An Overview of the Field of Civil Engineering

Sheng-Taur Mau

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By S.T. Mau and Sami Maalouf
California State University—Northridge

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www.cognella.com

ISBN-13: 978-1-60650-710-0 (e-book)

www.momentumpress.net

Cover and interior design by S4Carlisle Publishing Services Private Ltd., Chennai, India

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www.cognella.com 800-200-3908

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Preface

This book is written to inspire and empower students pursuing a Bachelor of Science in Civil Engineering (BSCE) degree. It is designed as a textbook for an introductory course in a civil engineering curriculum. Students who come to a BSCE degree program may have some vague idea of civil engineering as a discipline or a profession. Some may have mistaken civil engineering as being mainly about architectural design. While it usually takes four years of study to learn to some degree what civil engineering is about, it is possible to provide a general description of civil engineering as a discipline by going through its major technical areas and the attributes of civil engineers. This is accomplished in Chapter 1.

Furthermore, civil engineering freshmen usually have no clue about what it takes to succeed in the freshman year and subsequent years. Chapter 2 gives a description on all the beneficial skills and tools needed to succeed as a civil engineering student.

Chapter 3 describes the common BSCE curriculum design. It also includes a description of the Fundamentals of Engineering (FE) exam, which contains many of the topics taught in the first three years of a BSCE curriculum and is usually taken by civil engineering students in their senior year. Chapter 3 also contains a description of the accreditation agency, ABET Inc., and its requirements for all engineering degree programs.

The importance of extracurricular activities to students' academic performance and progress is now recognized by many educators and deemed an integral part of student life. In Chapter 4, the most relevant student organizations on many campuses are described with emphases on student competitions and scholarship opportunities. The competitions sponsored by ASCE (American Society of Civil Engineers), the annual steel bridge competition and the annual concrete canoe competition, are described in some detail to encourage student participation.

CHAPTER 1

An Introduction to Civil Engineering

1.1 Overview

Civil engineering is the oldest engineering discipline. From the pyramids in Egypt, the Roman aqueduct and roads, to the great walls and the grand canal of China, ancient civil engineers left their imprint on human history on a grand scale. While the basic needs for civil engineering have not changed throughout the ages, the content and level of expectation of civil engineering work have certainly changed with the time because the tools available to civil engineers are changing with the time.

Civil engineering is a branch of engineering that deals with providing people with a livable built environment consistent with the standards and expectations of modern living through the applications of mathematics, science, and human experience. Some of the contributions of civil engineering are visible and obvious: buildings, bridges, highways, railways, airports, and dams and levees. Some are less commonly known as the product of civil engineering: offshore platforms, cell phone towers, power transmission lines and substations, drinking water and wastewater treatment plants, traffic signals, air pollution control, International Space Station, and many more. In short, civil engineering deals with people's everyday needs and more. The following table illustrates the connection between five basic human needs and technical areas within civil engineering.

Civil engineering's progress throughout time introduces new contributions to people's daily lives. Take the 20th century, for example; the U.S. National Academy of Engineering, a non-government, non-profit organization, after an elaborate nomination-and-review process published the twenty greatest engineering achievements of the 20th century in 2000. These are:

Among the twenty, clearly Number 4 and Number 11 are the contributions of civil engineering. Even Number 1, Electrification, the generation and transportation of electrical power, cannot be achieved without the civil engineering contribution to the designing and constructing power transmission towers and lines. Same is true for Number 2 and Number 3.

As already indicated in Table 1.1, civil engineering includes several very different technical specialty areas. By describing these technical areas, it is hoped that a clearer picture of what civil engineering entails may emerge. Eight civil engineering technical areas are described below. Each technical area has its own sub-areas of specialty. They are described following the short overview of each technical area. When you begin to take civil engineering courses, you may identify each course with some of these technical areas. A student is not expected to be exposed to all the technical areas but at least four are included in the curriculum of any civil engineering degree program (see Chapter 3). Three contemporary issues confronting civil engineers are described following a description of other areas closely related to civil engineering. Personal attributes of a typical civil engineer is portrayed near the end. The chapter ends with a brief mentioning of all the steps leading to a civil engineering degree and career.

1. Electrification
2. Automobile
3. Airplane
4. Water Supply and Distribution
5. Electronics
6. Radio and Television
7. Agricultural Mechanization
8. Computers
9. Telephone
10. Air Conditioning and Refrigeration
11. Highways
12. Spacecraft
13. Internet
14. Imaging
15. Household Appliances
16. Health Technologies
17. Petroleum and Petrochemical Technologies
18. Laser and Fiber Optics
19. Nuclear Technologies
20. High-performance Materials

Table 1.1 Basic needs and civil engineering

Human Needs	Specific Nature of Needs	Civil Engineering Technical Areas
Breath	Clean air	Environmental Engineering
Drink	Safe water	Environmental Engineering
Sleep	Livable shelter	Structural/Construction Engineering
Move around	Ways to travel	Transportation/Construction Engineering
Safe from disaster	Earthquake mitigation	Structural/Geotechnical Engineering
	Flood mitigation	Hydraulic Engineering/Water Resources
	Wind mitigation	Structural Engineering
	Fire resistant	Structural Engineering

1.2 Structural Engineering

Structural engineering is the technical specialty that deals with the analysis and design of constructed structures. From spacecraft to deep sea submarines, from tiny micro-electro-mechanical system (MEMS) devices to long bridges and tall buildings, these are all human-made structures that serve specific functions. A structure is always subjected to the many "loads" the environment forces upon it. These loads include the omnipresent gravitational load of its own weight (called the dead load), the weight of things moving about in or upon the structure (the live load), and event-driven loads originated from the occurrence of earthquakes, strong wind, or heavy snow. Structural design aims at providing a structure with sufficient level of resistance against these loads with minimum cost. Within structural engineering, there are several technical sub-areas. Some are named according to the type of structure. Some are named according to the type of load.

Earthquake Engineering. The suddenness of earthquakes and the damage they could cause in a matter of seconds inspired the study of the nature of earthquakes and the effects they inflict on structures. The effects of earthquake ground motion create vertical and horizontal forces that change violently within a short duration. The time-varying nature and the multi-directional nature of the earthquake-induced load require special design and analysis considerations. The fundamental approach in earthquake engineering is not to design a structure to withstand any earthquake at all costs but to design a structure that will not inflict injury to human lives at a reasonable cost.

Wind Engineering. Strong wind caused by a hurricane, a tornado, or a storm creates effects on structures that are also time-varying and multi-directional. Strong wind around a structure may push against a surface while creating a partial vacuum behind another structural surface. Unlike earthquakes, which occur infrequently, especially the damaging ones, strong wind in some areas occurs frequently and so is the damage it incurs. Design against such wind-related effects is the realm of wind engineering. Here again, the design approach is to protect human lives with a reasonable cost.

Structural Reliability. The many loads a structure must withstand during its life span are mostly of a "random" nature, meaning it cannot be defined precisely with respect to its magnitude and time of occurrence. So are the resistance provided by the size and material of structural components. Design in the face of uncertainty requires the application of probability and statistics. Structural reliability is the methodology applying these mathematical tools to the load-resistance analysis in structural design. It is used in the development of design codes and specifications that are followed by designers to provide acceptable levels of safety against all loads.

Fire Engineering. In the event of a fire in a building, the high temperature created by the fire may cause the building material to lose its strength and eventually fail under the weight of the building. Fire engineering in the context of structural engineering deals with the effective application of protective materials to the structural components such as steel beams and columns such that sufficient time is provided for the occupants to escape and the firefighters to arrive. The research in fire engineering provides data to be incorporated into design and construction codes and specifications.

Bridge Engineering. Some structural engineers specialize in bridge design and construction. Bridge design can be categorized according to material and bridge type. One unique feature of bridge design is it is closely integrated with construction. From the bridge foundation to the superstructure, the process of construction and erection often requires detailed analysis by the design engineers and likely dictates the designers' choice of bridge type.

Dam Engineering. The design of dams requires detailed study of the geological characteristics of the site and the mechanical properties of the foundation before the dam type is selected. For some types of dams, it is necessary to ensure the dam material is placed in such a manner that seepage of water through and under the dam body is within acceptable limits. Dam engineers also design all details on how to divert water during construction and specify maintenance and operations procedures post construction.

Building Engineering. Structural engineers often become building design specialists because building design is more frequently in demand than bridge or dam designs, especially in urban centers. Building engineers also design special buildings such as stadiums and large dome structures.

Forensic Engineering. Forensic engineering refers to the study of causes of an engineering event, usually a disaster or failure of some kind. In the context of structural engineering, it refers to the investigation of a structural failure. There are no courses or programs for structural forensic engineering training, but experienced structural engineers who have investigated past failures are often called upon to investigate a new event. In case of major disasters, often a team of experts are assembled to study the cause of the disaster and to make recommendations to prevent future disasters. Even when the cause of disaster is terrorism, forensic engineering would reveal the weakness in design and provide guidance for future designs. A good example is the 1995 bombing of the Alfred P. Murrah Federal Building in Oklahoma City. The collapse of the building was caused by the bombing that destroyed ground-level columns in the front of the building. Experts recommended that future buildings should have sufficient redundancy in the design of supporting columns so that the damage of one or more columns would not lead to the collapse of the whole building.

In structural design in the context of civil engineering, there are three construction materials that are dominant: steel, reinforced concrete, and timber. Each has its own design specifications. Thus, steel structure design, reinforced-concrete structure design, and timber structure design are three main design disciplines.

1.3 Geotechnical Engineering

Most civil engineering structures are earthbound. They sit on soil and rock ground directly or on constructed foundations that transfer the load to the soil or rock below. Geotechnical engineering is the technical specialty that deals with soil and rock as supporting materials for structures. It deals with the various foundation types that work between the structure and the ground. In addition it deals with the stability of soil or rock slopes whose failure may cause loss of human lives or damage to property. There are several technical areas of study that are pertinent to geotechnical engineering.

Engineering Geology. While geology is a basic science that is concerned with macroscopic earth structures or movements, engineering geology provides geological data pertinent to constructed structures. One obvious example of the application of engineering geology is the mapping of active seismic faults that are to be avoided when making plans for human habitat development, roadway construction, or power plant construction. At a more fundamental level, understanding various geological formation and rock types provides geotechnical engineers the knowledge necessary in assessing the suitability of a site for human activities.

Soil Mechanics. Most people would not consider soil as an engineering material, but it is, because most constructed structures are situated on it by necessity. Without due consideration of soil's bearing capacity under various circumstances, a structure built over it may sink, tilt, or outright turn over. Soil mechanics is a branch of mechanics that studies the mechanical properties of various types of soil and its strength at different moisture-content levels. It provides the scientific base upon which design formulas and codes are developed for everyday engineering design practice.

Rock Mechanics. The properties of rock become relevant when it is used as the foundation of a high-rise building or a large dam. It is also relevant when one examines the stability of the slope of a mountain or a tunnel. It is also the subject of study for the occurrence of earthquakes.

Foundation Engineering. A foundation is the interface between a superstructure and its supporting soil. A common type of foundation for single-family homes consists of strip footings placed under loadbearing basement walls. Another common practice is to use a concrete slab to spread the weight of the building over the soil underneath. Foundation engineering is the study of different types of foundation and their proper applications. Depending on the properties of soil at a site, shallow or deep piles may be deployed. The construction of a bridge over water may require the use of deep caissons on which piers are constructed. To stabilize an excavated slope, various types of methods may be used including retaining walls and slope-protection vegetation growth.

Soil Improvement. When a structure must be placed at a site with very weak soil, various techniques can be used to improve the soil properties. These typically involve the use of replacement material through excavation or the injection of special material (grouts) into the original soil to change its properties. Another special technique is to place geosynthetic fabrics or textiles in horizontal layers to strengthen the soil or to limit soil's permeability, which is essential in the design for landfill and hazardous material deposit sites.

Tunnel Engineering. Tunneling through soil or rock is sometimes necessary in the construction of roadways or special storage spaces. Tunnel engineering deals with the route determination, selection of tunneling machines, and the analysis and design of the tunnel structure.

Most of the things designed by geotechnical engineers are not as visible as those by structural engineers because they are underground or under the superstructure above. But, it is safe to state that no civil engineering work can be constructed without the contribution of geotechnical engineers.

1.4 Environmental Engineering

Environmental engineering is the application of engineering means to protect human health and to preserve the natural environment by managing and developing water, air, and land resources. The application of environmental engineering relies on the fundamental sciences of chemistry, biology, ecology, and health sciences. Most modern environmental engineering projects are planned and implemented under the auspices of the Clean Water Act, Safe Drinking Water Act, Clean Air Act, and other federal and state environmental legislation. Several technical areas in environmental engineering are described below.

Water Treatment and Supply. Before water is consumed, it has to be collected first from either underground or above-ground sources. Therefore, source control is one of the most important tasks of water supply. Except for a few municipalities where the source water derived from deep aquifers, source water has to be treated to remove contaminants such as pathogenic bacteria, heavy metals, and pesticide residues. The process of treatment involves the removal of suspended solids and the use of chemicals or ultraviolet (UV) radiation to disinfect unwanted organisms so that the effluent water satisfies quality requirements dictated by the Federal Safe Drinking Water Act. For water used by industrial plants such as paper mills or nuclear power plants, special treatment is needed and its discharge is regulated.

Wastewater Treatment and Disposal. In a modern municipality, household wastewater is collected through underground pipelines to a treatment plant. The wastewater treatment process is very different from drinking water treatment and is classified into primary treatment, secondary treatment, and tertiary advanced treatment. Primary treatment removes suspended solids from wastewater by a sedimentation process. Secondary treatment is to remove dissolved organic wastes from wastewater by biochemical decomposition followed by further sedimentation. The Federal Clean Water Act establishes nationwide minimum treatment requirements for all wastewater. For municipal wastewater discharge, the minimum treatment is the secondary treatment, which removes 85% of biochemical oxygen demand (BOD) and total suspended solids (TSS). BOD is a measurement of oxygen-demanding organic wastes. In situations in which these minimum treatment levels are not sufficient, the Clean Water Act requires additional treatment, which is accomplished by membrane filtration and other physical-chemical processes.

The outcomes of the wastewater treatment are solid sludge and effluent water. The solid sludge sometimes can be used for landfill or even as fertilizers. The effluent water can be used for irrigation or groundwater recharge or may be directly discharged into river, stream, or lake or sea. For a municipality, the amount of rainfall determines the ways of collecting and treating wastewater. Obviously if a large amount of rainfall is expected, especially when storm water comes in a very short period of time, rainwater runoff should be separated or diverted either temporarily or permanently from household wastewater in order to avoid overwhelming the treatment plant. Thus, a wastewater collecting system can either be combined (for more arid areas) or separated. Some industrial plants produce special wastewater that requires the removal of heavy metal or hazardous chemicals before being discharged.

Air Pollution. Environmental engineers monitor, analyze, and assess the air quality around municipalities. Air pollution comes from natural and human-activity sources. Volcanic eruption is a major natural source of air pollution. The gaseous and particulate contents of a volcanic eruption are often studied by scientists rather than engineers. Around a large municipality, however, air pollutants come from automobile emissions, nearby industrial plant emission, and even from faraway sources. Health science advances have discovered that tiny solid particles in the air such as soot are hazardous to human health. The monitoring of these particles is as important as that for gases. Tracing plant emission in the atmosphere, called plume analysis, is important in the assessment of the environmental impact of a plant. Another form of air pollution is sand storm. Monitoring of sand storms may lead to the sources of the storm and policy for conservation or planting of new vegetation.

Solid Waste Disposal. Solid wastes, commonly known as trash and garbage, from domestic, commercial, and industrial sources are to be collected, separated, and partially recycled, and disposed of in landfills and special disposal sites. Environmental engineers, working with other civil engineers, select, design, and construct sanitary landfill sites. Water percolating through a sanitary landfill is intercepted, collected, and treated in order to prevent the seepage of hazardous materials into ground water strata. Some solid waste maybe burned by specially designed incinerating plants.

Nuclear Waste Disposal. Nuclear waste comes from used fuel rods in nuclear power plants. Though the degree of radiation from these spent fuel rods is low, long-term exposure to low-level radiation is hazardous to human health. Disposal of these wastes has few options. The basic approach is to store them in places far from human habitat. Furthermore, it must be assured that the storage containers will not leak to the environment in any way. Leakage to underground water would be disastrous because the contaminants can travel far and reach sources for human water consumption.

Noise Pollution. In modern municipalities, human activities often generate sustained high levels of sound that are hazardous to the physical and mental wellbeing of habitants. Sound barriers are often needed to shield neighborhoods from highway traffic noises. Power plants or air-conditioning plants on large campuses produce high levels of noises that also require containment and shielding. Environmental engineers monitor the noise levels and design and implement mitigation strategies.

Environmental Impact Assessment. Environmental engineers are often called upon to assess the impacts on human health and the natural environment by a new development, a new industrial plant, or even a new commercial establishment such as a large shopping mall. Such assessment may entail the study of noise, traffic, water consumption and discharge, power requirements, air pollution potential, and other factors.

Environmental engineering as a part of civil engineering is unique in its extensive applications of knowledge from health sciences and biology and chemistry. Its practice is also very much impacted by environmental laws enacted at the state and national levels.

1.5 Water Resources Engineering

Water resources engineering is a specialty dealing with the use of water in support of modern living, including the agricultural, industrial, domestic, recreational, and environmental needs. Its scope includes the finding and preservation of aboveand underground water sources, understanding the movement of water in nature, engineering the transport of water, and managing erosive effects of water wave and current on shorelines. Some core and related specialties are described below.

Water Resources System Engineering. The understanding of the circulation of water on earth and managing the sources of water in a region requires a system approach. Decision on the water supply for a city or a region requires the knowledge of water sources and the quality and quantity of each source. The application of system analysis in water resources management and the design and operations of multipurpose reservoir and river systems is at the core of water resources system engineering.

Hydraulic Engineering. Hydraulic engineers design artificial waterways such as canals, channels, and aqueducts as well as manage water movement by designing and constructing dams, levees, canal locks, and other water-regulating devices. For many regions a major task of hydraulic engineers is flood prevention and control, which entails the assessment of potential rainfall quantity, prediction of water levels along natural rivers, streams, or channels, and strategies to mitigate flooding hazards by improving the natural topography. Hydraulic engineering is also fundamental to hydraulic-power generation. In hydraulic-power generation a prerequisite is a high water-level differential (water head). When water moves from a high level to a lower level, the difference in the water levels provides the energy potential for power generation. Some dams are constructed mainly for power generation although usually a dam also has the potential to be used for flood control. The stored water in a dam's reservoir can be used for agricultural, industrial, and domestic consumption as well as recreational sports.

Coastal Engineering. The movement of water in oceans and lakes has erosive effects on their shorelines. The preservation of wetland for flood mitigation or marine ecology requires the knowledge of such effects. Use of artificial barriers such as breakwaters or dikes at a shore or a harbor can result in reducing the water wave level within protected areas, eliminate or reduce the effects of shoreline erosion, and redirect natural sediment so that new land can be created over time.

Ocean Engineering. Ocean engineering deals with the effects of ocean currents and waves on ocean-bound structures and the analysis and design of such structures to withstand the wave forces. The most prominent ocean-bound structures are offshore platforms for oil exploration and production. Ocean engineers provide estimates of forces generated from waves and currents and the interaction of wave and structure so that structural engineers can design a platform to withstand such forces. Other ocean-bound structures include offshore wind farms and pipelines to transport materials from offshore to shore. While ships are obvious ocean-bound structures, their design usually falls in the realm of naval architecture, which integrates several engineering disciplines: structural, ocean, mechanical, and electrical for the design of ships. Naval architecture is not considered as a part of civil engineering.

1.6 Transportation Engineering

Transportation engineering deals with the efficient transport of people and goods. The content of transportation engineering changes whenever a new mode of transportation becomes viable. For example the advent of airplanes and air travel led to new technical fields such as airport design and air traffic control. Several sometimes overlapping technical specialties are part of transportation engineering:

Transportation Planning. Transportation infrastructure is mostly government funded or at least government approved. Before any physical facilities are designed and built for moving people and goods, decisions must be made from policy and political considerations. Transportation planning considers policy formation processes, cost, financing, and projected performance of potential transportation systems, including intermodal transportation that involves more than one mode of travel such as sea-land-air travels.

Transportation System Engineering. Transportation System Engineering entails the efficient management and operation practices, design, and assessment of the cost-effectiveness of transportation systems. The assessment of transportation systems requires performance modeling techniques, traffic simulation, and environmental impact (noise and air pollution) analyses.

Highway Engineering. Highway engineering focuses on the planning, design, construction, and operation and maintenance of highways. Unique to highway engineering is the design and construction of highway pavements and foundations, and the design of highway interchanges. The operation of highways includes the use of high-occupancy lanes and networked signals and displays that can alter lane direction during rush traffic and warn travelers of road conditions ahead. Design and construction of toll booths and ways of collecting tolls are part of highway engineering as well.

Railway Engineering. With the advent of high speed railway, light-rail systems, and magnetic levitation systems, railway engineering gained renewed interest in civil engineering. Railway transportation remains a cost-effective way of transporting large quantities of goods on land. Railway engineering focuses on the planning, design, construction, operation, and maintenance of railways. Advances in electronic signal design and communication technology provide new tools in the control of railway traffic for efficiency and safety.

Port and Harbor Engineering. Even under the most favorable natural conditions, a port requires additional engineering to make sure ships can safely navigate through and dock, and cargoes can be efficiently unloaded and uploaded for shipping elsewhere. Some harbors require routine dredging to maintain the navigation channel. Some harbors need breakwaters to tame the ocean waves. These are the scope of port and harbor engineering.

Airport Engineering. The construction of a new airport requires extensive planning, including the study on demand, environmental impact, cost analysis, and investment returns. Since an airport is part of an air transport system, the impact of a new airport must consider the regional air traffic demand. Airport site selection requires extensive study of regional topography, including local constructed structures, prevailing winds, and, for airplane safety, movements of birds. The impact on nearby neighborhoods includes the new land traffic generated by travelers and the inevitable noise generated along air traffic routes. The engineering of airport infrastructure such as runways, terminals, and signals falls in the domain of other civil engineering specialties.

Traffic Engineering. Traffic engineering sometimes is considered as synonymous to transportation engineering but it is usually defined as the narrower field of management of traffic flow. From huge metropolises to small towns, surface traffic must be controlled and modulated for safety and speed. Traffic engineers use projected and monitored traffic patterns and volume to design automated or centrally controlled street signals to modulate traffic. Tools used for traffic control include weight sensors for triggering of left-turn signals and ramp-entry signals for freeway entry during rush hours.

Intelligent Transportation Systems. New and emerging electronic and computer technologies make it possible to efficiently monitor, evaluate, and improve the performance of transportation systems. An example of the applications to new vehicle engineering is the possibility of high-speed automated highway travel by automobiles in groups. Another example is the centrally controlled traffic monitoring and management systems used in large cities. Fully automated automobiles without drivers are in development and testing.

Transportation engineering is a specialty whose content is changing with emerging technologies. The operational aspect of transportation engineering is heavily influenced by the advances in new technologies.

1.7 Construction Engineering

Transforming design details on paper or a computer file into physical reality is the task for construction engineers and managers. The successful completion of a construction project requires the integration of several areas: human resources management; financial resources and cost management; construction processes; schedule design and control; construction machinery; electric and mechanical facilities; legal, health, and safety issues; and risk management. Construction firms may specialize in one or more types of structures: buildings, bridges, dams, highways, airports, and ports and harbors. In the following some of the engineering and management aspects of construction engineering are described.

Construction Processes. Depending on the types of structures to be constructed and the materials to be used, each project has a unique process to follow to erect the structure step by step. The execution of a physical construction process often requires the knowledge of geotechnical engineering, structural engineering, construction materials, and site surveying. For example the construction of a multi-story building starts with the placement of foundations, which may consist of multiple steel or concrete piles. The story-by-story erection process depends on whether the building is of concrete or steel construction. These processes follow well-developed practices deeply rooted in accumulated experience of construction engineers. Intertwined with the construction process is construction scheduling, which lays out in detail the daily activities to be performed. Creating a construction schedule must consider the critical phases that determine the time length of the project.

Electric and Mechanical Facilities. In most construction projects electric and mechanical facilities are to be installed. Basic knowledge of common electrical and mechanical facilities is required for the installation of these facilities and their integration into the main structure.

Construction Machinery. From conveyer belts and bulldozers to scrapers, excavators, loaders, graders, compactors, cranes, and pipe-layers, many different machines are used in construction. Knowledge of these machines' capabilities is required in planning the types and quantity needed for a construction project.

Financial and Cost Management. From the bidding for a project to the actual execution, financial management is at the center of concern of construction management. Bidding is the critical process by which potential contractors compete to earn the contract from the owner of the project. Cost estimating is done at the beginning of a potential project and updated throughout the project. During the project period, cash flow management is needed to keep the project going. Successful contractors often have sufficient cash reserve or credit to ride through tough periods of low income cash flow and high outward cash payments.

Contracts and Specifications. A contract is a legal document that specifies the responsibilities of both the contractor who delivers the service and the owner who receives the service. Specifications are also legal documents that the contractor must follow throughout the project. Specifications are often based on well-developed construction practices but sometimes may include special requirements added by the owner. These legal documents are developed, negotiated, and decided upon between the contractor and the owner.

Health and Safety Issues. The health and safety of not only construction workers but also neighboring residents or passersby is regulated by the government. The Occupational Safety and Health Administration (OSHA) of the Department of Labor enforces regulations and laws pertaining to construction. Knowledge of these regulations and the strict adherence to the regulations are the responsibilities of the construction engineers or managers.

Legal Issues and Risk Management. Examples of potential liabilities of a construction project include negative cash flow, missing construction time milestones, mistakes in the constructed configurations or the strength of materials used, and accidents resulting in human injury or death. The prevention of any of the above and the timely management of the damage once any of them has occurred are the realm of risk management. Legal and ethical guidelines are to be followed at all times.

1.8 Geomatics (Surveying Engineering)

Geomatics is the new name for an expanded technical area of what used to be called surveying or surveying engineering. Surveying engineering is the technical specialty that applies the science of measurement to the assembling of spatial data on land and sea and any natural or constructed objects thereof. Its applications often involve legally required documentation related to the transaction of property, the location of routes or points needed in construction, and the collecting of global data for resources analysis and utilization. Some of the technical areas in surveying engineering are described herein.

Plane Surveying. The earth is a near circular sphere with a curved surface. When the area of interest on the earth's surface is small enough such that the curvature throughout the area can be neglected in measuring and locating any point in the area without causing any significant amount of error, the earth surface is treated as if it is a plane. With this simplification, the measuring and locating of points or routes are mathematically much simpler. Plane surveying deals with the techniques and skills in carrying out such tasks within the limit of the simplification. In plane surveying, optical instruments are used in conjunction with basic mathematics to accurately locate points and lines, to calculate areas and volumes, and to map existing surface features. Since no scientific measurements can be made without error because of limited resolution of instruments or even human mistakes, techniques are developed to minimize measurement errors.

Route Location. For highway or railway construction, the roadway configuration contains straight lines and curves in the horizontal and vertical planes necessitated by the change of natural topography and the need to minimize the cost of changing the natural topography. These lines and curves are designed and documented on paper or in computer files. Route location is the technique to transform points on these lines and curves on file to points on location with reference to some existing points on the earth's surface.

Land Surveying. Land surveying pertains to the measuring and documentation of property lines, streets and alleys, subdivisions and lots within a city or a village. The map of the area is called a plat, which forms the legal document in ownership transactions.

Geodetic Surveying. In contrast to plane surveying, geodetic surveying includes the earth's surface curvature in its calculations and mapping. More advanced mathematical tools such as spherical geometry and curvilinear coordinate systems are utilized for the computation of measure data and locating of points and lines. Surveying instruments may include the use of aerial photography, satellite imaging, and the global positioning system (GPS). Geodetic survey is necessary in the construction of long-span bridges and other structures covering a large stretch of area (a long tunnel, for example).

Aerial Photography and Satellite Imaging. With the advances in optical and electronics technologies resulting in improved measurement resolution and accuracy, images produced from airplane- or satellite-based instruments can be used in the mapping of ground features for various applications. Advances in digital photography and computer automation make the mapping efficient and much less time consuming. Applications of such images and maps range from real estate information generation and agricultural resources evaluation to military and intelligence information evaluations.

Geographical Information System. Surveying engineering provides the basis for the geographical information system (GIS) of a state, city, town, or smaller unit. Useful information such as basic population data, infrastructure, average income of population, demographic distribution, educational and recreational resources, crime rate, etc., is compiled in a single database for easy retrieving and application. GIS is also an example of the increasing application of information technology to surveying engineering.

It should be mentioned that surveying nowadays is often considered a technical area outside of civil engineering or engineering in general. After all, the organization in charge of testing for professional licensing in engineering and surveying, National Council of Examiners for Engineering and Surveying (NCEES), has separate exams for engineers and surveyors. Some civil engineering programs do not require any surveying courses.

1.9 Urban Planning

Urban planning integrates land use planning, infrastructure planning, and public policy for new developments or renewal of urbanized communities. Successful urban planning requires the application of the knowledge developed in social, economic, architectural, and engineering studies. Educational programs for future urban planners can be found in Bachelor of Arts degree programs in arts, architecture, and public policy colleges. Bachelor of Science degree programs are also available in some universities. The application of civil engineering to urban planning emphasizes the physical aspects of urban planning: street patterns, park and recreational areas, industrial and residential areas, transportation systems such as freeway access, airport access, public works and utilities, infrastructure management, etc.

1.10 Related Disciplines

Some of the disciplines that interact or overlap with civil engineering are described here.

Applied Mechanics. Mechanics is one of the early and basic areas in physics. It studies the nature and effects of force. Applied or engineering mechanics emphasizes the application aspects of the theory of mechanics. Civil engineering structures are subjected to the effects of gravitational force, wind, and earthquakes, and effects of temperature change. Various applied mechanics areas ranging from the fundamental statics, dynamics, fluid mechanics, and mechanics of materials to more advanced areas such as thermal stress and wave propagation have direct applications in structural engineering, geotechnical engineering, water resources engineering, environmental engineering, and construction engineering.

Architectural Engineering. Architectural engineering specializes in the aesthetics and structural design of buildings. The structural design aspect of architectural engineering overlaps with structural engineering. The aesthetical design aspect of architectural engineering applies the knowledge developed in architecture studies. Architectural engineers also study and apply knowledge in electrical and mechanical systems to building designs.

Agricultural Engineering. Agricultural engineering traditionally entails two technical areas: irrigation engineering and mechanization. Irrigation engineering is part of hydraulic engineering while the mechanization of agricultural engineering is part of mechanical engineering. Since the advent of DNA engineering, the use of basic molecular biology techniques to change the properties of a specific crop becomes an important addition to agricultural engineering and a new and broader field of bio-engineering emerges.

Aerospace Engineering. Aerospace Engineering entails aeronautical engineering and astronautical engineering, which develops vehicles that fly through the earth's atmosphere and beyond, respectively. The structural analysis and design of the flying vehicles, airplanes, and spacecraft, is most similar to that of civil structural engineering. The difference is in the nature of forces acting on the structures.

Biomedical Engineering. Biomedical engineering specializes in the applications of engineering to the medical field, including medical imaging, surgical devices, and implant devices. The structural analysis and design of medical devices and implants overlaps with civil structural engineering in the basic tools used and differs in the nature of forces acting on the devices.

Naval Architecture. As briefly described before, naval architecture specialized in the design of ships. The analysis and design of ship structures is similar to that of civil structures and uses similar computational tools. The difference is in the nature of forces acting on the structures.

1.11 Civil Engineering Processes

No matter what kind of civil engineering project is involved, all civil engineering projects go through four main phases: planning, design, construction, and maintenance/operation. These phases sometimes are intertwined and overlapped.

Planning. As any civil engineering projects, private or public, involve public interest and major funding, the planning phase could sometimes run into many years. The very first stage of the planning phase is a feasibility study, which usually includes not only a financial study but also a study of legal issues. Virtually all major civil engineering projects must go through environmental impact studies and public hearings. For these studies and hearings, at least a preliminary design must be prepared and presented.

Design. At least two stages are involved in the design phase: preliminary design and final design. Sometimes it is necessary to have an additional intermediate design stage. The preliminary design is to create an outline of the concept, scope, structure, materials to be used, method of construction, and cost and timeline estimate of the project. The preliminary design can be part of the planning phase. The final design includes all detailed designs of every structure involved in the project and every associated facility such as electric and mechanical facilities.

Construction. The actual construction phase includes the physical erection of all the structures and in the meantime the observation of all applicable safety and environmental regulations during the construction phase.

Maintenance. When the construction phase ends and the owner takes over the project, the maintenance/ operation phase begins. The owner of the project usually takes over all responsibilities, but the contractor is usually bound by a warranty agreement. During the warranty period interaction between the owner and the contractor could be very frequent and intense. Beyond the warranty period, the physical structures require constant maintenance. A well-known example is the constant painting of the cables of the Golden Gate Bridge in San Francisco.

1.12 Contemporary Issues: Civil Infrastructure Renewal

Infrastructure is the underlining fabric that makes a society function properly. Civil infrastructure refers to the underlining structures or facilities that are the product of civil engineering. These civil infrastructures can be grouped into the following categories, according to ASCE (The American Society of Civil Engineers):

Transportation: Aviation, Roads, Bridges, Transit, Inland Waterways.
Environment: Drinking Water, Wastewater, Solid Waste, Hazardous Waste.
Energy: Power Plants, Electric Grids.
Education: School Buildings.
Public Safety and Recreation: Dams, Levees, Public Parks and Recreation

As the United States is a developed country, many of the above civil infrastructures have been in service for 50 years or more. Most physical structures require maintenance to avoid breaking down or outright failure. The American Society of Civil Engineers evaluates the civil infrastructure status every four years since 2001 and publishes an American Infrastructure Report Card. The 2013 Report Card, as in previous years, assigns a letter grade (from A to F) for each of the infrastructure types as shown below:

ASCE 2013 Grades (with the 2009 Grades in Parentheses)

America's Infrastructure cumulative GPA: D_+ (D)

ASCE also estimates the investment need in civil infrastructure is $3 trillion by 2020.

Renewal of America's civil infrastructure obviously will cost a large sum of money. ASCE's 2005 estimate for the five-year investment need was $1.6 trillion. By 2009 it became $2.2 trillion and by 2013 it is $3 trillion. It becomes obvious: the longer we wait because of cost and funding concerns, the more will it cost later.

Aviation	D (D)
Bridges	C_+ (C)
Dams	D (D)
Drinking Water	D (D_-)
Energy	D_+ (D_+)
Hazardous Waste	D (D)
Inland Waterways	D (D_-)
Levees	D (D_-)
Ports (New Category)	C
Public Parks and Recreation	C (C_-)
Rail	C (C_+)
Roads	D (D)
Schools	D (D)
Solid Waste	C_+ (B_-)
Transit	D (D)
Wastewater	D (D_-)

Civil infrastructure renewal also needs different technology than just new construction. Replacing or repair leaky wastewater pipes may be accomplished with micro-tunneling methods that require no lengthy open trenching. Finding leakage in drinking water and wastewater pipes may utilize new optical or electromagnetic wave sensors. Other monitoring technologies for civil infrastructures are being developed.

1.13 Contemporary Issues: Sustainable Engineering

Sustainability is a concept that gradually gains recognition and is being put into practice in many sectors of the global economy. The 1983 Brundtland Commission (World Commission on the Environment and Development, WCED) of the United Nations released its report *Our Common Future* in 1987, defining sustainable development as: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." To be practical sustainable development must meet the needs of **social, environmental, and economic** concerns. A **bearable development** is one satisfies environmental and social concerns. A **viable development** is one satisfies environmental and economic concerns. An **equitable development** is one satisfies social and economic concerns. A **sustainable development** is one satisfies all three concerns. This is called the "triple bottom line," and is best illustrated by the following diagram.

Not surprisingly civil engineering projects are at the center of the sustainable development concept and practice. The key concepts are endurance, energy efficiency, and reduction of waste. Of the major sustainable development practice categories, several are civil engineering related:

Water Conservation and Water Quality. Once water rationing, even just for lawn use, became reality in southern California in 2009, water conservation was no longer a theory embraced only by environmentalists. Many practices for individuals and homeowners, such as limiting showers to five minutes and using more efficient toilets, can reap significant savings in water consumption. For civil engineers, using moisture sensors to regulate watering lawns is an excellent technical solution to water conservation. Another major technical challenge in water conservation is the reduction of leakage from water-supplying pipes. These leaks occur from both water mains and from the link between water mains and homes. The latter is the responsibility of homeowners. Unless cost-effective new technology is developed, large-scale improvement is unlikely because of the financial burden on homeowners. Drinking water quality is often taken for granted in America, but a 2009 report claiming 40% of people were exposed to dirty drinking water raised alarms.

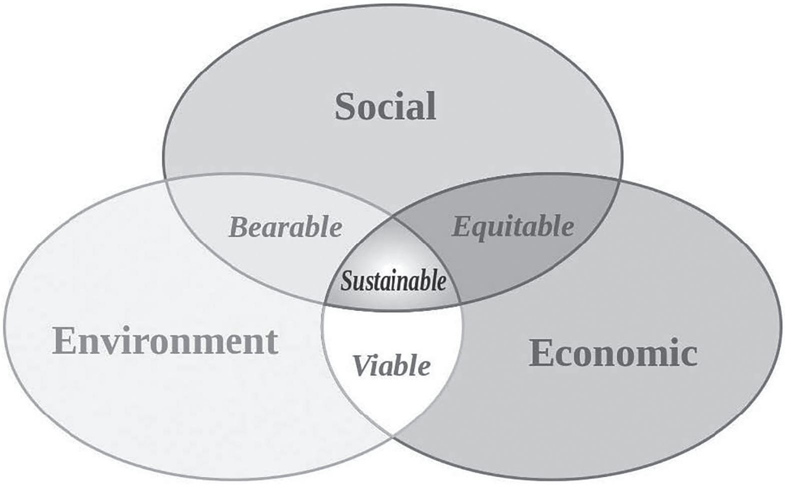


Figure 1.1 A sustainable development satisfies social, environmental, and economic concerns.

Wastewater Collection and Treatment. Wastewater collecting pipes are prone to chemical and biological corrosion especially in warm weather. Leakage from wastewater pipes creates environmental hazards that are difficult to mitigate. Thus cost-effective corrosion-resistant pipes that are more enduring are needed. Wastewater treatment uses large amount of chemicals and results in large amounts of sludge. Recycling sludge cake as fertilizers has been in practice for years. More energy-efficient and cost-effective treatment methods are much in need.

Green-Building Technology. Buildings, large or small, commercial or residential, are major sources of energy consumption. Building owners are increasingly aware of the ever-increasing cost for building maintenance and operations. They are taking steps to curb energy consumption and increase sustainability. The owner of the Empire State Building, opened in 1931, announced in April, 2009 that it was spending $20 million to enhance environmental efficiency by cutting energy use by 38 percent. The owner of one of the tallest buildings in the world, TAIPEI 101, opened in 2004, announced in November 2009 that $1.9 million was to be spent over a 20-month period in a transformational effort to reduce energy consumption by 10%, and water usage by 10%. The energy cost saved was estimated to be $600,000 a year. TAIPEI 101 planned to apply for the gold certificate from the **LEED** certification (see below).

The LEED certification is a consensus process that standardizes the recognition of energy-efficient buildings. LEED stands for Leadership in Energy and Environmental Design; it is pioneered by the **U.S. Green Building Council** (**USGBC**), which was founded in 1993 and is a non-profit trade organization promoting sustainability in how buildings are designed, built, and operated.

The LEED certificate system offers four levels of recognition: Certified, Silver, Gold, Platinum, with a 100-point scoring system. Factors considered for new constructions includesustainable sites (construction pollution, alternative transportation, site development, storm water, heat effect, light pollution), water efficiency (water-efficient landscaping, innovative wastewater technologies, water-use reduction), energy and atmosphere (optimize energy performance, on-site renewable energy, refrigerant management, green power), materials and resources (storage and collection of recyclables, building reuse, construction waste management, material reuse, regional materials, rapidly renewable materials, certified wood), indoor environmental quality (tobacco smoke control, ventilation, low-emitting materials, thermal comfort, daylight, views), innovative design, and regional priority. Factors for existing buildings are similar but take into account that only certain factors can be changed once a building is already built.

Solid Waste Management. Commonly known as trashes and garbage, industrial, commercial, and domestic solid wastes are becoming increasingly difficult to manage, not only because of ever-increasing volume but also because of ever-increasing variety and new waste types. The best strategy in waste management is to reduce waste. For example in late 2009, Japan promoted the use of reusable cups for drinks. Recycling is the next best approach. Civil engineers design and build solid waste distribution centers, where incoming garbage is sorted and redistributed. The last approach is to safely transport and deposit garbage in well-designed and -constructed landfills. As landfill materials often generate gas, which can be used to generate power, use of micro-turbines at landfill sites to generate power for onsite power needs is gaining momentum. Civil engineers design and construct safe and durable landfill sites.

Hazardous Waste and Nuclear Waste Management. Hazardous waste from industrial and domestic sources as common as battery cells and computer monitors cannot be simply dumped into landfill sites. Materials contained therein, most commonly heavy metals, are regulated materials and must be processed and recovered safely. Civil engineers design and construct treatment plants. For nuclear waste from nuclear power plants, defense establishment, and medical usage, the only solution now is to safely stow it away from population centers. Because of the long life of radiation materials, storage sites are to be selected for long-term geological stability and safe distance from underground water sources. The selection, design, and construction of such sites typically involve geotechnical engineers and geologists.

Other sustainable development issues such as renewable energy, greenhouse gas control, and air pollution control also require civil engineers in the design and construction of various plants and energy farms.

1.14 Contemporary Issues: The IT Revolution

The Information Technology revolution since the 1990s, with the advent of personal computer in the early 1980s and the internet in the late 1980s, touches every aspect of modern living today. It is a fact, albeit less well known, that the oldest engineering field, civil engineering, has been a heavy user and promoter of high-speed computing. As described in Chapter 5, by the 1960s the stage was set for solving structural design problems using digital computers. The demand for large computer memory for structural problems that contained thousands of unknowns hampered the progress. In the meantime complex interactive graphical display software was developed by civil engineers, architects, medical researchers, and others for applications in their fields. The advent of personal computers, laptops, and tablets and ever-decreasing cost of computer memory finally made it easy for civil engineering–related complex computing. Today, not only structural engineers perform high speed computing on a daily basis, but civil engineers in virtually every other technical area of civil engineering also use computers professionally. New software applications, or new versions of existing applications, are introduced every year. IT literacy becomes a pre-requisite for civil engineers.

The impact on civil engineering from the IT revolution goes beyond the direct use of computers. Civil engineers are heavy users of instruments, from surveying equipment to sensing equipment for earthquake motions and flow monitoring. The surveying equipment today is much easier to use and with much less error than that of a generation ago because of digital computing, not to mention the well-known applications of the Global Positioning System (GPS). In general a sensor picks up a signal, the signal is "conditioned" to filter out "noises" and then it is recorded. The IT revolution greatly simplifies the conditioning and recording because digital computers are so fast and inexpensive and the signal processing can be accomplished by miniature micro-processors imbedded in the instrument packages. Furthermore, the use of wireless digital signal transmission allows distant monitoring. This potential is there to monitor the "health" of structures to avoid any impending danger of failure.

1.15 Attributes of a Civil Engineer

In order to carry out the engineering work outlined above, a civil engineer is likely to possess certain attributes, in addition to the abilities and skills acquired through the educational process of a Bachelor of Science in Civil Engineering (BSCE) degree program described in Chapter 3 and Chapter 4. These attributes are listed here.

Analytical and Organized. The application of the vast amount of knowledge in civil engineering to solving real-life problems requires an analytical approach and an organized mind. Civil engineers are generally very organized in their daily lives as well.

Bold in Conception and Careful in Details. Seeking solutions to real-life problems requires a bold conceptual design. Every new project is different and requires the exploration of different solution outlines. In carrying out the details of the design, the civil engineer must be careful in every step to ensure safety and accuracy.

Creative but Conservative. Finding new and economical solutions to civil engineering problems requires a creative mind that thinks beyond the accepted and regular practices, but the reliability and safety of the created product requires a conservative assessment in every aspect, because for every civil engineering product, failure is not an option.

Dependable and Trustworthy. Civil engineers depend on each other in teamwork. Everyone is entrusted to produce reliable and accurate work. Civil engineering projects are all time-sensitive. On-time delivery is highly valued and even financially rewarded as may be written in a contract.

Ethical and Honest. The impact of a civil engineering project is usually wide ranged and concerns the public interest because it entails the creation of a new built environment, large or small. A civil engineer must be ethical in practice and honest in character in order to earn the public trust. In Chapter 6, engineering ethics issues are described.

Forthright but Personable. Civil engineers need to communicate with others effectively. Very rarely does a civil engineer work alone. The teamwork necessitated by the nature of the engineering work requires a civil engineer to possess excellent interpersonal skills to be able to fit in and work well with others.

Passionate About Work. The authors never met a civil engineer who is not passionate and proud of what they do. Because civil engineer products are everywhere and visible, it is possible to see a civil engineer pointing to a building, a bridge, a river, or other structures and proudly announcing his/her contribution.

1.16 What It Takes

To practice in any one or a combination of these civil engineering technical areas, one must have (a) the fundamental education, institutionalized as a Bachelor of Science in Civil Engineering (BSCE) degree, (b) passed the Fundamentals of Engineering (FE) examination, (c) the internship experience under the supervision of a licensed professional engineer for four years after the BSCE degree, and (d) the license to practice civil engineering, regulated by each state through an examination, which can be taken only after (b) and (c). Details of the requirements for (c) and (d) are described in Chapter 7. But the very first step for anyone admitted to a BSCE degree program is to complete all requirements of the degree program and get the degree. That requires the right commitment, attitude, and learning skills. Chapter 2 is devoted to exactly the kind of knowledge and skills that are necessary for obtaining a BSCE degree in a reasonably short period of time.

Acknowledgments

The authors are grateful for the contributions/suggestions made by Professors Clark Liu (University of Hawaii), Eugene Tseng (University of California, Los Angeles), and Yue-hwa Yu (National Taiwan University) to part of the content of this chapter.

CHAPTER 2

Keys to Student Success

2.1 Overview

You have successfully graduated from high school and have been admitted to a college program to pursue a Bachelor of Science degree in Civil Engineering (BSCE). To successfully complete such a program requires your commitment, a positive attitude, and new learning skills that are different from what you were required to have to be successful in high school.

A BSCE degree program is defined by its curriculum, which will be described in Chapter 3. For the time being, it suffices to say that doing well in every course you are taking is a prerequisite to the eventual success in earning this degree. Your curriculum is different from your high school curriculum in one major aspect: it is full of prerequisites, courses that must be passed before taking on courses following them. These prerequisites are not set up for the sake of putting up roadblocks; your mastering their contents is actually necessary for you to succeed in courses downstream. Thus failure is really not an option. Actually you do want to succeed in any college courses, prerequisites or not.

It is logical then to set your immediate goal: excel in the courses you are taking. The suggestions contained in this chapter are designed to help you achieve your immediate goal as well as overall success in your college career.

2.2 Commitment Is Key

One of the authors of this book once served in a university with a predominance of engineering students. The university conducted a study on factors affecting freshman retention, i.e., the percentage of students returning after one year. At the beginning of the freshman year, students were asked to fill in a survey on the degree of commitment to the program they were in. While the factor of commitment is subjectively determined by students, the university also included other more objectively measurable factors such as math preparation, science preparation, family financial background, etc. After one year, the retention of each student was correlated with all factors included in the study. It turned out the degree of commitment correlated the most with freshman retention. It was a more reliable predictor for retention than math preparedness, which was considered the most important to engineering student retention according to common wisdom.

What this study revealed was the power of personal will. If one is determined to succeed, then there is no obstacle one cannot overcome. To overcome obstacles takes commitment as well as learning skills. With commitment there comes the will to learn skills that help overcome any obstacle. These skills are covered below. For most students, however, to succeed does not always mean to overcome obstacles. Rather it means not to take any courses lightly.

2.3 Taking Every Course Seriously

When one of the authors was a freshman he witnessed an unbelievable event: one of his high school classmates was flunked out at the end of the freshman year. The classmate was an excellent student in high school. At the time the university had a rule: anyone who failed two-thirds of the courses taken was automatically dismissed. He virtually failed every course he had taken, not just math and science courses but also general education courses. What had happened? Well he was observed to cruise around campus in his new scooter with a new friend every week riding on the back. He hardly studied; was too busy enjoying the newfound freedom as a college freshman.

What one learns from this story is one can fail any course in college. There is no "easy" course in college. A common fallacy for civil engineering students is to believe only math, sciences, and engineering courses are "hard" and everything else is "easy." The authors had studied freshman retention by examining the records student by student and found there are no easy courses no one ever fails. Students who failed freshman courses typically failed in one or more math and sciences courses AND one or more general education courses.

One should approach every course with the understanding that one can fail and should take it seriously. But how? First of all, you should not "fight" the course. We often heard students complain: oh, the course was boring, I am not interested. Well the course is put on your curriculum for a reason. Please do not second-guess the wisdom of your faculty who designed your curriculum every time you feel you are not interested in the subject matter of a course. Practically speaking, you just need to excel in the course, interested or not, and the first step in that direction is to know the requirements of the course.

2.4 Knowing the Course Requirements

Instructors are required to make it clear to students what the course requirements are: textbook, homework (if any), quizzes/tests/exams, term project (if any). These are included in the course syllabus, which also includes a course outline. The course outline gives you a general idea on the scope of the topics covered.

If a textbook is required, that means the book needs to be read and studied frequently enough that one should own it. For math, sciences, and engineering courses, owning the right edition is important because often homework problems are assigned from the book and different editions usually have different homework problems. It is advisable to consult the instructor before buying an older edition. We found students doing the wrong homework problems because they were using the older edition.

You need to have access to the book as early as possible. Even before the first class meeting you can read the preface of the book and go over the table of contents to get a general idea of the scope and subjects covered in the book.

Knowing the test frequency helps you manage your time more effectively for before-test review when all the courses are considered. Time management is of paramount importance and is covered at the end of this chapter.

2.5 Attending Classes Religiously

Class meetings are important for the following reasons:

1. They are the only venue from which students can learn from instructors and sometimes interact with them as well for an extended time and on a regular basis.
2. They are the only venue in which students can learn by listening, watching, thinking, and writing during the meeting time.
3. They are the only venue students can listen to and watch fellow students when they ask questions, thereby know the key matters of concern to others.
4. They are the only venue where additional insights on the lecture subject can be learned from the instructor and other students (if active interaction is prevalent).
5. They are the only venue in which stimuli from lecture and discussions can lead to in-depth understanding of the subject.

To reap the above benefits, you need be fully engaged in terms of concentration and participation during class meetings. One can start by attending classes on time and be there a few minutes before a class starts and be seated within good hearing range and good sight of the lecturer's moving space. Many instructors give an overview of the whole lecture at the very beginning. Missing the first few minutes of the lecture is to miss the direction of the whole lecture.

Missing classes seems to be a favorite expression of the newfound freedom of college students. Stories are abundant from successful people who took pride in skipping classes for other favorite activities. A famous example, perhaps, comes from the 42nd president Bill Clinton. When he was studying at Georgetown University, he routinely skipped classes for political activities. When exam times came he would cram on notes from friends and, unbelievably, always would pass. Well, he was not a civil engineering student. The subjects of math, sciences, and engineering are difficult, if not impossible, to digest and master in a short period of time (cramming before exams simply does not work). And, most of us are not endowed with the special ability of Clinton. Consider this: during one of his state of the union addresses, the teleprompter was feeding him an old version of his address that he had already completely revised. He went on to deliver his new address from memory for about ten minutes before his staff discovered the mistake and fed the right version into the teleprompter. Extraordinary people may be entitled to exceptions. You would benefit, however, by not assuming you are an extraordinary civil engineering student but by trying to earn the grades with proven practices.

Another reason we hear all the time from students skipping some classes: I don't like the instructor. Well, you don't have to like the instructor to excel in the course. You don't want to fail because you don't like the instructor either. Missing classes is one of the major reasons students fail a course.

There is one more practical reason that you should not miss any classes. The time needed to catch up with and make up the subject material of a missed class meeting is much more than the time saved by missing the meeting. Furthermore, most students skip a meeting to do something else, not to study the subject material on his/her own during the meeting time. That means additional time is needed to study the subject material and that may very well lead to a downward cycle of digging deeper into a hole of needing even more time to study.

2.6 Preparing for Class Meetings

Besides attending classes religiously and on time, another good practice is to read the textbook and review notes from the last meeting before the class. We regularly ask students how that practice benefits them. These are the benefits they told us:

1. The lecture is much easier to follow, because they already have an idea on what to expect, although only vaguely.
2. It is easier to interact with the instructor by asking questions that have emerged from pre-class reading.
3. It is much easier to remember the subject material because the lecture reinforces the pre-class reading.
4. It takes only a fraction of the time of the meeting to prepare for the meeting.

They also told us that they often used time spent on buses or between classes to read through textbooks quickly. They picked up things that were not fully understood with the quick read and paid special attention when the topics were covered during the class meeting, and if necessary, asked questions.

2.7 Making the Most of Class Meetings

Students learn in different ways and instructors lecture in different ways. No instructor can lecture the way every student appreciates. Most instructors try to lecture the way most students in the class appreciate. That means sometimes a student does not appreciate the way an instructor lectures and may choose to skip the class. That is a mistake because the person who suffers the most from the consequences is the student already described.

From your perspective, it can only be a lucky coincidence that all your instructors lecture in the way you appreciate. You will benefit by adjusting to the way the lecture is delivered and not to be judgmental about the instructor. No matter how the lecture is conducted, there are skills you can use to gain the most from the class meetings:

1. Concentrate on what is being presented, not what one expects to be presented. In other words, make oneself an empty vessel so that one can absorb whatever is being poured into it.
2. Concentrate on the concepts behind any new terminology and grasp and remember the definition of each new term.
3. Concentrate on the new tools being introduced and the different ways the tools are applied to solving problems.
4. Take notes on what is in addition to the textbook materials. This is assuming you have previewed the subject being covered in the textbook.
5. Practice interactive learning by asking questions and answering any questions the instructor asks.

Taking notes is a good practice but notes must be in clear handwriting so that they are easy to review. Using laptops/tablets for note-taking is excellent especially if you can also draw figures with them.

2.8 Practicing Post-Class Review

Learning is a process of continuing to digest and absorb new knowledge and skills. Reviewing the textbook and notes after a class serves to solidify what you have learned in class and discover what is still not clear to you despite the class meeting.

When reviewing textbooks, especially for math, sciences, and engineering courses, one pays special attention not only to pertinent mathematical formulas and equations but also to the **example problems**, even when they are already covered in the class.

Usually there are multiple example problems. One should go over the solution process quickly; follow the analytical flow and logic of the solution and appreciate the path from the given known factors to the solution of the unknown factors. One should also analyze the difference in consecutive example problems to see the change of formulation of the problem in terms of the lineup of known factors versus the unknown factors. This is the way to thoroughly understand a subject. Only through understanding will you remember the solution methods and their natural logic flow.

When you have reviewed the textbooks and notes, you are ready to tackle the homework problems.

2.9 Doing Homework Assignments Diligently

Most instructors of math and science and civil engineering courses assign homework problems. Doing homework is a critical part of learning. In attending classroom lectures and from reading textbooks, you learn the concept of a subject and the tools in problem solving. The example problems in the textbook demonstrate the use of tools for problem solving. Students are tempted to feel that they have already learned everything there is to learn about the subject. The key question, however, is whether or not they can solve problems using the concept and tools just learned.

Many years ago a student got an F in Statics, a required course in civil engineering, from one of the authors. The student came to complain and said "I feel I understand all the subjects and can teach the course, but you gave me an F." Well, he failed to mention that he skipped all the homework assignments and was thus without the benefit of testing his problem-solving skills. An ability not tested is an ability not acquired. Homework also plays the role of reinforcing the memory of what has just been learned. You not only understand but now you also remember.

There are three **levels of difficulty** in homework problems. The easiest are those problems similar or even identical to the example problems. Doing those problems serves the purpose of an exercise or a drill. The second level of difficulty is for those problems that are variations of example problems such as changing the role of variables from unknown to known or vice versa. The highest level of difficulty is for problems involving synthesis of two or more concepts or using two or more tools. Those problems often appear as out of the blue and require careful analysis of what is given and what is to be found.

It is important to develop the ability to ascertain the correctness of one's answer, not by checking to see if it is identical to what is given at the end of the book, but by verifying the steps taken in arriving at the answer. That involves checking the solution method itself and the numerical computation. The ability to **double check** one's own work is at least as important as the ability to do the problem. After all in real-life engineering problems, there won't be answers at the end of a book and you are the only one who can ascertain the correctness of your results.

Time spent on doing homework is time well spent in the learning process and should be budgeted generously in the time-management section later in the chapter.

For classes in which homework assignments are graded and will be part of the overall term grade, one question often comes up: can a student participate in **group learning** by doing homework together in a group? The best policy is to ask for guidance from the instructor. If the instructor explicitly forbids doing homework together, then clearly students should follow the guidance. Even if the instructor allows it, students should understand the limit of group learning and the purpose of doing homework as delineated above. The proper way to do homework together is to discuss the sticking points of the homework problems and how you overcome these sticking points. You should still work out the solution on your own and earn the grade on your own. After all one the purpose of homework is to test **your** ability to solve problems.

For essay-type homework problems, you would benefit to learn to present the solution in a logical and clean manner whether they are graded or not. The ability to **present solutions well** can be learned by practicing it constantly. There are two ways of presenting a solution well: Do it first on scrap paper then copy a clean version or to think through in the mind and organize it first and write down a clean version. The former is often necessary for complicated problems involving several steps and the latter is doable for simpler problems. It is a good practice to always try to mentally work out a clear path to a solution before putting anything down on the answer sheet.

This brings up the obvious question: what is the **best strategy for problem solving**? In the context of solving homework problems and taking tests, we suggest the following steps:

1. Read the problem statement carefully to find out what you are asked to determine.
2. Find out what the variables/factors are that are given and known.
3. Figure out the path connecting the known to the unknown.
4. Formulate the solution in terms of mathematical expressions.
5. Carry out the mathematical manipulations toward the solution for the unknown.
6. Review the formulation and then the mathematics.
7. If possible, check the answer to see if it fits the given factors.

Sometimes one simply gets stuck in the process and cannot move forward toward a solution. We always advise, in case of homework problems, to **seek help** if you have already spent more than 20 to 30 minutes on a problem and cannot move forward despite all efforts. There are several possibilities that your university offers:

1. Teaching assistants: Many universities hire graduate students as teaching assistants who should be able to assist undergraduate students in solving homework problems.
2. Learning/tutoring center: Many universities or colleges organize their learning centers to assist students in problem solving. Tutors are graduate students or upper-class undergraduate students who have already taken most of the courses for which some students seek help.

3. Instructors: Most universities have explicit policies on faculty office hours. Students should be able to go to the instructor during those posted office hours or make appointments outside of the office hours if the instructor encourages it.

When seeking help in solving homework problems, one should never expect a tutor or an instructor give a solution line by line. When helping students we always ask students to explain first what the sticking points are. We then ask leading questions and encourage students to think along step by step. When the sticking points are clarified and you are clear on the path to the solution, you can do the rest successfully on your own.

We now offer a relatively simple example problem, which the authors were taught in their elementary school days. We find it useful to illustrate the problem-solving process without anything other than arithmetic and simple reasoning.

Problem. Numerous rabbits and chickens are confined in a big cage. There are 50 heads and 140 legs. How many rabbits and how many chickens are in the cage? Solve this problem without using algebraic equations.

Solution. We shall go through all the steps outlined above one by one:

1. *Read the problem statement carefully to find out what you are asked to determine.*
   You are asked to find the number of rabbits and the number of chickens.
2. *Find out what are the variables/factors that are given and known.*
   You know the number of heads and legs, **50** and **140** respectively. **You also know** that each rabbit has **4** legs and each chicken has **2** legs.
3. *Figure out the path connecting the known to the unknown.*
   The **Key** is the difference in the number of legs of the two animals. If the cage contained only chickens (2 legs), there would be a total of only $50 \times 2 = 100$ legs. The 40 additional legs (140 – 100) are due to the 2 additional legs for each rabbit in the cage. Dividing the 40 by 2 gives the number of rabbits.
4. *Formulate the solution in terms of mathematical expressions.*

5. *Carry out the mathematical manipulations toward the solution for the unknown.*

   The difference in the number of legs between one rabbit and one chicken: 4–2 $= 2$

   If rabbits had two legs each, the number of legs would be $50 \times 2 = 100$

   The additional legs due to rabbits having 2 more legs: $140 - 100 = 40$

   The number of rabbits must be $40/2 = 20$

   The number of chickens must be $50 - 20 = 30$

6. *Review the formulation and then the mathematics.*

   The above computation is accurate.

7. If possible, check the answer to see if it fits the given factors.

   $20 + 30 =$ **50** Check!

   $20 \times 4 + 30 \times 2 =$ **140** Check!!

Now try to solve this problem focusing on the fact that a chicken has **2 fewer** legs instead of a rabbit has **two more** legs. This is one of the assignments at the end.

2.10 Creating a Course Portfolio

It is beneficial to have a course portfolio in the form of a three-ring binder so that course syllabus, notes, handouts, homework solutions, graded exams, and solutions can be organized by category and within each category in chronological order. The portfolio makes review easy, be it for exam preparation, for doing homework, or for preparation several terms later for the Fundamentals of Engineering exam described in the next chapter.

For each course there should be one course portfolio. We observed that many students like to have a large notebook for every course taken in the same term, but that is not a course portfolio. A portfolio is a much broader collection of important materials for a course, as just described. Learning to organize a portfolio is an important experience for a civil engineering student. An added benefit for having course portfolios is to show off your organizational skills and achievements in any particular course to your potential employers when the time comes for job interviews.

Many BSCE programs begin to ask students to create course portfolios for ABET review. ABET is the organization that reviews and accredits engineering and technology programs. ABET formerly stands for Accreditation Board for Engineering and Technology but now its formal name is simply ABET Inc. ABETrelated topics are covered in the next chapter.

2.11 Interacting with Instructors

It is not unusual that students do not know the name, the office location, the email address, or telephone number of instructors. Just ask yourself and you would agree. Most universities today encourage faculty–student interaction beyond classroom meetings. Most faculties encourage students to visit them if students have questions. From students' perspectives they do need to find out first if communication with the instructor is welcome and how best to reach them. Some instructors encourage email communications but discourage office visits. As long as interaction is encouraged, one should fully utilize this particular resource. Benefits to students include:

1. Instructors are most equipped to answer questions from students in homework and course content and may be willing to provide study guidance beyond simply solving problems.
2. Instructors may be able to provide career advisement in general.
3. Instructors may be able to provide internship and summer job recommendations or even job recommendations after graduation.

In seeking recommendations from instructors for jobs, scholarships, or awards, you are encouraged to choose those who are most likely to give credible, strongly positive recommendations. They must have direct knowledge of your academic or extracurricular activities or performances. Otherwise a recommendation letter they write will have no effect or even negative effects on your opportunities. One simple rule is to seek out instructors with whom you have excellent grades or working relationships, such as assisting in laboratory work or research work or even grading.

2.12 Studying with Classmates

It is not uncommon, especially among those who commute to campus, that students hardly know any classmates. For one thing, students go from class to class usually in a rush and hardly have time to talk to each other. For another, they may not have many classes in common. As a result students become loners as far as taking courses is concerned: they go to a class alone and study alone. If you are used to studying alone and still excel in course work, so be it.

Many educators today believe **group study** is beneficial to most students. The study group typically of three to five students becomes a network. They help each other if anyone missed a class for good reason or simply missed some key points during a class meeting. The sense of belonging to a group is by itself beneficial, according to educators. The group is a source of support and a place to learn interpersonal communication skills as well. A group for a course may be formed naturally among students who know each other. Or it is formed with a leader who organizes the group. Either way, the first step is to know each other in a class. Knowing someone's first name makes starting a conversation easy. Many instructors encourage students to know each other by asking students to introduce themselves during the first meetings.

The best place for group study is either a studying space designated by your program or in the group study rooms set aside by the university library.

2.13 Using the University Library

In the age of computers and internet, the library is often ignored by students. But many university libraries have caught up with the internet age and offer online searches and book ordering. Another important service to students is providing study space. In addition to the traditional individual studying space, such as tables and chairs or even individually reserved study carrels, many libraries provide group study rooms that are enclosed and relatively sound-proof with large glass doors or windows. These rooms are perfect for small group discussions.

Other resources of a university library include new media materials such as DVDs and CDs. Interlibrary services allow students to order books or journal articles from almost any other library.

So far we have suggested several things for you to do, but we know many students have complained to us: we don't have time to do all these things. But you do, if you know how to manage your time.

2.14 Time Management: Exam Preparation

Common wisdom dictates that one shall never walk into an exam unprepared or under prepared. There is no chance that you can simply guess a solution right. Solutions must come from what you have learned. Preparing for exams is much easier and less time consuming if you keep up with the progress of a course and review and do homework assignments promptly. Still a plan for preparation for an exam is always beneficial. Shown below is a simple worksheet for exam preparation.

The studying time needed is to be matched by the available time total. If you keep up with the course progress on weekly basis, then the time

Table 2.1 An Exam Planner

Exam Planner for ___________
Exam Date: ___________
Exam Coverage: ___________ Chapters of Textbook, ___________ Pages
___________ Pages of notes
___________ Example problems
___________ Homework problems
___________ Other reference materials

Study hours needed before the exam:
____________ for textbook
____________ for notes
____________ for example problems
____________ for homework problems
____________ for other reference materials
____________ for general overview

Study hours needed total: ____________ hours

Devoted Study Time—Exam Date minus 1: ____________ hours
Devoted Study Time—Exam Date minus 2: ____________ hours
Devoted Study Time—Exam Date minus 3: ____________ hours
Devoted Study Time—Exam Date minus 4: ____________ hours
Devoted Study Time—Exam Date minus 5: ____________ hours
Devoted Study Time—Exam Date minus 6: ____________ hours
Devoted Study Time—Exam Date minus 7: ____________ hours

Available Time Total: ____________ hours needed before an exam is expected to be much lower than otherwise. The number of days before the exam day to be included in the above planner can be adjusted accordingly.

2.15 Time Management: A Weekly Planner for Success

Your Need for Study Time. The knowledge embedded in mathematics and basic sciences courses and all the engineering sciences and civil engineering courses are cumulative in nature. Within each course the knowledge learned in this week may be needed to learn what is going to be covered in the next week and the weeks to follow. Another important feature of these courses is the new concepts and new tools introduced weekly. The new knowledge is to be understood thoroughly and remembered, and new tools need to be practiced and mastered. That means:

a. Homework assignments must be taken seriously and worked on as soon as possible but not before the textbook and notes taken during classes are thoroughly reviewed.
b. Exams must be thoroughly prepared well in advance of the exam date by reviewing the textbook, notes, and homework problems worked on and solved.

Every student must develop a sense of how much time is needed to carry out the above tasks for a particular course. In the book *Study Engineering* by Raymond Landis (see suggested reading at the end), he cited a **60-hour rule** credited to Dean Tom Mullinazzi. The 60-hour rule is based on two assumptions. First it is assumed that a student can spend 60 hours a week over the period of a term on academic study, working a paying job, and commuting. It also assumes that a student studies two hours for every hour spent in the classroom. This rule provides a useful guidance on how many credit-hours a student can take without overburdening oneself.

As an example, let us consider someone spends 15 hours on a job and a negligible amount of time commuting. The number of hours left for studying is 60–15 = 45. For each credit-hour taken one needs 1 + 2 = 3 hours of studying. Thus the maximum number of credit-hours to take is 45/3 = 15.

When you apply this rule, you can adjust both assumptions based on your own situation. We learned in the past that some students committed 70 hours or more a week instead of 60 hours. You may need more than three hours for some courses and fewer for some other courses.

Now you work on a weekly planner as an important tool for effective time management. You review the actual time spent on each of the following activities in a typical week.

Sleep (SP): Everyone sleeps every day of the week but may not sleep the same number of hours from day to day. A day-by-day review and summary will reveal how many hours are spent each day of a week. Medical experts advise that for an average adult, at least seven hours of sleep a day is needed, with eight hours being the preferred amount.

Work (WK): Many students do work part time or even full time. A daily summary of the hours spent on work gives one the total number of hours spent in a week.

Attending Classes (CL): Attending classes is a privilege and an obligation. In a semester-based system, for every credit-unit taken there is close to one hour in class meeting time.

Eating (ET): Eating is a daily necessity. Reviewing your time spent on eating does not imply you should eat fast in order to save time; medical experts would not approve eating fast. It is merely necessary to account for the time spent on eating.

Commuting (CM): Time spent on moving from one place to another varies greatly depending on whether one lives on campus or off campus in a faraway location. The obvious advantage of living on campus or near campus is the time saved from commuting.

Studying (ST): Studying can be achieved with the combination of long periods of time and short periods of time. If there is one hour between classes, 30 to 50 minutes of it can be effectively used for studying by reviewing what transpired in the last class or previewing what is going to be covered in the next class.

Relaxation and the Rest (RR): This is a catch-all category. Any other activities that are not accounted for by the above six categories are lumped into this category. Many students spend a significant amount of time every week on recreational activities such as web surfing, listening to music, playing computer games, or talking to friends either face to face or by text messaging and cell phone. Recreational and relaxation activities are necessary in anyone's life.

The easiest way of reviewing how the 168 hours of a week is being spent is to use a simple table as shown below **in Table 2.2**. Using the seven notations: SP, WK, CL, ET, CM, ST, RR, one fills in the half-hour blocks with one of the seven notations day by day. The weekly sum of hours spent on each of the seven categories is then added up and put in **Table 2.3 Weekly Activities Summary**. These are the numbers for the actual situation. We observed that many students were surprised at the numbers and decided to make some changes.

Table 2.2 Typical Weekly Activities

24-hour day	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
0-5							
5-5:30							
5:30-6							
6-6:30							
6:30-7							
7-7:30							
7:30-8							
8-8:30							
8:30-9							
9-9:30							
9:30-10							
10-10:30							
10:30-11							
11-11:30							
11:30-12							
12-12:30							
12:30-13							
13-13:30							
13:30-14							
14-14:30							
14:30-15							

(*Continued*)

Table 2.2 Typical Weekly Activities (*Continued*)

24-hour day	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
15-15:30							
15:30-16							
16-16:30							
16:30-17							
17-17:30							
17:30-18							
18-18:30							
18:30-19							
19-19:30							
19:30-20							
20-20:30							
20:30-21							
21-21:30							
21:30-22							
22-22:30							
22:30-23							
23-23:30							
23:30-24							
SUM	24	24	24	24	24	24	24
SP: sleep; **WK:** work; **CL:** class; **ET:** eat; **CM:** commute; **ST:** study; **RR:** relaxation & the rest							

Table 2.3 Weekly Activities Summary

Activities		Hours
SP	Sleep	
WK	Work	
CL	Class	
ET	Eat	
CM	Commute	
ST	Studying	
RR	Relaxation and the Rest	
		168

The key question to ask is if the time spent on studying is sufficient to ensure the success in every course you are taking. One useful guide is the average number of hours needed in studying mentioned above: two hours for every one hour in the classroom. Studying time for every week should be maintained more or less constant from one week to another. Upon an honest review and assessment of the weekly activities, many students will make changes, often adding more time to studying.

Every hour added to studying must come from the hours reduced from other activities. It is not advisable to reduce sleep time unless one is spending more than eight hours a day and one's doctor approves of the reduction. In most cases, hours can be relocated to studying from the RR category relatively painlessly. You can now use the same tables as your new weekly planner.

Once you decide to make specific adjustments, you shall commit to the change and review the effects of the adjustment from time to time.

There are more learning skills and useful attitudes for success contained in the open literature.

CHAPTER 3

Civil Engineering Curriculum

3.1 Overview

Upon completion of an undergraduate civil engineering education, one receives a Bachelor of Science in Civil Engineering (BSCE) degree. In the United States of America, BSCE and other engineering and technology degree programs are accredited by the ABET Inc., formerly the Accreditation Board for Engineering and Technology, Inc. The purpose of accreditation is to serve the public interest by providing quality assurance of accredited degree programs or institutes. Receiving accreditation is important in higher education because 1) accreditation is the primary means to assure academic quality to students and the public, 2) accreditation allows students to gain access to federal funds (such as the Pell grant) in U.S. (especially the regional and national accreditation of universities and institutes), 3) accreditation facilitates transfer of credit among similar programs, and 4) accreditation provides employers with important information when they make decisions on job applicants and continuing education for their employees. To get a BSCE program accredited, the requirements of ABET are the common base from which the unique features of a particular program are built. As a result, while no two BSCE programs are identical in their curricula, all civil engineering curricula have a common structure. To understand this common structure, you need to understand ABET requirements and the role of ABET in higher education accreditation in America.

In this chapter you will see the ABET requirements for your program as well as your program's curricular structure. Descriptions are given for many civil engineering courses for you to gain an overall sense on the courses you will soon take.

3.2 Higher Education Accreditation and ABET

ABET is one of more than 60 specialized and professional accreditors in the United States. Specialized accreditors accredit special programs in law schools, medical schools, engineering and technology schools, and health professional programs. In addition to specialized and professional accreditors, there are regional and national accreditors. The regional accreditors are institutional accreditors who review entire institutes. There are eight regional accreditors covering six geographical regions in U.S. National accreditors are also institutional accreditors that accredit single-purpose institutions, private career institutions, and faith-based colleges and universities. There are eleven national accreditors.

These accreditors are private, nonprofit organizations. To gain the public trust, these accreditors must be "recognized" by either the United States Department of Education or the Council for Higher Education Accreditation (CHEA). The former is a cabinet-level federal government organization and the latter is a private, nonprofit organization. CHEA is governed by a 17-person board of college and university presidents, institutional representatives, and public members. ABET is recognized by CHEA. That means ABET satisfies the following CHEA standards:

TO ADVANCE ACADEMIC QUALITY. To confirm that accrediting organizations have standards that advance academic quality in higher education; that those standards emphasize student achievement and high expectations of teaching and learning, research, and service; and that those standards are developed within the framework of institutional mission.

TO DEMONSTRATE ACCOUNTABILITY. To confirm that accrediting organizations have standards that assure accountability through consistent, clear, and coherent communication to the public and the higher education community about the results of educational efforts. Accountability also includes a commitment by the accrediting organization to involve the public in accreditation decision making.

TO ENCOURAGE, WHERE APPROPRIATE, SCRUTINY AND PLANNING FOR CHANGE AND FOR NEEDED IMPROVEMENT. To confirm that accrediting organizations have standards that encourage institutions to plan, where appropriate, for change and for needed improvement; to develop and sustain activities that anticipate and address needed change; and to stress student achievement.

One continually reassesses the accreditation practice: Accreditors are required to undertake self-scrutiny of their accrediting activities.

ABET is a federation of about 30 professional and technical societies representing engineering, technology, computing, and applied science. It does not accredit universities or colleges (that is the responsibility of regional accreditors) but individual programs. It accredits about 2,500 programs at over 550 colleges and universities in U.S. in 2013. Among the 2,500 programs, about 220 BSCE programs are accredited by ABET.

For over 60 years, the ABET (and its predecessor the Engineers Council for Professional Development) requirements remained structurally the same: it prescribed the curriculum content and other minimum requirements on faculty and facilities. By the end of the twentieth century, these requirements were increasingly considered by the industry as ineffective in ensuring accredited programs were producing graduates that satisfied the needs of the industry. The ABET requirements were considered by engineering educators as too restrictive. By 1997, ABET concluded a ten-year study and put in place a revolutionary approach to the accreditation of engineering programs. The new approach is outcome-oriented and was to be applied to all engineering program reviews by 2000, thus named Engineering Criteria 2000, **EC2000**. It is flexible in its requirements on curriculum, allowing each program to design its own unique features while satisfying some common requirements.

3.3 Program Outcomes Requirements of EC2000

ABET has well-defined criteria on the following nine categories: student, program educational objectives, program outcomes, continuing improvement, curriculum, faculty, facilities, support, and program criteria. The first eight are common to all engineering programs. The last is program specific, established by the relevant professional organization associated with ABET. The program outcomes specify the abilities to be acquired by the students by the time they graduate:

a. an ability to apply knowledge of mathematics, science, and engineering
b. an ability to design and conduct experiments, as well as to analyze and interpret data

c. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
d. an ability to function on multidisciplinary teams
e. an ability to identify, formulate, and solve engineering problems
f. an understanding of professional and ethical responsibility
g. an ability to communicate effectively
h. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
i. a recognition of the need for, and an ability to engage in life-long learning
j. a knowledge of contemporary issues
k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

These outcomes are commonly known as the a-to-k criteria. In addition ABET encourages each program to add other criteria that are unique to the program. It is beneficial for you to learn what the outcomes of your BSCE program are and how the outcomes are linked to the courses you are required to take. Your advisor can provide you with specific information on this linkage, but you will learn from the following what the general structures of your curriculum are.

3.4 Curriculum Requirements of EC2000

ABET specifies the structure and subject areas of curriculum but not the specific courses:

> The curriculum requirements specify subject areas appropriate to engineering but do not prescribe specific courses. The faculty must ensure that the program curriculum devotes adequate attention and time to each component, consistent with the outcomes and objectives of the program and institution. The professional component must include:
>
> a. one year of a combination of college-level mathematics and basic sciences (some with experimental experience) appropriate to the discipline

b. one and one half years of engineering topics, consisting of engineering sciences and engineering design appropriate to the student's field of study. The engineering sciences have their roots in mathematics and basic sciences but carry knowledge further toward creative application. These studies provide a bridge between mathematics and basic sciences on the one hand and engineering practice on the other. Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs.

c. a general education component that complements the technical content of the curriculum and is consistent with the program and institution objectives.

> Students must be prepared for engineering practice through a curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints.

The above requirements are for all engineering programs. Each specific engineering program may subject to additional requirements developed by the relevant engineering professional organization.

3.5 BSCE Curriculum Requirements

The lead society responsible for the formulation of BSCE curriculum requirements for ABET is the American Society of Civil Engineers (ASCE). The resulting requirements are described in the following single paragraph:

> The program must prepare graduates to apply knowledge of mathematics through differential equations, calculus-based physics, chemistry, and at least one additional area of basic science, consistent with the program educational objectives; apply knowledge of four technical areas appropriate to civil engineering; conduct civil engineering experiments and analyze and interpret the resulting data; design a system, component, or process in more than one civil engineering context;

explain basic concepts in management, business, public policy, and leadership; and explain the importance of professional licensure.

3.6 BSCE Curriculum Structure

A BSCE curriculum satisfying the general EC2000 requirements (Section 3.4) and the BSCE requirements (Section 3.5) has five elements in its structure: General Education, Science and Mathematics, Engineering Science and Civil Engineering Fundamentals, Civil Engineering Technical Areas, and Capstone Design. While no two BSCE curricula are identical, these five elements are common to all BSCE curricula and add up to 120 to 132 credit units in a semester-based system in most universities. In the following, whenever a course title is used, it is to be understood that the title is meant to be descriptive and your program may use a different title. Sometimes one or two courses may be bundled as a series under a more general title. Your program may offer the opportunity for you to select from an approved list of courses in each of these five elements.

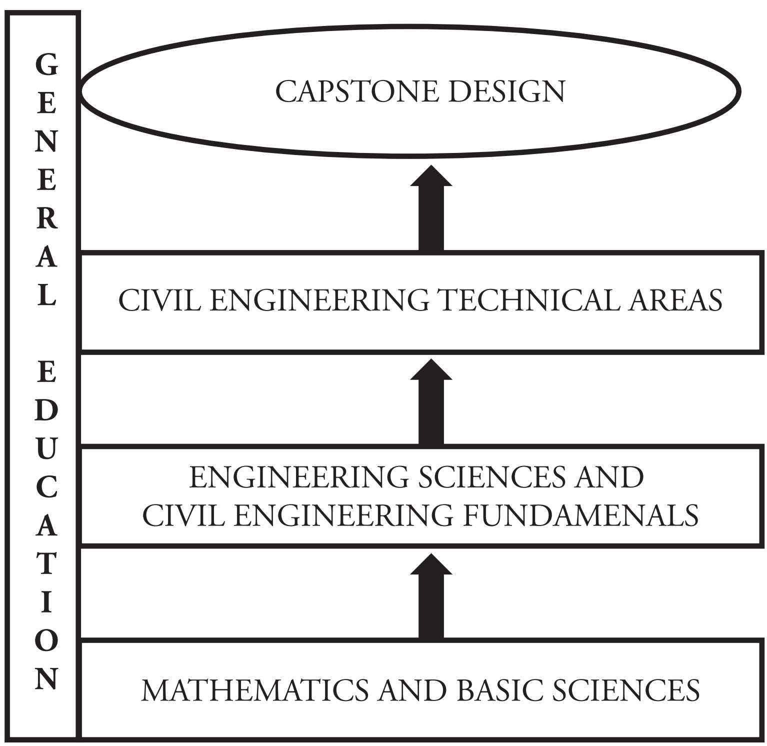


Figure 3.1 Basic Structure of a BSCE Program

The following diagram summarizes the basic structure of a BSCE curriculum.

General Education. Since the 1960s, educators in higher education recognize that a college graduate should have knowledge and skills not only in his/her chosen field of study but also in other areas that are vital to the understanding of a modern society. Each higher learning institute began to select these areas of study to form a core of its curriculum that best defines the institute's educational mission. These areas of study are required for all of its students. Liberal studies students are required to learn basic mathematics and science while science and engineering students are required to learn humanities and social studies. Some state governments also require students in state-supported universities to take history and government courses. These general education courses satisfy EC2000's requirement of "a general education component that complements the technical content of the curriculum and is consistent with the program and institution objectives." Usually you are given the liberty of choosing from a long list of eligible courses from a wide range of disciplines. The general education units add up to roughly one year's worth of study.

Mathematics and Basic Sciences. As described in Section 3.5, ABET required for civil engineering students: "knowledge of mathematics through differential equations, calculus-based physics, chemistry, and at least one additional area of basic science, consistent with the program educational objectives."

The mathematics requirement is typically satisfied by one year of basic calculus courses and one year of multivariable calculus, differential equations, and linear algebra courses.

The additional area of science requirement for BSCE is unique among engineering programs and can be satisfied by one single course in biology, geology, or other science courses. The mathematics and science requirements amount to about one year's worth of study.

Engineering Sciences and Civil Engineering Fundamentals. The engineering science courses are required for most engineering disciplines. Civil Engineering fundamental courses are required for civil engineering but are not for most other engineering disciplines.

Engineering science courses in a civil engineering curriculum typically include: statics, dynamics, thermodynamics, and fluid mechanics.

A brief description of each emphasizing its relevance to civil engineering is given below.

Statics: Civil engineering structures are subjected to forces that either do not vary in time or do not vary rapidly in time. An example of such forces is the gravitational force commonly known as weight or dead load. According to Newton's First Law, the summation of all forces acting on an object at rest is zero. These forces are said to be in equilibrium. Statics deals with **force and equilibrium** and the tools derived thereof. These tools are to be applied in several subsequent courses in civil engineering.

Dynamics: Civil engineering structures are subjected to incidental environmental events such as wind and earthquakes that may cause structures to vibrate. Dynamics deals with motion of objects and the relationship between force and motion. Dynamics forms the basis for the study of the vibration of structures and the motion of fluids in pipelines and open channels. Dynamics and Statics form the two-course series usually called Engineering Mechanics.

Thermodynamics: In the study of fluid motion involving the effect of temperature, the application of Statics and Dynamics alone is not sufficient. It requires the knowledge of Thermodynamics, which studies the conversion among different forms of energy: heat, mechanical, electrical, and chemical. Of importance to civil engineering applications is the interrelation of variables such as temperature, pressure, and volume of fluids.

Fluid Mechanics: Fluids include gases and liquids. In the context of civil engineering, fluids are water and air. Movement of air is relevant in environmental engineering while movement of water is relevant in both water resources engineering and environmental engineering. Fluid mechanics studies the movement of fluids in open and enclosed environment. It applies the principles and tools developed in Statics and Dynamics to a special medium, fluid, which changes its shape easily.

Civil Engineering Fundamental Courses typically include engineering materials (or construction materials), mechanics of materials (mechanics of deformable bodies or strength of materials), soil mechanics, and hydrology.

Engineering Materials: Engineering Materials studies the manufacturing and the properties of materials for engineering applications. In the civil engineering context, steel, concrete, and timber are the major construction materials. The main material properties are the mechanical properties such as strength, hardness, toughness, and ductility. The Engineering Materials course for civil engineers often concentrates on steel and concrete and leaves timber to a separate timber design courses. **Mechanics of Materials**: Mechanics of Materials relates forces acting on structural members (such as prismatic bar, beams, and columns) to the effects on the material of the members. These effects result in changing the shape and size of structural members. Thus, the course is sometimes entitled **Mechanics of Deformable Bodies**. It is also called **Strength of Materials**. In some BSCE programs, the content of this course is included in an Introduction to Solid Mechanics course.

Soil Mechanics: Virtually all civil engineering structures are supported by soil or rock foundations. The strength of soil for load bearing is developed in soil mechanics. Unique to the strength of soil is its dependence on the degree of the presence of moisture, or water. The laboratory component of soil mechanics is usually included as a part of the course. In some BSCE programs, the content of this course is included in an Introduction to Geotechnical Engineering course, which may include rock mechanics.

Hydrology: Hydrology studies and quantifies the circulation and movement of water. At a local or regional scale, the flow of river water can be predicted under normal or storm circumstances. For example, knowing the rainfall at an upstream region, the level of river water downstream can be computed and proper warning may be issued. Hydrology is the base on which scientific tools are for solving practical water resources problems. In some BSCE programs, the content of this course is included in an introductory Water Resources Engineering course.

In addition to the engineering science and civil engineering fundamental courses just described, some BSCE programs also require one or more of the following: **Electric Circuit** (or Electric Network), which covers electric circuit analysis, transformers, power supplies, etc.; **System Engineering**, which covers the mathematical basis for system analysis of civil engineering systems and its impact on the environment; **Introduction to Computing**, which covers either fundamentals of computer programming or tools of computing for civil engineers; and **Probability and Statistics for Civil Engineers**. All the engineering sciences and civil engineering fundamental courses add up to close to one year's worth of credit units.

Civil Engineering Technical Areas. As required by **EC2000**, a BSCE program "must demonstrate that graduates can apply knowledge of four technical areas appropriate to civil engineering." Reflected in a BSCE curriculum for each of the four or more technical areas is at least a two-course series with at least one course in the upper-division level, i.e. junior or senior level. All BSCE programs have structural engineering as one of the four or more technical areas they offer. Beyond structural engineering each BSCE program offers a variety of other technical areas based on the expertise of its faculty. In the following, only the structural engineering area and its three most commonly offered courses are briefly described.

Structural Engineering Area: Structural engineering is the earliest developed civil engineering technical specialty area. It has the most undergraduate courses to offer. Beyond the engineering mechanics courses and the mechanics of materials, there are Structural Analysis, Reinforced Concrete Structures Design, and Steel Structures Design.

Structural Analysis: Sometimes called Theory of Structures, the Structural Analysis offers further analytical tools for computing the member forces and the deflections of beams, trusses, and frames. The law of materials used in the development of the analytical tools is limited to that of linearly elastic, which means the relationship between stress and strain is proportional, and once the force acting on a structure is removed, the structure members return to its original position. The linearly elastic material law is applicable to most situations when the deflection of a structure is much smaller relative to the dimension of the structure member. More complicated material laws are covered in advanced structural analysis courses.

Reinforced Concrete Structures Design: The reinforced concrete structures design course covers beam design, simple slab design, column design, and simple foundation design using concrete and reinforcing steel bars. The design of these structural members follows the design code and specifications developed by professional societies. The design processes include, for a given set of forces acting on a member, the selection of concrete strength and steel reinforcing bar strength, member size determination, and the number and spacing of reinforcing bars in the member.

Steel Structures Design: For steel structures, the design deals with tension and compression members, and beams and beam-columns. Unlike concrete structures, which are usually cast in situ to form an integral structure (except for precast members connected in situ), steel structures are formed by connecting steel members with the use of bolts or welding. The design of the connection is unique to steel structures and is governed by design codes and specifications. In most applications, the design of a structural member entails the eventual selection of the member size and strength from a list of manufactured steel sections provided by the steel manufacturing industry.

Other undergraduate courses in structural engineering may include design of timber structures, masonry structures, advanced structural analysis, and pre-stressed concrete structure design.

In addition to structural engineering, many BSCE programs offer geotechnical engineering, water resources engineering, environmental engineering, transportation engineering, and construction engineering as part of the four or more areas required by ABET EC2000.

Capstone Design Course. The EC2000 of ABET requires: "Students must be prepared for engineering practice through a curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints." Among the EC2000 a-to-k outcomes are two criteria: (c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability, and (d) an ability to function on multidisciplinary teams. Most BSCE program requires one course or a two-course series of design at the senior level to address these requirements. The teamwork component of the design experience is addressed by requiring the design be completed by a team of students working together. The ability of students to function on a multidisciplinary team is acquired through the capstone design course by requiring each team member to perform different tasks preferably in more than one technical area.

It should be emphasized that each BSCE curriculum is developed over time with historical perspectives and the vision and experience of the program faculty. While the above curriculum structure and courses are described according to the ABET EC2000 framework, it is not implied that ABET creates the BSCE curriculum.

3.7 Navigating a BSCE Curriculum

While each of the more than 200 BSCE curricula is designed for four years of study, it is possible to complete the four-year curriculum in three or three and a half years. On the other hand, students who need more courses before starting on the first calculus course in their freshman year need more than four years to complete. This is due to the fact that almost every BSCE program has prerequisites built into its curriculum. Prerequisites are necessary to ensure students taking a particular course have the required preparation because many of the courses do build on knowledge learned in other courses.

A key sequence of courses that determines the minimum length of study is shown in Figure 3.2.

The above is for a curriculum requiring structural design in its capstone design course. Each preceding course is the prerequisite of the course

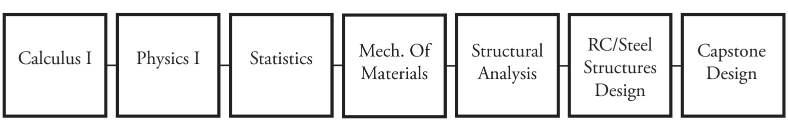


Figure 3.2 A key sequence of courses

following it. Even if the capstone design course in a particular curriculum does not include structural design, the requirements in another civil engineering technical area would produce another sequence of at least six courses. Thus, in order to graduate in four years or a shorter period, a student must not only pass all the key courses on the first try but also take these courses at the first possible opportunity. Your program has a curriculum flowchart for a 4-year plan, a 5-year plan, or a 6-year plan. You may have your own plan on how many courses you wish to take semester by semester. Do not be discouraged if you need more than four years to graduate. Many students need more than four years. In the assignments at the end, you are encouraged to work out your own flowchart with your advisor.

Before you graduate, there is one particular exam administered by the National Council of Examiners for Engineering and Surveying (NCEES) that you are encouraged to take and pass. The content of the exam is closely related to your curriculum. This is briefly introduced in the following section using contents published at the official NCEES site (www.ncees.org).

3.8 Fundamentals of Engineering Exam

The Fundamentals of Engineering (FE) Exam is the first step in the process leading to the professional engineer license. It is designed for students who are close to finishing an undergraduate engineering degree. The exam lasts 8 hours and is administered in April and October by the National Council of Examiners for Engineering and Surveying (NCEES). (This may change as NCEES is, as of 2013, discussing internally switching to an online exam format at different periods of a year.)

The FE exam contains 180 multiple-choice questions and is split into a morning session (120 questions) and an afternoon session (60 questions), each lasts four hours, with a one-hour lunch break in between.

The morning session is the same for everyone. For the afternoon session, you will be asked during registration to select the module (options are listed below) that best corresponds to your undergraduate degree:

Chemical	Civil	Electrical	Environmental	Industrial
Mechanical	Other Disciplines			

Let us take a look at the content of the **Morning Session**. It has 120 questions in 12 topic areas as listed below in detail with the approximate percentage of the test content following the topic area.

I. Mathematics 15%

A. Analytic geometry
B. Integral calculus
C. Matrix operations
D. Roots of equations
E. Vector analysis
F. Differential equations
G. Differential calculus

II. Engineering Probability and Statistics 7%

A. Measures of central tendencies and dispersions (e.g., mean, mode, standard deviation)
B. Probability distributions (e.g., discrete, continuous, normal, binomial)
C. Conditional probabilities
D. Estimation (e.g., point, confidence intervals) for a single mean
E. Regression and curve fitting
F. Expected value (weighted average) in decision-making
G. Hypothesis testing

III. Chemistry 9%

A. Nomenclature
B. Oxidation and reduction
C. Periodic table
D. States of matter
E. Acids and bases
F. Equations
G. Equilibrium
H. Metals and nonmetals

IV. Computers 7%

A. Terminology (e.g., memory types, CPU, baud rates, Internet)
B. Spreadsheets (e.g., addresses, interpretation, "what if," copying formulas)
C. Structured programming (e.g., assignment statements, loops and branches, function calls)

V. Ethics and Business Practices 7%

A. Code of ethics
B. Agreements and contracts
C. Ethical vs. legal
D. Professional liability
E. Public protection issues (e.g., licensing boards)

VI. Engineering Economics 8%

A. Discounted cash flow (e.g., equivalence, PW, equivalent annual FW, rate of return)

B. Cost (e.g., incremental, average, sunk, estimating)
C. Analyses (e.g., breakeven, benefit-cost) D. Uncertainty (e.g., expected value and risk)

VII. Engineering Mechanics (Statics and Dynamics) 10%

A. Statics: 1. Resultants of force systems, 2. Concurrent force systems, 3. Equilibrium of rigid bodies, 4. Frames and trusses, 5. Centroid of area, 6. Area moments of inertia, 7. Friction
B. Dynamics: 1. Linear motion (e.g., force, mass, acceleration, momentum), 2. Angular motion (e.g., torque, inertia, acceleration, momentum), 3. Mass moments of inertia, 4. Impulse and momentum applied to: a. particles, b. rigid bodies, 5. Work, energy, and power as applied to: a. particles, b. rigid bodies, 6. Friction

VIII. Strength of Materials 7%

A. Shear and moment diagrams
B. Stress types (e.g., normal, shear, bending, torsion)
C. Stress strain caused by: 1. axial loads, 2. bending loads, 3. Torsion, 4. shear
D. Deformations (e.g., axial, bending, torsion)
E. Combined stresses
F. Columns
G. Indeterminate analysis
H. Plastic versus elastic deformation

IX. Material Properties 7%

A. Properties: 1. Chemical, 2. Electrical, 3. Mechanical, 4. Physical
B. Corrosion mechanisms and control
C. Materials: 1. engineered materials, 2. ferrous metals, 3. nonferrous metals

X. Fluid Mechanics 7%

A. Flow measurement
B. Fluid properties
C. Fluid statics
D. Energy, impulse, and momentum equations
E. Pipe and other internal flow

XI. Electricity and Magnetism 9%

A. Charge, energy, current, voltage, power
B. Work done in moving a charge in an electric field (relationship between voltage and work)

C. Force between charges
D. Current and voltage laws (Kirchhoff, Ohm)
E. Equivalent circuits (series, parallel)
F. Capacitance and inductance
G. Reactance and impedance, susceptance and admittance
H. AC circuits
I. Basic complex algebra

XII. Thermodynamics 7%

A. Thermodynamic laws
B. Energy, heat, and work
C. Availability and reversibility
D. Cycles
E. Ideal gases
F. Mixture of gases
G. Phase changes
H. Heat transfer
I. Properties of enthalpy and entropy

Each of the 120 problems involves a single concept and counts for one point. You have on average two minutes for each problem.

The **Afternoon Session** for the **Civil Engineering Option** covers the following nine topic areas.

I. Surveying 11%
II. Hydraulics and Hydrologic Systems 12%
III. Soil Mechanics and Foundations 15%
IV. Environmental Engineering 12%
V. Transportation 12%
VI. Structural Analysis 10%
VII. Structural Design 10%
VIII. Construction Management 10%
IX. Materials 8%

We did not list the details for the Civil Engineering Option because many students prefer the **Other Discipline** option, which contains the following topics:

I. **Advanced Engineering Mathematics 10%**
   A. Differential equations
   B. Partial differential calculus
   C. Numerical solutions (e.g., differential equations, algebraic equations)
   D. Linear algebra
   E. Vector analysis

II. **Engineering Probability and Statistics 9%**
   A. Sample distributions and sizes
   B. Design of experiments
   C. Hypothesis testing
   D. Goodness of fit (coefficient of correlation, chi square)
   E. Estimation (e.g., point, confidence intervals) for two means

III. **Biology 5%**
   A. Cellular biology (e.g., structure, growth, cell organization)
   B. Toxicology (e.g., human, environmental)
   C. Industrial hygiene (e.g., personnel protection equipment [PPE], carcinogens)
   D. Bioprocessing (e.g., fermentation, waste treatment, digestion)

IV. **Engineering Economics 10%**
   A. Cost estimating
   B. Project selection
   C. Lease/buy/make
   D. Replacement analysis (e.g., optimal economic life)

V. **Application of Engineering Mechanics 13%**
   A. Stability analysis of beams, trusses, and frames
   B. Deflection analysis
   C. Failure theory (e.g., static and dynamic)
   D. Failure analysis (e.g., creep, fatigue, fracture, buckling)

VI. **Engineering of Materials 11%**
   A. Material properties of: 1. Metals, 2. Plastics, 3. Composites, 4. Concrete

VII. **Fluids 15%**
   A. Basic hydraulics (e.g., Manning equation, Bernoulli theorem, open-channel flow, pipe flow)
   B. Laminar and turbulent flow

C. Friction losses (e.g., pipes, valves, fittings)
D. Flow measurement
E. Dimensionless numbers (e.g., Reynolds number)
F. Fluid transport systems (e.g., pipes, ducts, series/parallel operations)
G. Pumps, turbines, and compressors
H. Lift/drag

VIII. Electricity and Magnetism 12%

A. Equivalent circuits (Norton, Thevenin)
B. AC circuits (frequency domain)
C. Network analysis (Kirchhoff laws)
D. RLC circuits
E. Sensors and instrumentation
F. Electrical machines

IX. Thermodynamics and Heat Transfer 15%

A. Thermodynamic properties (e.g., entropy, enthalpy, heat capacity)
B. Thermodynamic processes (e.g., isothermal, adiabatic, reversible, irreversible)
C. Equations of state (ideal and real gases)
D. Conduction, convection, and radiation heat transfer
E. Mass and energy balances
F. Property and phase diagrams (e.g., T-s, h-P)
G. Tables of thermodynamic propertie
H. Cyclic processes and efficiency (e.g., refrigeration, power)
I. Phase equilibrium and phase change
J. Thermodynamic equilibrium
K. Combustion and combustion products (e.g., CO, CO2, NOX, ash, particulates) L. Psychrometrics (e.g., humidity)

Comparing the topics covered by these two options, you will find that the Other Discipline option covers topics similar to the morning session topics but more in depth, while the Civil Engineering option covers seven civil engineering technical areas and civil engineering materials. Depending on how widely your curriculum covers these topics, you may choose one option against the other. In either case, the problems are more in depth and generally contain more than one concept and you have four minutes for each problem.

We list the topics herein not because you need to memorize them, but because you can compare the content with the course content of the corresponding course when you take it and pay due attention to the topics included in the FE exam. You are encouraged to update the content every year by visiting (www. ncees.org).

You are encouraged to take the exam as soon as you have taken all or most of the relevant courses in your program for the FE exam. Your program may offer a refresher non-credit course for you to prepare for the exam. Preparation is the key to passing the exam. In addition, the following data will encourage you the make every effort to pass on your first trial. According to NCEES, the pass rate for first-time takers of the Morning + Afternoon Civil Engineering Option was 67% and repeat takers 28% for the October 2012 FE exam. For the first-time takers of the Morning + Afternoon Other Discipline Option, the pass rate was 67% and repeat takers 30%. The percentage numbers do not add up to 100% because some exam takers did not provide the relevant information.

While the full scope of the FE exam is intimidating, you will be relieved to know that you are not expected to be able to answer all or even most of the questions. If every problem is answered correctly, one would receive 240 points ($120 \times 1 + 60 \times 2$). According to the statistics of NCEES, one would pass the exam if one scores in the neighborhood of 110 points. Furthermore, there is no penalty for a wrong answer. You know what that means.

CHAPTER 4

Learning in a Co-Curricular Environment

4.1 Overview

Learning by taking courses is the core of college education for many years, but students on any campus also have opportunities to participate in a variety of campus-based activities other than taking courses. These activities used to be characterized as extracurricular. In recent years educators increasingly view these extracurricular activities as complementary to the curricular learning and called such activities as cocurricular learning instead of extra-curricular to emphasize its usefulness to students. These co-curricular activities are organized by campus-sanctioned student organizations. For civil engineering students there are three types of student organizations of interest: civil engineering–related organizations, engineeringrelated organizations, and other organizations. A civil engineering student may choose to participate in activities of an organization not related to civil engineering or engineering because of personal preference or hobby. Whether or not an organization has anything to do with civil engineering, the common benefits to a participant are:

1. It provides **a sense of belonging**. Members of a student organization form a small community within the larger community of a campus. For active participants it becomes a home away from home. Educators believe a sense of belonging is a factor in encouraging learning and overcoming academic challenges.
2. It provides an environment for **improving interpersonal skills**. Rarely does a civil engineer work alone. Whether one works with his/her colleagues in a firm or a government agency, dealing with people is a daily occurrence. Interaction within a student organization

provides the opportunity for an active participant to learn from mistakes and successes in dealing with people.

3. It provides a training ground for **teamwork**. Most student organizations have group activities. Active participants learn to be **good leaders and good followers**. Followership is as important as leadership in making a team function properly and in personal development.
4. It provides an opportunity to **know people from other majors**. To a civil engineering student, this is true for non-civil engineering organizations. Knowing people from other majors broadens one's perspective on issues concerning the larger community of a society.
5. It provides an opportunity in **networking with people from the outside world**. This is true for the participants of the student chapter of a national organization. Typically such a student chapter has one or more advisors from the national organization and has regional and national activities sanctioned by the national organization. These outside advisors may provide career mentorship as well as academic advisement.
6. It provides scholarships to qualified members.

For an active member of a student organization, time spent on the activities of the organization is time not spent directly on studying for courses. The obvious question is if such activities hurt the academic performance of a student. That depends on how a student manages time. Students active in student organizations usually manage their time wisely. Of course if excess amount of time is spent on a student organization, then it will hurt one's academic performance. One useful rule of thumb is: time spent on activities of a single student organization is equivalent to that of taking one 3-credit course. One should manage time accordingly.

The following student organizations are most relevant and most likely to be joined by civil engineering students. Following the description of these relevant organizations, other co-curricular learning opportunities are introduced.

4.2 ASCE

ASCE Overview. Founded in 1852, the American Society of Civil Engineers is the oldest national engineering society. Presently its local organizations are organized in nine US regions and an international region.

Each region is further organized in sections, and within each section, branches.

ASCE serves its members and the public interest. An example of its commitment to public interest is its annual report by its Committee on Critical Infrastructure (CCI) focusing on areas related to critical infrastructure resilience. Its Report Card for America's Infrastructure calls the public's and political leaders' attention to the urgent need in infrastructure renewal.

The Society has eight Institutes created to serve professionals working within specialized fields of civil engineering:

Architectural Engineering Institute (AEI)
Coasts, Oceans, Ports and Rivers Institute (COPRI) Construction Institute (CI)
Engineering Mechanics Institute (EMI)
Environmental and Water Resources Institute (EWRI) Geo-Institute (G-I)
Transportation and Development Institute (T&DI) Structural Engineering Institute (SEI)

ASCE's Technical Activities Committee (TAC) has ten Divisions and Councils:

Aerospace Engineering
Cold Regions Engineering
Computing in Civil Engineering
Energy
Forensics Engineering
Geomatics
Lifeline Earthquake Engineering
Disaster Risk Management
Pipelines and Sustainability
Technical Activities Committee

ASCE is the largest publisher of civil engineering technical and professional information. Its thirty-three journals are the premier source of technical information for the civil engineering profession.

In addition to these journals, ASCE also publishes books and the ***ASCE News*** and ***Civil Engineering*** magazine, which is an important resource for nation-wide job postings in industry and academe.

ASCE annually honors achievements of its members for important contributions to the technical and professional areas with numerous technical and professional awards, and presents the awards in public meetings or conferences. These awards are considered the most prestigious in the profession.

4.3 ASCE Student Chapter Activities

Student chapters of ASCE are generally associated with BSCE programs, but some community colleges also host ASCE student chapters if they offer an associate degree in civil engineering. To maintain good standing, a student chapter of ASCE must submit an annual report on its activities to show that its members have indeed participated in a variety of technical activities and community service projects. Specific benefits to student chapter members include free online access to the *Civil Engineering* magazine and *ASCE News*, access to career resources such as information on internship and job opportunities, professional guidance through the chapter's advisors and ASCE's mentoring program, and networking opportunities through annual conferences and competitions.

For student chapter members, ASCE offers a free national student membership, but students do pay dues to their own local student chapter. Each student chapter has three advisors: one Faculty Advisor and two Practitioner Advisors formerly referred to as "Section Contact Members." The Faculty Advisor is a member of the civil engineering faculty. The Practitioner Advisors are members of an ASCE Section or Branch and provide contact between the students and the civil engineering professionals in the area. These individuals provide guidance to the student leaders, help maintain a balance in group activities, and foster the development of professionalism and leadership in the members of the ASCE group. The Faculty Advisor is selected by the Civil Engineering Department Head. The Practitioner Advisors are selected by the ASCE Section or Branch.

To provide guidance to the student chapters, ASCE has a Committee on Student Activities (**CSA**) with ten civil engineering educators and practitioners who help guide the overall national ASCE student program.

4.4 ASCE Student Awards and Competitions

Awards and competitions available to individuals or groups are briefly described here. The concrete and steel bridge competitions are described in more detail because they are the most popular annual activities participated in by the most student chapters.

Student Organization Awards: Based on activities recorded in the annual report of the student chapters, the CSA determines the recipients of awards honoring student organizations, faculty advisors, and practitioner advisors:

1. **Robert Ridgway Student Chapter Award**: This award was endowed by Isabel L. Ridgway in honor of her husband, Robert Ridgway, 1925 national president, ASCE. It was officially instituted in May 1965. The award is made annually to the single most outstanding Student Chapter of the ASCE. Several chapters are also honored as the Ridgway Award Finalists.
2. **Regional Governors Award**: The CSA selects the best student chapter from each of the nine domestic regions and the international region to receive the Regional Governors award.
3. **Richard J. Scranton Outstanding Community Service Award**: This award honors the student chapter with the most outstanding community service activities.
4. **Other Student Chapter Awards**: **Certificates of Commendation**, **Letters of Honorable Mention**, **Most Improved Award**, **Letters of Significant Improvement**: There are non-student awards: One faculty from each of the ten ASCE regions is selected to receive the **Outstanding Faculty Advisor Awards**. Numerous outstanding faculty advisors are selected for the **Faculty Advisor Certificates of Commendation**. One or more practitioner advisors are selected for the **Outstanding Practitioner Advisor Awards**. One or more practitioner advisors are selected for the **Practitioner Advisor Certificates of Commendation**.

Daniel W. Mead Student Contest: This is a single essay competition on a topic selected annually by the CSA. The contest is established in 1939 in honor of ASCE's 67th president, Daniel W. Mead, and to further young civil engineers' professional development. Only one essay is allowed to enter the competition from each student chapter and is to be submitted through the faculty advisor. The faculty advisor becomes the de facto arbitrator on selecting the best essay out of the chapter for the national competition. Up to five winners receive cash awards, ranging from $1,000 to $200.

Student Leadership Award: This award is granted to someone with demonstrated leadership in terms of serving as chapter officers, leading chapter activities, interacting with university administration, and interacting with ASCE branches/sections. Candidates for this award must be nominated by the faculty or practitioner advisor, department head, or branch/section officers.

ASCE National Concrete Canoe Competition: The use of concrete in floating vessels can be traced back to Joseph-Louis Lambot who built concrete boats for use on his estate in France in 1848. ASCE has been sponsoring this national competition since 1988 when the then-Masters Builder offered to become the sole corporate sponsor. ASCE student chapter activities in concrete canoe, however, had been in existence for more than 20 years by 1988. The idea of a national competition was initiated in 1985 by Dr. R. John Craig, a professor of the New Jersey Institute of Technology. By 1987 the rules were formulated and approved but Dr. Craig was diagnosed with a rare form of brain tumor. He passed away only two months before his vision of a national concrete canoe competition became reality in 1988.

The objectives of the national competition are described by ASCE as follows:

- To provide civil engineering students an opportunity to gain hands-on, practical experience and leadership skills by working with concrete mix designs and project management.
- To increase awareness of the value and benefits of ASCE membership among civil engineering students and faculty in order to foster lifelong membership and participation in the Society.
- To build awareness of the versatility and durability of concrete as a construction material among civil engineering students, educators and practitioners, as well as the general public.

- To build awareness of concrete technology and application among civil engineering students, educators and practitioners, as well as the general concrete industry.
- To increase awareness among industry leaders, opinion makers, and the general public of civil engineering as a dynamic and innovative profession essential to society.
- To generate and increase awareness of all sponsoring companies' commitment to civil engineering education among civil engineering students, educators and practitioners, as well as the general public.

The competition generally includes the design and construction of a concrete canoe, a paper presentation and an oral presentation, and five types of races. Over the years ASCE has developed clearly defined rules and regulations governing the competition. Entry to the national competition, which is hosted by a different school every year, is limited to the top two schools (winners) of the eighteen student conference competitions, plus the host team. The same canoe must be used in both the conference and the national competitions. Some of the rules and regulations and the components of the competition are highlighted below.

Figure 4.1 The co-ed concrete canoe sprint race at the 2008 National Concrete Canoe Competition in Montreal, Quebec

Source: http://en.wikipedia.org/wiki/File:Coed_Sprint.jpg. Copyright in the Public Domain.

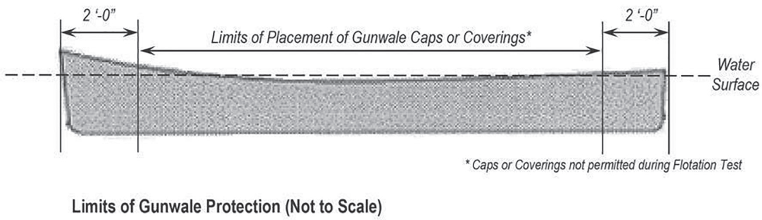
a. **Materials**: By definition concrete canoes are made of concrete with reinforcement. For the competition, there are strict specifications on the material used. The concrete used must be designed by the team. Prepackaged or premixed concrete, mortar, or grout is not permitted. Each of the four components of the concrete material: cement (including other cementitious materials such as fly ash or silica fume), aggregate, fiber, and admixture are subject to a variety of established requirements.
b. **Size and Shape**: The length of the beam width and the depth are specified every year. While the specified dimensions cannot be changed, the designer has the discretion of determining the hull thickness and the dimension of any thwarts and ribs.
c. **Design Paper**: Each team must submit a design paper detailing the design and construction of the concrete canoe, including the project management and the innovations and sustainable aspects of the design. The paper shall include an organization chart with names of team members and their tasks and contributions, a project schedule, a design drawing, and bill of materials form, among other required contents.
d. **Engineer's Notebook**: The Engineer's Notebook is a technical document providing supportive information on the design and construction of the concrete canoe. It includes photographs of the construction of the canoe at various stages, hull thickness and reinforcement-related calculations, and technical datasheet on the products used in the concrete canoe.
e. **Oral Presentation**: Each team is to make a five-minute live technical presentation on the various aspects of the project, followed by seven minutes of questions and answers. Video is permitted but no prerecording of the speaking parts is allowed.
f. **Final Product: Canoe and Cutaway Section Display**: In addition to the finished concrete canoe, a cutaway section of at least three feet is to be displayed alongside the canoe. The cutaway section shall demonstrate the concrete casting, finishing, and the reinforcement techniques used.
g. **Canoe Floating Test**: To assure safety and durability, the concrete canoe is required to survive a floating test. The canoe is placed in water and filled up inside with water. To pass the floating test, the point within 2 feet and 6 inches of the two extreme ends of the canoe must break the water surface simultaneously within five minutes of being completely filled with water.

h. **Races**: A total of five races are held ranging in distance from 200 m to 600 m: women's slalom/endurance (3 women), men's slalom/endurance (3 men), women's sprint (2 women), men's sprint (2 men), and co-ed sprint (2 women, 2 men). All paddlers shall be competent swimmers and shall wear U.S. Coast Guard-approved life jackets at all times while they are in the canoe. A powered rescue boat is required to be present during all races.

Seventy-five percent of the total team score is based on engineering design and construction principles, the written report, and oratory skills. The remainder is based on the performance of the canoe and the paddlers in five different race events. Based on the overall scores, scholarship awards and trophies are given to the three teams with the highest scores: $5,000, $2,500, and $1,500, respectively. Special plaques are given to the fourth and fifth-place teams, best design paper, best oral presentation, best final product, spirit of competition, and each of the winners of the five races. The winner of the co-ed sprint race receives a special plaque honoring the founder of the national race, Dr. R. John Craig.

One of the challenges of the concrete canoe competition is the transportation of the canoe itself. Many times, the canoe is damaged during transportation and handling to the point that further participation becomes untenable. Despite the potential problem of failure, the competition remains a popular one because it entails a wide range of activities challenging participants' minds and bodies. The above description is usually changed from year to year in its details but not in its general outline. You are encouraged to find the most up-to-date information at the ASCE site: (http://www.asce.org/concretecanoe/).

ASCE/AISC Student Steel Bridge Competition: This national competition is sponsored by ASCE and American Institute of Steel Construction (AISC) and co-sponsored by several steel industry organizations or companies. AISC is a not-for-profit technical institute and trade association established in 1921. Its mission as described by AISC is "to serve the structural steel design community and construction industry in the United States. AISC's mission is to make structural steel the material of choice by being the leader in structural-steel-related technical and market-building activities, including: specification and code development,



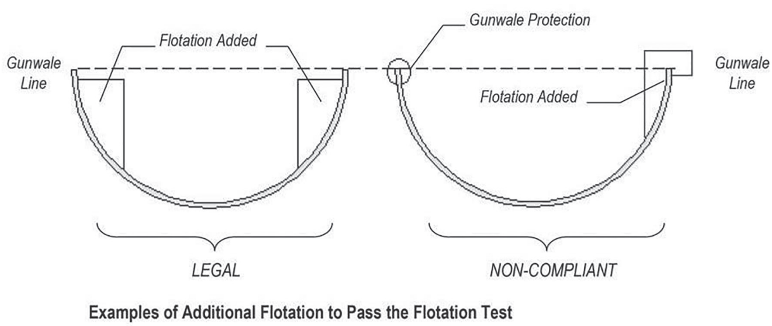


Figure 4.2 Two Figures from the 2013 Official Rule book

Figure 2.2, 2013 Rules and Regulations, pp. 8. Copyright © 2013 by American Society of Civil Engineers (ASCE). Reprinted with permission.
Figure 2.3, 2013 Rules and Regulations, pp. 8. Copyright © 2013 by American Society of Civil Engineers (ASCE). Reprinted with permission.

research, education, technical assistance, quality certification, standardization, and market development."

Teams enter the competition first at the regional level through the ASCE Student Conferences. Up to three teams from the winners of each of the regional competitions are qualified to enter the national competition. The rule of the competition is changed every year to enhance the competitiveness. Some of the main features of the competition are described below.

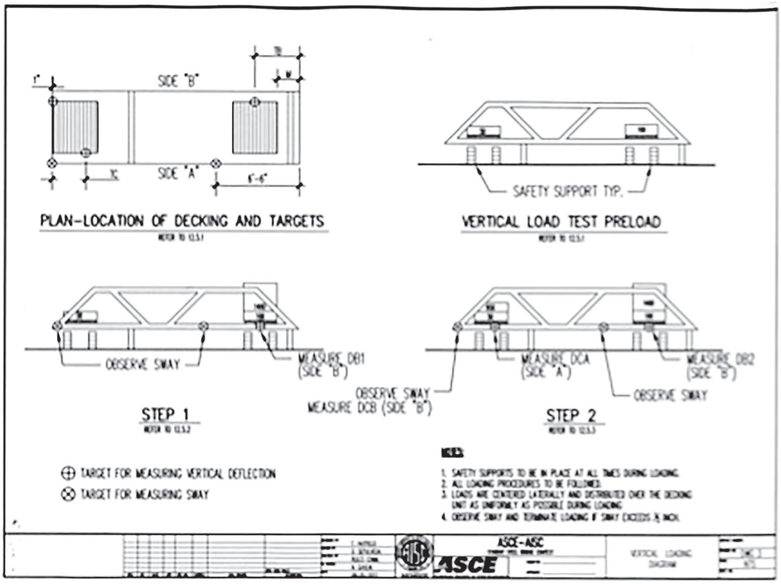
a. Material and Size: Obviously only steel is used. The steel bridge's dimension, the sizes of each member of the bridge, and the nuts and bolts connected by steel fasteners specified/limited.
b. Display and Timed Construction: The bridge is first displayed. Design of the bridge is to be described on a poster displayed with the bridge.

The appearance of the bridge is judged by its balance, proportion, elegance, and finish. After the display, the bridge is disassembled. It is assembled again on site at a designated location provided by the host school during the timed construction competition for construction speed. Time of assembling is the main factor of this competition. A penalty is assessed if the assembling time exceeds 30 minutes. In addition, the number of "builders" participating in the construction is also a factor in assessing the overall construction economy.

c. Weight and Stiffness: Obviously the lighter the better, but it is not the weight alone that is judged. Various penalties are assessed in terms of added weight. During the load tests, three points of the bridge are measured for their vertical deflection. The aggregated deflection amount reflects the stiffness of the bridge.
d. Loading and Unloading: A lateral load test is conducted and the lateral sway amount is measured. If excessive sway is observed, the bridge is deemed unsafe and no further tests are to be conducted. If a bridge passes the lateral load test, the vertical load test is conducted. The vertical loading test actually has a preload phase and a loading phase, and then the loads are taken off. If a bridge collapses during the unloading phase, the team will not receive any awards.
e. Awards: Seven categories of performance are used for competition: display, construction speed, construction economy, lightness, stiffness, structural efficiency, and overall performance. The top three teams in each category are recognized with a plaque. For the national competition each team is provided a cash travel subsidy.

During the construction and loading of the bridge, safety is of major concern. The construction is not as easy as one might imagine; there are rules governing the behavior of all the builders. For example, no builder can use any other builder for support. No builder is allowed to cross the line of "floodway" of the "river." Sometimes the builders twist their body to reach the target bridge. Falling and twisted angles may result from overextended postures. Despite these potential hazards, the excitement of putting together a bridge designed by students themselves always attracts many participants. For updates, check the official website:

http://www.aisc.org/WorkArea/showcontent.aspx?id=21576.



Student Steel Bridge Competition: 2013 Rules, pp. 40. Copyright © 2013 by American Society of Civil Engineers (ASCE). Reprinted with permission.

4.5 Student Chapter of Chi Epsilon: Civil Engineering National Honor Society

Many BSCE programs have a student chapter of Chi Epsilon, the national honor society for civil engineering students, faculty, and alumni. The society, as described by Chi Epsilon, is "Dedicated to the purpose of maintaining and promoting the status of civil engineering as an ideal profession, Chi Epsilon was organized to recognize the characteristics of the individual civil engineer deemed to be fundamental to the successful pursuit of an engineering career, and to aid in the development of those characteristics in the civil engineering student." The society's history can be traced back to 1922 when two fraternities at University of Illinois were independently established. A national society was established in 1923. By 1958 the national society had 49 chapters. It grows at a rate of 20 chapters every decade. By 2008, there were 233 chapters.

As an honor society it initiates student members by their scholastic achievements. In other words, not every civil engineering student can apply to become a member. For civil engineering undergraduates, only juniors and seniors in the top one-third of their class (typically ranked according to GPA) are eligible.

To be a member of Chi Epsilon is an honor for a civil engineering student. They are also eligible to compete for numerous scholarships from $1,500 to $3,000. In case your institute does not have a student chapter of Chi Epsilon, you can initiate one. Check with your department chair and official site: (http:// xe.uta.edu/xewebgeneral2/).

4.6 Student Chapter of Tau Beta Pi, Engineering Honor Society

While Chi Epsilon is a civil engineering honor society for civil engineers only, Tau Beta Pi is a national honor society for all engineering disciplines. As described by Tau Beta Pi, its mission is "to mark in a fitting manner those who have conferred honor upon their Alma Mater by distinguished scholarship and exemplary character as students in engineering, or by their attainments as alumni in the field of engineering, and to foster a spirit of liberal culture in engineering colleges. Its vision: Tau Beta Pi will be universally recognized as the premier honor society. Its creed: Integrity and excellence in engineering." Its history traces back to 1885 when it was founded at Lehigh University. By 2009 it had 241 chapters.

Eligibility requirements for undergraduate students include scholastic achievements measured by ranked in the top one-eighth of their major for juniors and top one-fifth for seniors. Members are eligible to compete for a variety of scholarships.

4.7 Other Student Chapters

There are other student chapters of national societies on many campuses that civil engineering students are likely to join. Only a few engineering societies are briefly described below, in the order of the year they were founded.

AWWA, American Water Works Association. Founded in 1881 by 22 men, the purpose of the association has been "for the exchange of information pertaining to the management of water-works, for the mutual advancement of consumers and water companies, and for the purpose of securing economy and uniformity in the operations of water-works."

AWWA has more than 50,000 members working to protect public health and water resources for future generations and 41 student chapters on campuses in U.S.A., Canada, and Mexico (www.awwa.org). While many BSCE programs offer introductory undergraduate courses related to drinking water, the majority of drinking water courses are usually offered at the graduate level. As a result student chapters of AWWA are populated mostly by graduate students. The scholarship program also concentrates on M.S. and Ph.D.-level students, and so is its student competition program.

ACI, American Concrete Institute. Founded in 1904, ACI has become the premium organization advancing concrete technology in the world. Its detailed specifications on concrete design and application are adopted into national and local government codes. ACI offers the following general description: "With 99 chapters, 37 student chapters, and nearly 20,000 members spanning 108 countries, the American Concrete Institute has always retained the same basic mission—to develop, share, and disseminate the knowledge and information needed to utilize concrete to its fullest potential."

ACI student members are active participants in ACI's activities and student competitions even without a student chapter. Self-organized student teams can participate in the following competitions:

a. **ACI FRC Bowling Ball Competition**: The object is to design and construct a fiber-reinforced concrete bowling ball to achieve optimal performance under specified failure criteria and to develop a fabrication process that produces a radial uniform density while maximizing volume.
b. **ACI Concrete Cylinder Competition**: The objective is to produce concrete cylinders with an average compressive strength of 7,000 psi (48.3 MPa) and a saturated surface-dry density of 150 lb/ft (2.39 kg/l) with the highest cementitious efficiency and the lowest cost, and to write a report explaining the design and production process.
c. **ACI Concrete Projects Competition**: Virtually any project that focuses on concrete design, materials, and/or construction is eligible. These projects can include computer programs, term papers, student activities, senior design projects, or special projects.

d. **ACI FRP Composites Competition**: Students design, construct, and test a concrete structure reinforced with fiber-reinforced polymer (FRP) bars to achieve the optimal load-to-weight ratio, predict the ultimate load, and predict the load that will result in a piston deflection of 2.5 mm (0.1 inch).
e. **ACI Concrete Cube Competition**: Students produce a concrete cube that achieves, as closely as possible, a target design strength of 50 MPa and a target mass of 270 grams per cube.
f. **ACI Egg Protection Device Competition**: Students design and build the highest-impact load-resistant plain or reinforced concrete Egg Protection Device.
g. **ACI Concrete Construction Competition**: The Concrete Construction Competition is for undergraduate students with interests in construction technology, construction management, and concrete industry management. Student teams (comprising up to 5 students each) are given one week to provide a response to a realistic, open-ended question on the subject of concrete construction.

Through its non-profit subsidiary, ACI Foundation, ACI offers fellowships and scholarships every year. The scholarships are for graduate students only. The fellowships are for undergraduate and graduate students with educational stipends to cover tuition, residence, books, and materials valued at $7,000 to $10,000. Candidates must be nominated by a faculty who must be a member of ACI. A 500-word essay is required along with transcripts and two references submitted online (www.concrete.org).

SWE, Society of Women Engineers. Founded in 1950, SWE is "a not-for-profit educational and service organization that empowers women to succeed and advance in the field of engineering, and to be recognized for their life-changing contributions as engineers and leaders." SWE has about 400 professional and collegiate sections throughout ten regions in the United States (www.swe.org).

SWE has a very active scholarship program. In 2012, SWE disbursed 198 new and renewed scholarships valued at $577,000. Recipients include freshmen through graduate students. Individual scholarships range from $1,000 to $10,000. Many local professional sections also award scholarships.

The student sections are encouraged to participate in the SWE's collegiate competition program. The available competitions include

a. Outstanding Collegiate Section Award: It recognizes the best sections for their overall performances. Its gold level award typically recognizes five student sections.
b. Outstanding New Collegiate Section Award: It recognizes the best of the new sections.
c. Collegiate Technical Poster Competition: it recognizes the best ability to deliver visual presentations.
d. Team Tech Competition: Sponsored by the Boeing Company, this award emphasizes the importance of teamwork and interface with industry in the engineering educational process.
e. SWE Bowl: Sponsored by the ExxonMobil Company, the Subject Matter Expert (SME) Bowl is a competition that challenges collegiate students to show their stuff in the areas of science, math, physics, engineering, and technology. It also challenges these students in their knowledge of SWE history and policies.

NSBE, National Society of Black Engineers. Started as a student organization at Purdue University in 1971, NSBE became a national nonprofit organization in 1976. It has more than 250 student chapters. NSBE's mission (www.nsbe.org) is "to increase the number of culturally responsible Black Engineers who excel academically, succeed professionally and positively impact the community."

NSBE has a wide range of programs: collegiate programs, pre-college initiative programs, graduate student programs, technical professional programs, community outreach and service programs, and scholarship programs.

For undergraduate students, NSBE offers seventeen NSBE and corporation-sponsored scholarships ranging in value to individual recipients from $500 to $7,500.

SHPE, Society of Hispanic Professional Engineers. Founded in 1974 by several professional engineers in Los Angeles, SHPE has quickly grown into a very active national organization. More than 250 local and student chapters on engineering campuses are organized in seven national regions.

As described by SHPE, the society's mission: "SHPE changes lives by empowering the Hispanic community to realize their fullest potential and impacts the world through STEM awareness, access, support and development." Vision: "SHPE's vision is a world where Hispanics are highly valued and influential as the leading innovators, scientists, mathematicians and engineers." Student members are eligible to compete for internships, scholarships, and awards.

The SHPE has an extensive scholarship program offered through the **Advancing Hispanic Excellence in Technology, Engineering, Math and Science (AHETEMS) Foundation,** which is an independent non-profit organization working exclusively to develop educational enrichment and academic outreach initiatives, for Latinos/as that extends throughout the pre-college to Ph.D. pathway. Several types of scholarship are shown below:

a. AHETEMS General Scholarships: These merit-based and need-based general scholarships are awarded, in the amount of **$1,000–$3,000**, to qualified high school graduating seniors, undergraduate students, and graduate students who demonstrate both significant motivation and aptitude for a career in science, technology, engineering, or mathematics.
b. AHETEMS/ExxonMobil Scholarship: These merit-based scholarships are awarded in the amount of **$2,500 to undergraduate students** who demonstrate both significant motivation and aptitude for a career in science, technology, engineering, or mathematics.
c. AHETEMS/Kellogg Corporation Scholarship, Northrop Grumman Scholarships, U.S. Steel Corp. Scholarships, Verizon Scholarships: Each of the four scholarships is merit-based and awarded in the total amount of **$5,000 to undergraduate students** who demonstrate both significant motivation and aptitude for a career in engineering.

SHPE sponsors student competitions for undergraduates and makes its awards to winners during its annual conference:

a. Student Technical Paper Competition: Participants submit abstracts and full papers (if abstracts are accepted), and make presentations during the conference. Winners are selected based on papers' originality, social impact, and completeness.

b. Student Technical Poster Competition: Participants submit abstracts and full posters (if abstracts are accepted), and avail themselves during the poster session of the conference. Winners are selected based on posters' originality, social impact, and completeness.
c. Academic Olympiad and Design competition are sometimes sponsored.

4.8 Other Co-Curricular Options

Undergraduate Research Experience (URE)

Benefits. Participating in a research program as an undergraduate has many benefits. You will observe up close how research is conducted. You have the opportunity to work closely with a faculty. Most likely you will interact with other students (graduate research assistants and/or other undergraduates) on a team. Your experience gives you advantage if and when you apply for graduate study and research assistantships. You will be paid for your work.

Duration. The duration of your participation often depends on the funding available and your availability. It could be a summer program, a semester program, or a year-long program. You could work full time during the summer and part time during the school year.

Place of Research. The place of conducting research usually is on your own campus, but many universities offer undergraduate research programs on an open-competition basis. It usually is a summer program. There will be an open application announcement sent to your university or your department by the host institute inviting applications. You apply according to the requirements announced. If accepted, you will then spend a summer at another institute, giving you the additional benefit of experiencing a new campus and a new location.

Funding. Usually you will work for a faculty who has a funded research project with a budget that pays you for your work. A major funding agency, the National Science Foundation (NSF) has a long-running program for undergraduate research experience. Any faculty director of an NSF-funded project can apply for supplemental funding for URE and has a high probability of getting approved. NSF also funds URE at an institute that supports a group of undergraduate students from other campuses as described above.

Where to Apply. For URE on your own campus, you need to watch out for announcements and seek help from your faculty advisor. You can also ask each faculty who has a funded research program for the opportunity. For opportunities at other campuses, check with your faculty advisor or department chair in spring or late winter. These opportunities are usually for summer only as described above.

Keep a Record. It will benefit you to keep a daily work log. It includes a description of your assignment and how the assignment is fulfilled. You may add any thoughts on your work of that day. It is like a diary but devoted to the URE only. The daily log shall follow an overview describing your responsibilities and the project you are in. At the conclusion of the URE period, you can add a summary on your overall experience. Such a record will come in handy when you apply for graduate study and assistantship and when you apply for a job.

Design Clinics

Benefits. Design clinics are funded by industrial sponsors for a faculty-student team to solve a particular problem for the sponsor. The participating students usually are paid to work on the real-world problem. Students have all the benefits of an undergraduate research experience project but work on a problem more on the development side than the research side.

Duration. It depends on the nature of the problem and funds available; it ranges from a summer or a semester to more than a year. Students typically work on a part-time basis during semesters and full time in summer.

Place of Work. It is usually on campus unless the sponsor has a special need for working on its campus, e.g., use of a special instrument or lab available only from the sponsor.

Where to Apply. Since the design clinic is supervised by a faculty, usually the faculty recruits the student(s) to form a team. This is another reason you need to interact more with your faculty.

Keep a Record. You will reap the same benefits as you do for the URE project.

Internships

Benefits. Internship is a temporary on-the-job training opportunity. Because it is work experience in civil engineering, it becomes relevant to your career development. Potential employers like people with internship experiences. Some employers even hire only people who have successfully completed an internship with them. Thus a temporary job has the potential of becoming a permanent one. You will work directly under a supervisor and learn real-world knowledge.

Types of Internship. You may participate in a paid, unpaid, or partially paid internship. A partially paid internship pays you a stipend instead of a salary. You may work full time in summer and part time during semesters. We encourage our students to look for paid internships. Not only do you gain financially, but your employer usually takes you more seriously and gives you "real" work worthy of the money paid to you. But unpaid internship experience is also valuable if the sponsor is a reputable organization or company.

Place of work. Internship is usually off campus, similar to an off-campus job.

Where to Apply. Your faculty advisor and department chair may have information on internships. You can also search on the web for internships offered by large companies and public organizations in your area. In civil engineering, state departments of transportation and water companies usually have internship and job opportunities.

Keep a Record. As for Undergraduate Research Experience, you will benefit similarly to keep a record.

Many years ago internship was a part of the required curriculum for some civil engineering programs. At California State University, Northridge it is still required for one semester for the Construction Management program of the civil engineering department. This is possible because the program has a strong industrial advisory board, whose members have access to the resources needed to fund the internships for all students.

Co-Ops

Benefits. Cooperative Education (Co-Op) is a system for students to alternate full-time study and full-time work but not work and study at the same time. The work is related to their major. When students work full time, they are treated as regular full-time employees and have all the benefit of a real job. It is like a try-out for a permanent job, to experience what is in the future when they graduate. When students study full time, they are no different from regular full-time students taking a full load of academic work.

Duration. It could be one semester of work and one semester of study or as long as a full year of work before returning to study. Rarely does it go beyond one full year of work. If students find full-time work on their own, of course they may choose to work as long as they want, but they will run the risk of giving up on their academic study altogether. Without completing their civil engineering degree, they will suffer in the long run even though they may feel rewarded at the moment working full time.

Where to Apply. Usually the Co-Op program is part of the civil engineering degree program and is administered by the department and supervised by faculty. Some programs also award grades.

A modified version of Co-Op, practiced at the California State University, Northridge, is called the Honors Co-Op. Only students with a GPA of 3.0 or better and are taking senior-level courses can apply. The sponsors are companies and organizations who pay students for working full-time during summer and half-time during the semesters. It is a full-year program with designated faculty and industrial representative advisors for every student. Students receive grades at the end of each semester. It has been a popular program for over 40 years and the number of participating students is limited only by the availability of industrial sponsors.

Undergraduate Thesis and Independent Studies

Many years ago an undergraduate thesis was part of the required curriculum at most universities. Nowadays, some institutes offer it as an elective course. The demand on faculty time is significant and is similar to that of the undergraduate research experience, except a grade must be given at the end. The demand on a student's effort is also similar to that of the URE with additional commitment to write a thesis or a report (for independent studies).

Volunteering

By volunteering your time and effort you will gain knowledge of the work and nature of what you are volunteering for. You will make an impact on other people's lives and feel a sense of accomplishment. There are numerous opportunities on and off campus. When you first come to your campus to register, you may have been greeted by one or more students who guided you. They are volunteers usually called university ambassadors. Some universities have courses that require volunteering work as part of the academic content. Off campus, almost all charity organizations need volunteers. You are encouraged to join one according to your interest or faith.

Study Abroad

Benefits. By studying abroad students have the opportunity to explore another culture first hand and gaining a new perspective on their own culture. Students also learn to be independent and mature by managing their daily lives in a different world. Of course learning the use of another language is another benefit.

Duration. Usually studying abroad lasts for one year or shorter. Prolonged absence from the homeland is not advised.

Where to Apply. Many institutes now offer Studying Abroad (Education Abroad) programs that allow direct transfer of credits. The cost is reasonable and is often offset by scholarships or financial aid. There are also independent organizations specializing in study-abroad programs that you can easily find from a web search. You are encouraged to focus on your institute's program first and seek references and advice if you have to go off campus for study-abroad opportunities.

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An Overview of the Field of Civil Engineering

Sheng-Taur Mau

S. T. Mau earned his PhD in structural engineering at Cornell University. He was Dean of Engineering and Computer Science at California State University, Northridge. Dr. Mau has published widely on structural mechanics and earthquake engineering..

MOMENTUM PRESS ENGINEERING

cognella academic publishing
www.cognella.com 800-200-3908

ISBN 978-1-60650-710-0
90000
9 781606 507100