mullions, sills, stool, flashing, and lintels.

13.4.1 Glazing

Glazing is the process of installing materials into a frame. The most common materials glazed into a frame for doors, windows, curtain walls, storefronts, and other types of structures is glass, but plastic laminates, metal panels, plywood, porcelain, and other materials can be installed into the frame as well. The types of glass are indicated in the plans, in the door and window schedules, or in the specifications. In building construction, different openings require different types of glass with common types being float, tempered, insulating, patterned, and wire. Float glass is used for interior and some residential windows, and tempered glass is typically used for entrance doors and window walls where the glass is located less than 460 mm from the floor. Tempered glass has been heat treated to increase its toughness and its resistance to breakage. Both float glass and tempered glass

TABLE 13.6 Costs of Labor and Materials for Windows and Frames

Code 08510	Steel windows	Crew[a]	Daily output	Labor (hrs)	Unit	Bare cost Mat.	Bare cost Labor	Bare cost Total	Total[b]
700-0020	Screens, for metal sash, aluminum or bronze mesh, flat screen	2 Sswk	111.00	0.144	m^2	31.5	4.57	36.07	43.5
750-0200	Steel sash, custom units, glazing and trim not included, casement, 50% vented	2 Sswk	18.58	0.861	m^2	310	27.50	377.50	395
770-1000	Steel windows, stock, including frame, trim, and insulating flash	2 Sswk	12.00	1.333	Ea	485	42.50	527.50	615
Code 08520	Aluminum windows								
100-0050	Aluminum sash, stock, grade C, glaze and trim not incl., double hung	2 Sswk	18.58	0.861	m^2	274	27.50	301.50	350
120-0010	Aluminum windows, incl. frame and glazing, grade C								
120-4000	Sliding aluminum, 915 × 610 mm opng., standard glazed	2 Sswk	10.00	1.6	Ea	139	50.50	189.50	246
120-4300	Sliding aluminum, 1525 × 915 mm opng., standard glazed	2 Sswk	9.00	1.778	Ea	177	56.50	233.50	298
Code 08550	Wood windows								
750-0010	Sliding window, including frame, screen, and exterior trim								
750-0100	Average quality, 900 × 900 mm high, standard glazed	1 Carp	10.00	0.8	Ea	128	22.50	150.50	177
750-0200	Average quality, 1200 × 1050 mm high, standard glazed	1 Carp	9.00	0.889	Ea	152	25	177	207

[a] Crew 2 Sswk indicates 2 structural steel workers. Crew 1 Carp indicates 1 carpenter.
[b] Includes O&P.
Source: Means, 1999.

are available in thicknesses of 5 to 25 mm. They can also be classified as insulating glass, which is used for most exterior windows when glass film is added to increase the heat reflection of the glass. Insulating glass units, made of two sheets of glass with a sealed air space between, are used to decrease heat loss through windows, the air space between them varying from 4.65 to 12.5 mm. Patterned glass is primarily used for decoration and is available in thicknesses of 3 and 5 mm. This glass not only provides a degree of privacy but also allows diffused light into a space. Patterned window glass is available in 3 and 5 mm thicknesses and has a characteristic surface wave that is more apparent in the larger sizes. Lastly, wire glass is available with a variety of designs, colors, patterns, and polished finishes. Wire glass, with a common thickness of 6 mm, is used when fire rating and breakage safety may be required. These common glass types are further described in Table 13.7, and their average costs are presented in Table 13.8.

The frame around any glass may be single or double glazed. A double-

TABLE 13.7 Glass Types for Doors and Windows

No.	Glass types	Description
1	Float	Glass that was fire polished to remove all distortion, allowed to cool, and then cut to sheet size
2	Tempered	Glass that was strengthened by heat treatment to increase its toughness and resistance to breakage
3	Insulating	Double or triple sheets of glass with a sealed air space between
4	Patterned	Glass that can be rolled or figured for decoration and light diffusion
5	Wire	Glass in which a wire mesh was embedded during manufacturing for use in fire doors and windows, and in other places where breakage is a concern
6	Spandrel	Heat-strengthened glass used for spandrels and other opaque panels of curtain walls
7	Laminated	Safety glass consisting of outer layers of glass laminated to an inner layer of tough, transparent vinyl plastic under heat and pressure to form a single unit and hold the unit together when the glass cracks
8	Crown	Glass formed by spinning an opened globe of heated glass
9	Cylindrical	Glass produced by blowing a large, elongated glass cylinder, cutting off its ends, slitting it lengthwise, and opening into a flat rectangle
10	Heat strengthened	Glass that was strengthened by heat treatment, but not to as great an extent as tempered glass

TABLE 13.8 National Average Costs of Common Glass for Doors and Windows

No.	Glass type	Thickness (mm)	Standard max. size (mm × mm)	Cost ($/m²)
1	Float glass	2.34	1000 × 2500	13.5
		3.12	2000 × 3000	16.25
		4.69	3250 × 5300	18.75[a]
2	Float/plate	6.25	3250 × 5300	21.50[a]
		9.38	3100 × 5100	29.56[a]
		12.50	3100 × 5100	43.00
3	Tempered glass	6.25	1800 × 3000	[b]
4	Insulating glass—2 sheets of 3.12 mm for 12.5 mm thick units	12.50	N/A	37.70
	Insulating glass—2 sheets of 6.25 mm for 25 mm thick units	25.00	N/A	48.40
5	Patterned glass	3.12	1200 × 3300	17.25
		5.50	1500 × 3300	16.10
6	Wire glass	6.25	1500 × 3600	40.30
	Clear wire glass in diamond pattern	6.25	1500 × 3600	48.40
	Clear wire glass in pin stripe	6.25	1500 × 3600	72.63
7	Spandrel glass—standard colors	6.25	N/A	43.00
	Spandrel glass—nonstandard colors	6.25	N/A	48.40
8	Laminated glass	6.25	2000 × 3000	45.75
		12.50	2000 × 3000	107.60

[a] Add $8.00 per m² for gray or bronze tint.
[b] Add $21.50 per m² premium to base prices for custom orders.

glazed frame requires twice as much area as a single-glazed frame and provides better sound and heat insulation. Many stock frames, especially window frames, are preglazed at the factory, whereas custom frames are usually glazed on the job. Generally, the glass and glazing subcontractor present more than one manufacturer who can provide materials and perform bidding, shop drawing preparation, ordering, door erection, and glass installation. The project estimator needs to identify who will perform the glazing by checking with the subcontractor and supplier.

13.4.2 Hardware

Hardware can be classified as rough or finished. Rough hardware consists of bolts, screws, small anchors, nails, and any other fasteners. This type of hardware is usually required for the installation of doors and frames but it is not included in the hardware schedule. Finished hardware, on the other hand, is specified in the hardware section of the specifications or probably on the plans. Finished hardware is usually sent unattached to fit to a door and frame at the jobsite and perform a specific function. This type of hardware includes handles, hinges or butts, kickplate, locks and latches, locking bolts, closers, stops, and other miscellaneous items. Most finished hardware items are available in various finishes that conform to a US Code Symbol Designation.

13.4.3 Accessories

Door and window accessories include weather stripping, screen, mullion, sill, stool, flashing, and lintel. Each item has its own function and can usually be made of various materials. Some of these accessories were listed previously and descriptions shown in Table 13.1. Weather stripping is a ribbon of resilient materials used to reduce air inflation through the crack around a sash or door and is made of vinyl, polypropylene woven pile, neoprene, metal flanges and clips, polyvinyl, or adhesive-backed foam. Weather stripping for the jambs and head may include metal springs, interlocking shapes, felt or sponge, neoprene in a metal frame, or woven pile. At the bottom of the door (sill), the weather stripping may be aluminum, bronze, or stainless steel. It is important to know that weather stripping is sometimes preinstalled at the factory, so the estimator needs to ensure that it satisfies project specifications. Weather stripping can be purchased by linear measurements for the rigid types or by the roll for the flexible types. The cost of weather stripping varies with the sizes of openings, types of windows, and thicknesses of the sashes.

Screen for frames is made of steel, aluminum, fiber, or bronze. There are various sizes of screens, so the estimator needs to ensure that the screen and the frame are compatible. Mullion is a vertical or horizontal bar between adjacent window or door units. Made of the same or different materials as the frame, mullions can be either small T-shaped sections that are hardly noticed or large elaborately designed shapes for decoration. The sill lies on the exterior of the building, which is just below the bottom member of the frame. On the other hand, the stool is the interior horizontal member at the bottom of the frame. Both sill and stool can be made of brick, stone, precast concrete, wood, or metal. Flashing is required at the head and sill of the frame to direct water away from the concrete masonry units (CMU) and window. Lastly, the lintel is a beam or horizontal member of the openings required to support the upper wall portion. Installed during wall construction, lintels can be made of CMU, precast concrete, reinforcing concrete, wood, or steel.

13.4.4 Costs of Labor and Materials for Glazing, Hardware, and Accessories

This section presents some of the average national costs for glass, hardware, and accessories as shown in Table 13.9, according to Means (1999). The plain float

TABLE 13.9 Costs of Labor and Materials for Glass, Hardware, and Accessories

						Bare cost			
Code 08810	Glass	Crew[a]	Daily output	Labor (hrs)	Unit	Mat.	Labor	Total	Total[b]
260-0010	Float glass, 5 mm thick, clear, plain	2 Glaz	12.08	1.325	m^2	38	36	74	97
260-0200	Tempered, clear	2 Glaz	12.08	1.325	m^2	45.5	36	81.50	105
460-0010	Insulating glass, 2 lites 3 mm float, 13 mm thick, under 1.3 m^2	2 Glaz	8.83	1.813	m^2	66	49.50	115.50	148
650-0010	Patterned glass, colored, 3 mm thick, minimum	2 Glaz	13.01	1.230	m^2	75	33.50	108.50	134
650-0100	Maximum	2 Glaz	11.61	1.378	m^2	88.5	37.50	126	154
850-0010	Window glass, clear float, stops, putty bed, 3 mm thick	2 Glaz	44.59	0.359	m^2	31.5	9.80	41.30	49.50
900-0010	Wire glass, 6 mm thick, rough obscure (chicken wire)	2 Glaz	12.54	1.276	m^2	107	35	142	171
Code 08710	Door hardware								
150-0010	Average percentage for hardware, total job cost, minimum								0.75%
150-0050	Maximum								3.50%
150-0500	Total hardware for building, average distribution					85%	15%		

150-1000	Door hardware, apartment, interior				Door	107		107	118
200-0020	Bolts, flush, standard, concealed	1 Carp	7.00	1.143	Ea	17.55	32	49.55	70
220-0020	Bumper plates, 40 × 20 mm U channel	2 Carp	24.38	0.656	m	10.35	18.45	28.80	40.50
300-0020	Door closer, adjustable backcheck, 3-way mount, all sizes, regular arm	1 Carp	6.00	1.333	Ea	114	37.50	151.50	185
340-0010	Doorstops, holder and bumper, floor, and wall	1 Carp	32.00	0.250	Ea	27	7.050	34.05	41
400-0010	Entrance locks, for over 315 mm wide doors, single-acting	1 Carp	9.00	0.889	Ea	103	25	128	153
520-0010	Hinges, full mortise, avg. freq., steel base, 114 × 11 mm, USP				Pr	17.90		17.90	19.70
550-0010	Kickplate, 150 mm high, for 900 mm door, stainless steel	1 Carp	15.00	0.533	Ea	14.25	15	29.25	39
650-0020	Lockset, standard duty, cylindrical, with sectional trim, nonkeyed, passage	1 Carp	12.00	0.667	Ea	37	18.75	55.75	70.50
750-0010	Panic device, for rim locks, single door, exit only	1 Carp	6.00	1.333	Ea	330	37.50	367.50	42.5

[a] Glaz indicates a glazier, and Carp indicates a carpenter.
[b] Includes O&P.
Source: Means, 1999.

glass with a thickness of 5 mm, which requires two glaziers and a productivity of 12.08 m^2 per 8-hour day, has the total installation cost of $74/unit. The tempered float glass with the same thickness, however, has the total bare cost of $81.50/unit. Average hardware costs may range from 0.75 to 3.5% of the total job cost. Table 13.9 also shows that approximately 85% of the total hardware cost is in materials cost with approximately 15% of the total hardware cost being labor costs.

13.5 DOORS AND WINDOWS COST ESTIMATION

Generally, quantity take off is simply a counting of all items required for doors and windows. Pricing provides costs of all items by multiplying each materials quantity by the unit cost of that item and totaling all materials costs. Unit costs can be obtained from the estimator's database, suppliers, manufacturer's catalogues, Means (1999), Walker (1999), or other sources. The estimator, however, must keep in mind that the Means and Walker references typically contain average industry cost data, so adjustments must be made for the particular company crew and project location. Table 13.10 presents five major steps in cost estimation for doors and windows. These steps will help the estimator to acquire a broad picture of doors and windows cost estimation.

Step 1. Study specifications, drawings, and all contract documents. Most information for doors and windows can be found in the door and window schedules located in the specifications or drawings. Other important issues such as hardware and specialties may be included in different sections of the specifications.

Step 2. Take off quantities for doors and windows by simply counting the number of units and accessories required and then determining the total cost of doors and windows. It is wise to list all needed units by type, materials, size, and associated accessories. It is common to have a zero waste factor for door and window units. For big projects, the estimator may perform a rough estimate and may stop the cost estimation process at this point because costs of glazing and accessories are included in doors and windows or otherwise in a

TABLE 13.10 Major Steps for Door and Window Cost Estimation

Step	Description
1	Specifications and drawing
2	Takeoff pricing for doors, window, accessories (numbers of doors, windows)
3	Takeoff pricing for glazing (width × height, m^2
4	Takeoff pricing for accessories (m)
5	Total costs of doors, windows

contingency budget. Total costs for doors and windows can be obtained by totaling all materials, labor, and equipment costs. For small projects, however, the estimator should continue the procedure and conduct the next step.

Step 3. Take off and price for glazing. In this step, the estimator needs to determine the area (length $\times$ height) of glass to be installed, along with its thickness, type, and color, and the installation process and the installer.

Step 4. Determine the quantity of required accessories and their prices. Costs for hardware installation must be determined and the simplest way is to request the information from the hardware installer or materials suppliers.

Step 5. Add up all costs including overhead, profit, materials, labor, and equipment for doors, windows, glazing, and their accessories.

13.5.1 Cost Estimating for Doors and Windows

Most of the items covered in this chapter are furnished by materials suppliers and installed on the job by carpenters hired by the subcontractor. In the estimate, labor costs should be included under their proper trade. Quantity take off for doors and windows means simply counting or copying all required items from the schedules and specifications to a take off sheet, especially for residential construction. The estimator counts the number of exterior and interior doors and lists the quantity by size, materials, unit, and installation cost.

During the take off procedure for metal doors and frames, the estimator first determines each opening in accordance with the items in the schedule and any other relevant data. Secondly, the estimator combines all the quantities surveyed, including doors and frames, and checks to ensure that none have been overlooked. It is important to count the total number of openings and to ensure that two doors have been included where double doors are used. The estimator needs to check requirements for materials and installations, including size, style, materials, glazing, fire-rating label, finish, installation process, and installer. Lastly, for a detailed estimate, the estimator needs to identify all accessories including hardware, castings, stops, and grounds.

Similar to that for metal doors and frames, quantity take off for wood and plastic doors requires the estimator to identify openings, combine all the quantity surveys, check specialty requirements, and determine accessories. For entrances and storefronts, the estimator should submit the plans and specifications to an installer for take off and pricing. The quantity take off for entrance units determines total length of framing, number of joints, hardware, threshold, and closers. The quantity take off for storefront units determines height and width; length of intermediate, horizontal, and vertical members; and number of joints. For metal and wood windows, the estimator finds basic information regarding windows in the window schedules and identifies all details in the plans and specifications. Major items for metal windows include materials, glazing, screen, trim, gauge, and hardware. The estimator also needs to know the type of glass required and its installation procedure. However, wood and plastic windows are sold as complete units including hardware, weather stripping, and glazing.

After the take off has been done, the estimator transfers all items to a pricing sheet. Materials and labor costs can be obtained from several resources including manufacturers, suppliers, subcontractors, Means', Walker's, or the estimator's database. The estimator should pay close attention to specialty or custom items regarding materials, finish, compliance, installation process, and installer, since these factors significantly affect materials and labor costs. In general, materials costs usually vary with types, sizes, specialty requirements, installation process, locality, and manufacturers. The labor cost for many doors can be figured based on a crew of two carpenters with various types of crews being required for different types of door and window units. The estimator needs to adjust a crew and its productivity according to the type of work performed and productivity records.

13.5.2 Cost Estimating for Glazing

Generally, glazing costs are a function of materials, method, and the area to be glazed. Referring to the drawings, glazing can be taken off by square meters (length $\times$ width). The estimator should carefully check specifications because there are many different glass grades, sizes, and thicknesses with each type figured separately. When taking off, the estimator can list glass by the items presented in Table 13.11.

Both materials and labor costs for glazing are generally included under a single item by the glazing subcontractor. Glazing cost usually depends on the type of frame and the specified glazing method. For wood frames, glazing compounds are usually needed, where neoprene gaskets or glazing compounds are required for metal frames. If glazing is specified for the exterior, the estimator may need to include costs of scaffolding, lifts, and ladders required. In multistory

TABLE 13.11 Items Considered for Glazing Cost Estimation

No.	Items to be considered	Description
1	Type, thickness of glass	List each type and thickness separately
2	Size or area of glass	List the length and width of glass
3	Type of frame	List wood, metal frames separately
4	Installation method	Determine additional labor, equipment for different installation methods (inside or outside building)
5	Height above the ground	Determine additional labor, equipment for distributing materials

building construction, timing the delivery and installation are of prime importance and coordination with other construction trades is essential. Therefore, the estimator needs to determine whether glazing is to be preinstalled in the unit or installed at the jobsite. Additionally, the estimator needs to ensure that preglazing complies with both project specifications and local union rules.

13.5.3 Cost Estimating for Accessories

Accessories for doors and windows include glass and glazing, screening, weather stripping, hardware, grilles, mullions, sills, stools, sound control, light control,

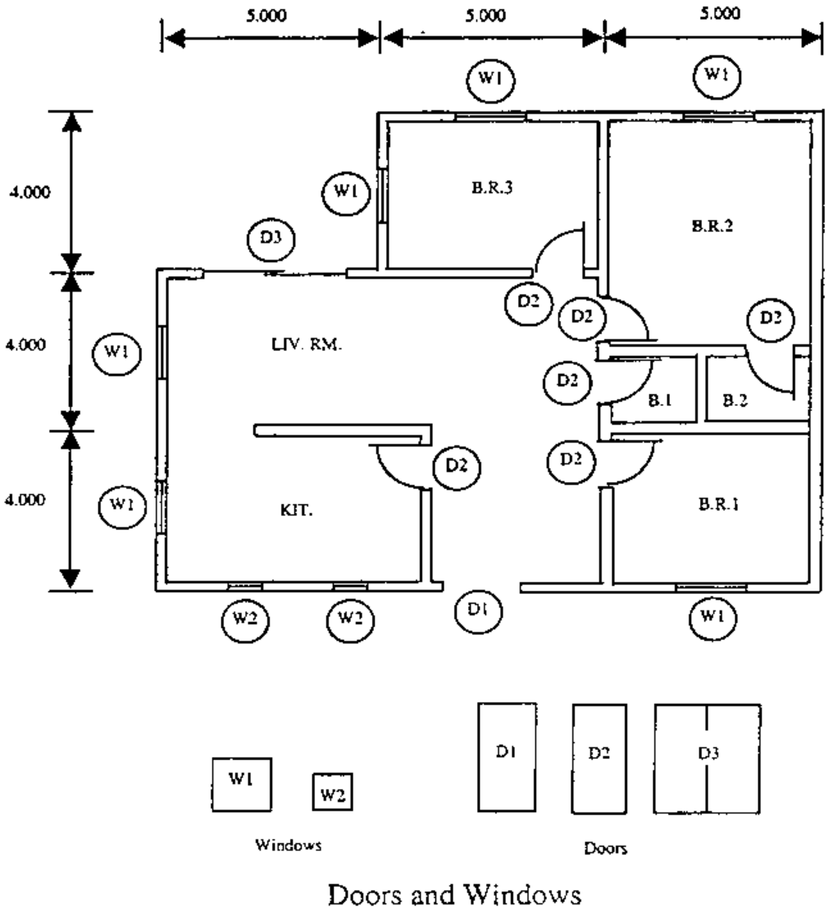


FIGURE 13.6 Apartment floor plan.

TABLE 13.12 Apartment Door and Window Schedules

Mark	Units	Size (mm)
Door schedule		
D1	Entrance door, colonial	44 × 2035 × 926
D2	Hollow-core passage door with 117 mm solid jamb	35 × 2035 × 915
D3	Sliding wood door, vinyl clad, 25 mm insulating glass	1830 × 2085
Window schedule		
W1	Sliding standard-glazed window	1200 × 1050
W2	Sliding standard-glazed window	900 × 900

and saddles. Based on the specifications and other contract documents, the estimator needs to make a list of all needed accessories and their requirements including type, size, materials, fire rating, finish, and installation methods. For small projects, the estimator needs to perform a detailed estimate identifying all accessories required for the project because these items significantly affect total door and window costs. For big projects, the estimator may determine such costs plus a contingency cost to cover the cost of accessories based on the estimator's experience and cost database.

In general, the most efficient method for taking off accessories for doors and windows in a project is to review the door and window schedules along with specifications. The take off for accessories is normally made in linear meters or the number of each size piece. In building construction, prehung doors are widely used. Locksets and interior casings are sometimes not stated in the specifications, so the estimator needs to include them as well. In fact, exterior prehung doors require casing on the interior whereas interior prehung doors require casing on both sides. To perform quantity take off for hardware, the estimator needs to check specifications and codes for several items including base metal, finish, door closers, stoppers, and specialty items such as panic and handicap devices.

Regarding the pricing process, costs of accessories vary significantly from one supplier to another. The estimator should acquire a price quote from materials suppliers for the specific type, function, finish, and style of finished hardware and other accessories specified for the project. For instance, the cost of metal weather stripping depends on the type of window, whether double hung or casement, the size of the opening, and the thickness of the sash. To take off the quantity of weather stripping required for the project, the estimator should simply take the perimeter around the window (sides, head, and sill strips) plus the weather stripping width needed to cover any overlap. Mullion should be taken off by linear measurements with a note as to thicknesses, finish, and color. Sill

Company Logo

Quantity Takeoff Date Sheet No. 1 Of

Project Title ______________________ Project No ______________

Take Off By ______________________ Approved By ______________

Code*	Description	No.	Dimensions			Unit	Quantity	Unit		Unit		Unit	
08210-430-1000	Entrance door, colonial, 44×2035×914 mm (D1)	1				Ea.	1						
08220-310-4440	Hollow-core passage door w/ 113 mm solid jamb 85×2035×45 mm (D2)	6				Ea.	[illegible]						
08210-340-4010	Sliding wood door, vinyl clad, 25 mm insulating glass 1830×2035 mm (D3)	1				Ea.	1						
08550-380-0100	Sliding window, standard glazed 1200×1050 mm (W1)	6				Ea.	6						
08550-350-4100	Sliding window, standard glazed 900×900 mm (W2)	2				Ea.	2						

* Masterformat, Uniformat, WBS, other, etc.

FIGURE 13.7 Quantity take off for doors and windows.

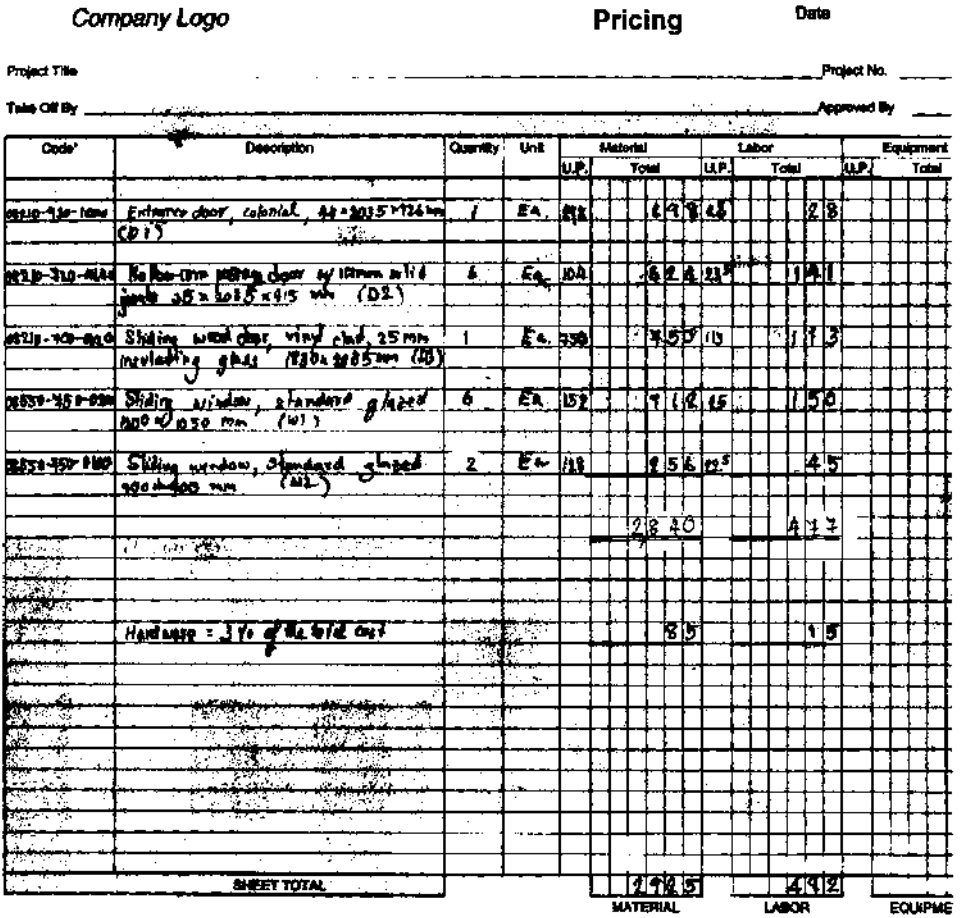


FIGURE 13.8 Pricing for doors and windows.

and stool also are taken off by linear measurements accompanied by notes and sketches that show necessary details such as material sizes and installation requirements. The cost for installation of finished hardware also varies depending on type and quantity of the hardware required on each door. The estimator should request hardware installation costs from the hardware installer in order to double check the estimator's own estimate.

13.5.4 Computation Example

Determine the total quantity, materials, and labor costs for the doors and windows of an apartment project. Figure 13.6 shows a plan for doors and windows required for one apartment unit with three types of doors, two types of windows, and their accessories. Door and window schedules are given in Table 13.12. The cost of doors, windows, and accessories are provided in Tables 13.4, 13.6, and 13.9. This project requires a preliminary cost estimate, so the cost of the hardware is assumed to be 3% of the total door and window cost. One can assume that the costs provided include the costs for glazing and accessories.

Step 1. Perform a quantity take off for doors and windows as shown in Figure 13.7. This project requires one door of D1, six doors of D2, one door of D3, six windows of W1, and two windows of W2.

Step 2. Determine the materials and labor costs for the door and window work. According to Figure 13.8, the total materials cost is \$2925, and the total labor cost is \$492, which results in a total cost of \$3417.

13.6 REVIEW QUESTIONS

1. What are the major components of doors and windows?
2. What are the types of doors based on their method of opening?
3. What are the most widely used door types in building construction?
4. What are the types of metal frames?
5. What are the major types of wood doors for residential building construction?
6. What are the types of windows based on their use in building construction?
7. What are the pros and cons of stock versus custom doors and windows?
8. What are the major requirements for doors and windows?
9. What are the major types of glass for doors and windows?
10. What are the major hardware and accessories for doors and windows? Specify at least five.
11. What are the minimum and maximum average percentages for hardware costs?
12. What major items must be considered when pricing glass?

14

Finishes

14.1 LATH AND PLASTER WORK

14.1.1 Plaster, Bases, and Support Systems

Both gypsum and Portland cement plasters can be applied directly to concrete and masonry surfaces that have sufficient bonding capabilities. The surfaces should be clean (no grease, paint, efflorescence, waterproofing compounds), firm, and sound, and should provide adequate suction for a good bond. When the bonding capabilities are in question it is recommended to use a dash bond coat made of one part cement and two parts of fine sand by volume. The dash coat is applied with a small straw broom and should not be troweled. Another method to improve the bonding on concrete or masonry is to apply a waterproof bonding agent for exterior surface use.

Other supporting systems for the plastering operation are metal and wood framing with furring. Installation over metal framing is not common in low-rise residential construction. Exterior wood-framed construction is of two types: sheathed and unsheathed (Figure 14.1).

When plaster is to be applied directly to masonry (bricks, concrete blocks, or stone) the joints should be struck flush, and the masonry surface should be clean and firm. It is recommended for masonry surfaces, which absorb water too quickly, to spray water prior to applying the first plaster coat. Metal reinforcement should be used when Portland cement plaster is applied over sheathed or unsheathed wood framed construction.

The most common types of metal reinforcement are expanded and wire lath. Expanded metal lath is formed from thin steel sheets that have been cut in

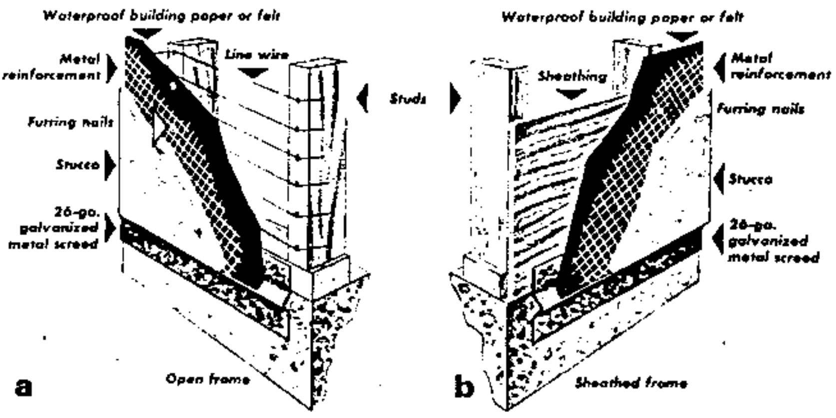


FIGURE 14.1 Exterior wood framed construction: (a) unsheathed; (b) sheathed. Line wire is not required with paper-backed reinforcement. (Courtesy of Portland Cement Association.)

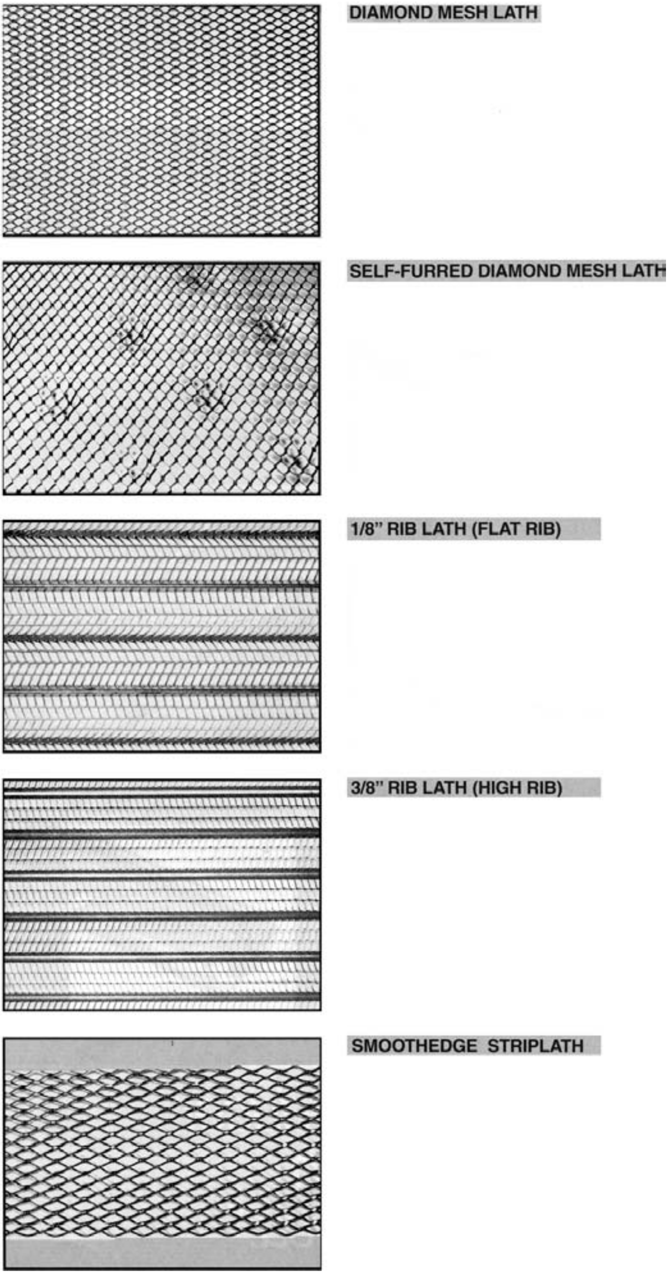


FIGURE 14.2 Expanded metal lath patterns.

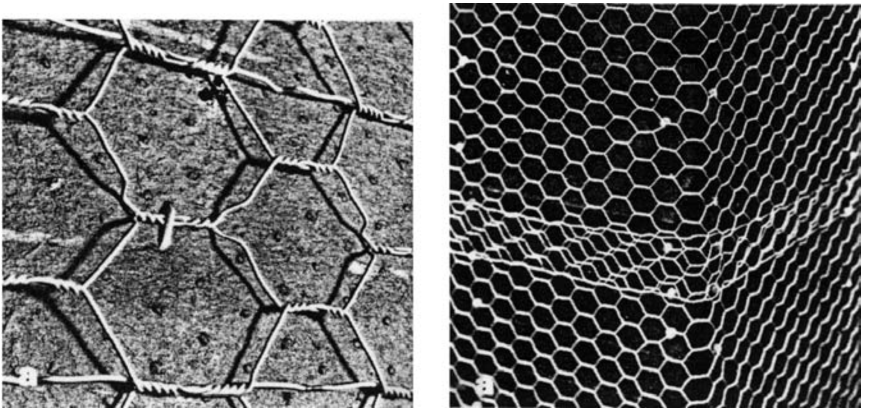


FIGURE 14.3 Wire lath.

a pattern and stretched to form diamond-shaped openings (Figure 14.2). Wire lath, shown in Figure 14.3, is used as a base for exterior Portland cement (stucco) finishes. Wire lath is a hexagonal woven wire fabric. The plain type is nailed to supporting construction; the self-furring type eliminates the need for furring fasteners or the installation of backing paper. Metal reinforcement should have a backing paper in exterior locations, in wet interior places (bathrooms), and when the plaster is applied by spraying.

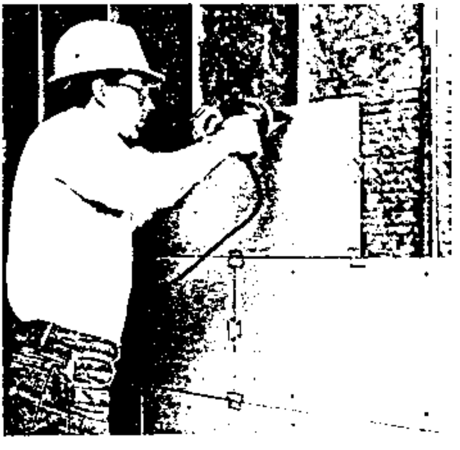


FIGURE 14.4 Application of gypsum plaster base to metal studs using screws, with clips at corners and end joints. (Courtesy of United States Gypsum Company.)

Gypsum lath as a base for plastering is fastened to wood or metal framing with nails or screws in accordance with industry standards (Figure 14.4).

Metal plaster accessories need to be considered by the estimators. Exposed plaster edges require protection from damage and should be trimmed with metal casing beads. Other accessories currently used in plastering operations are control joints, striplath, and cornerite. Typical accessories for Portland cement plaster operations are shown in Figure 14.5.

Gypsum plaster is applied in two or three coats and is used only for interior surfaces. Gypsum plaster components are calcined gypsum, lime, sand, and fibers. The two-coat application consists of base and finish coat. Three-coat work requires a scratch coat, a brown coat, and a finish coat. Each coat is applied

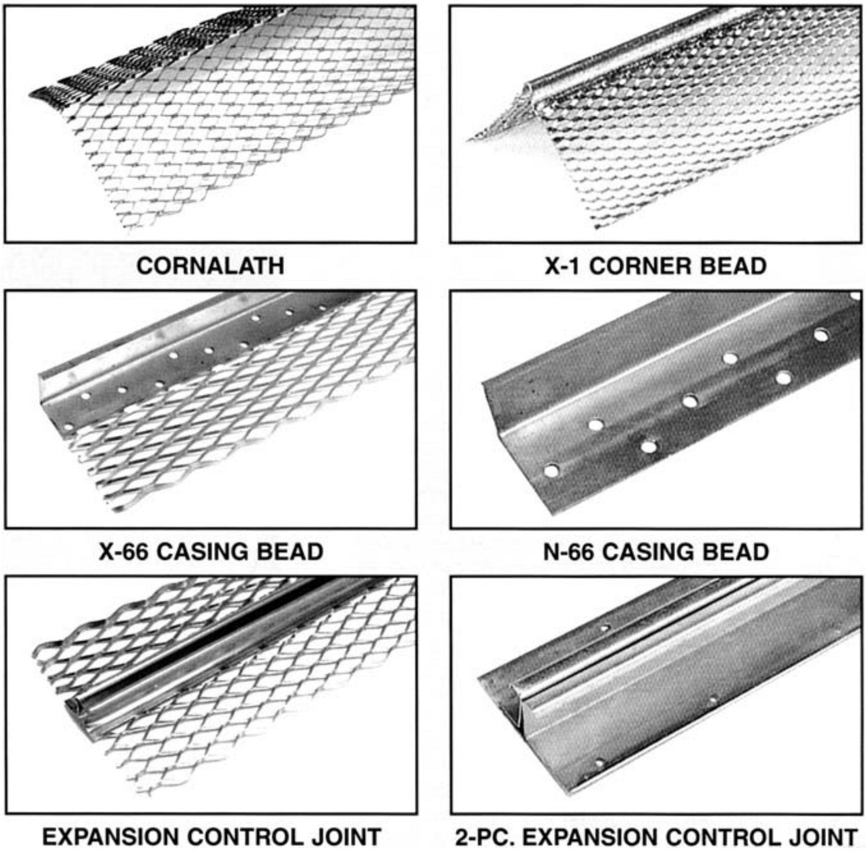


FIGURE 14.5 Plaster accessories.

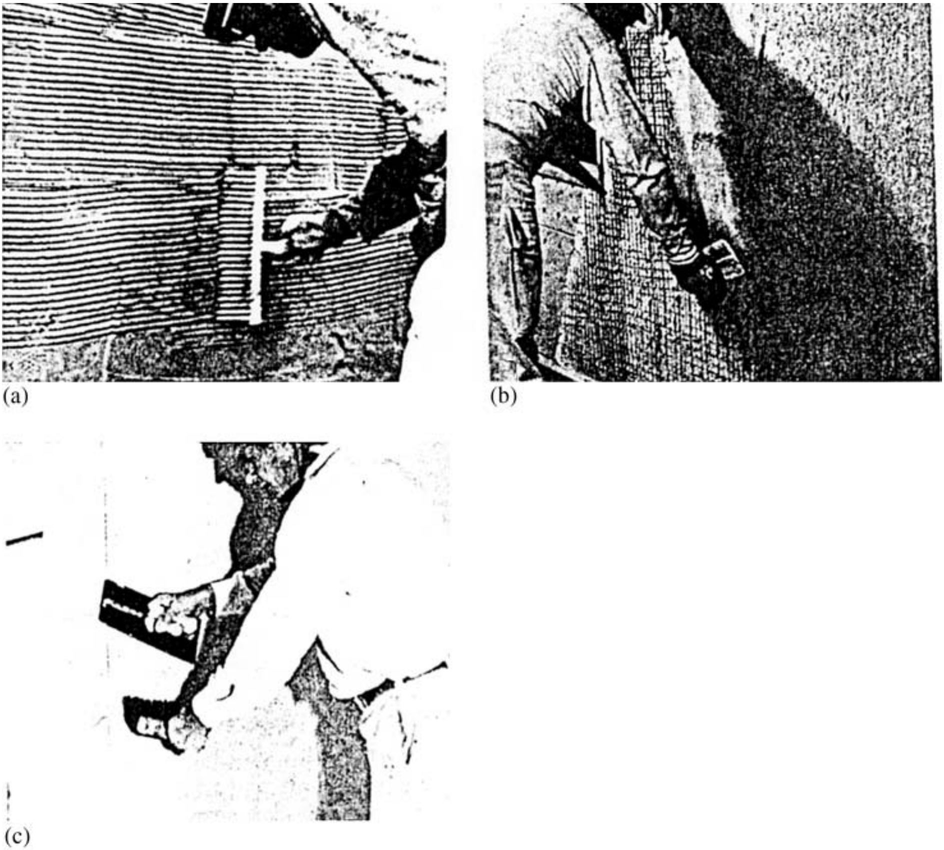
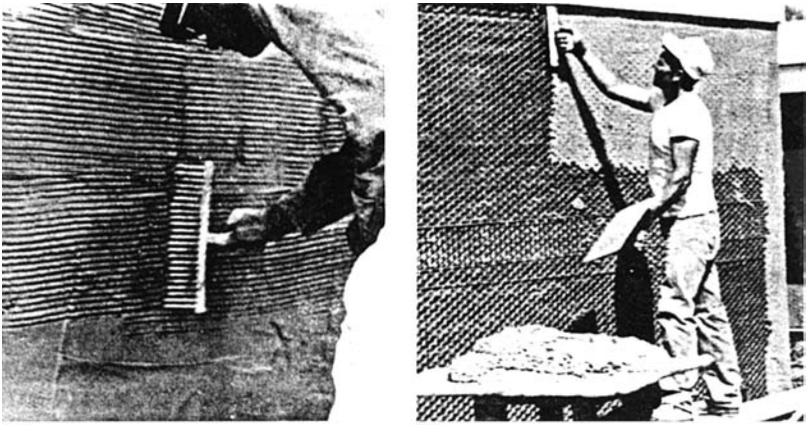


FIGURE 14.6 Scratch and brown coat application: (a) scratch coat is raked for three-coat work; (b) brown coat is applied over scratch coat, followed by (c) finish coat in separate operations. (Courtesy of Portland Cement Association.)

separately and allowed to set. Figure 14.6 shows the application of three-coat plaster. The base coats (scratch and brown) can be applied by hand trowel or machine. For finish coat application there are three methods in use: trowel (hand or power), float, or spray. The method used dictates the type of finish and also dictates the productivity and cost per unit of measure.

Portland cement plaster is used on both exterior (stucco) and interior surfaces and in locations where exposure to wetting is probable. Portland cement, sand, and sometimes lime are the major components. The application takes place in two or three coats, depending on the supporting system. Two-coat application is recommended over concrete or masonry bases. The first (scratch) coat is spread



(a) (b)

FIGURE 14.7 Scratch coat application: (a) the first (scratch) coat is spread on reinforcement with a trowel; (b) the surface is scored horizontally. (Courtesy of Portland Cement Association.)

on the reinforcement with a trowel [Figure 14.7(a)]. Then the surface is scored horizontally [Figure 14.7(b)].

The brown coat is spread with a trowel, as shown in Figure 14.8(a) and leveled with a rod, as shown in Figure 14.8(b).

The finish coat for interior surfaces to be painted should be moisture cured.

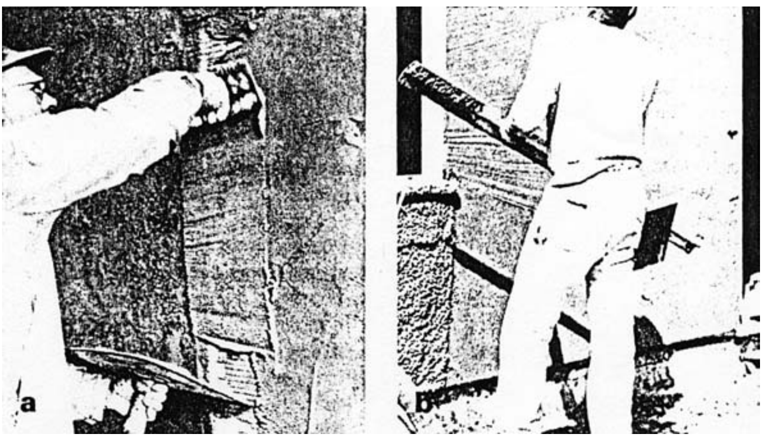


FIGURE 14.8 Brown coat application: (a) spread by trowel; (b) leveled with rod. (Courtesy of Portland Cement Association.)

Stucco finish (for exterior surfaces that contain curing agents) does not require moist curing. For curing, Portland cement plaster requires sufficient water and temperatures above freezing for several days from the application. The estimator should consider, in pricing, whether relief joints and control joints are specified to localize movement and to minimize the shrinkage stresses.

14.1.2 Estimating Areas and Quantities

14.1.2.1 Areas

Lathing and plastering for walls and ceilings are estimated by m^2, but procedures for deducting for doors and windows vary with subcontractors. Many contractors do not deduct; others deduct for 50% of all openings. No deductions should be made for openings less than .5 m^2. For example, to obtain the total m^2 for plastering a room (walls and ceiling) $6 \times 4 \times 3$ m, with two windows 1×1 m and one door 1.5×2 m, the computation follows.

$$\begin{aligned} \text{Walls } (6 + 6 + 4 + 4) \times 3 &= 60 \text{ m}^2. \\ \text{Ceilings } (6 \times 4) &= 24 \text{ m}^2. \\ \text{Total} &= 84 \text{ m}^2. \end{aligned} \tag{14.1}$$

Deduct 50% of door and window openings:

$$\begin{aligned} &\text{Windows } 2 \times 1 \times 1 = 2 \text{ m}^2 + \text{door } 1 \times 1.5 \times 2 = 3 \text{ m}^2 = 5 \text{ m}^2. \\ &\text{Quantity to be priced: } 84 - 5 \times .5 = 81.5 \text{ m}^2. \end{aligned} \tag{14.2}$$

For columns, beams, or girders to be plastered, measure the actual area figured in m^2 with no deductions. Plaster cornices should be measured and area converted in m^2. Circular work on a small radius should be doubled as the straight surface work.

14.1.2.2 Estimating Plaster Quantities

The covering capacity of 1 m^3 of plaster on various bases given in Table 14.1 is based on the following application thickness: 20 mm if applied on metal lath,

TABLE 14.1 Plaster Mix Covering Capacity of 1 m^3 in m^2

Coat type	Metal lath	Unit masonry	Rough concrete
Scratch	55–65	—	—
Brown	75–85	65–70	65–70
Finish	400	400	400

TABLE 14.2 Average US[a] Cost of Plastering Materials

Material	Unit	Cost ($)
Gypsum plaster	36 kg bag	14
Gauging plaster	45 kg bag	21
Keen's cement	45 kg bag	23
Perlite vermiculite	45 kg bag	12
Metal lath 1.36 kg/m^2 galvanized	m^2	1.76
Metal lath 1.85 kg/m^2	m^2	2.56
Stucco mesh, painted 0.82 kg/m^2	m^2	3.60

[a] As of March, 2001.

10 mm on gypsum lath, and 15 mm on unit masonry. Gypsum plaster is sold by the ton (1000 kg) and is packed in 45-kg sacks.

Standard specifications call for the first (scratch) coat on all types of lath to be mixed in proportions of 1 part gypsum plaster to no more than 2 parts sand by weight. The covering capacity of plaster depends upon the application method (manual or mechanical), thickness of grounds, type of base or lath, and the quality of workmanship required.

Perlite, vermiculite plaster aggregate, is a lightweight material (120 to 240 kg/cm perlite, 480 to 720 kg/cm vermiculite) compared with the traditional sand (1590 kg/cm). The plaster mixed with this aggregate will weigh 480 to 720 kg/cm depending on proportions used.

Bondcrete is used as a bond coat on rough concrete surfaces only. If the concrete surfaces are smooth, they must be roughened, which will add to the cost of plastering operations. It usually requires 920 to 1200 kg per 100 m^2, depending on concrete surface and thickness of the coat.

Finishing lime is necessary for white putty coat trowel finish and in sand float finish operations. For the trowel finish a coat of 1 part gypsum gauging plaster to 2 parts hydrated dry lime is recommended; 0.25 m^3 of lime putty mix will finish about 100 m^2. For sand float finish the mix is 1 part lime putty, gypsum

TABLE 14.3 Average US Metal Lath Production Rates

Installation method	Unit	Hours/unit
Nailed on wood studs	100 m^2	8
Tied on joists or hanger	100 m^2	8
Furred and suspended	100 m^2	16
Beam and columns	100 m^2	32

Table 14.4 Plastering Production Rate[a]

Coat type	Unit	Ordinary workmanship	First-grade workmanship
Scratch	m^2	120–140	110–130
Brown	m^2	75–90	60–70
White finish (putty)	m^2	80–110	65–95
Sand finish	m^2	80–100	60–85

[a] Per 8hr/day for a crew of one plasterer and one helper.

gauging, or cement, and 2-1/2 to 3 parts sand. There is a variety of prepared gypsum trowel and sand float finish mixes, which require only adding water on the job. The coverage capacity for gypsum trowel finish is 270 to 320 kg/100 m^2, and 380 to 400 kg/100 m^2 for sand finish coat.

14.1.3 Pricing Materials

The average cost of plastering materials in the United States as of March 2001 is given in Table 14.2. In figuring the materials cost, the estimator must consider the waste during mixing, application function of the site conditions, and craftsman skill.

Table 14.5 Man-Hours to Apply, 100 m^2 of Plaster to Various Bases

Plaster type	No. coats	Base	Plaster[a] (hrs)	Helper (Hrs)
Gypsum	2	Gypsum lath	9.6	6
Gypsum	2	Unit masonry	10.8	7.2
Gypsum	2	Unit masonry	15.6	12
Gypsum	3	Gypsum lath	15.6	12
Gypsum	3	Metal lath	16.8	13.2
Gypsum	3	2 sides, hollow studs	43.2	31.2
Lime	2	Unit masonry	10.2	6.6
Lime	3	Metal lath	18	12
Portland cement	Brown coat	Gypsum lath	14–16	4
Portland cement	Scratch coat	Gypsum lath,	5.5	5.5
Perlite/vermiculite	Brown coat	metal lath,	9.0	6.0
Perlite/vermiculite	Finish white coat	or unit masonry	9.5	4.5

[a] For first-grade workmanship increase the plasterer hours by 25%.

TABLE 14.6 Average US Total Cost of Plastering Operation

Operation	Unit	Hours/ Unit	Materials ($)	Labor ($)	Equipment ($)	Total ($)
Gypsum plaster						
2 coats, no lath on walls	m^2	.456	4.09	11.35	.62	16.06
2 coats, no lath on ceilings	m^2	.520	4.09	12.95	.71	17.75
2 coats, incl. gypsum lath on walls	m^2	.592	8.20	15.00	.67	23.87
2 coats, incl. gypsum lath on ceilings	m^2	.692	8.20	17.55	.79	26.54
3 coats, no lath on walls	m^2	.550	5.70	13.70	.75	20.15
3 coats, no lath on ceilings	m^2	.613	5.70	15.30	.83	21.83
3 coats, incl. metal lath on wood studs	m^2	.668	8.45	16.90	.76	26.11
3 coats, incl. metal lath on ceilings	m^2	.750	8.45	19.00	.86	28.31
Perlite/ vermiculite plaster						
2 coats, no lath on walls	m^2	.520	3.88	12.95	.71	17.54
2 coats, no lath on ceilings	m^2	.606	3.88	15.10	.82	19.80
2 coats, incl. gypsum lath, metal studs	m^2	.683	7.05	17.30	.78	25.13
2 coats, incl. gypsum lath on ceilings	m^2	.820	9.05	21.00	.93	28.98
3 coats, no lath on walls	m^2	.646	6.35	16.10	.88	23.33
3 coats, no lath on ceilings	m^2	.759	6.35	18.95	1.03	26.33
3 coats, incl. metal lath on wood studs	m^2	.797	10.15	20.00	.91	31.06
3 coats, incl. metal lath on ceilings	m^2	.941	10.15	24.00	1.07	35.22
3 coats, on and incl. suspended ceilings	m^2	1.552	16.70	39.50	1.77	57.97
Thin coat plaster						
1 coat veneer, not incl. lath	m^2	.120	.75	2.99	.16	3.90
Portland cement plaster						
3 coats, stucco w/mesh on wood trawe	m^2	.425	4.37	10.75	.48	15.60
3 coats, stucco on masonry, no mesh	m^2	.240	2.43	5.95	.33	8.71
3 coats exterior stucco, with bonding agent, no mesh	m^2	.240	3.89	5.95	.33	10.17
3 coats exterior stucco, with bonding agent, no mesh, on ceilings	m^2	.265	3.89	6.60	.36	10.85
3 coats on beams	m^2	.598	3.89	14.90	.65	19.60
3 coats on columns	m^2	.478	3.89	11.95	.65	16.49

Source: Means, *Building Cost Data* 2000 *Metric*.

14.1.4 Pricing the Labor

Plastering costs vary with the class of workmanship required. The "ordinary work" is used on most types of buildings where the walls are permitted to have some variations and waves in finish up to 5 mm, and fairly straight angles and corners are allowed. "First-grade workmanship," which permits wave variations up to 2 mm, is recommended for top-of-the-line residences, hotels, and public buildings (schools, libraries, courthouses, etc.). All interior and exterior angles must be absolutely straight and plumb.

Before estimating the cost of labor, the quality of required work must be considered. Labor cost may vary 25 to 35% from ordinary work to first-grade workmanship. Production rates for installation of metal lath are provided in Table 14.3. For plastering operations, a plasterer with one helper should apply, assuming normal site conditions (including normal weather) during an 8-hour work day, the areas indicated in Table 14.4.

The man-hours needed for applying 100 m^2 of plaster on various bases are given in Table 14.5. This will be useful for estimators to figure the total labor hours and expected duration of the plastering operation. Considering the local labor rates, including the cost of fringe benefits, the estimator can easily estimate the total labor cost.

The total cost of plastering operations, which includes the materials, labor, fringe benefits, and required equipment, such as a mixer or air compressor with hoses, is given in Table 14.6, which is an adaptation from Means' *Building Cost Data* 2000—metric version. The prices reflect the United States average at the date of compilation.

14.2 GYPSUM PLASTERBOARD SYSTEMS

14.2.1 Description of Finishing Operations

Gypsum wallboard, commonly referred to as drywall, is used as a finishing material for walls or ceilings, and a rigid backing material for board laminated assemblies, acoustical tile, ceramic tile, wall coverings, and other finishes. Gypsum boards, shown in Figure 14.9, are manufactured in different sizes and thicknesses, with square, tongue-and-groove (T&G), tapered, or beveled edges. The 6 mm board is used as a lightweight, low-cost utility wallboard. The 9 mm board is used primarily for repair, remodeling, and double wall or multilayer construction. The 13 mm board is used in new construction and/or remodeling installations. The 16 mm board is used for one-hour fire rating requirements or for framing space that exceeds 13 mm wallboard limitations. Typical wallboard sizes range from 1.2×2.4 to 4.2 m.

14.2.1.1 Types of Gypsum Wallboard Panels

Foil-back gypsum/panels are comprised of a sheet of aluminum foil laminated to the back surface of the wallboard. This is used to reduce outward heat flow in the winter and inward heat flow in the summer. It serves as an effective vapor barrier, water vapor retarder, and thermal insulator when facing an air space of 19 mm or greater. Its use is not recommended over tile, double layer installations, and areas where high outside temperatures are prevalent.

Moisture-resistant gypsum panels are comprised of special asphalt, gypsum core (brownish color) covered with chemically treated face papers (light green finish) to prevent moisture penetration. They are predominantly used in bathrooms, kitchens, utility rooms, and other high moisture areas.

Made of a specially formulated mineral gypsum core that must meet or exceed ASTM C36 standards, fire-rated gypsum panels at minimum provide 45-minute, and up to 4-hour, fire-resistance ratings. They are used to make 13 and 16 mm thick panels for wall, ceiling, and column applications where fire-rated assemblies are required.

Cement boards have a Portland cement core wrapped in a fiberglass mesh and are covered with a specially formulated smooth covering. They are ideally used for interior/exterior construction areas where water, moisture, or high humidity is prevalent (e.g., bathroom showers, tubs, kitchen countertops).

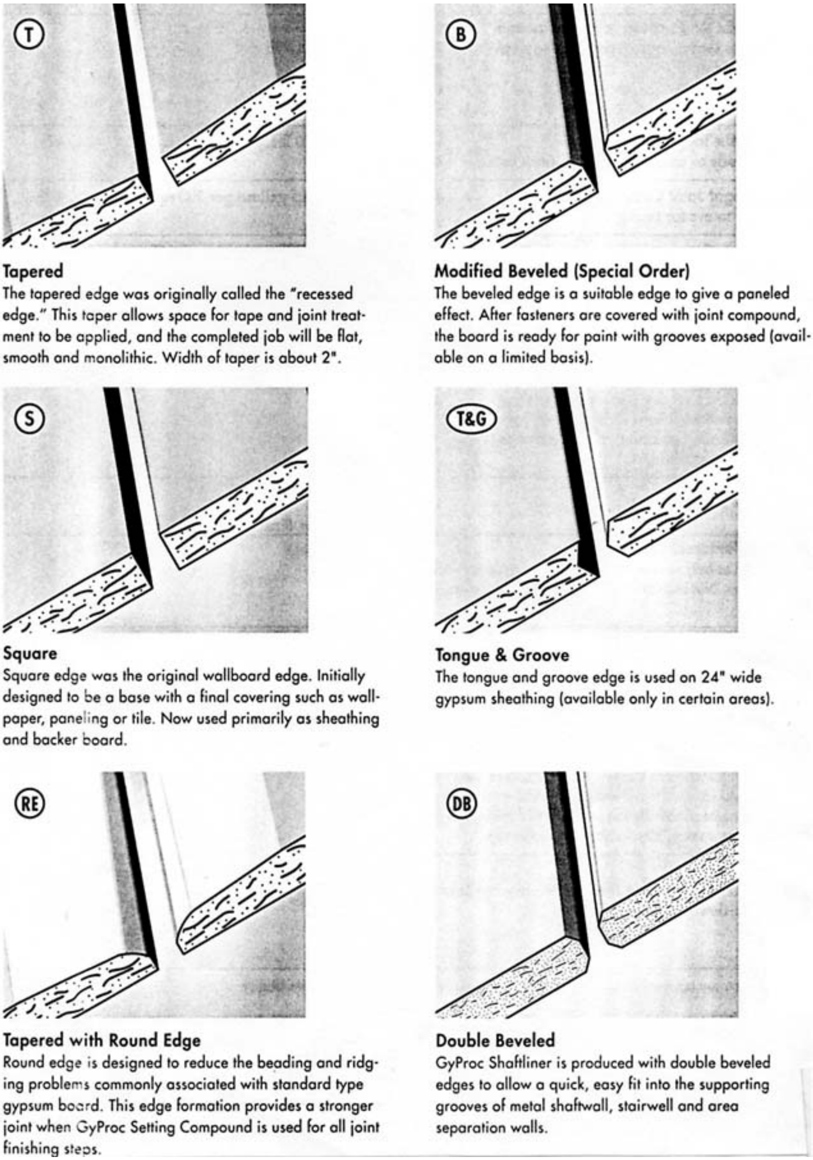


FIGURE 14.9 Typical edge designs for gypsum boards.

14.2.1.2 Drywall Installation Accessories

Gypsum wallboard can be attached to framing by various methods depending on the type of framing being used and the results that are desired. Mechanical fasteners (nails and screws), adhesive, or a combination of adhesive and mechanical fasteners can be used for wallboard and the backing board attachment to the supporting framing. Figure 14.10 shows the installation and finishing, and Figure 14.11 gives the terminology used.

Applied with a hammer, the nail is seated in a shallow dimple not greater than 0.75 mm. Nails are driven at least 8 mm from ends or edges of wallboard. For single nailing along supports, nails are spaced 175 mm on centers of ceilings and 200 mm on centers of walls. Screws are applied with an electric power positive drill/screw gun or clutch tool. Screws (Type W) are driven at least 10 mm from ends or edges of wallboard. Other fasteners include staples, which should be of 16-gauge flattened galvanized wire, and provide a minimum penetration of 16 mm into wood framing. Staples are primarily used to attach base layer boards to wood framing in a double-layer application.

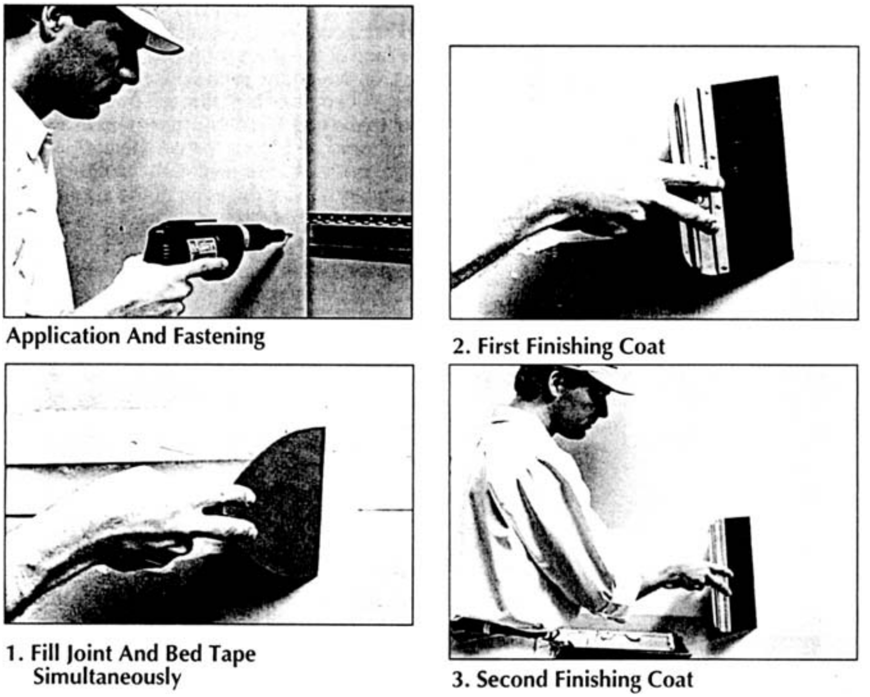


FIGURE 14.10 Gypsum wallboard installation and finishing operation.

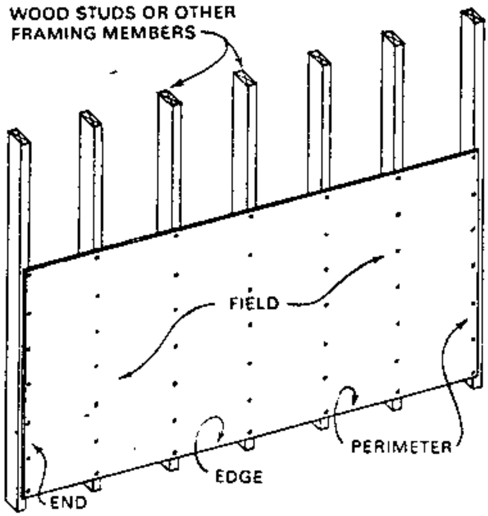


FIGURE 14.11 Gypsum wallboard installation terminology.

In the double nailing or screwing application perimeter screws are spaced 175 mm on-center for ceilings and 200 mm on-center for walls. Nails and/or screws are not doubled on the perimeter. For attachment at supports, pairs of nails or screws are placed 50 mm apart, and spaced 300 mm between pairs. Double nailing ensures better board-to-stud contact and the occurrence of fewer defects than does single nailing. Although the total number of nails per panel is about 10% greater with double nailing, the required concealing of nail spots is about 20% lower than for single nailing.

Another application calls for a continuous bead of adhesive applied to a wood stud, the wallboard pressed onto it, and supplementary nails or screws attached. This is used to secure single-ply wallboard to wood framing, furring, masonry, and concrete, or to laminate face-ply to a base layer of gypsum board, sound-deadening board, or rigid foam insulation. As a result, adhesive–nail attachment reduces the number of nails in the middle of a panel by at least 50%.

Other accessories used in gypsum or drywall board installation include the following.

Corner bead: Either metal or plastic, corner bead is installed at all external corners of drywall construction to provide a true and straight-line finish. It is available in 2.4 and 3.0 m lengths.

Stop bead: Either metal or vinyl, stop bead is used to cap the gypsum panel edge whenever it is exposed. It may otherwise be covered with tape, a compound finish, or some other trim.

Joint tape: Joint tape is a fibrous tape with feathered edges that is creased to allow its use at corners. It is commonly used with joint compound for butting and finishing of joints.

Joint compound: Joint compound is available in ready-mixed, powdered, fast setting, all-purpose, lightweight, and other forms.

14.2.1.3 Installation and Finishing of Gypsum Wallboard

Gypsum board application and finishing standards must comply with ASTM C840. Gypsum board can either be applied as a single- or multi-ply construction, with ceiling panels installed first. With the exception of 10 mm thick wallboard on ceilings, which are applied perpendicular to the supports, ceiling boards can be applied either perpendicular or parallel to supporting members. In addition, wallboard installation can be performed in a perpendicular or parallel fashion, as shown in Figure 14.12.

Perpendicular application is generally preferred because it provides greater strength, stiffer finish surface, and shorter joint lengths. Prior to the gypsum board application, sound installation batts are installed where specified unless they can be installed easily after the board. Exposed end-butt joints are to be located as far as possible from the centers of walls and ceilings, and staggered not less than one framing member in alternate courses of board. Ceiling members are installed across framing in a manner that minimizes the number and exposure of end-butt joints, especially in the central area of the ceiling. Abutting end joints of adjacent panels are to be staggered not less than one framing member. Wall and partition

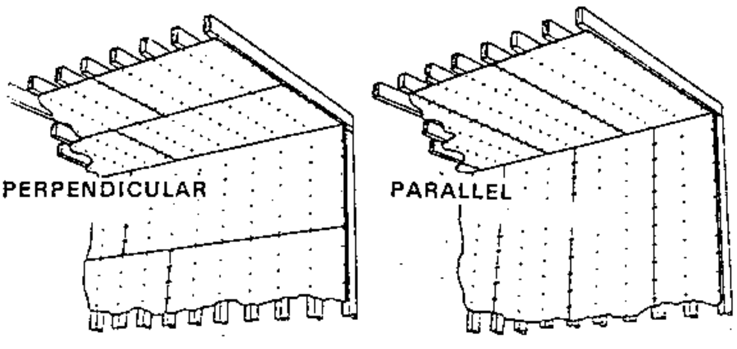


FIGURE 14.12 Horizontal and vertical application of wallboard to wood-framed construction.

boards are to be installed in a manner that minimizes or avoids end-joint butts entirely. For stairwells and similar high walls, boards are installed horizontally with end joints staggered over studs.

Gypsum boards are installed face side out. Defective, damaged, or damp boards are not used. Boards are butted together at the edges, with not more than a 2 mm open space between board ends. At no time should boards be forced into place. Edge and end joints should be located over supports, except in horizontal applications where intermediate supports or back blocking is used behind end joints. Adjoining boards should be positioned to ensure that the edges abut, with tapered to tapered, mill-cut, or field-cut ends to like, respectively. Unlike edges should not be placed against each other. The vertical joints are staggered over different studs on opposite sides of partitions, as shown in Figure 14.13. Joints at corners of framed openings should be avoided if possible. Gypsum board should be attached to steel studs so that the leading edge or end of each board is attached to the open (unsupported) edge of the stud flange first. For additional support at openings and cutouts, attaching to framing and blocking, if provided, is possible. Spout grout hollow metal door frames for solid core wood doors, hollow metal doors, and doors exceeding 0.8 m wide.

For nonload-bearing drywall partitions at structural abutments, 6 and 13 mm spaces should be provided edges trimmed with “U” bead edge trim, and sealed with an acoustical sealant. Where sound-rated drywall construction is specified, the construction is sealed at both partition faces with a continuous bead of acoustical sealant at perimeters, control and expansion joints, openings, and penetrations. ASTM C919 and the manufacturer’s recommendations are complied with for edge trim locations, sound flanking path close-offs around or through construction, and sealing of partitions above acoustical ceilings.

14.2.2 Cost Estimating Procedures

14.2.2.1 Estimating Finish Area

The wall and ceiling surfaces to be covered with the gypsum board system are first identified and measured to establish the total surface area to be finished. Typically, the perimeter of the room times the maximum wall height can be used. No deductions are made from the measured surface area for openings, such as doors, windows, and duct vents that are less than 4 m^2. If inside or outside corners exist, allowances are made to price out these areas as well. Given the total surface area, categorize the panel quantities in terms of type, size, and thickness of board required for each area. As a result, a subcategory should exist for each separate type of wallboard panel to be installed, and the area of these subcategories should be known, with the total of these summing to the estimated finish area plus any allowances.

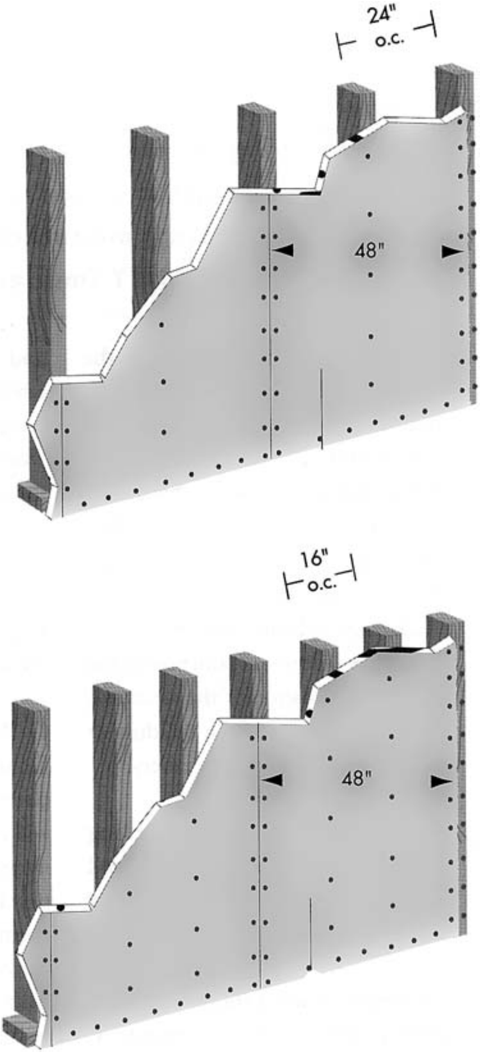


FIGURE 14.13 Vertical application of gypsum wallboard to wood-framed construction.

TABLE 14.7 Drywall Materials Prices (Austin, TX)

Type of gypsum panel	Thickness (mm)	Price/m^2
Regular—1.22 × 2.44 m	9	1.50
Regular—1.22 × 2.44 m	13	1.50
Regular—l.22 × 3.05 m	13	1.51
Regular—1.22 × 3.66 m	13	1.50
Fire rated (Fireguard)—1.22 m × 2.44 m	16	1.72
Fire rated (Fireguard)—1.22 m × 3.05 m	16	1.71
Fire rated (Fireguard)—1.22 m × 3.66 m	16	1.71
Moisture resistant—1.22 m 2.44 m	13	2.26
Fire rated moisture resistant—1.22 × 2.44 m	16	2.68
Fasteners		Price/unit (1 kg)
Nails		
Phosphate coated—35 mm		3.50
Electrogalvanized ring shank—38 mm		4.11
Smooth—50 mm		2.09
Screws		1000 pieces
#6 × 25 mm A		13.97
#6 × 41 mm A		15.97
Roll paper drywall tape		Price/roll
23 m		0.97
Joint tape (roll)		Price/roll
76 m	50.0	0.07
76 m	52.5	1.12
152 m	52.5	2.89
152 m	52.5	2.40
Joint compound		Price/container
13.2 L lightweight all purpose		4.15
13.2 L (3.5 gal.) midweight all purpose		4.65
8.2 kg lightweight setting type		5.48
Other accessories		Price/unit
Cornerbead—32 mm × 32 mm × 2.44 m		0.68
Regular galvanized cornerbead—32 mm × 32 mm × 2.44 m		38.55
Plastic cornerbead—32 mm × 32 mm × 2.44 m		1.14
Galvanized J-trim—16 mm × 3.05 m		1.39
Galvanized J-trim—13 mm × 3.05 m		1.36
Paper faced metal outside cornerbead—22 mm × 2.44 m		1.05

TABLE 14.8 US National Average Drywall Materials Prices

Type of gypsum panel	Thickness (mm)	Price/m^2
Backerboard—0.9 × 1.52 m	13	11.20
Backerboard—0.9 × 1.52 m	16	11.65
Regular—0.9 × 1.52 m	10	2.80
Regular—0.9 × 1.52 m	13	2.80
Regular—taped, finished (level 4)	13	3.23
Fire resistant, no finish included—0.9 × 1.52 m	13	2.69
Water/moisture resistant—0.9 × 1.52 m	13	3.44
Regular—0.9 × 1.52 m	16	3.12
Regular—taped, finished (level 4)	16	3.55
Fire resistant, no finish included—0.9 × 1.52 m	16	3.12
Water/moisture resistant—0.9 × 1.52 m	16	3.77
Core board—0.9 × 1.52 m (on columns)	25	7.45
Foil backed core board—0.9 × 1.52 m (on columns)	25	8.53
Other accessories		Price/m
Cornerbead, galvanized steel—32 × 32 mm		0.30
Vinyl cornerbead—32 × 32 mm		0.69
Galvanized J-trim—13 mm wide		0.39
Galvanized J-trim—16 mm wide		0.41
Galvanized L-trim		0.49
Galvanized U-trim		0.51

Source: Means' *Construction Metric Cost Data*, 2000.

14.2.2.2 Estimating Accessories Required

Given the known area for each type of board to be installed, accessories are estimated for each specified category. The fasteners, available in nails, screws, and staples, are estimated at 1 fastener per 0.09 m^2 (approximately 12 fasteners per m^2). Joint tape is estimated on the required class of the finish or approximately 1.4 m per m^2 of finished surface area. Likewise, joint compound is estimated at 0.28 L per m^2 where external corners are to be finished, or 0.21 L per m^2 where few external corners are to be finished. Alternatively, an estimate of 0.68 kg per m^2 of ready-mixed joint compound can be used. If a lightweight ready-mixed joint compound is used, the estimate is 0.39 L per m^2.

14.2.2.3 Support Systems

Studs, furring, and other support systems used in the installation process are estimated in accordance with specifications and expressed in linear meters. The total quantity of runner channels, studs, furring, and required fasteners needed to install the partition is determined by measuring the total length of each required, directly

TABLE 14.9 Drywall Installation Labor Cost[a]

Type of gypsum panel	Daily output (m^2)	Labor hours/m^2	Labor cost/m^2	Texas labor cost/m^2
Crew—2 carpenters				
Backerboard—0.9 m × 1.52 m × 12.7 mm	48.77	0.328	9.25	6.11
Backerboard—0.9 m × 1.52 m × 15.9 mm	48.77	0.328	9.25	6.11
Regular—0.9 m × 1.52 m × 10 mm	186.00	0.086	2.42	1.60
Regular—0.9 m × 1.52 m × 13 mm	186.00	0.086	2.42	1.60
Regular—Taped, finished (level 4)	89.65	0.178	5.00	3.30
Fire resistant, no finish included—0.9 × 1.52 m	186.00	0.086	2.42	1.60
Water / moisture resistant—0.9 × 1.52 m	186.00	0.086	2.42	1.60
Regular—0.9 m × 1.52 m × 16 mm	186.00	0.086	2.42	1.60
Regular—Taped, finished (level 4)	89.65	0.178	5.00	3.30
Fire resistant, no finish included—0.9 × 1.52 m	186.00	0.086	2.42	1.60
Water / moisture resistant—0.9 × 1.52 m	186.00	0.086	2.42	1.60
On columns				
Core board—0.9 m × 1.52 m × 25 mm	44.59	0.359	10.10	6.67
Foil backed core board—0.9 mm × 1.52 mm × 25mm	328.59	0.415	11.69	7.72
Other accessories				
Crew—1 carpenter:				
Cornerbead, galvanized steel—32 × 32 mm	88.39	0.091	2.55	1.68
Vinyl cornerbead—32 × 32 mm	91.44	0.087	2.46	1.62
Galvanized J-trim—12.9 mm wide	91.44	0.087	2.46	1.62
Galvanized J-trim—15.9 mm wide	89.92	0.089	2.50	1.65
Galvanized L-trim	91.44	0.087	2.46	1.62
Galvanized U-trim	89.92	0.089	2.50	1.65

[a] US and Austin, TX labor productivity, output and bare costs (Austin labor productivity factor = 66.0).

Source: Means, *Construction Metric Cost Data*, 2000.

Table 14.10 Waste Factors for Gypsum Wallboard Systems

Surveyed source	Min (%)	Max (%)	Avg. (%)
F.L. Crane & Sons Inc.	1	2	1.5
Live Oak Construction	1	—	1.0
Lone Star Interiors Inc.	—	5	5.0
Average waste factor			2.5

Source: Field survey conducted in Austin, Texas, Spring, 2001.

at the finishing location. An extra 0.3 m is allowed for each accessory miter or stop to allow for variations. Again, the thickness, gauge, and type of each material is used to categorize them, along with whether wood or metal support systems are to be used.

In estimating the materials to be used, typical waste factors in the range of 1 to 5% are used as multipliers in the preparation of the final finish quantities to be purchased. It is noted that the typical crew to install a gypsum board system consists of two skilled carpenters. Established waste factors, along with market labor rates and productivity factors based on the installation conditions and local material costs, are used to price the installed cost of the gypsum board systems. Tables 14.7 and 14.8 show drywall materials prices for Austin, Texas, and the US, respectively.

Table 14.9 illustrates US labor productivity and output rates to be used in cost estimating, as well as the labor costs per m^2 of installed wallboard. A labor cost relocation factor of 0.66 from Means (2000) was used to adjust the US average labor rates to that of Austin, Texas. Tables 14.10 and 14.11 show the

Table 14.11 Gypsum Wallboard Installation Productivity Loss Due to Changed Conditions in the Field

		Estimated % average surveyed field		
No.	Changed conditions	Minor	Moderate	Severe
1	Congestion: change prohibits use of optimum crew size including physically limited working space and material storage	8	17	22
2	Morale and attitude: change involves excessive inspection, multiple change orders and rework, schedule disruption, or poor site conditions	12	20	27
3	Labor reassignment: change demands rescheduling or expediting, and results in lost time to move out/in	7	15	20

TABLE 14.11 Continued

No.	Changed conditions	Estimated % average surveyed field		
		Minor	Moderate	Severe
4	Crew size change: change increases or decreases in optimum crew size results in inefficiency or work-flow disruption	7	15	20
5	Added operations: change disrupts ongoing work due to concurrent operations	4	13	18
6	Diverted supervision: change causes distraction of supervision to analyze and plan changed work, stop and replan ongoing work, or reschedule	10	14	19
7	Learning curve: change causes workers to lose time while becoming familiar with and adjusting to new work or new environment	13	18	23
8	Errors and omissions: change causes time loss due to mistakes engendered by changed circumstances	10	15	22
9	Beneficial occupancy: change requires the use of premises by owner prior to work completion, restricted work access, or working in close proximity to owner's personnel or equipment	12	17	23
10	Joint occupancy: change requires work to be done while other trades not anticipated in the bid occupy the same area	11	20	25
11	Site access: change requires physically inconvenient access to work area, inadequate workspace, remote materials storage, or poor man-lift management	10	14	19
12	Logistics: change involves unsatisfactory supply of materials by owner or general contractor, causing inability to control material procurement, and delivery and rehandling of substituted materials	12	17	22
13	Fatigue: change involves unusual physical exertion causing lost time when original plan resumes	7	12	17
14	Work sequence: change causes lost time due to changes in other contractors' work	3	9	12
15	Overtime: change requires overtime causing physical fatigue and poor mental attitude	13	17	23
16	Weather or environment: change involves work in very cold or hot weather, during high humidity, or in dusty or noisy environment	8	13	20

Source: Field survey conducted in Austin, Texas, Spring, 2001.

typical waste factors used in estimating the materials for gypsum wallboard construction, and the typical labor productivity factors as surveyed in Austin, Texas, during Spring 2001.

14.3 CERAMIC TILE WORK

14.3.1 Installation Procedures

Ceramic tile is used in many areas of a construction project, such as bathrooms, interior walls, exterior walls, on wood or concrete subfloors, and for other decorative purposes. Installation procedures are mainly the same, regardless of location or installation, but there are some important aspects that the installer or estimator must consider when tile is the type of finish that will be used in the chosen area.

14.3.1.1 Tile Installation on Floors

The most common type of floor installation is performed either on wood or concrete subfloors, the latter being the most common for commercial buildings. Before any type of installation takes place, floor construction requirements must be met in order to proceed with the installation process.

Concrete Subfloor. There are two methods that can be used when installing tile on concrete: thinset and Portland cement mortar. The most common materials used for installation on interior concrete are Portland cement mortar, latex-Portland cement and dry-set mortars, organic adhesives, and epoxy mortars and adhesives. When using Portland cement mortar, an isolated reinforced mortar setting bed with a cleavage membrane should always be used over a structural slab. The amount placed should not exceed 30 mm in thickness; the thin layer of neat cement should be in the range of 1 to 2 mm (for exterior concrete the coat thickness should be in the range of 6 to 10 mm). This layer should be troweled over the setting bed or on the back of the tile. In order to achieve maximum contact and strong bond, the tile should be tamped firmly into the mortar. After placing the tile, leveling and tamping must be completed within an hour. Sand Portland cement grout is typically used with quarry tile, pavers, and ceramic mosaic tile. Filling of the voids and gaps should be completed before the grout is thought to be set. This entire installation, including damping and curing (using Portland cement), should not take more than 72 hours.

Latex-Portland cement and dry-set mortars are commonly used for bonding tile to concrete, which has a variation of 6 mm in 3 m. Mortar should be troweled in a layer about 10 to 6 mm thick for quarry and paver tile, and 6 mm for mosaic. Tamping of the tile to the mortar is a must in order to achieve better bonding quality and to ensure a level surface. When using organic adhesives, the thickness of application should be 2 mm. A slab surface should be steel-troweled and fine-broomed, and the variation of the surface should be in the range of 2 mm in 9 m. The thickness of the installed layer should be in the range of 6 to 10 mm. Tamping into the setting bed is required as well. The installation should be shaded from sun exposure and kept at relatively even temperature for at least 8 hours after grouting.

Wood Subfloors. The most common installation procedures for wood subfloors consist of a reinforced mortar setting bed and a latex, dry-set, or neat cement bond coat over a cleavage membrane. Tile can be bonded to plywood as well, but it is recommended that organic adhesives be used when performing this type of installation. When Portland cement mortar is used, the installation procedure for installing tile on wood is the same as for concrete, although the mortar bed should have a thickness of 25 to 35 mm. For organic adhesives, the subfloor can be 25 mm nominal boards or 16 mm plywood; the underlayment should be 10 mm or thicker plywood, and finally, for epoxy mortars and adhesives, the subfloor should have a thickness of 16 mm plywood or 25 mm nominal boards. The underlayment should be 13 mm or thicker plywood. Gaps of 6 mm should be installed in the underlayment between the panels; these gaps must also be filled with epoxy mortar. The grouting procedure should be delayed for at least 16 hours. Again, the installation should be shaded from direct exposure to the sun, and a suitable temperature for installation is required for at least 8 hours after installation has taken place.

14.3.1.2 Tile Installation on Walls

The thinset method requires that the wall surface should not vary more than 3 mm in 2.5 m. On the other hand, when the wall surface is irregular, cracked, and so on, a mortar setting bed must be used over a base coat of mortar applied to metal lath over a cleavage membrane. Moreover, the wall surface cannot vary more than 6 mm in 2.5 m when mortar beds are being used (Simmons, 2001).

Interior Surfaces. Portland cement mortar, dry-set and latex-Portland cement mortars, and organic adhesives can be used as bonding materials. There are two methods of using Portland cement mortar: the “one-coat method,” where the thickness of the coat is normally between 10 and 19 mm, and the “two-coat method,” where total mortar thickness should not exceed 38 mm on wood studs, and be no more than 25 mm on metal studs. Two important recommendations are to let the scratch coat cure for at least 24 hours before the mortar bed is applied, and apply tile when the mortar is still plastic. The bond coat is used either in the one- or two-coat method. The grout could be neat Portland cement, or combined with sand, latex, or epoxy. Another important recommendation is that the finished job be cured for at least 72 hours when Portland cement grout or Portland cement is used.

Dry-Set and Latex-Portland Cement Mortars. In order to have a perfect installation, the mortar should be troweled on until a thickness of 2 to 6 mm maximum is ensured, and the tile must be installed before the mortar begins to dry out. When applying organic adhesives over relatively smooth surfaces, the maximum variation should be in the range of 3 mm in 2.5 m. There are two types of adhesives, Type I and Type II. Type I is used in areas where water resistance is required, and Type II where the area is subject to occasional wetting. Before grouting, it is necessary to wait at least 24 hours to allow solvent evaporation from the adhesive.

Exterior Surfaces. Setting tile on exterior surfaces requires more care due to temperature variation and exposure to moisture. It is necessary to use proper metal reinforcement in concrete and masonry. Exterior tile can be put in place with either the thinset method or conventional mortar bed.

Portland Cement Mortar Bed. The procedure for setting tile on exterior walls using cement mortar bed is similar to that in interior walls. Metal lath should also be used on exterior walls, and it has to be cut at the expansion joints in order for the tile to set correctly. The mortar bed should be cured for at least

24 hours, but a longer period (up to 10 days) is highly recommended when a dry-set or latex-Portland cement mortar is used (Simmons 2001). Finally, the recommended grouts for exterior walls are commercial cements and dry-cure.

Thinset Installation. The most important factor in this method is to use waterproof backings such as monolithic concrete, concrete and brick masonry, structural clay tile, and cured Portland cement mortar bed. The most common types of bonding material used to set tile are latex-Portland cement and dry-set mortar. After grouting with either latex or dry-set grout, the finish should be damp-cured for at least 72 hours.

14.3.2 Estimating Procedures

The area where tile is to be set can be measured in m^2, and the estimator should deduct areas such as door and window openings. The estimator should also take into consideration special tiles for trim, bullnose, surface bullnose, or base tile, which are measured in linear meters.

It is important to mention that the total price of setting tile will depend on the quality and the size of the tile (Walker, 1998). The total cost may be divided into five items: cost of ceramic tile delivered to the jobsite, costs of materials and accessories, cost of mixing and placing floor fill, and direct labor cost for tile installation.

In addition, when the quantity of tile has been estimated, a waste factor should be added. Finally, according to Means, the appropriate crew (D7) for setting tile is made up of one tile layer and one tile layer helper whose production rate depends on the type of tile to be installed. Table 14.12 shows the productivity rate for the crew mentioned.

14.3.3 Cost Trends

Table 14.13 shows the average cost trends in the United States for the past six years. This information was obtained from Means' *Building Construction Cost Data* (1996–2001). It is important to mention that ceramic tile cost varies greatly,

TABLE 14.12 Ceramic Tile Installation—Crew Productivity

Type of work	Crew	Daily output m^2
Walls interior 6 × 6 in.	D7	18.6
Walls exterior 4-1/4 × 4-1/4 in.	D7	9.5
Floors natural clay, random, or uniform thinset	D7	17

Source: Means, *Building Construction Cost Data*, 2001.

TABLE 14.13 Ceramic Tile Average US Cost Trends[a]

Tile description	1996 Mat ($)	1996 Labor ($)	1996 Total ($)	1997 Mat ($)	1997 Labor ($)	1997 Total ($)	1998 Mat ($)	1998 Labor ($)	1998 Total ($)
Walls interior 6 × 6 in.	24.10	19.48	43.58	24.75	19.80	44.55	25.29	20.23	45.51
Dry mortar			45.84			46.81			47.88
Portland mortar			57.03			58.21			59.50
Walls exterior 4-1/4 × 4-1/4 in.	37.66	38.31	75.97	38.95	38.95	77.90	39.70	39.70	79.41
Dry mortar			78.23			80.16			81.78
Portland mortar			89.42			91.35			93.40
Floors natural clay, random or uniform thin set	33.36	21.30	54.66	3.20	21.74	56.17	35.08	22.17	57.24
	1999			2000			2001		
Walls interior 6 × 6 in.	27.55	20.66	48.20	28.30	21.30	49.60	27.22	21.84	49.07
Dry mortar			50.57			52.08			51.54
Portland mortar			62.52			64.34			64.13
Walls exterior 4-1/4 × 4-1/4 in.	43.26	40.57	83.82	43.26	41.86	85.11	43.26	42.93	86.19
Dry mortar			86.19			87.59			88.66
Portland mortar			98.13			99.85			101.25
Floors natural clay, random or uniform thin set	38.20	22.60	60.79	38.20	23.35	61.55	38.95	23.89	62.84

[a] 1996–2001; square meters.

Source: Means, *Building Construction Cost Data*, 1996–2001.

Table 14.14 Ceramic Tile Waste Factors

Source	Waste factor (%)
Master Tile Company	10
Ceramic Tile International	5–7
Color Tile Company	5
Tileworks of Texas	5–8

Source: Tile companies (Austin, TX/2001).

since there are many types of tile and methods of installation. As one can see in Table 14.13, the ceramic tile costs are only for those specific tiles.

14.3.4 Waste Factor

When estimating ceramic tile quantities, the estimator must consider the appropriate waste factor. This depends on the shape of the surface where the tile is to be installed, the direction in which the tile is to be laid down, the design, the workmanship, and so on. The waste factors are shown in Table 14.14, which states a range of waste factors from 5 to 10%. The higher the percentage, the more complex is the installation.

14.3.5 Productivity Loss in the Field

The information regarding productivity loss shown in Table 14.15 was obtained from surveys that were distributed among local companies in the city of Austin, Texas, in April, 2001.

14.4 MARBLE AND STONE FLOORING

14.4.1 Description of the Finishing Operations

14.4.1.1 Introduction

There is a great variety of stones used for interior and exterior flooring, ranging from polished granite and marble to split-face slate and sandstone. Depending on the country they come from and their color and quality, the prices of the different types of stones vary to a great extent. For the purpose of standardization and clearer definition, the Marble Institute of America has classified all marbles and stones into four groups (Table 14.16).

14.4.1.2 Installation

Before starting the installation of marble or stone flooring, the material must be hauled to the jobsite. The distance between the mill and the place of installation

TABLE 14.15 Ceramic Tile Productivity Loss in the Field Due to Changed Conditions

		Estimated Percentage		
No.	Changed condition	Minor (%)	Moderate (%)	Severe (%)
1	Congestion: Change prohibits use of optimum crew size including physically limited working space material storage	25	50	100
2	Morale and attitude: change involves excessive inspection, multiple change orders and rework, schedule disruption, or poor site conditions	10	25	50
3	Labor reassignment: change demands rescheduling or expediting, and results in lost time to move out/in	10	20	50
4	Crew size change: Change increases or decreases in optimum crew size results in inefficiency or work flow disruption	0	15	25
5	Added operation: change disrupts ongoing work due to concurrent operations	15	30	60
6	Diverted supervision: change causes distraction of supervision to analyze and plan changed work, stop and replan ongoing work, or reschedule work	25	50	75
7	Learning curve: change causes workers to lose time while becoming familiar with and adjusting to new work or new enviroment	10	20	30
8	Errors and omissions: change causes time loss due to mistakes engendered by changed circumstances	10	30	80
9	Beneficial occupancy: change requires the use of premises by owner prior to work completion, restricted work access, or working in close proximity to owner's personnel or equipment	25	30	50
10	Joint occupancy: change requires work to be done while other trades not anticipated in the bid occupy the same area	25	40	50
11	Site access: change requires physically inconvenient access to work area, inadequate workspace, remote materials storage, or poor man-lift management	25	50	65
12	Logistics: change involves unsatisfactory supply of materials by owner or general contractor, causing inability to control materials procurement, and delivery and rehandling of substituted materials	20	30	40

Table 14.15 Continued

No.	Changed conditions	Estimated Percentage		
		Minor (%)	Moderate (%)	Severe (%)
13	Fatigue: change involves unusual physical exertion causing lost time when original plan resumes	20	40	50
14	Work sequence: change causes lost time due to changes in other contractors' work	10	20	50
15	Overtime: Change requires overtime causing physical fatigue and poor mental attitude	25	40	50
16	Weather or enviroment: change involves work in very cold or hot weather, during high humidity, or in dust or noisy enviroment	20	25	30

has a great effect on the cost, especially if the material is to be shipped from another country. Marbles and stones must be carefully packed and loaded for shipment using all reasonable precautions against damage. Upon arrival at the jobsite, special care must be taken regarding storage. In particular, wet or green wood, mud, oils, construction waste, and asphalt compounds may cause damage to the stored materials. According to the specifications of the National Building

TABLE 14.16 Marble and Stone Classification

Group	Characteristics	Varieties
Group A	The most favorable qualities of stones and marbles. They require no sticking, waxing, or filling because they have no natural faults. They are characteristically uniform.	Blanco P, Georgia, Italian White, Italian English Vein, Tennessee Gray and Pink, Vermont Black, Vermont White grades, Alabama—usual grades, Brocadillo
Group B	The most favorable qualities of stones and marbles. They require no sticking, waxing, or filling because they have no natural faults. They are characteristically uniform.	Belgian Black, Champville, Cremo Italian, Travertine (Italian), Imperial Black (Tennessee), Alabama Cream Veined A, etc.
Group C	Marbles and stones in this group have natural faults and it is common shop practice to repair them by sticking, waxing, and filling. They have an uncertain variation in working qualities.	Belgian Grand Antique, Botticino, Escalette, Red Verona, Red Levanto, Rosato, Verona Yellow, Westfield Green, Ozark Rouge, etc.
Group D	The worst quality of marbles and stones. They have the largest proportion of natural faults and the maximum variation in working qualities. They require the same type of repair as those in Group C.	Alps Green, Bleu Belge, Forest Green, Sienna, Verde Antico (Italian), Breche Oriental, Breche Rosora, etc.

Source: The Marble Institute of America.

Granite Quarries Association, the stones and marbles for installation "must be stacked on timber or platforms at least 8 cm above ground, to prevent staining during storage. If storage is to be for a prolonged period, polyethylene or other suitable plastic film shall be placed between any wood and finished surfaces, and shall be used also as an overall protective covering." In addition to storage, the hoisting of the material to the upper floors should also be taken into consideration.

The procedures for marble, granite, and other stone flooring installations are almost the same. The common method of installation is by placing the flooring over a cement bed. The cement bed is usually 60 to 75 mm thick, and composed of cement and sand.

First the mortar is prepared and carried to the working area. Then the marble or stone setter places the cement base on the floor and, after this, lays the marble tiles over it. In rooms like baths or kitchens, or for exterior flooring where slopes must be given to the floor, the marble setter must be very careful when installing the marble or stone tiles. Mistakes on the thickness of the cement bed may result in water stagnating on the floor.

Instead of mortar, in some cases, chemical products might be used for the installation, such as mastic or epoxies. Moreover, many companies today provide plenty of admixtures that improve the adhesion of the mortar. Epoxy grouts are the most common. In these cases, a thin grout layer of 10 to 20 mm is enough to provide the optimum adhesion (thinset application). Although wooden subfloors are not recommended for heavy use, when slate has to be installed over plywood for such a case, the plywood should be covered with felt and nailed on metal lath.

The easiest way to install marble and stone flooring is to purchase the material in tiles. However, for exterior flooring the stone material might come simply cut in slices, without uniformity in the pieces. In this case, some additional cutting work is needed in order to fit the pieces in the horizontal layer. Additional cutting work is also needed in curved bases or in bases with many corners. In general, the harder the stone material (e.g., granite or sandstone), the more difficult it is to cut it, and thus the higher the cost of installation.

Marble and stone floors need rubbing and smoothing before they can be used. Special equipment is used for this purpose, ranging from rubbing to sandblasting machines. Their productivity depends on the hardness of the material to be smoothed. Usually this type of equipment requires only one operator. Due to the fact that it is the general contractor's responsibility to maintain the floor properly until it is accepted by the owner, all reasonable precautions for this purpose must be taken. According to the specifications of the National Building Granite Quarries Association, "Boxing or other suitable protection shall be provided wherever required, but no lumber which may stain or deface the marble or stone flooring shall be used. All nails used shall be galvanized or non-rusting."

14.4.2 Cost Estimating Procedures

Before estimating the cost of marble and stone flooring, one should bear in mind that it takes almost the same time to install a small piece of marble (less than 30 cm long) as a larger one. The same is true for other stone materials such as granite, travertine, sandstone, and slate. For this reason it costs more to install small pieces than larger ones, and in general small pieces should be avoided when they are not necessary.

Depending on the size of the pieces to be installed, the units of quantity measurement vary. Table 14.17 gives the recommended units for quantity take off.

In order to come up with an accurate estimate, the cost estimator should

TABLE 14.17 Marble and Stone Flooring Quantity Take Off Units

	Unit of measure
Horizontal surfaces	square meter
Base under 30 cm high	linear meter
Base over 30 cm high	square meter
Die or wainscot	square meter
Stair treads	square meter
Stair risers	linear meter
Stone floor tile, regular size	square meter
Stone floor tile, small size	square meter
Circular base	linear meter
Circular die or wainscot	square meter

Source: Walker, *Building Estimator's Reference Book*.

use the following procedure. First he or she must estimate the cost of hauling the material to the jobsite. As mentioned before, this cost is a function of the distance between the mill and the project. It is advisable to consider the storage of the material, especially if there is not enough space near the place of installation, because in some cases this fact may add to the final cost. Moreover, if the material is to be stored for a prolonged period, the protective covering must also be taken into account. If the place where the material will be installed is not on the first floor, the subcontractor can use the hoisting equipment of the general contractor; thus the cost of hoisting the material is not usually reflected in the estimate. The material price is usually agreed upon between the general contractor and the mill, or the company that imports the specific type of stone or marble used. In some cases though, the companies that provide the material also provide the installation. In the first case the estimator must make clear whether the same company can also provide the transportation of the material, and in such a case to figure out what is of more interest to him. However, he also has to estimate the labor cost of the installation. In the second case things are simpler for the estimator, since these companies provide the cost per m^2 of installed stone or marble flooring.

In order to calculate the labor cost for marble or stone flooring the estimator should determine the proper crews to be used and their respective productivities. The size and thickness of the marbles or stones, as well as the shape of the place (rectangular or circular) where they are to be installed, greatly affect the productivity of the crews and, consequently, the labor cost. In addition, the cost of rubbing and smoothing the final surface should also be included in the labor

TABLE 14.18 Marble and Stone Flooring Material Cost Comparison

Material type	Austin, TX ($/m^2)	Walker ($/m^2)[a]	Means ($/m^2)[a]
Sandstone	21.5–43.0	N/A	N/A
Slate 13 mm thick or greater	43.0–64.5	41.7–55.6	44.5
Travertine	43.0–75.3	N/A	104
Marble tile 22 mm thick	129.0–215.2	94.4–235.6	72–94

[a] N/A = not available.
Source: Walker, *Building Estimator's Reference Book* 26th *edition* (1999), Means, *Metric Edition* (2000). The prices for the Austin area were taken from the Austin branch of the company Custom Stone Supply.

cost. If no measures have been taken for protection of the stone or marble flooring, a supplementary cost may occur for cleaning before the owner accepts the project.

14.4.3 Materials Cost

The cost of materials for marble and stone flooring per m^2 are summarized in Table 14.18, based on research in the Austin, Texas, area. This cost is also compared with the material cost from Walker's *Building Estimator's Reference Book*, and from Means. Table 14.19 provides the material cost per m^2 for marble tiles, as can be found in the Home Depot Stores. It should be mentioned that these tiles belong in the Groups *D* and *C*, according to the Marble Institute classification. The above prices give the estimator only a feeling for the material cost of marble and stone flooring. In order to come up with a more accurate estimate, the estimator must contact the local store where the material will come from and ask for prices for the specific types of marbles or stones to be installed.

TABLE 14.19 Marble Tiles Materials Cost per Square Meter

Marble tile name	Company providing the marble	Cost/m^2 ($)
Mexican Travertine	Austin Stone Works	52.18
Georgia Plack CA	Ointon Inc. LC	58.21
Cream Gray	Ointon Inc. LC	56.17
Oriental Green	Ointon Inc. LC	78.22
Mystic Brown Marble	Ointon Inc. LC	69.83
Majestic Black CA	Ointon Inc. LC	56.38
Sedona Marble CA	Ointon Inc. LC	58.31

Source: Home Depot in Northern Austin, TX, and Austin Stone Works.

The prices of marbles depend on their color. It is the common trend to prefer even colors, whereas colorful marbles are not usually requested. In addition, the prices of some colorful marbles might be extremely high due to scarcity (e.g., the pink marbles used in the pleasure craft of the former richest man in the world, Aristotle Onassis). The quality of the marbles as described in Table 14.16 also plays a major role in the materials price of marbles. The same is true for the hardness. The above-mentioned factors also affect the material prices of slate, travertine, and sandstone flooring.

As previously mentioned for thinset flooring, special bonding mortars are sometimes used instead of a cement base. Although these mortars come in plenty of colors and prices when used for tile flooring, this is not the case in natural stone flooring installation. Great variety does not exist and, in most cases, white bonding mortars are preferred. Most of these products come in bags of 22.7 kg, their working time after mixing is 2 hours, and they need 24 hours to set. The 22.7 kg sack of white marble and granite mortar mix costs $19.64 and can cover between 4.7 and 7.5 m^2, resulting in an average cost of $3.21 per m^2. Other brands such as Tile Perfect offer premixed thinsets in containers of 3.8 and 13.8 liters. The price of this product is $14.64 for the 3.8 liter container and $51.24 for the 13.8 liter container. It should be mentioned that premixed latex thinsets such as the above have increased bonding strength, are workable for about three quarters of an hour, and usually need 48 hours to set. The 3.8 liter container can cover an area between 1.8 and 2.8 m^2, and thus the average cost is $6.37 per m^2.

For thickset application, the cement bed under the marble or stone flooring consists of cement and sand, mixed rather dry. As mentioned before, an area of 3×3 m requires one and a half bags of Portland cement and 0.76 m^3 of water. This results in a cost of $4.24 per m^2.

TABLE 14.20 Marble and Stone Flooring Installation Labor Cost—Comparison

	Means ($/m^2)[a]	Walker ($/m^2)
Marble flooring, <1 cm thick	71	86.40
Marble flooring, >1 cm thick	N/A	116.64
Slate tile flooring	23.5	27.77

[a] N/A = not available.

Source: Walker, *Building Estimator's Reference Book* 26th *Edition* (1999) and Means, *Metric Edition* (2000).

14.4.4 Labor Cost

As mentioned before, the labor cost depends on the crew that performs the work, and on its productivity. The labor cost per m^2 for marble and stone flooring from Means 2000 and Walker's *Building Estimator's Reference Book* 1996 can be found in Table 14.20. Means assumes a crew of one tile setter and one helper (crew D-7), whereas Walker's *Building Estimator's Reference* assumes a crew of one marble or stone setter, one helper, and one laborer, and assigns some hours to a superintendent for supervision. Walker's *Building Estimator's Reference Book* breaks down the labor cost for marble and stone flooring in more detail. These labor cost categories are summarized in Table 14.21. In order for this table to be used, the estimator must have followed the quantity take-off recommendations provided in Table 14.18.

Labor cost also depends on the type of installation of the marble or stone flooring. In general, thickset installation is more expensive than thinset, at about \$13 per m^2. The pattern in which the stone or marble tiles are installed also affects the cost. As a rule of thumb, a diagonal pattern is more expensive than a square for about \$5.40 per m^2. Labor cost in the Austin area for marble flooring is sum-

TABLE 14.21 Average US Labor Cost for Marble and Slate Floor Installation[a]

Operation	Labor cost ($)
Interior marble floor setting, 22 or 31 mm thick	86 per m^2
Interior marble floor setting 50 mm thick	117 per m^2
Marble base setting in boundaries with many corners	
Marble base setting in reasonably long pieces	21 per m
Marble wainscot setting, up to 0.9 m high	81 per m
Marble wainscot cap setting	26 per m
Marble stair treads setting, 90 cm × 105 cm, 3.1 cm	25 per m
Marble stair treads setting, 90 cm × (120 to 180) cm, 3.1 cm	22 per m
Marble stair risers setting, 90 to 105 cm wide	25 per m
Marble stair risers setting, over 120 cm wide	22 per m
Marble stair wainscot on the rake, 90 to 105 cm high	25 per m
Marble thresholds, 90 to 105 cm long	30 per threshold
Marble columns bases setting, 23 to 38 cm square	63 per base
Marble tile setting, 15 × 15 cm to 30 × 30 cm	64 per m^2
Rubbing and surfacing soft marble	21 per m^2
Rubbing and surfacing hard marble	24 per m^2
State flooring, thinset, 15 × 15 cm to 30 × cm, interior	28 per m^2

[a] As of 1998.

TABLE 14.22 Cost of Installation for Marble and Stone Flooring

Flooring type	Labor cost $/m^2
Marble flooring thinset, square	48.42
Marble flooring thinset, diagonal	53.80
Marble flooring thickset, square	61.33
Marble flooring thickset, diagonal	66.71

Source: Austin Stone Works Inc.

marized in Table 14.22; the information was taken from the Austin Stone Works company.

14.4.5 Waste Factors for Materials

Average waste factors for marble and stone flooring are 3% for good quality stones, over surfaces surrounded by straight walls and installed by experienced marble or stone setters, and 6% for bad quality stones and surfaces defined by curved boundaries.

14.4.6 Labor Productivity in Man-Hours per m^2

When installing marble or stone flooring, the productivity of the crew performing the work depends on the following factors: the size and hardness of the material to be installed, the shape of the surface where it is to be installed (e.g., circular boundaries), surfaces defined by a perimeter with straight walls, or walls broken up with pilasters, piers, and the like, and on some other factors leading to productivity loss. Table 14.23 summarizes the productivities given by Means' *Building*

TABLE 14.23 Man-Hours per m^2 for Marble and Stone Flooring Installation

Flooring type	Man-hours/m^2
Marble, thin gauge tile, 305 × 152 mm, 10 mm (interior)	2.87
White Carrera Travertine thin gauge tile, 305 × 152,100 mm (interior)	2.87
Marble, 305 × 305 mm, 10 mm (interior)	2.87
Slate natural cleft, irregular 2 cm thick (exterior)	1.87
Slate, random rectangular, gauge 1 cm thick (exterior)	1.64
Slate, random rectangular, butt joint, gauged 6 mm thick (exterior)	1.15
Slate tile 152 × 152 mm, 6 mm (interior)	0.98

Source: Means, *Building Cost File* 2000.

TABLE 14.24 Marble and Slate Floor Installation—Man-Hours[a]

Operation	Man-hours
Interior marble floor setting, 22 or 31 mm thick	3.8/m^2
Interior marble floor setting, 50 mm thick	5.1/m^2
Marble base setting in boundaries with many corners	1.1/m
Marble base setting in reasonably long pieces	1/m
Marble wainscot setting, up to 0.9 m high	3.50/m^2
Marble wainscot cap setting	1.1/m
Marble stair treads setting, 90 × 105 cm, 3.1 cm	1/m
Marble stair treads setting, 90 × (120 to 180) cm	1/m
Marble stair risers setting, 90 to 105 cm wide	1/m
Marble stair risers setting, over 120 cm wide	1/m
Marble stair wainscot on the rake, 90 to 105 cm high	5.6/m
Marble thresholds, 90 to 105 cm long	0.8 ea
Marble columns bases setting, 23 to 38 cm square	0.4 ea
Marble tile setting, 15 × 15 cm to 30 × 30 cm	2.8/m^2
Rubbing and surfacing soft marble	0.8/m^2
Rubbing and surfacing hard marble	0.9/m^2

[a] Crew composition = 1 marble setter and 1 helper.
Source: Walker, *Building Estimator's Reference File*.

Cost File 2000 for a crew of one marble or stone setter and one helper. Table 14.24 also shows the productivities in man-hours per m^2 as calculated from the data in Walker's *Building Estimator's Reference File*.

14.4.7 Labor Productivity Loss in the Field

Labor productivity loss in the field for marble and stone flooring can be seen in Table 14.25. The Texas Stone and Tile Company, in Austin, Texas, provided the information, and it should be considered as a guide only.

14.5 TERRAZZO WORK

14.5.1 Introduction

Terrazzo has a long history. Because of its economical and durable characteristics, terrazzo is still widely used today as both an outdoor and indoor flooring finish. The National Terrazzo and Mosaic Association (NTMA) defines terrazzo as the following: "Terrazzo consists of marble, granite, onyx or glass chips in Portland cement, modified Portland cement or resinous matrix. The terrazzo is poured, cured, ground and polished. Typically used as a finish for floors, stairs or walls, terrazzo can be poured in place or pre-cast."

TABLE 14.25 Marble and Stone Flooring Productivity Loss in the Field Due to Changed Conditions

		Estimated % Productivity Loss if change is . . . (0 to 100% in each column)		
No.	Changed condition	Minor	Moderate	Severe
1	Congestion: change prohibits use of optimum crew size including physically limited working space and material storage	8	16–24	40
2	Morale and attitude: change involves excessive inspection, multiple change orders, or poor site conditions	10	15	20
3	Labor reassignment: change demands rescheduling or expediting, and results in lost time to move out/in	5	20	30
4	Crew size change: change increases or decreases in optimum crew size results in inefficiency or workflow disruption	10	30	50
5	Added operations: change disrupts ongoing work due to concurrent operations	10	25	40
6	Diverted supervision: change causes distraction of supervision to analyzed and plan changed work, stop and replan ongoing work, or reschedule work	5	15	25
7	Learning curve: change causes workers to lose time while becoming familiar with and adjusting to new work or new environment	30	40	50
8	Errors and omissions: change causes time loss due to mistakes engendered by change circumstances	10	20	30
9	Beneficial occupancy: change requires the use of premises by owner prior to work completion, restricted work access, or working in close proximity to owner's personnel or equipment	0	20	40
10	Joint occupancy: change requires work to be done while other trades not anticipated in the bid occupy the same area	20	40	60
11	Site access: change requires physically inconvenient access to work area, inadequate workspace, remote materials storage, or poor man-lift management	35	25	10
12	Logistics: change involves unsatisfactory supply of materials by owner or general contractor, causing inability to control material procurement, and delivery and rehandling of substituted materials	N/A	N/A	N/A

Table 14.25 Continued

No.	Changed condition	Estimated % Productivity Loss if change is . . . (0 to 100% in each column)		
		Minor	Moderate	Severe
13	Fatigue: change involves unusual physical exertion causing lost time when original plan resumes	10	30	50
14	Work sequence: change causes lost time due to changes in other contractors' work	10–20	30–40	50–60
15	Overtime: change requires overtime causing fatigue and poor mental attitude	0	5	10
16	Weather or environment: Change involves work in very cold or hot weather, during high humidity, or in dusty or noisy environment	0	5	10

Source: Texas Stone and Tile, 2001.

14.5.1.1 Materials Used in Terrazzo

Portland cement is still the most common material used for terrazzo finishes. Natural Portland cement is less expensive and is widely used and accepted. When a vivid or light-colored matrix is essential to the color scheme, white Portland is more suitable than the natural. Type IA air-entraining Portland cement is recommended for exterior applications subject to freezing and thawing. Portland cement terrazzo requires an underbed over subfloors other than concrete.

Currently, synthetic binders available for terrazzo finishes include catalyst-cured resins and latex (emulsion) resins. Resinous binders possess most of the desirable properties of magnesite and Portland cement binders and have greater strength, chemical resistance, and abrasion resistance. In addition, the ability of resinous binders to bond with most subfloor materials and to be applied in very thin toppings makes them suitable for many installations where Portland cement cannot be used.

Decorative chips in terrazzo toppings play an important role for the look and the resistance performance of terrazzo flooring. Chips of various types and colors are quarried and carefully selected to avoid off-color or contaminated material. Normally, they consist of marble, which is capable of being ground and polished. Granite is extremely hard and weather resistant, and it is often used for heavy-duty industrial and rustic terrazzo.

Pigments can be added to the binder in the terrazzo topping to cover the natural color of the binder and produce a wide variety of colors. To avoid contamination, pigments should be stable, nonfading mineral or synthetic formulations compatible with the binder.

Accessories for terrazzo installations include divider strips, expansion strips, and baseboards. Half-hard brass or white alloy zinc (approximately 99% zinc) is commonly used as metal strips. Stainless steel strips are produced for use in exterior terrazzo; aluminum strips are used primarily for resinous terrazzo.

14.5.1.2 Installation Methods

Two methods are used in laying terrazzo floors: unbonded and bonded installation, the latter of which is categorized by whether it is bonded to the subfloor/underbed.

Unbonded Installation. Since the terrazzo is isolated from the subfloor/underbed by using this method, the possibility of surface cracking is minimized. This method is suitable over any tight, structurally sound subfloor, and should always be considered because it is most effective in reducing cracking. Unbonded installation requires the use of a reinforced underbed to support the topping. Separation between subfloor and underbed can be provided by an isolation membrane alone, or by a membrane spread over a layer of sand.

Bonded Installation. The chief advantages of bonded installation are smaller dead load and a thinner finish. Most bonded methods allow the topping to be placed directly over the subfloor without an intervening underbed. However, these methods do not generally develop the degree of crack control obtained when an underbed is used with conventional divider strips. Therefore, the bonded underbed method is often used if the greater dead load and thickness can be accommodated.

The general process of terrazzo installation includes subfloor preparation, underbed placement, strip placement, and topping installation. There are four steps involved in the terrazzo topping installation: mixing, placing the topping, preliminary finishing, and final finishing.

14.5.2 Cost Estimating Procedure

14.5.2.1 Scope of Cost Estimating of Terrazzo Flooring

Generally, terrazzo flooring begins after the subfloor is ready. The cost of materials, equipment, and laborers enters into the scope of cost estimating of terrazzo flooring. Allowances for carborundum stone for rubbing, wiring for electric power, depreciation on machines, use of hoist, cleaning up rubbish, freight and trucking of machines, and tools all need to be estimated.

The cost of terrazzo flooring is based on m^2. It can vary greatly due to many factors, such as the size of the job, the layout of the floor, the size of the rooms, the floor designs, strips of brass or other nonrusting material, and the method of installation.

14.5.2.2 Materials Cost

The underbed for terrazzo consists of one part Portland cement and four parts sharp screened sand. Its level should not be less than 13 mm or more than 19 mm below the finished floor. The terrazzo topping is cast directly onto the subfloor; there is no intervening underbed.

Brass strips or other nonrusting metals are used in practically all terrazzo floors and are measured by meters. The price for the different strips varies greatly: for example, divider strips, B&S gauge No.14, 32 mm deep, brass, cost $5.60/m; divider strips, B&S gauge No.14, 32 mm deep, zinc, cost $2.99/m; heavy top strips, 6 mm thick, 32 mm deep, zinc, cost $5.05/m; and heavy top strips, 6 mm thick, 32 mm deep, galvanized bottoms, brass, cost $8.50/m.

Topping and cleaning operations are measured in m^2. Materials for topping include Portland cement and decorative chips used in terrazzo flooring. The price of the chips plays an important role in the price of the topping. Cleaning materials cost is the cost for neutral liquid cleaner.

14.5.2.3 Labor Cost

Labor cost for terrazzo flooring represents 50% of the total cost of the flooring. It also varies with the size of the rooms, design of the floor, size of the squares or pattern requiring brass strips, and so on. Generally, the more complicated the pattern, or the smaller the spacing, the more metal strips are required and the higher the cost. Installing terrazzo flooring is time consuming, especially when rubbing the corners and small areas where a rubbing machine cannot reach.

Table 14.26 shows approximate quantities of various classes of terrazzo work that a crew of two terrazzo workers and three helpers should install per 8-hour day.

TABLE 14.26 Terrazzo Work Crew Output[a]

		Hrs./10 m^2	
Description: floor blocked	m^2/ 8-hr. day	Terrazzo workers	Helper
1.5 m squares	40	4.2	6.5
1.2 m squares	36	4.5	7
1.0 m squares	34	4.7	7
0.5 m squares	32	5.1	8
0.3 m squares	27	6	9
Border 300–600 mm wide	28	6	9

[a] Crew composition: 2 terrazzo setters and 3 helpers.

Table 14.27 Rental Cost for Mixer and Grinder for Terrazzo Floor Installation

	Hourly oper. cost ($)	Rent/ day ($)	Rent/ week ($)	Rent/ month ($)	Crew equip cost/day ($)
Grinder, concrete and terrazzo, electric, floor	1.81	76.5	230	690	60.50
Mixer, powered, mortar and concrete, gas					
6C.F. 18H.P.	3	58.5	175	525	59
10C.F. 25H.P.	4.2	50	160	480	65.60
616.F.	4.4	75	225	675	80.20

Source: Means' *Construction Cost Data*/59th annual edition, 2001.

14.5.2.4 Equipment Cost

Primarily, equipment used in terrazzo flooring includes a mortar mixer and grinder. Rental costs are shown in Table 14.27.

14.5.3 Materials Cost (/m²)

14.5.3.1 Materials Cost

In order to calculate the entire cost for a terrazzo flooring system, the estimator has to take off various terrazzo, as it comes in many different types, and the divider strips. The prices shown in Table 14.28 are for the different types of

Table 14.28 Terrazzo Flooring Total Cost

Description	Price/m² ($)
Cast-in-place bonded	
Gray, 4.45 cm thick, 1.59 cm topping Portland cement	22.04
White, 4.45 cm thick, 1.59 cm topping Portland cement	23.12
Add $10 per percent of area that is abrasive heavy-duty terrazzo	
Cast-in-place nonbonded	
Gray, 7.62 cm thick, 1.59 cm topping Portland cement, 0.64 cm sand	29.25
White, 7.62 cm thick, 1.59 cm topping Portland cement, 0.64 cm sand	32.15
Monolithic, 8.89 cm base, 1.22 to 1.52 m square topping panels	37.74
Thinset terrazzo	
0.64 to 1.27 cm chips	52.58
0.95 to 2.54 cm chips	58.60

TABLE 14.28 Continued

Description	Price/m^2 ($)
Nonslip thinset precast terrazo	
22.9 × 22.9 × 2.54 cm	215.05
30.5 × 30.5 × 2.54 cm	232.26
30.5 × 30.5 × 3.81 cm	243.01
45.7 × 45.7 × 3.81 cm	317.20
61.0 × 61.0 × 3.81 cm	408.60
Add for white cement	4.84
For Venetian type terrazzo	14.52
Conductive terrazzo industrial flooring	
Epoxy system	73.23
Polyacrylate system	59.03
Polyester system	20.75
Synthetic latex mastic system	51.08
Cast-in-place terrazzo wainscot	
30.5 × 30.5 cm, 2.54 cm thick, bonded to concrete or masonry	191.40
40.6 × 40.6 cm, 3.81 cm thick, bonded to concrete or masonry	237.63
45.7 × 45.7 cm, 3.81 cm thick, bonded to concrete or masonry	292.47
Precast terrazzo wainscot	
30.5 × 30.5 cm × 2.54 cm	380.65
40.6 × 40.6 cm × 3.81 cm	260.22
45.7 × 45.7 cm × 3.81 cm	286.02
Cast-in-place terrazzo curb and base	
Cover base, 15.2 cove type	4.23
Curb, 15.2 × 15.2 cm, polished top, 2 faces	12.37
Precast gray cement terrazo base	
15.2 cm high, straight	29.89
15.2 cm high, coved	37.40
20.3 cm high, straight	37.40
20.3 cm high, coved	41.01
Conductive terrazzo industrial base	
Epoxy system	73.23
Polyacrylate system	59.03
Polyester system	20.75
Synthetic latex mastic system	54.84
Divider strips	
14 gauge, 3.18 cm thick, zinc alloy	2.82
14 gauge, 3.18 cm thick, half hard brass	5.77
0.64 cm thick, 3.18 cm deep, zinc-white alloy	2.99
0.64 cm thick, 3.18 cm deep, half hard brass	5.18
Vinyl plastic	1.44

Source: www.get-a-quote.com.

terrazzo flooring, as well as the cost for material per m^2 for cast-in-place terrazzo bonded to the concrete underbed.

14.5.3.2 Trends in the Price of Terrazzo

Using the R.S. Means' *Construction Cost Data* books from the years 1991, 1996, and 2000, the price of terrazzo generally went up in each year, as can be seen in Table 14.29.

TABLE 14.29 US Terrazzo Flooring Cost Trend

Material	Unit	1991 Price ($)	1996 Price ($)	2000 Price ($)
Precast terrazzo base, 150 mm high, straight	m	19.69	22.97	27.50
Precast terrazzo base, 150 mm high, cove	m	23.62	26.25	29.50
Precast terrazzo base, 200 mm high, straight	m	21.65	26.25	25.50
Precast terrazzo base, 200 mm high, cove	m	25.59	29.53	39.50
Precast terrazzo floor tiles, nonslip, 25 mm thick, 300 × 300 mm	m^2	96.77	108.60	157.00
Precast terrazzo floor tiles, nonslip, 32 mm thick, 300 × 300 mm	m^2	107.53	120.43	180.00
Precast terrazzo floor tiles, nonslip, 32 mm thick, 406 × 406 mm	m^2	120.43	134.41	196.00
Precast terrazzo floor tiles, nonslip, 38 mm thick, 406 × 406 mm	m^2	145.16	162.37	179.00
Precast terrazzo wainscot, 305 × 305 × 25 mm tiles	m^2	96.77	86.02	54.00
Precast terrazzo wainscot, 406 × 406 × 38 mm tiles	m^2	145.16	107.53	126.00
Cast-in-place terrazzo base, 152 mm H, 16 ga. Zinc, cove	m	3.61	6.07	8.65
Cast-in-place terrazzo floor, bonded to concrete, 44 mm thick, gray cement	m^2	18.82	20.97	25.50
Cast-in-place terrazzo floor, bonded to concrete, 44 mm thick, white cement	m^2	21.51	23.66	29.00
Cast-in-place terrazzo floor, not bonded to concrete, 76 mm thick, gray cement	m^2	26.45	25.81	32.00
Cast-in-place terrazzo floor, not bonded to concrete, 76 mm thick, white cement	m^2	30.11	28.49	35.00
Cast-in-place terrazzo wainscot, bonded, 38 mm thick	m^2	29.57	18.82	29.00

Source: Means, *Construction Cost Data* 1991, 1996, 2000.

14.5.4 Labor Productivity

14.5.4.1 Labor Productivity (Man-Hours/m^2)

R.S. Means' *Construction Cost Data* provides the data in Table 14.30 for terrazzo flooring installation productivity. A typical terrazzo crew consists of 1 terrazzo worker, 1 terrazzo helper, 1 terrazzo grinder (electric), and 1 terrazzo mixer. One crew-day consists of $4 \times 8 = 32$ work hours. These productivity figures do not include the needed work hours for subfloor preparation, underlay, and strip placement. They include the activities involved with the topping only.

The productivity of terrazzo flooring may also vary with the size of the rooms, design of the floor, size of the squares or pattern requiring brass strips, and so on. The more complicated the pattern is, the lower the daily output.

14.5.4.2 Labor Productivity Loss in the Field

There are many factors that lead to labor productivity loss in the field, such as lack of material, rework, lack of equipment, lack of planning, poor workmanship, complex specification, interference, absenteeism, unclear instruction, and so on. Results from a survey conducted in Austin, Texas, in 2001 are shown in Table 14.31.

TABLE 14.30 Terrazzo Flooring Labor Productivity

09420 Precast terrazzo			Crew	Daily output	Labor (hrs)	Unit
900	3600	Stair tread and riser, single piece, straight minimum	2 Mstz	18.29	0.875	m
	3700	Maximum	2 Mstz	12.19	1.312	m
	3900	Curved tread and riser, minimum	2 Mstz	12.19	1.312	m
	4000	Maximum	2 Mstz	9.75	1.640	m
	4200	Stair stringers, notch, 25 mm thick	2 Mstz	7.62	2.100	m
	4300	50 mm thick	2 Mstz	6.71	2.386	m
	4500	Stair landings, structural, nonslip, 38 mm thick	2 Mstz	7.90	2.206	m^2
	4600	75 mm thick	2 Mstz	6.97	2.296	
	4800	Wainscot, 305 × 305 × 25 mm tiles	1 Mstz	1.11	7.176	
	4900	406 × 406 × 38 mm tiles		0.74	10.764	
09450 Cast-in-place terrazzo 406 mm						
100	10	Terrazo, cast-in-place cove base, 152 mm, 16 ga. zinc	1 Mstz	6.10	1.312	m

TABLE 14.30 Continued

09420 Precast terrazzo			Crew	Daily output	Labor (hrs)	Unit
	100	Curb, 152 mm high and 152 mm wide	1 Mstz	1.83	4.374	m
	300	Divider strip for floors, 14 ga., 32 mm deep, zinc	1 Mstz	114	0.070	m
	400	Brass	1 Mstz	114	0.070	m
	600	Heavy top strip 6 mm thick, 32 mm deep, zinc	1 Mstz	91.44	0.087	m
	900	Galv., bottoms, brass	1 Mstz	91.44	0.087	m
	1200	For thinset floors, 16 ga., 13 × 13 mm, zinc	1 Mstz	107	0.075	m
	1300	Brass	1 Mstz	107	0.075	m
	1500	Floor, bonded to concrete, 44 mm thick, gray cement	J-3	12.08	1.325	m^2
	1600	White cement, mud set	J-3	12.08	1.325	m^2
	1800	Not bonded, 76 mm total thick, gray cement	J-3	10.68	1.498	m^2
	1900	White cement, mud set	J-3	10.68	1.498	m^2
	2100	For Venetian terrazzo, 25 mm topping, add				
	2200	For heavy duty abrasive terrazzo, add				
	2400	Bonded conductive floor for hospitals	J-3	8.36	1.914	m^2
	2500	Epoxy terrazzo, 6 mm thick, minimum	J-3	9.29	1.722	m^2
	2550	Average	J-3	6.97	2.296	m^2
	2600	Maximum	J-3	5.57	2.870	m^2
	2700	Monolithic terrazzo, 13 mm thick	J-3			m^2
	2710	3048 mm panels	J-3	11.61	1.378	m^2
	3000	Stairs, cast-in-place, pan-filled treads	J-3	9.14	1.750	m
	3100	Treads and risers	J-3	4.27	3.750	m
	3300	For stair landings, add to floor prices	J-3			
	3400	Stair stringers and fascia	J-3	2.79	5.741	m^2
	3600	For abrasive metal nosings on stairs, add	J-3	45.72	0.350	m
	3700	For abrasive surface finish, add	J-3	55.74	0.287	m^2
	3900	For raised abrasive strips, add	J-3	45.72	0.350	m
	4000	Wainscot, bonded, 38 mm thick	J-3	2.79	5.741	m^2
	4200	Epoxy terrazzo, 6 mm thick	J-3	3.72	4.306	m^2
200	10	Tile or terrazzo base scratch coat only	1 Mstz	13.94	0.574	m^2
	500	Scratch and brown coat only		6.97	1.148	m^2

Source: Means, *Construction Cost Data*, 58th annual edition, 2000.

TABLE 14.31 Terrazzo Work Productivity Loss Due to Changed Conditions in the Field

No.	Changed condition	Estimated % productivity loss, if change is . . . (0 to 100% in each column)		
		Minor	Moderate	Severe
1	Congestion: change prohibits use of optimum crew size including physically limited working space and materials storage	10	40	90
2	Morale and atitude: change involves excessive inspection, multiple change orders and rework, schedule disruption, or poor site conditions	0	20	50
3	Labor reassignment: change demands rescheduling or expediting and results in lost time to move out/in	0	30	75
4	Crew size change: change increases or decreases in optimum crew size results in inefficiency or workflow disruption	20	60	90
5	Added operations: change disrupts ongoing work due to concurrent operations	0	20	50
6	Diverted supervision: change causes distraction of supervision to analyze and plan changed work, stop and replan ongoing work, or reschedule work	0	20	50
7	Learning curve: change causes workers to lose time while becoming familiar with and adjusting to new work or new environment	10	20	30
8	Errors and omissions: change causes time loss due to mistakes engendered by changed circumstances	0	40	80
9	Beneficial occupancy: change requires the use of premises by owner prior to work completion, restricted work access, or working in close proximity to owner's personnel or equipment	0	30	75
10	Joint occupancy: change requires work to be done while other trades not anticipated in the bid occupy the same area	0	20	90
11	Site access: change requires physically inconvenient access to work area, inadequate workspace, remote materials storage, or poor man-lift management	20	60	90

TABLE 14.31 Continued

No.	Changed condition	Estimated % productivity loss, if change is . . . (0 to 100% in each column) Minor	Moderate	Severe
12	Logistics: change involves unsatisfactory supply of materials by owner or general contractor, causing inabilty to control material procurement and delivery and rehandling of substituted materials	10	20	80
13	Fatigue: change involves unusual physical exertion causing lost time when original plan resumes	0	0	10
14	Work sequence: change causes lost time due to changes in other contractors' work	10	30	90
15	Overtime: change requires overtime causing physical fatigue and poor mental attitude	0	0	20
16	Weather or environment: change involves work in very cold or hot weather, during high humidity, or in dusty or noisy environment	0	0	10

Source: *Survey on Productivity Loss in Terrazzo Due to Changed Conditions*, April 2001.

14.6 ACOUSTICAL TREATMENT

14.6.1 Introduction

The purpose of this section is to give an overview of estimating procedures and techniques for commercial construction to be applied to acoustical treatment installation. The section contains all the important information related to acoustical treatment in commercial construction.

14.6.2 Installation Methods

A baffle is a standard acoustical wall panel of the back-mounted type that is finished on both faces and all edges. Baffles are either mounted or suspended by special hangers that are either built into or attached to the baffle. Installation difficulty can range from simple wall mounting to suspending baffles in large auditorium halls.

Acoustical wall panels include standard and custom spline-mounted, back-mounted, and metal panels. Acoustical wall panels mostly consist of a fabric or vinyl facing over mineral, glass, or wood fiberboard.

The first step in installation requires that a layout plan be prepared for spaces where acoustical ceilings will be installed to ensure coordination with lighting fixtures and other ceiling-mounted equipment and devices. Extra material in the amount of 2 or 3% of the total amount installed is often left at the site for repair or extra work (so-called building stock). Acoustical materials and suspension system components should be kept dry before and after use, and they should be allowed to acclimate to the surrounding temperature and humidity before installation. Acoustical ceiling components should not be installed until the building is weather-tight, glazing has been completed, exterior openings have been closed, and mechanical and electrical, fire suppression, and other work above the ceiling has been completed.

Furring should be installed properly to support the acoustical ceiling. It should be placed on lines and levels necessary to cause the acoustical materials to fit into the proper location. Width of the surface of wood furring varies depending on the type of furring. Closers should be installed at edges and openings. Bolts, screws, and other anchors are used for various fastening purposes. As far as furring spacing is concerned, minimum spacing is dictated by acoustical material thickness and size, and varies from manufacturer to manufacturer.

In the case of a hung-suspension system, the hangers should be attached to wood, concrete, or steel structure supports by connecting them directly or indirectly, depending on the type of structure. Direct connection to steel decks is not recommended due to a proven history of failures. Hangers should never be attached to pipes, conduits, ducts, or mechanical or electrical devices. Other components of a hung-suspension system include frames for grilles, registers, additional hangers, and main runners and cross furring members placed in proper location and tees.

Composition acoustical tiles are used in combination with a grid system. If required, tiles should be cut to fit around fixtures and accessories. Splines and other grid members should be placed into the kerfed edges of tiles. If no grid system is used, tiles should be held in place using fasteners, adhesives, or both, depending on the manufacturer's requirements. Lay-in panels should be placed into each opening of the exposed grid members. If necessary, panels should be cut neatly around the fixtures to fit properly. Linear metal ceiling strips should be placed into the supporting grid members according to the ceiling manufacturer's recommendations. Sound insulation blankets are installed close to sound-rated partitions. Acoustical sealant is applied to areas where light and sound leak, and air movement at the edge of acoustical ceilings is not acceptable.

Integrated ceilings are comprised of acoustical materials, a suspension system, outlets for air distribution, and electrical devices such as lights, and so on. System components for integrated ceilings are: acoustical materials, support system, air diffusion, lighting, acoustical performance, and fire suppression. Coordination of all these trades and/or crews is paramount to timely and cost-effective

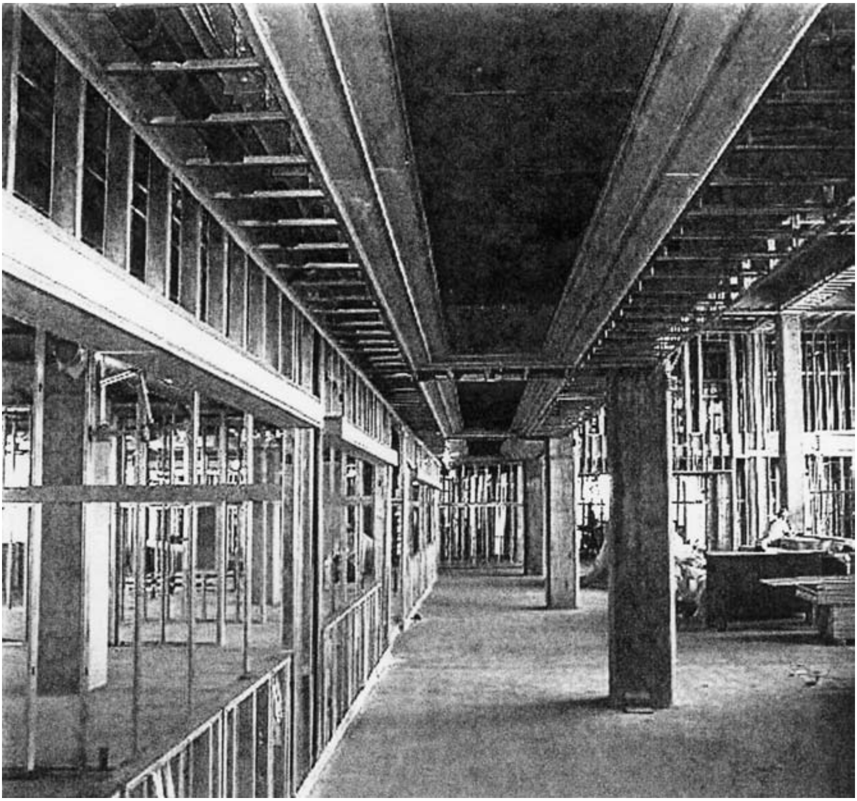


FIGURE 14.14 Concurrent drywall and integrated ceiling installation.

installation. Figure 14.14 shows a concurrent installation. A code of practice for sharing responsibilities can be obtained through the Ceilings and Interior Systems Construction Association (CISCA).

14.6.3 Cost Estimating Procedures

Baffles require little effort in estimating as they come in pieces. However, sizes may vary, and the acoustical contractor has to account for this when reading blueprints and specifications. Usually the estimator should not allow for waste. Only building stock is relevant for pricing the bids or quotes. Typically, one skilled carpenter installs wall-mounted baffles. For suspended baffles, a carpenter and a helper or larger crew sizes may be required, depending on the height of installation above ground.

Estimating wall panels follows the same rules as estimating gypsum drywall installation. However, due to higher material prices for high-performance wall panels, the installation may not allow for waste.

The ceiling to be covered with a suspended ceiling system is taken off from the blueprints by categorizing areas of installation and corresponding specifications. Typical installation areas in commercial construction are: conference and office rooms, hallways and corridors, and wet rooms such as restrooms and kitchens. No deductions should be made for area openings such as HVAC intakes/outlets, ducts, sockets, or lighting installation, if integrated into the ceiling tiles or boards. Lighting and openings usually come in the size of standard tiles so that they can be easily identified and subtracted. Standard sizes for ceiling tiles are 0.6 by 0.6 m and 0.6 by 1.2 m. Lighting and HVAC openings come in the same sizes. For identifying the amount of required building stock (overage), the estimator must read the specifications.

Suspension system components such as hangers, tees, and channels are to be planned and estimated by the acoustical contractor for standard ceilings. Hangers can be estimated at 1 hanger per 1.44 m^2. Tees follow the standard grid of the ceiling system. Larger channels may be installed depending on the static requirements imposed on the system by lighting and other heavier components.

TABLE 14.32 Acoustical Materials Cost Comparison

			2001 Bare cost ($)		
No.	Materials	Unit	Means	Walker	Austin
	Acoustical tiles				
1	Fiberglass	m^2	7.50	6.00	5.10
2	Mineral fiber, fine	m^2	12.00	12.00	4.00
3	Mineral fiber, rough	m^2	8.00	10.00	16.10
4	Luminous panels	m^2	17.00–35.00	35.00	24.20
5	Metal pan	m^2	17.00	22.00	37.70
	Complete suspended acoustical ceilings				
1	Fiberglass	m^2	12.00	12.00	8.30
2	Mineral fiber	m^2	19.00	18.00	6.70
3	Luminous panels	m^2	28.00	16.00	27.40
4	Metal pan	m^2	35.00	41.00	40.80
5	Tile	m^2	16.00	28.00	7.20
6	Channel carriers (add)	m^2	N/A	2.00	3.20
	Acoustical wall treatment (wall panels)				
1	Standard	m^2	72.00	N/A	N/A
2	High quality	m^2	10.00–215.00	N/A	N/A
	Acoustical baffles				
1	Sound-absorbing panels (hung)	m^2	80.00	N/A	86.00
2	Sound-absorbing panels (mount)	m^2	50.00	N/A	53.80

Table 14.33 Acoustical Materials Waste Factors

No.	Materials	Waste factor—estimated % material wasted
1	Acoustical wall panels—for every 1000 m^2	5
2	Ceiling tiles/panels—for every 1000 m^2	5
3	Ceiling grid—for every 100 m	2.5
4	Acoustical baffles—for every 1000 m^2	2.5

Estimating procedures for complex integrated ceilings require less effort on the ceiling contractor's side. The architect usually prepares a full set of specifications in collaboration with the integrated ceiling supplier. The ceiling contractor estimator usually corresponds with the supplier or architect in order to obtain quantities and price quotes. The estimating process, therefore, consists mainly of identifying the proper installation method (including tools and equipment) and the schedule constraints in order to quantify the level of labor and add markup (overhead and profit).

Crew sizes vary between one skilled carpenter to one carpenter and a helper. For more complex integrated ceilings, work in greater heights, or for increased productivity, larger crew sizes with more than one helper may be required. Typical material cost, productivity rates for one skilled carpenter, and loss factors can be found in Tables 14.32 and 14.33.

14.6.4 Materials Cost (USD/m^2)

The cost data given in Table 14.32 is comprised of data taken from Means (2000), Walker (2000), and from a local Austin acoustical materials supplier as of April, 2001.

14.6.5 Waste Factors

Waste factors for the major installation components in acoustical treatment construction are given in Table 14.33. The table provides only a guide to possible waste factors when estimating.

14.6.6 Labor Productivity (Man-Hours/m^2)

Productivity data given in Table 14.34 are taken from Means (2000) and Walker (2000). Productivity data for sound absorbing panels (baffles) are given only for simple mounted (wall, modular space units) or simple hung (low ceiling hung).

The labor cost per m^2 was calculated assuming a skilled carpenter's base rate of $31.26 per hour on an 8-hour working day (20-city average). For helpers,

Table 14.34 Labor Productivity Comparison for Acoustical Materials

No.	Materials	Crew size[a]	Unit	Daily output	
				Means	Walker
	Acoustical tiles				
1	Fiberglass	1 Carp	m^2	50.00	54.00
2	Mineral fiber, fine	1 Carp	m^2	50.00	54.00
3	Mineral fiber, rough	1 Carp	m^2	50.00	54.00
4	Luminous panels	1 Carp	m^2	38.00	54.00
5	Metal pan	1 Carp	m^2	38.00	54.00
	Complete suspended acoustical ceilings				
1	Fiberglass	1 Carp	m^2	40.00	45.00
2	Mineral fiber	1 Carp	m^2	30.00	45.00
3	Luminous panels	1 Carp	m^2	24.00	22.50
4	Metal pan	1 Carp	m^2	7.00	22.50
5	Tile	1 Carp	m^2	14.00	22.50
6	Channel carriers (add)	1 Carp	m^2	N/A	45.00
	Acoustical wall treatment (wall panels)				
1	Standard	1 Carp	m^2	30.00	N/A
2	High quality	1 Carp	m^2	30.00	N/A
	Acoustical baffles				
1	Sound-absorbing panels (hung)	1 Carp	m^2	10.00	N/A
2	Sound absorbing panels (mount)	1 Carp	m^2	20.00	N/A

[a] Carpenter average base rate $31.26/h.
Source: Means, 2000 and Walker, 2000.

a base rate of $24.78 per hour was used. City indices available from R.S. Means may be applied to account for local deviation in labor cost. This includes all benefits and insurance cost. The data were taken from the *Engineering News-Record* (2001) quarterly cost report.

14.6.7 Labor Productivity Loss in the Field

The data given in Table 14.35 are based on a survey (March, 2001, Austin, TX). The table provides only a guide to possible productivity losses in the field due to changed conditions.

14.7 FINISHED WOOD FLOORING

14.7.1 Introduction

Wood flooring is made from either hard woods or soft woods. Soft wood flooring, usually made from pine, fir, and the like, is commonly 100 and 150 mm wide. Hardwood flooring, usually made from oak, maple, birch, or beech, is manufac-

TABLE 14.35 Acoustical Materials Installation Productivity Loss in the Field Due to Changed Conditions

No.	Changed condition	Estimated % productivity loss		
		Minor	Moderate	Severe
1	Congestion	9	20	42
2	Morale and attitude	15	27	47
3	Labor reassignment	8	15	22
4	Crew size change	8	15	23
5	Added operations	8	17	28
6	Diverted supervision	11	19	31
7	Learning curve	13	23	33
8	Errors and omissions	12	22	35
9	Beneficial occupancy	13	27	45
10	Joint occupancy	18	33	45
11	Site access	11	21	34
12	Logistics	13	22	37
13	Fatigue	7	17	32
14	Work sequence	6	15	29
15	Overtime	17	16	22
16	Weather or environment	6	18	28

tured in a variety of thicknesses and widths. Oak is the most common wood flooring material. Maple is next in order of popularity because although it lacks the beauty of oak, it is harder. Beech and birch are similar to maple, but they are not as abundant. Pecan, walnut, cherry, hickory, and teak are scarce and expensive. According to the size of flooring boards, wood flooring is divided into three standard types, described as follows.

Strip Flooring. Strip flooring accounts for the majority of installations. Strips usually are 56 mm wide, but also come in widths ranging from 36 to 81 mm. They are installed in nail-down installation.

Plank Flooring. Plank flooring boards are at least 75 mm wide. They may be screwed or nailed to the subfloor. Screw holes can be covered with wooden plugs.

Parquet Flooring. Parquet flooring comes in standard patterns of 15 × 15 cm blocks. Specialty patterns may range up to 90 cm^2 units. Parquet often achieves dramatic geometric effects with special design patterns.

Flooring lumber is usually sawed in two ways: plain-sawed or quarter-sawed. Each way produces varying grain configurations. Once flooring lumber is sawed into boards, they should be evaluated and graded. The class of workmanship is graded according to the thickness, defects, appearance, and length distribution of wood flooring. As an example, oak flooring is classified into four classes of workmanship—Clear, Select, No.1 Common, and No.2 Common—according to the grading system of the National Oak Flooring Manufacture Association (NOFMA). Many grading systems currently exist, because different species of wood have their specific characteristics and many manufacturers establish their grading systems for their products. Table 14.36 lists the common grading systems for strip flooring. According to its manufacturing process, wood flooring is divided into the following types.

Unfinished Wood Flooring. Unfinished wood flooring comes from the manufacturer sawed, sized, and dressed, but not sanded and finished before its installation. Wood species commonly used for unfinished wood flooring in North America are oak, maple, and pine. Use of many species of wood from all corners of the world, such as Brazilian cherry, Australian cypress, and European oak, are on the increase for wood flooring in the US.

Prefinished Wood Flooring. Technology has allowed the wood flooring industry to supply customers with prefinished wood flooring, which is sanded and finished in the factory. Many years ago, it was available in limited species, thicknesses, and widths. Today, it can be offered in almost any species of wood and in a wide variety of thicknesses and widths.

Engineered Wood Flooring. Engineered wood flooring consists of multiple layers of wood laminated together. It is more stable and does not expand and contract as much as solid wood flooring because of the advantage of engineered lamination. The top layer of this flooring is finished and thick enough to be sanded several times if necessary. Most types of this flooring can be glued, nailed, or floated for proper installation. It is most commonly used in areas of high humidity.

14.7.1.1 Installation

In most cases, three approaches—nail down installation, glue down installation, and floating installation—are utilized to install wood flooring. They are briefly described as follows.

Nail-down installation includes the following steps.

1. Prepare the surface: Sweep the subfloor clean and nail its loose area; mark the position of joists on the surrounding walls; cover the asphalt felt or building paper.
2. Direction of finish flooring: The direction of finish flooring should be at right angles to the joists.
3. Lay the floor: Leave a gap between the wood flooring and the wall for

Table 14.36 Grading for Strip Flooring

Species	Size: Thickness (mm)	Width (mm)	First grade	Second grade	Third grade	Fourth grade
Softwood						
Douglas fir	20	56–130	B and better	C	D	—
Southern pine	8–33	45–138	B and better	C and better	D	—
Hardwood						
Oak	20	38–50	Clear	Select	No. 1 common	No. 2 common
Oak	9	38,50	Clear	Select	No. 1 common	No. 2 common
Oak	13	38,50	Clear	Select	No. 1 common	No. 2 common
Beech, birch	20	38–51	First grade	Second Grade	—	—
Maple	9	38,50	First grade	Second Grade	—	—
Pecan	13	38,50	First grade	Second Grade	—	—

Source: Sarviel, *Construction Estimating Reference Data*, 1981.

expansion purposes; make a straight alignment for the first course; lay the first strip along the straight line, tongue out, and drive 6d or 8d flooring nails or 25 mm casing nails from the grooved side.

4. Rack the floor: Lay out the strip flooring end to end in a staggered pattern, with end joists at least 15 cm apart.
5. Nail the floor: Blind nail through the tongue along the length of the strip; countersink all nails; continue to install across the room, ending up on the far wall with the same 20 mm expansion space; rip the strip to fit and face nail the last runs.
6. Nail to screeds: When nailing direct to screeds, nail at all screed intersections and to both screeds where a strip passes over a lapped screed joint.
7. Shoe molding: Nail this to the baseboard, not the flooring, after the entire floor is in place.

Glue-down installation includes these steps.

1. Mark the starting line: Measure out 62 mm for 56 mm products or 81 mm for 75 mm products; snap a straight chalk line.
2. Spread the adhesive: Spread sufficient amount of adhesive to achieve proper bonding to the subfloor.
3. Install flooring: Simply place the long tongue into the adjoining long groove as close as possible to the short adjoining end and adjust to the final position; the first row of planks should be installed with the end of the groove lined up on the chalk line; check for a tight fit between all edges and ends of each plank.
4. Shoe molding: Nail this to the baseboard, not the flooring, after the entire floor is in place.

Floating installation includes these steps.

1. Level the subfloor: The subfloor must be level to 3 mm in 250 cm; use approved level compound, roofing felt, and the like to fill low spots.
2. Roll out the required plastic moisture barrier, then 3 mm foam sheets.
3. Install flooring: Use expansion shims to maintain the required 13 mm expansion gap; start in the left-hand corner of the room; use a tapping block against the tongue when joining a flooring board; glue should be applied to the top inside edge of the groove.
4. Mark and cut the last row, allowing for the required 13 mm expansion gap.
5. Shoe molding: Nail this to the baseboard, not the flooring, after the entire floor is in place.

After installing wood flooring, sanding and finishing should be applied on unfinished wood flooring to enhance its appearance and protect its surface. The sanding process will remove dirt and minor scratches that occur during installation. These floorings are first sanded with a floor sanding machine, and then the edges are finished using a disc-type edging machine, which is capable of sanding up to the base shoe or quarter round. Sanding several times is necessary to produce a satisfactory job. The finishing process will enhance both grain and color and provide a protective layer to the floors. Finishing a wood floor involves applying a stain, if preferred, and a coating that protects the surface from moisture and spills (Fleming, 1997).

The final step to finish wood flooring is trims and molding. After the finishing process, some gaps and trips are still visible because expansion gaps at all walls are reserved, and the relative thickness of the product causes trips. Some type of molding, such as wall base, quarter-round, or shoe molding, is necessary to hide the visible gap. Trims, including such items as reducer strips, thresholds and stair nosings, are also required to eliminate those trips.

14.7.2 Cost Estimating Procedures

When estimating wood flooring, estimators should measure and calculate the total area of wood floors first. Based on the obtained total area, they can determine the quantity of material and labor required for installation, sanding, and finishing. Table 14.37 lists the cost per m^2 of fir, oak, and maple flooring, including sanding and finishing. To determine the amount of molding, the perimeter of each room where molding will be installed is measured. The total perimeter of all rooms less the length of openings is the amount of molding.

14.7.2.1 Materials Cost Estimating

Most of the various types of wood floors are measured on a m^2 basis. Moisture barriers and subfloors are also measured on a m^2 basis. Trims and molding are usually measured on a linear meter basis. Nails are estimated on a kilogram basis. If adhesive materials are to be quantified, they are estimated on a liter basis (Means, 2001).

Wood flooring can be installed over either a concrete slab or wood joist. When wood flooring is directly installed over a flat and trowel finish concrete slab, the excessive moisture existing in the concrete slab will be absorbed by the wood flooring and will cause cracking. To be certain normal slab moisture does not reach the finished floor, proper moisture barriers must be used on the top of the slab.

When wood flooring is installed over wood joists, the required materials are moisture barrier, subfloor, flooring board, nails, grit, finishing material, trims, and molding. Moisture barriers are usually used between subfloors and wood

Table 14.37 Strip Flooring Material and Installation Costs

Type of wood floor	Item	Cost ($/m^2)
Wood floor—fir: vertical grain, 25 × 102 mm, B & better	Material cost of flooring	25.00
	Labor cost of installaton	9.50
	Material cost of sanding and finishing	7.00
	Labor cost of sanding and finishing	4.50
Unit cost (bare cost) incl. sanding and finishing		48.00
Unit cost incl. subcontract's overhead and profit		59.90
Wood floor—oak: white or red, 20 × 56 mm, #1 common	Material cost of flooring	29.00
	Labor cost of installaton	14.25
	Material cost of sanding and finishing	7.00
	Labor cost of sanding and finishing	6.50
Unit cost (bare cost) incl. sanding and finishing		56.75
Unit cost incl. subcontract's overhead and profit		72.40
Wood floor—maple: 20 mm thick, #2 & better, on rubber sleepers, with two 13 mm subfloors	Material cost of flooring	48.50
	Labor cost of installaton	32.00
Unit cost (bare cost) incl. sanding and finishing		82.50
Unit cost incl. subcontract's overhead and profit		104.00

Source: Means, *Building Construction Cost Data*, 2001.

floors not only to act as good moisture barriers, but also to properly seat the finish floor nails, lessen squeaks, keep out insects and dust, and create a clean, suitable work area to install the new floor (Fleming, 1997). The most widely available moisture barriers are asphalt felt and building paper. Subfloors are made of either softwood or plywood. In addition to moisture barriers and subfloors, nails and adhesive materials are also required to fasten subfloors and process the installation of wood floors. Table 14.38 lists the required amount of nails when installing strip flooring and block flooring. Table 14.39 lists the required amount of adhesive materials when glue-down installation is used on block flooring. Ac-

Table 14.38 Nails for Strip Flooring and Block Flooring

Size (mm)	Nails Kg/10 m^2
Strip flooring	
20 × 38	1.81
20 × 50	1.47
20 × 56	1.47
20 × 81	1.12
9 × 38	1.81
9 × 50	1.47
13 × 38	1.81
13 × 50	1.47
Block flooring	
200 × 200	1.95
225 × 225	1.71
300 × 300	1.37

Source: Sarviel, *Construction Estimating Reference Data*, 1981.

cording to information from Means (2001) the material cost of trim 5 cm wide × 90 cm long, is $7.41 per linear meter. The material cost of reducer molding is $14.99 per linear meter.

Based on prices from Hardwood Floors Direct (Table 14.40), the price of quartered white or red oak natural is $126.68 per m^2. At the same thickness and face, the price of clear white or red oak natural is $84.74 per m^2. The difference in the cost between quarter-sawn and plain-sawn oak flooring is obviously large.

Table 14.39 Block Flooring—Adhesive

Size (mm)	Adhesive Liter/10 m^2
Block flooring	
200 × 200	4
225 × 225	4
300 × 300	4

Source: Sarviel, *Construction Estimating Reference Data*, 1981.

The thickness and width of wood flooring are also factors affecting flooring material cost. The thicker and wider flooring is more expensive.

If wood flooring is installed over a concrete slab and sleepers are used, asphalt primer must be used to prime the concrete slab. After that, cold or hot mastic is spread to settle the sleepers. The required materials are moisture barrier, adhesive materials, sleepers, nails, wood flooring, grit, finishing materials, and trims and molding. Asphalt primer, 0.5 to 1.0 liters per m^2, is approximately \$1.19 per liter. Hot mastic, 0.61 liters per m^2, is approximately \$0.93 per liter. Cold mastic, 0.98 to 1.23 liter per m^2, is approximately \$0.86 per liter. Forty to 45 m of sleepers, applied for an average-size room, are necessary for 10 m^2 of floor area (Sidens, 1999).

14.7.2.2 Waste Percentage of Flooring

When estimating the quantity of bundles of wood flooring required for any job, take the actual number of m^2 in any room or space to be floored and add waste as given in Table 14.41. When estimating the quantity of m^2 of wood flooring, take the actual number of m^2 in any room or space and add 5 to 6% for the waste of cuts and culls (inferior or useless pieces). If an area has a lot of angles or the material is to be laid on a diagonal, adding 10% or more for the waste is recommended (Fleming, 1997). Some manufacturers also provide users with their recommended waste factors to calculate the required amount of wood flooring. For instance, Hardwood Floors Direct suggests that customers add 10% on the single width flooring or add 15% on the multiple width flooring for waste. Wood Flooring America said, "When figuring waste to install wood flooring you would want to add 5 percent to the actual coverage (length × width of the room) needed unless the floor would be installed at a diagonal, add 10 percent or more."

14.7.2.3 Estimating Labor Cost

The types of trades people use for wood flooring installation are carpenters and floor layers. Table 14.42 shows the required labors of installing strip flooring. Table 14.43 shows the required man-hours for laying 10 m^2 of wood flooring according to building types, flooring types, and classes of workmanship. Table 14.44 is the list of labor bare cost of wood flooring based on Means' (2001) data.

If wood flooring is installed over a concrete slab, priming the concrete floor, spreading mastic, and placing wood sleepers must be completed before installation. Therefore, the labor cost of wood flooring contains the labor cost of the preceding operations plus installing wood flooring, sanding, finishing, and trims and molding. Under ordinary processes of laying wood flooring over concrete slabs, a floorlayer has to prime the concrete floor, spread mastic, and place wood sleepers at the rate of 9 m^2 per hour.

Most unfinished wood floorings need to be sanded and finished after their installation. The better classes of workmanship of wood flooring require more

TABLE 14.40 Wood Flooring Materials Cost Comparison (Three Distributors)

Source	Description	Actual Thickness (mm)	Actual Face	Price/m^2
Authentic Pine Floors Inc.	Colonial heart Pine	8	8cm–18cm	75.35–80.73
	Victorian heart pine	8	8cm–28cm	51.13–64.58
	Country heart pine	8	8cm–28cm	37.67–43.06
	Wide plank yellow pine	8	8cm–28cm	24.22–29.6
	Vertical grain (quarter-sawn)	8	8 cm	34.98
	C-grade SYP	8	8cm–28cm	26.91–29.6
Horris	(Red oak natural, oak bronze, white oak wheat) 3 in. plank	18	75 mm	46.17
	Oak (toffee, burnt umber, wheat, toast, wheat, sable), (white, red) oak natural	18	56 mm–76 mm	58.28
	Oak (heather, russet, wheat), red oak natural 3 in.	8	75 mm	55.08
	Oak (heather, russet, wheat, toast), red oak natural 2.25 in.	8	56 mm	57.09
	Red oak natural, white oak wheat 4 in. plank	18	100 mm	61.42
	Red oak natural, oak (amber, cinnamon, sable, wheat) 3 in.	12	75 mm	65.23
	Red oak natural, oak (amber, cinnamon, sable, wheat) 2.25 in.	12	56 mm	67.25
	(Red oak natural, white oak wheat, oak bronze) 2.25 in. strip	18	56 mm	76.22
	(Red oak natural, white oak wheat, oak bronze) 5 in. plank	18	125 mm	76.90
	Clear (white, red) oak natural	18	56 mm	84.74
	Quartered (white, red) oak natural	18	56 mm	126.68

	Lake forest walnut 3 in.	12	75 mm	65.23
	Walnut natural	12,18	125,56 mm	89,111
	Breckenridge Brazilian cherry natural	14	19 cm × 240 cm	74.42
	American cherry natural	12,18	56,125 mm	89,111
	Glen Ellen wheat ash	12–18	56–125 mm	55–84
	Beech natural	13	120 mm	72.96
	Maple	9–14	56 mm–76 mm	62–72
	Pecan burgundy 3 in.	9	76 mm	53–58
	Smoky Mountain Merbau natural	14	19 cm × 240 cm	68.76
Hardwood Floors Direct	Red oak, clear, quarter-sawn	18	56 mm–100 mm	44.1–53.8
	White oak, clear, quarter-sawn	18	56 mm–100 mm	44.1–53.6
	Red oak, clear, plain-sawn	18	56 mm–100 mm	35.5–42.5
	White oak, clear, plain-sawn	18	56 mm–100 mm	40.4–49.0
	Cherry, clear	18	56 mm–100 mm	47.3–57.0
	Hard maple, clear	18	56 mm–100 mm	42.5–51.6
	Birch, clear	18	56 mm–100 mm	36.6–44.7
	Soft maple, clear	18	56 mm–100 mm	36.6–41.4
	Sanding	add $1.62 per square meter		

Source: Authentic Pine Flooring Inc., Website, March, 2001; Horris Hardwood Flooring, Website, March, 2001; Hardwood Floors Direct, Website, March, 2001.

TABLE 14.41 Wood Flooring Installation Waste

Measured size (mm)	Finished size (mm)	No. pcs. in bundle	Add for Waste (%)
25 × 50	9.4 × 37.5	24	38.33
25 × 63	9.4 × 50.0	24	30
25 × 56	19.5 × 37.5	12	55
25 × 69	19.5 × 50.0	12	42.5
25 × 75	19.5 × 56.3	12	38.33
25 × 100	19.5 × 81.3	8	29

Source: NOFMA Website, March, 2001.

TABLE 14.42 Wood Strip Flooring Installation Productivity

Work element	Man-hours/ 10 m^2
Fir flooring (1.2 to 6.0 m long, 25 × 100 mm)	
C and better vertical grain	3.3
C and better flat grain	3.2
Oak flooring (20 × 56 mm)	
Clear quartered	3.8
Clear plain	3.9
Select plain	4.2
No.1 common	4.2
Prefinished prime grade	4.3
Maple flooring (20 × 56 mm)	
First grade	5.6
Second grade and better	5.4
Maple flooring (20 × 81 mm)	
First grade	4.1
Second grade and better	3.2
Pine flooring (20 × 56 mm)	
First grade	4.1
Second grade and better	3.8

Source: Sarviel, *Construction Estimating Reference Data*, 1981.

TABLE 14.43 Wood Flooring Productivity—Ordinary/First-Grade Workmanship

Description of work		m^2/ 8 hr	Carp. hours/ 10 m^2	Labor hours/ 10 m^2
Ordinary workmanship	20 × 81 mm face softwood floors for porches, kitchen, factories, stores, etc.	40	2.0	0.7
	20 × 56 mm face third-grade maple, for warehouse, factory, and loft building floors	36	2.2	0.7
	20 × 56 mm face oak or birch in residences, apartments, stores, offices, etc.	23–27	3.2	0.7
	21 × 56 mm face oak or birch in residences, apartments, stores, offices, etc. (laid by experienced floor-layer)	30	2.8	0.7
	20 × 38 mm face third grade maple for warehouse, factory, and loft building floors	28	2.6	0.8
	20 × 38 mm face oak or birch in residences, apartments, stores, offices, etc.	16	5.0	0.9
	21 × 38 mm face oak or birch in residences, apartments, stores, offices, etc. (laid by experienced floor-layer)	22	3.6	0.9
First-grade workmanship	20 × 56 mm face oak or birch in fine residences, apartments, stores, offices, etc.	19	4.2	0.7
	21 × 56 mm face oak or birch in fine residences, apartments, stores, offices, etc. (laid by experienced floor-layer)	22	3.7	0.7
	20 × 38 mm face oak or birch in fine residences, apartments, stores, offices, etc.	13	6.7	0.9
	21 × 38 mm face oak or birch in residences, apartments, stores, offices, etc. (laid by experienced floor-layer)	18	4.8	0.9

TABLE 14.44 Wood Flooring Labor Cost

Work element	Unit	Unit cost (bare cost) ($)
Wood block flooring		
End grain flooring, coated, 51 mm thick	m^2	8.50
Natural finish, 25 mm thick, fir	m^2	20.13
38 mm thick, pine	m^2	20.13
Wood strip flooring		
Fir, vertical grain 25 × 102 mm, not incl. finish, B and better	m^2	9.80
C grade and better	m^2	9.80
Maple flooring, over sleepers #2 and better		
20 mm thick	m^2	25.08
26 mm thick	m^2	25.62
For #1 grade maple, add	m^2	—
For 19 mm subfloor, add	m^2	7.21
With two 13 mm subfloors, 20 mm thick	m^2	36.28
Maple, incl. finish, #2 and better, 20 mm thick, on rubber		
Sleepers, with two 13 mm subfloors	m^2	33.05
With steel spline, double connection to channels	m^2	34.34
Portable hardwood, prefinished panels	m^2	30.25
Insulated with polystyrene, 25 mm thick, add	m^2	15.18
19 mm plywood surface, finished	m^2	25.08
Maple strip, 20 × 57 mm, not incl. finish, select	m^2	14.75
#2 and better	m^2	14.75
26 × 83 mm, not incl. finish, #1 grade	m^2	14.75
Oak, white or red, 20 × 56 mm, not incl. finish		
#1 common	m^2	14.75
Select quartered, 56 mm wide	m^2	14.75
Clear	m^2	14.75
Prefinished, white oak, prime grade, 57 mm wide	m^2	14.75
83 mm wide	m^2	13.56
Hardwood blocks, 229 × 229 mm, 20 mm thick	m^2	15.72
Parquetry, 8 mm thick, oak, minimum	m^2	15.72
Maximum	m^2	25.08
Sanding and finishing, 2 coats polyurethane	m^2	6.67
Transition molding, 57.1 mm wide, 1524 mm long	ea	12.75
Floating floor, wood composition strip, complete	m^2	14.75
Adhesive	m^2	—
Trim, 50 mm wide × 900 mm long	m	—
Reducer moulding	m	—

Source: Means, *Building Construction Cost Data*, 2001.

sanding to provide a higher-quality appearance. On the other hand, prefinished wood flooring can save some labor costs on sanding and finishing, but its materials costs are more expensive.

An ordinary grade of workmanship is frequently applied to average-size rooms in houses, apartments, offices, and the like. A good machine and operator should finish and edge 72 to 81 m^2 per 8-hour day. Applied to store rooms, auditoriums, and other large floor areas, a machine and operator should finish and edge 90 to 112.5 m^2 of new floor per 8-hour day. For those floors requiring first-grade workmanship, an experienced operator should finish and edge 36 to 45 m^2 per 8-hour day.

After the flooring is sanded, it is ready for the seal. An experienced worker can finish about 90 m^2 of natural finish floor per 8-hour day. If a colored seal is used, it will take more time, as the excess pigment must be removed by hand wiping (Sidens, 1999). According to the information in Means (2001), the labor bare cost for sanding and finishing with two coats of polyurethane is \$6.67 per m^2.

14.8 RESILIENT FLOORING

14.8.1 Introduction

Resilient flooring is normally used where economical, dense, nonabsorbent wear surfaces are required. Depending on the product, resilient floor finishes can provide a wide range of decorative effects, underfoot comfort, good durability, and relative ease of maintenance. Resilient flooring is manufactured in tile and sheet form from various ingredients, according to which they can be classified into (1) vinyl, (2) vinyl composition, (3) rubber, and (4) cork. The selection of a flooring product should be based on the intended use and the product's physical properties such as moisture, grease, and alkali resistance.

14.8.2 Installation Methods

14.8.2.1 Sheet Flooring Installation

Vinyl is the most common resilient flooring material in sheet form. When the installation of sheet materials is planned, the number and the total length of seams should be minimized. The procedure for sheet flooring installation can be divided into fitting and cutting, adhesive bonding, and seam treating.

For fitting and cutting, folding the strip back on itself, thus working only half of the strip at a time, facilitates spreading adhesive prior to bonding. In the tubing method, the strip is folded back along its length. In the lapping method, it is folded back along its width. Sheet flooring is mainly cut and fitted to walls and to each other by knifing, scribing, and seam cutting. After the end of a roll is squared, strips are cut 7.5 cm longer than the distance between end walls for wall recesses or irregularities. The first strip is placed in position with side edges and the ends of the material bent up against the end walls. The material is scribed along the length of the sidewalls with dividers or a scribing tool and cut to fit snugly to the wall surface.

Adhesive is spread with a notched trowel, spreader, or brush, depending on the type of adhesive. As each strip is pasted down, the seam should be smoothed with a hand roller, and the entire strip should be rolled with a heavy roller. For installations with tubing, adhesive is spread in the exposed area as each strip is tubed back. Seams must be cut before adhesive is spread in the seam area, which spreading occurs when the next tubed half is cemented down. For installations with lapping, the first strip is scribed to the sidewall, and starting at the center of the room, adhesive is spread under strips to within 90 cm of the end wall. The strips are cemented down and rolled. Each strip is end-scribed, and the remaining area is spread with adhesive, cemented down, and rolled.

With seam treating, when the vinyl sheet is cut, burrs made on the cut edges should be removed. After hand rolling the seams, these burred edges may be removed with the back of a linoleum knife moved in a chisel motion along the seam. Alternately, a hammerhead or scrap of flooring doubled in half may be rubbed along the burrs while the seam is kept damp to avoid scuffing.

14.8.2.2 Tile Flooring Installation

For tile flooring installation, the center of two opposite walls needs to be measured to divide the room in half, and another centerline perpendicular to the first line should be selected. These two lines can be used as reference lines as shown in Figure 14.15. A row of tiles needs to be laid down on both lines to the width and length of the room without using adhesive. Some adjustments can be made to increase the number of full tiles to be installed.

A tile should be laid from the center of the floor where two adjusted refer-

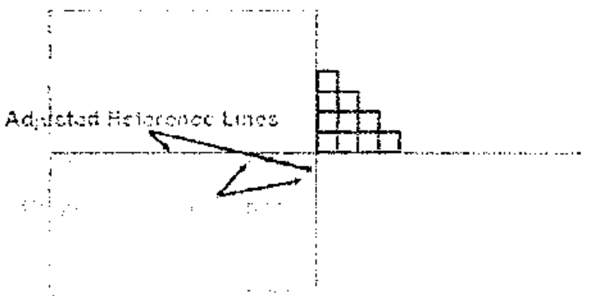


FIGURE 14.15 Reference lines as a guide for tile installation.

ence lines are crossed. These reference lines can be used as a guide as tiles are installed toward the walls in each quadrant. If tiles are not self-adhesive, vinyl flooring adhesive should be spread with the trowel's notched edge. After several rows of tile are installed, they should be bonded firmly to the floor by applying pressure and rolling over them with a floor roller or rolling pin. After all the whole tiles that will fit are laid, tiles for the perimeter of the room should be cut and adhered.

14.8.3 Cost Estimating Procedures

Vinyl sheet is available in 1.8 and 3.6 m wide rolls up to 36 m in length. Thickness normally ranges from 1.6 and 2.25 mm for noncushion-backed vinyl sheet. Material prices for vinyl sheet will vary from \$1.50 to \$3.00 per m^2 depending on the gauge and backing. Labor for vinyl sheet installation varies depending on the size and shape of the area to be covered and the number of cuts to be made. One worker lays about 54 m^2 in a large area per day, and about 31.5 m^2 in a smaller area per day.

Vinyl tile is furnished in 225 × 225, 300 × 300, and 450 × 900 mm sizes, and in 2 and 3 mm thicknesses. The material cost of vinyl tile ranges from \$8.33 per m^2 for marbleized patterns to \$33.33 per m^2 for translucent patterns, for 3 mm thick tiles. The 2 mm thick tiles cost about 15 to 20% less.

Rubber tile is furnished in 225 × 225, 300 × 300, and 450 × 900 mm sizes, 3 mm thick and in various colors. Rubber tile has lost its market to vinyl, but is still used as a stair tread covering. When laying lining felt over wood subfloors, an experienced worker should spread paste, lay, and roll 22.5 m^2 of felt per hour depending on the room size. Material prices of rubber floor tile for 3 mm thickness range from \$11.67 per m^2 to \$20 per m^2.

Asphalt tile is suitable for basement rooms because is not affected by moisture. It also can be used in residences, stores, and offices where a low-cost floor is desired. Asphalt tile is furnished in 225 × 225 mm size in 3 mm thicknesses.

Cork tile is furnished in 150 × 300, 225 × 225, and 300 × 300 mm sizes in 3, 5, and 8 mm thicknesses. The approximate m^2 prices of cork tile range from \$11.11 for 3 mm thicknesses to \$16.67 for 8 mm thicknesses. Materials cost for 9 m^2, 225 × 225 × 3 mm cork tile floors over wood flooring is shown in Table 14.45.

14.8.3.1 Materials Cost Estimate

The estimator needs to calculate the actual m^2 of area to be installed and add a percentage for waste. The selection of the waste factor is based on the material and the size of the area. Table 14.46 shows the approximate percentage of allowable waste for various room sizes. After the gross area has been determined, multiply it by the m^2 price of specified material.

Table 14.45 Cork Tile Flooring Material Cost ($/m²)

Material	Unit	Quantity	Average cost (2000)
Adhesive	1	0.31	0.71
Lining felt	m	1.10	0.42
Cork tile	m^2	1.05	11.10
Wax	1	0.05	0.045

When priming concrete floors is required, one liter of primer can cover 4.75 to 7.13 m^2 of surface depending on the porosity of the surface. It costs approximately $1.32 per liter. With one liter of asphalt cement, about 4.16 to 5.35 m^2 of asphalt tile over concrete floors can be installed. It costs about $3.17 per liter. One liter of asphalt emulsion for installing asphalt tile over lining felt on wood subfloors and directly on above-grade concrete floors can cover about 3.33 to 4.16 m^2. It costs approximately $1.32 per liter.

14.8.3.2 Labor Cost Estimate

The cost of laying vinyl tile varies with the size and shape of the room. A tile setter will lay more m^2 of tile in a large room and lay more m^2 of large size tile than of the smaller sizes. According to Means, a tile setter can install 46.45 m^2 of 305 × 305 mm vinyl tile per day. Labor cost per m^2 for vinyl tile installation is $4.73.

Labor cost for vinyl sheet installation varies, ranging from $4.73 per m^2 to $11.80 per m^2. One worker lays about 54 m^2 in a large area per day, and about 31.5 m^2 in a smaller area per day.

Table 14.46 Resilient Flooring Waste Factor

Area (m^2)	%
5	14
10	10
20–30	8
30–40	7
40–100	5
100–400	4
400–900	3
>900	2

TABLE 14.47 Rubber Tile Installation Productivity

Tile size (mm)	m^2/ 8-hr day	Crew hrs/ 10 m^2
225 × 225	37	2.4
300 × 300	28	1.8

The productivity of an experienced tile setter laying rubber tile is shown in Table 14.47. This table also shows that a worker can lay more m^2 of large size tile than of the smaller sizes. Labor cost for 225 × 225 × 3 mm cork tile floors over wood flooring is shown in Table 14.48. Total labor cost for 1 m^2 installation is about $18.

14.8.4 Resilient Flooring Total Cost Trend in the US

Prices for material and labor from 1996 to 2001 shown in Table 14.49 were obtained from Means. Selected resilient flooring materials include vinyl composition tile, vinyl sheet, cork tile, rubber sheet, and rubber tile. There has been a steady increase in labor cost for all resilient flooring materials. Rubber sheet has the highest labor cost, and vinyl tile has the lowest. The results also show that sheet installations mainly require higher labor cost than tile installations, because the rubber and vinyl sheets have higher labor costs than other tile materials.

14.8.5 Productivity, Waste, and Productivity Loss

14.8.5.1 Waste Factor

For figuring waste factors, three resilient flooring materials were surveyed and are shown in Table 14.50: vinyl tile, vinyl sheet, and rubber tile.

TABLE 14.48 Cork Tile Installation on Wood Flooring Cost/m^2

	Hrs/m^2	Labor rate ($)	Total ($)
Tile setter	3.8	27.45	104.40
Sanding 10 m^2 finishing floor	1.1	27.45	30.20
Clean and wax floor	2.2	27.45	60.40
Cost per m^2			19.50

Source: Means, 2000.

TABLE 14.49 Resilient Flooring Total Cost Trend in US[a]

Flooring type		1996 Mat.	1996 Labor	1996 Total	1997 Mat.	1997 Labor	1997 Total	1998 Mat.	1998 Labor	1998 Total
Vinyl tile	(305 × 305 mm, 2 mm thick)	9.90	4.31	14.21	10.23	4.41	14.64	10.44	4.52	14.96
Vinyl sheet	(2 mm thick)	23.57	10.76	34.34	24.22	11.09	35.31	24.76	11.19	35.95
Cork tile	(standard, 3 mm thick)	24.76	6.89	31.65	25.51	7.00	32.51	26.05	7.10	33.15
Rubber sheet	(914 mm wide, 3 mm thick)	30.89	17.98	48.87	31.75	18.41	50.16	32.40	18.73	51.13
Rubber tile	(305 × 305 mm, 3 mm thick)	30.89	5.38	36.27	31.97	5.49	37.46	32.61	5.60	38.21
		1999			**2000**			**2001**		
Vinyl tile	(305 × 305 mm, 2 mm thick)	10.44	4.63	15.07	10.44	4.74	15.18	10.76	4.84	15.61
Vinyl sheet	(2 mm thick)	24.76	11.52	36.27	24.97	11.84	36.81	27.02	12.16	39.18
Cork tile	(standard, 3 mm thick)	26.05	7.32	33.37	36.70	7.53	44.24	37.14	7.75	44.89
Rubber sheet	(914 mm wide, 3 mm thick)	32.40	19.16	51.56	33.26	19.70	52.96	34.23	20.24	54.47
Rubber tile	(305 × 305 mm, 3 mm thick)	32.61	5.70	38.32	37.67	5.92	43.59	38.32	6.03	44.35

[a] 1996–2001.

Source: Means, *Building Construction Cost Data* from 1996 to 2001.

TABLE 14.50 Resilient Flooring Waste Factors[a]

Material	Units	Minimum (%)	Average (%)	Maximum (%)
Vinyl tile	m^2	2	4	9
Vinyl sheet	m^2	1	4	9
Rubber tile	m^2	2	4	10

[a] Austin, TX survey.

14.8.5.2 Labor Productivity

Productivity data are based on one tile setter, and daily output and labor hours needed to install one m^2 of each material are shown in Table 14.51.

14.8.5.3 Productivity Loss Due to Changed Conditions

The survey results (April, 2001, Austin, Texas) are shown in Table 14.52.

14.9 CARPETS, UNDERLAY, AND TRIM

14.9.1 Carpet Installation

Carpet can be selected and specified broadly according to its type, which defines how it is made, by the fibers used to make it, and by its face construction.

TABLE 14.51 Resilient Flooring—Labor Productivity

Tile	Material	Crew	Daily output	Labor hours
Tile	Vinyl composition tile (305 × 305 mm, 2 mm thick)	1 tile setter	46.45 m^2	0.172 hr/m^2
	Cork tile (standard finish, 3 mm thick)	1 tile setter	29.26 m^2	0.273 hr/m^2
	Rubber tile (305 × 305 mm, 3 mm thick)	1 tile setter	37.16 m^2	0.215 hr/m^2
Sheet	Vinyl sheet (backed, 2 mm thick, maximum)	1 tile setter	46.45 m^2	0.172 hr/m^2
	Rubber sheet (914 mm wide, 3 mm thick)	1 tile setter	11.15 m^2	0.718 hr/m^2
Adhesive	Adhesive cement (3.75 L does 20–30 m^2, maximum)	1 tile setter	18.58 liter	0.431 hr/liter

Source: Means, *Building Construction Cost Data*, 2001.

TABLE 14.52 Resilient Flooring Productivity Loss in the Field Due to Changed Conditions

No.	Changed condition	Estimated % productivity loss Minor	Moderate	Severe
1	Congestion: change prohibits use of optimum crew size including physically limited working space and material storage	5.5	12.5	25
2	Morale and attitude: change involves excessive inspection, multiple change orders and rework, schedule disruption, or poor site conditions	4.5	10.5	21.5
3	Labor reassignment: change demands rescheduling or expediting and results in lost time to move out/in	4	12.5	25
4	Crew size change: change increases or decreases in optimum crew size results in inefficiency or work flow disruption	4.5	14	22.5
5	Added operations: change disrupts ongoing work due to concurrent operations	4.5	11	21.5
6	Diverted supervision: change causes distraction of supervision to analyze and plan changed work, stop and replan ongoing work, or reschedule work	4	12	20.5
7	Learning curve: change causes workers to lose time while becoming familiar with and adjusting to new work or environment	4	11.5	21.5
8	Errors and omissions: change causes time loss due to mistakes engendered by changed circumstances	3	11.5	16
9	Beneficial occupancy: change requires the use of premises by owner prior to work completion, restricted work access, or working in close proximity to owner's personnel or equipment	4.5	12	22
10	Joint occupancy: change requires work to be done while other trades not anticipated in the bid occupy the same area	7	20	32.5
11	Site access: change requires physically inconvenient access to work area, inadequate workspace, remote materials storage, or poor man-lift management	6	13	19.5
12	Logistics: change involves unsatisfactory supply of materials by owner or general contractor causing inability to control materials procurement, and delivery and rehandling of substituted materials	7	17.5	27.5
13	Fatigue: change involves unusual physical exertion causing lost time when original plan resumes	2.5	8.5	13.5

Table 14.52 Continued

No.	Changed condition	Estimated % productivity loss		
		Minor	Moderate	Severe
14	Work sequence: change causes lost time due to changes in other contractors' work	6	17.5	27.5
15	Overtime: change requires overtime causing physical fatigue and poor mental attitude	5	10	15
16	Weather or environment: change involves work in very cold or hot weather, during high humidity, or in dusty or noisy environment	7	16	27

14.9.1.1 Types of Carpet by Fibers

Fiber is carpet's basic ingredient. The type of fiber used and the way the carpet is constructed determine how well the carpet will stand up to spills, pets, and daily traffic. Approximately 97% of all carpet is produced using synthetic fibers that are designed to feature style, easy maintenance, and outstanding value. There are four basic types of carpet pile fibers, as shown in Table 14.53.

Nylon is the most popular fiber and represents two-thirds of the pile fibers used in the United States. Wear-resistant and resilient, it withstands the weight and movement of furniture and provides brilliant color. It also has the ability to conceal and resist soils and stains. Nylon is generally good for all traffic areas. Solution-dyed nylon is colorfast because color is added in the fiber production.

Olefin (polypropylene) is strong, resists wear and permanent stains, and is easily cleaned. It resists static electricity, and is often used in both indoor and outdoor installations because of its resistance to moisture and mildew. Olefin is

Table 14.53 Carpet Flooring by Type—US Market Share

Carpet fiber	Market share ($)
Nylon	59.40
Olefin	33.40
Polyester	6.80
Wool	0.40

Source: Carpet & Rug Institute.

also used in synthetic turf for sports surfaces, and in the home for patios and game rooms.

Polyester is noted for luxurious, soft “hand” when used in thick, cut-pile textures. It has excellent color clarity retention, is easily cleaned, and is resistant to water-soluble stains.

Acrylic offers the appearance and feel of wool without the cost. It has low static level and is moisture and mildew resistant. Acrylic is commonly used in velvet and level-loop constructions, and often in bath and scatter rugs.

Noted for its luxury and performance, wool is soft, has high bulk, and is available in many colors. Generally, wool is somewhat more expensive than synthetic fibers.

14.9.1.2 Installation Methods

Carpet that is not rubber-backed can be readily installed over a nailable surface by tacking the edges or by using tackless strips around the perimeter. Tackless strips consist of pieces of plywood the thickness of the padding and with two or three rows of metal pins that pass through the plywood at an angle and are designed to grip carpet when it is stretched over the pins. Regardless of the installation method, tacked or tackless carpet should be located, stretched sufficiently to eliminate wrinkles and buckles, and attached firmly with tacks or to strips.

In direct glue-down applications, carpet is glued to the substrate with no padding between them. Such carpet should be fit in place before adhesive is applied. The adhesive should then be applied uniformly to the substrate following the adhesive manufacturer’s instructions. Carpet edges should be butted tightly so that there are no gaps. The carpet should then be rolled lightly to ensure uniform bond to the substrates with no air pockets.

14.9.2 Cost Estimating Procedures

1. Determine the net m^2 of the area in the building that requires carpet by the type, and multiply by the waste factors to calculate total quantity of carpet in m^2 required.
2. Multiply the average price per m^2 shown by the m^2 required for the area to be carpeted.

Rooms of the exact same width as the carpet may require a little extra width for easier installation. Smaller or larger rooms will need trimming or piercing. This means some loss or extra cost, depending on the space and shapes involved. To determine the approximate quantity of carpet needed, the length of the room is multiplied by its width. Because there are room irregularities and

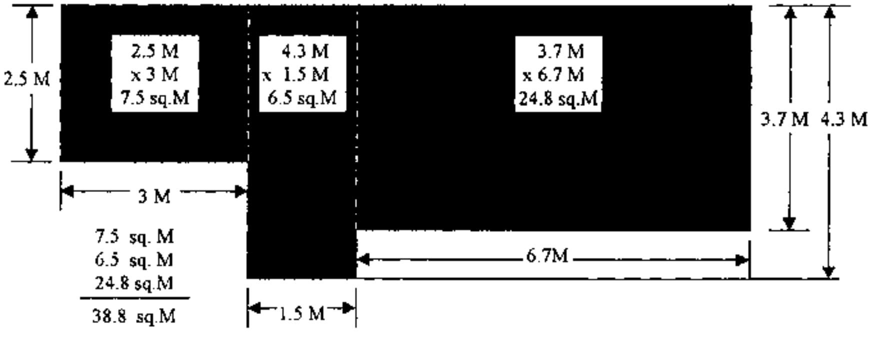


FIGURE 14.16 Example of estimating.

pattern match, the waste factor should be considered in estimating quantities. An example of how this is done is shown in Figure 14.16.

Padding is estimated the same way. In some instances, the price per m^2 quoted includes the padding and installation costs. In other cases those are additional costs. Stairs often cost slightly more than flat installations.

14.9.3 Materials Cost/ m^2

Among carpet materials, wool is the most expensive, with an average price of \$77.14 m^2. Olefin is the cheapest material at \$13.04/m^2. Table 14.54 shows the various costs. For tackless methods, it is necessary to add padding. Padding prices run from \$3.40 to \$6.21/m^2 as shown in Table 14.55.

14.9.4 Waste Factors for Materials

The waste factor, which should be considered in estimating, can be different due to the shape of the room. With regard to Table 14.56, there is a difference not

TABLE 14.54 Carpet Cost/m^2 Trend by Fiber Type

Fiber type	1998	1999	2000	2001
Nylon, level loop	23.50	23.50	23.85	25.69
Nylon, plush	26.98	26.98	26.85	29.25
Olefin	12.93	10.81	12.93	13.04
Wool, level loop	69.67	69.67	71	76.84
Wool, patterned	70.57	70.57	71.50	77.14

Source: Means data from 1998 to 2001.

TABLE 14.55 Padding Cost/m^2—US Trend

Pad type	1998	1999	2000	2001
Sponge rubber	5.45	5.62	5.71	6.21
Felt	4.72	4.87	4.76	5.47
Bonded urethane	5.05	5.14	5.24	5.63
Prime urethane	2.96	3.05	3.10	3.40

Source: Means data from 1998 to 2001.

TABLE 14.56 Carpet Flooring Installation Waste by Building Type

Building usage	Type of house/room	Low (%)	Medium (%)	High (%)
Residential	1 bed house	4.00	6.75	9.25
	2 bed house	4.25	6.75	9.25
	3 bed house	4.25	6.75	9.25
	Complex	4.50	6.75	8.75
Commercial	4 corner	4.50	6.75	9.00
	6 corner	4.50	6.75	9.00
	8 corner	4.50	6.75	9.25
	10 corner	4.50	6.75	9.25

TABLE 14.57 Productivity Man-Hours/m^2—Carpet Installation

	2001
Nylon, level loop	0.13
Nylon, plush	0.14
Olefin	0.13
Wool, level loop	0.13
Wool, plush	0.14
Padding	
Sponge rubber pad	0.063
Felt pad	0.063
Bonded urethane pad	0.063
Prime urethane pad	0.063
For stairs	0.319

Source: Means data (2001).

Table 14.58 Carpet Installation Productivity Loss in the Field Due to Changed Conditions

No.	Changed condition	Estimated % productivity loss if change is . . . (0–100% each column)		
		Minor	Moderate	Severe
1	Congestion: change prohibits use of optimum crew size including physically limited working space and materials	6	13.5	26
2	Morale and attitude: change involves excessive inspection, multiple change orders and rework, schedule disruption, or poor site conditions	6	13.5	26
3	Labor reassignment: change demands rescheduling or expediting, and results in lost time to move out/in	8.5	18.5	31
4	Crew size change: change increases or decreases in optimum crew results in inefficiency or workflow disruption	5	12.5	25
5	Added operations: change disrupts ongoing work due to concurrent operations	6	15	27.5
6	Diverted supervision: change causes distraction of supervision to analyze and plan changed work, stop and replan ongoing work, or reschedule work	5	12.5	25
7	Learning curve: change causes workers to lose time while becoming familiar with and adjusting to new work or new environment.	6	13.5	26
8	Errors and omissions: change causes time loss due to mistakes engendered by changed circumstances	12.5	20	32.5
9	Beneficial occupancy: change requires the use of premises by owner prior to work completion, restricted work access, or working in close proximity to owner's personnel or equipment	5	17.5	32.5
10	Joint occupancy: change requires work to be done while other trades not anticipated in the bid occupy the same area	10	27.5	37.5
11	Site access: change requires physically inconvenient access to work area, inadequate work space, remote materials storage, or poor man-lift management	11	21	31
12	Logistics: change involves unsatisfactory supply of materials by owner or general contractor, causing inability to control materials procurement, and delivery and rehandling of substituted materials	8.5	17.5	25

Table 14.58 Continued

No.	Changed condition	Estimated % productivity loss if change is . . . (0–100% each column) Minor	Moderate	Severe
13	Fatigue: change involves unusual physical exertion causing lost time when original plan resumes	5	12.5	25
14	Work sequence: change causes lost time due to changes in other contractors' work	6	20	32.5
15	Overtime: change requires overtime causing physical fatigue and poor mental attitude	7.5	15	23
16	Weather environment: change involves work in very cold or hot weather, during high humidity, or in dusty or noisy environment	6	15	30

Source: 2001 Survey Results, Austin, TX, 2001.

caused by type of building and number of rooms, but caused by the shape of the room shown as low, medium, and high in the table.

14.9.5 Labor Productivity Man-Hours/m^2

With regard to Table 14.57, productivity in terms of man-hours/m^2 does not change by the type of carpet, because the difference is too small to be considered for estimating. If padding is used, 0.063 man-hours/m^2 is added. There is no difference in productivity man-hours according to type of padding. For stairs, 0.319 man-hours/m^2 are added.

14.9.6 Labor Productivity Loss in the Field

Productivity loss results due to changed field conditions for carpet installation are shown in Table 14.58.

14.10 PAINTING AND DECORATING

14.10.1 Introduction

Most types of paints are described according to the type of binder. The most common are (1) solvent-based (oil or alkyd): in oil-based paints the liquid solvent is mineral spirits; they dry slower than latex, usually taking 24 hours to cure; and (2) water-based (latex): the liquid component is water; an advantage of latex paint is that it dries relatively fast, which may or may not be desirable in hot weather or direct sunshine (Lowe, 2001).

14.10.1.1 Primers

The painting process is divided into the application of two different materials, the primer and the finish coating. Primers are paint or transparent-finish materials designed and formulated for application over bare surfaces. They serve as the base for succeeding coats, helping them adhere to the surface and providing a more uniform appearance. Without priming, new wood, plaster, or drywall surfaces soak up more finish paint in some areas than in others. In addition to sealing the surfaces, good primers also cover different textures, such as the difference between drywall and joint compound.

Latex primers generally work best over drywall, plaster, and concrete surfaces. They dry fairly quickly (usually about an hour) and are water-soluble so they can be cleaned up with soap and water. Alkyd primers generally work best on raw wood. They take a fairly long time to dry (usually overnight) and require mineral spirits or paint thinner for cleanup.

14.10.1.2 Finish Coatings

Finish paints are categorized by the amount of surface shine they produce when dry. Terms like "gloss" and "flat" often dictate where such paints are used in the project, but their use does overlap in some areas.

Often referred to as "enamels," high-gloss paints are the shiniest and most reflective paints. They produce the hardest, most water-resistant, and most washable surface coating, so they are most often used on wood trim and kitchen, bath, and playroom walls, or where high traffic is expected. However, surface flaws show most when covered with high-gloss paint.

Also known as "eggshell," "velvet," or "satin" paints, semi-gloss paints produce a somewhat shiny surface that is more reflective than a flat paint but less reflective than a high-gloss surface. They resist moisture better than a flat paint, so they are more washable and serve well on walls in hallways, kitchens, baths, and children's bedrooms. For exterior painting, as with gloss paint, semi-gloss paint is suitable for trim work and casings. Satin paint, which usually has less sheen, is a good choice for siding that is in good condition.

Flat paints leave a "dull" or "matte" finish, with no gloss, shine, or reflectivity. They work best on irregular wall surfaces where you try to hide imperfections as much as possible. For interior surfaces, flat paint is most typically used on ceilings, living rooms, and dining rooms over drywall surfaces. Outdoors, the best uses are for vinyl and aluminum siding that is scratched or dented, since imperfections will be better hidden and the paint is easier to touch up.

14.10.1.3 Methods of Application

The most common methods of applying paint are by brush, roller, and spray. The choice of method is determined by different factors, which are mainly productivity and appearance. Of the three methods, brushing is the slowest and spraying is the fastest. This statement, however, may not apply to situations where adjacent areas are not to be covered, so these areas must be masked before application. If the time spent in masking preparations is extensive, the speed advantage of spraying may be offset (Walker, 1998). In general, roller coating is efficient on large flat surfaces. Corners, edges, and odd shapes generally require brushing. Spraying is especially suitable for large surfaces, and it can be used for round or irregular shapes. Brushing is ideal for small surfaces or for cutting in corners and edges.

In addition to productivity and efficiency, one must consider the final appearance of the paint. Coatings applied by brush may leave brush marks in the dried film; rolling leaves a stippled effect; spraying, if done properly, yields the smoothest finish. Other factors that can determine the method of application include environmental conditions, and the type of surface and coating.

14.10.1.4 Surface/Materials Preparation

Surface preparation prior to painting is essential to achieve maximum coating life. The best paint will not perform effectively if applied on a poorly prepared surface. In the same manner, proper materials preparation and handling prior to installation is necessary to avoid materials damage, explosion hazards, and application problems.

14.10.2 Cost Estimating Procedures

Since there are a great number of variables that have an impact on the cost of painting, forecasting the most probable cost becomes a challenging task. In order to achieve an accurate estimate, the following variables should be addressed: surface materials, surface shape, height, type of paint, method, labor productivity, materials prices, labor wages, burdens, equipment cost, location, overtime, weather, waste factors, coverage ratios, thickness of the coats, and so on.

Due to the variety of paints, surfaces, and painting procedures, the preferred estimating method is consulting standard cost databases such as Means' *Building Construction Cost Data* (RSM) or Walker's *Building Estimator's Reference Book* (WERB). These tables are constantly updated, cover the most common types of work, and are easy to access and to use. Figure 14.17 shows an estimate process and Table 14.59 shows some calculation methods.

The take offs, the total surface areas to be painted, are calculated from the

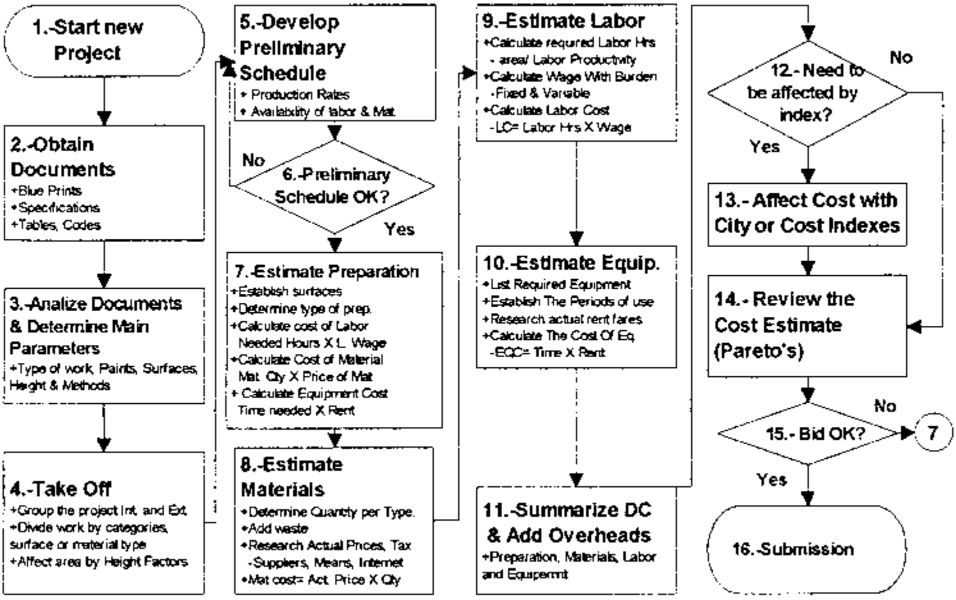


Figure 14.17 Painting cost estimate process. (Courtesy of Craftsman Book Company, Carlsbad, CA.)

blueprints. It is important to be as accurate as possible, since this is the major determinant of the direct cost. It is also important to approach the estimation with conservative numbers, using the methods outlined in Table 14.59, as well as considering unusual situations like high walls, where factors such as the ones outlined in Table 14.64 need to be incorporated.

The estimator needs to determine the preparation cost. Preparation is the preliminary work that is required before starting to paint (sanding, burning off paint, setup, cleanup, waterblasting, washing, taping, and sandblasting). Table 14.60 is a guide to production rates and the data from Table 14.61 are used to determine the preparation man-hours required.

For the next step, estimating materials, the estimator should assess the amount of paint required for each type of work and multiply it by the appropriate price. The amount of material depends on several variables, such as the coverage capacity of the paint (usually found on the container label), the surface, the waste factors, the mil thickness, the usage, the shape of the surface, and the skills of the painter. Although there are formulas that consider waste factors (see Table 14.67), mil thickness, and spread rates, the most practical way to estimate the

TABLE 14.59 Methods of Measuring Painting Quantities

Area	Surface	PA	Calculation
Ceilings	Plaster	Actual Area	1. Calculate actual area without deduction of openings less than (3 × 3 m)
	Wood	Actual Area	
Columns and pilasters	Fluted	Total Area*1.5	
	Paneled	Total Area*2	
Doors and frames		(W + 0.6 m)*(H + 0.3 m)	
Eaves	Different color side walls	Total Area*2	
	Over 9 m above ground	Add 1/2 (total area) for each 3 m	1. Obtain width of frame = W
	Over brick, stucco, or stone	Total area*3	2. Obtain height of frame = H
	Same color side walls	Total area*1.5	
	With rafter running through	Total area*3	
Floors		Actual area	
Walls	Brick, wood, stucco, cement, and stone	(TWS-OS)	
	Clapboard or drop siding walls	(TWS-OS)*1.1	1. Obtain total area of the wall and gables = TWS 2. Obtain the total area of the openings larger or equal to (3 × 3 m) = OS
	Plastered	TWS	1. Calculate actual area without deduction for doors and openings
	Shingle siding	(TWS-OS)*1.5	
Windows		(W + 0.6 m)*(H + 0.6 m)	1. Obtain width of frame = W 2. Obtain height of frame = H

Source: Gleason, *Estimating Painting Cost*, 1989.

Table 14.60 Painting Guide for Defining Production Rates

Man-hours			Material usage rates	
Slow	Medium	Fast	Heavy	Light
Good quality	Average quality	Minimum quality	Standard paint	Production paint
High difficulty	Average difficulty	Low difficulty	New construction	Repaint
Poor conditions	Average conditions	Good conditions	Heavy application	Light application
Small job	Medium size job	Large projects	Heavy coverage	Light coverage
Low production	Average product	High production	Heavy usage	Light usage
Unskilled painter	Semiskilled painter	Skilled crews	High waste factor	Low waste factor
			Unskilled painters	Skilled painters

Source: Gleason, *Estimating Painting Cost*, 1989.

TABLE 14.61 Painting Preparation Productivity m²/Man-Hour[a]

Description of work	Surface	Work rate (m^2/hr) Slow	Medium	Fast
Sanding, medium (before first coat)	Interior flatwall areas	25.5	27.9	30.2
	Interior enamel areas	23.2	25.5	27.9
Taping gypsum wall-board	Preparation bead, spot nail heads, sand	7.9	9.3	10.7
	Taping hand operation	11.6	13.9	16.3
Burning off paint	Exterior plain surfaces	3.3	4.2	5.1
	Interior plain surfaces	1.9	2.8	3.7
Sandblasting near white	Large surfaces			
	Tight mill scale, little or no rust	7.0	9.3	11.6
	Hard scale, blistered, rusty surface	4.6	7.0	9.3
	Pipe up to 12″ O/D	2.8	4.2	5.6
	Structural steel			
	Up to 2 SF/LF	3.7	5.1	6.5
	Steel from 2 to 5 SF/LF	4.2	5.6	7.0
	Steel over 5 SF/LF	5.1	6.5	7.9
	Tanks and vessels			
	Up to 12 ft OD	6.0	7.4	8.8
	Over 12 ft OD	6.5	7.9	9.3
Washing, interior	Walls	16.3	18.6	20.9
	Flat smooth			
	Flat rough	11.6	13.9	16.3
	Enamel	17.7	20.4	22.3
	Plaster smooth	13.9	16.3	18.6
	Plaster sand finish	10.2	12.5	14.9
Waterblasting	Concrete, block, brick, wood, or stucco surfaces	41.8	46.5	51.1
Wire brushing	Pipe up to 12 in. O/D	4.6	7.0	9.3
	Structural steel			
	Up to SF/LF	8.4	10.2	11.6
	Steel from 2 to 5 SF/LF	9.3	11.1	13.0
	Steel over 5 SF/LF	10.2	12.1	13.9
	Tanks and vessels			
	Up to 12 ft	10.2	12.1	13.9
	Over 12 ft	11.1	13.0	14.9

[a] MH = man-hours rate, S = slow, M = medium, F = fast, L = light.
Source: Gleason, *Estimating Painting Cost*, 1989.

amount of paint required is by using material coverage ratio tables that include the combination of all the named variables (see Tables 14.62 through 14.64).

The amount of paint is calculated by dividing the area (m^2) by the corresponding coverage ratio (m^2/liter). The calculated quantity of paint already includes the waste factors and the skill level of the painters (see Table 14.60). The materials cost is obtained by multiplying the amount of paint by the price of the paint (see Table 14.66). For further reference, Means provides tables that break down the bare cost of materials. Since the final consumer will pay sales tax, the tax should be added to the materials price.

Labor estimation depends on variables shown in Tables 14.60 and 14.61. Tables 14.62 and 14.63 provide production rates that incorporate most of the variables involved. Table 14.64 takes into account unusual situations where the height of the surface to be painted is higher than usual.

In addition, production rates can be affected by other factors such as the weather, overtime, and congestion (see Table 14.68). The man-hours required can be calculated by dividing the area (m^2) by the production rate (m^2/hr) from Tables 14.62 and 14.63.

The estimator needs to determine the equipment to be used, the length of time it will be needed, and the price of rental (see Table 14.65). The equipment rental rate can be per day, per week, or per month.

After the elements of the direct cost of painting (preparation, material, labor, and equipment) have been determined, the estimator gathers all the information in an estimate summary sheet (Figure 14.17). At this point, the estimator calculates the overhead and adds it to the direct cost.

14.10.3 Materials Cost

Paint material prices are shown in Table 14.66.

14.10.4 Waste Factors

Waste factors are the quantifiable way to account for imperfections during the application of paint. These waste factors are described as a percentage of the total amount of paint (expressed as volume) necessary to finish a job. The waste factor considered relates to the loss of paint based on the method of application. Table 14.67 shows the commonly assumed waste factors for the most prevalent painting methods. Painting waste factors also depend on other criteria, such as the surface where the paint is being applied, the paint manufacturer, the skill of the painter, and the weather.

14.10.5 Productivity Loss in the Field

Based on a survey conducted in Austin, Texas (2001), Table 14.68 indicates productivity deviations from normal conditions.

TABLE 14.62 Interior Painting Production Rate (PR) and Material Coverage Ratio (CR)[a,b]

			Interior painting														
			Brush					Roller					Spray				
			PR (m^2/hr)			CR (m^2/l)		PR (m^2/hr)			CR (m^2/l)		PR (m^2/hr)			CR (m^2/l)	
Description of work	Paint	Coat	S	M	F	H	L	S	M	F	H	L	S	M	F	H	L
Ceilings, drywall	Oil base	First	13.9	16.3	18.6	8.0	8.6	25.5	32.5	37.2	6.7	7.4	65.0	74.3	83.6	6.7	7.4
		Second	18.6	20.9	23.2	9.2	9.8	32.5	37.2	39.5	8.0	8.6	74.3	83.6	92.9	8.0	8.6
		Third	20.9	23.2	25.5	9.8	10.4	39.5	41.8	44.1	8.6	9.2	83.6	92.9	102.2	8.6	9.2
Doors, wood	Enamel	Undercoat	7.0	9.3	13.9	7.4	9.6	7.0	9.3	13.9	7.4	9.6	27.9	31.0	34.8	11.0	12.5
		First finish	8.4	11.1	16.4	8.1	10.3	8.4	11.1	16.4	8.1	10.3	34.8	34.8	39.8	11.8	13.3
		Add coat	11.1	8.0	19.9	8.8	11.0	11.1	8.0	19.9	8.8	11.0	39.8	46.5	46.5	12.5	14.0
Floors, concrete	Oil base	First	8.4	13.0	18.6	6.7	7.4	12.5	22.3	27.9	7.9	9.1	74.3	83.6	92.9	4.3	4.9
		Second	11.6	17.2	29.7	9.2	9.8	18.1	25.5	31.6	11.0	12.3	83.6	92.9	102.2	6.7	7.4
Floors, wood	Oil base	Prime	25.5	27.9	30.2	11.0	12.3	37.2	39.5	44.1	10.4	11.7	—	—	—	—	—
		Second	27.9	30.2	32.5	12.3	13.5	39.5	41.8	46.5	11.7	12.9	—	—	—	—	—
Siding, smooth wood	Oil base	First	9.3	11.6	13.9	8.0	9.8	9.3	11.6	13.9	7.4	8.6	37.2	46.5	55.7	3.2	4.2
		Second	12.5	15.3	18.6	9.2	11.0	16.3	23.2	30.2	8.6	9.8	51.1	67.4	83.6	6.0	7.4

Wall, gypsum, drywall flat	Oil base	First	16.3	18.6	20.9	8.0	8.6	27.9	46.5	67.4	6.7	7.4	69.7	79.0	88.3	6.7	7.4
wall paint, smooth finish		Second	20.9	23.2	25.5	9.2	9.8	34.8	51.1	69.7	8.0	8.6	79.0	88.3	97.5	8.0	8.6
	Epoxy	First	16.3	18.6	20.9	—	—	27.9	46.5	67.4	—	—	69.7	79.0	88.3	—	—
		Second	20.9	23.2	25.5	9.2	10.4	34.8	51.1	69.7	8.6	9.8	79.0	88.3	97.5	—	—
Wall, gypsum, drywall flat	Oil base	First	16.3	18.6	20.9	8.0	8.6	25.5	46.5	65.0	6.1	7.4	65.0	74.3	83.6	6.1	6.7
wall paint, sand finish		Second	18.6	20.9	25.5	8.6	9.8	32.5	51.1	67.4	7.4	8.0	74.3	83.6	92.9	7.4	8.6
	Epoxy	First	16.3	18.6	20.9	6.1	6.7	25.5	46.5	65.0	—	—	65.0	74.3	83.6	—	—
		Second	18.6	20.9	25.5	8.0	9.2	32.5	51.1	67.4	7.4	8.6	74.3	83.6	92.9	—	—
Wall plaster, smooth finish	Oil base	First	13.9	16.3	18.6	8.6	9.8	24.2	41.8	59.5	8.0	9.2	46.5	55.7	69.7	8.6	10.4
		Second	16.3	18.6	20.9	9.2	10.4	27.9	41.8	62.7	8.6	9.8	51.1	65.0	79.0	9.2	11.0
	Epoxy	First	13.9	16.3	18.6	—	—	24.2	41.8	59.5	—	—	46.5	55.7	69.7	—	—
		Second	16.3	18.6	20.9	9.2	9.8	27.9	41.8	62.7	8.0	9.2	51.1	65.0	79.0	8.0	9.2
Wall plaster, medium texture	Oil base	First	11.6	13.9	16.3	7.4	8.0	20.9	41.8	60.4	6.1	6.7	44.1	53.4	67.4	8.0	9.8
		Second	13.9	15.3	17.2	8.6	9.8	23.2	44.1	62.7	7.4	8.6	48.8	62.7	76.6	8.6	10.4
	Epoxy	First	11.6	13.9	16.3	—	—	20.9	41.8	60.4	—	—	44.1	53.4	67.4	—	—
		Second	13.9	15.3	17.2	9.2	9.8	23.2	44.1	62.7	7.9	8.6	48.8	62.7	76.6	7.4	8.6

[a] For heights over 2.44 m (8 ft), use high time difficulty factors.
[b] S = slow, M = medium, F = fast, H = heavy, L = light.
Source: Gleason, *Estimating Painting Cost*, 1989.

TABLE 14.63 Exterior Paint Production Rate (PR) and Material Coverage Ratio (CR)[a,b]

			Exterior painting														
			Brush					Roller					Spray				
			PR (m^2/hr)			CR (m^2/l)		PR (m^2/hr)			CR (m^2/l)		PR (m^2/hr)			CR (m^2/l)	
Description of work	Paint	Coat	S	M	F	H	L	S	M	F	H	L	S	M	F	H	L
Beams from 4 × 6 in. to 8 × 14 in., one coat	Oil base	to 13 ft high	8.5	9.7	10.9	2.6	3.2	—	—	—	—	—	—	—	—	—	—
		to 17 ft high	5.8	6.5	7.2	2.6	3.2	—	—	—	—	—	—	—	—	—	—
		to 18 ft high	3.9	4.3	4.8	2.6	3.2	—	—	—	—	—	—	—	—	—	—
Doors, wood	Paint grade	Two coats	5.6	7.0	9.3	3.7	5.2	5.6	7.0	9.3	3.7	5.2	—	—	—	—	—
	Polyurethane	Two coats	4.0	4.6	5.6	2.9	3.7	—	—	—	—	—	—	—	—	—	—
	Varnish	Two coats	5.6	7.0	9.3	2.9	4.4	—	—	—	—	—	—	—	—	—	—
Floors, concrete	Oil base	First	8.4	13.0	18.6	6.7	7.4	12.5	22.3	27.9	7.9	9.1	74.3	83.6	92.9	4.3	4.9
		Second	11.6	17.2	29.7	9.2	9.8	18.1	25.5	31.6	11.0	12.3	83.6	92.9	102.2	6.7	7.4
		Third	13.9	20.0	31.6	12.3	13.5	19.5	26.9	36.2	12.3	13.5	92.9	102.2	111.5	8.0	8.6
Masonry brick	Oil base	First	18.6	20.9	23.2	9.2	8.6	30.2	32.5	34.8	6.1	8.0	60.4	69.7	79.0	5.5	6.7
		Second	23.2	25.5	27.9	8.0	9.8	34.8	37.2	39.5	6.7	8.6	69.7	79.0	83.6	6.7	7.4
	Water base	First	18.6	20.9	23.2	6.1	7.4	30.2	32.5	34.8	4.3	6.1	60.4	69.7	79.0	4.9	6.1
		Second	23.2	25.5	27.9	6.7	8.0	34.8	37.2	39.5	5.5	6.7	69.7	79.0	83.6	6.1	6.7

Masonry concrete	Oil base	First	10.2	12.1	13.9	2.7	3.2	22.8	27.9	32.5	2.1	2.7	55.7	65.0	74.3	1.6	2.5
		Add coat	17.2	19.5	21.4	3.9	4.9	25.5	30.2	39.0	3.8	4.5	65.0	74.3	83.6	3.1	3.9
	Epoxy	First	10.2	12.1	13.9	2.1	2.7	22.8	27.9	32.5	1.8	2.5	55.7	65.0	74.3	1.2	2.1
		Add coat	17.2	19.5	21.4	4.3	4.9	25.5	30.2	39.0	3.6	4.3	65.0	74.3	83.6	2.8	3.6
	Water base	First	10.2	12.1	13.9	1.8	2.5	22.8	27.9	32.5	1.6	2.2	55.7	65.0	74.3	1.3	2.5
		Add coat	17.2	19.5	21.4	3.8	4.4	25.5	30.2	39.0	3.1	3.9	65.0	74.3	83.6	2.7	3.8
Plaster and stucco	Water base	First	9.3	11.1	13.0	2.5	3.7	22.8	24.6	27.9	3.7	5.5	55.7	62.7	69.7	2.2	4.9
		Second	13.9	15.3	16.3	4.9	6.1	27.9	29.7	31.6	5.2	6.7	65.0	74.3	83.6	3.1	5.5
	Oil base	First	7.4	9.3	11.1	5.8	6.5	18.6	23.2	27.9	4.9	6.1	51.1	55.7	60.4	3.7	4.9
		Second	13.5	15.3	17.2	6.1	7.4	20.9	25.5	30.2	5.5	6.7	60.4	69.7	83.6	6.7	8.6
Roofing shingle of	Penetrating	First	9.3	14.4	19.5	3.4	3.9	19.5	23.7	28.3	4.4	4.9	55.7	65.0	74.3	3.4	4.9
shake	stain	Second	13.9	18.1	22.3	4.5	5.0	23.2	27.9	32.5	6.7	7.2	65.0	74.3	83.6	5.9	7.4
Siding rough wood	Water base	First	9.3	12.5	15.8	5.5	6.1	13.9	20.9	25.5	5.2	5.8	37.2	46.5	55.7	5.9	6.9
		Second	12.5	15.8	18.6	6.7	7.4	18.6	25.5	32.5	6.4	7.0	41.8	51.1	60.4	7.1	8.1
		Third	13.9	17.2	20.0	8.6	9.2	24.2	31.1	38.1	8.0	8.6	51.1	60.4	69.7	9.6	10.6
Lightweight struc-	Oil base	First	6.8	7.2	7.5	11.0	12.3	—	—	—	—	—	37.5	39.8	41.7	3.3	3.7
tural steel after	Industrial	First	6.8	7.2	7.5	11.0	12.3	—	—	—	—	—	37.5	39.8	41.7	3.3	3.7
erection	enamel	Second	9.3	9.8	10.4	13.5	14.7	—	—	—	—	—	35.1	37.3	39.3	4.0	4.4
Medium to heavy-	Oil base	First	8.8	9.3	9.9	11.0	12.3	—	—	—	—	—	45.1	47.9	50.8	3.3	3.7
weight structural	Industrial	First	8.8	9.3	9.9	11.0	12.3	—	—	—	—	—	45.1	47.9	50.8	3.3	3.7
steel after erection	enamel	Second	10.4	11.0	11.6	13.5	14.7	—	—	—	—	—	58.1	61.6	65.1	4.0	4.4
Siding smooth wood	Oil base	First	9.3	11.6	13.9	8.0	9.8	9.3	11.6	13.9	7.4	8.6	37.2	46.5	55.7	3.2	4.2
		Second	12.5	15.3	18.6	9.2	11.0	16.3	23.2	30.2	8.6	9.8	51.1	67.4	83.6	6.0	7.4
		Third	13.9	16.7	20.0	11.0	12.9	24.2	31.1	38.1	9.8	10.4	60.4	76.6	92.9	8.5	9.8

[a] For heights over 8 ft (2.44 m), use high time difficulty factors.

[b]S = slow, M = medium, F = fast, H = heavy, L = light. *Source*: Gleason, *Estimating Painting Cost*, 1989.

Table 14.64 Painting Difficulty Factors Affecting Productivity

Height	Add to surface area (%)	Multiply by
2.4 to 4 m	30	1.3
Over 4 to 5.2 m	60	1.6
Over 5.2 to 5.8 m	90	1.9
Over 5.8 to 6.4 m	120	2.1

Source: Gleason, *Estimating Painting Cost*, 1989.

14.11 WALL COVERINGS

14.11.1 Types of Wall Coverings

Vinyl and vinyl-coated wallpapers are the most commonly used type of wallpaper owing to their durability, water resistance, ease of cleaning, and ease of installation and removal. Vinyl wall coverings also cost less than other types of common wall coverings and are, therefore, the most popular wall covering choice today. Vinyl wallpaper is available in a variety of designs, although complicated designs and motifs may make the wallpaper susceptible to dirt, water, and difficulty in handling and installing.

Foils and mylars are wall coverings with a highly reflective, thin metal coating. They are not very durable, and any surface flaw is very easily seen.

Paintable wall coverings are neutral in color and manufactured to be painted after application. They can be made of many different materials, and after painting are both resistant to water and easy to clean. They can be found in all kinds of patterns, which give different effects to the room.

Grasscloths are highly textured wall coverings woven from natural fibers. They are durable, but may be difficult to remove from the wall.

Flocked wall coverings have raised fiber patterns that look like velvet, and require a special clay adhesive for installation. They are no longer available in the US, and need to be special-ordered from Europe.

Embossed wall coverings are papers stamped to create a 3-D relief pattern. They are very effective and are often used in rooms with special design. They are not very durable, are difficult to clean, and should, therefore, not be used in rooms with high occupancy.

Flexwood is a genuine wood veneer, usually about 3 mm thick and glued to cotton sheeting with a waterproof adhesive. It is installed in the same way as other types of wall coverings.

TABLE 14.65 Painting Equipment Rental Rates

Equipment		Purchase	Rental $/day	Rental $/week	Rental $/month
Air compressors	185 CFM-diesel		61	200	475
	600 CFM-diesel		224	700	1790
Boomlifts 3 × 4 to 3 to 8 ft basket	30 ft two-wheel drive		150	600	1800
	50 ft 1000 lb		330	1000	3020
Rolling ladders 30 in. wide, 7 step with rails		360			
Rolling towers manual, adjustable	scissor type to 15 ft				475
	scissor type to 25 ft				790
Safety nets, stock sizes	Nylon 1/2 in. mesh	1.65/SF			
	Nylon 4 in. mesh	1.45/SF			
	150 lb		31	82	240
Sandblast machines	300 lb		45	130	325
	600 lb		53	154	390
Sandblast hoses	50 ft lengths 1 in. I.D.		12	27	65
	10 ft lengths whip lines 1 in. I.D.		8	18	48
Sandblast accessories	1 sack sand pot		35	64	185
	3 sack sand pot		55	90	262
	Silica sand abrasive	25.00/ton			
Scaffolding: rolling stage, caster mounted, 2 ft to 8 ft 8 in. high	7 to 11 ft			40	80
	17 to 21 ft			66	132
	27 to 30 ft			74	148
	2 frames high 15 to 20 ft				.48/SF
Scaffolding: stationary, running footage unlevel ground; per face footage of reach	4 frames high 28 to 33 ft				.49/SF
	6 frames high 41 to 46 ft				.52/SF
	8 frames high 53 to 58 ft				.55/SF

Source: Means, *Building Construction Data*, 2000.

Table 14.66 Paint Material Prices

Interior work description	Paint	$/liter	Exterior work description	Paint	$/liter
Ceilings, drywall	Oil base	10.99	Beams from 4 × 6 in. to 8 × 14 in. one coat	Oil base	5
Doors, wood	Enamel	4			
Floors, concrete	Oil base	4.80	Doors, wood	Paint grade	3
Floors, wood	Oil base	4.80		Polyurethane	4.80
Siding, smooth wood	Oil base	4.80		Varnish	7.90
Wall, gypsum drywall flat wall paint, smooth finish	Oil base	4.20	Floors, concrete	Oil base	4.80
	Epoxy	4.20	Masonry brick	Oil base	4
Wall, gypsum drywall flat wall paint, sand finish	Oil base	5		Water base	4.80
	Epoxy	4	Masonry concrete	Oil base	4
Wall plaster, smooth finish	Oil base	5		Epoxy	4
Wall plaster, medium texture	Epoxy	4		Water base	4.80
			Plaster and stucco	Water base	4.80
				Oil base	4.80
			Roofing shingle of shake	Penetrating stain	4
			Siding, rough wood	Water base	4
			Lightweight structural steel after erection	Oil base	4.80
				Industrial enamel	5
			Medium to heavyweight structural steel after erection	Oil base	4.80
				Industrial enamel	5
			Siding, smooth wood	Oil base	4

Source: Means, *Building Construction Data*, 2000, and Home Depot On-Line Store, 2001.

Table 14.67 Painting Waste Factors Based on Method of Application

Method of application	Waste factor (%)
Brush	3–5
Roller	5–10
Airless spray	20–25
Conventional spray	25–35

Source: Gleason, *Estimating Painting Cost*, 1989.

14.11.2 Characteristics of Wallpaper

Table 14.69 provides a good selection chart for choosing the most appropriate type of wallpaper.

Washable wallpapers can be sponged occasionally with soap and warm water. Scrubbable wallpapers, on the other hand, are strong enough for washing with a soft brush if required.

Strippable and peelable wallpapers easily pull off the wall in one piece, and are a good choice for those who tend to redecorate every few years. Peelable papers usually come off in a couple of layers, with the top layer pulling off as easily as a strippable paper. That usually leaves a second, thin layer stuck to the wall, which needs to be moistened to loosen the adhesive before it can be removed.

Prepasted wallpaper has the adhesive paste already applied to the surface of the reverse side. Soaking the wallpaper in water activates the paste, which makes it ready for immediate use.

Some wallpapers need special adhesives made from clay and the like for their installation. The installation is normally done in a straightforward method, but some wallpapers require special handling and additional tools, making their installation more difficult.

14.11.3 Method of Installation

Before beginning, the wall surface must be smoothed to remove any irregularities. The methods used depend on the wall surface, which may be painted, have an old layer of wallpaper, bare gypsum, and so on. The characteristics of the wall surface also influence the choice of method for gluing the wallpaper to the wall. Most paperhangers first use a layer of oil-based primer on the wall to create a hard surface before they size the wall to ensure that the paste adheres. Even if the paper is prepasted (as most are), size should be utilized to ensure good adherence between the wall and the paper.

Table 14.68 Painting Productivity Loss in the Field Due to Changed Conditions

No.	Changed condition	Estimated % productivity loss if change is . . . (0 to 100% in each column)		
		Minor	Moderate	Severe
1	Congestion: change prohibits use of optimum crew size including physically limited working space and materials storage	5	30	60
2	Morale and attitude: change involves excessive inspection, multiple change orders and rework, schedule disruption, or poor site condition	10	22	87
3	Labor reassignment: change demands rescheduling and expediting, and results in lost time to move in/out	7	33	65
4	Crew size change: change increases or decreases in optimum crew size results in inefficiency or workflow disruption	15	25	52
5	Added operations: change disrupts ongoing work due to concurrent operations	43	20	40
6	Diverted supervision: change causes distraction of supervision to analyze and plan changed work, stop and replan ongoing work, or reschedule work	43	17	30
7	Learning curve: change causes workers to lose time becoming familiar with and adjusting to new work or new environment	23	30	27
8	Errors and omissions: change causes time loss due to mistakes engendered by changed circumstances	17	33	90
9	Beneficial occupancy: change requires the use of premises by owner prior to work completion, restricted work access, or working in close proximity to owner's personnel or equipment	7	27	73
10	Joint occupancy: change requires work to be done while other trades not anticipated in the bid occupy the same area	7	37	53
11	Site access: change requires physically inconvenient access to work area, inadequate workplace, remove materials storage, or poor man-lift management	7	57	38
12	Logistics: change involves unsatisfactory supply of materials by owner or general contractor, causing inability to control materials procurement, and delivery and rehandling of substituted materials	10	15	58

Table 14.68 Continued

No.	Changed condition	Estimated % productivity loss if change is . . . (0 to 100% in each column)		
		Minor	Moderate	Severe
13	Fatigue: change involves unusual physical exertion causing lost time when original plan resumes	10	13	53
14	Work sequence: change causes lost time due to changes in other contractors' work	10	32	77
15	Overtime: change requires overtime causing physical fatigue and poor mental attitude	7	30	53
16	Weather and environment: change involves work in very cold or hot weather, during high humidity, or in dusty or noisy environment	15	22	25

Source: Field survey responded to by painting contractors (3) in the Austin, TX, area, March, 2001.

Wallpaper is installed vertically, and the length of each strip should be the distance from the baseboard to the ceiling plus about 10 cm. All the strips needed should be cut before beginning the installation to ensure enough paper, discover any irregularities, and so on. Before installing the paper, the adhesive side should be wetted with plain room temperature water to ensure that the prepasted glue is activated.

When hanging wallpaper, the first strip of paper is installed by placing the top of the cut paper just a couple of inches over the ceiling line and pushing it gently downward on the wall surface in the direction from top to bottom, maintaining its vertical direction at the same time. A brush is then used to press the air bubbles out of the paper. This process will force glue out the side of the paper as well, which must removed by using a lightly wetted sponge or rag. Finally the strip is fitted to the height of the wall by cutting it under the ceiling and above the baseboard. The same process is used for the next strip, but this strip should be put on the wall a quarter of an inch from the other paper and then slid gently into place. Lastly, the seams between the papers must be pressed with a roller.

14.11.4 Tools Required for Wallpapering

There are a number of small tools required for the activities described in the earlier sections. Table 14.70 indicates the basic tools needed for installing wallpaper, with their estimated (2001) average price.

TABLE 14.69 Wallpaper Characteristics[a]

Types and features	Vinyl and vinyl-coated	Foils and mylars	Paintable	Grasscloth	Flocked wall	Embossed	Flexwood
Washable/scrubbable	Yes	No	Yes	Yes	No	No	Yes
Strippable/peelable	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prepasted/unpasted	Prepasted	Prepasted	Prepasted	Unpasted	Unpasted	Prepasted	Prepasted
Special adhesive	No	No	No	Yes	Yes	No	Yes
Availability	Everywhere	Most places	Everywhere	Special order	Import only	Special order	Special order
Ease of installation	Very easy	Easy (few extra tools needed)	Easy	Easy	Difficult	Difficult	Easy
Durability	High	Low	Medium	High	Medium	Low	High
Price range per double roll	\$11–\$16	\$30–\$46	\$11–\$14	\$75–\$105	N/A	\$100–\$140	N/A
Price range per m^2	\$0.64–\$0.92	\$1.73–\$2.66	\$0.64–\$0.81	\$4.33–\$6.07	N/A	\$5.78–\$8.09	N/A
Price range per roll of border	\$6–\$12	N/A	\$6–\$12	N/A	N/A	N/A	N/A
Price range of border per meter	\$1.31–\$2.63	N/A	\$1.31–\$2.63	N/A	N/A	N/A	N/A

[a] Wallpaper is sold in double rolls, each of which contains 17.3 m^2. Borders are sold in rolls containing 4.71 meters.

TABLE 14.70 Wallpapering Cost for New Tools

Tool	Purpose	Average price ($)
Tape measure	Laying out walls and measuring wall coverings	6
Scissors	Cutting and trimming	4
Paint roller and tray	Applying paste to unpasted wall coverings	8
Water tray	Soaking prepasted wall coverings in water to activate paste	2
Seam roller	Small roller designed to roll out wallpaper seams	3
Smoothing brush	Smoothing out paper during installation	2
Broad knife	Creasing paper at top and bottom of walls (4–6 in.)	3
Razor knife	Trimming paper	4
Sponge, bucket, and water	Rinsing wallpaper after application	5

14.11.5 Cost Estimating Procedure

Figure 14.18 shows the procedure for estimating the quantity of wallpaper required and the final cost of wallpaper and tools that will be required to cover the given area.

14.11.6 Waste Factors

There is typically some waste encountered in installing wallpaper due to matching, cutting, fitting, and so on. Although precise waste factors have not been obtained, different sources estimate this to be between 10 and 20%. Accuracy of this figure depends very much on the geometry of the room, the number of obstacles encountered in the actual area, and the pattern of the wallpaper used. For simple repetitive designs, this figure will be lower, whereas for highly patterned papers with low repetition, this figure can be quite high due to exact matching of the pattern.

14.11.7 Labor Productivity

Most commonly, wallpaper for homes is installed by the owner, after buying the wallpaper from a store. These stores offer free classes and demonstrations to show their customers the best way to install the paper. However, there are a number of contractors who can be hired to install the paper after the customer has chosen the type of paper to be used. Depending on the type of contract, Table 14.71 can be used to calculate the total number of man-hours required for various types of wall coverings.

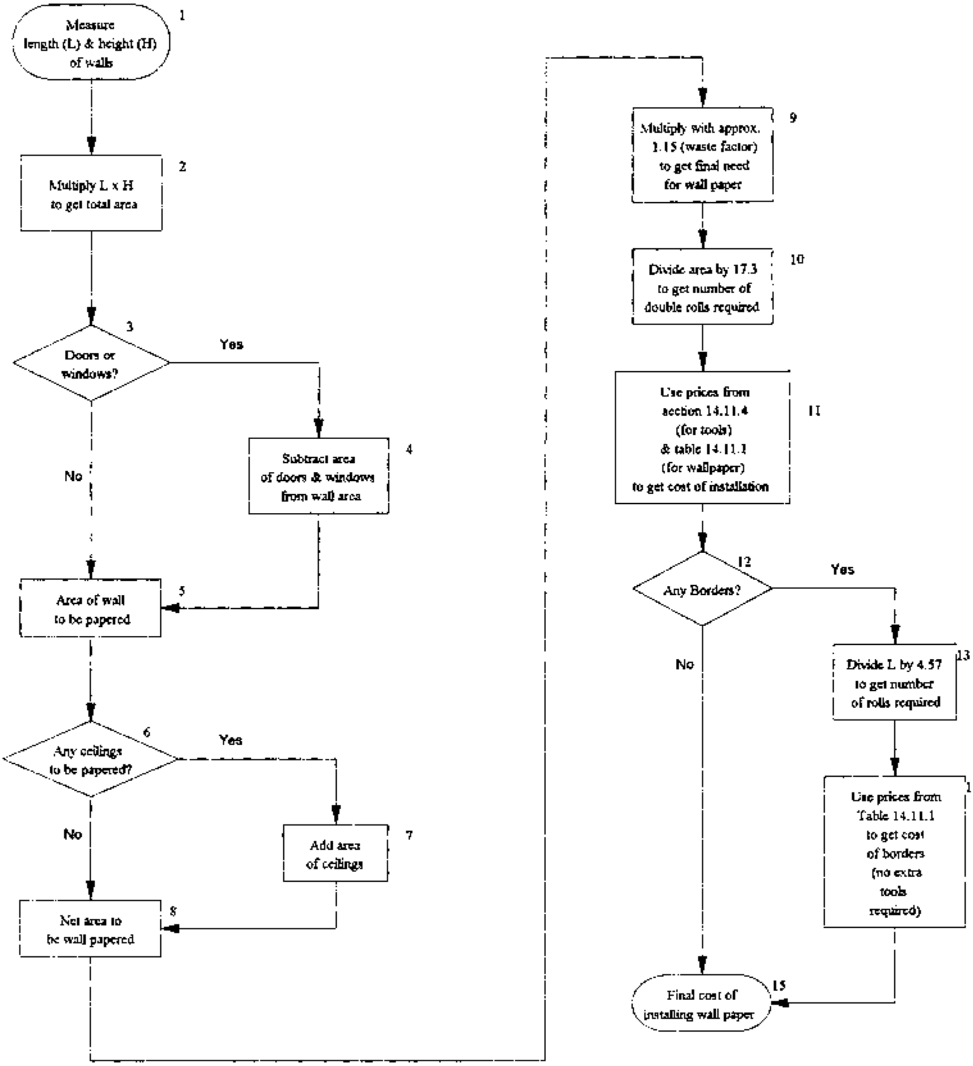


FIGURE 14.18 Wallpapering flowchart for cost estimating procedure.

TABLE 14.71 Wallpaper Installation—Labor Productivity

Types and productivity	Vinyl and vinyl-coated	Foils and mylars	Paintable	Grasscloths	Flocked wall	Embossed	Flexwood
Man-hours/10 m^2	1.67	N/A	1.61	2.37	N/A	N/A	8.6

14.12 REVIEW QUESTIONS

1. Which variables dictate the covering capacity of prepared plaster?
2. What is the expected labor cost variation range between ordinary and first-quality plastering operations?
3. Describe the various available methods in drywall installation.
4. What is the productivity loss in gypsum board installation if severe field conditions related to “joint occupancy” exist?
5. How many m^2 of interior wall tiles can be installed in eight hours by a tile layer and one helper?
6. What is the total direct cost for installing 1 m^2 of wall tiles using Portland cement mortar?
7. What is the average cost of 1 m^2 of marble tiles?
8. What is the waste factor to be considered by an estimator for marble tiles in regular-shaped rooms?
9. Describe the unbonded method for terrazzo flooring installation.
10. What is the average productivity installing terrazzo flooring with divider strips 1 m apart?
11. Please explain the differences between acoustical baffle and composition acoustical tiles.
12. What is the expected productivity per day when installing acoustical tiles?
13. Please explain the differences between plank and parquet flooring.
14. What is the expected productivity per day for parquet flooring installation in a residence assuming ordinary workmanship?
15. Which of the available resilient floorings show a high productivity in installation?
16. What is the percentage of productivity loss for resilient flooring installation if the room’s temperature and humidity are very high?
17. Please describe the tacked and tackless carpet installation methods.
18. What is the carpet percentage loss in residential construction installation?
19. Why is it necessary to apply a primer coat of paint on new surfaces?
20. Referring to Table 14.61, please comment about slow and fast modes in painting operations.
21. Which are the basic types of wall covering materials?
22. What is the daily production rate for vinyl-coated wallpaper installation?

15

Mechanical Work

The mechanical work is generally subcontracted out to mechanical specialties, which prepare detailed estimates for plumbing and heating, ventilation, and air conditioning systems (HVAC). From the general contractor's point of view, this simply transfers the preparation of the detailed estimate to another party, but it does not eliminate the need for estimating and analyzing the prices quoted. To accurately estimate plumbing costs, general contractors therefore should have field experience and a good knowledge of various plumbing systems, materials, labor, and equipment, as well as an understanding of the drawing and specifications. In this chapter, mechanical work refers to plumbing and sewage systems and HVAC.

15.1 INTRODUCTION TO PLUMBING AND SEWAGE SYSTEMS

Plumbing involves three general tasks: bringing water and gas to a building, supplying and installing fixtures, and conveying the discharged water and waste from the building. Plumbing materials, fixtures, and associated equipment are usually defined in the specifications. The materials include various types and sizes of pipes, fittings, valves, fixtures, and accessories, which are more fully described later. Water usually is obtained from a water main, whereas the waste is collected from a building and discharged into a sanitary sewer line. Plumbing can be classified as piping for potable water purposes, and plumbing for waste

disposal purposes. Piping can refer to any carrier of potable water including fixtures and accessories from the water treatment, filtration, and purification plants. Plumbing can refer to any pipe or fixtures installed for the express purpose of waste disposal. In this text, however, plumbing refers to rough and finish plumbing.

15.2 ROUGH AND FINISH PLUMBING

Plumbing work can be separated into two categories, rough and finish plumbing. Rough plumbing involves the installation of all piping required to supply hot and cold water in and through a building, as well as piping for waste removal. Rough plumbing also involves the installation of soil pipes, drains, vents, traps, plugs, cleanouts, and so on, excluding the installation of plumbing fixtures. In preparing a detailed estimate for rough plumbing, a comprehensive list of required materials should be used as a check and for establishing all costs. Each item should be listed separately by description, grade, size, quantity, and unit and total costs. Costs of materials for rough plumbing will vary with grades, quantities, locations, and time, so up-to-date costs of materials from local warehouses and stores must be obtained in preparing an estimate for bid purposes. Also, other costs such as tapping fees, permits, or removing and replacing pavement must be included in an estimate. Labor required in rough plumbing usually includes a team of a plumber and a helper. To install water pipe, the operations include cutting and threading the pipe and screwing it together with the appropriate fittings. Cutting and threading may be done by hand and power tools. The labor time required will vary with the size of pipe, tools used, and working conditions at the job.

On the other hand, finish plumbing involves the installation of fixtures such as lavatories, bathtubs, shower stalls, kitchen sinks, dishwashers, garbage disposals, water closets, water heaters, washers, dryers, and the accessories and fittings for each fixture. The prices of finish plumbing vary significantly with the type, size, and quality specified. The estimator first lists all items and fixtures furnished and installed by a contractor, as well as accessories and fittings for each fixture. After listing all items, the estimator must obtain a current cost of each item from local manufacturers and price them according to the specifications and contracts. Labor required to install plumbing fixtures will vary with the kind and quality of fixture, the kind of accessories used, and the type of building. The simplest fixtures will generally require less time, whereas the more complicated fixtures will usually require more time. All factors that affect the rates of installation must be considered in preparing an estimate.

15.3 PLUMBING CODES AND SPECIFICATIONS

Plans and specifications should clearly identify the type, grades, sizes, and quantities, and furnish further information required for a complete plumbing installation. For most residential and small commercial construction, the floor plan shows all fixtures and horizontal pipe runs, whereas the schematic diagram shows the size and vertical locations. All major parts of the piping system such as meters, valves, and angle stops, excluding the fixtures, are indicated. All major parts of the plumbing system from the sewer connection to, but not including, the fixtures also are included in the specifications or on the architectural or plumbing floor plans. Depending on the specifications, certain plumbing materials or equipment may be supplied by the owner or general contractor.

For small buildings and residential homes, some plans and specifications furnish limited information, so the plumbing contractor takes the responsibility for determining what is needed to satisfy the owner and the local plumbing regulations. The regulations require that plumbing installations should conform to the local plumbing codes for the city in which the building project will be constructed. The city plumbing codes will govern materials, design, and fabrication of plumbing work. The plumbing contractor must obtain a plumbing permit prior to starting an installation, and the work is verified by a plumbing inspector for compliance with the code. Such professional codes include the Uniform Plumbing Code, Basic Plumbing Code, National Plumbing Code, Southern Standard Plumbing Code, and regulations of ASHRAE and OSHA.

15.4 PLUMBING SYSTEMS

Plumbing systems can be classified into five groups: sanitary drainage, waste, and vent system; hot and cold water system; fire protection system; gas system;

and trailer park or sanitary sitework system. The first two are the main systems found in plumbing work. The following paragraphs refer to these five systems in detail, as well as giving a cost estimate for each.

15.4.1 Sanitary Drainage, Waste, and Vent System (DWV System)

The DWV system involves several types of pipes connecting the fixture to the stacks: (l) water closets discharge, which connects to soil pipes; (2) sinks and dishwashers, which connect to waste pipes; and (3) vent pipe, which connects the above fixtures to permit air to enter the drainage system. The vertical drainpipes in the building are called stacks, and the horizontal drain which leads out of the building is called the house drain. Drainage pipes are sized according to their location in the system and the total number and type of fixtures served. The waste is carried from the building to the sewer by cast iron or vitrified clay pipes. Vents permit offensive gases to escape while admitting fresh air into the system, whereas a trap is a seal used to prevent sewer gases from entering the interior of a building. Building drains, stacks, branch lines, and vents may be of extra heavy cast iron, copper, or plastic. In other words, soil, waste, and vent pipes are pipes that convey the discharge liquids from plumbing fixtures to the house drain. Soil and waste pipes receive the discharge from water closets and other fixtures, respectively. Vent pipes provide ventilation for a house drainage system and prevent siphonage of water from the traps.

To estimate the DWV system, the estimator should consider its main components, which are the building drain, building sewer, vent piping, and above-grade waste. On a small job, these four components may be placed on a single quantity sheet. A larger job, however, requires separate sheets for each component. At the beginning of the estimate, the estimator can start from a set point on the drawing and begin measuring the pipe length along each run. Each different size pipe must be kept separately on the quantity sheet. Once a section of pipe is taken off, the estimator should mark off the section with a pencil. On a quantity sheet, the estimator can list each pipe size and its length in linear meters. Fittings taken off the drawings are listed separately from the piping itself. When a fitting is taken off, its location is marked. Fittings are entered on the quantity sheet by type, size, and quantity.

15.4.2 Hot and Cold Water System

The cold water supply in a building begins once it enters the building wall, whereas the hot water supply starts from the hot water generation equipment. Water meters can also be located outside the building in concrete vaults. In a building, the water system is routed to fixtures, water meters, heating units, and the fire protection system. Standard piping materials for this system include type L copper tubing, brass pipe, galvanized steel pipe for above-ground construction, and polyvinyl chloride (PVC) cold water, type K soft or hard copper tubing for below-grade construction. In some cases, trench excavation is required and the plumbing contractor is responsible.

The takeoff procedure for the hot and cold water system is similar to the takeoff procedure for the DWV system. First, a pipe material must be chosen depending on locale and budget. Once the material is chosen, the same steps should be followed as in the DWV takeoff.

15.4.3 Fire Protection Systems

Fire protection systems are strictly governed by codes. These systems are designed to promote safety for building inhabitants from fire and must be built correctly. The most widely used fire protection system is the standpipe system, where the hose connections or standpipes connect to a public water main at one end, and the other end may connect to an automatic sprinkler system. The standpipe with sprinklers can shoot the water over a large area thus increasing the effective range of the system. The sprinkler systems are classified into two types, wet and dry. For the wet sprinkler system, all pipes and sprinkler heads are at all times filled with water under pressure. For the dry sprinkler system, the piping up to the sprinkler heads is filled with air, the water supply is controlled by a dry pipe valve, and the sprinkler heads are designed to activate according to a certain temperature range such as 135° to 600°F.

Estimating a fire protection system requires determining the cost of piping, nozzles, and pumps. Any alternate source of water must be determined. If the fire standpipe system is not connected to or part of a sprinkler system, the standpipe system is installed by the plumbing contractor and needs to be included in the estimate. However, in some cases the standpipe system is installed by sprinkler contractors belonging to the steamfitters union. Finally, connections must be estimated.

15.4.4 Gas System

In most buildings, gas is used as fuel for several appliances such as boilers, hot water generators, laboratories, and kitchen ranges. For medical purposes, gas refers to oxygen, nitrogen, vacuum, compressed air, and nitrous oxide. Gas pipes are connected from shutoff valves at the main property line to stoves, heaters, and various other appliances. The common piping material for medical gas systems, which is not common in typical housing gas systems, is the type L or K copper tubing for audio-visual monitoring alarm systems against pressure drop. Utility companies furnish the shutoff valve and gas meter, whereas the plumbing contractor runs the gas line from the valves to the building. The plumbing contractor must obtain water and gas permits prior to construction. One of the most common piping materials for natural gas systems is steel pipe.

Estimating the cost of a gas system is somewhat different from estimating the cost of a water distribution system. The estimator is only responsible for the gas piping that lies within the building. The type of gas used in a system, which ranges from natural gas to liquefied petroleum gas, will often determine the complexity of the system. The gas system is sized according to the demand at each appliance outlet and the length of piping required to reach that outlet. Appliance demands are listed on the architect's blueprints and on metal plates attached to the actual appliances. These demands are the maximum demands of the appliance and are summed with the length of piping in the system.

15.4.5 Trailer Park or Sanitary Sitework Systems

Designing sanitary plumbing facilities for trailer parks requires a knowledge of codes and standards governing the erection of these facilities. Most codes differentiate trailers into two categories; a dependent travel trailer, and an independent trailer coach. A dependent trailer is a trailer coach used as a temporary dwelling for traveling and recreation. Most sanitary facilities are built in and can not be connected to park sewage and water supply systems. An independent trailer coach is designed for permanent occupancy and has an internal plumbing system suitable for connection to park sewer and water systems.

Estimating the required plumbing system begins with the materials required for the erection of a sanitary sewer. These materials include bedding, backfill, vent pipes, vents, and cleanouts. Once the sewer system has been completed, the water distribution system should be estimated as a water service piping below grade.

15.5 SEWAGE SYSTEMS

Sewage systems include one or more types of pipes and other subsystems necessary to permit the system to collect waste water and sewage and transmit them to a suitable location for disposal purposes. One of the most common sewage systems is the sanitary sewer system which includes four major parts: sewer pipes and fittings, manholes, service connections, and cleanout services. Sewer pipes are manufactured of various materials including vitrified clay, ductile iron, and PVC. These pipes are available in various sizes, lengths, and wall thicknesses. They have joints made by inserting the spigot end of one pipe into the bell end of the connecting pipe, but vitrified clay pipe with a rubberlike gasket installed and PVC pipe create a more flexible watertight joint. Sewer fittings include single and double wyes, tees, curves, increasers, decreasers, and stoppers or plugs.

The second part of sewage systems is manholes installed along sewer lines, to permit access to the sewer for inspection and cleaning. Manholes are usually installed at intersections with laterals, at changes in the size of pipe, and at changes in the grade or directions. The third part of sewage systems is service connections used to provide access to the pipe for future connections from users of the facility. This can be done by installing wye branches in the main line at the time it is installed. The last part of sewage systems is cleanout services, where cleanout boots are installed at the upper end of the sewer lines for cleaning and flushing purposes. The boots are typically made of cast iron, with a base, throat, and cover installed in concrete for stability.

15.6 MATERIALS FOR PLUMBING AND SEWAGE SYSTEMS

Plumbing materials are the fundamental basis for estimating plumbing costs because taking off the required material will result in the final estimate for a job.

Plumbing materials come in various forms, but the main categories for plumbing material are piping, fittings, valves, and fixtures.

Piping or pipe is the basic material of most plumbing systems, and is priced by its length. It is usually designated by the material and the diameter of the pipe. Pipe is usually made of several materials such as plastic, steel, brass, copper, vitrified clay, or concrete. Among these, plastic pipe is the least expensive, whereas brass and copper pipe are relatively the most expensive. Plastic pipe for water is manufactured in 20-meter standard lengths, and is made of several types of plastics such as polyvinyl chloride (PVC), chlorinated polyvinyl chloride (CPVC), polyethylene (PE), polypropylene (PB), and fiberglass reinforced plastic (FRP). Among those, PVC is the most common one with a high rigidity which can withstand internal water pressures up to 12 or 15 ksc. Other advantages of PVC pipe include its light weight, high resistance to corrosion, low resistance to the flow of water, economy, and ease of installation. However, this pipe is not recommended for use with hot water and water under high pressures.

Steel pipe is one of the solutions for use under high water pressures. It is made from either black or galvanized steel with plain or threaded ends, and manufactured in three basic grades: schedule 40 or standard weights, schedule 80 or extra-strong weights, and schedule 160 or double-extra-strong weights, with the standard weights being the most widely used for plumbing purposes. In cases where steel pipe is not permited, brass and copper pipes which are made in standard and extra-strong grades are commonly used. Steel, brass, and copper pipes are available in the same external diameters and number of threads per unit length. Other types of pipe for plumbing systems are vitrified clay and concrete pipes. Vitrified clay pipe is made in standard and extra strength, with lengths of 0.75 and 0.90 m. Concrete pipe can be reinforced or nonreinforced, with lengths ranging from 1.50 to 3.00 m.

The second category of plumbing materials is fittings or pipe connections where separate pieces of pipe join. Common fittings include elbows, tees, and wyes, and generally the fittings are of the same material as the pipe itself. For example, common fittings for PVC pipes are made of PVC. If different types of plastic are used, the solvent cement will not be effective on both types of materials. Adapters are therefore used to join one type of pipe or fittings to another type. For plastic pipes, methods of joining pieces are threading, solvent cement, and heat fusing. The most common installation practice for plastic pipes requires cutting these pipes into desired lengths using a hacksaw, applying solvent cement to the ends, and then inserting the ends into plastic fittings that finally form a solid joint without leakage.

The next category of plumbing materials is valves and control devices used to control the content of piping systems to ensure the proper operation for plumbing systems. Valves are installed to shut off the flow of water, whereas control devices control pressure, temperature, and other properties of water. Typical control devices for piping include pressure-reducing valves, temperature and pressure relief valves, strainers, vacuum breakers, shock absorbers, and expansion joints. Based on their operation, several types of valves are available on the market including gate, globe, check, sill, cocks, and drain. They are usually made of cast steel, stainless steel, bronze, iron, plastic, or brass, the last being the most common because of its resistance to corrosion. Common valves used in building construction include gate and globe valves. Gate valves are used where full and unobstructed flow is required, whereas globe valves are used where close flow control is essential.

The last category of plumbing materials is plumbing fixtures attached to the piping or connection. These are often the only visible pieces of plumbing systems. Common plumbing fixtures include lavatories, sinks, laundry trays, faucets, bathtubs, and the like. Lavatories can be classified into three groups including wall-hung units, units installed in or as part of countertops, and pedestal types. Sinks commonly refer to kitchen sinks available with one, two, or three bowls to permit simultaneous use. Kitchen sinks are manufactured in porcelain-enameled cast iron or steel, stainless steel, or plastic. Likewise, laundry trays are made of the same materials as kitchen sinks but are larger and deeper. Faucets are designed to deliver the water flowing through the valve into a fixture. Bathtubs are made of various shapes, sizes, and materials. Three common shapes are recessed square with walls on three sides, sunken rectangular, and recessed rectangular. The most common and durable tub material is cast iron with a thick porcelain-enamel finish, but synthetic marble, acrylic-modified polyester, or similar homogeneous materials also can be found. Special sizes and shapes such as round and octagonal can be made using these materials.

15.7 LABOR FOR PLUMBING AND SEWAGE SYSTEMS

Plumbing and sewage systems are usually installed by the plumbing contractor's crews. These crews vary in size and can range from plumbers and their apprentices to pipefitters. Labor for plumbing and sewage systems includes, but is not limited to, plumbers, plumber apprentices, steamfitters, steamfitter apprentices, and steamfitter foreman, if required. Based on Means' *Building Construction Cost Data* (1999), there are various crew sizes depending upon the types of plumbing work. For building services piping, valves, plumbing, and fixtures, a crew of one plumber and one plumber apprentice is suitable for 150 mm diameter piping, whereas a crew of two plumbers and one plumber apprentice is required for larger-sized piping. For most heat generation, refrigeration, and HVAC work, a crew of one or two steamfitters and one steamfitter apprentice is required. For air distribution work, a crew of one or two sheet metal workers and one sheet metal apprentice is needed.

15.8 COST ESTIMATE FOR PLUMBING AND SEWAGE SYSTEMS

Typically, costs of plumbing and sewage systems can be estimated in two ways: as a percentage of the total cost of a project, or as the grand total of the cost for the installation of required materials. Plumbing estimates as a percentage of the total job will range from 3 to 12% depending upon the number and type of fixtures required. However, in general, buildings that require a low percentage ranging from 3 to 7% include assembly, warehouses, banks, office buildings, shops, stores, and industrial buildings, where plumbing can be easily installed. On the other hand, buildings that require a high percentage ranging from 8 to 12% include nursing homes, hotels, hospitals, high-rise buildings, and studio apartments. The nursing homes, hotels, and hospitals generally require plumbing spread out over a large area, whereas high-rise buildings and studio apartments require extensive installations of plumbing in relatively small living areas. This percentage method is common for general plumbing estimates, whereas special items and conditions should be of interest to the subcontractor only.

The second method for estimating labor costs involves the detailed estimate of the total cost for the installation of required materials. Even though this method requires more time, it is more accurate. The estimating procedure involves four major steps: studying plumbing plans and specifications, taking off material quantity and determining material costs, determining labor costs based on man-hours needed, and determining supplementary costs related to the job and office overhead. The summation of these costs without equipment cost is considered as the total cost for the plumbing system. The equipment and tools costs involved in the plumbing and sewage systems is relatively low compared to other costs, and most plumbing contractors already have the equipment and tools for the work. Due to the fact that equipment and tools are simple and reusable and there is little maintenance cost, these costs are not included in the cost estimate. The following subsections refer to the four steps in the cost estimate for plumbing and sewage systems.

15.8.1 Study Plumbing Plans and Specifications

To prepare an accurate detailed estimate on plumbing systems, the estimator must be familiar with plumbing systems including the DWV system, hot and cold water system, and others, and be able to read plumbing plans and riser diagrams and thoroughly understand the plumbing specifications. Prior to taking off the material quantity, the estimator must study the plans and specifications. The plot plan indicates the street where the project is to be built, the water main depth, the sewer line, where the sewer and water lines enter the structure, and where the potable water supply enters from the street. The schedule in the plan indicates several types of pipes, and the specifications indicate the type of pipe to be used. If a conflict between specifications and plans occurs, the specifications take precedence over the blueprints.

15.8.2 Take Off and Pricing Materials

After studying the plans and specifications, the estimator must prepare a list of all materials and equipment that will be required. All work must be listed on various take-off forms for piping, fitting, and plumbing fixtures because different types of materials are taken off by different units. If there are several plumbing systems to be taken off, the estimator can go through the following take-off sequence for plumbing: plumbing fixtures, equipment, sanitary DWV system, hot and cold water system, fire protection system, gas system, and sitework system.

To estimate piping, the estimator will determine the number of linear meters of each size pipe, and the number of pieces, sizes, and kind of fittings required. Each kind and size should be kept separately. After completion of the take-off step, the estimator can proceed to the pricing step by determining materials and installation costs using current market prices. After the cost of pipes has been calculated, the estimator can take off approximately 50 to 70% of the cost of the pipe to cover the cost of all fittings required. Otherwise, the estimator can proceed with a detailed estimate by pricing the fittings per unit.

During the estimation of piping and fitting, the estimator must also take into consideration the piping and fitting installation, especially the installation of underground plumbing. The estimator must consider the removal of excess earth, trenching, backfilling, and resurfacing of the ground. The estimator should consider a trench to be dug for the underground plumbing installation. The depth of the trench depends upon the depth of the frost line and the depth of the water main. The best method is to estimate the number of cubic meters of excavating required for piping. If the depths exceed a certain depth specified by an engineer, a shoring system must be included to prevent soil collapse. If the trench or shoring is required, the estimator must include the expense of the trenching, backfilling, and resurfacing of the street in the labor and equipment costs. Based on federal and state Department of Transportation regulations and city ordinances, sand or a certain type of soil must be used to replace the removed earth when the pipe is installed. After completing the estimate of piping and fitting, the estimator can determine the cost of the valves. All different size valves should be listed separately on the estimating forms, along with the amount required of each size. The estimator can then price the valves at the current market prices.

The next items to consider are fixtures that are listed with the unit price of each. The estimator can figure the quantity of fixtures such as sinks, lavatories, laundry trays, water closets, bathtubs, and shower baths from blueprints. These items should be listed separately and priced at the current market price as well.

15.8.3 Determine Labor Cost

Once all material quantities and their prices are determined, the estimator can proceed to the next step of determining the labor cost. The estimator typically allows a certain percentage of the cost of the materials to cover the labor cost of installing them, which varies with the type of building and grade of work. To estimate labor cost of roughing in, for average one- and two-story residences, the labor cost for roughing in the materials ranges from 75 to 85% of the cost of required rough-in materials. For apartment buildings of nonfireproof construction, the labor cost for roughing in can range from 90 to 100% of the total cost of rough-in materials, whereas for public garages the labor cost for roughing in can range from 90 to 110% of the rough-in materials cost. To compute costs for labor handling and placing fixtures, the labor cost of handling and placing fixtures ranges from 25 to 30% of the fixtures cost.

15.8.4 Determine Supplementary Costs

After computing the direct cost of labor and materials, the estimator should calculate the total of all the cost sheets and add these amounts in the project summary sheet to obtain the direct job cost. The final step for the plumbing estimate is to add supplementary costs to the direct job cost to obtain the total project cost. The supplementary costs include contingency, tools and miscellaneous items, sales tax, plumbing permits, insurances, overhead, and profit. The contingency includes the uncertain costs such as labor problems and acts of God, which generally vary between 1 to 5% of the total direct cost. Tools and miscellaneous items include cost for lost, stolen, or worn-out tools, which ranges from 1 to 2% of the total direct cost. Sales tax charged on material purchases varies from state to state. Plumbing permits refer to a charge assessed by municipalities for sewer connection, water service, and plumbing fixtures. Insurance cost varies from company to company. Overhead includes two major overhead cost categories: job and general overhead. Job overhead is a job-variable cost category used for running an office, which varies from 6 to 10% of the total direct cost. Job overhead covers costs for salesperson commission, contingencies, tool and material sheds, shop drawings and wiring diagrams, and permits, taxes, insurance, and bonds. On the other hand, general overhead includes all costs necessary to maintain the contractor business. The general overhead may vary from 1/2 shill to 10% of the total direct cost depending upon the size and efficiency of the organization. The last

cost item in the supplementary costs is profit. Profit refers to the return on the investment which typically varies from company to company as well.

15.9 INTRODUCTION TO HEATING, VENTILATION, AND AIR CONDITIONING

The mechanical contractor generally supplies shop drawings for the installation of the HVAC system, and is responsible for all fees and permits for the HVAC installation. Also, the mechanical contractor coordinates all mechanical work with the plumbing and electrical contractors when required. In some cases, the responsibilities of the mechanical and electrical trades may appear to overlap. The mechanical contractor can check the specifications as to where the responsibility of each lies. If there is no such matter in the specifications, owner and contractors should establish the responsibility prior to the contract. However, in many instances the recognized agreement between the trades is that the electrical contractor is responsible for the installation and maintenance of all wiring and conduits from the power supply to the disconnect controlling the HVAC unit.

And the mechanical contractor is in charge of the conduit installation, and maintenance of the units and internal controls and wiring, including the thermostat cable from the unit. An alternative approach is that the electrical contractor is responsible for the installation of the conduit and wiring from the power supply, the disconnect, and the internal wiring of the control system, whereas the mechanical contractor is liable only for the installation of the equipment and maintenance of the mechanical parts within the unit.

15.10 HEATING, VENTILATING, AND AIR CONDITIONING SYSTEMS

Heating, ventilating, and air conditioning systems use mechanical means to cool, heat, clean, humidify, and replace air within a building. To perform such work, energy sources of the systems include electrical, natural gas, coal, and/or oil, whereas heating and cooling media include water, air, steam, or chemical refrigerants. During the system design, the choices of energy source and heating and cooling media are based on the climate, building use, and local energy costs. Regardless of the design and its choices, each HVAC system usually consists of five basic components including heating equipment, cooling equipment, air handling equipment, exhaust systems, and piping.

Heating equipment is used to generate heat to warm the building. Heating equipment includes electrical heaters, heat pumps, gas and oil fired unit heaters, and boiler systems. Boiler systems may use either water or steam as a medium and electricity, gas, or oil as an energy source. Boiler systems include pumps, piping, expansion tanks, terminal units, vents, and controls. In addition to heating equipment, HVAC systems typically include cooling equipment. The primary function of cooling equipment is to cool a building by removing excess heat. Common cooling equipment includes water- and air-cooled chillers, water- and air-cooled condensers, cooling towers, coils, piping, pumps, and controls. Cooling systems use water, air, and/or chemical refrigerants as a medium and electricity as an energy source.

Another component of HVAC systems is air handling equipment. Air handling equipment moves conditioned air to the areas where it is needed in the building. This category includes duct work, fan coil units, air handling units, VAV boxes, fans, dampers, duct heaters, and coils. The next component of HVAC systems is exhaust systems. Exhaust systems can remove air to help control fumes, odors, and smoke. Common exhaust systems are duct work, exhaust fans, and ventilators. The last component of HVAC systems refers to piping. Piping is the means by which water, steam, and chemical refrigerants are distributed throughout the building. Piping systems include pipe, coupling, fittings, valves, and hangers.

15.11 LABOR FOR HVAC SYSTEMS

There are specific trades required for HVAC system installations, which include asbestos workers, boiler makers, insulation workers, plumbers, plumber helpers, sheet metal workers, and pipefitters. Asbestos workers are commonly involved in operations where pipe and ductwork insulation using asbestos-related materials and insulation of outside exposed surfaces of the air-conditioned spaces are carried out. Boiler makers are needed to use all necessary tools and materials to install the boiler units of a heating system. Insulation workers are required to install the heat insulators such as insulating fiberboard, plasterboard, rockwool, and woodwool to insulate the pipes or ductwork that carry the air-conditioning or heating media. Plumbers perform several tasks including shaping and fixing flexible metal roofing, cutting, bending, and joining water pipes, installing soil pipes and water systems, and sometimes gas pipes as well. The usual metals they work in are copper, lead, iron, zinc, and mild steel. Plumber helpers are usually required to help plumbers perform such work. Sheet metal workers are needed to shape sheet steel with a hammer or machines. They join sheets by riveting, seaming, welding, soldering, or brazing. They may be specialized as air-duct makers, chimney-cowl makers, or ventilator makers. Steamfitters, sometimes called pipefitters, are required to install pipes for water, steam, gas, oil, or chemical plans. The pipes may be screwed, flanged, loose-flanged or arc-welded.

15.12 COST ESTIMATE FOR HVAC SYSTEMS

Cost estimation for HVAC systems requires expert knowledge because most jobs are designed and laid out prior to the estimate. In residential and small commercial work, designers rarely provide information other than the type of system desired, the performance expected, and the kinds of material to be used. The mechanical contractor therefore needs to determine the heating loads and design a system to fit the required conditions before the estimating process takes place. On the other hand, larger work requires the heating contractor to develop details for piping, equipment connections, and controls. The estimator can acquire the necessary technical knowledge through daily participation and studying the HVAC estimate. Useful and current data and information can be obtained from manuals published by the HVAC associations. To perform a detailed cost estimate for HVAC systems, the estimator must consider the categories: (1) materials, (2) equipment, (3) labor, and (4) supplementary costs. The summation of these costs is the final total cost for HVAC systems. The estimating procedure therefore involves five major steps including studying HVAC plans and specifications, and determining the four costs, as described below.

15.12.1 Study HVAC Plans and Specifications

To perform a detailed cost estimate for HVAC systems, the estimator must study the plans and specifications to familiarize herself with the required HVAC systems. The plans should show the proposed HVAC features and system components. As a rule of thumb, if a conflict between specifications and plans occurs, the specifications take precedence over the blueprints. The estimator must ensure that everything needed for the HVAC systems will be included in the final cost. A checklist can be developed for this purpose, and if any item seems to be out of the estimate according to the check against the shop drawings and specifications, the estimator can contact the general contractor or designer for further clarification.

15.12.2 Take Off HVAC Materials and Compute Materials Costs

Major types of materials used in any HVAC system include pipes, fittings, insulation materials, and ducts. Pipes can be made of seamless alloy steel, carbon steel, and carbon–molybdenum alloy steel, and major pipe connections include threaded joints, bolted flange joints, welded joints, and expansion joints. Pipes and pipe connections account for approximately 20 to 30% of the total cost of an HVAC system. To perform a detailed estimate, pipes can be measured in meters and should be separated by types, sizes, and fittings. Also, expansion joints and loops and pipe supports should be noted by types and weights of pipes. The same type of estimate sheet used for the plumbing may be used for the HVAC estimate. In an HVAC system, the main types of pipings are chilled water piping, condensate piping, and hot water piping. The chilled water pipe circulates from a chiller that is usually in the building's basement up to the air handling units, usually high up in the building. The total length of the chilled pipes is found by adding the length required in the mechanical room plus the length of the flow and return to and from the air handling units. The connections to the air handling units are measured separately and each hookup includes a short length of piping with valves, flanges, and a strainer. The condensate water pipe is measured between the chiller and condenser in the cooling tower and from the chiller to the cooling coils. The hot water pipe is sized and measured in the same way as the chilled water pipe. Generally, the supply pipings and the return pipings are of the same sizes and the same lengths so measurement is simplified.

The insulation materials consist of rock wool, asbestos pipe covering fibrous glass slabs, and insulating cements. The cost of piping insulation may be taken as a percentage of the total piping costs, usually about 20 to 28%. Another option for the insulation estimate would be to price the insulation taken from the piping quantities on a unit price basis. Current price of the insulation materials must be obtained from the market. To estimate ductwork, the estimator can take off sheet metal ducts for supply air, return air, and exhaust air. Historical estimating data from previously completed projects are essential in computing the quantity of sheet metal to be used. The weight of the ductwork is related to the system's capacity for the air system supply, and a weight factor is commonly applied to the total system capacity to obtain the total weight. In a detailed estimate, sheet metal ductwork is taken off by sizes of straight runs and by types and sizes of fittings.

15.12.3 Fixed Equipment Costs

HVAC equipment in machine and equipment rooms includes chillers, pumps, and exchanger, and equipment in isolated areas includes heaters, fans, and collectors. HVAC equipment costs are estimated using assemblies' costs where possible and actual local unit costs are necessary. These costs must be adjusted using a modifier based upon its quality and complexity. The range for the modifier is from 0 to 5% for economy installations, 5 to 15% for good quality work, and 15 to 25% for excellent quality work with great complexity.

15.12.4 Labor Costs

Labor costs for an HVAC system are estimated using assemblies' costs and unit costs. In both cases the labor costs are incorporated into the total cost on the basis of work hours used for any particular job item within the planned system. The work-hour standards for the installation of HVAC equipment can be found in many publications such as Means' and Walker's construction cost files.

15.12.5 Estimate Supplementary Costs

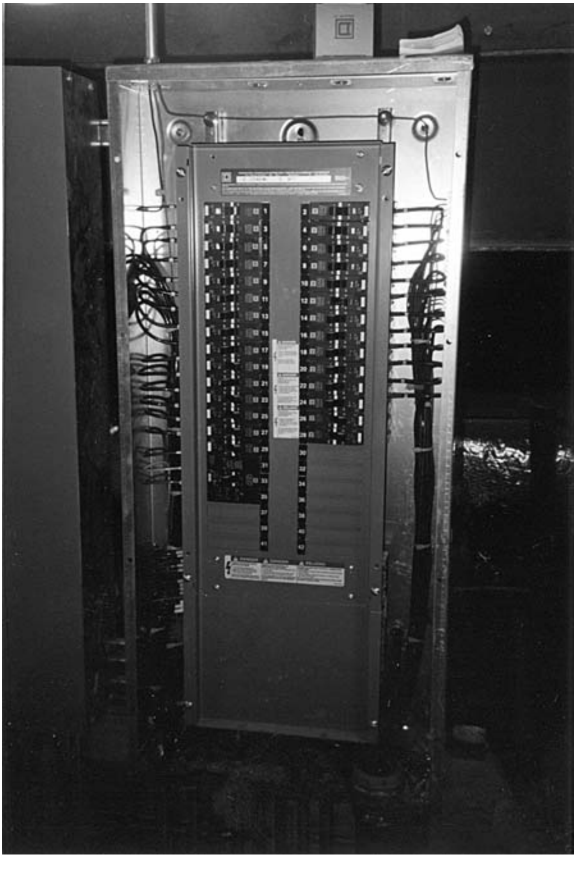
After determining the direct costs of materials, equipment, and labor, the estimator needs to compute the total direct cost, which is the summation of all the obtained costs. The final step for the estimate is to add supplementary costs to the direct cost to obtain the total project cost. The supplementary costs for HVAC systems involve contingency, miscellaneous items, sales tax, permits, insurances, job overhead, and profit.

15.13 REVIEW QUESTIONS

1. What are the three general tasks of plumbing systems?
2. Please explain rough and finish plumbing.
3. What are the five categories of plumbing systems?
4. What are the differences between wet and dry sprinkler systems?
5. What are the major plumbing materials?
6. What are the factors affecting cost of plumbing materials?
7. What are the fundamental functions of HVAC systems?
8. Please indicate the major trades involved in HVAC system installations.

16

Electrical Work



16.1 INTRODUCTION TO ELECTRICAL WORK

If the shell and structure of a building are like the skin and bones of a body, then the mechanical and electrical systems of the building are considered the equivalent of the body's nervous and circulatory systems. Generally, a modern building needs electricity for lighting, power, operating building services, and air conditioning. Without electricity, most buildings cannot serve their intended functions.

Electrical work is a specialized trade and is often subcontracted out to specialized electrical subcontractors, either through a single contract with the general contractor or under a separate contract with a specialist. For a single contract, the owner has a single contract with a general contractor who is responsible for all construction work, including the electrical work. The selected electrical subcontractor commonly submits a lump sum price for the electrical work to the general contractor, who then adds his own overhead and profit to the estimate. The general contractor then submits the total amount in his bid price for the project. Alternatively, the electrical subcontractor may be required to tender the bid directly to the owner and be contracted directly with the owner. Under the latter condition, less responsibility is placed on the general contractor for the work performance by the electrical contractor.

For a small project, there may only be one set of specifications and plans for the whole project, with electrical specifications and plans included in the set. However, typically electrical specifications and plans often come in their own packages as separate sets of documents. The electrical plans include the electrical symbol legend, fixtures and devices schedules, various floor plans showing where different electrical components are required, and may also include drawings of some electrical details.

16.1.1 Codes and Regulations in Electrical Work

The design and installation of an electrical system is subject to compliance with community, state, and/or national codes and standards. This covers the entire electrical system, including its design, layout, equipment, materials, and the methods used to install it. An adequate wiring installation must conform to applicable safety regulations. The standard for electrical safety is the National Electrical Code (NEC), developed and published by the National Fire Protection Association (NFPA). Most local ordinances and state building codes are based on the NEC or make it part of their requirements by reference. The local codes may expand the requirements, but generally the NEC establishes the minimum standards. The NEC is one of the most widely adopted codes in the world and is used in every state in the US.

Contract specifications will often state the codes to be considered as part of the specifications. In addition, the specifications will also dictate conformance of the electrical components to the standard requirement, such as those set by the National Electrical Manufacturers Association (NEMA) and Underwriters Laboratories, Inc. (UL). Testing of electrical components and installations may also be governed by codes from the National Electrical Testing Association (NETA) and applicable UL and NEMA standards. In addition to the NEC, the installation of all electrical components (such as transformers, generators, motors, switchgear, metering, and disconnects) can also be governed by codes established by utility companies.

16.1.2 Components of Electrical Work

Electrical work can be classified into four general categories as shown in Figure 16.1: service, distribution, branch work, and devices/loads. The service category deals with feeders, meters, and main disconnect switches. The distribution category includes the panelboards, switchboards, and circuit breakers. The branch work category refers to the circuitry that links the distribution equipment to the devices/loads and consists of raceways, conduits, and wires. The devices/loads category is the most visible part of the electrical work, which includes the receptacles, switches, and lighting fixtures.

Electrical service installation is usually carried out in two phases: the contractor's portion followed by the utility company's portion. The extent of the work performed by each party varies for each locality. Generally, the contractor is usually required to install and set the main disconnect switches and the meter pans before the utility company can perform the installation of the primary feeder, connecting it to the meter pan and installing the meter.

Electrical work can also be classified as rough electrical work and finish electrical work. Rough electrical work deals with the electrical components that are generally not visible, such as the installation of raceways, conduits, and wiring. Finish electrical work deals with the more visible items such as the installation of the wall outlets, switches, and light fixtures. Rough electrical work can take place throughout the project, such as the laying of conduits during site preparation and the installation of conduits or wiring within the walls during wall

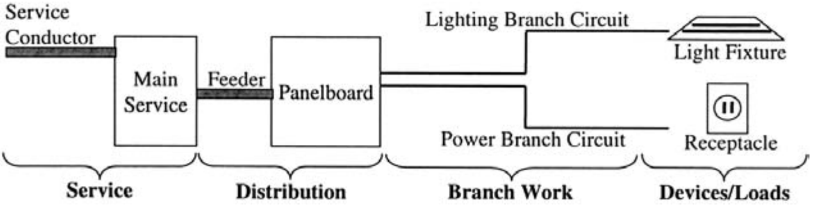


FIGURE 16.1 Electrical work components.

framing. Finish electrical work, on the other hand, is executed toward the end of the project after structural construction and most of the finishing are completed.

16.1.3 Electrical Symbols

The indications of items on the drawings can be facilitated by the use of symbols. Symbols for electrical work are based on standards recommended by the Institute of Electrical and Electronics Engineers (IEEE). Figure 16.2 shows a sample of electrical symbols commonly used. Most electrical drawings include the legend for the symbols used in the drawing. It is important to check the electrical symbol legend in the drawings as symbol usage may vary from draftsman to draftsman. Familiarity with applicable codes and standards and the symbols used on the drawings is essential for estimators performing take off for electrical work.

16.1.4 Coordination Requirements

Electrical work is performed in many stages throughout the construction project. Although some portions of the electrical work may have less dependency on other construction operations, such as the installation of the light fixtures, many electrical installation activities, especially electrical rough-in, can be highly integrated with other critical construction work. For example, the installation of embedded conduits in the concrete floor slab requires the electrical subcontractor to work alongside other parties responsible for the floor construction. The floor decking and formwork must be constructed before the electrical subcontractor

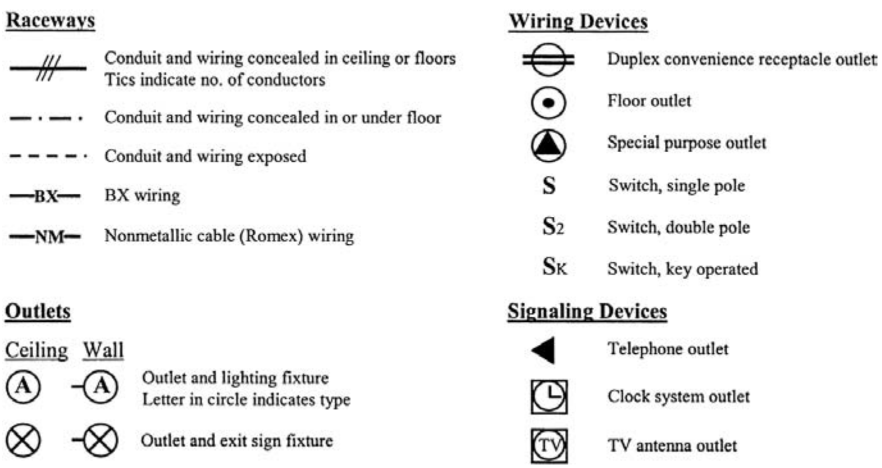


FIGURE 16.2 Electrical symbols.

can start installing the embedded conduits. This installation of the conduits must also be coordinated with the installation of the steel reinforcement and other required embedded items. Only after all the embedded items are properly installed and inspected can the concrete be placed. In this example, the interdependency of the many construction activities and the interactions between the different crafts in the project are clearly illustrated. Consequently, the importance of coordination between the work and the parties involved can also be seen.

Coordination issues can be addressed at coordination meetings. The general contractor or owner may mandate participation in the coordination meetings by all the parties involved so as to minimize the likelihood of delay due to poor work coordination. Although coordination meetings are helpful in facilitating construction operations, the meetings can incur valuable time that must be considered along with other required meetings.

16.2 TAKE-OFF PROCEDURES FOR VARIOUS ELECTRICAL COMPONENTS

The take-off procedure must produce a list of material items by type, size, quality, and quantity required. The following subsections list the electrical components that are usually included in electrical work and present the associated take-off methods.

16.2.1 Service Equipment

Service equipment consists of a circuit breaker or switch, fuses, and their accessories. Service equipment is generally located near the point where power supply conductors enter the building and provides the means to control or cut off power to the building. Take off for the service equipment involves the identification of the type of material specified and the number of units required. Service equipment is connected to the distribution equipment via a feeder. The feeder is defined as the conductor between the service equipment and the final branch-circuit overcurrent device, such as a panelboard or switchboard.

16.2.2 Distribution Equipment

Distribution equipment includes the panelboard or switchboard. The panelboard can be a single panel or an assembly of a group of panel units. It includes the buses and automatic overcurrent devices, and can come with or without switches for controlling the branch work circuits that supply power to the rest of the building. The panelboard is designed for placement in a cabinet mounted against the wall and is accessible only from the front. The switchboard is similar to the panelboard, except that the switches and other devices can be mounted on both sides, front and rear of the switchboard. Generally, the switchboard is accessible on both sides and is not intended for installation in a cabinet. Panelboards and switchboards are typically supplied by manufacturers as a package that includes most of the components. The take off for distribution equipment is to identify the type and all the material specifications required and to determine the total number of units required.

16.2.3 Branch Work

Power is distributed throughout the building via the electrical branch work or branch circuit. A building's electrical branch circuit links the distribution equipment to the devices/loads system. Electrical branch work consists of raceways and conductors or wiring.

16.2.3.1 Raceways

A raceway is an enclosed channel designed expressly for holding electrical conductors, such as wires, cables, or bus bars. Many types of raceways have been developed for the many applications in building construction projects and include cable trays, conduits, underfloor ducts, surface metal raceways, and wireways. Cable tray systems, shown in Figure 16.3, are prefabricated metal raceway sys-

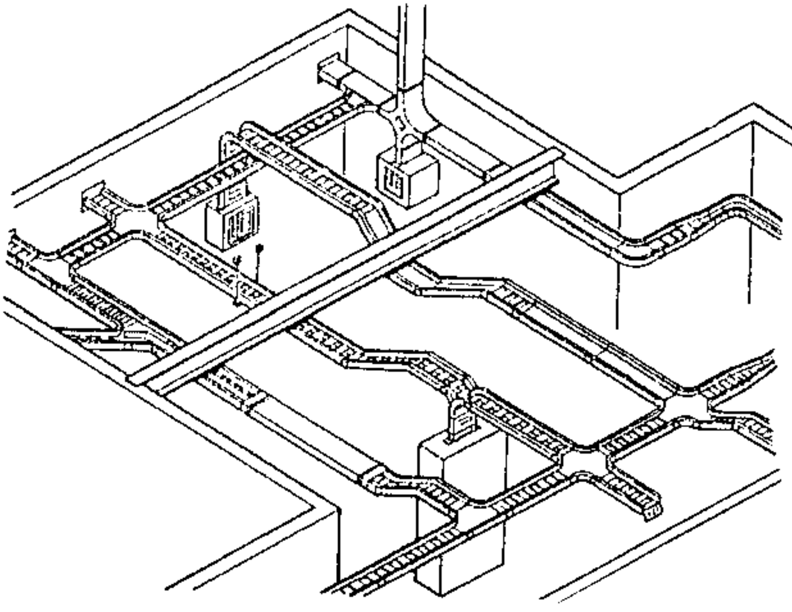


FIGURE 16.3 Cable trays. (From Means, 1986.)

tems usually made of galvanized steel or aluminum. The three basic types of tray are ladder, trough, and solid bottom. A tray system is constructed by assembling lengths of trays and various fittings to form a continuous rigid support system for cables and wiring.

Conduits are pipelike elements designed for housing electrical wires (see Fig. 16.4). The most common conduit in residential and commercial building construction is electrical metallic tubing or EMT. EMT is used extensively due to its light weight which enhances both its handling and workability. In addition, conduits can be made from other materials to suit various construction applications. For embedded conduit in concrete slab, PVC, rigid galvanized steel, or intermediate metallic conduit are typically used. Flexible conduits, which consist of interlocking spirals of steel armor, are used where frequent changes in direction may be required along the length of the installation, or in an area that is subject to vibration.

An underfloor duct such as shown in Figure 16.5 is another type of raceway installed in the floor system. Unlike embedded conduits, which are generally designed to carry cables or wires over long distances, underfloor ducts are designed more for distribution functions, to make power and communication wiring

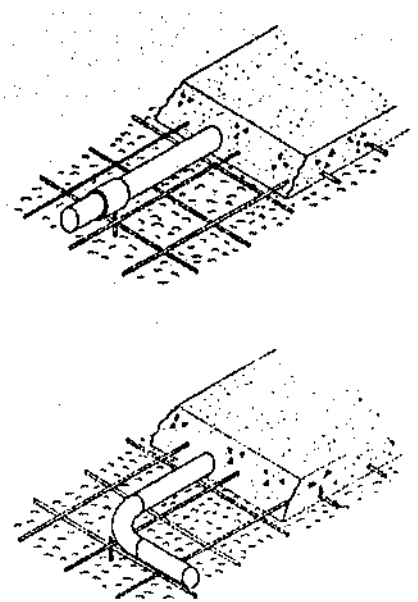


FIGURE 16.4 Conduit installation in concrete slabs. (From Means, 1986.)

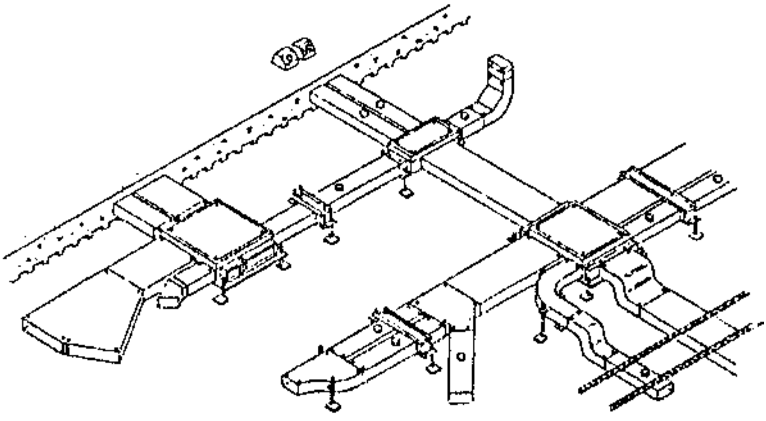


FIGURE 16.5 Underfloor ducts. (From Means, 1986.)

available at numerous locations within a room. Underfloor ducts are used almost exclusively in office areas.

An alternative to underfloor ducts is a surface mounted metal raceway. A surface metal raceway or wiremold can be installed on walls or floors where it would be too costly or difficult to install the raceway within the wall or floors. Surface metal raceways, shown in Figure 16.6, are available in many sizes and configurations.

A wireway (shown in Fig. 16.7) is a raceway fabricated from sheet metal into channels with hinged or removable covers for housing and protecting electric wires and cable. Generally, wireways are permitted only for exposed work.

The take off for various raceways is generally in linear meters of run length. In addition to the run length, the number of turns, elbows, and special fittings (such as splits), must also be counted and considered in the take off so that both the material and labor costs can be accurately calculated.

16.2.3.2 Conductors

Electrical current is carried and distributed by conductors. Electrical wire is made of either a copper or aluminum conductor with an insulating jacket. On the other hand, cable refers to a wire with two or more conductors, which are encased in a protective covering. The protective covering can be metallic (as in an armored cable), or plastic or cloth (as in a nonmetallic-sheathed cable). Wires and cables are normally rated for voltage and insulating materials. The size of the wire or cable used will affect the size selection of appropriate conduits. Wires and cables are taken off by length in meters.

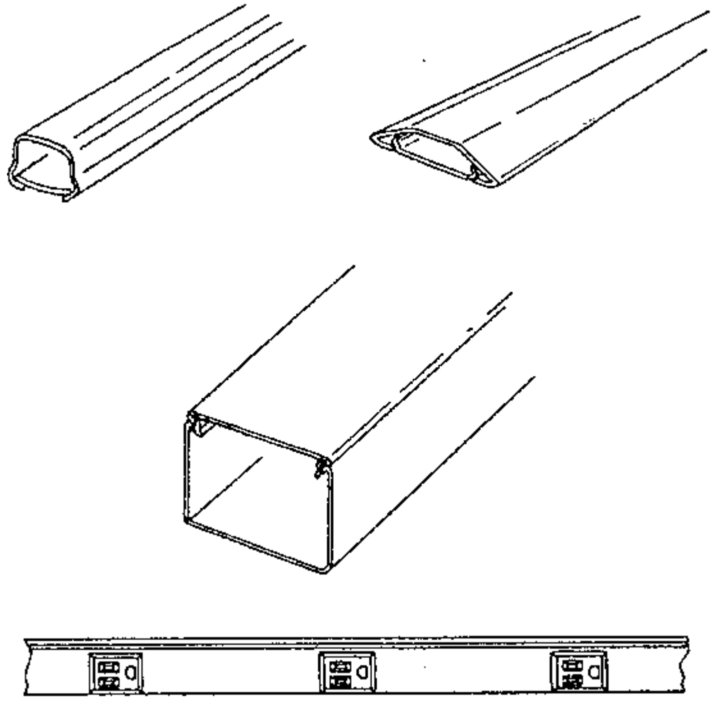


FIGURE 16.6 Surface metal raceways. (From Means, 1986.)

16.2.4 Devices and Loads

Outlets are points on the wiring system at which current is taken to supply the utilization equipment. Outlets are generally classified as lighting or receptacle outlets. Other types of available outlets include those for fans, clocks, and other permanently installed equipment. Devices are units of an electrical system intended to carry, but not utilize, electrical energy. Common electrical devices are light switches and receptacles. A receptacle is a contact device installed at an outlet for the connection of a single attachment plug. Loads refer to the units in the electrical system that utilize electrical energy, such as the light fixtures. Devices/loads are taken off by the quantities of the electrical unit, such as the number of receptacles, cover plates, switches, or light fixtures.

16.2.5 Electrical Work Take Off

There are generally two take-off methods in electrical work. The first involves the determination of the total number of pieces required for the selected element.

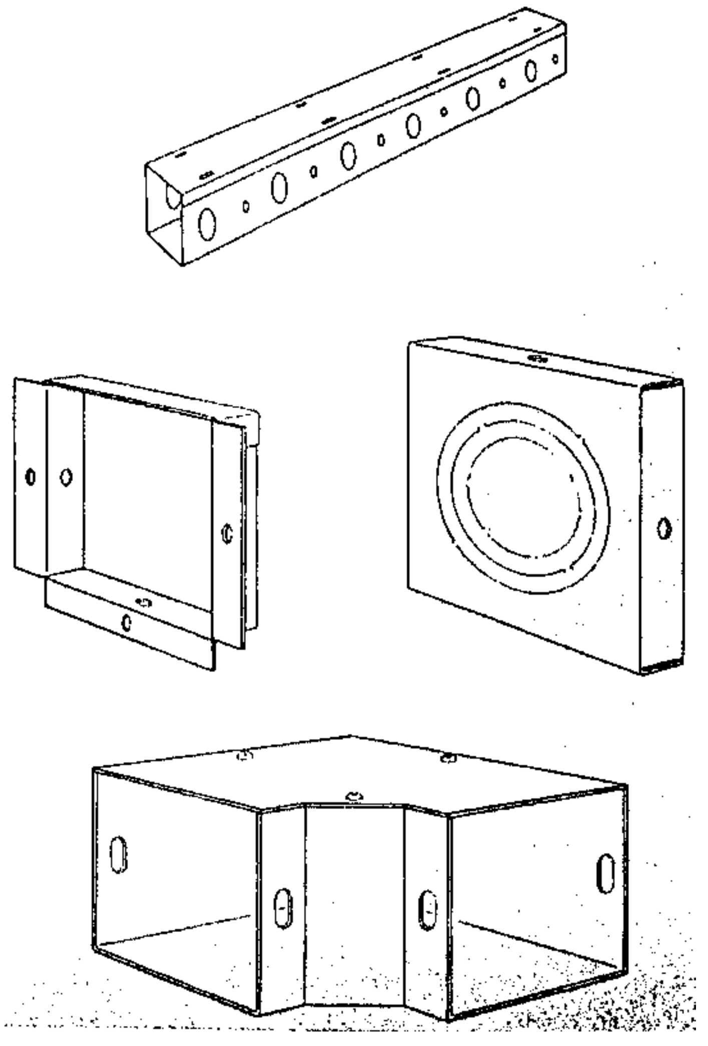


FIGURE 16.7 Wireways. (From Means, 1986.)

The other take-off method, which is more applicable to raceways and conductors, involves determining the total length of the item under consideration.

Most electrical components are taken off by the first method, which is by counting the number of required devices or equipment. The associated take-off unit is "each." This method is applied toward service equipment, panelboards, switchboards, switches, receptacles, and light fixtures. This take-off procedure identifies each item by going through the plans. From the various plan views, the electrical components are identified by symbols with or without designations. When an element has more then one type available in many varieties, such as light fixtures, designations may accompany the symbol to identify the types used. In this case, a schedule for the element is provided in the drawing to identify and describe the various types of associated elements. The take off is carried out for each type, and is often tabulated floor by floor and then the total quantity for each type is calculated. It is recommended that the drawing be marked as the take off is carried out so as to minimize omissions or duplications. Colored pencils are used for high visibility. Many colors can be used for the various take offs, such as green for fixtures take off and red for receptacles take off. A mechanical counter is also helpful in speeding up the counting process while at the same time minimizing the likelihood of counting error.

The second take-off method is typically applied to raceways and conductors where take off is by lengths. Generally, the electrical drawings only show where panelboards, switches, receptacles, and light fixtures are located, but do not show the layout of the raceways and conductors. Determining the layouts of the raceways and conductors is the first critical step in estimating electrical work. The electrical estimator must first design the layout of the branch work by determining where the panelboard and the devices/loads are located and how power is distributed to all the elements. The raceway layouts are then drawn on the plans and the run length can be measured off from the drawing with a scale. For raceway take off, it is also important to note the number of turns, elbows, and special fittings required so as to account for the additional materials and work involved with these fitting installations. It is important to determine as accurately as possible all the fittings involved as the number of fittings can significantly affect the material costs as well as the productivity and cost of the raceway installations.

In taking off for wires and cable, the estimator must identify the wire and cable types. The lighting and power plan will often specify these types, as well as provide for the locations of outlets from which the wires are to be connected. The branch circuit take off can be broken into lighting circuit branch take off and power circuit branch take off. The estimator will be required to plan the wire routing for the circuits. A rotometer, an instrument that records the length of a path trace, is sometimes used as an aid for length take off for branch circuits. Rotometers are made in a variety of scales and can permit direct reading from the construction plans if both use the same scale. As the rotometer traces the path of the circuit, the length of the circuit is measured. The procedure is repeated for all the circuits having the same type of wires or cables. Only the total length is typically recorded. In tracing the circuit with a rotometer, the estimator should consider the nature of the building since it will affect the routing of the wire and conduits. Allowance should be made for routing around stairwells and elevators. In addition, in tracing with the rotometer from point to point the estimator should not follow a straight path but should trace the rotometer in a gentle arc from fixture to fixture. In this way extra footage is added to cover the cost of fitting, hanger, and bends.

In addition, take off for conduits and wires must allow for extra lengths for vertical run distances for drop or riser lengths to the devices/loads installed on the wall. The plan view generally gives the location of the outlet on the wall, but the height of the outlet on the wall must be determined from the specifications or other elevation detail drawings. The easiest method for computing this extra length is to determine the switch/receptacle count and multiply by the distance from switch/receptacle to ceiling or floor.

When designing the layout for raceways, conduits, and wiring, the electrical estimator should consider and coordinate his routing with the mechanical and plumbing subcontractors. Although formal coordination between the parties usually takes place after the bids have been awarded, it would be wise to anticipate the route that the other contractors will use.

16.3 PRICING ELECTRICAL WORK

Take off is a crucial process since the quantities determined will be used later for pricing the electrical work. A sample of a completed pricing form for electrical work can be seen in Figure 16.8. In addition, Table 16.1 provides estimated costs for electrical work in average dollars per square meter for various types of building construction projects. The cost of electrical work is a significant amount, generally representing about 10% of the total project cost.

16.3.1 Items Included in Electrical Work

Like other construction divisions, the cost of electrical work includes materials, labor, and equipment costs. The materials costs for electrical components can be determined from current wholesale prices, direct quotations from suppliers for special items (such as distribution equipment and lighting fixtures), and subcontract prices for special systems (such as grounding work). Materials for rough electrical work, such as distribution equipment, raceways, and wires, are purchased during the early phases of the project, whereas the materials for finish electrical work, such as receptacles, switches, and the various light fixtures are generally purchased and brought into the job toward the final phases of the project.

Labor costs are always the most unpredictable part of all construction operations. Electrical work is performed by electricians. Getting the prevailing rate for an electrician can be easy, but determining the productivity for installation can be very difficult. For electrical work, equipment costs are usually a small portion of the total direct job cost and are generally associated with the cost of

Company Logo	Pricing	Date: Nov. 22, 2000	Sheet No. 1 Of 1

Project Title: Service Station — Project No.: A 103

Take Off By: Keith Johnson — Approved By: John Doe

Code*	Description	Quantity	Unit	Material U.P.	Material Total	Labor U.P.	Labor Total	Equipment U.P.	Equipment Total	Subcontract U.P.	Subcontract Total	Total U.P.	Total
16440 720 2200	Panelboard, 4 wire, 120/208 V CB 225 A main 32 circuits	1	each	1550	1,550.00	735	735.00					2285	2,285.00
16132 205 1870	Conduit, rigid galvanized steel 50 mm Ø	12	m	17.55	210.60	19.25	231.00					36.80	441.60
16132 205 5000	EMT Conduit 15 mm Ø	730	m	1.18	861.40	5.10	3,723.00					6.28	4,584.40
16120 900 0280	Wire 600V, type THW, copper, stranded 2/0	35	m	3.75	131.25	2.98	104.30					6.75	236.25
16120 900 0920	Wire 600V, type THWN-THHN, copper solid #14	360	m	0.13	49.40	0.67	254.60					0.80	304.00
16120 900 0940	" " #12	1420	m	0.17	241.40	0.79	1,121.80					0.96	1,363.20
16120 900 0960	" " #10	310	m	0.26	56.80	0.80	247.70					1.15	356.50
16120 900 1350	Wire 600V, type THWN-THHN, copper stranded, #6	15	m	0.84	12.60	1.33	19.95					2.17	32.55
16139 700 4360	Receptacle devices GFI with #12/2, EMT & wire	8	each	45.00	360.00	62.50	500.00					107.50	860.00
16140 910 0200	Wiring device, toggle switch, quiet type, 15 A	16	each	4.63	74.08	6.60	105.60					11.23	179.68
16140 910 2460	Receptacle, duplex, 120V, grounded, 15 A	45	each	1.14	51.30	6.60	297.00					7.74	348.30
16136 600 0150	Outlet boxes - square, 102 mm	62	each	1.98	122.76	13.20	818.40					15.18	941.16
16136 600 0300	Outlet boxes - square, 102 mm, plastic rings	62	each	1.11	68.82	4.13	256.06					5.24	324.88
16510 440 2300	Fluorescent, strip fixture, surface mounted 1200 mm long, two 40 W RS	54	each	28	1,512.00	33	1,782.00					61	3,294.00
16410 800 2710	Safety switch, Heavy duty, 240V, 3 pole NEMA 1, 30A	1	each	106	106.00	82.50	82.50					188.50	188.50

SHEET TOTAL	MATERIAL	LABOR	EQUIPMENT	SUBCONTRACT	TOTAL
	5,439.11	10,310.04			15,740.97

* Masterformat, Uniformat, WBS, other, etc.

FIGURE 16.8 Sample pricing form for electrical take off.

TABLE 16.1 Electrical Cost Component for Various Building Types

Building types	Unit cost ($/m²) Electrical cost	Unit cost ($/m²) Total cost	Total cost (%)
Apartments, low-rise (1 to 3 story)	35.00	580.00	6.70
Apartments, mid-rise (4 to 7 story)	58.00	735.00	7.50
Apartments, high-rise (8 to 24 story)	61.00	845.00	7.70
Auditoriums	80.50	975.00	9.00
Automotive sales	64.50	600.00	10.00
Banks	133.00	1,300.00	10.30
Churches	80.00	880.00	8.80
Clubs, country	85.50	875.00	9.30
Clubs, social	75.50	850.00	9.50
Clubs, Y.M.C.A.	76.00	880.00	9.20
Colleges: classrooms, administration	110.00	1,150.00	10.00
Colleges: science, engineering, laboratories	171.00	1,675.00	9.60
Community centers	82.00	915.00	9.40
Court houses	116.00	1,250.00	9.80
Department stores	63.50	545.00	12.20
Dormitories, low-rise (1 to 3 story)	73.50	940.00	8.90
Dormitories, mid-rise (4 to 8 story)	109.00	1,225.00	8.90
Factories	69.50	525.00	10.60
Fire stations	84.00	920.00	9.20
Fraternity houses	100.00	905.00	9.90
Funeral homes	60.50	1,000.00	4.40
Garages, commercial (service)	59.00	645.00	9.00
Garages, municipal (repair)	67.50	820.00	8.00
Garages, parking	14.85	335.00	5.20
Gymnasiums	63.50	850.00	8.30
Hospitals	179.00	1,600.00	12.00
Housing—for the elderly	63.50	795.00	8.50
Housing—public (low-rise)	48.00	735.00	6.60
Jails	195.00	1,775.00	11.40
Libraries	109.00	1,050.00	11.00
Medical clinics	98.00	1,000.00	10.00
Medical offices	87.50	940.00	9.80
Motels	58.50	720.00	8.20
Nursing homes	94.50	970.00	11.00
Offices, low-rise (1 to 4 story)	72.00	785.00	9.60
Offices, mid-rise (5 to 10 story)	64.50	825.00	8.20
Offices, high-rise (11 to 20 story)	61.00	1,050.00	7.00
Police stations	164.00	1,325.00	11.90
Post offices	90.50	975.00	9.60
Power plants	825.00	7,300.00	12.80
Research: laboratories, facilities	184.00	1,375.00	12.00

TABLE 16.1 Contined

Building types	Unit cost ($/m²) Electrical cost	Unit cost ($/m²) Total cost	Total cost (%)
Restaurants	121.00	1,175.00	10.60
Retail stores	52.50	580.00	9.90
Schools: elementary	81.50	840.00	10.00
Schools: junior high, middle	84.00	855.00	9.40
Schools: senior high	97.00	855.00	10.10
Schools: vocational	87.00	855.00	11.20
Sports arenas	72.50	715.00	9.80
Supermarkets	71.00	580.00	12.40
Swimming pools	93.50	1,350.00	8.00
Theaters	79.00	860.00	10.00
City halls, municipal buildings	90.50	945.00	9.50
Warehouses, storage building	31.00	390.00	7.30
Warehouse, offices	33.50	450.00	7.70

Source: Means, *Building Construction Cost Data, Metric Edition*, 2000.

lifting equipment or an elevating platform. The materials costs for electrical work, on the other hand, usually account for about 60% of direct job costs.

The total bid package prepared by the electrical subcontractor will include all the direct costs for the work, jobsite overhead, general overhead, and profits. Included as an indirect cost under jobsite overhead would be costs for permits and inspections for electrical installations. Generally, the electrical contractor will be required to obtain any permits and make arrangements for official inspections of electrical installations.

16.3.2 Factors Affecting the Productivity and Costs of Electrical Installation

As discussed in Chapter 4, numerous factors can affect the productivity and cost of any construction operation and installation. For electrical work, these main factors should be considered while performing the estimate:

1. Weather conditions;
2. Site logistics: layout, high-rise or low-rise; and
3. Degree of site congestion or other adverse conditions.

These factors can have a serious impact on the operations and productivity of electrical installation. However, these factors are difficult to quantify; thus the

Table 16.2 Adjustment Factor for Height of Installation

Installation height	Labor cost adjustment factor
under 4.5 m (15 ft)	1.00
4.5 m (15 ft) to 6.0 m (20 ft)	1.10
6.0 m (20 ft) to 7.5 m (25 ft)	1.20
7.5 m (25 ft) to 9.0 m (30 ft)	1.25
9.0 m (30 ft) to 10.5 m (35 ft)	1.30
10.5 m (35 ft) to 12.0 m (40 ft)	1.35
over 12.0 m (40 ft)	1.40

Source: Means, *Electrical Estimating*, 1986.

judgment and experience of the estimator will be critical in assessing them. In addition to the above general factors, the height of installation is another important factor that can affect the cost of electrical installation. Higher installation work generally decreases work productivity and increases the installation cost. Productivity is usually lower due to slower materials flow and increased materials handling as the materials must move up and down to the points of installation. Mobility of the electrician is also severely restricted in above-ground installation. Table 16.2 provides some suggested factors for adjusting labor costs for above-ground electrical installations.

16.4 REVIEW QUESTIONS

1. Name one of the most important codes governing all electrical safety standards and installation practices.
2. What are the four general categories for electrical work?
3. What is rough electrical work? List some of the components included in this portion.
4. What is finish electrical work? List some of the components included in this portion.
5. Describe how electrical installation can affect other construction work.
6. Why is it important, and a good practice, to always check the symbol legends when performing electrical take off?
7. What are the two general methods for taking off electrical work?
8. List some of the steps and methods used by the estimator to minimize the likelihood of making an error in taking off electrical work.

9. What is a rotometer? How is it used?
10. Why must allowance be considered in the wiring and conduits take off?
11. What are some of the factors that can affect the productivity and cost for electrical installation work?
12. Why are installation costs higher for above-ground installation than for normal installation?

17

Jobsite Overhead

17.1 INTRODUCTION: THE COST OF DOING BUSINESS

To accommodate various site situations, it is a good idea for a construction company to develop comprehensive checklists for general jobsite requirements regarding its specialized line of business. Such a list would aid the estimator, ensuring that no important cost items are forgotten under the time pressure of finalizing the bid. Visits to the jobsite by an experienced estimator and a principal of the firm are a must after a preliminary review of drawings and specifications. A site investigation report can be used to collect needed information useful for organizing the future jobsite and, above all, to determine prior bidding costs.

Certainly not all items are relevant for each report. If the project is in a remote area or in a harsh environment (cold, heat, floods, etc.), more items will be checked and questions answered during the site visit. Later, they will be converted to line items with an estimated cost toward jobsite overhead. Any missing items will reduce overall profit. A prudent contractor and subcontractor will not be satisfied applying a fee to the direct estimated costs, a fee that is supposed to cover jobsite overhead and markup. The shaded area in Figure 17.1 indicates only those items requiring collection during the primary site visit. They are priced later in the office.

Estimated total jobsite overhead costs will become the baseline budget for jobsite overhead expenditure control. These items might include:

1. Jobsite personnel wages and fringe benefits;
2. Jobsite personnel project-related travel expenses;
3. Outside contracted engineering support (surveying, materials testing, etc.);
4. General use equipment for the benefit of the general contractors and subcontractors (cranes, hoists);
5. Field buildings;
6. Site utilities for the job duration;
7. Horizontal structures (roads, parking, fences, and gates);
8. Temporary environmental controls requirements;
9. Winter and summer protection of completed works or works in progress;
10. Related camp facilities for remote jobs;
11. Jobsite production facilities (concrete batching plants, quarry, various shops);
12. Protective aids for workers (gloves, hard hats, etc.) during construction and final cleanup of the project; and
13. Bonds, insurance, permits, and taxes required in the contract general conditions.

Figure 17.2 is an example of calculating jobsite overhead costs for a hypothetical project. Blank estimating forms can be found in Appendix 2 and with

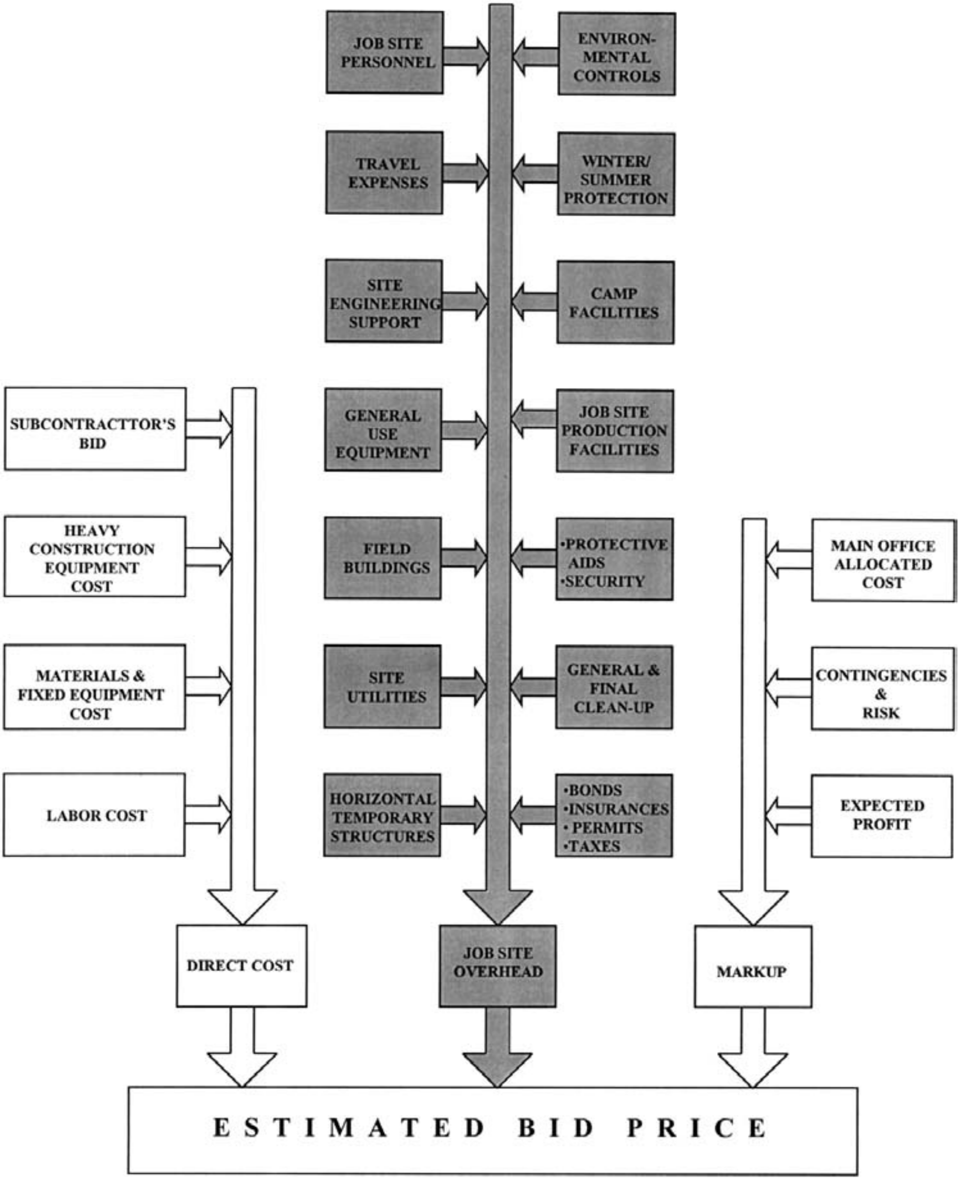


FIGURE 17.1 Total components of costs within a bid.

Company Logo

Project Site Overhead

Project Title HIGH RISE MULTY FUNCTION BUILDING. Project No. XXXX

Take Off By CMP AUGUST /2000 Approved By J.D.

Description		Quantity	Unit	Mat'l/Equip. Unit	Labor Unit	Subcontract Total	Total
• Superintendence							
Superintendent	1245/W	1 x 80	WEEK		99600		99600
Project Manager	1500/W	1 x 80	WEEK		120000		120000
Engineers	800/W	2 x 80	W		128000		128000
Timekeeper	600/W	1 x 70	W		42000		42000
Material Clerk							
Clerical							
Safety							
Watchman							
First Aid							
JOB DURATION	15 MONTH						
• Travel Expenses							5000
• Engineering							
Layout						1500	1500
Quantity/Inspection							
Drawings						500	500
Schedule						10000	10000
Soil Testing						2000	2000
Material Testing						3000	3000
Concrete Testing						1000	1000
Page Total				Mat'l/Equip.	Labor 389600	Subcontract 18000	Total 412600

NOTE: JOB CONTRACT DURATION 15 MONTH
JOB ESTIMATED DIRECT COST 60 MIL / 10 MIL LABOR.

FIGURE 17.2 Jobsite overhead.

Company Logo

Project Site Overhead

Description	Quantity	Unit	Mat'l/Equip. Unit	Labor Unit	Subcontract Total	Total
• Construction Aids						
Cranes Rent 12800/M	1x15	Month	92000			192000
Conveyors						
Elevators						
Hoists Rent 2250/m	2x15	Month	67500			67500
Scaffolding and Platforms						
Small Power Equipment and Tools						15000
Enclosures						10000
Bareers: Fences and Barricades						8000
Safety Nets						5000
JOB DURATION 15 MONTH						
• Field Offices & Laboratories						
Contractor RENT	1x15	Ea			3900	3900
Subcontractors RENT	1x15	Ea			3900	3900
Owner/Architect RENT	1x15	Ea			3900	3900
Materials Storage and Protection RENT	2x15	Ea			7800	7800
Storage Equipment & Tools RENT	1x15	Ea			3900	3900
NOTE: 15 MONTH DURATION $260/M						
• Temporary Utilities						
Heating 300	6	M				1800
Water 500	15	M				7500
Sanitary 500	15	M				7500
Lighting 200	15	M				3000
Power 400	15	M				6000
Telephone 200/M	2x15	EA				6000
NOTE: 15 MONTH JOB DURATION						
• Access Roads (railroads, waterways)						
TEMPORARY ROAD	3000	s.m.			15000	15000
Page Total			159500		38400	367700
			Mat'l/Equip.	Labor	Subcontract	Total

Company Logo

Project Site Overhead

Description	Quantity	Unit	Mat'l/Equip. Unit	Mat'l/Equip.	Labor Unit	Labor	Subcontract Total	Total
• Environmental Controls								
Noise		EA					3000	3000
Dust								
Water								
Polution								
Erosion		EA					2000	2000
JOB DURATION 15' MONTH								
• Camp Facilities								
• Site Production Unit								
Concrete Related								
Asphalt Related								
Precasting Yard								
Assemblying Platform								
Carpentry Shop								
Reinforcing Shop								
Structural Steel Shop								
Welding Shop								
Mechanical Shop								
Electrical Shop 8 month	1 x 8	Ea					2000	2000
HVAC Shop 8 mont	1 x 8	Ea					2000	2000
Painting Shop								
Rent 250/month								
• Personal Protective Equipment								
Respiratory	40	Ea	25	1000				1000
Encapsulating Suits								
Overboots								
Gloves	500	Ea	2	1000				1000
Protective Gloves								
Page Total				2000 (Mat'l/Equip.)		(Labor)	9000 (Subcontract)	11000 (Total)

Company Logo

Project Site Overhead

Description	Quantity	Unit	Mat'l/Equip. Unit	Mat'l/Equip.	Labor Unit	Labor	Subcontract Total	Total
• Security								
Watchman								
Person and Command Dog								
• Project Signs & Photo								
$400 / each	3	Ea					1200	1200
• Surety Bonds								
Bid Bond								
Performance Bond .6%	1	JOB						360000
Labor & Material Bond								
JOB COST 60 MIL								
• Insurances								
Builder's Risk .22%		Job						132000
Equipment Floater .50%		Job						5000
Public Liability								900000
Worker's compensation 18.5%	10 MIL	LABOR						1850000
JOB COST 60 MIL								
LABOR 10 MIL.								
• Building Permits		JOB						3000
• Clean Up/Removing Rubbish								
400 / month	15	MONTH					6000	6000
• Touch-Up & Repair				40000				40000
Page Total				40000			7200	822200
Total Page 1 - 4				201500		389600	72600	1613500
				Mat'l/Equip.		Labor	Subcontract	Total

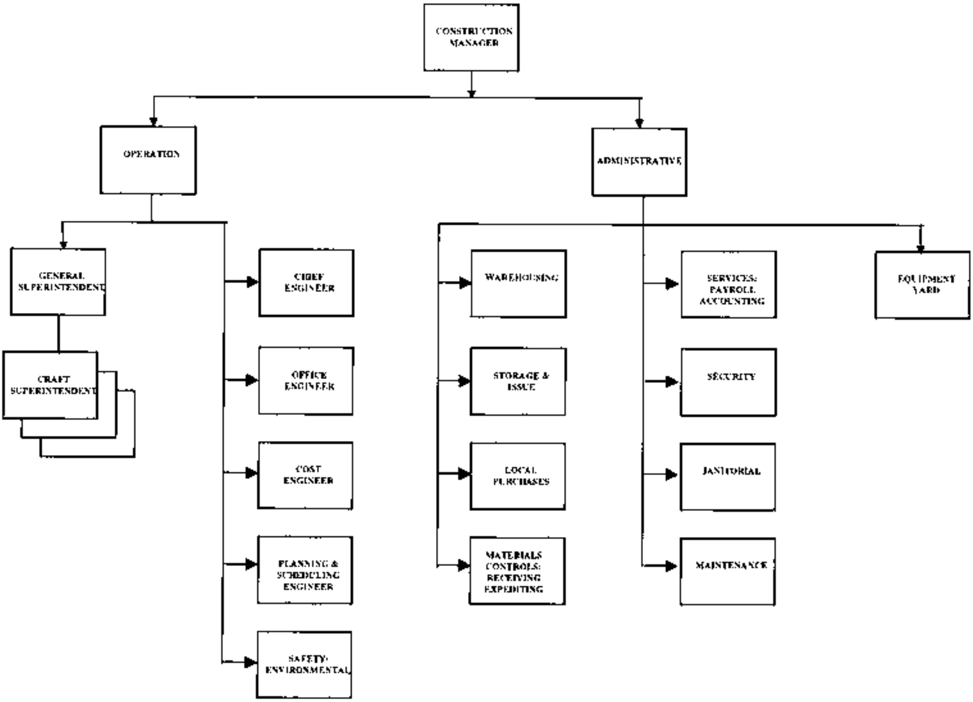


Figure 17.3 Typical large job personnel organization chart.

minor modifications can be used for determining costs in order to secure construction production for the project.

17.2 JOBSITE PERSONNEL

Usually, field supervision has the largest line item cost and may represent as much as 60% of total jobsite overhead. Normally, it includes all site staff. This should include the salary and payroll expenses of the project manager, superintendent, assistant superintendent, field engineer, timekeeper, materials clerk, and all foremen. This expense is time sensitive and it is important to estimate accurately how many months the staff will be on the job payroll. The starting point is seen in the job supervision organizational chart in Figure 17.3. For smaller jobs it needs to be scaled down; for larger jobs more field positions need to be added.

Salary ranges for field personnel should be aligned with those paid by other subcontractors in the project area to minimize turnaround. Table 17.1 is provided as a guideline for weekly salary ranges for field personnel.

TABLE 17.1 Construction Field Personnel Weekly Salaries—2000

Title/function description	Weekly salary (US $)		
	Minimum	Average	Maximum
Project manager	1220	1370	1545
Project superintendent	1165	1290	1455
Field engineers	650	845	970
Clerks		270	
Timekeeper		750	

Source: Means, *Building Construction Cost Data*, 58th edition, 2000.

Estimated salaries (per week or month) are multiplied by the estimated time. It is expected that each position will be required on the projects as shown in Table 17.2. Additional expenses related to salaries are often encountered by the contracting organization. Those expenses strictly related to the job include: Social Security, Medicare, unemployment, workers' compensation, and premium and bonuses paid to key personnel upon successful completion of the project. The estimator bases salary estimates on company executive recommendations while also estimating time on the job for each payroll position. The estimator must be neither optimistic nor pessimistic.

17.3 TRAVEL EXPENSES

Expenses directly related to support field personnel on the project are as follows: assigned truck rental and operating expenses, fares and travel related to the project, and board and lodging for staff. It is not easy to develop a detailed budget

TABLE 17.2 Job Site Personnel Estimate[a]

No.	Title/function description	Personnel no.	Weekly bare cost ($)	No. weeks	Total cost ($)
1	Project manager	1	1220	100	122,000
2	Project superintendent	1	1165	100	116,500
3	Field engineers	2	845	80	135,200
4	Clerks	2	270	80	43,200
5	Timekeeper	1	750	80	60,000
	Total project	8			476,900

[a] Estimated projection duration 100 weeks.

for this category, but an estimated figure as part of the jobsite overhead will help to monitor future expenses.

17.4 SITE ENGINEERING SUPPORT

Site engineering support includes the cost of employing independent (subcontractors) for subsurface exploration, testing laboratories for soil, concrete, masonry, metals (welding), moisture protection, and so on. In addition, surveying cost could be added to the list. Table 17.3 provides the average cost criteria for most common site-required testing.

17.5 CONSTRUCTION EQUIPMENT AND AIDS FOR GENERAL USE

The costs for delivery, rental, erection, dismantling, and removal of heavy construction equipment for general onsite use (not only for a single category of

TABLE 17.3 Field Testing Costs

Field test (each)	Total cost[a] average US ($)
Asphalt	
Strength (set of 3)	165
Density (3)	87
Specific gravity (1)	37
Concrete	
Sieve analysis	65
Compressing test	13
Core—comprehensive with drilling	50
Mis design (batch)	285
X-ray concrete slab	
Masonry	
Absorption (5 bricks)	50
Compressing (5 bricks)	70
CMU—moisture	35
Mortar—compressive (3)	25
Soil	
Liquid/plastic limit	61
Specific gravity (1)	48
Sieve analysis	57
Density/classification undisturbed	75
Proctor compaction	125

[a] Includes O&P.
Source: Means, *Building Construction Cost Data*, 2000.

work), as well as operator wages and the costs of normal equipment maintenance should be estimated. This includes mobile cranes, climbing and tower cranes, hoists, lifting jacks, and all general-use equipment. Rental per month, not including operator costs, is provided in Table 17.4 as a guideline. It is recommended that the estimator obtain quotations from local suppliers.

17.6 Temporary Field Buildings—Offices

Every major construction project must have some form of onsite shelter from which the field organization operates. The shelter type, size, and permanence

TABLE 17.4 General Use Construction Equipment Monthly Rental Rates[a]

Equipment description	Monthly rent ($)
Climbing crane, 30 m jib, 3 ton capacity	11,000
Static tower crane, 40 m high, 3 ton	13,000
Truck mounted hydraulic, 12 ton	4,000
Hoist and tower 2300 kg capacity, 30 m high	2,400
Hoist and tower, personnel only, 1 ton	6,600

[a] Operator cost not included.

vary with project size, duration, and location. For example, a small commercial office building in a large city may only require one office trailer to house the field operation. At the other end of the spectrum, a $1 billion industrial complex project with a schedule duration of 10 years, located in a remote site, will require the construction of the equivalent of a small town to sustain the field organization. This remote site will not only need office space for the staff, but will need lodging, dining, recreation, and commercial facilities to accommodate the entire labor force. In essence a "company town" to support the crew and their families must be created. This group of facilities can be termed "site habitability facilities" as they provide the necessary shelter for living. As every project and project location is unique, there is no standard "cookbook" list of specific habitability needs. Every owner and contractor will have different objectives and desires. There are, however, several important considerations that must be addressed when estimating for office and living space.

The cost of securing temporary offices for use by contractors, subcontractors, architects, engineers, and owner representatives during construction should be included in the detailed estimate. The costs of providing (purchased or rented), transporting, erecting, maintaining, dismantling, and removing facilities from the site are estimated during the early construction phase and become budget items for future construction operations. If the general contractor owns the temporary office, bought previously for other projects, a charge to the project is still made for depreciation and return on investment (as an internal rental rate). If the office trailers are rented from local suppliers, it should be determined if the fee includes setup, dismantling, and removal from the jobsite at the end of the project. Office space requirements should be based upon the number of professional and clerical staff, including subcontractors. The superintendent and project manager will have larger offices than the field engineers and clerical staff.

TABLE 17.5 Office/Storage Trailers Cost

Type	Cost new ($)	Rental monthly rates ($)
6.1 × 2.5 m office trailer	5,500	134
10 × 2.5 m office trailer	8,480	165
15 × 3 m office trailer	14,000	295
15 × 3.7 m office trailer	16,700	345
Portable building (economy), 2.5 × 2.5 m	5,300	—
Portable building (deluxe), 2.5 × 3.7 m	9,000	—
Storage box, 6 × 2.5 m	3,500	75
Storage box, 12 × 2.5 m	3,700	85

Source: Means, *Building Construction Cost Data*, 2000.

In addition to space for site personnel, additional areas must be reserved for project documentation (drawings) storage, for computers and duplicating equipment, and for a conference room. In estimating the number of trailers needed, calculate 3 m^2 for each clerical person and field engineer, and 5 m^2 for each project manager, superintendent, owner representative, architect, and engineer located at the jobsite. Table 17.5 provides rental rates for trailer-type offices.

17.7 TEMPORARY SITE UTILITIES

17.7.1 Temporary Heat

The average cost of heating during the winter months, including fuel and operation, is roughly \$.75/m^2 of the building per week assuming a 12-hr operation/day or \$1.20 m^2 of the building floor per week for a 24-hr/day operation. Calculate only the number of weeks needed and not the entire job duration. Heat also includes supply, rental, installation, and removal from the site of heating units for curing concrete work or drying the building.

17.7.2 Temporary Power Services

Lighting (service lamps, wiring, outlets, and bulbs), excluding the cost of power, ranges between \$1 to \$2/m^2 of floor area. Power for temporary lighting only should cost from \$.0.08 to \$0.24/m^2 lighted floor area per month. Power for the duration of the project and used for construction tools (including elevators) can range between \$0.5 to \$1.2/m^2 of the building, or between \$12 to \$13 per kilowatt.

17.7.3 Temporary Water Services

Water service costs include the installation and removal of services, meters, and the water supplied. It is customary to provide cold water or ice water throughout the summer. Remember, the estimated cost must include the containers, cups, and someone to service these. When a water main is available, a water meter must be installed and a water line run to the jobsite. Charges made by the local water (utility) department for the anticipated volume of water used should be included in the estimate. The cost of treated water varies from location to location with an average of \$1.30 to \$0.75 per 1000 liters This item can become a high-cost operation, especially if the job is in a remote area that is underdeveloped and where a well must be drilled or water must be hauled to the job.

17.7.4 Sanitary Facilities

Projects must provide toilets for the workers. The most common types rented are chemical portable toilets. Large projects may require several portable toilets.

This item is one of the first things needed on the jobsite. Maintenance frequency (waste hauling) depends on the site population, number of shifts, and workweek schedule. Most ordinances require 1 portable toilet for 1 to 15 workers, with an additional unit for every 15 workers. Assuming an 8-hr/day 40 hrs per week, the average monthly rental and servicing costs range from $85 to 100 per month. It is recommended that one contact local suppliers for a more accurate estimation of job parameters (location, duration, number of units, frequency of service, etc.).

17.7.5 Telephone and Communications

Costs arising from the use of all communication equipment and means includes: telephones, long distance calls, fax machine, car, cell, and CB telephones, beepers, couriers, postage, Internet access, and email. Local specialized companies should be contacted during the site visit investigation to obtain the degree of' available services and their fees.

17.8 HORIZONTAL TEMPORARY CONSTRUCTION

17.8.1 Roads, Ramps, and Parking

In all types of construction projects, it is critical to construct and maintain roadways in order to transfer a project's resources. This may include laborers, materials, and construction equipment. In addition to certain basic needs, construction of adequate haul roads directly enhances the economic benefits of a construction project. Increased productivity as well as a reduction in fuel consumption are direct benefits of a well-maintained haul road. In preparing temporary roadway facilities for construction, there are basically three methods of road construction that may be chosen: dirt haul, asphalt haul, and concrete roads. Normally the dirt and asphalt roads will be used for "true" temporary roadways, whereas a concrete roadway will be used during construction and turned into a permanent roadway at the termination of the project. In working with dirt roads, there are characteris-

TABLE 17.6 Temporary Roads Cost $/m^2

Road type	Cost ($/m^2)
Gravel fill—10 cm depth	3
Gravel fill—20 cm depth	5
dirt—2 lanes 8 m wide	0.7
Asphalt—2 lanes 8 m wident	33
Concrete—2 lanes 8 m wide, 10 cm depth	36

Table 17.7 Fencing Cost/m, Installed

Fencing type installed[a]	Height (m)	Cost ($/m)
Chain link	1.5	24
Chain link	2.0	26
Rented chain link	1.5/12 month	16
Plywood painted	1.2	29
Plywood painted	2.5	45
Wire mesh	1.2	30
Wire mesh	2.5	46

[a] Including gate.

tics that will be made apparent during the site investigation that will delineate possible roadway construction methods. Table 17.6 provides the average cost per m^2 of temporary roads. The cost of periodic maintenance is not included.

17.8.2 Fences and Gates

The cost of materials, labor, and equipment for erection and removal of fencing from the site should be estimated. Fencing needs to be identified as rented or charged in full and estimated at a salvage value. Cost in $/m for installation and removal is provided in Table 17.7.

17.9 MATERIALS STORAGE FACILITIES

Four general types of storage facilities include laydown, shed, warehouse, and climate-controlled warehouse. A laydown or platform storage area consists of compacted or stabilized soil, or when soil or weather conditions require, an asphalt or concrete pad. This area may be enclosed by a 2.5 to 4 m high fence, possibly topped by barbed wire if circumstances warrant the effort. Area lighting must be provided for safe operations at night and for security. Durable materials that are not seriously affected by the elements can be stored inexpensively in a laydown area. Coarse and fine concrete aggregates, masonry block and brick, structural steel, reinforcing bars, roofing materials, piping, and electrical wire and conduit may be stored in laydown areas. A storage shed is covered with a roof, but is not enclosed by walls on all sides. Typical sheds have metal roofs and are framed in wood or steel. Depending on soil and weather conditions, a concrete slab-on-grade floor may be constructed. Security fences and lighting facility provide a dry enclosed space for storage of items that will be destroyed by moisture.

Warehouses can be constructed from concrete masonry units (CMU), concrete, steel frame with siding, or temporary construction methods such as tension membrane or K-Span. Warehouses must have electrical lighting, and roll-up or other doors large enough to accommodate forklifts, trucks, or other materials handling equipment. Warehouses should be ventilated and may be heated or moisture controlled. Materials that are usually stored in warehouses include cement mortar dry mix, some lumber materials, insulation, doors and windows, and finish materials such as gypsum board, flooring, and ceiling materials. Paints and other liquids must be stored in a heated warehouse in cold climate environments. A climate-controlled warehouse is usually framed with steel, masonry, or concrete and clad with metal or concrete materials. This warehouse must be well insulated and air conditioned as well as heated. This type of storage is used for sensitive materials such as instrumentation, controls, and chemicals used in construction. Other specialized storage facilities that may be required are silos for dry pulverized materials and storage tanks for liquids. These special facilities must be considered on a case-by-case basis. Table 17.8 provides the average costs for storage facilities. The costs are based on a 15 × 15 m area with a ceiling height of 4 m.

Table 17.9 provides the factors necessary to calculate the area required for materials considered. The primary CSI division construction materials for concrete, masonry, metals, wood and plastic, thermal and moisture protection, doors and windows, finishes, and mechanical and electrical components are analyzed.

TABLE 17.8 Storage Facilities Cost/m^{2}[a]

Facility type	Cost/m^2
Laydown area	
Compacted earth	21
Soil stabilization	29
Asphalt	54
Concrete pad	67
Shed, metal roof	
Wood framed/no floorwork	114
Wood framed/concrete floor	148
Steel framed/no floorwork	123
Steel framed/concrete floor	155
Warehouse	
CMU/concrete	166
Steel frame, siding	160
Tension membrane	209
Climate-controlled warehouse	
CMU/concrete	195
Steel frame, siding	190

[a] Costs based on a 15 × 15 m area or 15 × 15 m structure with 4 m column height; larger facilities = lower cost per unit.

Information to consider in calculating the required space of a unit of measure of a given material includes:

1. Type of storage facility required,
2. Delivery mode,
3. Quantity delivered per delivery mode,
4. Dimensions of the materials as delivered, and
5. Height of the materials in terms of how many may be stacked on one another (H_{stack}).

The m^2 needed by one unit of delivered material is shown in Table 17.9. From this information, the net m^2 ($m^2_{unit,net}$) and cubic meters required to store a unit of materials can be calculated. These figures are then modified by two factors: the storage factor (F_{stor}) and the utilization factor (F_{util}). The storage factor indicates the percentage of total storage space that can be used for the actual storage of materials. The rest of the space must be left open for aisles and access to the materials. After considering these two factors, the gross m^2 ($m^2_{area,gross}$) and m^3 required may be determined.

TABLE 17.9 Construction Materials Storage Areas

Material	Storage	Unit Size	Units/sm	Factor	sm/Unit
Rebars	L	Ton	2	0.85	1.2
Cement	SL	Ton	2	0.95	1.05
Gravel	L	Ton	3	0.95	1.05
Sand	L	Ton	3	0.95	1.05
CMU	L	100	3	0.9	1.1
Bricks	L	1000	3	0.9	1.1
Mortar/B	W	Bag/32Kg	25	0.9	1.1
Steel Str.	L	Ton	3	0.8	1.25
Wood	S	CM	3	0.8	1.25
Plywood	W	SM 100	1	0.8	1.25
Roofing	S	SM 100	2	0.8	1.25
Felt-Rolls	S	SM 100	10	0.9	1.1
Insulation	W	SM 100	0.25	0.9	1.1
Doors	S/W	Each	10	0.8	1.25
Windows	S/W	Each	10	0.8	1.25
Drywall	W	SM 100	0.25	0.8	1.25
Tiles/Floor	W	SM 100	0.25	0.8	1.25
Tiles/Acst	W	SM 100	0.5	0.8	1.25
Paint	W	L 100	3	0.9	1.1
Pipes/Iron	L	LM 100	0.5	0.8	1.25
Pipes/Pvc	L/W	LM 100	0.5	0.8	1.25
Conduits	S	LM 100	1	0.85	1.2
Wires	W	LM 100	30	0.85	1.2

L = Laydown; S = Shed; W = Warehouse; SL = Silo.

After determining unit storage space requirements for the materials studied, the next estimate is the quantity of each material to be stored at a given time. Once the total quantity of a given material used per million dollars on a specific project is known, the total project life and the total time that specific materials will be utilized must be considered. After assuming the duration for a construction activity requiring a specific material, an average usage per month can be calculated. A peak usage, relative to the monthly usage, is then estimated by considering variation in the production schedule and the possibility of producing product more quickly than planned. Productivity and workforce morale can be severely compromised when work is halted due to materials shortages.

17.10 CAMP FACILITIES

The primary factor to consider when gauging camp facilities is the location of the project site with respect to major population centers. If the project is located in a large urban area, no living facilities will need to be constructed. Workers will be able to find suitable housing, dining, entertainment, recreation, and commercial facilities in the local economy. A remote project (located in a rural or uninhabited area) will require that the contractor construct adequate facilities in which the workers will live. There is no set distance from population centers that defines a remote project. As a guideline, if the project is located more than 50 km from a city of 25,000 people the planner should consider constructing living facilities. A smaller town probably will not be able to absorb a large construction-worker population without high rent inflation.

The second most important consideration in the decision to construct living facilities is the scheduled duration of the project. Projects of a short duration may not require living facilities if housing is available within a reasonable transportation distance. As the duration of a project grows, the type and permanence of the living facilities increases as well. For projects less than three years in length, the most feasible solution for living facilities is temporary structures such as trailers. For projects of this duration there is no need for extensive entertainment, recreation, or commercial facilities. Projects of three to five years should include more complex quality-of-life facilities such as banking and retail stores and may be a mixture of temporary and permanent structures. For projects greater than five years in duration, cinemas, gymnasiums, grocery stores, and other improvements should be constructed and all structures should be permanent.

Lodging requirements can vary greatly depending on the makeup of the workforce population, from open barracks to private family houses. OSHA regulations 1910.142 for temporary labor camps establish a minimum of 5 m^2 of floor area per occupant with beds spaced 1 m apart. Suitable storage facilities for clothing and personal articles should be provided for each occupant.

17.10.1 Dormitories

A dormitory is defined as a structure for housing a number of people. Dormitories can be suitable for all classes of personnel with the exception of families. They can be in the form of open bunkrooms, private or shared rooms, and private suites. Depending on company or union policy, low-level helpers and apprentices may be housed in bunkrooms or in shared rooms with shared bathrooms. Journeymen, foremen, and clerical staff should be provided more space and more privacy with assignment to single rooms, possibly with private baths. Superintendents and professional staff should be allotted even more space and be given a two-room suite with private bath in the dormitory. Table 17.10 provides guidance on minimum space requirements and cost ranges for dormitories.

17.10.2 Bungalows

A bungalow is defined as a small one-story cottage. Bungalows are only suitable for professional staff and families. They can vary in size depending on seniority and family size. Bungalows will include private bedrooms, kitchen, dining, and living

Table 17.10 Dormitory

Category	Type	Size (m^2/person)	Low ($/$m^2$)	High ($/$m^2$)
Unskilled worker	Large bunkroom Max 8/room	5	600	1000
Skilled worker	2/room	6.5	600	1000
Staff/supervisor	1/room	12	600	1000

areas. In addition to bungalows, multifamily apartment units are a possible solution for lodging. Table 17.11 provides a guideline of average costs for bungalows.

17.10.3 Dining Facilities

Dining facilities must be sized to accommodate the preparation, serving, and consumption of meals by the entire site population during a short period, unless it is possible to break the workforce into shifts for the noon meal. An inefficient dining operation can cause a great loss in construction productivity. Table 17.12 estimates areas for maximum site populations. Cost ranges include kitchen equipment for food preparation and serving.

17.10.4 Entertainment and Recreation

Since entertainment and recreation opportunities from local towns will be out of range for most of the workforce, the camp should include various facilities to enhance the morale and quality of life of the workers. Most camps will have a club where the workers can gather, drink, and visit with friends. Table 17.13 lists the suggested minimum areas for such clubs and their cost ranges.

17.10.5 Commercial Facility

In a remote area, basic commercial establishments must be constructed and operated for the construction labor force. These include facilities necessary to conduct personal business (such as banks and post offices) as well as retail establishments where workers can purchase assorted sundries (Table 17.14).

Table 17.11 Family Housing

Family	Type	Area (m^2)/person	Cost $/$m^2$	
			Low	High
Skilled worker	Apartment unit	12	$400	$670
Staff/supervisor	Bungalow	12	$470	$780

TABLE 17.12 Dining Facility Area Gross and Cost Range

Population to be served at one time	Gross area (m^2)	Cost ($)	
		Low	High
Up to 40	200	172,223	279,862
41 to 80	325	279,862	454,775
81 to 150	465	400,417	650,678
151 to 250	595	512,362	832,588
251 to 400	825	710,418	1,154,429
401 to 650	1200	1,033,335	1,679,170
651 to 1000	1600	1,377,780	2,238,893
1001 to 1500	2100	1,808,337	2,938,547
1501 to 2200	2740	2,359,449	3,834,105

Living and office facility needs can be met in a variety of ways. The most costly solution is the construction of permanent structures; however, this may make economic sense as the owner can utilize these facilities for similar uses upon completion of the project. If there is no need for housing for future plant operations and the project is of a relatively short duration (less than five years), the most economical solution for the contractor is to use temporary, modular, or prefabricated facility systems.

17.10.6 Temporary, Modular, and Prefabricated Structures

Temporary facilities such as trailers and mobile homes are commonly used on most construction projects. These structures provide a relatively inexpensive, flexible alternative to the cost and time associated with the construction of permanent facilities. In addition, most suppliers can configure the trailers to meet the specific needs of the contractor, as offices, living quarters, change rooms, showers, toilets, and many recreation and commercial uses. Trailers can be bought, leased, or rented. Since these costs vary from year to year and from area to area,

TABLE 17.13 Clubs—Sizes and Cost Ranges

Population	Gross area (m^2)	Cost ($)	
		Low	High
Up to 500	1/person	560	1,040
501 to 1000	930	520,000	970,000
1001 to 3000	1770	990,000	1,900,000

TABLE 17.14 Temporary Commercial Facilities Cost

Facility	Site population	Gross area (m^2)	Total cost (in \$1000) Low	Total cost (in \$1000) High
Bank	Up to 1000	70	60	105
	1000–2000	110	95	165
Post office	Up to 1000	70	50	80
	1000–2000	100	80	125
Retail and grocery store	Up to 2000	650	245	420
Laundry, coin-operated	Up to 1000	70	270	320
	1000–2000	110	330	400
Barber shop	Up to 1000	36	18	22
	1000–2000	50	25	32
Health care	Up to 1000	45	31	45
	1000–2000	200	140	200

the project manager or chief estimator should consult local dealers for up-to-date pricing and sizing availability.

Simple economic analysis can help determine whether to buy, lease, or rent. Purchase may make sense for a very large contractor who will be able to reuse the facilities for future projects. However, the wear and tear on these buildings may reduce their lifespan significantly.

Modular facilities are in many ways similar to trailers in that they are relatively inexpensive and flexible, but they can be more easily transported. These facilities are standard ISO sizes making them readily shippable and they can be preconfigured for a variety of uses. They can also be stacked and interconnected, reducing the site area required for living facilities. These structures are in use throughout Europe and have been used to house refugees and provide shelter in disaster relief situations.

Prefabricated structures are extremely convenient solutions for the contractor. They do require some construction, although much less than permanent facilities, but their main selling point is that they come as a package with all materials and erection details provided. Prefabricated structures can range from pre-engineered metal buildings to tension fabric structures. These are quickly and easily assembled and provide large floor space. They would be best used for large public facilities such as dining halls, clubs, stores, and gymnasiums. Pre-engineered metal buildings are available from a wide array of manufacturers and come in many different configurations. Costs for these buildings depend primarily on the length of span and height: the higher each of these numbers, the higher the cost regardless of floor area. These buildings also require reinforced concrete footings.

TABLE 17.15 Prefabricated Temporary Structures[a]

Company	Telephone	Web site	Office trailers	Living facilities	Fabric structures	Pre-engineered buildings
G.E. Capital	800-523-7918	—	x			
Wells Cargo, Inc.	800-348-7553	www.wellscargo.com	x			
Williams Mobile Offices	800-782-1500	www.willscot.com	x			
Arthur	800-692-1234	—	x			
Mobile Structures, Inc.	800-348-8541	—	x	x		
Olympic Prefabricators, Inc.	206-486-9151	—	x	x		
World Homes	706-485-8506	www.net-magic.net/worldhomes/index.htm		x		
Clamsbell Buildings, Ventura, CA	800-360-8853	www.clamsbell.com			x	
Rubb Building Systems, Sanford, ME	800-289-7822	www.rubb.com			x	
Dura Building Systems, Milton, Ontario	800-663-7538	www.dura_bldg.com				x
CECO Building Systems	—	www.mbg.com				x
Phoenix Construction, Tampa, FL	813-874-7425	—				x
IBS International	800-432-2536	www.netline.net/~ibsbldgs				x
Garco Building Systems, Spokane, WA	509-244-5611	www.midcoinc.com				x
American Steel Span, Pittsburgh, PA	800-581-5843	members.sol.com/amsteelspn				x
American International Building Systems, Houston, TX	713-444-6591	—				x

[a] US sources.

Fabric structures are increasing in popularity due to their ease of erection, flexibility, low cost, and lifespan. Table 17.15 provides sources for ready available temporary prefabricated/modular buildings.

The development of living facilities for a major, remote construction project is a very complex and costly undertaking. Senior people of the owner's organization and the contractor should be involved in determining what auxiliary facilities should be constructed.

17.11 PRODUCTION FACILITIES FOR REMOTE SITES

17.11.1 Introduction

Site shops and auxiliary production units are a vital part of any large, remote construction project. These shops are needed to work on materials that need adjustments made to them prior to installation. In a controlled environment site, shops also offer the advantage of centralization of effort and all of the benefits that come with working in a centralized location.

Auxiliary production units provide many of the materials that are required on the site. Some of the production units transform raw materials into usable condition (e.g., a rock crushing and aggregate plant), whereas others combine and manipulate materials to produce a different type of material (e.g., a concrete plant combines aggregate and cement; an asphalt plant combines aggregate and liquid asphalt). Because of the diversity in size, complexity, and type of project inherent in construction activities, there is no one recipe that can be followed to set up a site shop or an auxiliary production unit that is perfect for a project. Estimating their installation cost and operation is a difficult task for estimators and the project manager.

17.11.2 Site Shops

Factors that affect the size and cost of a site shop include the quantity of raw materials to be fabricated or manipulated onsite, the time available in the project schedule, the weather, and the construction season. The estimator also has to price the various power tools and equipment that are to be included in the shop. For example, a concrete reinforcing bar shop would need the following for production: rebar shears, rebar bender, stirrup bender, abrasive cutter, welding machine, pedestal grinder, roller conveyor, scrap skin pan, and electric drinking fountain.

17.11.2.1 Rigging

Rigging involves the handling of loads suspended from lifting machinery such as cranes and hoists. Riggers are concerned with assembling hoisting equipment to safely lift a given load from a hook. The rigging shop is a place to store the materials and accessories used for hoisting.

The rigging shop will usually be set up as a warehouse. Most rigging accessories must be stored indoors to protect them from heat and moisture. Ideally, most rigging materials require a cool, dry, well-ventilated place for storage. Exposure to direct sunlight should be avoided because it may dry and weaken natural materials, such as fiber ropes and wood ladders. A rigging shop typically contains fiber ropes, wire strand rope, slings, end attachments and fittings, blocks, sheaves, revving, and drums, jacks, rollers, skids, safety belts, lifelines, nets, and portable ladders. The shop should also include equipment for testing the rigging accessories. The quantity and types of equipment will vary greatly for each job. It will be necessary to consult each contractor involved in a project to determine what rigging equipment will be needed and in what quantities. Some US distributors and manufacturers of rigging equipment are given in Table 17.16.

17.11.2.2 Paint and Sandblasting

Most construction sites require a lot of painting and sandblasting to be done. The equipment used to prepare and apply paint and to sandblast, as well as the materials themselves, can be stored in an onsite paint shop. The two main purposes of an onsite paint and sandblast shop are to offer a location where painting materials can be organized, inventoried, and monitored and to provide a storage site where proper conditions are maintained. Equipment needed in such a shop would include paint application equipment (sprayers, rollers, brushes), sandblasting equipment, paint mixing machines, spray booth, drying equipment, sign room (for creating signs used on the construction site), and testing equipment. Some distributors and manufacturers to be contacted for prices or quotations are given in Table 17.17.

17.11.2.3 Carpentry

The carpentry shop on a construction site is where form parts or entire forms can be fabricated before being moved to the structure for assembly and erection. The carpentry shop is typically a covered mill containing carpentry equipment. Adjacent to the mill there should be a large area where formwork may be fabricated. There should also be a nearby storage area for the completed forms.

Different jobs may require different carpentry equipment. The following list, however, identifies the most common machines used in a carpentry shop: cut-off saw, rip saw, radial arm saw, woodcutting band saw, portable electric saw, table saw, plywood saw, planer, sander, pedestal grinder, drill press, bolt threading machine, filing and sharpening equipment, and roller conveyors. Information and prices about carpentry shop equipment can be obtained from the distributors and manufacturers identified in Table 17.18.

TABLE 17.16 US Distributors and Manufacturers of Rigging Equipment[a]

Company	Type	Phone	Fax	Address	Equipment
WRAC, Inc.	Manufacturer	816-233-0287	816-236-5000	PO Box 288 St. Joseph, MO 64502	Fiber rope, wire rope, slings
DBI/Sala	Manufacturer	800-328-6146 612-338-8282	612-338-5065	PO Box 46 Red Wing, MN 55066	Safety equipment
VER Sales, Inc.	Distributor	818-567-3000	818-567-3018	2509 Naomi Street Burbank, CA 91504	All rigging equipment
Bishop Lifting Products, Inc.	Distributor	800-972-1041 713-674-2266	713-672-9229	PO Box 15619 Houston, TX 77220	All rigging equipment
Ladder Man, Inc.	Distributor	800-783-8887	N/A	N/A	Ladders
Louisville Ladder	Manufacturer	502-635-9320	502-636-1014	1163 Algonquin Pkwy. Louisville, KY 40208	Industrial-grade ladders

[a] Partial listing.

Table 17.17 Distributors and Manufacturers of Coating and Sandblasting Equipment[a]

Company	Phone	Fax	Address	Equipment
Applied Coatings & Linings, Inc.	818-280-6354	818-288-3310	3224 N. Rosemead Blvd. El Monte, CA 91731	Industrial coatings
Carboline Company	314-644-1000	314-644-4617	350 Hanley Industrial Court St. Louis, Mo 63144	Industrial coatings
Fuji Industrial Spray Equipment Ltd.	416-650-1430	416-663-6238	65 Martin Ross Ave. #5 Toronto, Ontario M3J2L6, Canada	HVLP spraying equipment
H.E.R.O. Industries Ltd.	800-494-4376 604-420-6543	604-420-8725	2719 Lake City Way Burnaby, British Columbia V5A 2Z6, Canada	Airless sprayers, power washer
Valvoline Industrial Coatings	800-231-6022	412-728-6825	N/A	Industrial coatings
CePe	++49 6105 71006	++49 6105 75688	CePe SYSTEM Strahltechnik GmbH Posfach 464 D-64535 Morfelden-Walldorf, Germany	Sandblasting equipment
Finishing Equipment Company, Inc.	800-826-6641	805-523-8020	5325 Commerce Ave., #3 Moorpark, CA 93021	Abrasives, sandblasting machinery, supplies

[a]Partial listing.

TABLE 17.18 Carpentry Equipment Suppliers

Company	Type	Phone	Fax	Address	Equipment
RBI	Manufacturer	800-487-2623	N/A	1801 Vine Street PO Box 369 Harrisonville, MO 64701-0369	Woodworking equipment
Diamond Blade Connection	Distributor	800-268-8870 305-717-6876	305-717-6876	7800 NW 34 Street Miami, FL 33122	Power saws, blades
Coastal Tool & Supply	Distributor	860-233-8213	860-233-6295	N/A	Power saws
Strelinger Company	Distributor	810-588-2100	N/A	N/A	Power saws

17.11.2.4 Small Power Tools Repair Shop

A current trend (2000) on many large projects is for the contractor to supply workmen with small tools for use. According to different sources, the cost of small tools for a project may cost from 3 to 6% of the payroll cost. The contractor can help keep these costs down by repairing small tools when they are broken instead of disposing of them and buying new ones.

17.11.2.5 Testing Laboratory

Most sites will need a testing laboratory. The testing laboratory must be equipped to handle several different types of materials testing. At the very least, the lab must be equipped to perform soil tests, concrete testing, and aggregate testing. Additional materials needing testing include asphalt, concrete, soil cements, and different types of metals. In addition to the building itself, specialized testing equipment may be needed, some of which is very expensive. A few sources of testing construction materials are listed in Table 17.19.

17.11.2.6 Weld Testing

A weld test shop is a facility that provides materials, equipment, and space to perform weld tests. There are two primary weld testing requirements in construction: testing of welders and verification of welding procedures. These tests must be performed to ensure that all welding operations on a project comply with industry standards.

For testing welder performance, most major codes require bend tests or radiography. If a large quantity of tests are anticipated, and local codes allow, radiography is usually more economical. It is, however, more difficult for welders to pass radiography tests. For procedures testing, most codes require the following tests: tensiles, bends, macro sectioning, and charpy impact testing. The most common elements in a weld shop on a large, remote construction site include welding machines, metal-cutting band saw, pedestal grinder (8 to 10 in.), test coupon bender, and weld rod ovens. Welding machines would be of the following

Table 17.19 Testing Equipment Sources

Name	Phone	Address
Tech-Lab Industries	800-832-6188	
Forney, Inc.	412-535-4391 800-367-6397	RD 2, Rte. 18 Wampun, PA 16157-9309
Triggs Technologies	216-585-0111	33977 Chardon Rd. Willoughby Hills, OH 44094
Geoken, Inc.	603-448-1562	48 Spencer St. Lebanon, NH 03766
Olsen, Tinius, Testing Machine Co., Inc.	215-675-7100	Easton Rd. Box 429 Willow Grove, PA 19090

Table 17.20 Weld Test Shop Equipment Contact Information

Company	Type	Phone	Fax	Address	Equipment
National Welders	Distributor	800-295-2925	704-596-9432	N/A	Welding equipment
Welding Technologies	Distributor	610-278-9325	610-278-9325	N/A	Welding equipment
The Lincoln Electric Company	Manufacturer	216-481-8100	216-481-5473	22801 St. Clair Ave. Cleveland, OH 44117-1199	Welding equipment
Strelinger Company	Distributor	810-588-2100	N/A	N/A	Band saws
Perfection Machinery Sales, Inc.	Distributor	847-427-3333	847-427-8884	2550 Arthur Ave. Elk Grove Village, IL 60007	Pedestal grinder

types: 8 pack, 200 amp rectifier-type; 250 amp MIG process; and 300 amp TIG process. Other weld testing machines may be included as necessary. Weld testing equipment can be purchased from manufacturers or distributors. Table 17.20 lists some distributors and manufacturers of welding equipment.

17.11.3 Auxillary Production Units

17.11.3.1 Concrete Batch Plant

The remoteness of the jobsite governs the need for an onsite concrete plant. Standard requirements usually limit the time between mixing and discharge to 1.5 hours. If no concrete plants are within this haul time, an onsite plant is needed. A backup plant should be available on the jobsite in case the primary plant breaks down. Also, multiple units may be needed depending on the age of the unit (proneness to breakdown), types of mixes required, concrete demand, and plant production size.

Many support areas are needed for a concrete batch plant in order to store cement, aggregates, water, and admixtures. Separate bins are required for different types of aggregate. Cement is usually stored in vertical silos or in trailer storage tanks, depending on the method of delivery and the type of plant. Several types of storage elements are needed for the different admixtures. A pond is often located near the plant for water recirculation and cleansing.

Various suppliers for concrete mixing equipment need to be surveyed for prices to buy new or old mixers or to rent them for the job duration.

17.11.3.2 Concrete Precast Yard

On a large, remote construction site, there may be a need for a yard for prefabricating concrete components that can be moved and assembled into their final position. Components can range from major structural elements (beams, columns, piles) to exterior cladding to architectural elements. Thus many of the details of the design of a concrete precasting yard are based on the type of operation that is being performed, which will in turn influence the cost. The three main types of production are jobbing, batch, and flow line.

Jobbing production is normally used when small numbers of varied types of elements are to be produced. It requires a large number of diverse forms and molds, a high standard of labor, and high attention to planning and supervision at all stages of the process. *Batch production* involves the casting of specific elements for a job. The number of different elements cast is lower than jobbing production. Elements that are most commonly produced using batching techniques include, but are not limited to, cladding, frame, architectural landscaping, elements and structural elements (i.e., reinforced concrete beams and columns). *Flow line production* is recommended where there are a high number of similar units to be produced, and where standard elements are produced for stock. Table 17.21 shows a comparison of three types of production where labor, equipment, and special considerations are given.

TABLE 17.21 Comparison of the Three Main Types of Precast Processes

Production	Labor	Equipment	Special consideration
Jobbing	1. Fairly skilled labor required 2. Very experienced supervision necessary 3. Frequent mold changes call for trades' involvement in setting up and alteration	1. Simple equipment adequate for most work 2. Mainly timber molds or steel molds with liners	1. Consider possibility of minor inaccuracies 2. Space consuming 3. Accurate details and highly skilled inspection necessary 4. Each item one-off or special Considerable demands on drawing office 5. Expensive to hold comprehensive stores
Batch	1. Semiskilled workers 2. Skilled supervision 3. Normal degree of inspection gives adequate coverage	1. Multiple molds or molds with extra pallets 2. Equipment can be more specific to clearly defined processes	1. Extra attention to storage facilities. 2. Capital required to finance high stocks of standard items 3. Careful maintenance of standards within production runs
Flow line	1. Semiskilled workers (training simplified) 2. Method and work study techniques can be applied.	1. Soundly designed, well-constructed mold suited to repetitive casting 2. Mechanical handling requires special attention 3. Standby equipment for breakdown coverage 4. High standard maintenance essential	1. Line inspection 2. Planned stockholding facility for subassembly 3. Fully coordinated service facilities essential 4. Considerable capital required for equipment and finance stockholding

17.11.3.3 Rock Crushing Plant

A rock crushing plant is a type of auxiliary production unit that converts raw materials from a quarry into a refined aggregate for use on a construction site. Rock crushing plants are available in many different sizes and configurations. The type of plant selected for a project will depend on the type of aggregate used on the project, the peak quantity of refined aggregate required, and the size of aggregate needed for the job. The required production for the job determines the production rate for the entire rock crushing plant, which in turn sets the rate for the crushers. The rate of the crushers determines the necessary capacity for the feeders and screens. The six basic components of a rock crushing plant are feeders, conveyors, crushers, screens, washing equipment, and storage bins. Table 17.22 presents some manufacturers and distributors from whom prices and information about rock crushing plants can be obtained.

17.11.3.4 Asphalt Plant

The main factor affecting the need for an asphalt plant on a construction site is the amount of asphalt that will be applied. On a large, remote construction project, it would be extremely expensive to transport asphalt to the site from a distant, offsite asphalt plant. It would also be difficult to keep the asphalt in good application condition during transit. However, asphalt plants are not cheap. If only a small amount of asphalt is needed for the project, it may be better to import the asphalt than to assemble an onsite asphalt plant to produce a minimal quantity of asphalt.

The purpose of an asphalt plant on a construction project is to produce a hot, homogeneous asphalt paving mixture. The plant does this by blending aggregate and asphalt cement. In the United States, there are two types of asphalt plants in use: batch and continuous mix plants. Both produce the same final product but the operation and flow of materials in the two plants are different.

17.11.4 Conclusions

Planning the buildings, equipment, and layout for site shops and auxiliary production units on a large construction site is a very difficult task. All of the plans for the shops and production units must be based on the peak manpower requirements and/or the peak demand that is expected to be required of the shop or production unit. Planners should use a possible growth factor of up to 25% of the peak capacity of the shop or unit in case the job schedule is changed. The best and perhaps the most efficient way to perform the planning is to compare the current project with similar units from past jobs of similar size. Acquiring equipment for use in the shops or production units is no simple task. Planners must be concerned with the durability as well as the price of the equipment. New advances in technology such as the World Wide Web and Internet are making material and equipment acquisition easier. Many manufacturers and suppliers for all types of equipment, tools, and supplies can be found by doing simple keyword searches

Table 17.22 Contact Information for Rock Crushing Plants[a]

Company	Type	Phone	Fax	Address
Rock Systems, Inc.	Distributor	916-921-9000	916-921-9070	1395 Garden Highway, Suite 100 Sacramento, CA 95833
Conquip	Distributor	209-538-8712	N/A	1408 Wallin Way Modesto, CA 95351
Hewitt-Robins	Manufacturer	800-845-2710	803-788-1320	PO Box 23227 Columbia, SC 29224

[a] Partial list.

in any of the Web search engines. Many countries have homepages on the Web that give links to manufacturers and suppliers in their country as well.

Planners must remember that the design for the site shop or production unit must be a safe design as well as an economical one. Planners must adhere to local building regulations and codes as well as the regulations of safety organizations (such as the Occupational Safety and Health Administration in the US) when designing the shops and/or production units. If the planner does not have expertise in this area, there are professional construction camp planners. Pricing the cost of site production facilities, whether buying or renting, and the operating costs for the duration of the job is a challenge for an experienced estimator and almost impossible for a novice.

17.12 PERSONAL PROTECTIVE AIDS

In the US, Occupational Safety and Health Administration Standard 1910.132 requires employers to provide workers with the proper personal protective equipment (PPE) and for workers to wear it. On some construction jobsites, the work may call for protective clothing as well as a full armament of gear to guard the eyes, face, head, and extremities. An estimate for protective clothing, hard hats, boots, first-aid equipment, and fire extinguishers is important and should be included during the bidding phase. It should consider demands of the peak labor force on the job. Table 17.23 provides estimated prices for the most common construction protective aids used on jobsites today.

TABLE 17.23 Personal Protective Equipment Cost (2000)

No.	Description	Average unit price ($)	Price ($) discounts 20 or more
1	Fire extinguishers	46.00	—
2	Safety glasses	5.25	4.52
3	Safety goggles	2.75	2.50
4	Paint spray respiratory assembly	8.50	7.70
5	Mask—comfort, dust	4.00	3.50
6	Hearing protection	6.25	5.65
7	Knee pads	20.00	16.00
8	Leather palm gloves	1.60	1.40
9	Chemical resistant gloves	3.00	2.50
10	Hard hat	497/ea	4.52
11	Comfort boot	37.00	—
12	Rainwear	2.75	2.25
13	Adjustable fit harness	64.00	58.00

Source: Distribution International.

TABLE 17.24 Cost of Site Security

Description	Unit	Total (O&P) Min	Total (O&P) Max
Watchman—uniformed	hour	7.8	14.15
Person and command dog	hour	10.3	15.3
Sentry dog—leased	week		19.5

Source: Means, *Building Cost Data*, 2000.

17.13 SITE SECURITY

The estimated cost of uniformed security guards, guards with command dogs, or leased sentry dogs for job patrol should be included as jobsite overhead expenses. The average US costs for security guards and dogs are shown in Table 17.24.

17.14 MISCELLANEOUS EXPENSES

1. *Job progress photographs*. Required or not, it is strongly recommended that photographs be taken at various stages of construction. A still camera and a video camera should be kept at each jobsite. The project manager should use them to record progress or to record various discrepancies that may occur. In addition to the cost of the cameras, the cost of supplies and processing the films is an additional expense. Pictures must be dated and properly titled on their reverse side for future use.

2. *Site signs and advertising*. Costs of providing, erecting, maintaining, and removing signs are included here. The average cost of having these made is \$100 to \$150/m^2.

3. *Models and mockups*. These are most often required by the contract and need to be itemized.

4. *Rubbish removal*. This includes all rentals of bins, their timely removal from the site and related dumping costs. During construction there is always rubbish (such as concrete, broken bricks and tiles, stone drywalls) that must be removed at intervals. For removal of hazardous materials the prices are two to three times higher than for normal rubbish. Table 17.25 provides estimated prices for container rental and disposal in Austin, Texas (Summer 2000).

A cost computation example for rubbish removal will assume one 30 m^3 container rented for a month. The cost for this would be $95 + 5 \times 30 + 355 =$ \$600 or $600/30 =$ \$20/m^3 container capacity.

5. *Final cleanup*. Before acceptance or occupancy of the building, all floors must be swept or scrubbed, at an estimated cost of \$.30 to \$.50/m^2. For

TABLE 17.25 Disposal Containers Cost

Container size (m^2)[a]	Capacity m^3	Delivery fee ($)	Rent day ($)	Dumping[b] charges ($)
2.5 × 6.8 × 1.25	20	95	5	315
2.5 × 6.8 × 1.83	30	95	5	355
2.5 × 6.8 × 2.44	40	95	5	395

[a] 30 km radius, full or partial; the most popular size among contractors 1.83 m high; 2.44 m high requires mechanical device for loading.
[b] Charges may vary with function or proximity of jobsite.
Source: B&I, Austin, Texas, June, 2000.

cleaning the windows, allocate an additional cost of \$0.90 m^2 for both sides. Count the windows and calculate the area of the openings and use it as the base for estimating the final cleanup.

6. *Street and pavement repair*. This item should cover the repair and/or replacement of all the sidewalks and pavement damaged during construction.

7. *Protection of newly completed work during construction*. Examples of this are carpet, ceramic flooring, and marble cut stone, bathtubs, and so on. The cost of protective materials and the labor to install and remove the protection should be estimated.

8. *Building permits*. Permit costs vary from country to country, and from city to city within a country. As a general rule, building permits will cost 0.001 to 0.0025 of the total building cost. For example, the city of Austin, Texas, requires a permit for any person, firm, or corporation to erect, construct, enlarge, alter, repair, improve, remove, convert, move, or demolish any building or structure within the city's zoning jurisdiction or in a Municipal Utility District (MUD). Often a separate permit is required for each building or structure where work occurs. Nonstructural repairs to a residence do not require a permit. All permitted building work must commence within 180 days from the date of the permit issuance. If work is not commenced, or is suspended or abandoned for 180 days, the permit expires by limitation and becomes null and void; a new permit must be obtained to continue work. Figure 17.4 enables applicants to figure the cost for obtaining construction permits in Austin, Texas. It is recommended that estimators obtain up-to-date information from local municipalities or counties.

9. *Bonds, insurance, and taxes*. Information is provided in Chapter 18 for estimating these costs.

10. *Site office equipment*. This includes the rental costs for everything in the site offices, such as furniture, filing cabinets, fax machines, computers, sta-

R. iable Quality Service

City Austin
Development Review and Inspection Department

PERMIT FEE SCHEDULE

BUILDING
PLUMBING
ELECTRICAL
MECHANICAL

NEW CONSTRUCTION: Groups A, E, I, H, B

ALL BUILDINGS, EXCEPT APARTMENTS, MOTELS, HOTELS, SHELL BUILDINGS, WAREHOUSES, PARKING GARAGES, AND RESIDENCES.

BUILDING AREA SQUARE FEET	BLDG FEE	ELEC FEE	MECH FEE	PLMB FEE
500 or Less	$ 34	$ 34	$ 34	$ 34
501 to 1,000	78	43	43	43
1,001 to 1,500	120	55	55	55
1,501 to 2,000	160	70	70	70
2,001 to 2,500	200	77	77	77
2,501 to 3,000	240	96	85	85
3,001 to 3,500	280	105	88	94
3,501 to 4,000	325	230	91	115
4,001 to 4,500	360	275	105	120
4,501 to 5,000	400	305	115	125
5,001 to 8,000	610	330	130	150
8,001 to 11,000	840	365	145	170
11,001 to 14,000	1,070	400	180	205
14,001 to 17,000	1,295	445	205	230
17,001 to 20,000	1,525	490	245	260
20,001 to 25,000	1,905	540	270	285
25,001 to 30,000	2,290	600	320	340
30,001 to 35,000	2,670	660	365	400
35,001 to 40,000	3,055	735	440	455
40,001 to 45,000	3,440	810	460	510
45,001 to 50,000	3,815	895	500	570
50,001 and above	SEE NOTE 1			

NEW CONSTRUCTION: SHELL BUILDINGS

All Groups.

BUILDING AREA SQUARE FEET	BLDG FEE	ELEC FEE	MECH FEE	PLMB FEE
500 or Less	$ 34	$ 34	$ 34	$ 34
501 to 1,000	78	43	43	43
1,001 to 1,500	120	48	46	48
1,501 to 2,000	160	53	48	59
2,001 to 2,500	200	57	52	62
2,501 to 3,000	240	66	59	69
3,001 to 3,500	280	78	69	83
3,501 to 4,000	325	91	73	89
4,001 to 4,500	360	105	83	95
4,501 to 5,000	400	120	91	100
5,001 to 8,000	610	165	105	115
8,001 to 11,000	840	235	135	140
11,001 to 14,000	1,070	265	140	165
14,001 to 17,000	1,295	315	210	185
17,001 to 20,000	1,525	395	220	205
20,001 to 25,000	1,905	470	270	230
25,001 to 30,000	2,290	550	320	280
30,001 to 35,000	2,670	630	365	320
35,001 to 40,000	3,055	705	415	365
40,001 to 45,000	3,440	795	430	410
45,001 to 50,000	3,815	875	475	455
50,001 and above	SEE NOTE 1			

NEW CONSTRUCTION: Residential and Miscellaneous

Groups R-3: SINGLE FAMILY, DUPLEX, P.U.D., AND TOWNHOUSE.
Group M: MISCELLANEOUS

BUILDING AREA SQUARE FEET	BLDG FEE	ELEC FEE	MECH FEE	PLMB FEE
500 or less	$ 33	$ 34	$ 34	$ 34
501 to 1,000	82	47	41	41
1,001 to 1,250	100	57	44	47
1,251 to 1,500	125	73	48	50
1,501 to 1,750	145	79	56	69
1,751 to 2,000	165	91	59	78
2,001 to 2,250	185	100	66	85
2,251 to 2,500	205	115	72	89
2,501 to 3,000	245	140	79	95
3,001 to 3,500	290	165	94	100
3,501 to 4,000	330	185	105	115
4,001 to 5,000	370	230	120	125
5,001 and above	SEE NOTE 1			
DUPLEXUNITS: Add		$ 34	$ 29	$ 29

	BLDG FEE	ELEC FEE	MECH FEE	PLMB FEE
GROUP R-1: Apartments	$0.10 sq. ft.+ $17/unit	$57 per unit	$46 per unit	$57 per unit
Motel-Hotel	$0.10 sq. ft.+ $17/unit	$29 per unit	$18 per unit	$29 per unit
GROUP B: Warehouse Space and Parking Garages Only	$0.10 sq. ft.	$17 per 1000 sq. ft.	$11 per 1000 sq. ft.	$17 per 1000 sq. ft.

REMODEL, REPAIR & ALTERATIONS: All Groups.

INCLUDING COMPLETION OF SHELL BUILDINGS AND MOBILE HOMES.

DOLLAR VALUATION	BLDG FEE	ELEC FEE	MECH FEE	PLMB FEE
$500 or Less	$ 23	$ 23	$ 23	$ 23
$501 to $2,000	41	29	29	29
$2,001 to $6,000	64	55	55	55
$6,001 to $10,000	78	77	70	70
$10,001 to $20,000	135	94	86	86
$20,001 to $25,000	165	105	100	100
$25,001 to $30,000	200	125	120	120
$30,001 to $35,000	225	140	130	130
$35,001 to $40,000	255	155	150	150
$40,001 to $45,000	290	180	170	170
$45,001 to $50,000	320	195	190	190
$50,001 and above	SEE NOTE 1			

MISCELLANEOUS FEES

1.	DEMOLITION PERMIT: RESIDENTIAL OR COMMERCIAL	$ 44 EACH
2.	RELOCATION	$ 44 EACH
3.	PERMITS OUTSIDE CITY LIMIT	$ 41 ADDITIONAL PER FEE
4.	ELECTRIC METER CONVERSION	$ 23 PER METER
5.	ELECTRIC SERVICE INSPECTION FEE	$ 23 PER INSPECTION
6.	DRIVEWAY	$ 1.65 PER LINEAR FOOT
7.	SIGN INSTALLATION PERMIT	$ 0.55 PER SQUARE FOOT ($30 MIN.)
8.	SOUND PERMIT	$ 11 / $ 22 / $ 33
9.	SIDEWALK / CURB / GUTTER	$ 17 EACH

PLAN REVIEW FEE

(ALL BUILDING PERMITS EXCEPT ONE AND TWO-FAMILY BUILDINGS)

VALUATION	REVIEW FEE
$ 2,500 OR LESS	$ 29 FLAT FEE
$ 2,501 TO $ 5,000	$ 57 FLAT FEE
$ 5,001 TO $ 10,000,000	$ 115 PLUS $ 1.00 FOR EACH $ 1,000
$ 10,000,001 AND ABOVE	$ 11,775 PLUS $ 1.00 FOR EACH ADD'L $ 10,000 ABOVE $ 10,000,000

UPDATE/REVISION FEES

Building Plan Update $325.00
Building Plan Addition Revision - see note 6.......................(Minimum) $315.00
Building Plan Alteration Revision - see note 6......................(Minimum) $175.00

INVESTIGATION FEE

Charged when work is commenced without a permit. Fee shall equal the cost of a permit and is collected in addition to the fee for the permit.

AFTER-HOURS INSPECTION FEE

Fee for inspections conducted outside normal business hours. Fee shall be equal to $ 29 per hour with a minimum charge of two hours.

REINSPECTION FEE

A reinspection fee of $29 per inspection may be charged for inspections or reinspections when the work for which the inspection is called is not complete, when corrections from prior inspections have not been made, or if the site is not accessible for inspection.

REFUNDS ON PERMITS

- No refund will be granted on individual permit fees assessed at the minimum fee amount for a specific type of permit.
- Refunds of permit fees greater than minimum fee amounts may be made at a rate not to exceed 75% of that portion of the fee in excess of the minimum fee amount, provided: (a) no work has commenced, (b) no inspections have been made, and (c) the refund claim is submitted within 180 days after the issuance date of the permit.
- Refund claims must be submitted in writing with a copy of the permit receipt (a receipt is not required for refunds of escrow debits).
- Fees collected in error by the Development Review and Inspection Department will be refunded in full.

NOTES

1. The fees for structures over 50,000 square feet in area, or over $50,000 in valuation, are determined by combining fees to equal the square footage or valuation.
2. Mechanical, electrical, and plumbing fees determined by service area.
3. Unpaid permit fees stated on a permit application or other document are estimates only. Fees charged for any permit type are fees on the schedule in effect at the time payment for the permit is tendered.
4. Plan review fee is payable at time of submittal for all building permits except one and two-family buildings. Permit fee is payable at time of permit issuance for all building and trades' permits.
5. Fee schedule effective October 1, 1996.
6. Applicant pays minimum revision fee or plan review fee, whichever is greater.

FIGURE 17.4 City of Austin, Texas, fee permit schedule, 2000.

tionery, and coffee supplies. The estimator needs to check whether office communication equipment is included in the telephone and communication category. It should only be listed in one category!

17.15 REVIEW QUESTIONS

1. Explain why the estimator should visit the project jobsite prior to submitting the bid.
2. What are the major categories of expenses related to jobsite overhead? (Refer to Figure 17.1.)
3. For a large complex building at the fringe of a major city, how much do you expect jobsite personnel to cost relative to total jobsite overhead? Explain how you figure this cost.
4. Who develops the construction organization jobsite personnel organization chart?
5. Name a few expenses that fall into the category of "site engineering support."
6. What should be included in the class of construction equipment for general use on the building site?
7. Who needs field temporary building space on the jobsite? Why do they need to be separated into various trailers or offices?
8. What utilities are needed on the jobsite? What is the average cost per KW? For 1000 L of water?
9. How does the estimator figure the number of portable toilets needed on the jobsite?
10. Describe the type of facilities for materials storage. Give examples of materials related to each type.
11. When should a "camp" be considered for a new project? What types of buildings are needed to sustain a good standard of living for a site population?
12. Which "commercial facilities" should be considered for a remote jobsite?
13. Name a few jobsite production facilities. Explain why they are needed.
14. What US legislation regulates personal protective aids on a construction jobsite?
15. What additional expenses need to be estimated as described under "Miscellaneous"?

18

Surety Bonds, Insurance, and Taxes

18.1 SURETY BONDS

A surety bond, or bonds, is a three-party instrument: the principal (in construction, the contractor), the obligee (the owner) who is the party requiring the protection of the bond, and the surety. Surety guarantees payment of another party's obligation. Bonds are written documents that guarantee that the construction contract agreement will be followed and that the contractor will pay all costs relative to the project.

Bonds are usually issued to cover a single job and represent a line item cost in jobsite overhead estimated expenses. Bonds are not purchased by contractors, but rather are the payment of a fee based on the contract or subcontract cost. Some bonds cover only a single trade and may be included in a subcontractor contract. Bonds are usually issued by the surety which guarantees that the contractor will make whole any loss the owner might sustain by reason of the contractor's failure to carry out and perform all the conditions of the agreement entered into by the contractor and the owner. If for some reason the contractor fails or is unable to fulfill his contractual obligations, the surety then performs in accordance with conditions of the bond. The surety can then seek recovery of any losses from the principal (contractor or subcontractor) (see Fig. 18.1). When the general contractor furnishes a bond to the owner, the bond provides protection to the owner and not to the contractor.

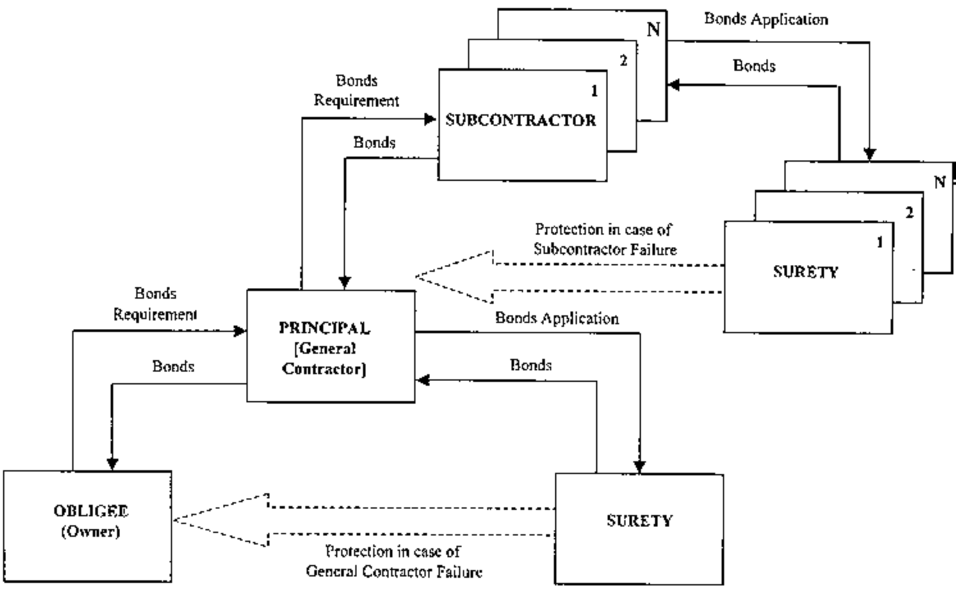


FIGURE 18.1 Project bonds—three-party instrument.

Webster's Dictionary defines the word "surety" as, "That which confirms or makes sure; a guarantee; one who makes a pledge on behalf of another and accepts certain accruing responsibilities." Webster defines "suretyship" as, "The obligation of a person to answer for the debt, default, or miscarriage of another." An experienced contractor who has definite arrangements for credit with his surety company already has furnished the surety with periodical financial statements, references, personnel records, and other vital data. Therefore, when he subsequently bids a contract requiring a bond, the surety requires of him specific information only as to the size, hazards, and nature of the proposed contract and the status of other work on hand.

On a new contractor account, the surety underwriter must build or create a credit file containing complete information as to the contractor's integrity, experience, organization, equipment, and finances. The underwriter normally utilizes the services of Dun and Bradstreet and other trade-reporting agencies to aid in accumulating all data possible on the contractor's background, credit record, and general reliability. The surety must place faith in its contractor clients. If the contractor's credit record and background indicate she does not pay her bills but instead is being sued and attacked constantly, a surety is not likely to be willing to guarantee that she will pay the bills incurred in the performance of a contract. If the contractor has a past record of failures, the surety cannot be certain that she will complete a difficult contract. The surety cannot afford to gamble on such a risk. When these circumstances prevail, the surety either will decline the risk, or will extend limited credit only until it is satisfied that the contractor is worthy of the trust and credit extended.

A surety underwriter is concerned with the contractor's methods of handling subcontractors. Most owners specify to bidders that they reserve the right to reject any or all bids, regardless of whether such a bid may be low. Too often, because of the press of time and last-minute arrangements necessary just prior to bid-letting, the general contractor is sorely tempted to accept a subcontractor's, or even a supplier's, low bid, not knowing fully the performance record, payment record, and financial stability of such a bidder. The general contractor, fearing that his competitors may use a very low subcontract bid, will often use it himself, but will add something to it to allow for any preaward negotiations with other subcontractors or suppliers who he may have to substitute for the questionable subcontractor.

Parenthetically, it should be stated that most sureties for the general contractor do not wish to become surety for the subcontractor on the same job. Obviously in dispute situations, the surety may find itself in the position of "choosing sides" or in a conflict of interest.

18.1.1 Bid Bonds

Bids are invited by advertisements and the bidder must submit with her bid a bid bond, usually for 10% of the bid amount. This requirement has a dual purpose:

first, that the bids will be submitted only by qualified contractors screened by surety companies, and second, if the contract is awarded, the general contractor (principal) within a specified time will sign the contract and will furnish the required performance and payment bonds. If the contractor fails to do so, the bid bond shall be forfeited to the owner. The amount forfeited shall in no case exceed the amount of the bid bond or the difference between the original bid and the next lowest bid accepted by the owner.

The bonding company (surety) usually provides bid bonds at no charge to qualified contractors, or for a minimal fee (symbolic) of $50 to $100 per project bid. Surety companies follow the practice of providing bid bonds only after the contractor has been carefully screened and after the performance and payment bonds (which are discussed later) have been underwritten. Very seldom do contractors default the bid bond under these conditions. For qualified contractors the bid bond cost represents 5 to 10% of the total bid cost.

18.1.2 Performance and Payment Bonds

Most public works projects (federal, state, city, county) and the majority of owners require that the general contractor or contractors to whom the contract is awarded furnish performance and payment bonds. The performance bond guarantees the owner that the general contractor will complete the work in accordance with the plans and specifications (quality, time, and cost). It protects the owner against contractor default up to the amount of the bond penalty.

The payment bond (labor and material bond) guarantees the payment of all bills incurred by the contractor for labor and materials incurred or supplied on the project. Payment bonds act as a protection for the owner, who is exempted from any liabilities in connection with claims against the project. For federally funded projects, it is required that the contractor furnish two separate bonds, one for performance and one for payment of labor and materials. Some states also follow this procedure. The surety risk is if the contractor fails in completing the contract (project) or in paying the bills for materials, labor, or construction equipment, the surety assumes the responsibility for completing the project and for paying pending and all newly incurred bills.

There are many causes for contractor failure and consequent surety losses. Surety statistics indicate that "overexpansion," that is, taking on more work than a contractor's working capital can handle, is probably the major cause of failure in the building field.

Consistent low bidding, subcontract failure, and unforeseen labor troubles also are constant factors in the failure of both building and heavy engineering contractors. Unknown soil conditions have contributed to huge unanticipated costs that have wrecked many concerns in the heavy construction field. Loss of key personnel, due to death, retirement, or the inroads made by competitors, has also caused a great many failures.

Dishonesty has played a leading part in contract losses as well. In many instances, contractors have diverted progress payments either for personal use or occasionally for gambling, instead of using the money to pay for labor and materials. In still other cases, contractors have spent anticipated profits before they were earned, only to discover that such profits were wiped out during the course of the work.

Of course, the surety underwriter cannot foresee all the contingencies; nevertheless, he must keep them in mind and strive to underwrite against the hazards. That is why underwriters often suggest and recommend that a contracting concern purchase substantial life insurance on its key officers or partners, as well as a fidelity blanket bond on all its employees, and that the subcontractors on the job be bonded.

To obtain performance and payment bonds costs substantial amounts of money to cover the surety risks of a bonded contractor's failure to perform. Table 18.1 shows the cost of performance and payment bonds where the time for completion as stipulated in the contract is not over 12 months. In practice, add 1% of the calculated premium cost per month for projects requiring more than 12 months to complete. The rates are offered to contractors that the surety company considers financially sound with good past performance portfolio records. Actual rates may vary from contractor to contractor and among surety companies. It is important for a contractor to prequalify through a surety company prior to submitting a bid that also requires performance and payment bonds.

Tables 18.2 through 18.5 define which projects or contracts fall into classes B, A, A.1, and Supply. These tables can be used for a quick estimate of performance and payment bond cost, license, or permit. If the general or subcontractor regularly operates in an area requiring such bonds, this cost should be part of the general overhead expenses. If these bonds are required for a specific project only, they can be charged as jobsite overhead and included in the detailed estimate prepared when bidding for the project.

18.1.3 Subcontractor Bonds

Most of the time, the general contractor performs less than 10% of the construction work for building projects within her organization. Various categories of work are subcontracted out. For modern buildings, 30 to 50 subcontractors may be involved. During the bidding phase, the general contractor requests in the invitation to bid that subcontractors must supply performance and payment bonds to the prime contractor. Usually the surety that bonded the prime contractor does not provide these bonds for subcontractors. These bonds protect the prime contractor against financial loss due to subcontractor nonperformance. Tables 18.1 through 18.5 are used for underwriting subcontractor bond agreements.

Table 18.1 Performance Plus Payment Bond Rates by Type of Project/Contract

Exposure units (unit = $1000)	Class B contracts ($)	Class A contracts ($)	Class A-1 contracts ($)	Supply contracts ($)	Maintenance guarantees ($)	Completion, finance, and/or design hazard bonds ($)	Miscellaneous contracts ($)
Each of first 100 units	25.00	15.00	9.40	3.50	2.50	25.00	19.50
Each of next 400 units	15.00	10.00	7.20	2.50	2.25	20.00	15.00
Each of next 2000 units	10.00	7.00	6.00	1.75	2.00	15.00	12.00
Each of next 2500 units	7.50	5.50	5.00	1.50	1.75	12.00	10.00
Each of next 5000 units	7.00	5.00	4.50	1.25	1.50	11.00	9.00
Each of next 7500 units	6.50	4.50	4.00	1.00	1.40	10.00	8.00

Table 18.2 Class B Contracts

Project
Airport buildings
Air conditioning systems
Apartment buildings
Aqueducts
Asbestos removal
Atomic energy plants (complete)
Buildings (unclassified)
Breakwaters
Building rehabilitation
Canals and canal lining
Carpentry
Coal stripping
Commercial buildings
Concrete work not otherwise classified
Dams (all)
Dikes, levees, and revetments
Ditches, including drainage
Docks and drydocks
Drilling contracts
Drywall
Educational wiring, furnishing and installing with or without fixtures or other devices
Embankments
Excavations
Filling stations (including bulk stations)
Filtering plants
Foundations
Fountains
Framing and finish
Garbage disposal plants
Gasoline cracking plants
Gas compressor stations
Gas mains and laterals running through city streets where contract includes trenching (excluding trenching—Class A-1)
Gas piping with or without fixtures
Golf courses
Grain elevators
Gunite contracts
Heating systems
Hospital, clinic, and rest home buildings
Incinerators
Industrial buildings and plants
Irrigation systems
Jetties
Landscaping
Locks
Masonry
Missile installations
Nuclear reactors
Office buildings
Off-shore platforms and towers
Painting
Piers
Piling
Pipelines for water, gas, filtering plants, waterworks, fountains, and sewage and water treatment plants
Plastering
Plumbing in new or old buildings
Power plants with or without distribution systems
Precipitators
Prefabricated houses, buildings, or structures (furnishing and erecting or erecting only—see Class A. Furnishing only—see Supply)
Public improvements
Rail transit systems
Roadbeds for railroads
Sandblasting
Scrubbers
Sculptures
Sea walls
Sewage disposal plants
Shipbuilding—construction conditioning or repair
Shipyards
Spillways
Stone, cut or dressed—furnishing and setting
Subways
Swimming pools
Terminals for bus companies or others
Test boring
Tile and terrazzo
Transmission or distribution lines (electrical or telephone)
Tunnels
Underwater cables
Ventilating systems
Waste disposal plants—hazardous or nonhazardous waste
Waterworks
Wells
Wharves
Wrecking demolition or dismantling contracts

TABLE 18.3 Class A Contracts

Project
Airports—grading, clearing, drainage, preparation, leveling, or surfacing of sites
Airport runways—see Highways
Aluminum and vinyl siding
Athletic fields
Beacon or floodlights
Bridges—complete construction or substructures, including painting, reflooring, or repairing bridge superstructures (other see A-1 or Supply)
Burial contracts
Ceilings—metal or acoustical tile
Clearing, grading, and grubbing where no ultimate improvement is involved
Coal storage
Construction forms
Curbing and guttering
Curtain walls (not structural)
Ducts, underground—for power, light, or telephone
Elevators (passenger or freight) and escalators
Fences—furnishing and erecting (other see Supply)
Filling up abandoned coal mines
Glazing
Granite—see Stone
Greenhouses
High pressure power piping
Highways, roads, street paving, airport runways—new construction or reconstruction (other see A-1 or Supply)
Janitor service
Laundry contracts
Machinery made to special order or design of purchaser and not catalogued as part of seller's stock designs or products
Mail chute contracts (installation of mail chutes in building, including three years' maintenance)
Mapmaking
Marble—see Stone
Millwork
Murals
Parking areas
Planting and cultivation of land
Plargrounds and parks
Prefabricated houses, buildings, or structures, furnishing and erecting or erecting only (other see Class B or Supply)
Research contracts
Riverbank protection
Road medians
Roofing
Ski lifts
Sprinkler systems
Stone, marble, or granite (other than crushed stone) furnishing and delivering only, cut or dressed stone (contracts for furnishing and setting cut or dressed stone or setting only for building or other structures or improvements are classified as Class B)
Storage tanks, metal (gasoline or oil)
Tennis courts
Water carriage of freight
Waterproofing (not including gunite contracts)
Wind tunnels

TABLE 18.4 Class A-1 Contracts

Project
Arms
Ash conveyors
Automatic stokers
Automotive service contracts
Band concerts
Bird control
Boiler retubing and repair
Bonds for superintendents of construction
Bookbinding
Bridges superstructure—furnishing and erecting only (other see A or Supply)
Cataloguing
Coal handling machinery—furnishing and erecting only (furnishing only see Supply)
Computers and data processing equipment
Computer software
Conveyors
Data processing and computer work
Doors—all types
Dynamos
Exterminating contracts
Fire alarm systems
Fire escapes
Flagpoles
Floats
Floors—asphalt tile, cork or rubber tile, parquet, wood or wood block
Furnishing food services
Gas tanks
Generators
Grain doors, salvage, care and disposal of
Guard rails
Heating—temporary and/or portable
Highways, roads, street paving, and airport runways and paving:
(a) Surfacing, resurfacing, or repairs to surface on existing roads, parking lots, or other existing hard surfaces. (contracts that do not include widening, bridges, or base construction)
(b) Road oiling contracts
(c) Bituminous materials and concrete plus equipment contracts (contracts for the furnishing or furnishing and delivering of bituminous materials (tar, oil, asphalt), concrete cement or similar materials and contractor rents his asphalt plant, roller, or other mechanical equipment with or without operators, without obligation to spread or manipulate materials) (bituminous materials and concrete contracts without equipment rental—see Supply)
(d) Striping
Incinerator operation
Insulation contracts
Iron or steel contracts—furnishing, delivering and erecting only (other see Supply)
Kitchen equipment
Laboratory equipment and apparatus
Leasing of motor vehicles
Lightning rods
Lock gates—furnishing only, or furnishing and installing
Mail handling machinery
Metal windows and shutters
Mosquito control contracts
Movies
Office personnel
Organ repairs
Ornamental iron work
Parking meters
Photogrammetric work
Pipelines for oil or gas (for gas mains running through city streets or pipelines under water see Class B)
Police alarm systems
Processing contracts
Projectiles
Public address and music systems
Radio towers
Radiological equipment and apparatus
Recapping auto tires
Refrigerating plants, on land
Repair of automobiles and trucks
Resmelting old metal
Rip rap stone (furnishing only)
Rolling stock
Scaffolding
Sidewalks
Signal systems on railroads
Signs
Stack rooms
Standpipes
Street and subway lighting systems
Telephone exchange equipment
Temporary personnel services
Thermostat equipment
Toll gates
Track laying
Traffic control sytems on highways
Training manuals
Tree trimming and removal
Watchmen and signal services
Water towers
Weatherstripping
Weed mowing
Window cleaning
Work and labor
X-ray inspection

Table 18.5 Supply Contracts

Project
Aircraft engines, spare parts, and equipment, not including construction, conditioning, or repair of aircraft
Ammunition
Apparatus in public or private offices, stores and schools, colleges, churches, hospitals, hotels, libraries, museums, theatres, exhibitions, clinics, etc.
Armament
Armor plate
Auditing contracts
Automobiles, trucks or parts
Awnings
Blackboards and bulletin boards
Boilers
Bridge superstructures only—furnishing and delivering without erecting
Cabinets
Clock and master clock
Clothing, tents, or uniforms, without processing
Coal
Concrete or cement (mixed) furnishing and delivering
Crushed stone, stone screenings, chats, sand, or gravel for purchase and sale only.
Curtains, draperies, or scenery
Electric current—sale of Electric fixtures (where electrical wiring or conduits are not included in contract)
Engines, spare parts and equipment
Fences—furnishing only (other see A)
Filing cases
Fire engines or fire hose
Fuel
Furniture
Headstones and mortuary—monuments of stock design
Highways, roads, street paving, airport runways, bituminous materials and concrete contracts-furnishing or furnishing and delivering, without obligation to spread or manipulate materials (other see A or A-1)
Iron or steel contracts—furnishing or furnishing and delivering with or without fabrication, but without erecting (other see A-1)
Jail cells (not including erection of jail buildings or walls
Laboratory animals
Laundry machinery
Lighting contracts including maintenance of street lighting system (contracts for supply of lighting to cities or municipalities)
Linoleum, carpets, rugs—furnishing or laying
Lockers
Machinery, however massive, if built, completed, and for sale at factory or premises of the seller
Munitions
Office furniture
Oil and burners
Partitions
Paving blocks
Pipe (furnishing only—not including laying or setting)
Pipe covering
Pipe organs
Placing fire or other insurance
Prefabricated houses, building, or structures—furnishing and delivering only by manufacturer (other see B or A)
Printing contracts
Printing cigarette, liquor tax stamps or railroad tickets
Printing presses
Pumps
Safe deposit vaults or safes
School book contracts—sale and delivery
Shipbuilding—engines, spare parts, and equipment when awarded under separate contract (other see B)
Showcases and counters
Steam, sale of
Stone, crushed
Timber—furnishing and delivering cut timber or forest products (other see Miscellaneous contracts)
Track materials, railroad ties, plates, pads, and ballast
Transcribing records
Uniforms
Venetian blinds
Water softener
Window screens or shades

18.1.4 Maintenance Bonds

Maintenance bonds are required by the surety and guarantee the owner that the general contractor agrees to correct all defects of workmanship and materials for a specified period (one to three years) following occupancy by the owner. Using Table 18.1, in the column "Maintenance guarantees," the bond fee schedule, the estimator will be able to figure the cost of securing maintenance bonds for the duration required by agreement for the project.

18.1.5 License or Permit Bonds

These bonds are required of the prime contractor when a state law or city local ordinance requires a contractor to be licensed or permitted to perform the work in a given municipality, county, or state.

18.2 INSURANCE

The contract documents stipulate for the owner's protection that the construction contractors must carry various types of insurance. Insurance is not similar to a bond. It is a two-party instrument. With an insurance policy, the specified losses encountered by a general contractor and various subcontractors and suppliers become the responsibility of the insurance company.

Along with the insurance required in the contract agreement provided at the invitation to bid, state or governmental agencies often require additional types of insurance. All this insurance is not free. It costs money and that cost must be estimated and included in the appropriate section of the project or construction estimate. The cost of insurance is an important cost component and is estimated to vary between 2 and 5% of the direct contract cost. It is usually included as a line cost item in jobsite overhead.

18.2.1 Workers' Compensation

Workers' compensation provides the contractor's employees with benefits as required by various state or federal agencies in the event of a work-related injury or death. Prior to the start of the general contractor's or the subcontractor's work, the contractors must procure workers' compensation insurance at the minimum limits:

$500,000 Bodily injury by each accident,
$500,000 Bodily injury by disease each accident, and
$500,000 Bodily injury by disease policy limit.

The rates charged for this insurance vary by county, state, category of work, and contractor per subcontractor's reputation and past history. The contractor field accident rating depends on work safety accident records and claims. Lower claims mean lower premiums and, finally, the higher probability of being a successful bidder.

Table 18.6 tabulates the national averages for US workers' compensation insurance rates by major construction trades and type of buildings for the year 2000.

Table 18.7 provides workers' compensation insurance rates by trade and state for the year 2000. The rates are for manual costs per $100 payroll. Rates are applied to straight-time wages only and not to overtime wages and other bonuses. The rates per trade, for example, in Texas, can vary from a high of

TABLE 18.6 USA Average Workers' Compensation Insurance Rate by Major Construction Trades[a]

		Building cost (%)		
Trade	Insurance rate (% labor cost)	Office bldgs.	Schools, apts.	Mfg.
Excavation, grading, etc.	11.4	0.55	0.56	0.51
Piles, foundations	29.9	2.12	1.55	2.60
Concrete	18.8	0.94	2.78	0.70
Masonry	17.8	1.23	1.34	0.34
Structural steel	42.6	4.56	1.66	7.50
Miscellaneous, ornamental metals	13.8	0.39	0.55	0.50
Carpentry or composition siding	19.9	0.74	0.80	0.10
Metal or composition siding	18.1	0.42	0.05	0.78
Roofing	34.6	0.80	0.90	1.07
Door and hardware	11.7	0.11	0.16	0.05
Sash and glazing	14.4	0.50	0.58	0.14
Lath and plaster	15.7	0.52	1.08	0.13
Tile, marble and floors	10.5	0.27	0.32	0.05
Acoustical ceilings	12.3	0.30	0.02	0.04
Painting	15.3	0.23	0.24	0.24
Interior partitions	19.9	0.78	0.86	0.88
Miscellaneous items	19.0	0.99	0.70	1.84
Elevators	8.5	0.18	0.09	0.19
Sprinklers	9.0	0.05	—	0.18
Plumbing	8.8	0.43	0.63	0.46
Heat, vent, air conditioning	12.3	1.66	1.35	1.59
Electrical	7.0	0.71	0.59	0.78
Total	—	18.48	16.81	20.67

[a] For the year 2000.

Source: Means, *Building Construction*, 58th Edition, 2000.

TABLE 18.7 Workers' Compensation

State	Carpentry — 3 stories or less 5651	Carpentry — interior cab. work 5437	Carpentry — general 5403	Concrete Work — NOC 5213	Concrete Work — flat (flr., sdwk.) 5221	Electrical Wiring — inside 5190	Excavation — earth NOC 6217	Excavation — rock 6217	Glaziers 5462	Insulation work 5479	Lathing 5443	Masonry 5022	Painting and decorating 5474	Pile driving 6003	Plastering 5480	Plumbing 5183	Roofing 5551	Sheet metal work (HVAC) 5538	Steel erection — door, sash 5102	Steel erection — inter., ornam. 5102	Steel erection — structure 5040	Steel erection — NOC 5057	Tile work — (interior ceramic) 5348	Waterproofing 9014	Wrecking 5701
AL	36.41	14.51	34.52	32.46	16.19	9.57	20.98	20.98	24.55	20.09	15.28	29.78	21.80	64.38	33.79	11.96	57.62	25.78	16.41	16.41	54.68	66.67	16.19	6.92	54.68
AK	9.30	6.63	9.58	9.26	5.69	5.31	8.16	8.16	9.44	8.72	6.37	9.33	8.41	36.08	11.46	4.46	16.70	6.03	10.43	10.43	18.69	18.69	6.28	5.07	25.07
AZ	14.89	9.11	26.40	13.69	8.09	6.28	8.66	8.66	12.90	15.63	7.83	13.69	10.23	19.88	12.27	7.77	19.67	10.13	10.02	10.02	36.62	23.31	7.24	4.94	50.31
AR	16.12	10.60	15.38	16.45	5.97	7.93	9.21	9.21	12.58	15.29	12.66	9.32	11.10	19.14	13.01	6.58	30.74	10.28	8.19	8.19	27.11	25.39	7.80	4.58	27.11
CA	28.28	9.07	28.28	13.18	13.18	9.93	7.88	7.88	16.37	23.34	10.90	14.55	19.45	21.18	18.12	11.59	39.79	15.33	13.55	13.55	23.93	21.91	7.74	19.45	21.91
CO	32.22	13.54	20.95	20.96	15.13	9.20	15.99	15.99	15.98	21.31	14.68	31.06	21.85	41.53	37.40	14.50	59.10	12.54	11.83	11.83	73.46	43.49	15.04	12.26	73.46
CT	19.25	13.14	24.07	20.48	14.17	6.68	8.42	8.42	21.25	34.89	13.64	25.45	18.84	24.54	17.60	12.25	33.98	13.93	13.67	13.67	50.36	35.83	13.94	5.02	50.86
DE	13.83	13.83	11.56	9.28	6.29	5.82	8.54	8.54	11.18	11.56	10.51	9.85	13.41	11.64	10.51	5.41	22.89	10.29	10.21	10.21	26.69	10.21	7.54	9.85	25.69
DC	17.51	10.80	18.88	29.27	16.85	8.76	17.96	17.96	28.00	22.14	12.07	29.67	16.85	42.12	17.06	12.83	22.39	15.78	33.66	33.66	66.43	42.52	16.42	4.66	66.43
FL	36.73	23.28	29.09	29.92	16.15	10.51	15.27	15.27	17.81	25.18	24.27	28.72	28.92	49.35	28.79	13.37	53.20	17.12	18.67	18.67	43.71	50.61	12.56	7.89	43.71
GA	31.04	16.02	32.71	20.67	15.12	9.82	19.55	19.55	21.97	19.15	26.66	23.03	21.20	40.88	19.50	11.14	40.72	18.65	13.74	13.74	36.03	53.09	13.08	10.16	36.03
HI	17.38	11.62	28.20	13.74	12.27	7.10	7.73	7.73	20.55	21.19	10.94	17.87	11.33	20.15	15.61	6.06	33.24	8.02	11.11	11.11	31.71	21.70	9.78	11.54	31.71
ID	12.68	6.50	16.29	9.46	9.04	5.37	6.87	6.87	8.58	11.01	8.97	9.38	8.83	18.27	8.94	5.04	21.34	7.76	7.51	7.51	26.68	24.89	5.35	7.44	26.68
IL	20.76	12.31	21.64	35.48	12.83	8.86	8.69	8.69	23.09	24.90	14.24	20.34	13.15	37.63	13.78	11.68	35.88	14.58	21.53	21.53	58.63	52.47	13.87	6.26	58.63
IN	6.86	3.76	6.99	7.50	3.50	2.89	4.01	4.01	5.67	7.82	3.97	5.79	6.06	12.19	5.30	2.96	12.65	4.33	5.55	5.55	27.19	12.61	3.49	3.67	27.19
IA	10.22	5.19	12.01	9.18	6.42	3.84	5.56	5.56	11.62	16.49	5.95	10.93	7.58	16.30	9.26	5.01	17.38	6.09	9.80	9.80	45.02	27.20	5.60	4.16	45.02
KS	11.44	7.93	9.21	9.68	6.17	4.12	4.14	4.14	6.93	16.00	7.06	11.86	8.63	13.22	9.21	5.11	22.98	5.57	5.38	5.38	16.49	22.99	3.90	3.77	16.49
KY	16.47	15.26	24.34	22.12	9.53	8.95	13.67	13.67	15.96	14.68	10.62	22.00	19.83	30.44	13.94	10.38	32.83	15.92	13.21	13.21	45.21	33.73	10.60	8.85	45.21
LA	29.63	22.95	26.01	20.86	14.80	10.48	24.73	24.73	23.88	20.82	14.00	21.27	27.63	54.39	21.42	13.78	49.11	21.35	15.51	15.51	66.41	36.94	12.82	10.26	66.41
ME	13.43	10.42	43.59	24.29	11.12	10.02	14.75	14.75	13.35	15.39	14.03	17.26	16.07	31.44	17.95	11.12	32.07	17.70	15.08	15.08	37.84	61.81	11.66	9.37	37.84
MD	10.55	5.95	10.55	11.35	5.05	5.15	9.25	9.25	13.20	13.05	6.45	11.35	6.75	27.45	6.65	5.55	22.80	7.00	9.15	9.15	26.80	18.50	6.35	3.50	26.80
MA	15.25	11.38	22.82	39.38	16.79	6.14	10.72	10.72	16.78	27.76	14.02	29.03	14.95	29.58	13.75	8.49	67.48	13.20	16.07	16.07	80.76	79.51	16.46	6.62	62.87
MI	16.08	9.61	17.85	24.50	12.37	5.71	10.99	10.99	9.62	20.95	11.61	19.18	17.86	64.20	18.33	8.19	43.08	10.91	14.52	14.52	36.41	31.20	13.08	10.42	41.58
MN	27.66	28.76	49.94	30.20	22.59	8.28	19.73	19.73	30.01	37.20	23.93	29.89	19.91	80.08	23.93	15.88	88.83	13.91	27.21	27.21	132.92	31.83	29.54	8.71	132.92
MS	21.77	16.71	28.09	17.88	11.02	10.84	13.03	13.03	18.18	21.21	14.41	22.67	17.90	77.98	20.06	10.84	36.25	20.16	14.52	14.52	37.42	42.77	12.76	8.68	37.42
MO	18.72	7.52	11.84	13.28	10.66	5.79	11.05	11.05	8.97	19.99	9.67	13.57	11.77	16.88	14.22	7.10	25.74	9.76	13.82	13.82	47.98	31.96	5.83	5.71	47.98

TABLE 18.7 Workers' Compensation (Continued)

State	Carpentry — 3 stories or less 5651	Carpentry — interior cab. work 5437	Carpentry — general 5403	Concrete Work — NOC 5213	Concrete Work — flat (flr., sdwk.) 5221	Electrical Wiring — inside 5190	Excavation — earth NOC 6217	Excavation — rock 6217	Glaziers 5462	Insulation work 5479	Lathing 5443	Masonry 5022	Painting and decorating 5474	Pile driving 6003	Plastering 5480	Plumbing 5183	Roofing 5551	Sheet metal work (HVAC) 5538	Steel erection — door, sash 5102	Steel erection — inter., ornam. 5102	Steel erection — structure 5040	Steel erection — NOC 5057	Tile work — (interior ceramic) 5348	Waterproofing 9014	Wrecking 5701
MT	30.63	15.19	47.53	32.78	24.74	1.01	26.63	26.63	25.04	38.54	19.54	48.55	41.06	53.68	27.00	15.03	85.06	16.93	33.95	33.95	86.98	55.25	13.30	12.10	86.98
NE	16.19	9.23	15.94	17.31	12.73	5.43	10.19	10.19	12.36	16.79	9.34	18.07	11.58	22.01	14.62	9.06	33.91	13.86	10.75	10.75	25.03	26.96	7.88	5.47	25.03
NV	19.86	10.88	14.94	14.89	11.46	9.64	9.26	9.26	13.64	22.78	14.60	14.48	16.01	27.25	17.93	10.76	33.53	18.03	16.53	16.53	45.36	32.56	18.03	7.43	45.36
NH	16.38	9.82	19.68	28.99	9.29	7.10	13.87	13.87	12.87	43.98	10.90	25.97	17.94	28.09	17.33	9.74	58.76	12.48	13.27	13.27	55.90	49.67	12.82	7.37	55.90
NJ	10.40	8.85	10.40	10.83	8.37	4.23	7.95	7.95	7.36	12.78	7.88	10.77	11.49	11.32	7.88	5.48	29.41	6.20	8.03	8.03	22.52	12.96	5.74	5.37	29.92
NM	25.35	13.09	20.45	19.66	13.39	6.34	10.95	10.95	14.58	31.49	16.25	26.97	16.87	33.27	15.64	12.10	43.41	16.46	21.26	21.26	67.82	29.91	9.67	10.65	67.82
NY	15.39	6.82	14.50	24.92	15.16	6.89	9.69	9.69	16.92	15.82	13.00	18.61	12.55	27.49	13.03	9.03	32.78	14.13	14.12	14.12	27.11	24.09	10.56	7.48	32.53
NC	14.43	9.91	15.37	16.82	6.37	7.64	7.73	7.73	9.52	12.92	8.00	12.94	10.40	17.95	14.47	6.93	25.39	10.26	13.32	13.32	39.03	16.68	7.68	3.86	39.03
ND	13.89	13.89	13.89	12.17	12.17	6.16	9.91	9.91	9.85	9.38	13.16	12.20	11.42	29.82	13.16	8.05	31.37	8.05	13.89	13.89	29.82	29.82	9.63	31.37	29.82
OH	13.27	13.27	13.27	13.45	13.45	6.02	13.45	13.45	18.28	16.31	16.31	15.62	18.28	13.45	16.31	7.96	28.62	24.12	13.45	13.45	13.45	13.45	13.08	13.45	13.45
OK	26.16	11.79	19.33	15.51	11.50	7.41	18.45	18.45	13.55	18.00	12.05	16.80	17.10	36.26	18.29	8.72	42.26	12.45	11.17	11.17	69.45	46.76	11.42	8.20	69.45
OR	29.51	9.28	20.03	16.50	10.61	6.63	12.94	12.94	14.95	19.68	12.27	12.43	19.83	22.05	13.85	8.38	38.11	11.85	11.01	11.01	61.69	25.54	9.92	12.10	61.69
PA	15.80	15.80	19.85	28.18	11.84	7.80	12.74	12.74	15.69	19.85	18.94	18.96	22.05	32.12	18.94	11.57	43.30	12.58	24.71	24.71	59.05	24.71	11.83	18.96	81.34
RI	21.32	11.02	18.77	22.11	15.55	5.86	12.16	12.16	17.02	20.95	11.89	20.66	19.86	41.76	14.19	7.25	29.48	10.52	13.18	13.18	78.79	49.67	14.34	9.90	78.79
SC	19.10	13.03	19.24	12.88	6.19	7.02	8.32	8.32	12.22	10.69	7.27	9.55	11.19	16.64	18.89	6.88	28.98	11.42	9.49	9.49	21.80	23.66	6.23	4.65	21.80
SD	14.61	9.94	20.92	21.64	9.04	5.72	11.73	11.73	14.77	17.73	10.89	13.30	13.25	32.14	16.96	9.50	29.39	11.35	11.51	11.51	46.57	33.20	9.85	5.59	46.57
TN	13.22	9.52	11.99	12.39	7.53	5.00	8.68	8.68	8.96	15.04	8.51	12.73	10.88	15.62	12.19	5.91	24.81	8.76	7.36	7.36	45.06	13.95	5.89	4.98	45.06
TX	28.29	18.95	28.29	25.59	19.49	1.60	18.16	18.16	14.17	25.84	13.47	23.12	18.29	43.91	20.99	12.88	47.24	22.92	14.29	14.29	50.47	31.01	9.94	11.38	54.81
UT	11.17	11.17	11.17	17.68	7.99	7.05	6.38	6.38	9.55	10.95	12.32	13.75	15.29	17.24	10.60	6.41	26.27	6.30	8.99	8.99	23.51	23.51	6.06	5.83	26.53
VT	11.93	7.61	14.88	34.92	9.35	4.51	7.91	7.91	11.95	11.32	8.84	13.76	7.82	19.81	10.86	6.71	24.32	10.29	10.29	10.29	32.12	35.79	6.45	8.56	32.12
VA	10.00	6.46	8.65	9.29	5.47	3.45	6.13	6.13	10.17	8.77	7.59	8.07	8.11	24.38	8.20	5.60	17.80	6.74	10.42	10.42	19.28	30.25	6.78	2.57	19.28
WA	8.78	8.78	8.78	8.53	8.53	3.68	8.82	8.82	8.71	9.93	8.78	11.54	10.23	20.99	11.78	5.41	23.39	3.94	16.21	16.21	16.21	16.21	9.81	10.23	16.21
WV	15.43	15.43	15.43	20.87	20.87	5.01	9.14	9.14	7.33	7.33	16.88	16.02	16.88	10.56	16.88	7.40	12.04	7.33	14.98	14.98	13.27	14.98	16.02	4.87	13.27
WI	10.47	10.13	19.98	8.91	8.50	5.73	7.00	7.00	9.67	13.88	13.48	15.43	12.10	17.04	11.81	5.95	29.35	8.64	11.52	11.52	36.51	18.72	8.45	3.92	36.51
WY	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13
AVG.	18.12	11.65	19.85	18.81	11.46	7.03	11.41	11.41	14.43	18.52	12.26	17.75	15.27	29.88	15.72	8.82	34.62	12.27	13.77	13.77	42.56	31.55	10.48	8.32	43.48

Source: Means, *Building Construction*, 58th Edition, 2000.

$54.81 per $100 of payroll for wrecking (demolition) to a low of $9.94 per $100 of payroll for interior ceramic tile work. The contractor per subcontractor pays the cost of the policy in full, and the estimated cost is included in the bid.

18.2.2 Contractors' Comprehensive General Liability Insurance

This policy protects the owner and contracting organization against liability for bodily injury against the public arising out of the contractor's operations, and against completed operations (property damage). Minimum recommendations for this type of insurance are: (1) Combined Single Limit Bodily Injury and Property Damage, $1,000,000—each occurrence, $1,000,000—aggregate; and (2) Bodily Injury, $500,000—each occurrence, $500,000—aggregate. The most common rates for general construction operations in most states are shown in Table 18.8.

Computation Example. Assuming a building construction contract of $5.7 billion, the estimated cost for general liability using Table 18.8 is:

$$\begin{aligned} 500{,}000 \times 0.029 &= \$145 \\ 500{,}000 \times 0.015 &= \$75 \\ 4{,}700{,}000 \times 0.004 &= \$188 \\ \text{Total Estimated Cost} &= \$408/\text{year}. \end{aligned}$$

18.2.3 Builder's Risk Insurance

Builder's risk insurance insures the building under construction against blasting, collapse, fire, and vandalism. Premiums are paid by the owner or the general contractor. If the contract agreement calls for the contractor to pay the premiums, the cost of this insurance is estimated and included in the jobsite overhead bid. in Table 18.9, builder's risk insurance represents the rates per $100 value considering a $1000 deductible. For a greater deductible of $2500, the insurance rates may be reduced 13 to 35%. Rates vary by state, project type, and contractor

TABLE 18.8 Contractors' Comprehensive General Liability Insurance

	Per $100 contract cost		
Contract cost	Bodily injury	Property damage	Total
First $500,000	0.018	0.011	0.029
Next $500,000	0.009	0.006	0.015
For additional	0.002	0.002	0.004

Table 18.9 Builder's Risk Insurance

Coverage[a]	Wood frame construction (Class 1) ($)	Brick construction (Class 4) ($)	Fire resistive (Class 6) ($)
Fire insurance	0.394	0.174	0.070
Extended coverage	0.144	0.101	0.100
Vandalism	0.015	0.011	0.010
Total annual rate/$100	0.553	0.286	0.180

[a] Rates per $100/contract value.

reputation. The policy is written annually for the total contract value in place (completed value base). For "all risk" insurance (excluding flood, earthquake, war, etc.), add $0.025 to the rates shown.

18.2.4 Contractors' Equipment Floater

Many contractors own a large inventory of machinery and construction equipment. To properly protect these assets, they are usually insured under a contractor's equipment floater policy. This insurance is quite flexible to accommodate various contractor needs, and protects the contractor organization against loss or damage by fire, explosion, windstorm, flood, earthquake, theft, landslide, collision, and vandalism. Contractor equipment floaters vary from a minimum of 0.5% of the equipment replacement value to a maximum of 25% for each calendar year. The policy cost is paid by the contractor and is included as a cost item in the jobsite overhead. Subcontractors are responsible for any of their equipment brought temporarily to the project site.

18.2.5 Contractors' Tool Floater

This is insurance for tools with a value of less than $1500. The cost varies according to project location and contractor reputation, from $3.00 to $7.50 for $100 insured value. Table 18.10 lists the most common tools used on building construction sites and their prices from The Home Depot, *ProBook* 2000.

18.2.6 Automobile Liability Insurance

Automobile liability insurance is another requirement in the contract agreement. Bodily injury and property damage coverage for owned vehicles, nonowned vehicles, or independent contractors' vehicles are obtained under a comprehensive form of commercial automobile liability insurance by the general contractor or

TABLE 18.10 Construction Site Power Tools

Power tools	Price ($) rounded to $1
3/4 in. VSR drill	28
1/2 in. Heavy duty	169
Cordless drill kit	232
18V 1/2 in. Drill/driver kit	269
3/8 in. Drill/driver kit	98
7/8 in. Rotary hammer	243
Deck/drywall Screwdriver	89
7 1/4 in. Circular saw w/ electric brake	129
Cordless circular saw	159
12 in. Compound cutter saw	280
Jigsaw, heavy duty	169
Reciprocating saw kit	169
Laminate trimmer	98
1 1/2 HP plunge router	60
Spiral cut saw	78
Orbit sander	39
Finishing sander	69
Belt sander	99
Belt sander, vacuum model	219
Profile sander kit	99
4 1/2 in. Sander/grinder	99
3 1/4 in. Planer	66
3 1/4 in. Planer kit	139
Power drive fastener tool (Remington)	198
Electric stapler/brad tocker	34/94
Arc welders	214
AC generators, 5500 watt	898
Portable electric generator	379
Portable air compressor 1.5–6.5 HP	229–799
Narrow crown stapler kit	97
Finish stapler kits	134
Nailers, cordless	399
Nailers, finish cordless	499
Angle nailer kits	209
Framing nailer	348
Brad nailer kit	97
Finish nailer kit	179
Impact wrenches	30–80

Source: Home Depot, *Probook, Professional Equipment and Supply Catalog*—2000.

subcontractors. As a minimum requirement, the policy must cover bodily injury and property damage with $500,000 for each occurrence, $250,000 bodily injury for each person or $500,000 for each occurrence, and $250,000 for property damage—with an umbrella of $1,000,000. The contractors and subcontractors will provide, prior to starting operations on a project, the certificate of insurance coverage as specified in the contract agreement. By not doing so, the general contractor can terminate the agreement with the subcontractor or the general contractor may purchase such coverage and charge the expense to the subcontractor. The coverage can be selected on the basis of either a list of owned vehicles on the jobsite or to all owned vehicles. Physical damage coverage (collision, theft, vandalism, fire) on owned vehicles may be under the same policy or a separate policy. The premiums paid by general contractors and subcontractors vary with many criteria including project location.

For a $1,000,000 umbrella policy, assuming that the contractor has 10 owned vehicles and has a good past history, the annual premium per vehicle can range between $800 and $900 for the calendar year. In practice, the contractors pay the premium for the first 2 months, and after that the insurance company will bill the contractor monthly for the next 10 months. Automobile liability insurance is required for owner protection, is expensive, and needs to be estimated and included as a cost line item in jobsite overhead expense.

18.3 TAXES (COUNTY, STATE, FEDERAL)

18.3.1 Sales Taxes

Many states have sales taxes applicable to construction materials and fixed components and equipment. This tax varies by state as shown in Table 18.11. It is important to learn about local jurisdictions, such as a county or city where the project is located, because additional sales tax may apply. Some projects (constructed with public funds) may be sales tax exempt, which can save as much as 7% on materials. It is the owner's responsibility to establish if she is tax exempt, inform the contractor about the project tax status at the invitation to bid, and thus allow the contractor and subcontractors to estimate the project cost accordingly.

Sales tax is applied to the total cost of materials and components installed by the general contractor. Likewise, subcontractors when figuring sales tax included in the bid submitted to the general contractor use the same procedure. Figure 18.2 shows the calculation of materials sales tax in Texas for a hypothetical project.

TABLE Table 18.11 Sales Tax by US State[a]

State	Tax (%)	State	Tax (%)	State	Tax (%)	State	Tax (%)
Alabama	4	Illinois	6.25	Montana	0	Rhode Island	7
Alaska	0	Indiana	5	Nebraska	4.5	South Carolina	5
Arizona	5	Iowa	5	Nevada	6.875	South Dakota	4
Arkansas	4.625	Kansas	4.9	New Hampshire	0	Tennessee	6
California	7.25	Kentucky	6	New Jersey	6	Texas	6.25
Colorado	3	Louisiana	4	New Mexico	5	Utah	4.75
Connecticut	6	Maine	6	New York	4	Vermont	5
Delaware	0	Maryland	5	North Carolina	4	Virginia	4.5
District of Columbia	5.75	Massachusetts	5	North Dakota	5	Washington	6.5
Florida	6	Michigan	6	Ohio	5	West Virginia	6
Georgia	4	Minnesota	6.5	Oklahoma	4.5	Wisconsin	5
Hawaii	4	Mississippi	7	Oregon	0	Wyoming	4
Idaho	5	Missouri	4.225	Pennsylvania	6	Average	4.71

[a] For the year 2000.

Company Logo **Estimate Summary** Date / / Sheet No. 1 Of 4

	Description	Material	Labor	Equipment	Subcontract	Total
13	**Special Construction**					
	Integrated Ceilings					
	Pedestal Floors					
	Pre Fabricated Rooms & Bldgs.					
14	**Conveying Systems**					
	Elevators, Escalators					
	Pneumatic Tube Systems					
15	**Mechanical**					
	Plumbing & Sewerage					
	Plumbing Fixture & Appliances					
	Heating & Air Conditioning					
	Fire Protection					
16	**Electrical**					
	Rough Electrical Work					
	Finish Electrical work					
	Page Total					

	Material	Labor	Equipment	Subcontract	Total
Total Direct Cost: Page 1 to 4	275800	352400	40000	1520800	2189000
Sales Tax 6.2 % (Materials) (Texas)	17100				17100
Project Site Overhead					
General Overhead					
SubTotal					
Profit **% (Subtotal)**					
Contingency **% (Subtotal or $)**					
Total Bid					

FIGURE 18.2 Estimate summary.

18.3.2 Payroll Taxes (Social Security and Medicare)

The Federal Insurance Contributions Act (FICA) provides for a federal system of old age, survivors, disability, and hospital insurance. The hospital part is financed by Medicare taxes. Social Security and Medicare taxes are levied on both employee and employer. The contractor organization must withhold and deposit in a timely fashion the employee's part of the taxes and the company (employer) must pay a matching amount.

For the year 2000, the federal government requires an employer to allocate 7.65% from the first $72,600 of wages earned per employee. This allocation is the same for all states and provides old age benefits to all US citizens. It may change with Congressional approval, as has happened many times in the past.

Example 18.1

If a carpenter works 2000 hours at a rate of $22/hour, the contractor organization's Social Security allocation will be

2000 hours × $22/hour × 7.65% = $3366.

Example 18.2

If a project manager is paid $90,000/year, the company's Social Security allocation will be

$72,600 (maximum allowed) × 7.65% = $5553.90.

The same amount is deducted from wages at each payroll. The deduction plus the company allocation is deposited with the Social Security Administration a short time after payroll distribution to avoid substantial penalties. The employee's tax rate for Medicare is 1.45% (amount withheld). The employer's tax rate for Medicare is also 1.45% (2.9% total). There is no wage base limit for Medicare tax; all covered wages are subject to Medicare tax.

Computation Example. For a project manager with a monthly salary of $6000, the company needs to withhold $6000 × 1.45% = $87, and the company must match this amount ($87) for a total monthly allocation to Medicare of $174.

18.3.2.1 Employer's Annual Federal Unemployment Tax (FUTA)

Unemployment tax is paid by the employer at a rate of 0.008 (0.8%) of the first $7000 of taxable wages per employee for the calendar year representing a maximum of $56/employee.

Computation Example. Assume that during the year 2000 a construction company had on payroll 20 carpenters, 5 masons, 10 laborers, and 2 mechanics, all with total taxable wages greater than $7000. The Federal Unemployment tax would be $(20 + 5 + 10 + 2) \times \$56 = \$2072$.

18.3.2.2 State Annual Unemployment per Training Tax

This tax varies from state to state and is paid by employers, with no deduction from employee wages. The tax rate for the year 2000 in Texas is 0.0027 (0.27%) of the first $9000 of wages paid to each employee during the calendar year. This represents a maximum of $24.30/employee.

18.4 REVIEW QUESTIONS

1. What is the bid bond and how does it protect the owner?
2. What is the customary bid bond amount? Where can information regarding bid requirements be found?
3. What are performance and payment bonds? What protection do they offer to the owner?
4. For what type of projects are performance and payment bonds always required?
5. What happens when a general contractor fails to complete a project as called for in the contractual agreement?
6. What percentage of the total building direct cost is assumed by the general contractor?
7. What is the subcontractor bond and how does it protect the general contractor and the owner?
8. What is the maintenance bond and how does it protect the owner?
9. What is the license or permit bond? Who may require these bonds?
10. How does insurance differ from the contractor's surety bond?
11. What is workers' compensation insurance? What type of protection does it offer to the general contractor and owner?
12. Which variables differentiate worker compensation rates?
13. What is the contractor's comprehensive general liability insurance? How does it protect the owner and contractor organization?
14. What is the base for estimating the contractors' comprehensive general liability insurance?
15. What is builder's risk insurance? How does it protect the general contractor and owner?
16. What is the base for estimating builder's risk insurance? What is the magnitude of the rate for wood-framed construction (residential home)?
17. What is the contractors' equipment floater? How does it protect the general contractor and subcontractor?

18. What is the base for the contractors' equipment floater insurance premium calculation?
19. What is the contractors' tool floater? How does it protect the contractors?
20. What is the contractors' tool floater premium range/$100 tools value?
21. What is the commercial contractor's automobile liability insurance? How does it protect the owner and the general contractor?
22. What is the commercial contractors' automobile umbrella policy? What is its purpose?
23. What is the base for estimating the total cost of sales tax for a building project?
24. What types of projects are tax exempt?
25. What is the Social Security tax? What is the base for calculating a company's allocation? How does it protect the employees?
26. What is the FUTA tax? What is its role?
27. What is the base for FUTA tax payment by contractors? What is the maximum payment per calendar year per employee?

19

General Overhead, Contingencies, and Profit

Table 19.1 Home Office (General Overhead) Estimate Summary

Home office expenses	Planned: Annual expenses	Planned: Percentage of total	Industry average (%)
Nonreimbursable salaries			
Exempt employees			
President			
Vice president			
Comptroller			
Estimating group			
Human resource personnel			
—			
—			
—			
—			60
—			
—			
Nonexempt employees			
Secretaries			
Payroll clerk			
Accounts payable clerks			
—			
—			
—			
Total office nonreimbursable salaries			
Benefits @ 40% of total office salaries			
Office/shops rent			4
Depreciation of capital expenditures			4
Office utilities and communication			2
Office supplies			0.50
Office equipment (rented, if owned depreciated)			0.50
Office maintenance			
Advertising/jobs procurement/public relations			1
Associations and clubs dues			1
Licenses and fees			1
Donations/sponsored research			2
Trade journals subscriptions and books			1
Travel			2
Entertainment			1
Company sponsored training programs			2
Accounting services			3
Legal services			
Estimating and project management (not salaries)			2
Consulting fees (legal, CPA, etc.)			2
Home office vehicles, depreciation			5
Home office vehicles, operation expenses			
Insurance expenses			6
Total anticipated home office expense		100	100

19.1 GENERAL OVERHEAD (HOME OFFICE EXPENSES)

The company home office expenses cannot be chargeable most of the time to a single project. These expenses are usually neglected by small contractors—a bad practice because it minimizes the net profit or generates a real loss. General overhead represents contractor fixed expenses. A general contractor's or subcontractor's main office expense consists of many items. A summary of the major categories is presented in Table 19.1, "Home Office (General Overhead) Estimate Summary," which can be used for budgeting expenses for the future calendar year. "Exempt" and "nonexempt" employees are designations from the Fair Labor Standards Act. The major difference between them is that employers are exempt from paying overtime to exempt employees. For these employees, referred to as salaried employees, the workweek is not limited to 40 hours.

The expense list presented in Table 19.1 is not appropriate for all contractors. For smaller contractors who operate from a truck, the list would contain considerably fewer items and for a large US top 40 contractor as listed by ENR (nationally and internationally), the list could fill pages, but the concept is the same. The expenses should be estimated, and all efforts must be made to stay in the budget and to generate the planned business volume.

In general, main office expense ranges from 2.5 to 10% of annual construction billings. Table 19.2 provides average percentages from total construction business volume based on the contractor site.

If the planned future construction operation calls for growth and diversification in other areas, attention should be paid to which office expenses need to be increased, and how much and when additional staff should be added.

As shown in Figure 19.1, main office expenses (allocated), estimated contingencies, and profit must be added by the estimator to figure the bid price, before the envelope is sealed. The contract provisions for additional work as a result of an anticipated change order may require the contractor/subcontractor to state the percentage to be added as an allowance for overhead (jobsite overhead + main office overhead + profit).

TABLE 19.2 Home Office Expenses as Percentage of Annual Business Volume[a]

Business ($ Millions)	<1	1–5	5–10	±20	±50	±100	±500
Home Office Expenses (%)	10	7	5	4.5	3.5	3.25	2.5

[a] US Average.

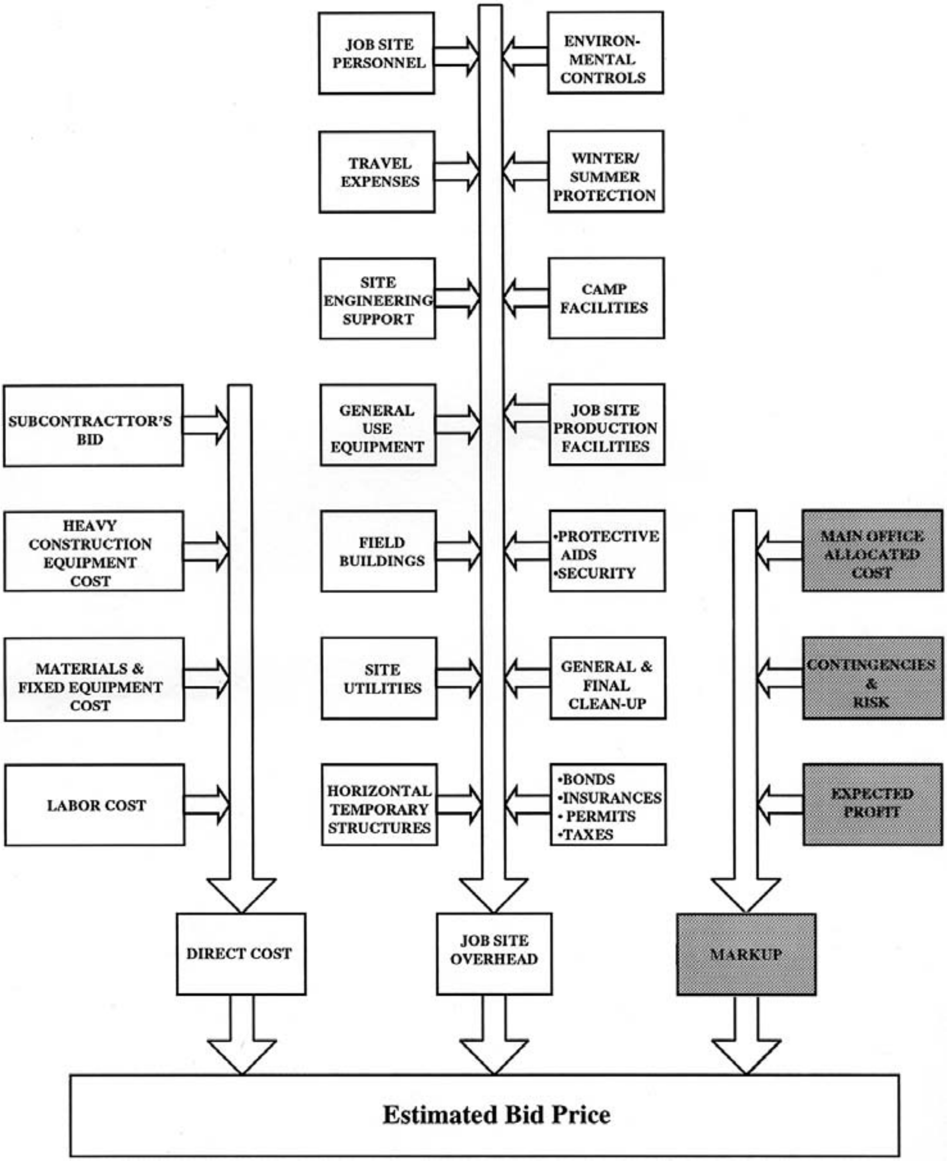


FIGURE 19.1 Total components of cost within a bid (the bid selection).

19.2 GENERAL OVERHEAD ALLOCATION

Once the business volume for the next year has been planned and the home office expenses to support the planned production have been budgeted, a planned percentage can be developed. This percentage will be applied with minor variations to all future bids as a portion of markup (see Figure 19.1). For example, suppose there is an estimated business volume (billings) of $7.5 million for the next year. To support this production the budgeted home office overhead would be $750,000/year.

The percentage of home office budget allocation to new projects should be $750,000/$7,500,000 = 10% applied to the total direct and jobsite overhead estimated bid cost. If a new estimated job (direct cost + jobsite overhead cost) is $2,000,000, the portion of home office expense to be allocated would be $2,000,000 × 10% = $200,000. This amount regarding market opportunities may be adjusted positive or negative based upon encountered home office expenses and realization of planned business volume, being the successful bidder on targeted projects.

19.3 CONSTRUCTION CONTINGENCIES

Contingency is that amount of money added to an estimate to cover the unforeseen needs of the project, construction difficulties, or estimating accuracy. Many chief estimators or contractor executives add a contingency to the estimate to cover one or possibly more of the following:

—Unpredictable price escalation for materials, labor, and installed equipment for projects with an estimated duration greater than 12 months;
—Project complexity;
—Incomplete working drawings at the time detail estimate is performed;
—Incomplete design in the fast-track or design-build contracting approach;
—Soft spots in the detail estimate due to possible estimating errors, to balance an estimate that is biased low;
—Abnormal construction methods and startup requirements;
—Estimator personal concerns regarding project, unusual construction risk, and difficulties to build;
—Unforeseen safety and environmental requirements;
—To provide a form of insurance that the contractor will stay within bid price.

Most often, if for any reason an accurate estimate is not made (95 to 100% accuracy), an estimator never knows how much money to allow for these "forgotten" items. Many times added contingencies are an excuse for using poor estimating practices such as not enough time, subcontractors not reporting, no time to visit

TABLE 19.3 General Construction Project Contingency Averages

Project phase	Contingency Range (%)
Planning	+25 to +35
Budget (engineering)	+10 to +20
Detail (bid)	+5 to +10

the jobsite, and so on. Contingency for these reasons is difficult to sell to management and can hurt the credibility of the estimating team.

On the other hand compounding building projects' bidding complexity justifies the need to add contingency as part of the markup (see Figure 19.1). This construction risk compensation is added to the final direct and jobsite overhead cost. The magnitude depends on the type of contract agreement, type of construction, and certainly project location.

Contingency is not potential profit. It includes risk and uncertainty but explicitly excludes changes in the project scope (change orders). The contingency should absolutely not be treated as an allowance. Allowances are costs that are foreseen to be spent, and need to be included in the detail estimate in the proper construction category of work and not as a total for the project.

There are many factors that affect the amount of contingency to be included in the estimate. Averages for general construction projects at various stages of design are listed as a percentage of direct and jobsite overhead in Table 19.3.

General contingency guidelines also apply to different types of construction. For underground work the contingencies should be increased by 2 to 5% for each design phase.For buildings it is recommended to decrease the contingencies by 1 to 3% for each phase. In general, contingency reflects the contracting organization's judgment decision to avoid bid cost overrun. On the other hand, too much contingency will create a "fat" estimate if management is not willing to accept some construction risks.

To management, contingency is money it hopes will not be expended, but instead returned as profit at project completion. If the amount of contingency added to the bid is too large the contractor risks not getting the project and recording an additional expense for doing the estimate and bidding. This is the reason that a cost line item is usually not included in the bid.

19.4 CONTRACTOR/SUBCONTRACTOR PROFIT

The last item to be included in the bid and representing contractor's return on investment is the profit. The magnitude of desired profit must be decided by the owner for each individual bid, depending on local market conditions, competition, and the contractors' need for new work.

In the construction industry, markup is defined as "the amount added to the estimated direct cost and estimated job into overhead cost" to recover the firm's main office allocated overhead (general overhead) and desired profit. The less profit added to a bid, the greater the chance is of being the successful bidder. Bidding a job with a high profit added does not mean the contactor will get the job. Bidding a job below cost with no planned profit or a minimum profit only to get the work is also no guarantee of being a successful contractor. A contractor can go broke by not obtaining enough profitable work. There are more than 3600 contractor bankruptcies each year in the US. To be competitive, a construction company's general overhead and profit should be close to industry norms, as reported annually by Dun & Bradstreet (New York). The concept of percentage of return on indirect cost investment must also be considered. The return on indirect cost is calculated by dividing the corporation's annual net profit before taxes by the general overhead cost. For example, a general contractor with $1 million pretax profit and $5 million general overhead has a return on indirect cost of $1Mil/$5Mil = 0.20 or 20%. General overhead and profit recovery factors are developed from the annual general overhead budget.

After bid opening, contractors occasionally ask close competitors what percent they added for profit. Surprisingly, competitors are refreshingly candid in revealing the amount added for profit. This natural curiosity is related to the many kinds of profit. Contractors are intuitively trying to ascertain why competitor A, who lost the job, marked up 2%, and competitor B, who marked up 4%, was awarded the bid.

Different kinds of profits are related to several considerations, including the following.

—The firm must recoup sufficient profit for return on equity.
—The profit must be commensurate with industry averages.
—The profit must consider competitive bidding strategies.
—The profit must be as high as possible or what the competitive market will bear, while commensurate with the contractor's risk.

The four general kinds of profit are return on equity, planned, optimum, and competitive bid. These are briefly described below.

19.4.1 Return on Equity

Return on investment is the profit necessary to meet a percent return in equity commensurate with the contractor's risk. A return of 20 to 40% is normal for construction risk.

19.4.2 Planned Profit Margin

Planned profit is the profit that must be achieved over a certain period to meet the firm's business goals. Again, financial surveys reveal what competitors are achieving. An organization must meet or exceed this profit percentage to remain in business.

19.4.3 Optimum Profit

The optimum markup for profit is the one that yields the greatest total profit—the greatest expected profit. The expected profit is the total possible profit multiplied by the likelihood of being the low bidder. Lowering the profit provides a greater chance of being the successful bidder. However, if the profits are too low, a contractor can go broke because he does not perform enough highly profitable work and/or does too much cheap work. A markup that is too low will not carry a contractor through dry bidding spells. In the US, optimum profit ranges average 8.0%.

19.4.4 Competitive Profit

Competitive profit is the amount chosen that represents the intangibles of past bidding history and competitors' need for work. For example, in lean times, contractors might average a 0.5 to 1.5% profit to remain competitive in the bidding game.

19.5 REVIEW QUESTIONS

1. What is the home office or general overhead?
2. What is the average percentage from total home office expenses of wages and benefits paid to home office employees?
3. What is the difference between exempt and nonexempt employees?
4. What competitive advantage is there for a contractor to keep the general overhead budget low?
5. What procedure is used to recover the home office expenses?
6. What is the base to allocate the general overhead among contractors' projects?
7. Develop a list of estimated home office overhead for a small ($500,000/year business volume) partner subcontractor.
8. Which are the components of the markup amount added to an estimate to finalize the bid?
9. What is the contingency amount to be included in the bid?
10. What are the reasons for a prudent contractor to add contingency in the bid?

11. What is the contingency range as a percentage of direct and jobsite overhead (direct during the detail estimating phase, drawings and specifications 100% completed).
12. To be competitive in building construction what is the recommended percentage range for contingency?
13. What does the profit amount added to the bid represent?
14. What is the competitive profit range in building construction, competitive bidding, as a percentage of total cost (direct) plus jobsite overhead as used in the US?
15. Who makes the final decision regarding the profit amount to be added to a bid?

Appendix 1

MasterFormat Lite and UniFormat Lite

A. MASTERFORMAT LITE

http://www.csinet.org/technic/techhome.htm; 06/20/2000.

Introductory Information

00001	Project Title Page
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00010	Table of Contents
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00020	List of Schedules

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00300	Information Available to Bidders
00400	Bid Forms and Supplements
00490	Bidding Addenda

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03600 Grouts
03700 Mass Concrete
03900 Concrete Restoration and Cleaning

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04800 Masonry Assemblies
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B. UNIFORMAT LITE

http://www.csinet.org/technic/uflite.htm; 06/20/2000.

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Appendix 2

Estimating Forms

Company Logo

Quantity Take Off

Date / / Sheet No. Of

Project Title ____________________ Project No. ____________________

Take Off By ____________________ Approved By ____________________

Code*	Description	No.	Dimensions						
						Unit	Unit	Unit	Unit

* Masterformat, Uniformat, WBS, other, etc.

Company Logo

Pricing

Date / / Sheet No. Of

Project Title ______________________ Project No. ______________________

Take Off By ______________________ Approved By ______________________

Code*	Description	Quantity	Unit	Material		Labor		Equipment		Subcontract		Total	
				U.P.	Total	U.P.	Total	U.P.	Total	U.P.	Total	U.P.	
SHEET TOTAL					MATERIAL		LABOR		EQUIPMENT		SUBCONTRACT		TOTAL

* Masterformat, Uniformat, WBS, other, etc.

Company Logo

Estimate Summary

Date / / Sheet No. 1 Of 4

Project Title ______________________ Project No. ______________________

Take Off By ______________________ Approved By ______________________

CSI Division	Description	Material	Labor	Equipment	Subcontract	Total
2	**Site Work**					
	Site Preparation, Demolition					
	Earth Work					
	Caissons & Piling					
	Drainage & Utilities					
	Paving & Surfacing					
	Site Improvements, Landscaping					
3	**Concrete**					
	Formwork					
	Reinforcing Steel & Mesh					
	Cast-in-Place Concrete					
	Precast Concrete					
	Cementitious Decks					
4	**Masonry**					
	Mortar & Reinforcing					
	Clay Masonry					
	Concrete Masonry Units					
	Stone Masonry					
	Page Total					
		Material	Labor	Equipment	Subcontract	Total

Company Logo

Estimate Summary

Date / /

	Description	Material	Labor	Equipment	Subcontract	Total
5	**Metals**					
	Structural Metal Framing					
	Metal Joists					
	Metal Decking					
	Light Gauge Framing					
	Misc. & Ornamental Metals					
6	**Wood and Plastic**					
	Rough Carpentry					
	Finish Carpentry					
	Architectural Woodwork					
7	**Thermal & Moisture Protection**					
	Water & Damp Proofing					
	Insulation & Fireproofing					
	Vapor Barriers					
	Shingles & Tiles					
	Roofing & Sheet Metal					
8	**Doors & Windows**					
	Door & Window Frames					
	Finish Hardware					
	Glass & Glazing					
	Curtain Walling					
	Page Total					
		Material	Labor	Equipment	Subcontract	Total

Company Logo

Estimate Summary

Date / /

	Description	Material	Labor	Equipment	Subcontract	Total
9	**Finishes**					
	Lath & Plaster Work					
	Gypsum Plasterboard Systems					
	Tile, Terrazo Work					
	Acoustical Treatment					
	Flooring & Carpets					
	Painting, Wall Covering & Decorating					
10	**Specialties**					
	Bathroom Accessories					
	Lockers					
	Partitions					
	Signs & Bulletin Boards					
11	**Equipment**					
	Appliances					
	Dock					
	Kitchen					
12	**Furnishings**					
	Blinds					
	Seating					
	Page Total					
		Material	Labor	Equipment	Subcontract	Total

Company Logo

Estimate Summary

Date / /

Sheet No. 4 Of 4

	Description	Material	Labor	Equipment	Subcontract	Total
13	**Special Construction**					
	Integrated Ceilings					
	Pedestal Floors					
	Pre Fabricated Rooms & Bldgs.					
14	**Conveying Systems**					
	Elevators, Escalators					
	Pneumatic Tube Systems					
15	**Mechanical**					
	Plumbing & Sewerage					
	Plumbing Fixture & Appliances					
	Heating & Air Conditioning					
	Fire Protection					
16	**Electrical**					
	Rough Electrical Work					
	Finish Electrical work					
	Page Total					

	Material	Labor	Equipment	Subcontract	Total
Total Direct Cost: Page 1 to 4					
Sales Tax ______% (Materials)					
Project Site Overhead					
General Overhead					
SubTotal					
Profit **% (Subtotal)**					
Contingency **% (Subtotal or $)**					
Total Bid					

Company Logo

Project Site Overhead

Project Title ______________________ Project No. ____________

Estimated By ______________________ Approved By ____________

Description	Quantity	Unit	Mat'l/Equip Unit		Labor Unit		Subcontract Total	Total
1 Job Site Personnel								
Superintendent								
Project Manager								
Engineers								
Timekeeper								
Material Clerk								
Clerical								
Safety								
Watchman								
First Aid								
2 Travel Expenses								
3 Automotive Expenses								
4 Engineering								
Layout								
Quantity/Inspection								
Drawings								
Schedule								
Soil Testing								
Material Testing								
Concrete Testing								
Page Total			Mat'l/Equip.		Labor		Subcontract	Total

Company Logo

Project Site Overhead

Description	Quantity	Unit	Mat'l/Equip. Unit	Mat'l/Equip.	Labor Unit	Labor	Subcontract Total	Total
5 Construction Aids								
Cranes								
Conveyors								
Elevators								
Hoists								
Scaffolding and Platforms								
Small Power Equipment and Tools								
Enclosures								
Bareers: Fences and Barricades								
Safety Nets								
6 Field Offices & Laboratories								
Contractor								
Subcontractors								
Owner/Architect								
Materials Storage and Protection								
Storage Equipment & Tools								
Change House								
First Aid Station								
Visitors Facility								
Training								
7 Temporary Utilities								
Heating								
Water								
Sanitary								
Lighting								
Power								
Telephone/Communication								
Compressed Air								
8 Temporary Horizontal Construction								
Roads								
Bridges								
Railroads								
Parking Area								
Laydown Areas								
Page Total				Mat'l/Equip.		Labor	Subcontract	Total

Company Logo

Project Site Overhead

Description	Quantity	Unit	Mat'l/Equip. Unit	Labor Unit	Subcontract Total	Total
9 Environmental Controls						
Noise						
Dust						
Water						
Air Polution						
Erosion						
Winter/Summer Protection						
10 Camp Facilities						
11 Site Production Facilities						
Concrete Related(Batching Plant & Quarry)						
Asphalt Related						
Precasting Yard						
Assemblying Platform						
Carpentry Shop						
Reinforcing Shop						
Structural Steel Shop						
Welding Shop						
Mechanical Shop						
Electrical Shop						
HVAC Shop						
Painting Shop						
12 Protective Aids						
Respiratory						
Encapsulating Suits						
Overboots						
Hard Hats						
Protective Gloves						
Page Total			Mat'l/Equip.	Labor	Subcontract	Total

Company Logo

Project Site Overhead

Description	Quantity	Unit	Mat'l/Equip. Unit	Labor Unit	Subcontract Total	Total
13 Site Security						
Watchman						
Person and Command Dog						
14 Project Signs & Photographs						
15 Surety Bonds						
Bid Bond						
Performance Bond						
Labor & Material Bond(Payment Bond)						
Maintenance Bonds						
Permit Bonds						
16 Insurances						
Builder's Risk						
Equipment Floater						
Public Liability						
Worker's compensation						
Automobile						
17 Building Permits						
18 Clean Up/Removing Rubbish						
Dumpster						
Final Clean-Up						
19 Touch-Up & Repair Budget						
Page Total						
Total Page 1 - 4						
			Mat'l/Equip.	Labor	Subcontract	Total

Appendix 3

Cost Estimating Software

Construction Cost Estimating Software Survey (2001)

Software name	Bid-Builder	BidMagic	BidWorx Takeoff & Estimating	Candy	Charm Estimating	CONTENDER
Version	2001 (10th version)	1.5	6.1	—	1.3	2.2
Company name	Eagle Point Software	Turtle Creek Software	Vertigraph, Inc.	Construction Computer Software Ltd	Charm Software	Snape Computers
Address	4131 Westmark Drive	102 W. State St.	12959 Jupiter Road, Suite 252	P.o. Box 2	6604 Winterberry Dr	134 High Street
City	Dubuque	Ithaca	Dallas	Lochwinnoch	Austin	Enfield
Zip code	52003	14850	75238	PA12 4DZ	78750	EN3 4ET
State	IA	NY	TX	Renfrewshire	TX	Middx
Country	USA	USA	USA	UK	USA	UK
Phone	800-678-6565	607-272-1008	214-340-9436, 800-989-4243	+44-1505-506118	5128369473	44+ 020 8805 8704
Fax	319-556-8392	—	214-340-9437	+44-1505-506117	512-836-3025	44+ 020 8443 5828
Email	nancy.conlon@eaglepoint.com	turtlecrk@aol.com	erich@vertigraph.com	ccsuk@ccsuk.com	sales@charmsoftware.com	info@snape-software.co.uk
URL	www.bid-builder.com	www.turtlesoft.com	www.vertigraph.com	www.ccsuk.com	www.charmsoftware.com	www.snape-software.co.uk
Type of construction[a]	R,C,H,I,E,M	R,C	R,C,H,I,E	R,C,H,I,E,M	R,C,I,E,M	R,C
Number of users	5000+	2500	over 1000	2500+	145	500+
Multiple users	No	No	Yes	Yes	No	Yes
Password protection	Yes	No	Yes	Yes	No	No

Foreign currencies	No	No	Yes	Yes	Yes	No
Foreign database import	No	No	Yes	Yes	No	Yes
Web sharing info	No	No	No	No	No	Yes
Integration with P3	Yes	No	Yes	Yes	No	No
Integration with Suretrack	Yes	No	Yes	Yes	No	No
Integration with spreadsheets	Yes	Yes	Yes	Yes	Yes	Yes
WBS	Yes	No	Yes	Yes	No	Yes
Main unit Cost database	Company developed	Company developed	Company developed	User's own	R.S. Means	Company developed
Other database used	R.S. Means	—	R.S. Means, Saylor	—	—	—
Service assistance	Yes	Yes	Yes	Yes	No	Yes
Manual	Yes	Yes	No	Yes	Yes	Yes
Help in the software	Yes	Yes	Yes	Yes	Yes	Yes
Standard reports	—	5	50	—	2	25
User defined reports	Yes	No	Yes	Yes	No	No
Database modification	Yes	Yes	Yes	Yes	No	Yes
Quantity take off	Yes	Yes	Yes	Yes	No	Yes
Digitizers	Yes	Yes	Yes	Yes	No	Yes
Training courses	Yes	No	Yes	Yes	No	No
Purchase cost USD ($)	795–2995	395	2399	N/A	100	995

[a] R = Residential; C = commercial; H = heavy construction; I = industrial; E = electrical; M = mechanical.

Software name	Corecon Application Suite	Costlink/CM	Deccapro	EasyEst Estimating	Espro	EstiMaster	Esti-Mate
Version	3.0	2.6	2.0	7.0	1.2.B	2.1	4.2
Company name	WendlWare, Inc.	Building Systems Design, Inc.	Deccan Systems, Inc.	Construction Software Center	Spearhead Software	EAH Estimating Systems	Esti-Mate, Inc.
Address	15592 Graham Street	1175 Peachtree Street	5935 Muncie Cl.	3510 Valley Vista Rd.	PO Box 590	PO Box 296	4044 Dunn Road
City	Huntington Beach	Atlanta	Dublin	Bonita	Armadale	Riverwood	Fayetteville
Zip code	92649	30361	43216	91902	6112	2210	28301
State	CA	GA	OH	CA	WA	NSW	NC
Country	USA	USA	USA	USA	Australia	Australia	USA
Phone	714-895-7222	404-876-4700	614-790-3496	619-479-7818	8-0390-8900	61-2-9534-1664	910-484-5518
Fax	714-895-7022	404-876-0006	—	619-479-3577	8-0390-8911	61-2-9534-1036	910-484-1626
Email	emeisel@corecon.com	svivino@bsdsoftlink.com	info@deccansystems.com	gateway@cscsoftware.com	sales@spearhead.com.au	erik@estimate.com.au	wayne@eolnow.com
URL	www.corecon.com	www.bsdsoftlink.com	www.deccansystems.com	www.cscsoftware.com	www.spearhead.com.au	www.estimate.com.au	www.eolnow.com
Type of construction[a]	R,C,I,E,M	C,H,I,E,M	I	R,C,H,I,E,M	E	R,C,H,I,E	R
Number of users	500	1k+	80	50,000+	100+	approx 50	125
Multiple users	Yes	Yes	Yes	No	Yes	No	No
Password protection	Yes	Yes	Yes	No	No	No	No
Foreign currencies	No	No	No	Yes	No	Yes	No
Foreign database import	No	No	No	No	No	No	No

Web sharing info	Yes	Yes	No	No	No	No	No
Integration with P3	No	Yes	No	No	No	No	No
Integration with Suretrack	No	Yes	No	No	No	No	No
Integration with spreadsheets	Yes	No	Yes	Yes	No	No	No
WBS	Yes	Yes	Yes	No	Yes	No	No
Main unit cost database	R.S. Means	R.S. Means	Company developed	Company developed	CodeBase	User's own	Company developed
Other databases used	—	US Army TRACES	—	—	—	—	—
Service assistance	Yes	Yes	No	Yes	No	Yes	Yes
Manual	Yes	Yes	No	No	No	No	Yes
Help in the Software	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Standard reports	200	5	8	75	—	4	5
User defined reports	Yes	Yes	No	Yes	No	No	No
Database modification	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quantity take off	Yes	Yes	No	Yes	No	Yes	Yes
Digitizers	Yes	Yes	No	Yes	No	Yes	No
Training courses	Yes	Yes	No	Yes	Yes	No	No
Purchase cost USD ($)	N/A	1995	799	150–1,000	695	248	895

[a] R = Residential; C = commercial; H = heavy construction; I = industrial; E = electrical; M = mechanical.

Software name	Estimateur 2000	Estimator	Expert Estimation	Goldenseal	ICE 2000	LiteningQuick Estimating
Version	3.0	5.2	3.0	1.04	2.7.1	5.2
Company name	Les Services d'Estimation Informatises de Montreal	Quest Solutions, Inc.	Project Cost Engineering	Turtle Creek Software	MC2	Litening Software
Address	8292, Place Montrichard	5011 Ocean Blvd	PO Box 3122	102 W State St.	5350 Poplar Ave., Suite 600	2450 Peralta Blvd., Ste. 207
City	Anjou	Sarasota	Bracken Ridge	Ithaca	Memphis	Fremont
Zip code	H1K 1H7	34242	4017	14850	38119-3674	94536
State	QU	FL	Queensland	NY	TN	CA
Country	Canada	USA	Australia	USA	USA	USA
Phone	514-351-7625	941-349-5400	+61-7-3261-6088	607-272-1008	800-225-5622	510-713-7090
Fax	514-351-1420	941-349-1593	+61-7-3261-6188	—	901-682-6118	—
Email	blavoie@estimation.qc.ca	mathewa@questsolutions.com	info@costengineer.com.au	turtlecrk@aol.com	mholland@mc2-ice.com	nick@litening.com
URL	www.estimation.qc.ca	—	www.costengineer.com.au	www.turtlesoft.com	www.mc2-ice.com	www.litening.com
Type of construction[a]	R,C,I	R,C,H,I	H,E,M	R,C,E,M	R,C,H,I,E,M	R,C,E
Number of users	50	2200	330	150	approx 4000	3500
Multiple users	Yes	Yes	Yes	No	No	No
Password protection	Yes	Yes	Yes	Yes	Yes	No
Foreign currencies	Yes	Yes	Yes	Yes	No	No
Foreign database import	Yes	Yes	Yes	No	No	No

Web sharing info	No	Yes	No	No	No	No
Integration with P3	No	Yes	Yes	No	Yes	No
Integration with Suretrack	No	Yes	Yes	No	No	No
Integration with spreadsheets	No	Yes	Yes	Yes	Yes	No
WBS	No	Yes	Yes	No	Yes	No
Main unit cost database	Company developed	—	User's own	Company developed	R.S. Means	Craftsman
Other databases used	—	Inhouse DB+ all third party DBs	—	—	—	—
Service assistance	Yes	Yes	Yes	Yes	Yes	No
Manual	Yes	Yes	Yes	Yes	Yes	Yes
Help in the software	Yes	Yes	Yes	No	Yes	Yes
Standard reports	20		43	60	262	6
User defined reports	No	Yes	No	Yes	Yes	No
Database modification	Yes	Yes	Yes	Yes	Yes	Yes
Quantity take off	Yes	Yes	Yes	Yes	Yes	Yes
Digitizers	Yes	Yes	No	Yes	Yes	No
Training courses	Yes	Yes	Yes	Yes	Yes	No
Purchase cost USD ($)	2495	4000	1390	395	Varies	79.95–249.95

[a] R = Residential; C = commercial; H = heavy construction; I = industrial; E = electrical; M = mechanical.

Software name	LUQS Bid	MacNail	Niche BID2WIN	Price Master II	PRISM Project Estimator
Version	5.85	3.4	2001	1.xx	3.0, 4.0
Company name	LUQS International inc.	Turtle Creek Software	Niche Software, Inc.	J Tolone Services cc	ARES Software Products Group
Address	1600, St-Martin East, Tower B, Suite 620	102 W. State Street	650 Islington Street	P.O. Box 20	3640 Mt. Diablo #201
City	LAVAL	Ithaca	Portsmouth	Allens Nek	Lafayette
Zip code	H7G 4S7	14850	03801	1737	94549
State	QU	NY	NH	—	CA
Country	Canada	USA	USA	South Africa	USA
Phone	888-682-5573 x210	607-272-1008	800-936-3808	+27-82-891-3826	925-299-6700
Fax	888-667-5807	—	603-430-7503	—	925-299-6701
Email	epellelier@luqs.com	turtlecrk@aol.com	elisa_ryng@nichesoftware.com	jouko@jat.co.za	vbehrendt@arescorporation.com
URL	www.luqs.com	www.turtlesoft.com	www.richsoftware.com	www.jat.co.za	www.prismpm.com
Type of construction[a]	C,H,I	R,C	C,H,I	I	C,H,I
Number of users	more than 1500	3000	2500+	—	200+
Multiple users	Yes	No	Yes	Yes	Yes
Password protection	Yes	No	Yes	Yes	Yes
Foreign currencies	Yes	No	Yes	No	Yes
Foreign database import	Yes	No	Yes	No	Yes

Web sharing info	Yes	No	No	No	Yes
Integration with P3	No	No	Yes	No	No
Integration with Suretrack	Yes	No	Yes	No	No
Integration with spreadsheets	Yes	Yes	Yes	Yes	Yes
WBS	Yes	No	No	No	Yes
Main unit cost database	Company developed	Company developed	Company developed	—	R.S. Means
Other databases used	R.S. Means	—	—	BDE, Borland database engine with Paradox tables	User-defined databases also supported
Service assistance	Yes	Yes	Yes	Yes	Yes
Manual	Yes	Yes	Yes	Yes	Yes
Help in the software	Yes	Yes	Yes	Yes	Yes
Standard reports	—	8	43	—	—
User defined reports	Yes	Yes	Yes	Yes	Yes
Database modification	Yes	Yes	Yes	Yes	Yes
Quantity take off	Yes	Yes	Yes	Yes	Yes
Digitizers	Yes	Yes	No	No	No
Training courses	Yes	No	Yes	Yes	Yes
Purchase cost USD ($)	7995 (1st license)	195	9,995	2000, site licenses available	2495 for 3.0; 3495 for 4.0

[a] R = Residential; C = commercial; H = heavy construction; I = industrial; E = electrical; M = mechanical.

Software name	ProEst Estimating	Pulsar	RoofWare	Success Estimator	Visual Estimator	win.it
Version	9.0	2001	2.02	4.3	4.0	9.23
Company name	CMS Construction Software	Estimating Systems, Inc.	True North Estimating Systems, Inc.	U.S. COST, Inc.	CPR International, Inc.	SEC Solutions
Address	15373 Innovation Drive, Suite 100	3 Sedgewick Lane	100 Broadview Ave., Suite 302	1200 Abernathy Road	2408 Birchtree Circle	The Lodge, Martley Road
City	San Diego	Sandwich	Toronto	Atlanta	El Dorado Hills	Worcester
Zip code	92128	02563	M4M 2E8	30328	95762	wr2 6rf
State	CA	MA	ON	GA	CA	Worcestershire
Country	USA	USA	Canada	USA	USA	UK
Phone	858-592-6322	800-967-8572	416-778-0843	770-481-1634	916-933-9746	+44-1905-640064
Fax	858-592-6316	508-428-3573	416-778-08648	770-481-1640	916-933-9746	+44-1905-640821
Email	cms@proest.com	pulsar@capecod.net	rob@roof-ware.com	bsmoak@uscost.com	cpr@cprsoft.com	wayne@secsol.co.uk
URL	www.proest.com	www.estimatingsystems.com	www.roof-ware.com	http://www.uscost.com	www.cprsoft.com	www.secsol.co.uk
Type of construction[a]	R,C,I,E,M	R,C,H,I,E,M	C,I	R,C,H,I,E,M	R,C,I,E,M	R,C,I,E,M
Number of users	6000+	200	3000	5000	1600	4500
Multiple users	No	Yes	Yes	Yes	No	Yes
Password protection	Yes	Yes	No	Yes	No	Yes
Foreign currencies	Yes	No	No	Yes	No	Yes
Foreign database import	No	No	No	Yes	No	Yes

Web sharing info	No	No	Yes	No	No	
Integration with P3	Yes	No	No	Yes	No	No
Integration with Sure-track	Yes	Yes	No	Yes	No	No
Integration with spreadsheets	Yes	Yes	No	Yes	Yes	No
WBS	Yes	Yes	Yes	Yes	No	Yes
Main unit cost database	Company developed	R.S. Means	Company developed	Company developed	BNI Publications, Inc.	Company developed
Other databases used	R.S. Means	—	—	—	—	—
Service assistance	Yes	Yes	Yes	Yes	Yes	Yes
Manual	Yes	Yes	Yes	Yes	Yes	Yes
Help in the software	Yes	Yes	Yes	Yes	Yes	Yes
Standard reports	45	5	30	—	20	25
User defined reports	Yes	Yes	Yes	Yes	Yes	Yes
Database modification	Yes	Yes	No	Yes	Yes	Yes
Quantity take off	Yes	Yes	Yes	Yes	Yes	Yes
Digitizers	Yes	Yes	Yes	Yes	Yes	Yes
Training courses	Yes	Yes	Yes	Yes	No	Yes
Purchase cost USD ($)	995–4995	2916	5,500	2995	395	700

[a] R = Residential; C = commercial; H = heavy construction; I = industrial; E = electrical; M = mechanical.

Software name	WinEst	WinJob Estimating	winRACE	Xactimate	X-DEV
Version	v5.0	—	4.0	2001	5.02
Company name	WinEstimator, Inc.	Deneb Software	Richardson Engineering Services, Inc.	Xactware, Inc.	Spectrum Project
Address	8209 S. 222nd	16824 Ave. of the Fountains, Ste 23	PO Box 9103/1742 So. Fraser Drive	1426 East 750 North	Oastei 2A
City	Kent	Fountain Hills	Mesa	Orem	Iasi
Zip code	98032	85268–8408	85214–9103	84097	6600
State	WA	AZ	AZ	UT	Iasi
Country	USA	USA	USA	USA	Romania
Phone	253-395-3631 x102	800-952-7888	480-497-2062	801-764-5900	+40-94-257-176
Fax	253-395-3634	480-836-1582	480-497-5529	801-224-1035	+40-92-147-810
Email	plarson@winest.com	denebsoftware@worldnet.att.net	info@resi.net	Gbstaples@Xactware.com	x-dev@iname.com
URL	www.winest.com	www.winjob.com	www.resi.net	www.Xactware.com	www.x-dev.ro
Type of construction[a]	R,C,H,I,E,M	R,C,H,I,E,M	R,C,I,E,M	R,C	R,C,H,I,E
Number of users	12000+	—	Private info	15,000+	75
Multiple users	Yes	Yes	No	No	Yes
Password protection	Yes	Yes	Yes	Yes	No
Foreign currencies	Yes	No	Yes	No	Yes
Foreign database import	Yes	No	Yes	No	No

Web sharing info	Yes	Yes	No	Yes	Yes
Integration with P3	Yes	No	Yes	No	Yes
Integration with Suretrack	Yes	No	Yes	No	No
Integration with spreadsheets	Yes	No	Yes	No	No
WBS	Yes	Yes	Yes	No	No
Main unit cost database	Company developed	Company developed	Richardson	Company developed	—
Other databases used	R.S. Means, Craftsman, Richardson, Saylor, MCAA, NECA	—	R.S. Means	—	I.N.D.-82,87
Service assistance	Yes	Yes	Yes	Yes	Yes
Manual	Yes	No	No	Yes	Yes
Help in the software	Yes	Yes	Yes	Yes	Yes
Standard reports	—	32	—	15	35
User defined reports	Yes	No	No	Yes	No
Database modification	Yes	Yes	Yes	Yes	Yes
Quantity take off	Yes	Yes	Yes	No	No
Digitizers	Yes	Yes	Yes	No	No
Training courses	Yes	Yes	Yes	Yes	No
Purchase cost USD ($)	Varies	1900	7195	N/A	135

[a] R = Residential; C = commercial; H = heavy construction; I = industrial; E = electrical; M = mechanical.

Appendix 4

Cost Estimating Sources

Construction Related Organizations

Organization	Address	Contact nos.
AIA: The American Institute of Architects	1735 New York Avenue, NW Washington, DC 20006	Phone: 1-800-AIA-3837 Fax: (202) 626-7547 www.aia.org
AISC: American Institute of Steel Construction	One East Wacker Drive, Suite 3100 Chicago, IL 60601-2001	Phone: (312) 670-2400 Fax: (312) 670-5403 www.aisc.org
AITC: American Institute of Timber Construction	7012 S. Revere Parkway, Suite 140 Englewood, CO 80112	Phone: (303) 792-9559 Fax: (303) 792-0669 www.aitc-glulam.org
AISI: American Iron and Steel Institute	1101 Seventeenth Street, NW, Suite 1300 Washington, DC 20036	Phone: (202) 452-7100 www.steel.org
ASID: American Society of Interior Designers	608 Massachusetts Avenue, NE Washington, DC 20002-6006	Phone: (202) 546-3480 Fax: (202) 546-3240 www.asid.org
ASPE: American Society of Professional Estimators	11141 Georgia Avenue, Suite 412 Wheaton, MD 20902	Phone: (301) 929-8848 Fax: (301) 929-0231 www.aspenational.com
AWC: American Wood Council	1111 Nineteenth Street, NW, Suite 800 Washington, DC 20036	Phone: 1-800-292-2372 Phone: (202) 463-2766 Fax: (202) 463-2791 www.aia.org
AWI: Architectural Woodwork Institute	1952 Isaac Newton Square West Reston, VA 20190	Phone: (703) 733-0600 Fax: (703) 733-0584 www.awinet.org
ARMA: Asphalt Roofing Manufacturers Association	1156 Fifteenth Street, NW, Suite 900 Washington, DC 20005	Phone: (202) 207-0917 Fax: (202) 223-9741 www.asphaltroofing.org
BIA: Brick Industry Association	11490 Commerce Park Drive Reston, VA 20191	Phone: (703) 620-0010 Fax: (703) 620-3928 www.bia.org
CRA: California Redwood Association	405 Enfrente Drive, Suite 200 Novato, CA 94949	Phone: 1-888-225-7339 Fax: (415) 382-8531 www.calredwood.org
CSI: Cast Stone Institute	10 West Kimball Street Winder, GA 30680	Phone: (770) 868-5909 Fax: (770) 868-5910 www.caststone.org
CSSB: Cedar Shake & Shingle Bureau	P.O. Box 1178 Sumas, WA 98295	Phone: (604) 462-8961 www.cedarbureau.org
CRSI: Concrete Reinforcing Steel Institute	933 North Plum Grove Road Schaumburg, IL 60173-4758	Phone: (847) 517-1200 www.crsi.org
CSI: Construction Specifications Institute	99 Canal Center Plaza, Suite 300 Alexandria, VA 22314	Phone: 1-800-689-2900 www.csinet.org
DHI: Door and Hardware Institute	14150 Newbrook Drive, Suite 200 Chantilly, VA 20151	Phone: (703) 222-2010 www.dhi.org
GA: Gypsum Association	810 First Street, NE, #510 Washington, DC 20002	Phone: (202) 289-5440 Fax: (202) 289-3707 www.gypsum.org
HPVA: Hardwood Plywood & Veneer Association	P.O. Box 1178 Reston, VA 20195	Phone: (703) 435-2900 Fax: (703) 435-2537 www.hpva.org
ISDI: Insulated Steel Door Institute	30200 Detroit Road Cleveland, OH 44145-1967	Phone: (440) 899-0100 www.isdi.org

Construction Related Organizations (continued)

Organization	Address	Contact nos.
ISO: International Organization for Standardization	1, Rue de Varembe Case Postale 56 CH-1211 Geneva 20, Switzerland	www.iso.ch
KCMA: Kitchen Cabinet Manufacturers Association	1899 Preston White Drive Reston, VA 20191-5435	Phone: (703) 264-1690 Fax: (703) 620-6350 www.kcma.org
MFMA: Maple Flooring Manufacturers Association	60 Revere Drive, Suite 500 Northbrook, IL 60062	Phone: (847) 480-9138 Fax: (847) 480-9282 www.maplefloor.org
MIA: Marble Institute of America	30 Eden Alley, Suite 301 Columbus, OH 43215	Phone: (614) 228-6194 Fax: (614) 461-1497 www.marble-institute.com
TMS: The Masonry Society	3970 Broadway, Suite 201-D Boulder, CO 80304-1135	Phone: (303) 939-9700 www.masonrysociety.org
MCAA: Mechanical Contractors Association of America	1385 Piccard Drive Rockville, MD 20850	Phone: (301) 869-5800 Fax: (301) 990-9690 www.mcaa.org
NAPA: National Asphalt Pavement Association	5100 Forbes Boulevard Lanham, MD 20706-4413	Phone: 1-888-468-6499 www.hotmix.org
NAAMM: National Association of Architectural Metal Manufacturers	8 South Michigan Avenue, Suite 1000 Chicago, IL 60603	Phone: (312) 332-0405 www.naamm.org
PHCC: National Association of Plumbing Heating Cooling Contractors	180 S. Washington Street P.O. Box 6808 Falls Church, VA 22040	Phone: 1-800-533-7694 www.naphcc.org
NCMA: National Concrete Masonry Association	2302 Horse Pen Road Herndon, VA 20171-3499	Phone: (703) 713-1900 www.ncma.org
NECA: National Electrical Contractors Association	3 Bethesda Metro Center, Suite 1100 Bethesda, MD 20814	Phone: (301) 657-3110 www.necanet.org
NEMA: National Electrical Manufacturers Association	1300 North Seventeenth Street, Suite 1847 Rosslyn, VA 22209	Phone: (703) 841-3200 www.nema.org
NFSA: National Fire Sprinkler Association	40 Jon Barrett Road P.O. Box 1000 Patterson, NY 12563	Phone: (845) 878-4200 Fax: (845) 878-4215 www.nfsa.org
NGA: National Glass Association	8200 Greensboro Drive McLean, VA 22102	Phone: (703) 442-4890 Fax: (703) 442-0630 www.glass.org
NHLA: National Hardwood Lumber Association	P.O. Box 34518 Memphis, TN 38184-0518	Phone: (901) 377-1818 Fax: (901) 382-6419 www.natlhardwood.org
NIST: National Institute of Standards and Technology	100 Bureau Drive Galthersburg, MD 20899-0001	Phone: (301) 975-3058 www.nist.gov
NIA: National Insulation Association	99 Canal Center Plaza, Suite 222 Alexandria, VA 22314	Phone: (703) 683-6422 www.insulation.org
NKBA: National Kitchen and Bath Association	687 Willow Grove Street Hackettstown, NJ 07840-9988	Phone: (877) NKBA-PRO Fax: (908) 852-1695 www.nkba.org

Construction Related Organizations (continued)

Organization	Address	Contact nos.
NOFMA: National Oak Flooring Manufacturers Association	P.O. Box 3009 Memphis, TN 38173-0009	Phone: (901) 526-5016 www.nofma.org
NPCA: National Paint & Coatings Association	1500 Rhode Island Avenue, NW Washington, DC 20005	Phone: (202) 462-6272 www.paint.org
NPCA: National Precast Concrete Association	10333 North Meridian Street, Suite 272 Indianapolis, IN 46290	Phone: (504) 366-7731 Fax: (317) 571-0041 www.precast.org
NRMCA: National Ready Mixed Concrete Association	900 Spring Street Silver Spring, MD 20910	Phone: 1-888-846-7622 www.nrmca.org
NRCA: National Roofing Contractors Association	10255 W. Higgins Road, Suite 600 Rosemont, IL 60018	Phone: (847) 299-9070 Fax: (847) 299-1183 www.nrca.net
NSC: National Safety Council	1121 Spring Lake Drive Itasca, IL 60143-3201	Phone: 1-800-621-7615 www.nsc.org
NSDJA: National Sash & Door Jobbers Association	10047 Robert Trent Parkway New Port Richey, FL 34655-4649	Phone: 1-800-786-7274 www.nsdja.com
NSPE: National Society of Professional Engineers	1420 King Street Alexandria, VA 22314-2794	Phone: 1-888-285-6773 www.nspe.org
NSA: National Stone Association	1415 Elliot Place, NW Washington, DC 20007	Phone: 1-800-342-1415 www.aggregates.org
NTMA: National Terrazzo & Mosaic Association	110 East Market Street, Suite 200A Leesburg, VA 20176	Phone: (703) 779-1022 Fax: (703) 779-1026 www.ntma.com
NTHP: National Trust for Historic Preservation	1785 Massachusetts Avenue, NW Washington, DC 20036	Phone: 1-800-944-6847 www.nthp.org
NWWDA: National Wood Window and Door Association	1400 East Touhy Avenue, Suite 470 Des Plaines, IL 60018	Phone: (847) 299-5200 www.nwwda.org
NAIMA: North American Insulation Manufacturers Association	44 Canal Center Plaza, Suite 310 Alexandria, VA 22314	Phone: (703) 684-0084 www.naima.org
NELMA: Northeastern Lumber Manufacturers Association	P.O. Box 87A, 272 Tuttle Road Cumberland Center, ME 04021	Phone: (207) 829-6901 www.nelma.org
PUB: Pacific Lumber Inspection Bureau	P.O. Box 7235 Bellevue, WA 98008-1235	Phone: (425) 746-6542
PPFA: Plastic Pipe & Fittings Association	800 Roosevelt Road, Building C, Suite 20 Glen Ellyn, IL 60137-5833	Phone: (630) 858-6540
PDI: Plumbing and Drainage Institute	45 Bristol Drive South Easton, MA 02375	Phone: 1-800-589-8956 www.pdionline.org
PHCC: Plumbing Heating Cooling Contractors	180 S. Washington Street Falls Church, VA 22040	Phone: 1-800-533-7694 www.naphcc.org
PIMA: Polyisocyanurate Insulation Manufacturers Association	1331 F Street, NW, Suite 975 Washington, DC 20004	Phone: (202) 628-6558 www.pima.org

Construction Related Organizations (continued)

Organization	Address	Contact nos.
PCA: Portland Cement Association	5420 Old Orchard Road Skokie, IL 60077	Phone: (847) 966-6200 www.portcement.org
PTI: Post Tensioning Institute	1717 W. Northern Avenue, Suite 114 Phoenix, AZ 85021	Phone: (602) 870-7540 www.portcement.org
PCI: Precast/Prestressed Concrete Institute	209 W. Jackson Boulevard Chicago, IL 60606-6938	Phone: (312) 786-0300 Fax: (312) 786-0353 www.pci.org
PCEA: Professional Construction Estimators Association of America	P.O. Box 11626 Charlotte, NC 28220-1626	Phone: (704) 522-6376 www.pcea.org
RPA: Radiant Panel Association	P.O. Box 717 Loveland, CO 80539-0717	Phone: 1-800-660-7187 www.rpa-info.com
RFCI: Resilient Floor Covering Institute	966 Hungerford Drive, Suite 12-8 Rockville, MD 20850	Phone: (301) 340-8580
SPRI: Single Ply Roofing Institute	200 Reservoir Street, Suite 309A Needham, MA 02494	Phone: (781) 444-0242 Fax: (781) 444-6111 www.spri.org
SFPA: Southern Forest Products Association	P.O. Box 641700 2900 Juliana Avenue Kenner, LA 70065-1700	Phone: (504) 443-4464 Fax: (504) 443-6612 www.spri.org
SPIB: Southern Pine Inspection Bureau	4709 Scenic Highway Pensacola, FL 32504-9094	Phone: (850) 434-2611 www.spib.org
SSINA: Specialty Steel Industry of North America	3050 K Street, NW Washington, DC 20007	Phone: 1-800-982-0355 www.ssina.com
SES: Standards Engineering Society	13340 SW 96th Avenue Miami, FL 33176	Phone: (305) 971-4798 www.ses-standards.org
SDI: Steel Deck Institute	P.O. Box 25 Fox River Grove, IL 60021-0025	Phone: (847) 462-1930 Fax: (847) 462-1940 www.sdi.org
SJI: Steel Joist Institute	3127 Tenth Avenue North Extension Myrtle Beach, SC 29577-6760	Phone: (843) 626-1995 Fax: (843) 626-5565 www.steeljoist.org
SPFA: Steel Plate Fabricators Association	11315 Reed Hartman Highway, Suite 104 Cincinnati, OH 45241	Phone: (513) 469-0500 www.spfa.org
SWI: Steel Window Institute	1300 Sumner Avenue Cleveland, OH 44115-2851	Phone: (216) 241-7333 Fax: (216) 241-0105 www.steelwindows.com
SBA: Systems Builders Association	28 Lowry Drive P.O. Box 117 West Milton, OH 45383-0117	Phone: 1-800-866-6722 www.systembuilder.org
TCAA: The Tile Contractors Association of America	11501 Georgia Avenue, Suite 203 Wheaton, MD 20902	Phone: 1-800-655-8453 www.tcaainc.org
TCA: Tile Council of America	100 Clemson Research Boulevard Anderson, SC 29625	Phone: (864) 646-8453 Fax: (864) 646-2821 www.tileusa.com
UL: Underwriters Laboratories	333 Pfingsten Road Northbrook, IL 60062-2096	Phone: (847) 272-8800 www.ul.com
OSHA: US Department of Labor	Office of Public Affairs, Room N3647 200 Constitution Avenue Washington, DC 20210	Phone: 1-800-321-OSHA www.osha.gov

Construction Related Organizations (continued)

Organization	Address	Contact nos.
VMAA: Valve Manufacturers Association of America	1050 Seventeenth Street, NW, Suite 280 Washington, DC 20036-5503	Phone: (202) 331-8105 www.vma.org
VSI: Vinyl Siding Institute	1801 K Street NW, Suite 600K Washington, DC 20006	Phone: (202) 974-5200 www.vinylsiding.org
WRC Welding Research Council	3 Park Avenue, 27th Floor New York, NY 10016-5902	Phone: (212) 591-7956 www.forengineers.org/wrc
WCLIB: West Coast Lumber Inspection Bureau	P.O. Box 23145 Portland, OR 97281-314	Phone: (503) 639-0561 www.wclib.org
WRCLA: Western Red Cedar Lumber Association	1200-555 Burrard Street Vancouver, Canada BC V7X 1S7	Phone: (604) 684-0266 www.wrcla.org
WWPA: Western Wood Products Association	522 SW Fifth Avenue, Suite 500 Portland, OR 97204-2122	Phone: (503) 224-3930 www.wwpa.org
WAI: Wire Association International	1570 Boston Post Road P.O. Box 578 Guilford, CT 06437-0578	Phone: (203) 453-2777 www.wirenet.org

Construction Forms

AIA Contract Documents—A Series: Owner–Contractor:	
A101:	Standard Form of Agreement Between Owner and Contractor—Stipulated Sum
A105:	Standard Form of Agreement Between Owner and Contractor for a Small Project
A205:	General Conditions of the Contractor for Construction of a Small Project
A107:	Abbreviated Standard Form of Agreement Between Owner and Contractor for Construction Projects of Limited Scope—Stipulated Sum
A111:	Standard Form of Agreement Between Owner and Contractor—Cost of the Work Plus a Fee, with a Negotiated Guaranteed Maximum Price (GMP)
A114:	Standard Form of Agreement Between Owner and Contractor Where the Basis of Payment Is the Cost of the Work Plus a Fee Without a Guaranteed Maximum Price (GMP)
A171:	Standard Form of Agreement Between Owner and Contractor—Stipulated Sum for Furniture, Furnishings, and Equipment (FF&E)
A177:	Abbreviated Owner–Contractor Agreement for Furniture, Furnishings, and Equipment (FF&E)
A201:	General Conditions of the Contract for Construction
A201/SC:	Federal Supplementary Conditions of the Contract for Construction
A271:	General Conditions of the Contract for Furniture, Furnishings, and Equipment (FF&E)
A305:	Contractor's Qualification Statement
A310:	Bid Bond
A312:	Performance Bond and Payment Bond
A401:	Standard Form of Agreement Between Contractor and Subcontractor
A501:	Recommended Guide for Competitive Bidding Procedures and Contract Awards for Building Construction
A511:	Guide for Supplementary Conditions
A521:	Uniform Location of Subject Matter
A571:	Guide for Interiors Supplementary Conditions
A701:	Instructions to Bidders
A771:	Instructions to Interiors Bidders

Source: The American Institute of Architects (1-800-365-2724).

Cost Manuals and Cost Files

R.S. Means: Annual Published Cost Guides
Means Assemblies Cost Data
Means Building Construction Cost Data
Means Building Construction Cost Data—Metric Version
Means Building Construction Cost Data—Western Edition 2002
Construction Costs in the Western United States and Canada
Means Concrete & Masonry Cost Data 2002
Means Contractor's Pricing Guide: Residential Repair & Remodeling
Means Contractor's Pricing Guide: Residential Detailed Costs
Means Contractor's Pricing Guide: Residential Square Foot Costs
Environmental Remediation Cost Data—Assemblies Cost Book
Environmental Remediation Cost Data—Unit Cost Book
Means Electrical Change Order Cost Data
Means Electrical Cost Data
Means Heavy Construction Cost Data
Means Heavy Construction Cost Data—Metric
Means Interior Cost Data
Means Labor Rates for the Construction Industry
Means Light Commercial Cost Data
Means Mechanical Cost Data
Means Open Shop Building Construction Cost Data
Means Plumbing Cost Data
Means Repair & Remodeling Cost Data
Means Site Work & Landscape Cost Data
Means Square Foot Cost Data

Source: R.S. Means Company, Inc. (1-800-334-3509).

Appendix 5

Construction Site Investigation Report

Project Title ______________________ Date ______________

Project Location ______________________

		Date	By Whom	Phone/Fax/Email
1.0	Site Characteristics	______	______	______
2.0	Subsurface Exploration	______	______	______
3.0	Excavation	______	______	______
4.0	Weather Conditions	______	______	______
5.0	Site Accessibility	______	______	______
6.0	Water	______	______	______
7.0	Waste Water Disposal	______	______	______
8.0	Electricity	______	______	______
9.0	Natural Gas	______	______	______
10.0	Communication	______	______	______
11.0	Security	______	______	______
12.0	Medical/Environmental	______	______	______
13.0	Personnel Availability	______	______	______
14.0	Subcontructors' Availability	______	______	______
15.0	Local Materials' and Suppliers' Availability	______	______	______
16.0	Construction Equipment Availability	______	______	______
17.0	Local Office Facilities	______	______	______
18.0	Local Housing and Recreational Availabilities	______	______	______
19.0	Local Financial Institutions	______	______	______
20.0	Local Insurance Availabilities	______	______	______
21.0	Local Legal and Audit Requirements	______	______	______

1.0 Site Characteristics

1.1 Draining conditions ______________________________

1.2 Slope of ground ______________________________

1.3 Trees in area (size, diameter, species) ______________________________

1.4 Boulders (size, easy to remove?) ____________

1.5 Nearby community information (Foreign Projects) ____________

Population: ____________ Predominant Language: ____________

Predominant Religion: ____________ Predominant Profession: ____________

Name and distance of the nearest community from site: ____________

Type of government: Democratic ( ) Dictatorial ( )

Key persons that make decisions in local government:

Name	Position	Address	Phone No.

Community attitudes regarding environmental issues: ____________

____

____

____

2.0 Subsurface Exploration

2.1 Secure subsurface investigation reports ( ) Check

2.2 Water table characteristics:

Depth average: ____________ Source: ____________

Water table fluctuations due to seasonal changes: Low ____________ High ____________

Secure water analysis ( ) Check

3.0 Excavation

3.1 Underpinning of adjacent structures required? ( ) No ( ) Yes

If yes, type, length? ____________

3.2 Shoring necessary? ( ) No ( ) Yes

If yes, type, length? ____________

Local Supplier/Subcontractor: ____________ Phone No. ____________

3.3 Piling necessary? ( ) No ( ) Yes
If yes, type? ______________________________
Local Supplier/Subcontractor: ______________________ Phone No. ____________

3.4 Sheeting necessary? ( ) No ( ) Yes
If yes, Local Supplier? ______________________ Phone No. ____________

3.5 Availability of soil to be excavated used as a backfill? ( ) No ( ) Yes
If yes, Borrow pit location (km): ______________________________
Charge ($/m^3) __________ Special permission required: ( ) No ( ) Yes
If yes, from whom? ______________________ Phone No. ____________

3.6 Excess soil dumping location: ______________________________
Charge ($/m^3) __________ Special permission required: ( ) No ( ) Yes
If yes, from whom? ______________________ Phone No. ____________

3.7 Clearing necessary: ______________________________
If yes, type of vegetation and density: ______________________________

3.8 Existing buildings/utilities to be demolished/removed: ( ) No ( ) Yes
Buildings:
Type: ( ) Adobe ( ) Brick ( ) R. Concrete ( ) Steel
Foundations: ( ) S. Concrete ( ) R. Concrete
Description: ______________________________
Demolition permit required? ( ) No ( ) Yes
If yes, from whom? ______________________ Phone No. ____________
Utilities (Existent):
Type: ( ) Water ( ) Sewer ( ) Natural Gas
( ) Telephone ( ) Electricity

3.9 Archeological sites? ( ) No ( ) Yes
If yes, institution or person to be contacted for reservation? ______________________________
______________________ Phone No. ____________

3.10 Blasting required? ( ) No ( ) Yes

4.0 Weather Conditions

4.1 Special provisions needed for:

Rain ____ Month/year ____________

Fog ____ Month/year ____________

Hurricanes ____ Frequency/year ____________

Snow ____ Average Inches/year ____________

Rust and mildew ____

Frost ____ Average Days/year ____________

Dust/sand storms ____ Frequency/year ____________

4.2 Weather data

Season:	Temp. Min./Max. Celsius	Average Humidity (%)	Winds Min./Max. km/h	Length in months
Spring	___ / ___	_______	___ / ___	__________
Summer	___ / ___	_______	___ / ___	__________
Fall	___ / ___	_______	___ / ___	__________
Winter	___ / ___	_______	___ / ___	__________

5.0 Site Accessibility

5.1 Road's pavement and width leading to the jobsite: ____

____

From the airport: ____

From the railroad station: ____

From the port: ____

From the aggregate source: ____

5.2 Driving conditions of roads during:

Wet weather:	( ) V. Good	( ) Good	( ) Poor
Dry weather:	( ) V. Good	( ) Good	( ) Poor

5.3 Capacity of bridges on access roads (metric tons) ________________________________

____

5.4 Restrictions on use: ______________________________

____

5.5 Is traffic heavy around jobsite? ( ) No ( ) Yes
If yes, peak hours ______________
Are loading and unloading hours regulated? ( ) No ( ) Yes
If yes, give hours for loading/unloading: ______________

5.6 Are temporary roads necessary?
If yes, type? ______________
______________ length? ______________

5.7 Do trucking companies stop near site? ( ) No ( ) Yes
If yes, truck stop distance: ______________ Company? ______________

5.8 Closest railroad station? ______________ Distance from jobsite? ______________
Type of lifting equipment available at the station? ______________
Possibility of temporary railroad connection to jobsite? ( ) No ( ) Yes

5.9 Closest port? ______________ Distance from jobsite? ______________
Lifting equipment available? ______________

5.10 Dock depth in m ______________

5.11 Custom requirements: ______________

____

Secure copy of local custom requirements ( ) Check

5.12 Port storage capabilities
Rate ______________ Company/Representative: ______________
Phone No. ______________

5.13 Closest airport ______________ Distance from jobsite? ______________
Flight schedule available? ( ) No ( ) Yes
If yes, obtain one and attach to this report. ( ) Check

6.0 Characteristics of Available Water

6.1 Onsite/brought from other site (km) ______________________________

____

6.2 Source/Conduction ______________________________

____

6.3 Maximum pressure ______________________ Time of day ______________

Minimum pressure ______________________ Time of day ______________

6.4 Hardness—Drinking use/Construction use ______________________________

____

6.5 Purity—Boiling purpose, desalination/reverse osmosis ______________________________

____

6.6 Local requirements to obtain water ______________________________

____

____

Person to contact ______________________ Phone No. ______________

Normal time required to obtain the service ______________________________

Cost of supplied water ______________________________

7.0 Sewer

7.1 Description of sewer lines available at jobsite [diameter of conductor, material, years in use, average slope, actual volume, maximum capacity (1/sec)]:

Sanitary ______________________________

Storm ______________________________

7.2 Special requirements for chemical sewage ______________________________

____

7.3 What is required to connect to public sewage? ______________________________

____

Person to contact ______________________ Phone No. ______________

Time involved ______________________________

8.0 Electricity

8.1 Is electricity available at jobsite? ( ) No ( ) Yes

If yes, voltage/cycles ______________ Distance to main lines ______________

Voltage in main lines ______________

Are generators required? ( ) No ( ) Yes

If yes, for how long? ______________ Capacity ______________

8.2 Special requirements to hook up ______________

____

Person to contact ______________ Phone No. ______________

Normal time required for approval ______________

Can we provide our transmission lines and have power authorities connect? ( ) No ( ) Yes

9.0 Natural Gas

9.1 Is natural gas available at jobsite? ( ) No ( ) Yes

If yes, type of conduction ______________

Cost of natural gas per 1000 m^3: $ ______________

Special requirements to hook up ______________

Person to contact ______________ Phone No. ______________

Normal time required for approval ______________

10.0 Communication

10.1 Are telephone lines available at jobsite? ( ) No ( ) Yes

If yes:

Computer modem capabilities? ( ) No ( ) Yes

Fax capabilities? ( ) No ( ) Yes

International direct dial available? ( ) No ( ) Yes

Special charges: ______________

10.2 Special requirements to hook up ______________

____

Person to contact ______________ Phone No. ______________

Normal time required for approval ______________

10.3 Distance of jobsite from telegraph office ____________________

Services available, charges ____________________

10.4 Airmail services available? ( ) No ( ) Yes

Type of service ____________________ Phone No. ____________________

Is next day delivery available? ( ) No ( ) Yes

If yes, companies and phone nos. ____________________

____

____

Nearest post office to jobsite (km) ____________________

10.5 Two-way radio systems special requirements ____________________

____

Are there restrictions on transmission hours? ( ) No ( ) Yes

If yes, specify ____________________

10.6 Is television cable available? ( ) No ( ) Yes

10.7 Local regulations regarding satellite TV systems ____________________

____

____

11.0 Security

11.1 What protection will be required around site? ____________________

____

____

Service	Local availability		Estimated Cost
Fencing	( ) No	( ) Yes	____________
Watchman	( ) No	( ) Yes	____________
Watchdog	( ) No	( ) Yes	____________
Illumination	( ) No	( ) Yes	____________
Roads	( ) No	( ) Yes	____________

11.2 Are local police or army/navy able to provide protection?

( ) No ( ) Yes

In what capacity? ____

____

11.3 Any unusual hazards at jobsite?

Fire	( ) No	( ) Yes
Flood	( ) No	( ) Yes
Hurricane	( ) No	( ) Yes
Dust/sand storms	( ) No	( ) Yes
Snowstorms	( ) No	( ) Yes
Volcano	( ) No	( ) Yes
Earthquakes	( ) No	( ) Yes
Animals/insects	( ) No	( ) Yes
Vandalism	( ) No	( ) Yes
Terrorism	( ) No	( ) Yes
War	( ) No	( ) Yes
Racial or religious prejudices	( ) No	( ) Yes

If yes, specify ____

____

____

____

12.0 Medical/ Environmental

12.1 Are there hospitals or infirmary near site? ( ) No ( ) Yes

If yes, distance (km) ____________________

Type of services available ____

____

Is fast evacuation possible? ( ) No ( ) Yes

Shortest route to the hospital from the jobsite ______________________________

____

By ambulance: ( ) No ( ) Yes Time required __________

By helicopter: ( ) No ( ) Yes Time required __________

12.2 Common diseases in the area and vaccination requirements ______________________
____
____
____
____

12.3 Are special medical precautions/vaccinations required on the jobsite?
( ) No ( ) Yes
If yes, specify ____
____
____

12.4 Is pest control necessary? ( ) No ( ) Yes
Are special provisions required? ( ) No ( ) Yes
If yes, specify ____
____
____

12.5 Environmental control
Control recommended/Authority
Noise ____
Odor ____
Garbage ____
Gases ____
Dust ____
Vibration ____
Government Environmental Agency ______________________ Phone No. ____________

13.0 Personnel Availability

13.1 Local nonmanual personnel availability:

	Availability:		Wage rate:
Secretary	( ) No	( ) Yes	________
Clerk	( ) No	( ) Yes	________
Survey crews	( ) No	( ) Yes	________
Draftsman	( ) No	( ) Yes	________
Bookkeeper	( ) No	( ) Yes	________
Civil engineer	( ) No	( ) Yes	________
Electrical engineer	( ) No	( ) Yes	________
Mechanical engineer	( ) No	( ) Yes	________

13.2 Local manual personnel:

Trades:	Availability:		Wage rate:
Heavy equipment operator	( ) No	( ) Yes	________
Heavy equipment mechanics	( ) No	( ) Yes	________
Riggers	( ) No	( ) Yes	________
Masons	( ) No	( ) Yes	________
Ironworkers	( ) No	( ) Yes	________
Carpenters	( ) No	( ) Yes	________
Electricians	( ) No	( ) Yes	________
Plumbers	( ) No	( ) Yes	________
Roofers	( ) No	( ) Yes	________
Laborers	( ) No	( ) Yes	________
Foreman	( ) No	( ) Yes	________

13.3 What unions operate in the area; what trades are involved?

Trade	Agent	Address	Phone No.

Secure copy of union rules ( ) Check

13.4 Can the project be done as open-shop contract? ( ) No ( ) Yes
Get copy of local trade contracts
When do they expire? ______ What rate of increase is expected? ______
When? ______
Where is labor recruited from? ______

______

13.6 Can labor be paid by piece? ( ) No ( ) Yes
Explain ______
13.7 Which local holidays are to be observed?

______

______

______

13.8 Is transportation of labor to jobsite necessary? ( ) No ( ) Yes
If yes, how far (km) ______
13.9 Labor working conditions:
Regular working hours ______
Premium on overtime ______
Premium on worked holidays ______
Termination pay ______
Social Security ______
Unemployment insurance ______
Sick benefits—disability ______
Bonus ______
Travel pay ______
Secure a copy of local labor law ( ) Check
13.10 How often are workers paid? ______
Payments are made in: ( ) Check ( ) Cash
What is included in each payment? ______
What is left until termination day? ______
Is security payroll service available? ( ) No ( ) Yes

If yes, Cost $ ______________ Person to contact ______________
Phone No. ______________

13.11 Are other major projects coming up in the nearby area that will affect labor availability
( ) No ( ) Yes
If yes, explain ______________
____

14.0 Local Subcontractor Availability

14.1 List of subcontractors:

	Name	Address/Phone No.
Excavation		
Concrete		
Masonry		
Carpentry		
Structural steel		
Roofing		
Painting		
Millwork		
Sheet metal		
Glass & glazing		
Plastering		
Tile, terrazzo, marble		
Plumbing		
Electrical		
Heating		
Air conditioning		
Refrigeration		
Ventilation		
Landscaping		
Others		

Secure a copy of local subcontractors directory ( ) Check

15.0 Local Materials' and Suppliers' Availability

15.1 Materials (locally produced)

	Manufacturer
Cement	______
R. Steel	______
S. Steel	______
Brick	______
Building block	______
Piling	______
Plaster	______
Paint	______
Roofing	______
Lumber	______
Nails, hardware	______
Electrical equip.	______
Mechanical equip.	______
Aggregates	______
Principal lumber species	______

______

______

Ready-mix concrete available? ( ) No ( ) Yes

If yes, Company ______ Person to contact ______

Phone No. ______ Cost ($) ______

16.0 Construction Equipment Availability

Type	Rental Cost ($)	Parts/Service locally available: No	Yes	Company Name Address Contact
Cranes	______	( )	( )	______
Concrete mixers	______	( )	( )	______
Concrete pumps	______	( )	( )	______
Generators	______	( )	( )	______
Compressors	______	( )	( )	______
Fork lifts	______	( )	( )	______
Shovels	______	( )	( )	______
Draglines	______	( )	( )	______
Dump trucks	______	( )	( )	______
Flatbed truck	______	( )	( )	______
Trailers	______	( )	( )	______
Hoist, tower crane	______	( )	( )	______
Drilling equip.	______	( )	( )	______

16.1 Identify local construction equipment rental/lease organizations:

____

____

17.0 Local Office Facilities

17.1 Office space availability?

If yes, rent cost ($/M^2) ______________ Purchase Cost ($/M^2) ______________

17.2 Office supplies, machines, and furniture. Available locally? ( ) No ( ) Yes

If yes, name and address of suppliers ______________

____

____

____

17.3 Is storage space for materials available near site? ( ) No ( ) Yes

If yes, type ______________ Purchase Cost ($) ______________

Is land for storage near jobsite for: ( ) lease? ( ) sale?

Description ______________

Cost of lease or purchase $ ______________

17.4 Is fire department near jobsite?

Distance (km) ______________ Person to contact ______________ Phone No. ______________

17.5 Is police department near jobsite?

Distance (km) ______________ Person to contact ______________ Phone No. ______________

17.6 Availability of educational facilities: ( ) School ( ) College ( ) University

Specify ______________

17.7 Local media news, number ______________

17.8 Are laboratories for quality control tests available locally? ( ) No ( ) Yes

If yes:

Type	Name, Address, Phone No.

18.0 Local Housing and Recreational Availabilities

18.1 Housing facilities:

	Capacity	Distance	Cost/night
Hotels	______	______	______
Motels	______	______	______
Condominium (rent)	______	______	______
Laundry	______	______	______
Restaurant	______	______	______
Fast food service	______	______	______

18.2 Existing recreation facilities:

	Number	Average distance from jobsite (km)
Swimming pool	______	______
Tennis courts	______	______
Golf course	______	______
Football	______	______
Baseball	______	______
Native sports	______	______
Fishing	______	______
Hunting	______	______
Night clubs	______	______
Movies, theaters	______	______

18.3 Are shopping centers near jobsite? ( ) No ( ) Yes

If yes, distance (km) ______

19.0 Local Financial Institutions

19.1 Banking Institution — Person to contact/Phone No.

______________________ ______________________

______________________ ______________________

______________________ ______________________

19.2 Corporation taxes from local and state authorities ______________________

____

Income tax ______________________

Payroll tax ______________________

Property tax ______________________

Tax exemptions ______________________

Are there special local taxes? ( ) No ( ) Yes

If yes, which ones? ______________________

____

20.0 Local Insurance Availabilities

20.1 Check types of coverage available in area:

Workmen's compensation—disability ( )

Property damage ( )

Public liability ( )

Fire and extended coverage ( )

Auto insurance ( )

Equipment insurance ( )

Get rates and copies of laws if possible ( ) Check

21.0 Local Legal and Audit Requirements

21.1 Local law requirements for:

Building permits ______________________

Registering foreign corporations ______________________

Social Security ______________________

Unemployment insurance ______________________

21.2 Are audit companies available in the area? ( ) No ( ) Yes

If yes, type of service that can be provided ______________________

____

21.3 Is the local attorney required? ( ) No ( ) Yes

References

Chapter 1

Journal Article, Conference Proceeding, and Papers

D M Umen. Is a standard needed for estimating building design and construction cost? Cost Engineering 32:8 (August).

Estimating Data (Manuals & Files)

Construction Specification Institute—Manual Practice, Master Format—Master List of Titles and Numbers for Construction Industry.

R.S. Means Company, Inc. Building Construction Cost Data. Metric Version 2000, 58th annual ed. Kingston, MA: Construction Publishers & Consultants, 1999.

Chapter 2

Journal Article, Conference Proceeding, and Papers

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