Guided Tour

Safety discussions are presented in every chapter covering machine and formwork use.

Operating and working around construction equipment and trucks is dangerous. A 6-ft-tall person within 70 ft of the right side of a 150 ton off-highway truck cannot be seen by the driver.

Web-based exercises have been added to many chapters to draw attention to the expanding volume of information available over the Internet. The computer monitor icon in the text margin will direct you to the text website (www.mhhe.com/peurifoy7e). In addition, extensive **Web resources** are provided at the end of every text chapter.

Visit the Caterpillar website and obtain the flywheel power (hp) rating for both a D6R and a D7R Series II track tractor. For these same tractors, check the blade specifications and determine the width (length) for both an "A" and an "S." Calculate the hp per foot of cutting edge ratio for all four conditions.

For **Instructors,** a comprehensive Solutions Manual and PowerPoint Lectures.

For **Students,** excellent Additional Resources, including video clips, tied directly to the text.

Our **website** contains additional resources for both instructors and students.

CHAPTER 1

Machines Make It Possible

Construction is the ultimate objective of a design, and the transformation of a design by construction into a useful structure is accomplished by men and machines. Men and machines transform a project plan into reality, and as machines evolve there is a continuing transformation of how projects are constructed. This book describes the fundamental concepts of machine utilization, which economically match machine capability to specific project construction requirements. The efforts of contractors and equipment manufacturers, daring to develop new ideas, constantly push machine capabilities forward. As the array of useful equipment expands, the importance of careful planning and execution of construction operations increases.

THE HISTORY OF CONSTRUCTION EQUIPMENT

Machines are a vital resource to the accomplishment of a construction project (see Fig. 1.1). One of the most obvious problems in constructing a project is how to transport heavy building materials. Machines provide the solution to that problem. The proof of how well the planner understands the work that must be accomplished and selects appropriate machines for that purpose is revealed by counting the money when the contract is completed. Did the company make a profit or sustain a loss?

From the time the first man decided to build some type of simple structure for protection from the elements through the construction of the Great Pyramids, the Great Wall of China, the temples at Angkor Wat in Cambodia, and continuing until the middle of the nineteenth century, work was accomplished by the muscle of man and beast. When Ferdinand de Lesseps began excavating the Suez Canal in April 1859, **corvée** laborers, provided by the Egyptian viceroy, did the work of digging that trench in the desert. Human labor assisted only by a very few machines continued the work for the next 4 years.

corvée
Labor required in lieu of taxes.

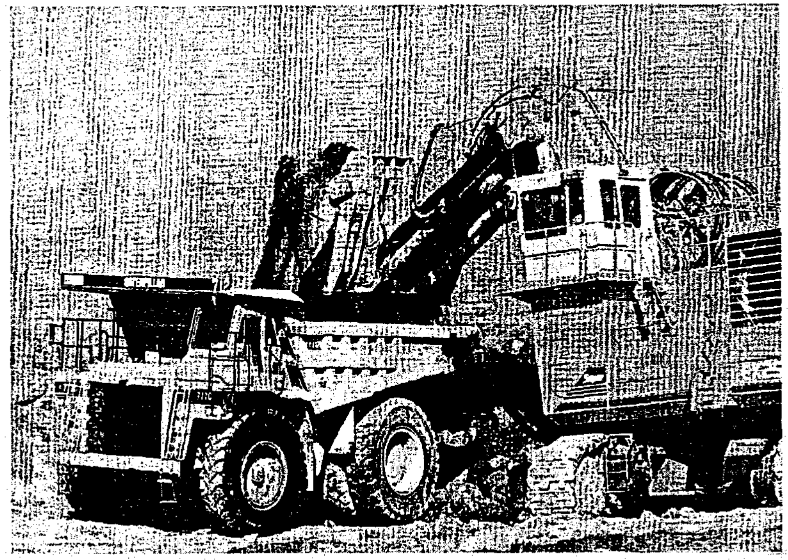


FIGURE 1.1 Modern hydraulic excavator loading a truck on a dam project in California.

But in 1864 Lesseps and his engineers began turning to machines, and ultimately 300 steam-powered mechanical dredges were at work. Those machines, in the final 3 years of the project, excavated the majority of the main canal's 74 million cubic meters. Mechanization—machines—transformed the project and continue to transform how projects are built.

The Dreams

The development of construction equipment followed the major changes in transportation modes. When travel and commerce were by water systems, builders dreamed of machines that would aid in dredging ports, rivers, and canals. As early as 1420, the Venetian Giovanni Fontana was dreaming and diagramming dredging machines. Leonardo da Vinci designed such a machine in 1503, and at least one of his machines was actually built but the power source was a lonely runner on a treadmill.

On July 4, 1817, at a site near Rome, New York, ground was broken for the 363-mile-long Erie Canal. It was built—excavated—by the efforts of local laborers and Irish immigrants, human labor. However, by 1852 construction in the United States was changing from canal building to railroad construction. The Middlesex Canal, which connected Boston to the Merrimack River at Lowell, had been in service since 1803, but in 1853 the Boston & Lowell Railroad superseded it. Nevertheless, construction, be it building canals or railroads, was still achieved by the brawn of man and beast.

Steam Power Machines

William S. Otis, a civil engineer with the Philadelphia contracting firm of Carmichael & Fairbanks, built the first practical power shovel excavating machine in 1837. The first "Yankee Geologist," as his machines were called, was put to work in 1838 on a railroad project in Massachusetts. The May 10, 1838, issue of the *Springfield Republican* in Massachusetts reported "Upon the road in the eastern part of this town, is a specimen of what the Irishmen call 'digging by stame.' For cutting through a sand hill, this steam digging machine must make a great saving of labor."

Continued development of the steam shovel was driven by a demand for economical mass excavation machines. In the early 1880s, an era of major construction projects began. These projects demanded machines to excavate large quantities of earth and rock. In 1881, Ferdinand de Lessep's French company began work on the Panama Canal. Less than a year earlier, on December 28, 1880, the Bucyrus Foundry and Manufacturing Company, of Bucyrus, Ohio, came into being. Bucyrus became a leading builder of steam shovels (see Fig. 1.2), and 25 years later when the Americans took over the Panama Canal work, the Bucyrus Company was a major supplier of steam shovels for that effort.

Still, the most important driver in excavator development was the railroad. Between 1885 and 1897 approximately 70,000 miles of railway were constructed in the United States. William Otis developed his excavator machine

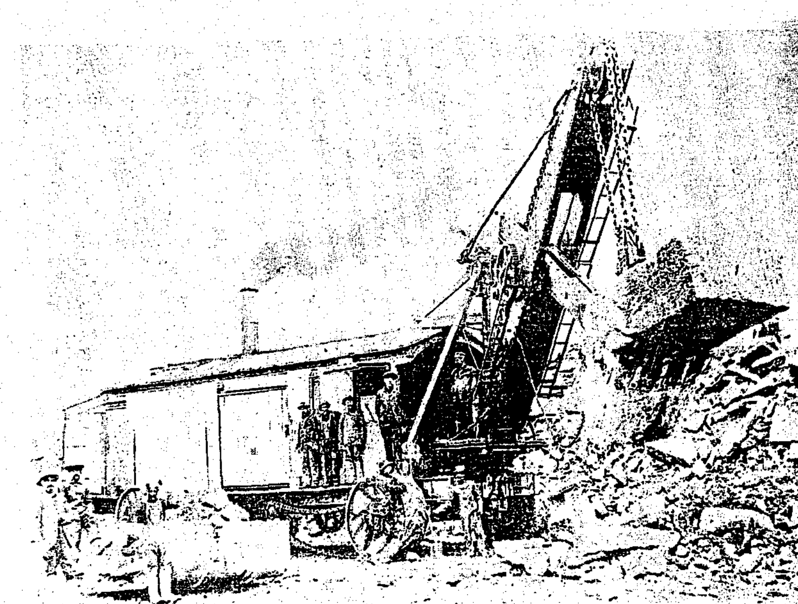


FIGURE 1.2 An early twentieth-century steam shovel; note this machine is mounted on steel traction wheels.

because the construction company Carmichael & Fairbanks, which he worked for and in which his uncle Daniel Carmichael was a senior partner, was in the business of building railroads.

The Bucyrus Foundry and Manufacturing Company came into being because Dan P. Eells, a bank president in Cleveland, was associated with several railroads. In 1882 the Ohio Central Railroad gave the new company its first order for a steam shovel, and sales to other railroads soon followed.

Internal Combustion Engines

By 1890 courts of law in Europe had ruled that Nikolaus Otto's patented four-cycle gasoline engine was too valuable an improvement to keep restricted. Following the removal of that legal restraint, many companies began experimenting with gasoline-engine-powered carriages. The Best Manufacturing Company (the predecessor to Caterpillar Inc.) demonstrated a gasoline tractor in 1893.

The first application of the internal combustion engine to excavating equipment occurred in 1910 when the Monighan Machine Company of Chicago shipped a dragline powered by an Otto engine to the Mulgrew-Boyce Company of Dubuque, Iowa. Henry Harnischfeger brought out a gasoline-engine-powered shovel in 1914. Following World War I, the diesel engine began to appear in excavators. A self-taught mechanic named C. L. "Clessie" Cummins, working out of an old cereal mill in Columbus, Indiana, developed the Cummins diesel engine in the early 1900s. The Cummins engine soon became popular in power shovels. Warren A. Bechtel, who in 1898 entered the construction profession in Oklahoma Territory and quickly built a reputation for successful railroad grading, pioneered the use of motorized trucks, tractors, and diesel-powered shovels in construction.

In the winter of 1922–1923, the first gas-powered shovel was brought into the state of Connecticut, and in the spring of 1923, it was employed on a federal-aid road construction project. The third phase of transportation construction had begun. Contractors needed equipment for road building. In 1919 Dwight D. Eisenhower, as a young army officer, took an Army convoy cross-country to *experience* the condition of the nation's roads (see Fig. 1.3). But as the country began to improve its road network, World War II intervened, and road building came to a near halt as the war unfolded.

Incubators for Machine Innovation

Los Angeles Aqueduct Large construction projects provide a fertile testing ground for equipment innovation. William Mulholland, as Los Angeles City Engineer, directed an army of 5,000 men for 5 years constructing the Los Angeles Aqueduct that stretches 238 miles from the Owens River to Los Angeles. In 1908 the Holt Manufacturing Company (the other predecessor to Caterpillar Inc.) sold three gas-engine caterpillar tractors to the city of Los Angeles for use in constructing the Los Angeles Aqueduct. Besides crossing several mountain ranges, the aqueduct passed through the Mojave Desert, a severe test site

FIGURE 1.3 Photograph with Eisenhower's description of conditions.
Courtesy Dwight D. Eisenhower Library

for any machine. The desert and mountains presented a challenging test for the Holt machines, but Benjamin Holt viewed the entire project as an experiment and development exercise.

Holt found that cast-iron gears wore out very quickly from sand abrasion, so he replaced them with gears made of steel. The brutal terrain broke suspension springs and burned up the two-speed transmissions in his tractors. The low gear was simply not low enough for climbing the mountains. Holt made modifications to the tractors both at his factory and in the desert. His shop manager, Russell Springer, set up repair facilities in the project work camps. After completion of the project, Mulholland in his final report labeled the Holt tractors as the only unsatisfactory purchase that had been made. But Holt had developed a much better machine because of the experience.

Boulder Dam In the years between the two world wars, one particular construction project stands out because of the equipment contributions that resulted from the undertaking. The Boulder Dam project (later named the Hoover Dam) was an enormous proving ground for construction equipment and techniques.

The use of bolted connections for joining machine pieces together came to an end in the Nevada desert as the project provided the testing ground for R. G. LeTourneau's development of welded equipment and cable-operated attachments. LeTourneau, through his numerous innovations in tractor/scraper design, made possible the machines that later went to build airfields around the world during World War II. Other developments that came from the Boulder

Dam project included sophisticated aggregate production plants, improvements in concrete preparation and placement, and the use of long-flight conveyor systems for material delivery.

Three Significant Developments

After World War II, road building surged and in 1956 Eisenhower, now president, signed the legislation that established the interstate highway program. To support the road-building effort, scrapers increased in capacity from 10 to 30 cubic yards (cy). With the development of the **torque converter** and the power shift transmission, the front-end loader began to displace the old "dipper" stick shovels. Concrete batch and mixing plants changed from slow manually controlled contraptions to hydraulically operated and electronically controlled equipment. But the three most important developments were high-strength steels, nylon cord tires, and high-output diesel engines.

torque converter *A fluid-type coupling that enables an engine to be somewhat independent of the transmission.*

1. *High-strength steels.* Up to and through World War II, machine frames had been constructed with steels in the 30,000- to 35,000-psi yield range. After the war, steels in the 40,000- to 45,000-psi range with proportionally better fatigue properties were introduced. The new high-strength steel made possible the production of machines having a greatly reduced overall weight. The weight of a 40-ton off-highway truck body was reduced from 25,000 to 16,000 lb with no change in body reliability.
2. *Nylon cord tires.* The utilization of nylon cord material in tire structures made larger tires with increased load capacity and heat resistance a practical reality. Nylon permitted the actual number of plies to be reduced as much as 30% with the same effective carcass strength, but with far less bulk or carcass thickness. This allowed tires to run cooler and achieve better traction, and improved machine productivity.
3. *High-output diesel engines.* Manufacturers developed new ways to coax greater horsepower from a cubic inch of engine displacement. Compression ratios and engine speeds were raised, and the art of turbo-charging was perfected, resulting in a 10 to 15% increase in flywheel horsepower.

Today there does not appear to be any radically new equipment on the horizon. However, manufacturers are continually refining the inventions of the past, and the development of new attachments will mean improved utility for the contractor's fleet. The future of equipment technology or innovation can be divided into three broad categories:

- *Level of control*: equipment advancements that transfer operational control from the human to the machine.
- *Amplification of human energy*: shift of energy requirements from the man to the machine.
- *Information processing*: gathering and processing of information by the machine.

The Future

A time may come when the base machine is considered only a *mobile counterweight with a hydraulic power plant*. The base machine will perform a variety of tasks through multiple attachments. This trend has started with hydraulic excavators having many attachments such as hammers, compactors, shears, and material-handling equipment. Wheel loaders have seen the introduction of the tool-carrier concept. Wheel loaders are no longer standard bucket machines. There are now other attachments such as brooms, forks, and stingers available so that a loader can perform a multitude of tasks. Other attachments will be developed, offering the contractor more versatility from a base investment. Ultimately, operators sitting in a machine cab may be eliminated altogether.

Safety features and operator station improvements are evolving to compensate for the less experienced workforce available today and in the foreseeable future. Related to workforce quality is the proliferation of supporting machine control technologies. Navigation of equipment is a broad topic, covering a large spectrum of different technologies and applications. It draws on some very ancient techniques, as well as some of the most advanced in space science and engineering.

The new field of geospatial engineering is rapidly expanding and a spectrum of technologies is being developed for the purposes of aeronautic navigation, mobile robot navigation, and geodesy. This technology is rapidly being transferred to construction applications.

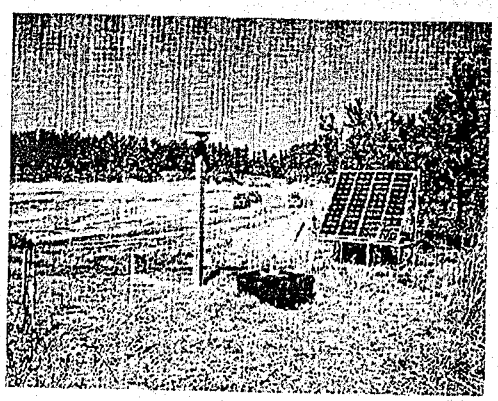
The U.S. Army Corps of Engineers conducted a field test of a Computer-Aided Earthmoving System (CAES) developed by Caterpillar Inc. in 2001 (see Fig. 1.4). From that limited test the Corps reported that CAES-equipped CAT 613 scrapers

- Moved 5.4% more earth in the 20-hr test period.
- Reduced preconstruction and restaking time by 28 hrs.
- Reduced manpower requirements by 54%.
- Achieved an accuracy of 2.3 in. vertical, 9.6 in. horizontal.

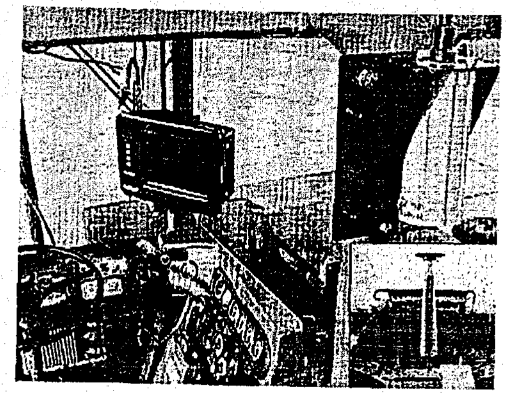
The laser and the global positioning system (**GPS**) guidance will become more common and reduce the need for surveyors. All the grader or dozer operator will need to do is load the digital terrain model into the onboard computer and then guide the machine where the display indicates. Machine position, along with cut or fill information, will be on a screen in front of the operator at all times. This may turn the operator's job into a video game.

GPS *A highly precise satellite-based navigation system.*

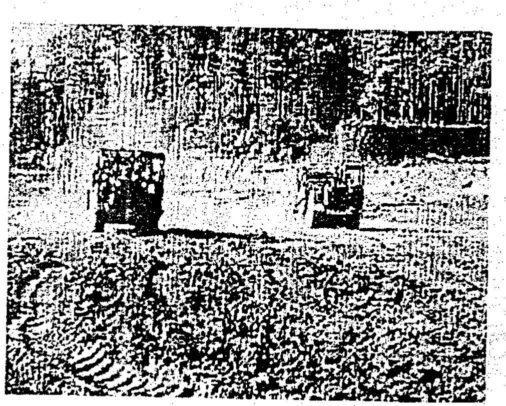
Ultimately, operators sitting in a machine cab may be eliminated altogether. Caterpillar is developing and testing automated rock-hauling units for mining. These units are linked by radio to the office and tracked by GPS. The superintendent need only use a laptop to send the start signal and the trucks do the rest. They leave the lineup at set intervals and follow the prescribed course. The superintendent can track the progress of each machine on the computer. If a truck develops a problem, the situation is signaled to the superintendent for corrective action.



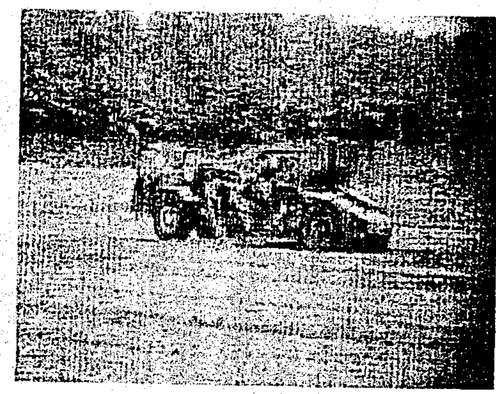
(a) Reference station



(b) System mounted on a CAT 613 scraper



(c) CAES-equipped scraper working



(d) CAES-equipped scraper working at night

FIGURE 1.4 Corps of Engineers field test of a Computer-Aided Earthmoving System.

BEING COMPETITIVE

This book introduces the engineering fundamentals for planning, selection, and utilization of construction equipment. It enables one to analyze operational problems and to arrive at practical solutions for completing construction tasks. It is about the application of engineering fundamentals and analysis to construction activities, and the economic comparison of machine choices.

The construction contractor's ability to win contracts and to perform them at a profit is determined by two vital assets: people and equipment. To be economically competitive, a contractor's equipment must be competitive, both mechanically and technologically. Old machines, which require costly repairs, cannot compete successfully with new equipment having lower repair costs and higher production rates.

In most cases, a piece of equipment does not work as a stand-alone unit. Pieces of equipment work in groups. An excavator loads trucks that haul material to a location on the project where it is required. At that point, the material

is dumped and a dozer spreads the material. After spreading, a roller compacts the material to the required density. Therefore, a group of machines, in this example an excavator, haul trucks, a dozer, and a roller, constitute what is commonly referred to as an equipment spread.

Optimization in the management of an equipment spread is critical for a contractor, both in achieving a competitive pricing position and in accumulating the corporate operating capital required to finance the expansion of project performance capability. This book describes the basic operational characteristics of the major heavy construction equipment types. More important, however, it explains the fundamental concepts of machine utilization, which economically match machine capability to specific project construction requirements.

There are no unique solutions to the problem of selecting a machine to work on a particular construction project. All machine selection problems are influenced by external environmental conditions. To appreciate how environmental conditions influence the utilization of heavy construction equipment, one must understand the mechanics of how the construction industry operates.

THE CONSTRUCTION INDUSTRY

By the nature of the product, the construction contractor works under a unique set of production conditions that directly affect equipment management. Whereas most manufacturing companies have a permanent factory where raw materials flow in and finished products flow out in a repetitive, assembly-line process, a construction company carries its factory with it from job to job. At each new site, the company proceeds to set up and produce a one-of-a-kind project. If the construction work goes as planned, the job will be completed on time and with a profit.

Equipment-intensive projects present great financial risk. Many projects involving earthwork are bid on a unit-price basis and there can be large variations between estimated and actual quantities. Some projects require an equipment commitment that is greater than the amount that a contractor will be paid for completing the work. Such a situation forces a contractor into a continuing sequence of jobs to support the long-term equipment payments.

Additional risk factors facing contractors in equipment-intensive work include financing structure, construction activity levels (the amount of work being put out for bid), labor legislation and agreements, and safety regulations. Project size and outdoor work that is weather dependent contribute to long project durations. Projects requiring two or more years to complete are not uncommon in the industry.

Government-initiated actions that seriously affect the operating environment of the construction contractor are labor legislation and safety regulation. In each of these areas, many regulations impact on a contractor's operations. These actions can directly influence equipment decisions. Legislative acts that exert direct pressure on equipment questions include the Davis-Bacon Act, which is concerned with wage rates, and the Occupational Safety and Health Act (OSHA), which specifies workplace safety requirements. Over one-half of the dollar volume of work in the equipment-intensive fields of construction is subject to wage determinations under the Davis-Bacon Act, and this strongly influences the labor costs incurred by contractors. OSHA, by its rollover protective structures (ROPS) mandate, substantially increased the cost of those pieces of construction equipment that had to have these structures included as part of the basic machine. That particular regulation had a single-point-in-time effect on equipment decisions, much like that resulting from the introduction of new equipment technology. Similarly, there remains the possibility of additional safety requirements. Sound and emissions are issues that are receiving greater regulatory attention. Some owners, by clauses in the construction contract, are limiting machine noise levels.

> Construction equipment to be certified includes any equipment of the types listed in Table XX brought on-site.
>
> This equipment shall be retested every 6 months while in use on-site. Any equipment used during construction may be subject to confirmatory noise level testing by the contractor at the request of the Engineer.

SAFETY

The rate of personal injury and death resulting from construction work is too high. Of all major industry classifications, construction has one of the poorest safety records. The construction industry employs nearly 6.4 million people. That is about 6% of the American workforce. However, according to the National Safety Council, the industry has about 23% of the deaths and 10.3% of the injury accidents every year. That translates into 1,150 to 2,000 deaths and 400,000 disabling injuries annually. The Construction Industry Institute estimates the direct and indirect costs of construction accidents may be as high as $17 billion annually. The major causes of deaths and injuries are falls from elevations, electrocution, being struck by equipment, being caught in between equipment, and trench excavation cave-ins. As an industry, we are responsible and accountable for those statistics. It is the responsibility of construction managers to create the safety programs that will prevent those accidents. We have both a moral and a business interest in doing so. The key is to provide the leadership, the programs, and the incentives to create a safe industry.

In the late 1960s, Congress began an investigation of construction safety, and in 1970 enacted the Williams-Steiger Act, more commonly referred to as the Occupational Safety and Health Act. The act provided a comprehensive set of safety rules and regulations, inspection procedures, and safety record-keeping requirements. It imposed nationwide safety standards on the construction industry. It also permitted the states to enact their own OSHA legislation as long as the state legislation is at least as stringent as the federal legislation. Employers are required to provide their employees a safe place to work and to maintain extensive safety records.

The act also established the Occupational Safety and Health Administration (OSHA), with regional offices in several cities throughout the country. OSHA is responsible for the administration of the legislation and the development of rules and regulations to implement the act. The OSHA rules and regulations are published in the *Federal Register*. *OSHA Safety and Health Standards*, Code of Federal Regulations, Title 29, Part 1910, contains the safety features that must be included in construction projects by the architect or engineer. *Construction and Health Regulations*, Code of Federal Regulations, Part 1926, pertains specifically to construction contractors and construction work. The act provides both civil and criminal penalties for violations of OSHA regulations. The civil penalty for failure to correct a violation is $7,000 per day with a maximum penalty of $70,000. Criminal penalties can include both fines and imprisonment. It is OSHA's intent to establish a uniform set of safety standards that apply to construction and to actively enforce those standards. Contractors must maintain a current, up-to-date file of OSHA regulations, and work proactively to comply with OSHA requirements (see Figs. 1.5 and 1.6).

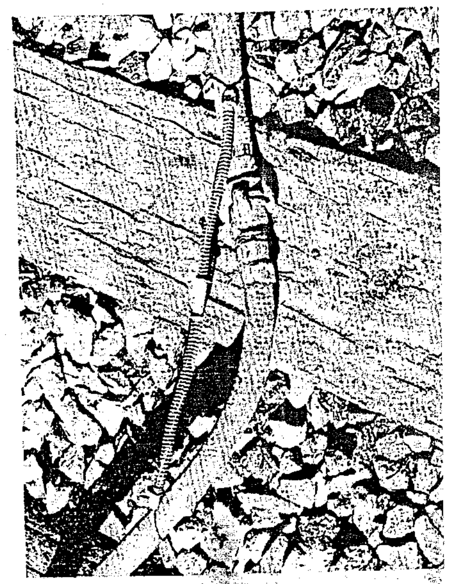


FIGURE 1.5 Proper connections for air hoses

THE CONTRACTING ENVIRONMENT

Construction contractors work within a unique market situation. The job plans and specifications that are supplied by the client dictate the sales conditions and product, but not the price. Almost all work in the equipment-intensive

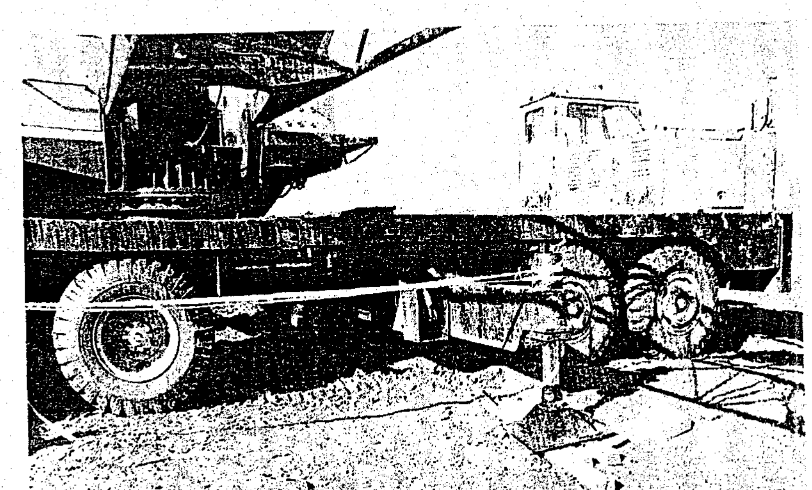


FIGURE 1.6 Failure to properly support the crane outriggers.

fields of construction is awarded on a bid basis, through either open or selective tender procedures. Under the design-bid-build method of contracting, the contractor states a price after estimating the cost based on a completed design supplied by the owner. The offered price includes overhead, project risk contingency, and the desired profit.

There is movement toward more design-build contracts, where the contractor also has control of the project design. With a design-build project, the contractor must state a guaranteed price before the design is completed. This adds an additional element of risk, because estimating the quantities of materials required to complete the project becomes very subjective. But the advantage to the contractor is that the design can be matched in the most advantageous way to the contractor's construction skills. In either case, it is tacitly assumed that the winning contractor has been able to underbid the competition because of a more efficient work plan, lower overhead costs, or a willingness to accept a lower profit.

Not infrequently, however, the range between the high and low bids is much greater than these factors would justify. A primary cause of variance in bids is a contractor's inability to estimate costs accurately. The largest portion of estimating variance is probably not caused by the differences between past and future projects but by a lack of accurate cost records. Most contractors have cost-reporting systems, but in numerous cases the systems fail to allocate expenses to the proper sources, and therefore cause false conclusions when used as the historical database for estimating future work.

A construction company owner will frequently use both contract volume and contract turnover to measure the strength of the firm. Contract volume refers to the total dollar value of awarded contracts that a firm has on its books (under contract) *at any given time.* Contract turnover measures the dollar value of work that a firm completes during a specific *time interval.* Contract volume is a guide to the magnitude of resources a firm has committed at any one time, as well as to possible profit if the work is completed as estimated. But contract volume fails to answer any timing questions. A contractor, who, with the same contract volume as the competition, is able to achieve a more rapid project completion, and therefore a higher capital turnover rate while maintaining the revenue-to-expense ratio, will be able to increase the firm's profits. Contractors who finish work ahead of schedule usually make money.

PLANNING EQUIPMENT UTILIZATION

Each piece of construction equipment is specifically designed by the manufacturer to perform certain mechanical operations. The task of the project planner/estimator or the engineer on the job is to match the right machine or combination of machines to the job at hand. Considering individual tasks, the quality of performance is measured by matching the equipment spread's production against its cost. Production is work done; it can be the volume or weight of material moved, the number of pieces of material cut, the distance traveled, or any similar measurement of progress. To estimate the equipment component of project cost it is necessary to first determine machine *productivity.* Productivity is governed by engineering fundamentals and management ability. Chapter 5 covers the principal engineering fundamentals that control machine productivity. Each level of productivity has a corresponding cost associated with the effort expended. The expenses that a firm experiences through machine ownership and use and the method of analyzing such costs are presented in Chapter 2.

Although each major type of equipment has different operational characteristics, it is not always obvious which machine is best for a particular project task. After studying the plans and specifications, visiting the project site, and performing a quantity take-off, the planner must visualize how to best employ specific pieces of equipment to accomplish the work. Is it less expensive to make an excavation with scrapers or to top-load trucks with a dragline? Both methods will yield the required end result, but which is the most economical method of attack for the given project conditions?

To answer that question the planner develops an initial plan for employment of the scrapers and then calculates their production rate and the subsequent cost. The same process is followed for the top-load operation. The type of equipment that has the lowest estimated total cost, including mobilization of the machines to the site, is selected for the job.

To perform such analyses, the planner must consider both machine capability and methods of employment. In developing suitable equipment employment techniques, the planner must have knowledge of the material quantities involved. This book will not cover quantity take-off per se, but that process is strongly influenced by the equipment and methods under consideration. If it is determined that different equipment and methods will be used as an excavation progresses, then it is necessary to divide the quantity take-off in a manner that is compatible with the proposed equipment utilization. The person performing the quantity take-off must calculate the quantities so that groups of similar materials (dry earth, wet earth, rock) are easily accessed. It is not just a question of estimating the total quantity of rock or the total quantity of material to be excavated. All factors, which affect equipment performance and choice of construction method, such as location of the water table, clay or sand seams, site dimensions, depth of excavations, and compaction requirements, must be considered in making the quantity take-off.

The normal operating modes of the particular equipment types are discussed in Chapters 5, 7 to 20, and 22. That presentation, though, should not blind the reader to other possible applications. The most successful construction companies are those that, for each individual project, carefully study all possible approaches to the construction process. These companies use project preplanning, risk identification, and risk quantification techniques in approaching their work. No two projects are exactly alike; therefore, it is important that the planner begins each new project with a completely open mind and reviews all possible options. Additionally, machines are constantly being improved and new equipment being introduced.

Heavy equipment is usually classified or identified by one of two methods: *functional* identification or *operational* identification. A bulldozer, used to push a stockpile of material, could be identified as a support machine for an aggregate production plant, a grouping that could also include front-end loaders. The bulldozer could, however, be *functionally* classified as an excavator. In this book, combinations of functional and operational groupings are used. The basic purpose is to explain the critical performance characteristics of a particular piece of equipment and then to describe the most common applications for that machine.

The efforts of contractors and equipment manufacturers, daring to develop new ideas, constantly push machine capabilities forward. As the array of useful equipment expands, the importance of careful planning and execution of construction operations increases. New machines enable greater economies. It is the job of the estimator and the field personnel to match equipment to project situations, and that is the central focus of this book.

SUMMARY

Civilizations are built by construction efforts. Each civilization had a construction industry that fostered its growth and quality of life. This chapter presented an abridged history of construction equipment, an overview of construction work, and the risk associated with bidding work. Machine production, the amount of earth moved or concrete placed, is only one element of the machine selection process. It is also necessary to know the cost associated with that production. The critical learning objective is

- An understanding of how construction equipment and machines have been developed in response to the demands of the work to be undertaken.

This objective is the basis for the problems that follow.

PROBLEMS

1.1 Research these engineers on the Web and write a one-page paper about their accomplishments.
William Mulholland
Stephen D. Bechtel Sr.
Benjamin Holt
R. G. LeTourneau
William S. Otis

1.2 Research these engineering accomplishments on the Web and write a one-page paper about the equipment used to accomplish their construction.
Hoover Dam
Panama Canal
Interstate highway program

1.3 What is the function of the Occupational Health and Safety Administration? What OSHA office administers your area?

1.4 Why do some construction workers resist the use of safety equipment such as hard hats and fall protection harnesses? Why does the practice of resisting the use of safety equipment persist? What should be done about it?

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WEBSITE RESOURCES

Significant additional information about the construction industry can be found posted on the following websites.

Associations and Organizations

Sites about construction associations and organizations include

1. www.asce.org The American Society of Civil Engineers (ASCE) is a professional organization of individual members from all disciplines of civil engineering dedicated to developing leadership, advancing technology, advocating lifelong learning, and promoting the profession.
2. www.asme.org The American Society of Mechanical Engineers (ASME) is a nonprofit educational and technical organization that publishes many standards in reference to construction equipment.
3. www.agc.org The Associated General Contractors of America (AGC) is an organization of construction contractors and industry-related companies.
4. construction-institute.org The Construction Industry Institute (CII) is a research organization with the mission of improving the competitiveness of the construction industry. CII is a consortium of owners and contractors who have joined together to find better ways of planning and executing capital construction programs.

Codes and Regulations

Sites that provide information about codes or regulations that impact the construction industry include

1. www.osha.gov The U.S. Department of Labor, Occupational Labor Safety and Health Administration (OSHA) establishes protective standards, enforces those standards, and reaches out to employers and employees through technical

assistance and consultation programs. OSHA's mission is to ensure safe and healthful workplaces in America.

2. www.nist.gov/welcome.html The National Institute of Standards (NIST) is a non-regulatory federal agency within the U.S. Commerce Department's Technology Administration. NIST develops and promotes measurement, standards, and technology.
3. www.ansi.org The American National Standards Institute (ANSI) is a private, nonprofit organization that administers and coordinates the U.S. voluntary standardization and conformity assessment system.
4. www.iso.ch The International Organization for Standardization (ISO) is a non-governmental organization. It is a network of the national standards institutes from 148 countries, with one member per country and a Central Secretariat in Geneva, Switzerland, that coordinates the system.
5. www.astm.org The ASTM International, formerly known as the American Society for Testing and Materials, is a not-for-profit organization that provides a global forum for the development and publication of voluntary consensus standards for materials, products, systems, and services.

Safety

1. www.nsc.org National Safety Council. Excellent library for workplace safety consultants and human resources managers offering resources, member information, services, and publications.
2. www.construction-institute.org Home page of the Construction Industry Institute, University of Texas at Austin. Source of construction management research relating to best practices.
3. www.osha.gov Occupational Safety and Health Administration site. Includes news, statistics, publications, regulations, standards, and reference resources.
4. www.ntsb.gov National Transportation Safety Board. This independent federal agency conducts investigations on significant transportation accidents, and offers synopses and public hearing overviews.
5. www.crmusa.com Contractors Risk Management. Explore details of this company offering manuals, customized plans, and training programs for construction industry safety and health guidelines.
6. www.agc.org Associated General Contractors of America. Deals with contracting and safety issues and construction laws.

CHAPTER 2

Fundamental Concepts of Equipment Economics

A correct and complete understanding of the costs that result from equipment ownership and operation provide companies a market advantage that leads to greater profits. Ownership cost is the cumulative result of those cash flows an owner experiences whether or not the machine is productively employed on a project. Operating cost is the sum of those expenses an owner experiences by working a machine on a project. The process of selecting a particular type of machine for use in constructing a project requires knowledge of the cost associated with operating the machine in the field. There are three basic methods for securing a particular machine to use on a project: (1) buy, (2) rent, or (3) lease.

IMPORTANT QUESTIONS

Equipment cost is often one of a contractor's largest expense categories, and it is a cost fraught with variables and questions. To be successful, equipment owners must carefully analyze and answer two separate cost questions about their machines:

1. How much does it cost to operate the machine on a project?
2. What is the optimum economic life and the optimum manner to secure a machine?

The first question is critical to bidding and operations planning. The only reason for purchasing equipment is to perform work that will generate a profit for the company. This question seeks to identify the expense associated with productive machine work, and is commonly referred to as ownership and operating (O&O) cost. O&O cost is expressed in dollars per machine operating hour (e.g., $90/hr for a dozer) because it is used in calculating the cost per unit