

# CONSTRUCTION<sup>a</sup>

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**ABSTRACT:** This paper, written for the *ASCE Manual of Professional Practice for Quality in the Constructed Project, Volume II*, presents an overview of the construction industry. The paper is organized in accordance with the recommendations of the Task Committee on Technical Supplements to the Guide. It provides a brief history of the development of the construction industry in the United States and its role in today's society. It describes how the industry is presently organized and functions and the types of construction companies. The paper discusses the various forms of construction contracts including: lump sum, unit price, guaranteed maximum price, cost reimbursable, construction management, and design construct. Important contract provisions are reviewed including: bonding, insurance and indemnification, changed conditions, change orders, schedule, liquidated damages, bonus and penalty provisions, payment terms and retainage, subcontracting, partnering and alternate dispute resolution. The writer explains how construction companies are organized, both in the main office and the field. The elements of construction engineering practice are explained and the qualifications for engineers in construction are presented. The relationships with other civil engineering disciplines and design professionals are discussed.

## SECTION I—INTRODUCTION

### History and Development

Man has been building from the earliest times. One still marvels at the accomplishments of earlier civilizations: the pyramids in Egypt, the Roman aqueducts and coliseums, the Great Wall of China, and others.

Ours is a relatively new country. Prior to the twentieth century, most building was done on a local scale by local contractors. An exception to this was the construction of major suspension bridges and, in particular, the work done by the Roebling family in constructing suspension bridges in Ohio, Missouri, and of course their crowning accomplishment, the Brooklyn Bridge.

Up to and through the 1920s, roads, bridges, railroads and buildings were built by local contractors of varying size. The Perini family had established a construction company in Massachusetts; the Jones family in North Carolina; the Walsh family in Iowa; the Groves family in Minnesota; the Bechtels, Atkinsons, and Kaisers in California; Kiewit in Nebraska; Brown in Texas; and other families in various cities and states around the country. Railroad building enabled some contractors to move out beyond their local area. Such work required expertise in constructing embankments, bridges, and tunnels.

The 1930s was a period for expansion. The Great Depression triggered the development by the federal government of some major hydroelectric projects. Most important among these were Boulder (later Hoover) Dam in Nevada and Grand Coulee Dam in the state of Washington. The former project was constructed by a joint venture (a grouping together of several construction companies) called the Six Companies, which included Bechtel, Kaiser, Shea, Utah Construction, Morrison-Knudsen, Pacific Bridge, Warren Brothers, and Felix Kahn (actually a total of eight companies). At about the same time, another joint venture of Guy F. Atkinson Company, Walsh Construction Company, Silas Mason Company,

and Kier Construction Company were undertaking the primary work on Grand Coulee Dam in the state of Washington. Thus a new era was started in the U.S. construction industry.

Also, during this period major suspension bridges were constructed both in the East and West. The Golden Gate and Oakland Bay bridges were constructed in San Francisco and the George Washington Bridge in New York City.

The 1940s saw the commencement of World War II. Although wars are horrible occurrences, they do provide opportunities for contractors. During World War II, the U.S. government hired contractors to work in the United States and various other parts of the world constructing airbases, roads, bridges, docks, and other port facilities. Overseas construction was performed in the Caribbean, the South Pacific, the Aleutians, North Africa, and ultimately in Europe. Some contractors were put to work building liberty ships and still manufacturing bombs and other ordnance. During this period, contractor organizations grew in size and experience and since all of the work was performed on a reimbursable basis, contractors were assured of a reasonable profit.

The postwar years continued to be a prosperous period for the construction industry. Military construction continued both in this country and abroad and there was also a major industrial building program. Cement, steel, and aluminum plants were major sources of work for contractors. Residential work also bloomed in many areas.

The 1950s saw the commencement of the interstate highway program. Such roads as the New Jersey Turnpike (the Pennsylvania Turnpike had been built in the 30s), New Jersey's Garden State Parkway, the New York State Thruway, and the Ohio and Indiana Turnpikes were constructed. Freeway construction was also under way in California. Major industrial expansion continued to take place. The St. Lawrence Seaway was constructed in the latter part of the 1950s. These were prosperous times for contractors. There was plenty of work for everybody.

*Engineering News Record* (later *ENR*) listed the top ten contractors of 1958 as follows ("77 Firms" 1959)

1. Peter Kiewit Son's Co., Omaha, Nebr.
2. Merritt-Chapman & Scott Corp., New York City
3. Diesel Construction Co. Inc., New York City
4. Morrison-Knudsen Co., Inc., Boise, Idaho
5. American Bridge Division, U.S. Steel Corp., Pittsburgh
6. George A. Fuller Co., New York City
7. Perini Corp., Framingham, Mass.
8. United Engineers & Constructors., Philadelphia

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9. Ebasco Services, Inc., New York City
10. S.J. Groves & Sons., Minneapolis, Minn.

What is happening in this country and the world, determines to a large extent what is taking place in the construction industry. The advent of jet travel in the late 1950s and early 1960s signaled the demise of transatlantic travel by ship and the construction of new airports in this country and around the world. Similarly, the passage of legislation by Congress resulted in the construction of sewerage treatment plants all over this country.

Generally, the 1960s continued to be good years for the construction industry. The first prototype nuclear plants were built in the early 1960s followed by larger plants later in the decade. These plants were originally contracted for on a fixed-price basis and after contractors incurred severe cost overruns, utility companies recognized the unfairness of the situation and thenceforth such work was performed on a reimbursable basis. Such work continued to be a profitable sector of the construction industry until the Three Mile Island incident in the early 1980s. That occurrence signaled the death knoll of future nuclear powerplant construction and thus eliminated a very profitable amount of work for contractors.

New highways and bridges continued to be built through the 1960s. New York City witnessed the construction of the Throgs Neck Bridge and The Verrazano-Narrows Bridge, and an extensive road building program in conjunction with the 1964 World's Fair. The Straits of Mackinac Bridge in Michigan was built in this period (1957) as well as the Lake Pontchartrain Causeway near New Orleans. Major hydroelectric projects were under way in the West by the Bureau of Reclamation.

Design-Construct work, where done, was either done on a reimbursable basis or on a negotiated basis. Competitive bid fixed price design-construct work was unheard of during this period.

The first oil embargo occurred in 1973. This had a dramatic impact on the distribution of the world's wealth. Much money flowed into the mideast (and in a lesser manner into some other parts of the world) and provided those countries with the funds to build large refineries, petrochemical complexes, industrial and power plants and other facilities. This provided a great deal of profitable work for U.S. contractors, particularly the large design-build companies. The 70's saw the continuation of nuclear power plant construction and a commitment to air cleanup. Congress passed OSHA and the period was characterized by high inflation and high interest rates.

In 1980, the top ten contractors on the *ENR* list were ("The *ENR* 400" 1981):

1. Bechtel Corp., San Francisco
2. Brown & Root, Houston
3. The Parsons Corporation, Pasadena, Calif.
4. Fluor Corp., Irvine, Calif.
5. Foster Wheeler Corp., Livingston, N.J.
6. Morrison-Knudsen Co., Boise, Idaho
7. C-E Lummus, Bloomfield, N.J.
8. Ebasco Services, New York City
9. Jacobs Engineering, Pasadena
10. M.W. Kellogg Co., Houston

The design-construct companies had virtually taken over the top spots in the industry, and much of this was due to their growth as a result of the Middle East and nuclear power work. Only a few pure general contractors (Raymond, Turner, J.A. Jones, and Guy F. Atkinson) were able to make it into the top 20 on the *ENR* list.

The 1980s saw several new trends: the appearance and spread of nonunion construction; work in the Middle East began to slow resulting in the major design-construct companies focusing more on the U.S. market and bringing foreign competition to the United States; the Three Mile Island accident signaled the demise of nuclear power work; American construction companies began to go to public ownership more; and more.

There was considerable industrial work performed during the early 1980s, particularly by the computer and service industry. IBM was in a major expansion mode. Industrial companies were concerned about the efficiency of the construction industry and, as a result, the Construction Industry Cost Effectiveness (CICE) program was launched as well as the Construction Industry Institute (CII).

The rebuilding of the nation's infrastructure continued. The building of prisons became a major source of work for construction contractors across the country. The commercial building market had been overbuilt, which resulted in many foreclosures and the failure of a number of lending institutions.

Fluor Daniel moved to the top of the *ENR* list in 1990 ("The Top" 1990) followed by Bechtel and Brown & Root. The industry continued to be in a recession: too little work for the number of competing contractors. Many jobs are being bid below cost and a number of well-established construction companies have collapsed and gone out of business. Foreign companies in particular are bidding and taking work at bids too low. After doing this for a while, they realize that the U.S. market is poor and leave. However, as one foreign company folds up its tent and goes home, another seems to appear to take its place. There is no indication at the present time, that the market will improve in the near future.

### Role in Today's Society

The construction industry today is the largest industry in the country. According to *ENR*, ("ENR Market Trends" 1994) spending for 1994, excluding one- and two-family housing, was \$151 billion. Industry spending is broken down as follows (in millions of dollars, numbers given show rounding errors):

Contract awards	
Heavy and highway	
Water use and control	16,861.0
Transportation	30,350.8
Electric, gas and communication	2,958.8
Other heavy	9,327.9
Subtotal	59,498.5
Nonresidential building	
Manufacturing buildings	9,038.1
Commercial buildings	37,097.4
Government buildings	6,057.8
Education buildings	19,354.0
Medical buildings	10,289.4
Other buildings	10,865.2
Subtotal	92,702.1
Multiunit housing	
Apartments	12,350.5
Hotels, motels, dormitories	3,973.2
Subtotal	16,323.7
Total	168,524.2

## SECTION II—CONSTRUCTION INDUSTRY TODAY

### Organization of Industry

Traditionally the construction industry has consisted of three major participants, with a number of other participants, as

well. The major participants are the owner, designer, and contractor. Up until relatively recent years, the owner engaged an architect or engineer to design the project and then put the project out for competitive bidding. In subsequent sections we will explain the changes that have taken place in this procedure.

Owner organizations can generally be broken down between public owners and private owners. In the former category are such federal agencies as the Defense Department (U.S. Army Corps of Engineers, Navy Facilities Command, Air Force), the Bureau of Reclamation, the Environmental Protection Agency, and General Service Administration. The various states have their own agencies, the most common being a department of transportation. Similarly, counties, cities, and other municipal governments have departments that are responsible for letting construction work within their jurisdictions.

Private companies account for a large part of the construction work awarded in this country. The amount of work let by private companies varies with the health of their particular industry. As recounted earlier, when the industrial capability of the country was developing and expanding, steel, cement, automobile, aluminum, paper, and other similar industries were building at a rapid rate. In more recent years, service industries such as computer and health industries have been active in building and thus awarding construction work. When economic expansion in the country slows down, the construction industry is directly affected.

The second major participant in the construction process is the designer. Where building work is involved, an architect usually leads the design team. Most all other types of construction are done by engineering companies. Certain governmental agencies perform the design of their projects with "in house" design staffs.

In earlier times, engineering companies were relatively small and specialized in a particular field of design; highway, bridges, dams, industrial facilities, and so on. With the growth of the construction industry over the last several decades, engineering companies have grown in size and in the diversity of services offered. There are now firms that do both architectural and engineering work as well as planning and environmental work. As presented earlier, there are a number of design-build companies that do both design and construction.

The third major participant in the construction process is the contractor. From small family companies, construction companies have also grown in size and diversity. More is said about construction companies subsequently.

In addition to the three major participants in the construction process, there are a number of other participants; among these are subcontractors. In building construction work, the general contractor may perform some of the work (excavation, concrete, and drywall) but they will subcontract a large part of the work to specialty subcontractors. Mechanical, electrical, instrumentation, elevator, painting, and structural steel are some of the trades that are generally subcontracted by most general contractors. In engineered work or heavy construction work, the general contractor performs most other work with his own forces. Among trades subcontracted in this type of work are reinforcing-steel installation, foundation grouting, caisson work, as well as mechanical and electrical work. Subcontractors play a major role in the construction industry in this country.

Another group whose ranks are also major participants in the construction industry are the material supply companies. Such companies include suppliers of cement, aggregate, ready mix concrete, asphalt, reinforcing steel, and structural steel. Electrical subcontractors purchase conduit, cable, lighting fixtures, switchgear, and similar items needed for their work

from electrical suppliers, while mechanical subcontractors purchase pipe, sheet metal, fans, and the like from companies that provide such material and products.

Equipment companies are also an important participant in the industry. Such companies manufacture and sell cranes, excavation equipment such as bulldozers and loaders, concrete and asphalt paving equipment, transportation equipment such as heavy-duty trucks and trailers, welding machines, lifts, and a whole range of smaller items of equipment.

There are also a number of other companies that are active and provide services to the construction industry. There are companies that design and provide forms, scaffolding, and sheeting and shoring systems.

There are also legal and accounting firms that devote their whole practice solely to construction matters. In addition, there are many consultants who provide safety, and occupational and environmental services to the industry.

When one examines the broad range of the construction industry and the different types and number of companies involved, one can quickly see why it is the largest industry in this country.

### Types of Construction Companies

Construction companies were simply organized until the 1950s. The industry consisted of general contractors and subcontractors. Most work was bid on a competitive fixed-price basis. A few construction companies began to take on some design capability. Design-construct work, when done, was performed on a reimbursable basis.

The 1960s saw the emergence of more design-construct companies and the introduction of the construction management concept in the late 1960s. Companies such as Bechtel, Brown & Root, Kaiser, United Engineers, Rust, and Lummus rose to the top rankings of the *ENR* list of contractors in the late 1960s. Some of these companies had their origins as general contractors doing engineered heavy construction work, but at this time ventured into the design and construction of manufacturing and process plants. These companies became expert in EPC-type contracts (engineer, procure, and construct) in such industries as refining, petrochemicals, and urea. Other companies, such as Stone & Webster began to design and construct power plants.

The oil embargoes of the 1970s, which brought much wealth to Middle East countries, offered expanded opportunities for design-construct companies to provide their services for steel, refining, petrochemical, process and power plants. Most of this work was performed on a reimbursable basis. Such work allowed the participating companies to be successful financially and to expand their staffs and organizations and to acquire considerable expertise in their particular fields.

It is only in the most recent time that design-construct is being used in the heavy construction sector. This has been mostly on toll-road projects.

Design-construct has been used mostly in this decade by the General Service Administration for the construction of federal office buildings and courthouses and by the U.S. Postal Service for mail-handling facilities.

In the late 1960s, the construction management concept emerged. As with design-construct work, which is utilized when an owner wishes to have his or her project completed and operating in a shorter time frame than can be accomplished in the traditional design and then bid process, the construction management process allows an owner to complete a project in a shorter time frame. The concept was initially utilized on building projects but over the years has expanded to industrial and power projects and more recently is being used on highway and bridge projects.

In summary, construction companies fall into three categories.

**General contractor**—This is a company that performs construction work on a fixed-price basis and has sufficient capitalization to secure a performance and payment bond and to finance their work during the project. General contractors fall into several categories: building, industrial, power, and heavy. Building contractors usually subcontract most of their work, which permits them to operate with less capital than the other types of general contractors.

**Design-construct contractor**—As discussed previously, such a contractor performs both the design and construction of a project. Whereas in earlier times, such work was performed on a reimbursable basis, some of the design-construct work now is being performed on a lump-sum fixed-price basis. Much of the powerplant work now being done in the country is being performed this way, as well as buildings and some toll-road projects. Some general contractors have entered the design-construct arena by hiring an engineering company or architect as a subcontractor to do the design work.

**Construction manager**—There are some companies that devote all of their efforts to construction management. Such companies have very little capitalization. There are also a number of engineering and architectural companies that provide construction management services. Many general contractors and design-construct companies also provide construction management services.

### SECTION III—CONSTRUCTION CONTRACTS

#### Types of Construction Contracts

In general, the best way to understand the various types of construction contracts is to view them from the perspective of the risk involved. The range of risk runs from a fixed-price contract at one end of the spectrum to a totally nonrisk cost-reimbursable contract at the other end of the spectrum.

**Lump sum**—As the name implies, the contractor provides a fixed price to the owner to do all of the work required by the contract agreement. Normally, a lump-sum contract is used when the scope of the work is clearly defined and understood by both parties to the contract. This type of contract offers the owner the best protection as to the price he will pay for the work. This type of contract is the riskiest for the contractor.

**Unit price**—This type of contract is a fixed-price form of contract and is utilized when the scope of work cannot clearly be defined. Various items of work are established, as is an estimated quantity of work for each item. The owner agrees to pay the contractor a fixed unit price for each item of work performed. The owner is at risk as to the quantity of work performed and the contractor is at risk that he can perform the work profitably for the various unit prices he has agreed to. This type of contract is most prevalent on highway, bridge, and dam contracts, and is used mostly by public agencies.

**Guaranteed maximum price**—This type of contract is usually used when the scope of work is not able to be as clearly defined as in a lump-sum contract. The contractor and owner agree that the contractor will perform an agreed scope of work (defined as best as possible) at a price not to exceed an agreed upon amount, the guaranteed maximum price (GMP). The contractor is obligated to keep track of all of the project costs and if these costs and the agreed upon contractors profit are less than the GMP, the owner and contractor will share the savings in cost based upon an agreed upon formula (60/40, 50/50, or such). If the costs exceed the GMP without any changes to the defined scope, the contractor must solely bear the additional costs.

**Cost reimbursable**—Under a cost-reimbursable form of

contract, the owner agrees to reimburse the contractor all of its costs (or certain defined costs) plus an agreed upon fee. Often, all of the contractor's main office costs, costs of financing, etc., are included in the fee.

**Construction management**—When construction management first started, the construction manager (CM) was involved only in the construction phase of the project. When design of parts of the project had been completed (excavation, foundation work, etc.) the CM would put together a bid package and go out to bid to an appropriate list of subcontractors. This would enable the construction work to commence long before the design of the entire project was completed.

As design of subsequent parts of the project were completed, the CM would proceed in the same manner. As construction got under way at the project site, the CM would provide a staff to supervise and coordinate the various subcontractors. The subcontracts were generally between the owner and the CM. The CM acted as an agent of the owner. All costs were reimbursable to the CM, and the CM usually received a fixed fee for their services.

As time went on, the advantages were recognized of having the CM involved right from the start of the project. In many instances now, the CM is hired about the time the engineer or architect is engaged, and the CM provides input to the design, offering ideas as to how the design might be more effective and economical. The CM develops a schedule and budget during the early stages of design. The schedule and budget are updated by the CM throughout the life of the project.

Many variations to the original construction management concept have taken place. In some instances, the CM is asked to contract with the subcontractors directly. In other instances, the owner asks that the CM establish a fixed price for their company's services.

Some projects commence in the normal construction management way, but at a certain time in the project, the owner expects the CM to provide either a lump-sum or guaranteed maximum price for the performance of all of the work, including all of the subcontract costs. At this point, the contract is no longer a CM contract, but rather a lump-sum or GMP contract.

**Design Construct**—As the name implies, such contracts are for both the design and construction of a project. Until more recent times, design-construct contracts were reimbursable form of contract and were used for such projects as nuclear power plants, oil refineries, and petrochemical plants. More recently, considerable work on smaller power plants, buildings, and some toll roads are being performed on a fixed-price basis.

#### Important Contract Provisions

**Bonding**—A performance and payments bond is usually required on all publicly bid projects and may also be required on some private projects. Such a bond is furnished by a surety company and guarantees to the owner that the project will be completed at the agreed upon contract price and that all vendors and suppliers will be paid for the goods and services provided to and incorporated into the project. Performance and payment bonds traditionally were in the full amount of the contract price. However, because of the failure of a number of contractors in recent years, surety companies have become concerned about writing bonds in the full amount of very large contracts (\$200,000,000 to \$300,000,000 and above) and on such contracts may provide a bond for a lesser percentage of the contract price.

Often a general contractor will require that subcontractors provide performance and payment bonds. Such bonds guar-

antee that the subcontractor will complete its work at the price agreed to in the subcontract and that the subcontractor will pay all of its vendors and suppliers. Such bonds are completely separate and have no relationship to the bond provided by the general contractor to the owner.

On publicly bid jobs that require that the general contractor provide a performance and payment bond, the general contractor normally is also required to provide a bid bond (or other security such as a certified check) with its bid. The bid bond guarantees to the owner that if the general contractor's bid is accepted by the owner, the general contractor will enter into a contract with the owner to perform the agreed upon scope of work at the bid price. If the contractor refuses to enter into the contract with the owner, the surety company will pay the owner the difference between the successful contractor's bid and the amount of the second bidders price (up to an agreed upon amount).

**Insurance and indemnification**—All construction contracts set forth the types of insurance and limits of coverage that the contractor must provide to the owner. Foremost among the types of insurance is workers' compensation insurance. The type of coverage required and the benefits payable to injured workers are determined by the state in which the work is being performed.

Another important policy the contractor is required to provide under all construction contracts is liability coverage. Such a policy protects the owner and other members of his team from being sued due to accidents, errors, or omissions by the contractor. Limits of liability coverage vary with the size of the particular project and are established by the owner. Besides general liability insurance, there is employers' liability insurance, comprehensive commercial liability insurance, owners' protective liability insurance, and automobile liability insurance. Often a contractor is either required or will carry on his own initiative umbrella liability insurance.

Other forms of insurance required of the contractor some or all of the time are builder's risk insurance (which covers the cost of replacing already completed work damaged by flood, fire, and the like) and contractor's equipment insurance.

**Changed conditions**—For many years in the construction industry there were a considerable number of disputes between contractors and owners over changed foundation conditions. If the contractor encountered an underground condition, such as ground water at an elevation different than what was expected, an argument would ensue as to who was responsible for the additional costs resulting from the changed or unexpected condition. In the mid-1970s, a committee was formed of prominent individuals in the construction industry and out of their efforts the changed conditions clause was developed. A typical clause follows.

Contractor shall promptly after discovery, and before such conditions are disturbed, notify owner in writing of: (1) any subsurface or latent physical conditions at the site differing materially from those indicated in, or reasonably inferable from, the contract documents that could not have been observed through a reasonable inspection of the site prior to the submission of the bid; or (2) unknown physical conditions at the site of an unusual nature differing materially from those ordinarily encountered and generally recognized as inhering in work of the character provided for in this contract. After receipt of such notice, owner shall promptly investigate the conditions. In the event that such conditions do materially differ and actually result in material increase or decrease in contractor's cost of, or the time required for performance of, the work, contractor shall be entitled to an equitable price adjustment and/or an equitable time adjustment.

**Change order**—It is important that the contract clearly state the events that will require the issuance of a change order by the owner or its representative. Change orders are unquestionably warranted when the owner changes the agreed upon scope of work. Similarly, if the owners do not provide the site of the work at the preestablished date or fulfill their other obligations under the terms of the contract, the owner is obligated to pay the contractor its additional costs and this is done through the issuance of a change order. If the owner delays the contractor in other ways, such as not providing owner furnished equipment at the times stated in the contract, a change order should be issued.

Generally, construction contracts require the contractor to notify the owner within a specified period of time of the occurrence of events for which the contractor will seek additional reimbursement in the form of a change order. Many contracts will stipulate the various methods by which the contractor will be reimbursed: by preestablished unit prices, by negotiated lump sum, or by time and material. In the latter two cases, contracts will contain a provision setting forth the markup the contractor is to receive.

Many claims develop because of the failure of the contractor and owner to agree on the issuance of change orders and in many instances after the issuance of a change order is agreed to, the contractor and owner are unable to agree on the amount of reimbursement. Such claims will never be totally avoided but they can be minimized by proper and clear contract language as to what constitutes the issuance of a change order and how the contractor will be reimbursed and when the change order is issued.

**Schedules, delays, liquidated damages, bonuses and penalties**—Time is an important part of all construction contracts. The owner generally states in the contract a completion time, either by stating a completion date or by stating that the work must be completed within so many calendar or working days. It is best if the owner sets a reasonable time for completion. In some instances, the owner or its representative establishes this very important element of the contract with little or no forethought. It is in the owners' interest to set a reasonable time for completion of the work. If the owner recognizes that it wishes to have the work completed within an accelerated time frame, it should indicate this in the bid documents, thereby eliminating unnecessary disagreements leading to costly litigation.

Most construction contracts require the contractor to prepare and submit to the owner for approval a schedule for the work. Many contracts spell out in detail what type of schedule will be required [such as a critical path method (CPM) schedule] and will indicate the minimum number of activities required to be shown. The contract will often state how frequently the schedule must be updated. Contractors have come to realize the importance of good scheduling to the successful completion of the project and generally put considerable effort into producing the schedule. Some contracts require that the contractor breakdown and "load" the schedule for payment purposes.

In addition to showing when the various items of work will be performed by the contractor, the schedule should also show when the owner will perform its work (such as providing owner furnished equipment, as mentioned earlier).

Delays occur on construction contracts for many reasons: weather, labor shortages, late delivery of equipment and materials, and other events beyond the control of the contractor. These latter occurrences are called "force majeure" events and it is very important that the contract contain such a provision. Many contracts state that any event that is beyond the reasonable control of the contractor shall constitute a force majeure event and shall entitle the contractor to an extension

of time. Other contracts spell out specifically the events that will be considered force majeure events. Generally, for such events the contractor is entitled to an extension of time but no additional reimbursement.

Delays are the reason for many claims and disputes. After the project schedule is prepared by the contractor and approved by the owner, it is important that the schedule be updated on a periodic basis, no less than monthly and, depending on the nature of the job, more frequent updates may be warranted. By following such a procedure, as delays occur, they can be analyzed and evaluated, and it can often be determined at that time who is responsible for the delay, what action will be taken to make up lost time, and who will pay for the additional costs that might result from corrective action.

Many contracts contain liquidated damage provisions. Liquidated damages are amounts stated in the contract that the contractor agrees to pay the owner for every day (or week or month) that the contractor is late in completing the project. Since it is often difficult for the owner to properly calculate damages if the project is late being completed, the contractor and owner agree in advance (in the contract terms) as to the amount payable to the owner in the event of late completion. One must be aware that the project completion date will be extended for justifiable reasons as provided in the contract.

Liquidated damages should be a reasonable amount, consistent with the costs an owner will incur in the event of late completion. It is advantageous to the contractor to have liquidated damage provision because in that way the contractor knows from the start exactly what will be assessed by the owner for late completion and will not be subject to claims by the owner for consequential damages.

Some contracts contain bonus and penalty provisions. A penalty provision is not enforceable unless the contract also contains a bonus provision. Bonus and penalty amounts are established in the contract at the time of execution. A bonus provision reimburses a contractor a set amount for each time period work is completed in advance of the completion date and a penalty provision penalizes the contractor for each period completion is late.

It is rare when a project is completed exactly in conformance with the schedule prepared at the start of work. Completing a construction project is a rather difficult undertaking when one considers all of the elements and forces a contractor must contend with: weather, unexpected underground conditions, labor disputes, late delivery of equipment and materials, less than complete plans and specifications, and the late provision of engineering information. One must look at a project schedule as a changing document, constantly being pressured by the aforesaid events as well as by others. The owner and contractor must work together in a spirit of cooperation and fairness to adjust the schedule properly. In this way many disputes can be avoided.

**Payment Terms and Retainage**—A construction contract must clearly set forth the terms of payment and the amount of retainage to be withheld. Normal construction contracts provide for the contractor to be paid on a monthly basis for the work completed during the prior month. Typically, on a lump-sum contract, at the start of work, the contractor will provide to the owner a payment breakdown schedule. This schedule often will include a hundred or more items of work and the value of each item of work. Each month, the owner and contractor will agree to the percent complete of each item of work and in that way will determine the value of the work completed to date. Subtracting the value of the work completed to date on the prior month's invoice will determine how much work was completed in the current month. Such a payment breakdown procedure is not necessary on a unit

price contract where the bid schedule containing the items, quantities, and unit prices of work are all established at the time of bidding.

Most construction contracts provide for the contractor to prepare an invoice and submit it to the owner shortly after the end of the previous month's work. The owner is then obligated to pay the contractor within a stated period of time after the submission of the invoice (often 25 to 30 days). Being paid properly and promptly is important to the contractor and is a serious obligation of the owner.

As to retainage, contracts usually provide for the withholding from each monthly payment, a certain agreed percentage. In past times, 10% was common, but in more recent times, 5% has become quite common. When 10% is withheld, the contract often provides that no further retainage will be withheld after the work is 50% complete.

**Subcontracting**—On almost all construction projects some of the work is subcontracted to specialty contractors, also known as subcontractors. The greatest amount of work is subcontracted on building projects, with a lesser amount usually subcontracted on heavy construction projects. Construction contracts generally have clauses pertaining to subcontracting. Such clauses often limit the amount of work to be subcontracted and generally provide that the owner retains the right to approve subcontractors. This latter provision can be troubling to general contractors if the owner withholds approval of a subcontractor whose price the general contractor relied on when bids were submitted. The best way to handle this potential problem is to state in the bid documents that the owner cannot unreasonably withhold approval of subcontractors.

Governmental agencies have in more recent years, in an attempt to assist minority and disadvantaged people, included requirements in the bid documents that the general contractor subcontract a certain percentage of the work to minority-owned business enterprises (MBEs), women-owned business enterprises (WBEs) and small businesses.

**Alternate Dispute Resolution**—Up until the mid-1980s, the only way to settle disputes arising out of construction contracts was through litigation. This was a very slow and costly method to resolve such disputes. The courts were not really equipped to deal properly with such matters.

One of the first steps taken to minimize disputes was the introduction of the changed conditions clause. The federal government and its agencies were the first to include such a provision in their contracts. Some private owners followed. Unfortunately today not all owners include such a provision. This provision in itself greatly lessened the number of contract disputes.

Arbitration has been utilized by private companies for a considerable period of time. It can be either binding or non-binding. It is not used very often in government contracts. An exception is the state of California, which established mandatory arbitration for state agencies' construction contracts by executive order in 1978 and by legislation in 1981.

Mediation, which is nonbinding, is now being used more frequently in the private sector.

Dispute review boards (DRBs) have come into existence more recently and have been utilized principally on public contracts. Under this process, the owner and contractor each appoint one person to the board, who then select the third member, who serves as chairman. The DRB meets periodically (usually every three months) at the project site, and inspects and becomes familiar with the work as it progresses. When a dispute arises, the DRB meets and considers each side's position and makes a nonbinding recommendation as to how the dispute should be resolved. By virtue of their knowledge of the job, their expertise and the respect the



parties have of them, it is rare that the parties do not accept the DRB's recommendation. This is a very expeditious and economical way to resolve construction disputes. In this way, most disputes are settled as they arise, rather than waiting for project completion.

**Partnering**—This is a very recent concept. It was developed by the Portland, Oreg. District of the U.S. Army Corps of Engineers and is now being used in both the public and private sector. In some instances, the contract documents provide for partnering and in other instances it has come as an afterthought. Under the partnering process, all of the major parties involved in the project, the owner, contractor, designer, major subcontractors, and suppliers, go off together on two-day retreat, often held at a conference center. A facilitator leads and guides the program. Through a series of exercises, the participants come to realize the advantage of working together towards mutual goals, which might include a safe job for all, on-time completion, and cooperation and understanding between all parties, all of which should lead to a profitable job for the contractor and subcontractors and a quality job completed on time for the owner. At the end of the partnering conference all parties sign the partnering agreement. Partnering is voluntary on the part of all the parties and nothing in the partnering agreement is enforceable—it is in the nature of a pledge. However, it has proved to be a very effective process.

## **SECTION IV—ORGANIZATION OF CONSTRUCTION COMPANIES**

### **Main Office Organization**

The three main departments of construction companies under the chief executive officer are operations, engineering and estimating, and administration. Whether the company is large or small, one can usually identify these departments. Larger construction companies have some other departments, such as legal, employee relations, business development, and public relations.

The operations department is responsible for overseeing the actual construction work being performed in the field. In large companies, the executive responsible for this function may have a number of assistants, vice presidents, and construction managers. A vice president would oversee several construction managers and the construction manager would oversee several projects. Each project would be in charge of a project manager. In smaller companies, one individual might constitute the entire operations department and might even be responsible for other functions as well.

The importance of estimating and bidding cannot be overemphasized. Unless a contractor secures new work at the right price and under the proper conditions, his company will not stay in business very long. In construction companies, the person in charge of the engineering and estimating department is often called the chief engineer.

Usually under the chief engineer is a staff of estimators and engineers. The function of the estimating department is to receive the bid documents for a project and do a "due diligence" in-depth analysis of the risks and cost of the project. Preparing the cost estimate entails the takeoff of quantities of work and pricing the work to be performed by the contractor; soliciting, receiving, and analyzing subcontractor bids; assembling the entire estimate; and submitting the bid to the owner. The estimating staff may consist of one person in a small construction company to a staff of 20, 30, or more in larger companies. In the latter companies, there will be a number of senior estimators and they will be assisted by junior estimators and engineering aides.

Within the engineering estimating department there are

usually one or more schedule engineers. It is their responsibility to prepare schedules for bidding purposes. When the contractor submits his bid, the schedule engineer must have a clear plan and schedule as to how the company will build the job, and must be confident that he can complete the work within the time frame established in the bid documents. On projects on which the contractor is the successful bidder, the schedule department will quite often develop a more detailed CPM schedule in conjunction with the operations group and this schedule will be used by the field staff to construct the project.

The design of all the permanent parts of a project are the responsibility of the owner (except for a design-construct project). The design of any temporary structures or facilities is the responsibility of the contractor. Such structures include formwork, shoring, cofferdams, and dewatering systems (more will be said about this subject in the next section). Within the engineering and estimating department is usually one or more engineers who have expertise in such design. In smaller companies, an estimator may be expected to have this capability, or it is performed by an outside consultant.

The quality assurance/quality control (QA/QC) group may or may not come within the responsibility of the chief engineer. During the era of nuclear power plant construction, this department was required to report directly to the chief executive officer (CEO). Some companies still maintain that line of reporting, whereas in other companies the QA/QC group comes within the engineering and estimating department or the operations group.

It might be pointed out at this time that all construction companies are organized somewhat differently, depending on the size, culture of the company, and the type of work done. What is presented here is what might be considered typical within the industry. All construction companies need to have the capabilities described herein, whether one or two persons provide the capability or it is provided by a staff of hundreds of people.

Purchasing is a group that may or may not come within the engineering estimating department. After a project is successfully bid and awarded, a contractor must purchase and issue orders for materials and must enter into subcontracts for certain items of work. This is the function of the purchasing group. Doing such work in a competent manner is very important to the success of the project. Some construction companies use purchasing people to secure material and subcontract pricing during the bidding period. In other companies, the purchasing group becomes involved only on those jobs successfully bid.

Earlier, reference was made to the three major departments within a construction company. We have discussed two: the operations department and the engineering and estimating department. The third department is the administrative department. Within this department are the payroll, accounting, and financial functions. This department is headed by a comptroller or chief financial officer. As mentioned earlier, it can consist of only one person in smaller companies or very large staff in other companies. Since this department does not have much to do with engineering, we will not devote much discussion to it except to say as we did earlier that it is important for a successful construction company to have the excellent capability in this area. Timely job cost information provided to field management is vitally important. Historical cost data are relied upon by the estimators.

The employee relations or industrial relations department (sometimes called the human resource department) of a contractor's main office staff is also a very important function. It may or may not be part of the administrative department. This department is responsible for good employee relations,

whether it be for salaried or hourly employees. Usually within this department is responsibility for safety. All contractors have a moral obligation for the safety of their employees. In addition to the grief that comes from accidents, accidents are costly financially. Workers' compensation rates are determined by a contractor's safety experience. Contractors have taken more notice of both of these consequences of accidents and are devoting considerably more attention to this area of responsibility than during the days of Hoover and Grand Coulee Dams. Of course, the passage of the occupational safety and health act in the early 1970s has also required contractors and all employees to be more observant and sensitive to employee working conditions.

In the mid-1970s, business development and public relations were not functions contractors paid much attention to. All of the officers and executives were responsible for bringing in new work and projecting a good image of the company. This was particularly so for construction companies that worked only in the public sector. Things have changed. Most construction companies now have a business development department and many have a public relations group. In some companies, these functions fall within the engineering and estimating department, in others within the administrative department, while in others they constitute a separate department reporting directly to the CEO. The function of business development is to bring to the company opportunities for the contractor to bid on or to negotiate work. Business development has taken on great importance within the construction industry.

Legal was also a department that did not exist in many construction companies in years past. Nowadays, it is not unusual for a contractor to have one or more attorneys on its staff. The legal department reviews the contract form in the bid documents, assists in negotiating the contract if the contractor is successful in its bid and provides other advice to the CEO, department heads, and key people. One must be aware that on most publicly bid jobs the contractor cannot take any exception to the bid documents so what is described previously would apply only to privately bid projects. Generally, if a contractor has a dispute with the owner and gets into litigation, the contractor will engage outside counsel.

### Project Staff

The contractor's project staff pretty much mirrors the contractor's main office staff. The staff is headed by a project manager. Under him or her are a project engineer (responsible for engineering functions), general superintendent (responsible for jobsite field operations), and an office manager (responsible for jobsite administrative functions), and on certain projects an individual responsible for safety.

The project engineer is responsible for the following functions: cost control, scheduling, preparation of payment estimates, design of temporary structures (forms and the like), material handling systems, shop drawings for materials and equipment, drafting, plans and specifications (to be sure that they are current and up to date), surveying, quality control, and providing the general superintendent with all necessary engineering support. The project engineer may have a staff of one or more engineers under him or her, depending on the size and complexity of the job.

The general superintendent is responsible for overseeing all field work. He or she will have a number of assistant superintendents, general foreman, and foreman to assist in supervising the work being performed by the contractor and to oversee and coordinate all work being performed by subcontractors. The general superintendent is responsible for all construction equipment at the jobsite and to see that all work is being performed properly and in a safe manner. Depending

on the size of the project, there may be a separate safety supervisor.

The office manager is responsible for all on site administrative functions: timekeeping, payroll preparation (many contractors do payroll, accounting, and cost report preparation in the main office by computer), jobsite accounting, purchasing, and warehousing.

## SECTION V—ELEMENTS OF CONSTRUCTION ENGINEERING PRACTICE

The scope of work performed by engineers in the construction industry has been discussed to some extent in the earlier sections. In this section we will review and expand upon what has been presented previously.

Coordination with designer—Engineers employed in construction often are required to work with and to coordinate work with the designer. This is particularly true on construction management projects where the CM's responsibility is to work with the designer during the design period providing value engineering and constructability input and to see that the design work is proceeding on schedule.

The term "value engineering" means different things to different people. One approach to value engineering calls for the owner's team (owner, designer, and CM) to prepare a fixed overall budget for the project and to allocate the budget to the various components of the project. Thus on a building job, 8% of the budget might be allocated for the exterior or facade of the building. The team then works together to get the best product for the money available for that portion of the project. The same is done with all other components of the project.

Under a less rigid form of value engineering, the owner's teams works together to see that all parts of the project are designed in the most effective way so as to end up with a product that is consistent with the owner's objective and within his budget.

Constructability advice requires the CM to review the design of every element of the project to confirm that each element can be constructed in the field in a proficient and economical manner. As an example, when designing a foundation, that there is sufficient space available for the contractor to efficiently install and remove formwork or that there is sufficient space between reinforcing steel to allow for the proper placement of concrete.

Temporary structures—The general practice within the construction industry is that the designer is responsible for the design of the permanent structure and the contractor is responsible for the design of all temporary structures. Included in the latter category are the following: formwork, scaffolding, sheeting and bracing, cofferdams, dewatering systems, structures necessary to support cranes and other construction equipment, and any other temporary structures needed during construction. (On some bridge projects the designer has taken on the responsibility for the design of cofferdams.) Some contractors have in-house staffs to do this design work. Some rely on outside companies and consultants. There are several companies that will design and provide prefabricated forming systems and there are others who will design and provide falsework. Some consulting engineering firms specialize in the design of sheeting, bracing, and cofferdams.

Inspection and quality control—Depending on the particular project, this function may be performed either by the owner (through its engineer) or the contractor, or by both. Contractors have a first-line responsibility on all projects to assure that their work is being done strictly in accordance with the plans and specifications. This is done by the project manager, general superintendent and assistants, job engi-



neers, and, in some instances, special quality-control engineers. The owner will often have an inspection staff overseeing the contractor. On design-construct projects, contractors have total responsibility for quality control.

**Shop drawings**—Although the designer is responsible for the design of the permanent construction, much of the detail design is accomplished through shop drawings. Such drawings fill in the details that are not provided by the designer. It is typical as to reinforcing steel that the designer will indicate on the drawings the number, size and spacing of reinforcing steel but not the exact length and end details. Similarly, for structural steel, the designer has often left the design of the connections to the contractor (or its structural steel fabricator). The same holds true on mechanical and other equipment. The designer will specify the model but will not provide all the precise dimensions. The drawings prepared by the contractor (and its subcontractors and suppliers) are called shop drawings. These drawings constitute an important part of the construction process. It is the contractor's responsibility to see that these drawings are prepared properly and submitted to the owner's designer in a timely manner. Thereafter, the contractor must see that the drawings are reviewed and approved by the designer in a timely manner. If this process does not flow smoothly, construction will be delayed. Overseeing the shop-drawing process is an important responsibility of the project engineer and his jobsite staff.

**Estimating and bidding**—This subject was discussed earlier. The function is performed in the contractor's main office and the staff doing this work must be competent and experienced if the contractor is going to be successful in securing "good" work. What is good work? Unfortunately, the outcome of a construction project is not known until the project is completed. What might have appeared to be a good bid at the time of bidding might result in a losing project, or vice versa. Nevertheless, estimating and bidding requires a great deal of detail and competent work by experienced people. A good estimator is one who has had considerable field experience and has acquired sound judgment. Estimating may be considered more of an art than a science. Within the rather short time frame allowed by the owner for bidding (sometimes only a few weeks—the more time that can be made available the better) the estimating staff must visualize what will take place over the life of the project, plan and schedule the job, estimate the costs for doing the work, and put together and submit the bid. A very difficult process to say the least.

**Scheduling**—This has also been discussed earlier. With the introduction of the critical path method (CPM) of scheduling in the early 1960s and the application of the computer with its continuing advancements, the art of scheduling, which had been done previously only with bar charts, has advanced to more of a science than an art. However, the schedule is still no better than the quality of effort devoted to the sequencing and the ability of the scheduler (with the assistance of the estimators and other personnel) to properly estimate the duration of the various activities. Properly done and updated, a CPM schedule is a very effective tool to control the time element and sequences of a project and to assist in manpower allocation and equipment scheduling.

**Cost control**—The other key element of all construction projects is cost. The contractor needs to know on a timely basis how he or she is doing on a project costwise. This is accomplished through the preparation of a budget and chart of accounts and the careful coding of all costs into the correct item of work. By comparing actual costs to estimated or budgeted cost, the contractor can determine whether he or she is making or losing money on a particular item of work. The contractor needs to know this on a timely basis so he or she can investigate and take timely corrective action (if attainable)

on those items of work where the cost is overrunning the estimated cost. Computers have helped a great deal in doing this. The author refers the reader to *ASCE Manual No. 65* (Task 1985), which was updated in 1982 by a committee of experienced construction experts and is a comprehensive guide on this subject.

## SECTION VI—QUALIFICATIONS OF ENGINEERS IN CONSTRUCTION

People working in the construction industry come from different backgrounds. Some people come up as we say "through the trades." These are people who have started as carpenters, ironworkers, equipment operators, and the like, who have learned the field work through first-hand experience and have advanced to superintendent, project manager, and beyond. Another group are those who have worked as surveyors. Like the tradesman, they have learned the business in the field observing how the work is done. There are others who come from a background of a family that has owned and been in the construction business. There are others who have started as timekeepers or purchasing people and have learned the business and advanced. Finally, there are the engineers who have obtained their degrees and who either have a great interest in construction or by chance land a job with a construction company and embark on a career working for a contractor.

In earlier days there were less engineers working in construction, whereas today there are a greater proportion of engineers holding key positions in the construction industry. The percentage of graduate engineers working in construction who have obtained a professional engineers license is much lower than the percentage of engineers working in other disciplines. The only area in construction that requires a license is the design of temporary facilities. All other work can be performed by unlicensed people. Thus, people who are bright, industrious, and ambitious can learn to supervise construction work; can learn estimating, scheduling, and cost control; and can move into the upper levels of management within construction companies.

Engineers certainly have an advantage over others, provided they have equivalent degrees of ambition and are willing to apply themselves. Although some people reaching the level of project manager and above in construction companies do not have an engineering degree, the majority of people in such positions today do have engineering degrees.

There are opportunities for engineers in all phases of construction: field work, estimating, scheduling, cost control, quality control, safety, and business development. Although many people in the latter category are not engineers, there are very definite advantages to having an engineer in business development. Having a technical background is extremely helpful when dealing with owners and engineers with like backgrounds. Business development people not so trained need assistance when discussions and negotiations get into technical areas and their effectiveness is lessened.

When one rises to the level of project manager and above, the ability to get along with people and to communicate well and overall management capability often is of greater importance than an engineering degree or professional license.

## SECTION VII—RELATIONSHIPS WITH OTHER CIVIL ENGINEERING DISCIPLINES AND DESIGN PROFESSIONALS

Civil engineers working in construction deal with almost the whole range of civil engineering disciplines, more so than civil engineers in other disciplines. Such disciplines include geotechnical, structural, environmental, transportation, and

surveying, as well as those working in energy, materials, urban planning and development, dams, and waterways. Of course, the amount of dealings a civil engineer in construction will have with a civil engineer in another discipline will depend to a great degree on what type of work is performed by the civil engineer's employer.

#### **SECTION VIII—REFERENCES**

"The ENR 400." (1981) *Engrg. News Rec.*, Apr. 16, 1981.  
"ENR market trends." (1994) *ENR*, Feb. 27, 1994, 72.

"77 firms join 25-million club." (1959) *Engrg. News Rec.*, Apr. 30, 1959.

Task Committee on Design Build. (1992). "Design Build in the Federal Sector." *Rep.*, ASCE, New York.

Task Committee on Revision of Construction Cost Control Manual of the Construction Division. (1985). "Construction Cost Control." *ASCE Manuals and Reports on Engineering Practice No. 65*, ASCE, New York.

"The top 400 contractors." (1990). *Engrg. News Rec.*, May 24, 1990.