

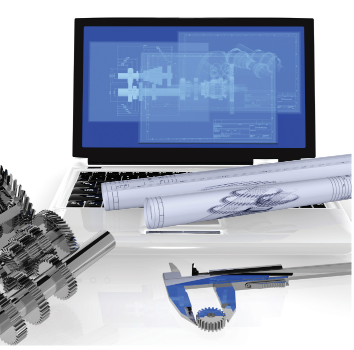

Becoming a Civil Engineer

Sheng-Taur Mau

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www.cognella.com

ISBN-13: 978-1-60650-712-4 (e-book)

www.momentumpress.net

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

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

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Preface

With its long history, civil engineering is associated with many famous landmarks and monuments, and stories of those who built them. Modern civil engineering development is marked by key milestones and the efforts of pioneers. Chapter 1 gives an account of the landmarks and milestones of civil engineering and the human story behind them.

Engineering Ethics is a required subject according to ABET, yet it is often difficult to include in other civil engineering courses. A treatment of the subject and a discussion on student ethics regarding academic honesty and student behavior in and out of classrooms are given in Chapter 2.

After the BSCE degree, there are many career paths open to the degree holder. A typical path is to work as a civil engineer. Some high-profile private companies and public agencies who hire civil engineers are described in Chapter 3. Opportunities for advanced studies in civil engineering are also described, as well as opportunities outside of the civil engineering profession. The PE (Principle and Practice of Engineering) exam, the final step before obtaining a professional engineer license, is described in some detail.

CHAPTER 1

Civil Engineering Landmarks and Legends

1.1 Overview

As civil engineering has always dealt with the basic needs of everyday life such as shelter and water, its history goes back to ancient times. Early designers and builders practiced trial and error and used experience accumulated in generations to achieve greatness, all without the benefit of modern science and technology. As described in this book, modern civil engineering is deeply rooted in the application of mathematics and science. While the genesis of mathematics and science can be traced back more than four thousand years, the main foundation for civil engineering is mechanics, which was developed only in the last five hundred years. Furthermore, civil engineering as practiced today is as young as the advent of the modern digital computer. In this chapter, some of the most famous landmarks and the most important people in the development of civil engineering, from ancient times to modern times, are described. Brevity necessitates the very selective inclusion of only a few American landmarks and legends when it comes to modern times. Ancient achievements from other cultures are included only for the most significant. Pictures of landmarks such as the Great Pyramid and all the others included herein are readily available on the internet and only a few are reproduced herein.

1.2 Ancient Monuments and Landmarks

The Great Pyramid. Of the Seven Wonders of the Ancient World around the Mediterranean rim described by Greeks 2,200 years ago (Great Pyramid of Giza, Hanging Gardens of Babylon, Temple of Artemis at Ephesus, Statue of Zeus at Olympia, Mausoleum of Maussollos, Colossus of Rhodes, and the Lighthouse of Alexandria), only the Great Pyramid of Giza in Egypt still stands today. Of the 100 or so pyramids built by the ancient Egyptians, the Great Pyramid of Giza is the grandest and tallest (146.6 m or 481 ft high). It is also called Khufu's Pyramid because it is the tomb of the Fourth Dynasty Egyptian King Khufu (2551–2528 B.C.).

Built around 2540 B.C., it is also the oldest and largest of the three pyramids at Giza near present-day Cairo, Egypt. Khufu's son Djedefre succeeded Khufu as pharaoh but reigned only eight years and was succeeded by another son of Khufu, Khafre, who built the second major pyramid at Giza. The Khafre Pyramid is not as tall as the Khufu Pyramid with a height of 143.5 m (470.8 ft). Khafre's son Menkaure built the last and the smallest of the three pyramids at Giza with a height of only 65 m (213.5 ft). All three pyramids at Giza are of similar design and construction and are a major departure from and improvement on previous pyramids.

Many scholars have studied the design and construction of the Egyptian pyramids. The latest book and the most comprehensive, published in 2004, entitled *How the Great Pyramid Was Built*, authored by Dr. Craig B. Smith, provides numerous new findings. Dr. Smith is an experienced engineer, a construction executive, and former president of a major global engineering, architecture, and construction company, in addition to being a well-known scholar on pyramid construction. His book provides the main source for much of the descriptions herein.

The evolution of pyramid design and construction can be summarized in the three different types of pyramids preceding the Khufu Pyramid: The Step Pyramid (2620 B.C.), The Bent Pyramid (2565 B.C.), and the Red Pyramid (2560 B.C.), as shown in Figure 1.1.

The step pyramid is named for its shape. At a height of 60 m, it presented an advance in building stone structures to greater heights at the time. It was built for the Third Dynasty pharaoh Djoser, who reigned from 2635 to 2610 B.C., by his chief architect Imhotep. The Bent Pyramid was built by the first pharaoh of the Fourth Dynasty, Sneferu. He reigned from 2613 to 2589 B.C. It was built on sandy desert soil, the bearing capacity of which was not enough to support the originally designed mass of the pyramid with an inclination angle of 54.5 degrees. Subsidence was observed during initial construction. Consequently

Figure 1.1 The Step (Left), Bent (Middle), Red (Right) pyramids

approximately one-third of the way up, the inclination is bent inward to an angle of 43 degrees, thus the name Bent Pyramid. The Red Pyramid, named for its red-pink limestone, was built by the same pharaoh Sneferu who apparently was seeking an improved new pyramid from the Bent Pyramid. It was built on a better foundation. The builders placed the king's burial chamber above the ground and in the body of the pyramid for the first time. The success of the Red Pyramid paved the way for the Great Khufu Pyramid, built by Sneferu's son Khufu. The Khufu Pyramid was built on a leveled strong rock base at a new site outside today's Cairo. Its King's Chamber and Queen's Chamber are located high in the body of the pyramid.

The present-day Khufu Pyramid has a height of 138.8 m (455 ft), which does not represent its original height because of erosion and its missing capstone, the pyramidion. The measurements done in 1880–1882 by the English Egyptologist Flinders Petrie (1853–1942) and later studies published in his book *The Pyramids and Temples of Gizeh*, in 1883, point to an original dimension of 280 cubits in height and 440 cubits in length at each of the four sides of its base. The cubit is an ancient Egyptian length unit that may have inspired the later English unit "foot," because a cubit was defined as the length of pharaoh's arm measured from his armpit to the farthest tip of his fingers. Numerous cubit rods were excavated and it was determined at Khufu's time that one cubit is equivalent to 0.524 m (20.6 in). Thus the original height of the Khufu Pyramid was determined as 146.6 m (481 ft) and its base was 230.4 m (756 ft)

Figure 1.2 The Great Khufu Pyramid

and its side faces inclined with an angle of 51.9 degrees. It is interesting to note that the base-to-height ratio of 440/280 = 1.571 is identical to $\pi/2=1.571$. Is this a mathematical coincidence or by design? Another mathematical coincidence/by-design pointed out by the Greek historian Herodotus in 450 B.C. is that the square of the height of the pyramid is equal to the area of each of the inclined faces of the four triangles. The enormity of the size of the base can be put in perspective by comparison to the standard football field in America: The size of the base of the Khufu Pyramid is close to the area of ten football fields. The height of 146.6 m held the world's height record for 4,300 years until the erection of the 169 m-high Washington Monument in 1885. Another interesting feature is the heights of the 218 courses (layers) are not constant. At the base, the height is 1.49 m (59 in). It generally becomes smaller going up, though it spikes up at irregular levels and then trends down. At the highest level it is less than 0.5 m (19.7 in).

Dr. Craig Smith described survey and measuring tools developed by the ancient Egyptians. Using the tools of their times, the builders of Khufu Pyramid achieved astounding precision. The four corner angles of the square base are off from a perfect 90 degrees by no more than 0.06 degrees. In fact two of the four corner angles are equal to a perfect

90 degrees. The four base lengths deviate from the average of 230.4 m (756 ft) by no more than 0.11 m (4.3 in).

The number of stone blocks is 2.2 million for internal core stones and 98,000 for casing stones, the exterior face stones. The weight of the internal blocks ranges from 1,359 kg to 14,656 kg (1 kg = 2.2 lb) according to Dr. Smith's computation. The transportation and placement of these heavy blocks and the time needed to complete the project has been the subject of numerous studies and speculations. Some even ventured the theory that extraterrestrial visitors must have been the source of advanced technology unknown to the Egyptians at the time. Considering all the available tools and knowledge of the Egyptians, Dr. Smith convincingly concluded that a multi-ramp approach in combination with tools to move large weights explains the way to raise the stone blocks to their spots in the pyramid. He also estimated that the project required a permanent work force of 4,655 including direct labor such as stonemasons, brick-makers, carpenters, foundry men, tool sharpeners, surveyors, rope makers, painters/artists, sculptors, and indirect labor such as supervisors, overseers, scribes and clerks, cooks, bakers, brewers, stevedores, warehouse workers, doctors and priests, and security were needed at the time, which was definitely achievable by the Egyptians. A detailed construction schedule, including all phases of a construction project worked out by Dr. Smith, shows that the Khufu Pyramid could have been completed in about ten years. His "optimal" scenario would require, at its peak demand of laborers, an additional 21,000 temporary workers to assist the quarry workers, and move stones to the site and onto the pyramid.

The Khufu Pyramid was covered with white limestone casing blocks with inclined outer surfaces when it was finished. Today one can only imagine what a magnificent sight a shining white monument, standing above the desert horizon, must have been; only the top one-third still has the casing stones mostly in place.

While Khufu was the king who commissioned the Great Pyramid, the man most responsible for the design and construction of the pyramid was Hemiunu, a cousin of Khufu. His title, roughly translated, was Master of Work and Vizier. His importance can be indicated by the site of his own tomb. Discovered in 1912, his tomb was located in the west cemetery behind the pyramid and one of the largest in the cemetery. His tomb

Figure 1.3 Entrance (Left), Corbel-Arched Gallery (Middle), and Statue of Hemiunu (Right)

contained a life-sized sitting stone statue of him. The statue is now in the Roemer and Pelizaeus Museum in Hildesheim, Germany.

The Great Wall of China. While the Egyptian Pyramids were built to honor the dead rulers, the Great Wall of China was built for a more practical purpose: to defend against the invasion of northern nomadic tribes, although its effectiveness was marred by the frequent success of the northern invaders in crossing the wall throughout the ages ever since the wall first appeared around or before the fifth century B.C. There is a famous story about a tyrant around that time amusing his favorite concubine by falsely raising fire on the watchtowers to summon the troops to the capital. The watchtowers are part of the great wall system, which consists of long stretches of earthen or brick walls dotted by the towers. When northern invaders were spotted, the defenders would fire up the camel dung from the watchtowers. Legend has it that the smoke from camel dung could be seen from afar. One tower after another signaled the invasion until the news reached the central government for urgent action. That was the defense system set up by the ancient Chinese. The Great Wall is one of the Seven Wonders of the World and was declared a UNESCO World Heritage site in 1987.

History books also described the human sacrifices in building the wall, especially during the reign of the First Emperor of China around

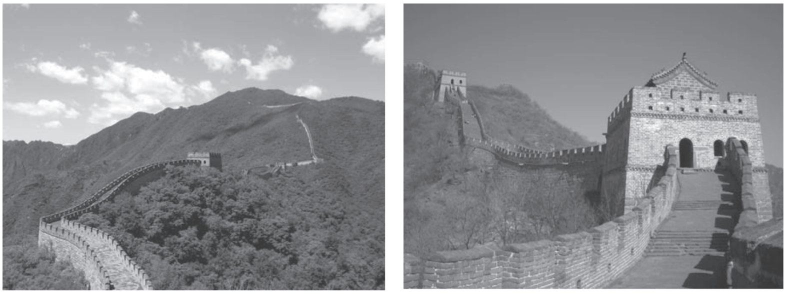

Figure 1.4 The Great Wall of China (Left), The East End (Right) at Shanhai Pass

Source: http://en.wikipedia.org/wiki/File:Great_Wall_of_China_July_2006.JPG. Copyright in the Public Domain.
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221 B.C. when he unified the Warring States into a single central government, the Qin dynasty. The present-day name of "China" was derived from "Qin." He destroyed several existing walls separating the formal warring states and built a new northern wall. Later dynasties built new walls connecting existing walls. There are large local loops of walls, presumably for the defense of local areas, connected to the long stretch of walls. The present-day Great Wall is believed to have been completed during the Ming dynasty around the year 1450 A.D. It stretches from the eastern seaboard of China just northeast of the present-day capital, Beijing, to the west, through Inner Mongolia, and ends in the western reaches of the Gansu province.

The wall was "great" because of its extraordinary length. Ironically the question of how long the great wall is does not have a definitive answer. According to the famed scholar on Chinese Science and Technology, Joseph Needham (*Science and Civilization of China*, Volume 4, Part 3. Civil Engineering and Nautics, Cambridge University Press, 1971), the main line of the Great Wall has a length of 2,150 miles (3,060 km) and the loops have a length of 1,780 miles (2,864 km), adding up to 3,930 miles (5,944 km). Since Needham's time, new discoveries and measurements (using GPS) were made. Today, the total length of the Great Wall is reported as 5,500 miles (8,851 km). See *Sydney Morning Herald*, April 20, 2009 (www.smh.com.au). But in 2012, a five-year archaeological survey, done by the Chinese State Administration of Cultural Heritage (SACH), found that the total length of the Great Wall was 13,170 miles and reached across 15 provinces (http://abcnews.go.com/blogs/headlines/2012/07/great-wall-of-china-longer-than-previously-reported/).

The body of the wall is made mainly from compacted earth. The walls built during the Ming Dynasty are stronger with the generous use of bricks and stones at its base and at the outer layers. A typical section of the wall has a height from 6 to 10 m (20 to 30 ft) and a base width of 8 m (25 ft). The watchtowers are wider (roughly 50% more) and taller (roughly 40%–60% more).

The Roman Aqueducts. The Romans built aqueducts throughout its empire to supply water to its cities. An aqueduct is a channel/bridge that was built to convey water from one place to another. The most famous are the eleven aqueducts built from 312 B.C. to 226 A.D. for the City of Rome with a total length of 418 km (260 miles). The longest was 95 km (59 miles). The construction of these aqueducts required careful planning and engineering. When the water reached the city, it was temporarily gathered at large pools and distributed to the emperor, sold to rich citizens, and provided free to the public through the numerous fountains. The water was not stored. Any excess was used to flush out sewers.

As only gravity was used to drive the water, the aqueducts were built with a gentle grade of about 1/200 throughout their entire lengths. Although pictures of Roman aqueducts often show magnificent arch construction, less than 10 percent, 47 km (30 miles), of Rome's 418 km aqueduct system crossed over valleys on raised stone arches. Most of the rest ran through underground conduits made mostly of stone and terra cotta pipes. The above-ground channel itself was about 1 meter wide (3 ft.) and 2 m high, allowing a man to walk through. It is estimated that the water supplied to Rome on daily basis was sufficient to provide for a population of one million. Such a vast aqueduct system requires constant maintenance. The Roman had an appointed official, Curator Aquarum, to oversee the maintenance.

The Roman aqueduct system was the grandest in ancient times, but it was not the first. Similar systems were built earlier in ancient Persia, India, Egypt, and other Middle Eastern countries. While the Roman aqueduct began to deteriorate around the 4th and 5th centuries, other similar systems were built throughout that time. Modern aqueducts are longer in length and larger. New York City uses three main aqueduct systems to supply 1,800,000,000 gal (6,800,000,000 liters) of water a day from sources 190 km (120 miles) away. The largest aqueduct system in the world is the famous California Aqueducts.

California Aqueducts. The aqueduct system in the state of California is by far the largest in the world. There are three main systems: Owens River Aqueduct (LA Aqueduct), Colorado River Aqueduct, and the Governor Edmund G. Brown California Aqueduct. They were designed to provide water for municipal and agricultural uses in Southern California.

Owens River Aqueduct: Also referred to as Los Angeles Aqueduct, the Owens River Aqueduct transports water from the central valley of California to the City of Los Angeles. The project started in 1907 and its initial phase was finished in 1913. The aqueduct ran 373 km (232 miles) from an intake at Independence, CA, through mountainous desert to Owensmouth in the San Fernando Valley, the northern part of the City of Los Angeles. It includes 24 miles of unlined canal, 37 miles of lined canal, 98 miles of pipe conduit, 43 miles of lined tunnel, and 12 miles of steel inverted siphons. Since 1913 the aqueduct has been extended northward another 100 miles to reach additional sources of supply. (See *Historic Civil Engineering Landmarks of Southern California*, by William Myers, The History and Heritage Committee, Los Angeles Section, ASCE, 1974.)

Figure 1.5 Tarragona Aqueduct, Spain (Left), Tarragona Aqueduct, Spain view from the top (Right)

Figure 1.6 Water entering the LA Aqueduct (Upper Left); LA Aqueduct Cascade (Upper Right);Parker Dam, Arizona of the Colorado Aqueduct (Lower)

Colorado River Aqueduct: The work for Colorado River aqueduct started in 1932 and was completed in 1941. Its 389 km length (242 miles) runs from the Parker Dam near Lake Havasu City, Arizona, to Lake Mathews in western Riverside County of Southern California, through some of the worst desert and mountainous terrain. It has 5 pumping plants and delivery lines, 148 km (92 miles) of tunnels, 101 km (63.9 miles) of canal, 88 km (54 miles) of cut-and-cover conduits, and 44 km (27 miles) of inverted siphons.

The Owens River Aqueduct and the Colorado River Aqueduct provide the water consumed by the City of Los Angeles and the surrounding areas not only for municipal uses but also for agricultural uses. The man most responsible for the two aqueducts was **William Mulholland** (1855–1935). Mulholland was born in Belfast, Ireland. He became a sailor and came to America in the 1870s, and worked in various jobs before moving to the Los Angeles area. In 1887 he began his work as a ditch cleaner for the private water company of Los Angeles. He rose through the ranks to become the superintendent of the company in eight years. When Los Angeles took over the company in 1902 and formed the Department of Water and Power, he was retained as its head, a job he held until 1928. During his tenure, the Owens River Aqueduct was built, not without political maneuver and deceit. The controversial story of his political endeavors was used as the background for the 1974 Oscar-winning movie *Chinatown* (for Best Writing, Original Screenplay). In 1923, he recommended a survey to investigate the feasibility of transporting water from the Colorado River to Southern California. That investigation eventually led to the construction of the Colorado River Aqueduct. Today, a major street in Los Angeles is named after him, so are a middle school and the William Mulholland Memorial Fountain in Los Angeles.

California Aqueduct (Governor Edmund G. Brown California Aqueduct): Started in 1960, the 714 km (444 miles) aqueduct is the world's largest. The aqueduct begins at the San Joaquin–Sacramento River Delta in northern California and flows south. It has three branches serving the central coast, central valley, and southern California. A typical section is concrete lined, 12 m (40 ft) wide at the base, with an average depth of flow of 9 m (30 ft). The system has 20 pumping stations, 130 hydroelectric plants, and more than 100 dams and flow-control structures.

Du-jiang-yan Water Conservancy Project. The Du-jiang-yan Water Conservancy Project consists of a system of hydraulic engineering constructions initially built around 256 B.C. in today's Sichuan Province of China, on the Min River upstream from the provincial capital of Chengdu. It is still in use today providing water for irrigation and municipal consumptions for an area of 6,687 km^2 (1.6 million acres) in 40 counties, roughly the size of the state of Delaware. It is the world's oldest and largest water conservancy project.

Figure 1.7 The California Aqueduct

Figure 1.8 The Du-jiang-yan Weir (Left) and the Fish Mouth Levee (Right)

In ancient China, the Min River, a large branch on the upper reaches of the Yangtze River, was an annual flood hazard for the people living on the Chengdu Plain. By 256 B.C. during the Warring States period of China, the Kingdom of Qin allocated funding to the Head of the Sichuan Province, Li Bin, to solve the irrigation and flooding problem. Li and his son, working with local farmers, completed three major projects

(Treasure Bottle Pass, Fish Mouth Levee, and Flying Sand Weir) in 14 years that forever eliminated the annual flooding problem and made Sichuan the "rice warehouse" of the region for more than 2,200 years. The three projects Li and his son completed achieved automatic river flow diversion, automatic flow control, automatic flushing, and flood elimination. The father-and-son team established easy-to-follow rules to keep the irrigation channels downstream open and functional. These rules were followed through the ages and even today. Thus, the Li team achieved this great water conservancy project over two thousand years ago by innovative design, construction, and operation/maintenance very much in sync with modern practices.

The Du-jiang-yan project was a tourist attraction throughout the ages. During the reign of the Mongolian Emperor Kublei Khan (1264–1294 A.D.) of the Yuan Dynasty, the famed Italian traveler Marco Polo visited the project site by traveling on horseback for twenty days from the northern province of Shaanxi. In his book *Travels of Marco Polo*, he wrote "The Du-jiang river system has rapid flow, abundance of fish, many boats carrying commerce go up and downstream."

The May 12, 2008 Wenchuan Earthquake of magnitude 7.9 struck the Du-jiang-yan area but incurred only minor damage to the project. In fact the project was among the first to reopen to tourists.

The Grand Canal of China. The world's oldest and longest canal is the Grand Canal of China. It is also called the Jing-Hang Grand Canal because it connects Beijing in the north and Hangzhou in the south. Its total length is 1,774 km (1,102 miles). The beginning of the canal can be traced to more than 2,600 years ago but it was completed to its present-day length about 800 years ago. The main work of the canal was credited to Emperor Yang of the Sui dynasty, who started the work around 600 A.D. He was also blamed for the excessive taxing of his citizens to support the canal project.

The canal is connected to five major river systems of China, including the Yellow River and the Yangtze River. Joseph Needham's study showed that at the end of the 19th century, there were 13 sections in the canal system with water depth varying from 3 m (10 ft) to 16 m (49 ft) (*Science and Civilization of China*, Volume 4, Part 3. Civil Engineering and Nautics, Cambridge University Press, 1971).

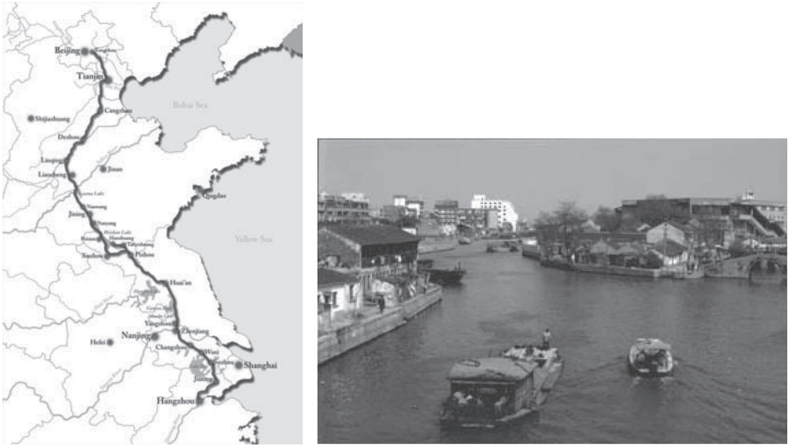

Figure 1.9 Modern Course of the Grand Canal (Left) and one southern section (Right)

For centuries, the canal was the main conduit to ship rice and goods from the abundant south to the political center in the north. The annual tribute (tax) of rice directly supported the imperial court and its officials. The importance of the canal waned in the late 19th century with the opening of railways and sea lanes.

Today, the canal is integrated with the other river systems of China to provide irrigation and for commerce shipping. Ships with tonnage of 500 or below can navigate the southern 660 km yearlong. Seasonal navigation extends to 1,100 km. Ongoing improvement will allow 1,000-ton ships to navigate the southern 60% of the canal by 2015.

Ancient Arch Bridges. The Romans were credited for building arch bridges, although corbel-arch bridges more than 3,000 years old were found in Greece. There were many different types of ancient arch structures. We shall explore only three.

The corbel arch is the easiest to construct. The weight of the construction and the load introduces tension in the arch, limiting its applications to creating narrow passageway underneath or to extend over small spans. It has been in use since Egyptians built their pyramids.

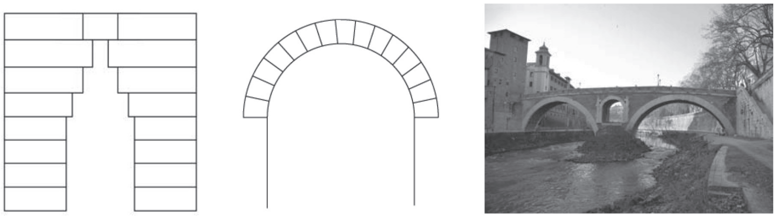

Figure 1.10 Corbel Arch (Left), Round Arch (Middle), and the Pons Fabricius Bridge in Rome (Right)

Romans used semicircular arches, in which the load was transmitted to the abutments through compression. Its span is limited to the radius of the semicircle.

To widen the span, the segmental arch, using part of the semicircle, was created. When the span-to-rise ratio becomes larger, however, more regions in the arch would be under tension. Thus, the art of construction is to balance the need for larger span and the need for limiting tension. The Pons Fabricius Bridge in Rome, Italy, is the world's oldest segmental arch bridge still standing today. It has two nearly identical spans, with the larger span at 24.5 m (80 ft). It was built in 62 B.C. Although it is segmental, it is very close to semicircular with a span-to-rise ratio of 2.4.

The Zhaozhou Bridge is the world's first stone open-spandrel segmental arch bridges, built around 610 A.D. in northern China. It has a span of 37.31 m (122.4 ft) and a rise of 7.23 m (23.7 ft), resulting in a span-to-rise ratio of 5.12:1 (*History of Ancient Chinese Bridge Technology*, by Yisheng Mao, Ming Wen Book Co., Ltd, Taipei, Taiwan, 1991, In Chinese). The main span is built with 28 pieces of limestone narrow blocks connected by iron dovetails. On each side there are two open smaller arches. Because of this design the bridge has survived numerous natural disasters such as flooding and earthquakes for more than 1,400 years. It is now a tourist attraction and a protected cultural heritage site. After Zhaozhou Bridge, the spandrel-arch design appeared in many 12th-century Chinese bridges, but it did not appear in Europe until the 14th century. The Zhaozhou Bridge stands today as one of the international landmarks recognized by the American Society of Civil Engineering.

Figure 1.11 The Zhaozhou Bridge in China

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

1.3 Modern Landmarks

The Brooklyn Bridge. When the Brooklyn Bridge, spanning the East River between Manhattan and Brooklyn, was completed in 1883, it was the longest bridge in the world, the first in using pneumatic caissons to build its foundation, and the world's first steel cable suspension bridge. Its 486 m (1596 ft) span was barely surpassed in 1903 by the nearby Williamsburg Bridge (488 m/1600 ft), also connecting Manhattan and Brooklyn.

The engineering achievements of the Brooklyn Bridge cannot be told without mentioning the human story of the three people most responsible for its design and construction: John, Washington, and Emily Roebling. **John Augustus Roebling** (1806–1869) was educated as a civil engineer at the Royal Polytechnic School of Berlin, Prussia (later Germany). He immigrated to the new world in 1831 and bought a tract of land west of Pittsburg, Pennsylvania, and started a farm community that he named Saxonburg. In 1837 he was appointed the engineer of the Pennsylvania Canal project. He developed steel-wire-rope technology

Figure 1.12 Brooklyn Bridge viewed from Brooklyn, with downtown Manhattan as a backdrop

Source: http://en.wikipedia.org/wiki/File:Brooklyn_Br%C3%BCcke.jpg. Copyright in the Public Domain.

and found its first application at the Allegheny portage canal project in 1842. By 1844, the John A. Roebling Company built a suspension aqueduct across the Allegheny River. The Roebling wire rope was a huge success and was used in the first Otis elevators in 1862. Between 1844 and 1957, Roebling built five suspension bridges in Pennsylvania and New York using his wire ropes. Legend has it that in 1852 when John and his eldest son **Washington**, then 15, were waiting for the ferry to take them from Brooklyn to Manhattan, his vision of a suspension bridge crossing the East River was formed.

Brooklyn was then a separate city. The only means of crossing the East River was through ferry, the operation of which was weather dependent and dangerous. Roebling's campaign for a bridge was approved in 1866 when the New York State Legislature passed a bill for the construction of the Brooklyn Bridge. John Roebling was appointed chief engineer of the Brooklyn Bridge in 1867. Roebling's design of the bridge was mostly completed in 1869. One day in July an incident at the Fulton ferry slip in Brooklyn crushed one of his feet. The injury and the ensuing infection claimed his life after only 16 days. The Brooklyn Bridge project was now in jeopardy, having lost its designer and chief engineer. His son Washington Roebling came to the rescue.

Washington Roebling got his civil engineering degree from the Rensselaer Polytechnic Institute in Troy, New York. He assisted his father in several suspension bridge projects before joining the army in 1960. During the Civil War, he participated in the Battle of Gettysburg. After the war he worked with his father on the Cincinnati-Covington Bridge (now the John A. Roebling Suspension Bridge). This experience turned out to be critical to his later responsibility with the Brooklyn Bridge. By 1868 he was appointed assistant engineer of the Brooklyn Bridge project. He was appointed chief engineer 17 days after his father's death, at the age of 32.

Washington immediately went to work and finalized the details of the pneumatic caisson. The construction began in January, 1870, and the Brooklyn-side caisson was launched in March. The wooden caisson was a huge rectangular (168 ft x 102 ft) inverted box of 14.5 ft depth. Its top was 15 ft thick and made of yellow pine. (See *The Builders of the Bridge: The Story of John Roebling and His Son*, by D.B Steinman; Harcourt, Brace and Co., Inc., 1945.) As the caisson was lowered, the tower of the bridge was constructed layer by layer. Workers went down to the river bed through two pressurized access shafts and excavated the river bed rock and soil to be raised to the top through two water shafts. The Brooklyn caisson reached the solid-enough bed at 44.5 ft depth and was completed in March, 1871 after its launch a year earlier. The New York-side caisson was launched in May, 1871. Although it was also completed in one year, its progress was agonizing for Washington. It went down without reaching any significant support until 78 ft below the water level. After carefully investigate the soil strength, Washington decided the bearing capacity was sufficient and there was no need to go further. His decision turned out to be correct, but at the time it also had a lot to do with the disease that workers suffered and he also suffered. Because the workers were in a pressurized environment for extended time and did not know at the time that they needed to come up slowly, they suffered the diver's disease, called "the bends" then. Several died. Washington spent more time in the caisson than any of his assistants and in 1872, he was so ill that he no longer had the strength to go to the site. Again the Brooklyn Bridge project was in jeopardy. His wife, **Emily**, came to the rescue. From that point on, he directed the construction from his residence in Brooklyn through Emily. Although not an engineer by training, Emily, through sheer determination and intelligence, was able to communicate effectively with the construction team to carry out Washington's directives in every detail.

The Brooklyn and New York towers were completed in 1875 and 1876, respectively. In August 1876, the first wire was passed between the two towers. The Brooklyn Bridge has four main cables, each with a diameter of 15.75 in., consisting of 19 strands. Each strand in turn contains 286 steel wires. Washington, in order to strengthen the bridge, added 400 diagonal stays, connecting the bridge deck structure to the two towers. The diagonal stays and the 1,520 suspenders (connecting the cables to the deck structure) create a unique appearance of the bridge. (See *The Brooklyn Bridge: They Said It Couldn't Be Built*, by Judith St. George, G.P. Putnam's and Sons, New York; 1982.) The manufacturing and placing of the cables and the construction of the bridge deck would take seven more years. When it was opened in May 1883, 14 years had passed since the construction began. On opening day, President Chester Arthur attended the ceremony and Emily Roebling was given the honor of being the first to cross the bridge by carriage.

The Brooklyn Bridge is still the world's 73rd-longest bridge and a major tourist attraction. The Brooklyn Bridge became a symbol of the triumph of the human spirit.

The Golden Gate Bridge. The record of the world's longest span bridge was broken in 1937 when the 4,200 ft (1,280 m) span Golden Gate Bridge was completed.

The need for a bridge to cross the Golden Gate between the northern tip of the San Francisco Peninsula and Marin County to the north was similar to that for the Brooklyn Bridge. Ferry was the only means of

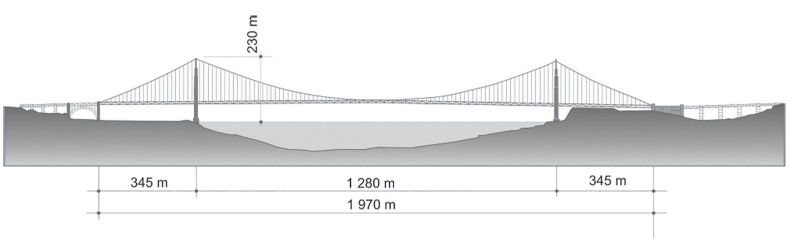

Figure 1.13 The Golden Gate Bridge

crossing the bay. By 1928 over 2 million automobiles used the ferry service. The overcrowding reached a crisis when traffic from Sausalito at the north had to wait until Tuesday morning to return to the city following a long Labor Day weekend.

The call for a bridge can be traced back to 1869 but little attention was given to the idea until 1916 when a newspaper reporter and a former engineering student by the name of James Wilkins began a campaign for the bridge. His effort eventually prompted the city engineer Michael O'Shaughnessy to solicit design proposals from three engineers in 1920. Only Joseph Strauss responded with a design involving a combination of a cantilever bridge and suspension bridge. Strauss was born in Cincinnati, Ohio, in 1870 and raised in the shadow of a suspension bridge in Cincinnati designed by John Roebling. At 1,057 ft (322 m) it was proclaimed to be the longest bridge when it was opened in 1866. Legend has it that this bridge by Roebling inspired Strauss to be a bridge engineer. He graduated from the University of Cincinnati and entered a career as a bridge

Figure 1.14 The Golden Gate Bridge viewed from the Marin Headlands

designer. He was credited for the design of many draw bridges. Strauss eventually became the chief engineer for the Golden Gate Bridge.

By 1930 Strauss's original design was changed to involve only a single suspension bridge. The structural design was credited to his senior engineer **Charles Ellis**. Ellis was a maverick, and taught engineering at University of Illinois before he obtained a civil engineering degree at the university. No other bridge's construction was more celebrated than the Golden Gate. When its official groundbreaking took place in February 26, 1933, a parade was held and a congratulatory telegram from President Hoover was read. The two towers were constructed using steel members riveted together and its height of 746 ft (224.7 m) is still the highest in U.S. among bridge towers. Two steel cables, each with a diameter of 35 in. (55 cm), span over the bridge. Each cable has 61 strands and each strand has 452 steel wires. Thanks to Strauss's invention of putting a running safety net under the cables, the construction had the best safety record in bridge construction with only eleven deaths; ten of whom fell onto the net and broke through.

The opening of the bridge was no less ceremonial, with two official opening days. May 27, 1937 was for pedestrians and May 28 was for auto mobiles. The Golden Gate Bridge has another first: the first to institute a toll system that collects tolls only one way. This does not reduce the revenue because it simply collects double the amount. The Golden Gate Bridge still ranks 9th in the world for its long span, but its fame surpasses all the other bridges.

The Verrazano-Narrows Bridge. Perhaps one of the least-known major suspension bridges in America is the Verrazano-Narrows Bridge, despite the fact that it is still the longest suspension bridge in America and ranked 8th in the world with its 4,260 foot (1,298 m) span. The bridge crosses the Narrows that separate Upper New York Bay from Lower New York Bay at the south end of the Hudson River, and connects Staten Island to Brooklyn. It was named after the Italian explorer Giovanni da Verrazano (1485–1528), who was the first European navigator to enter New York Harbor and the Hudson River.

When it was completed in 1964, the Verrazano-Narrows Bridge took away the world's longest suspension bridge title from the Golden Gate Bridge. It was the work of the famed Swiss-American bridge designer

Figure 1.15 Verrazano-Narrows Bridge at Night from Brooklyn

Othmar Ammann (1879–1965). Educated at the Federal Technological Institute in Zurich (Switzerland), Ammann immigrated to the U.S. in 1904 and worked on bridge design. Among his great achievements in bridge design are the George Washington Bridge and the Verrazano-Narrows Bridge. His bridges are known for their simplicity in shape. In 1946, he and Charles S. Whitney co-founded Ammann and Whitney, a design firm that to this day still specializes in bridge design and rehabilitation. Another legendary name associated with the Verrazano-Narrows Bridge is **Robert Moses** (1888–1981). As the New York State Parks Commissioner and head of the Triborough Bridge and Tunnel Authority, Moses oversaw the Verrazano-Narrows Bridge project (*Robert Moses and the Modern City: The Transformation of New York*, edited by Hilary Ballon and Kenneth T. Jackson). Moses was credited as the "Master Builder" for New York during the 1930–1950 period.

The Empire State Building. When the 102-story Empire State Building was opened on May 1, 1931, it was the world's tallest structure. The roof ends at a height of 1,250 ft (381 m) but the mooring mast/antenna extends to a height of 1,472 ft (448.7 m).

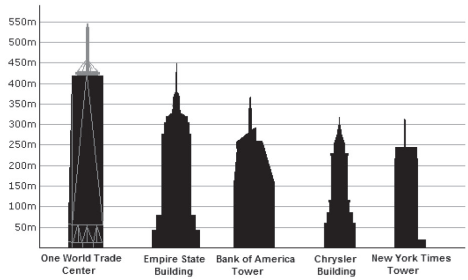

Figure 1.16 The Empire State Building seen from Brooklyn (Left), Height comparison of New York City Buildings (Right)

From the outset the Empire State Building was meant to be the world's tallest. It was the brainchild of Al Smith and John Raskob. Born to Irish immigrant parents in 1873 in the shadow of the Brooklyn Bridge, Smith began working odd jobs at the age of 15. At 22 he was appointed as a subpoena server for the commissioner of jurors. He was elected to the New York State Assembly at 30. He became a reformer in political circles and fought for social legislation such as workers' compensation and limiting working hours of women and children. He was elected governor of New York in 1918. He was a flamboyant and charismatic politician with an amazing memory and grasp of details. His tenure as governor coincided with the prosperous years after the end of World War I. In 1928 he was the Democratic Party's nominee for president but lost the campaign to the more conservative Herbert Hoover. After the defeat, he teamed up with John Raskob and launched the Empire State Building project. Raskob had similar humble beginnings to Smith. Born in 1879 in Lockport, New York, he worked as a bookkeeper for Pierre S. du Pont at the age of 21. Three years later, he became the assistant to Pierre when Pierre became the treasurer of the E.I. du Pont de Nemours & Co. He had the vision that the automobile industry would be important and persuaded du Pont to invest in General Motors. Soon du Pont became a major stock holder and GM chairman, and Raskob the vice president and chairman of the finance committee of GM. He was the man who created the General Motors Acceptance Corporation (GMAC), providing credit to buyers. How he teamed up with Smith on the Empire State Building project was a matter of various legends. (*Empire State Building: The Making of a Landmark*, by John Tauranac, published by Scribner, 1995.)

On August 29, 1929 the Empire State Building project was made public. By December, Smith announced that the building would be 1,250 ft high, more than 202 ft higher than the Chrysler Building, then still under construction. Furthermore, the opening date was set as May 1, 1931, a date chosen for commercial considerations. May 1 is the traditional starting date for renting contracts. To meet the deadline, the architecture firm of Shreve, Lamb and Harman and the contractor Starrett Brothers and Eken worked swiftly to start design and construction planning. The resulting design was a simple, elegant, slender building with steel girders and columns. The site was in lower Manhattan where the bedrock was strong enough to support a massive high-rise. At the basement level, 210 steel columns rose upward from simple footings sitting directly on the bedrock. Twelve of the 210 columns would rise all the way to the top, while others were terminated at different levels where moderate setbacks were made.

Careful planning by the designer and contractor resulted in an amazing speed of construction. The girders and column sections were made to one-eighth-inch accuracy at the American Bridge and McClintock-Marshall plant in Pittsburgh, shipped to a staging yard in Bayonne, New Jersey, to be marked for its final location in the building, and then sent to the construction site to be immediately erected. The whole process took only 80 hours for most sections. The resulting speed was four and a half stories per week while workers worked only five days a week and seven and half hours a day. By November 1930, the mooring mast at the top of the building was in place. Five more months were used to finishing up the exterior walls, windows, and other details.

On May 1, 1931, the Empire State Building was open. Smith's granddaughter cut the ribbon. President Hoover interrupted his cabinet meeting to switch on the lights of the Empire State Building from the White

House. The Empire State Building was conceived during the last stretch of the prosperous 1920s but opened in the depth of the Great Depression. The occupancy of the building was so low that it was ridiculed as the Empty State Building. More than 80 years and many renovations (new elevators, air conditioning systems, etc.) later, the building is now fully occupied and stands as the symbol of American ingenuity and can-do spirit. Tourists around the world flocked to its observation decks on the 86th floor and the 102nd floor. Despite new highs reached by other high-rises in the Middle East and Far East, the Empire State Building remains the world's most famous building.

The Sears (Willis) Tower. When the Sears Tower was completed in 1973, it was the tallest building in Chicago, the tallest in North America, and the tallest in the world. Its roof ends at a height of 1,451 ft (442 m). Two antennas were added later that extended to a height of 1,730 ft (527 m).

The Sears Tower was planned to be the new headquarters to house the 13,000 employees of Sears Roebuck and Co. in Chicago. It was designed by the famous architect-structural engineer team of Bruce Graham and **Fazlur Khan** of the architecture firm of Skidmore, Owings and Merrill. The basic structure of the building would be a system of steel-framed

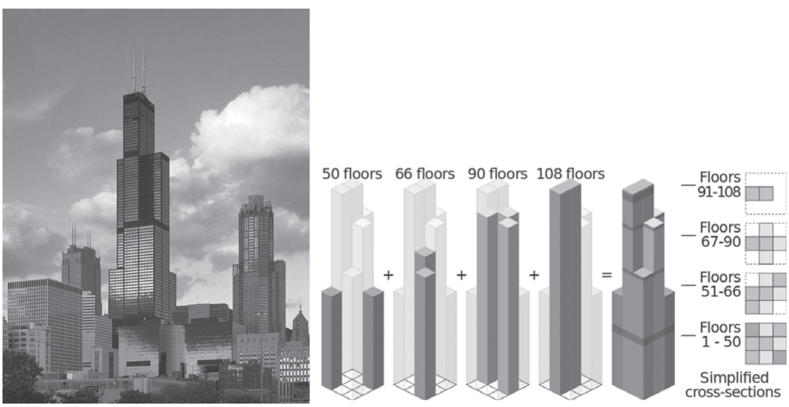

Figure 1.17 The Sears Tower (Left), Tube Structure with Simplified Floor Plans (Right)

Source: http://en.wikipedia.org/wiki/File:Sears_Tower_ss.jpg.

tubes. Fazlur Khan was credited as the first to use a tubular design for tall buildings. Educated at University of Dacca in Bangladesh and University of Illinois, Urbana-Champaign, Kahn became a leading tall-building structural engineer by the late 1960s.

The tubular structure Graham and Khan came up with for the Sears Tower has nine square tubes, each 75 ft × 75 ft (22.9 m × 22.9 m). Each side of the tube is not a solid wall but consists of six equally spaced columns. Not all tubes go all the way to the top. Two tubes were terminated at the 50th and 66th levels, respectively, and three more were terminated at the 90th floor. Only two rise to the full height. The figure below shows the cross-section at different floors.

Because of limited street access in a busy city, the manufacturing and transportation of the steel beams and columns were carefully planned. Two horizontal members of 15 ft (4.6 m) and a vertical member of 25 ft (7.6 m) were prefabricated into a module, nicknamed "Christmas tree," and shipped to the site immediately before being welded into the building frame. This process eliminated the need for any on-site storage and quickened the pace of construction.

The Sears Tower changed its ownership in 2009 and was renamed **Willis Tower**. A new glass-bottom sky-deck was added in 2009 on the 103rd floor and became an instant hit for tourists.

In May 2013 the 104-story One World Trade Center, built at the original World Trade Center site in New York City, became the tallest building in America when its 18-piece silver spire topped out the tower at 1,776 feet, symbolizing the year The Declaration of Independence was signed.

The Hoover Dam. The Hoover Dam on the Colorado River is the most famous dam in the world. When it was completed in 1936, during the Great Depression, it was number one in hydropower generation in the nation with its 1,434 megawatt capacity and was also the highest dam at 221 m (725 ft). The lake the dam created, Lake Mead, is still the largest artificial lake in the nation. The Hoover Dam is a gravity-arch dam.

There are four basic types of dam construction: Embankment dam, gravity dam, buttress dam, and arch dam. Embankment dams are made of earth and rock, and sometimes are called earth dams or rock-fill dams. Its upstream–downstream direction base is larger than the height. The weight of the dam is spread over the large base. It is therefore suitable for

Figure 1.18 The Hoover Dam (Left), The Hoover Dam Bypass (Right)

Source: http://www.usbr.gov/lc/hooverdam/images/C45-300-021094.jpg. Copyright in the Public Domain.
Source: http://en.wikipedia.org/wiki/File:MikeO%27Callaghan%E2%80%93PatTillmanMemorialBridge.jpg. Copyright in the Public Domain.

weak foundations underneath the dam. It has a core of compacted impervious soil so that water cannot easily seep through and under it. The gravity dam, on the other hand, is made of concrete. It stands to resist the lateral water pressure by its weight and the friction at its base. It is suitable for sites with strong foundations. The buttress dam can be considered a hollowed-out gravity dam with regularly spaced buttresses replacing the solid body, thus reducing the weight.

The arch dam is a thin shell curved both in the horizontal direction and the vertical direction. It is structurally the most efficient, resisting the lateral water pressure mainly through compression in the shell body. It is suitable for narrow canyons with strong abutments. Obviously it requires the least material, mainly concrete. The design of the arch dam is the most challenging and was not perfected until the advent of digital computer.

The Hoover Dam curves horizontally like an arch dam but its cross-section is that of a gravity dam. Because it has the cross-section of a gravity dam, with a base length of 201 m (659 ft), height of 221 m (725 ft), and crest length of 379 m (1243 ft), it is massive, containing 2.48 million cubic meters (3.24 million cubic yards) of concrete. It was the most massive dam in the States when it was completed. The amount of concrete is enough to cover the entire city of Atlanta, Georgia, by over a quarter of an inch of depth. Both its power-generation capacity and its mass, however, were surpassed in 1945 by the Grand Coulee dam of Washington State. Hoover Dam was the highest dam in the States as well, until 1968 when the Oroville dam in California was completed with a height of 235 m (771 ft).

Because the massive amount of concrete was poured during the construction, a special refrigeration plant was constructed to generate cold water piped throughout the dam mass to take away the heat generated by the concrete. Without such care, the excessive expansion caused by the heat and the subsequent shrinkage during the curing process would have created unacceptable cracks in the dam body.

The Hoover Dam is an engineering marvel, but its creation is the combination of engineering vision and political drama, which played out from 1922 to 1947, directly involving five presidents.

To understand the need for the Hoover Dam, one needs to understand the Colorado River first. The 2,334 km (1,450 miles) river traces its origins to the Green River in Wyoming and Lake Granby in Colorado. The Green River joins the main branch of the Colorado River in Utah and flows southwest into Arizona, then west to touch Nevada. It turns south at the Black Canyon, separates California and Arizona, enters Baja California, and eventually reaches the Sea of Cortez. Its eastern upper reach can be traced to the Little Colorado River in Arizona and further east into New Mexico. In its natural state the Colorado River flooded from time to time, causing damage in its downstream areas. From 1824 to 1904, the Colorado River flooded the Salton Basin in California at least eight times. In 1905 and 1907 it flooded the Imperial Valley in California and the Salton Basin again. The numerous floods created the Salton Sea today.

Back in 1902, a civil engineer, **Arthur Powell Davis**, had his first vision of damming the Colorado at Black Canyon. He produced a monumental engineering report and campaigned for twenty years for a dam. He became the director and chief engineer of the Reclamation Service (later renamed the Bureau of Reclamation). In 1923, out of frustration that his grand vision was bogged down in political mazes, he resigned from the Reclamation Service and went to California to work on local aqueducts, and to

Turkestan, where he became the Soviets' chief consulting engineer on irrigation. When the Hoover Dam project eventually started in 1931, Mr. Davis was not on many people's mind, but in 1933, the new Secretary of Interior Harold Ickes appointed him consulting engineer for the Boulder Dam project (see below for the name change). At 72 Davis was now old and frail. He died one month after his new appointment. (See the *Fortune* magazine article of September 1933, posted on the Bureau of Reclamation website.)

The eventual naming of the dam after **Herbert Hoover** had its origin in 1922 when a commission was formed with a representative from each of the seven basin states and one from the federal government. The federal representative was the Secretary of Commerce Herbert Hoover, under President **Warren Harding**. Hoover was credited for the division of the basin states into upper basin states (Colorado, New Mexico, Utah, and Wyoming) and the lower basin states (Arizona, California, and Nevada), and worked out an arrangement with all the basin states for the distribution of the waters of the Colorado River. The resulting Colorado River Compact opened the way for the passage of the Boulder Canyon Project Act by both houses in 1928, signed into law by President Calvin Coolidge on December 21 after Herbert Hoover was elected as the new president. The Bureau of Reclamation awarded the project in 1931 to a consortium of six contractors, named simply Six Companies, Inc.. President Roosevelt dedicated the dam on September 30, 1935, two years ahead of schedule. After the dam was named Hoover Dam in 1931 by the Secretary of the Interior Ray Lyman Wilbur, under President Hoover, following past practices, Hoover lost his bid for reelection to Roosevelt in 1932. The new Secretary of Interior Harold Ickes, under President Roosevelt, renamed the dam the Boulder Dam. Not until 1947 was the name changed back to Hoover Dam by an act of Congress and signed into law by President Truman.

Today the Hoover Dam serves four major purposes: flood control, irrigation, municipal water usage, and power generation. It is also a major tourist attraction in the southwest. The Lake Mead National Recreation Area is one of the busiest among all the Park Service areas. After an upgrade in 1993, Hoover Dam's power generation capacity is now over 2,000 megawatts. The lives of tens of millions of people in the southwest of the U.S. are directly touched by the Hoover Dam every day, not to mention the many more people in other regions who enjoy the inexpensive agricultural products of the southwest made possible by the Hoover Dam. The Colorado River today disappears in the desert long before it reaches the Sea of Cortez. It is estimated 90% of its water is used for agricultural irrigation.

A lasting legacy of the Hoover Dam was the creation of a city, **Boulder City**, Nevada. It was created on the west bank of Black Canyon to house the workers for the dam project. At the peak of the construction, 5,000 workers and their family members lived in the new city. After the completion of the dam, the population dwindled significantly, but by 2013, its population is 15,000 and it became a vibrant community for recreation and leisure living.

The crest of the Hoover Dam was a part of US Route 93. After the 9/11 terrorist attacks, safety concerns prompted the design and construction of a bypass downstream. It was completed in 2010.

It is also interesting to note that the Hoover Dam is ranked 38 in the world in hydropower-generation capacity. The number one is the **Three Gorges Dam** in China at 18,300 megawatts (22,500 megawatts by 2012) and the second is the **Itaipu Dam** of Brazil at 14,000 megawatts. The Three Gorges Dam is a gravity dam across the famed Yangtze River. The dam body was completed in 2006. The Itaipu Dam, completed in 1984, is a very long dam system (7,700 m long) across the Paraná River on the border between Brazil and Paraguay. Its main dam is composed of hollow concrete segments and its wing dams are earth and rock-fill dams. In 1994 the American Society of Civil Engineering sought nominations across the globe for the Seven Wonders of the Modern World. The **Empire State Building**, the **Golden Gate Bridge**, and the **Itaipu Dam** were among the seven selected. It is interesting to note that the Empire State Building, the Golden Gate Bridge, and the Hoover Dam were all completed during the Great Depression period from 1929 to 1939.

The Grand Coulee Dam. The Grand Coulee Dam is located in the northeastern part of Washington State on the Columbia River. The Columbia is the second-largest river in the United States, after the Mississippi River. It originates in Canada and flows south. Approximately 100 miles (161 km) into Washington, it is joined by the Spokane River and turns westward. After another 100 miles, it turns south until it is joined by the Snake River just north of the Washington–Oregon border. From

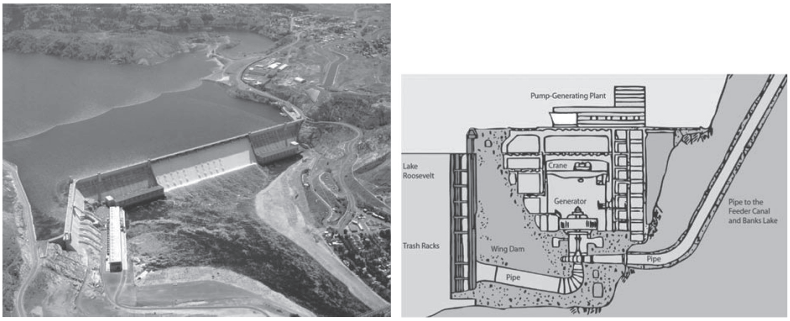

Figure 1.19 Aerial View of Grand Coulee Dam (Left), Cross-Section of the Pump-Generating Plant (Right)

Source: http://users.owt.com/chubbard/gcdam/highres/dam08.jpg. Copyright in the Public Domain. *Reclamation:* Managing Water in the West, pp. 1, U.S. Department of the Interior. Copyright in the Public Domain.

there on, it follows the border all the way to the Pacific Ocean. The section between the Spokane and the Snake rivers forms a half loop, called The Big Bend. The area east of the Big Bend is called Grand Coulee Basin; "Grand Coulee" is a geological term referring to the basin created from the erosion action of the water diverted by a glacier during the ice age. The town of Grand Coulee sits about halfway on the westward part of the Big Bend. The idea of building a dam near Grand Coulee to provide irrigation water to central Washington had been around for 30 years before Franklin D. Roosevelt's administration promised funding in 1933 and initial excavation at the dam site began in December of 1933. In 1935, Congress finally authorized full funding for the dam. The dam body was completed in 1941. In the meantime, the war effort escalated the need for electrical power in the region. More emphasis was put on power generation. By 1942 its power generation capacity was at 6,809 megawatts, the world's largest. It is still ranked fourth in the world.

The Grand Coulee dam is a concrete gravity dam with a height of 550 ft (168 m) and crest length of 5,223 ft (1,592 m). It contains 11,975,521 cubic yards (9,155,942 cubic m) of concrete, almost four times that of the Hoover Dam, and is the most massive concrete dam in the United States. Its reservoir is called Franklin D. Roosevelt Lake, which reaches to the Canadian border. Its pumping stations feed the Banks Lake south of the dam. The Grand Coulee Dam's irrigation area is about 600,000 acres (242,811 hectares).

The Oroville Dam. The Oroville Dam is located approximated 70 miles (113 km) north of Sacramento, California, on the Feather River. It is part of the California State Water Project and is operated by the California Department of Water Resources. Conceived in 1940 as a means to create a large water-storage reservoir to mitigate flooding of the surrounding areas, its construction did not begin until 1961, after California voters approved a bond issue in 1960 to fund the project.

The Oroville Dam is the tallest dam in the United States with a height of 770 ft (235 m) and the world's 22nd. It is an earth dam, completed in 1968. Its main function is to mitigate flooding. The Oroville Reservoir has a capacity of 3,537,577 acre-feet (436,353 hectare-m). By storing water from heavy rain or spring snow thaw and careful release of the water, it saves lives and prevents property damage. It is estimated one

Figure 1.20 The Oroville Dam

Source: http://www.dwr.water.ca.gov/newsroom/photo/facilities-swp/oroville_dam.jpg. Copyright in the Public Domain.

billion dollars of damage was averted during one major storm in 1997. Its ten power generators in two plants generate about 760 megawatts of power, mainly used to satisfy peak-hour electricity demand.

1.4 Modern Legends and Milestones

The First Civil Engineer. In the English-speaking world, the term "civil engineer" was coined by **John Smeaton** around 1770 in Britain. In the eighteenth century Britain engineers were engaging in military and non-military practices. Those specialized in military matters were called Military Engineers. By 1760 the people engaging in assessment and design of civil works projects were growing in number. By 1770 a dozen or so became well known throughout Britain. Because they were often needed to testify before Parliament on civil works, they resided in London. Among them John Smeaton (1724–1792) was the most prominent and a leader. Smeaton first identified himself as a civil engineer in 1768. In 1771, he and his colleagues founded a Society of Civil Engineers. The society remains today as a social society (renamed the Smeatonian Society of Civil Engineers after Smeaton's death). Smeaton had a good education and had talent for mechanical tools. By 1750 he started a business in improving instruments for navigation. Several papers of his on mechanical appliances were read before the Royal Society.

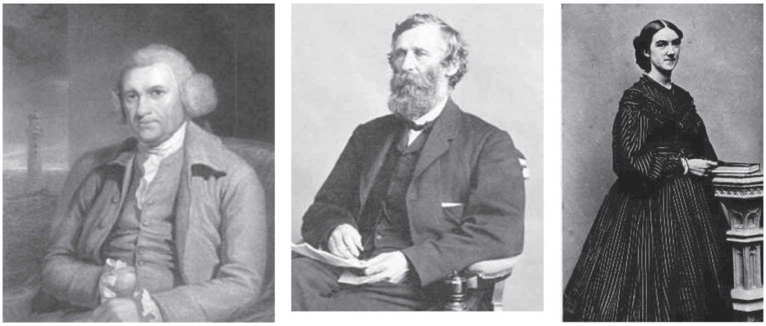

Figure 1.21 John Smeaton (Left), Ellis Chesbrough (Middle), Ellen Swallow (Right)

Source: http://en.wikipedia.org/wiki/File:John_Smeaton.jpg. Copyright in the Public Domain.
Source: http://chicagotribute.org/Markers/Chesbrough.htm. Copyright in the Public Domain.
Source: http://en.wikipedia.org/wiki/File:Ellen_Swallow_Richards.jpg. Copyright in the Public Domain.

He became a Fellow of the Society at age 29. His work then included windmills, watermills, bridges, lighthouses, and canals. The society he founded inspired the founding of the Institute of Civil Engineers, London, 1818, which in turn served as a model for the American Society of Civil Engineers, founded in 1852.

Safe Drinking Water. Improving drinking water quality through some kind of treatment has been recorded for thousands of years. Ancient Greeks used filtration, boiling, etc., to reduce particles, improve taste, and reduce odor. Ancient Egyptians used the chemical alum to settle particles in water. Filtration became the main treatment during the 1700s. In 1800 Europe, slow sand filtration was used. The discovery by Dr. John Snow in 1855 that the outbreak of cholera was linked to a public well in London polluted by sewage, and the medical knowledge advanced by Dr. Louis Pasteur in 1880 that microbes caused disease, focused attention on the removal of disease-causing microbes in drinking water supplies. In 1908, chlorine was used for the first time in the Boonton reservoir, which supplied drinking water to Jersey City, New Jersey. From that point on, the low cost and effective chlorine became the main disinfectant in drinking water treatment.

Federal regulation on drinking water safety began in 1914 when the Public Health Service set standards for the microbial quality in water, focusing only on bacteria that caused contagious disease. By 1962, the Public Health Service standards were expanded to limit 28 substances. The creation of the Environmental Protection Agency (EPA) by President Richard Nixon in 1970 marked a turning point in public awareness and government commitment to environment-related health issues. The ensuing Safe Drinking Water Act of 1974 set the most comprehensive standard for drinking water treatment.

Chlorine treatment for drinking water, however, is not without its side effects. In the mid-1970s a team of scientists and environmental engineers at the EPA conducted an exhaustive investigation and established that certain naturally occurring chemicals in the water interacting with chlorine creates disinfection byproducts (DBP) that are potentially cancer-causing substances. The amount of DBPs is so small that the risk of not using chlorine to kill disease-causing germs is far greater than the risk of cancer. Nonetheless drinking water treatment plants have been trying to remove these chemicals before chlorination and/or replace chlorine with ozone, a powerful but more expensive oxidant.

Wastewater Collection and Treatment. In 1855 Chicago, population over 84,000, became the first major city to have a comprehensive plan for a combined domestic and street water collecting system, to rid the city of cholera and dysentery epidemics. It was credited to chief engineer **Ellis Chesbrough** (1813–1886), appointed by the newly created Chicago Board of Sewerage Commissioners. Chesbrough came with impressive credentials. A self-educated engineer, he learned surveying, grading, and tunneling while working as an apprentice on several railroad construction projects. He later worked on the construction of Boston's new water system. He was elevated in 1850 to the position of commissioner of Boston's waterworks and then the first city engineer. His achievements, including centralization of Boston's building and maintaining waterworks, sewers, streets, and harbor facilities, became well known and he was the obvious choice to solve the Chicago's wastewater problem. (See ASCE News, Illinois Section, January 2002.)

Chesbrough's plan was to discharge wastewater into the Chicago River through the web of a drainage pipe system. Because only gravity was available to drive the flow, much of the city needed to be elevated by depositing soil to create a new ground surface. Some locations were elevated as much as 16 ft to allow the gravity flow. In 1861, a new Board of Public Works was formed and Chesbrough became its first chief engineer. For twenty years, he was responsible for the city's drinking water as well as wastewater collection and treatment. He was credited for new water supply tunnels dug deep in the ground and extended far into Lake Michigan to get to unpolluted clean water. He was also responsible for the construction of the famous Chicago Water Tower, one of Chicago's landmarks.

The development of modern wastewater treatment methods follows an evolutionary path. In 1914, liquid chlorine was applied to a sewage plant for disinfection in Altoona, Pennsylvania. In 1916 San Marcos, Texas, built the first activated-sludge plant. Milwaukee, Wisconsin, built the first large-scale activated-sledge sewage treatment plant in 1919 and recycled the sewage by drying the sludge and selling it as fertilizers. In 1932 the first large-scale pilot plant for dewatering and burning filter cake was operational at the West Side plant of Chicago and all sewage sludge was dried and burned. Daytona Beach, Florida, combined coagulation and sedimentation treatment using water-plant sludge as a coagulant in

1949. In 1957 two sewage plants in Corpus Christi, Texas, used new rotary dryers for sledge disposal. In 1969 Chicago became the first city to plan to apply tertiary sewage treatment with the installation of a 15 mgd (mega-gallon-day) micro-strainer in the treatment plant at Skokie. At this point the main ingredients of a modern wastewater treatment methodology were in place. (See *Turning Points in U.S. Civil Engineering History*, Special Issue: ASCE's 125th Anniversary, ASCE, 1977.)

The First Female Environmental Engineer. Ellen Swallow (1842–1911) was born to a family of modest means in Dunstable, Massachusetts. Both parents were school teachers. She attended the Westport Academy from 1895 to 1863 and saved enough money from various domestic jobs to attend Vassar College and graduated with a B.S. degree in chemistry in 1870. She became the first woman admitted to the Massachusetts Institute of Technology that year and earned a B.S. degree in chemistry in 1873. She also earned a Master of Art degree in chemistry from Vassar College in the same year. She became a teacher in the chemistry department of MIT and continued her study in chemistry, although at the time, MIT was not ready to grant a Ph.D. to her. She married Robert Richards, head of the Department of Mining Engineering in 1875 and collaborated on numerous projects on ore analysis.

In 1884 she began working in a newly established sanitary chemistry laboratory in the Lawrence Experiment Station and conducted a large-scale water-quality study in 1887 for Massachusetts and produced the world's first water purity table. Her work led to the first water-quality standards in America, and the first modern sewage treatment plant, in Lowell, Massachusetts. In 1892 she introduced German-coined-word **Ecology** into English. In 1900 she coauthored the textbook *Air, Water, and Food from a Sanitary Standpoint*, with A. G. Woodman. In 1999 the *Engineering News Record* honored her as one of the top environmental engineering leaders in the last 125 years and named her the first female environmental engineer. (See *Engineering Legends, Great American Civil Engineers*, by Richard G. Weingardt, ASCE Press, 2005.)

A Tunnel Named Holland. Clifford Milburn Holland (1883–1924) was born in Somerset, Massachusetts, and attended public schools. In his teen years he proclaimed that he wanted to be a "tunnel man." He started college study in Harvard in 1902 worked part-time jobs to pay his way to

Figure 1.22 Clifford Milburn Holland

Source: http://en.wikipedia.org/wiki/File:Cmholland.jpg.

a B.A. degree in 1905 and B.S. degree in civil engineering in 1906. Immediately after his graduation he worked as an assistant engineer at the Rapid Transit Commission of New York and designed and supervised construction of subways and tunnels. By 1914 he was promoted to tunnel engineer in charge of the design and construction of four subway tunnels under the East River. He was promoted to division engineer in 1916 and hired as the chief engineer in 1919 to build the **Hudson River Vehicular Tunnel**.

The need for the Hudson River Tunnel was similar to that of the Brooklyn Bridge over the East River: overcrowding of the only means of transportation between New York and New Jersey—ferries. A Joint Commission between New York and New Jersey considered a bridge crossing in 1906 but turned to favor a tunnel by 1913. Several tunnel designs were considered in the next few years but eventually the design submitted by Holland was selected and he was hired as the chief engineer for the Hudson River Vehicular Tunnel Project.

Holland's design called for two separate 29.5 ft (9 m) diameter tubes 50 ft (15.2 m) apart: the north tube is 8,558 ft (2,608 m) long and the south tube is 8,371 ft (2,551 m) long. The most innovative part of Holland's design was the way he solved the ventilation problem. The tube section was divided into three vertical segments: the middle segment for the traffic, the upper segment for the collection of dirty air, and the lower segment for the supply of fresh air. Eighty-four giant fans housed in four ventilation towers on both sides of the river provide the blowing and suction actions for the tubes.

Construction began in 1920. As described in the April 15, 1999 issue of *Engineering News Record*, "the tunnels were driven through the Hudson riverbed by shields working in both directions that were launched from pneumatic caissons. Each shield was pushed forward by 30 hydraulic jacks that had a total force of 6,000 tons. The tubes were lined with 2.5-ft-wide cast iron rings." Holland's dedication to the project was described in the same issue: "Holland spent most of his waking hours overseeing all tunnel design and construction. But in October 1924, he suffered what was termed a nervous breakdown. Three weeks later, he was dead of a heart attack at age 41." Within two weeks the tunnel was renamed the **Holland Tunnel**. His successor, Milton Freeman died five months later, and till the completion of the project in 1927, the project was under the direction of another famed tunnel engineer Ole Singstad. (See *Engineering Legends, Great American Civil Engineers*, by Richard G. Weingardt, ASCE Press, 2005.)

Father of Soil Mechanics. Soil Mechanics today is either a required course or a major portion in a required course in every BSCE curriculum. It characterizes the mechanical properties of soil through rigorous theory and experiments. Much of the content of soil mechanics can trace its origin to **Karl von Terzaghi** (1883–1963). He was born in Prague when it was part of Austria. He graduated with honors from the Technical University in Graz, Austria, in 1904 with backgrounds in mechanical engineering, theoretical mechanics, geology, and highway and railway engineering.

His engineering career began in Vienna when he gradually specialized in geological problems. His work took him to Croatia and Russia and he became well known. During a short period in 1912–1913, he came to United States touring some major dam sites in the West and gathered engineering reports on the major problems encountered in the design and construction of the dams. During World War I, he became a professor in the Royal Ottoman College of Engineering in Istanbul (later renamed Istanbul Technical University) and began his research on soil properties. His first published work on retaining walls established him as the leading scholar on the mechanical behavior of soil. After the war he taught at Robert College at Istanbul and started extensive laboratory work with new instruments he invented to measure soil permeability and the interaction between soil particles and water. His theoretical development based on his measurements cumulated in a 1924 publication that earned him international acclaim. He soon accepted an offer from the Massachusetts Institute of Technology and came to the United States for the second time. At MIT he again started a new laboratory with his own instruments. His publications in 1925 and 1926 greatly enhanced the civil engineers' understanding of this new field of soil mechanics.

He returned to Vienna in 1929 and for the next ten years, he lectured and consulted widely throughout Europe, all the while continuing his research into foundation settlement and foundation improvement through grouting. In 1939 he immigrated to the United States for good. He taught at Harvard University and continued his consulting work with many major international projects, including Egypt's Aswan Dam. He died in 1963 at the age of 80. From 1930 to 1955 he was the recipient of the prestigious Norman Medal of American Society of Civil Engineers four times (1930, 1942, 1946, and 1955) "for a paper definitively contributing to engineering science." It is a record yet to be broken in the history of the Norman Medal. He was also the recipient of nine honorary doctoral degrees from eight different countries.

Another giant in the development of soil mechanics and foundation engineering is **Arthur Casagrande** (1902–1981), who happened to be also an Austrian-American. He was Terzaghi's assistant during Terzaghi's MIT years and made contributions on his own in the complex tri-axial test development and the development of other sophisticated test apparatuses. Casagrande was a superb educator. He developed numerous training programs for the Army Corps of Engineers and was responsible for the development of a successful post-graduate soil mechanics and foundation Engineering program at Harvard University. When ASCE established the Terzaghi Award "for an author of outstanding contributions to knowledge in the fields of soil mechanics, subsurface and earthwork engineering and subsurface and earthwork construction," Arthur Casagrande became its first recipient in 1963.

The Interstate Highway System. Officially known as the Dwight D. Eisenhower National System of Interstate and Defense Highways, its origins can be traced back to 1922, when General John Pershing, General of the Armies, produced a map entitled "Project for Development of National Highways of United States." The routes in the map were decided mainly on the need for large-scale evacuation and military significance.

(See *The Interstate Highways System*, by Henry Moon, published by the Association of American Geographers, 1994.) The Federal-Aid Highway Act of 1938 called on the Bureau of Public Roads (BPR), the predecessor of the Federal Highway Administration (FHWA), to study the feasibility of a toll-financed system of three east–west and three north–south superhighways. The BPR's report concluded that a toll network would not be self-supporting and advocated a 26,700-mile interregional highway network. In 1944, a committee appointed in 1941 by President Franklin D. Roosevelt recommended a system of 33,900 miles, plus an additional 5,000 miles of auxiliary urban routes. Serious funding to carry out the recommendation would not come until 1956.

Under the leadership of President Eisenhower, two important pieces of legislation were passed and signed into law in 1956: Federal-Aid Highway Act of 1956 and the Highway Revenue Act of 1956. The first act increased the system's proposed length to 41,000 miles, required nationwide standards for design of the system, changed the name to the **National System of Interstate and Defense Highways**, and for the first time split the cost of federal/state share at 90/10 percent. The second act created the Highway Trust Fund for revenue from federal gas and other user taxes. It was the second act that guaranteed the funding of the interstate highways.

Figure 1.23 Interstate Highways in the 48 Contiguous States

Source: https://en.wikipedia.org/wiki/File:Map_of_current_Interstates.svg. Copyright in the Public Domain.

In the years after 1956, Americans' use of automobiles increased quickly and the interstate highway system has helped define the American way of life. The 2007 data of the FHWA show the total length of the system is 46,934 miles (75,533 km); the interstate highway of America is the world's longest highway system. It is remarkable that two generals, Pershing and Eisenhower, were responsible for the creation of the system and that its genesis was rooted in military/defense considerations.

From Moment Distribution to Finite Element. By the turn of the 20th century, the fundamental theory of structural analysis for linearly elastic beams, trusses, and frames is mostly developed. The practical application, however, was limited to statically determinant structures: structure for which static equilibrium equations alone determine the internal force distribution, for which the resulting equations can often be solved sequentially, i.e., two or three at a time. Thus hand computation was sufficient. For continuous beams and frames, however, the equations resulting from consideration of deformation often numbered in tens, even hundreds, even for relatively simple structures such as bridges and concrete buildings. For those structures only some approximate method of analysis could be applied. This situation was changed when a University of Illinois professor, **Hardy Cross** (1885–1959), published his moment distribution method in a paper entitled "Analysis of Continuous Frames by Distributing Fixed-End Moments" in 1930 in the *Proceedings of ASCE*. He later developed a similar method for the analysis of flows in pipeline networks.

The moment distribution method appeals to engineering intuition. It visualizes how a structure responds to loading. The method is an iterative method, mathematically, but it converges fast; normally after two circles the error became negligible. When the paper was formally published in the *Transactions of ASCE* in 1932, thus receiving wider notice, it became an instant hit among structural engineers because it made possible for them to solve heretofore intractable problems. Cross was awarded the Norman Medal by the American Society of Civil Engineers in 1933.

Hardy Cross was born in Virginia to parents from prominent southern families. He was an excellent student, receiving a B.A. degree in 1902 and a B.S. degree in 1903, both from Hampden Sydney College. He taught English and mathematics at Norfolk Academy before going to Massachusetts Institute of Technology to study civil engineering and earned another

B.S. degree in 1908. He worked briefly as a bridge engineer and then taught at Norfolk Academy before studying at Harvard and earned a M.S. degree in 1911. Between 1911 and 1937, he taught at Brown University and then University of Illinois, and worked as a structural engineer in the Boston and New York areas. He returned to academic life at Yale University in 1937 and served as its chairman of the Civil Engineering Department until his retirement in 1950. (See "Leonard K. Eaton, Hardy Cross and the Moment Distribution Method," *Nexus Network Journal,* vol. 3, no. 3, summer 2001, <http://www.nexusjournal.com/Eaton.html>.)

In 1952 McGraw-Hill published Cross' book *Engineers and Ivory Towers*, edited by Robert C. Goodpasture. The book contains his papers and insights on engineering education and practice. His legacy is not only as the inventor of the moment distribution method but also as an insightful engineer and educator.

The advent of digital computing basically solves the problem of large numbers of linear simultaneous equations, but its application in structural analysis was limited to discrete structures such as beams, trusses, and frames. For plates, shells, and other twoor three-dimensional structures, only analytical solutions for simple geometry or finite difference approximate solutions are available. Then, in 1956, a way of discretizing an airplane wing structure was presented in a paper entitled "Stiffness and Deflection Analysis of Complex Structures," by M.J. Turner, R.W. Clough, H.C. Martin, and L.J. Topp in the *Journal of the Aeronautical Sciences*. This is one of the origins of a new method called Finite Element Method, even though the term Finite Element was not coined until 1960, when **Ray Clough** published a paper entitled "The **Finite Element Method** in Plane Stress Analysis," in the *Transactions of ASCE*. The Finite Element Method treats a continuum as an ensemble of a number of discrete elements and generates a solution, which is close to the true solution when the elements are made smaller and smaller. Thus it is also an iterative method with a big difference: often an accurate enough solution is obtained when the elements are small enough in comparison to the general dimensions of the structure. By the late 1960s finite element analysis computer programs became available to structural engineers and the structural analysis practice was forever changed. Today, commercial programs with colorful interactive three-dimensional graphical presentations can be used to produce stress analysis results in a matter of seconds.

A Master Engineer and Educator. Nathan Mortimer Newmark (1910–1981) was born in Plainfield, New Jersey, and graduated from Rutgers University with special honors in civil engineering. He obtained his M.S. and Ph.D. degrees from University of Illinois in 1932 and 1934, respectively, and remained as a research assistant at the university. His time at the university as a graduate student coincided with the tenure of Hardy Cross and he studied under Cross.

During World War II he worked as a consultant to the National Defense Research Committee and served in the Pacific theater. For his excellent service he was awarded the President's Certificate of Merit in 1948. At University of Illinois he chaired the digital computer laboratory from 1947 to 1957 and helped develop the first large-scale digital computer ILLIAC II. He became the head of the Civil Engineering Department in 1956 and served for 17 years in this position. During his tenure the department's achievements and reputation reached new highs. He cared for his colleagues and young faculty. Many of them went on to become National Academy of Engineering members. His personal contribution to the field of civil engineering, especially structural engineering, were too numerous to describe. He worked in a broad range of areas and made lasting impacts. Several methods described in soil mechanics and earthquake engineering textbooks bear his name. His approach in solving a practical problem was unique in that he always zeroed in on the key factor of the problem and came up with something simple and amenable to mathematical treatment. His most-cited papers were published as a classic by ASCE in 1976 in *Selected Papers by Nathan M. Newmark: Civil Engineering Classics*, a rare honor for a living scholar.

Through his consulting engagements he left his footprint on many important civil and military projects: the Bay Area Rapid Transit (BART), Trans-Alaska Pipeline, Minute Man and MX missile systems, nuclear power plants, and most famously the Latino Americana Tower in Mexico City, Mexico. He came up with the idea of a relatively rigid structure resting on a foundation of a floating concrete box on piles to counter the poor soil conditions. The resulting 43-story high-rise (183 m/597 ft) has withstood the devastating earthquakes of 1957 and 1985 since its

Figure 1.24 Nathan Newmark

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

completion in 1956. (See *Engineering Legends, Great American Civil Engineers*, by Richard G. Weingardt, ASCE Press, 2005.)

He held many honors. He was a founding member of the National Academy of Engineering in 1964 and was elected a member of the National Academy of Sciences in 1966. He received the National Medal of Science from President Lyndon B. Johnson in 1969. ASCE established the **Nathan M. Newmark Medal** in 1975 "for his outstanding contributions in structural engineering and mechanics. The funds for the award were contributed by the honoree's former students in appreciation of the quality of education they received under his guidance at the University of Illinois." This is another testimonial to his personal achievements and his legacy as a master educator.

CHAPTER 2

Engineering Ethics

2.1 Overview

The word 'ethics' is defined as "the discipline dealing with what is good and bad and with moral duty and obligation," by the Merriam-Webster Dictionary. Martin and Schinzinger define ethics in their book, *Ethics in Engineering* (McGraw Hill, 4th edition, 2005), as "synonymous with morality, It refers to moral values that are permissible (all right), policies and laws that are desirable." Merriam-Webster defines 'Professional Ethics' as "the principles of conduct governing an individual or a group," while Martin and Schinzinger define 'Engineering ethics' as consists of responsibilities and rights that ought to be endorsed by those engages in engineering, and also of desirable ideals and personal commitments in engineering."

Engineering ethics are not laws in the legal sense but are laws in the sense of what are morally right and permissible in the engineering profession. From an individual conduct point of view, engineering ethics cannot be separated from individual integrity and honesty which should be learned and practiced as early as while a civil engineering student. We shall start with the student ethics issues, followed by detailed description of ethics guidelines issued by ASCE. We conclude this chapter with several actual incidents that are instructive in terms of ethics violations entailed.

2.2 Student Ethics

Many universities have explicit policies on 'academic honesty' and guidelines on 'student conduct.' Described herein are topics not considered serious ethics related as cheating in exams, but we recommend as good ethical practices that also benefit you.

Attending Classes. It is emphasized here that attending classes is both a privilege and a responsibility. Many students do not see the 're-sponsibility' side and offer comments such as "I paid the tuition to buy the education" and "I attend classes I like not ones I don't like." It must be pointed out, however, even for a private university, the tuition paid by students rarely cover the whole cost of education students received. The rest is covered by endowment funds contributed by well-wishing donors. For state universities, tuition and fees may cover some of the cost and the rest comes from tax payers' contributions. You therefore are accountable to others for your conduct.

From the university's perspective, facilities, equipments, and utilities are required for classes and instructors are hired to conduct class meetings. For instructors, going to a class requires pre-class preparation and in-class delivery and interaction with students. Skipping classes is a clear indication that the student does not appreciate the value of the class and the dedication of the instructor.

When an instructor stands in the front of a class, nothing escapes his/her notice, certainly not a couple of students keep talking to each other no matter how low their voices are. There are other behaviors that are distractive, disruptive and disrespectful not only to the instructor but to fellow students. We polled our students and they found the following disagreeable: come late and leave early, come and go at will in the middle of a class, eat and drink, use cell phone, text messaging, loudly type on laptop, cough or sneeze loudly, fart silently or loudly, yawn and fall into sleep, etc.

Doing Homework. We were puzzled when some students had excellent records on homework assignments but failed miserably in exams. It turned out that some homework solution manuals could be bought online and some students simply copied the solutions. Clearly coping solutions is an act of dishonesty. Even if the homework is not graded and counted toward a term grade, it is still an act of dishonesty to the student himself/herself, because the student deprives himself/herself of the opportunity to learn.

Writing Reports. Virtually any subject can be found on the internet and it is easy to copy in part or in whole an article already published. Citing from published work in writing a report is permitted if the report includes an element of research and the sources are identified. The word '**plagiarize**' is defined as: to steal and pass off (the ideas or words of another) as one's own; use (another's production) without crediting the source; in the Merriam-Webster Dictionary. Plagiarizing is clearly an act of unethical behavior but it is one easily caught. Just as easily to find something to copy, a simple search on the internet will find the evidence of plagiarism. Many universities offer access to faculty software that can easily identify plagiarized passages in a report.

Notice the word “ideas” in the definition above. Copying of ideas is just as bad as copying words if not worse. It is also easily caught. We identified two student reports with identical format and main contents but changed words here and there. Most universities have explicit policies dealing with student plagiarism. Some publishers have exact guidelines allowing copying up to 40 words or so without asking for permission.

Taking Exams. In the age of computers and internet, cheating on exams is increasingly easy. Unknown to students, however, is the fact that all cheatings are easily discovered. Severe punishments often accomplish exam cheating. Many universities have student/faculty panels to deal with exam cheating. Our experience in serving on these panels is that student members are often more strict, unforgiving and inclined to handout severe punishment than faculty. That is rightly so since a cheating incident dishonors not only the wrongdoer but the student body as a whole.

Exam cheating is not only unethical but unnecessary.

Being Responsible in Carrying out Organizational Duties. Each student organization has elected officer and each elected officer carries specific responsibilities and duties. To members of the organization and to the university, these responsibilities are expected to be executed by the elected officers who are the natural leaders of the organization. Being elected an officer means one is committed to carrying out the responsibilities and duties the position carries. When officers neglect to carry out the duties, the organization ceases to function and all members suffer. We observed that the level and quality of activities of student organizations changed from one leadership group to another, sometimes drastically. It simply reflected the commitment of the leadership group. Merely enjoying being an officer but not doing what is expected is unethical. Besides, it terms of boasting one's resume, simply listing a position is not enough. People expect to know what an officer has done.

2.3 Guidelines to the Standards of Professional Conduct of ASCE

Engineering ethics being the ethics of a profession, each professional organization in engineering has explicit code of ethics. For civil engineers, the most pertinent is the code of ethics of ASCE. ASCE also publishes its **Standards of Professional Conduct**, the purpose of which is described as follows: "The Standards of Professional Conduct were developed to provide individuals or small businesses that don't have the resources or a complete set of principles and guidelines to govern the day-to-day aspects of ethics practices in our profession. These guidelines reinforce ASCE's Code of Ethics, which all ASCE members are expected to practice." While the code of ethics are described in more general terms, the guidelines are more specific. These **Guidelines** to the Standards of Professional Conduct are briefly described below. For details please visit http://www.asce.org/uploadedFiles/Ethics_-_New/ethics_guidelines010308v2.pdf. The language in quotation marks is originally from ASCE,

1. **Conflict of Interest.** "The best interest of the Employer or profession is at issue. You are expected to avoid any relationship, influence, or activity that impairs your ability to make objective and fair decisions when performing your jobs. When in doubt, you should share the facts of the situation with your leadership and resolve the conflict." One example is you work full time in one company but occasionally for another company on temporary basis and both companies are sending bids to win the same contract.
2. **Ensuring Legal Compliance.** "ASCE members shall conduct their actions in accordance with applicable laws and regulations. As ignorance is not a defense against violations, you need to be knowledgeable of relevant laws and regulations first and following them faithfully." One example is on burial sites preservation. Most states have burial site preservation programs. If in the course of construction, your crew digs up suspected human remains, you need to stop the work and report to authority immediately.
3. **Employees and Public Safety.** "ASCE members shall be committed to maintaining a drug and alcohol free, safe, and healthy work environment. They shall comply with applicable environmental, health,

and safety laws and regulations. Most companies also have in-house regulations dealing with the same issues. For example, you are not allowed to keep alcohol in your office even you claim you never actually drink it.

4. **Workplace Quality.** "ASCE desires a workplace where its members feel respected, satisfied, and valued. Harassment, discrimination, or sexist behavior of any kind is unacceptable (in many cases it is illegal)." We learned that one supervisor was accused of workplace harassment by calling a subordinate four times a day to ask about the progress of an assignment.
5. **Use and Protection of Employer's Assets.** "Your Employer has many valued assets, such as cash, physical property, proprietary trade secrets, and confidential information. Protecting these assets against loss, theft, and misuse is every employee's responsibility." For example you must gaining approval before taking your company issued computer home for work.
6. **Maintaining Accurate and Complete Records.** "The importance of maintaining accurate and complete records cannot be overstated." For example transactions between your company and a client should be maintained in accordance with established Employer guidelines.
7. **Gifts, Meals, Services, and Entertainment.** "It is improper for an ASCE member or family member to knowingly request, accept, or offer anything that could be construed as an attempt to influence the performance of duties or to favor a customer, supplier, or competitor that is contrary to the best interests of the Employer, its clients, or the profession." For example you are not to accept gifts from a supplier to your company's business. Some companies have explicit guidelines on the maximum monetary value of gifts that you may accept.
8. **Confidential or Proprietary Information.** "In the course of normal professional activities, ASCE members may have access to information that is proprietary, confidential, privileged, or of competitive value to the Employer. ASCE members must respect these confidences by protecting the confidentiality and security of documents and related information." For example your company's in-house design manual is proprietary and cannot be disclosed to outsiders.

9. **Outside Employment/Activities. "**Outside employment or business activities not related to the Employer must not conflict with the employee's ability to properly perform his or her work. For example, you cannot work on outside activities to the extent that you feel tired working in your company's office." This is called conflict of commitment and some companies have explicit guidelines in terms of maximum hours per week you can spend on the other commitments.
10. **Purchases of Goods and Services.** "The acquisition of goods and services from external vendors may constitute a significant portion of the Employer's annual expenditures. Adherence to established guidelines and practices governing the procurement function are critical to ensure compliance with all commercial and legal requirements and to maximize the value received from these expenditures." For example you should avoid purchasing for your company from a business owned by your family members.
11. **Bribes and Kickbacks.** "ASCE prohibits its members to offer or accept bribes, kickbacks, and other similar payoffs and benefits to or from suppliers, regulators, government officials, trade allies, or customers." It is also illegal to offer bribes in foreign countries.
12. **Relationships with Competitors.** "ASCE members should be aware that the Employer may be in a competitive environment." This means your Employer's interested must be protected when dealing with competitors.
13. **Relationships with Clients, Outside Contractors, and Consultants. "**Clients, contractors, and consultants should be treated honestly, without unfair discrimination or deception, in a manner conforming to local, state, and national laws, and consistent with good business practice." Honesty is the best policy.
14. **Environmental Protection.** "ASCE members who are aware of situations in which the Employer may not be complying with environmental laws or is improperly handling, disposing of, or otherwise discharging any toxic or hazardous substance should immediately contact the Employer." The difficult part is what if the Employer ignores you. See the next one on Whistle Blowing.
15. **Whistle Blowing.** "Whistle blowing" is when an employee reports an employer who is breaking the law … To actually whistle blow, the

employee must report the illegal act outside the company to a government or law-enforcement agency … , he or she is protected by law. The employer cannot retaliate against the employee. The employer cannot fire the employee for the whistle blowing. The employer cannot mistreat the employee for whistle blowing." The employee can still be fired for reasons other than the whistle blowing.

2.4 The Four Fundamental Principles of the Code of Ethics of ASCE

The Four Fundamental Principles of the Code of Ethics of ASCE are reproduced below in italic.

Engineers uphold and advance the integrity, honor, and dignity of the engineering profession by:

1. Using their knowledge and skill for the enhancement of human welfare and the environment;
2. Being honest and impartial and serving with fidelity the public, their employers and clients;
3. Striving to increase the competence and prestige of the engineering profession; and
4. Supporting the professional and technical societies of their disciplines.

2.5 The Seven Fundamental Canons of ASCE and Guidelines to Practice

The word 'canon' means 'an accepted principle or rule; a criterion or standard of judgment; a body of principles, rules, standards, or norms,' according to the Merriam-Webster Dictionary. The seven canons of ethics of ASCE is reproduced below. For details on ASCE's guideline to practice on each canon, see http://www.asce.org/Leadership-and-Management/Ethics/Code-of-Ethics/. The seven canons cover the following: responsibilities to the public, limits of service scope, limits on public statement, relationship with employer/client, competition with others, professional honor and integrity, and lifelong learning.

CANON 1. *Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties.*

CANON 2. *Engineers shall perform services only in areas of their competence.*

CANON 3. *Engineers shall issue public statements only in an objective and truthful manner.*

CANON 4. *Engineers shall act in professional matters for each employer or client as faithful agents or trustees, and shall avoid conflicts of interest.*

CANON 5. *Engineers shall build their professional reputation on the merit of their services and shall not compete unfairly with others.*

CANON 6. *Engineers shall act in such a manner as to uphold and enhance the honor, integrity, and dignity of the engineering profession and shall act with zero tolerance for bribery, fraud, and corruption.*

CANON 7. *Engineers shall continue their professional development throughout their careers, and shall provide opportunities for the professional development of those engineers under their supervision.*

2.6 Theory and Practice of Whistle Blowing: A Case Study

While the 15th Guideline to the Standards of Professional Conduct of ASCE is clear in defining whistle blowing and the legal protection to the whistleblower, in reality it is a difficult decision on the part of the employee. In classroom discussions students often expressed the fear that an act of whistle blowing will end any good working relation with the current employer even if he/she is not fired and may also end potential employment with other employers once the employee is known as a whistleblower. These are legitimate concerns and the authors could not offer clear cut advice. In theory, however, an engineer's self interest is superseded by the interest of the employer while the public interest supersedes all other interests. If and when an illegal act by the employer is such that the employee must act to prevent any damage to the public interest, it is important for a whistleblower to act prudently to make sure he/she is on solid legal grounds. The following case study of whistle blowing may of value to those who would face similar situations (See *Ethics in Engineering*, by Mike W. Martin and Roland Schinzinger, McGraw Hill, 4th edition, 2005).

The Bay Area Rapid Transit system (BART) is a key public transportation system for San Francisco and surrounding areas. The design, construction, and operations of BART are governed by the Board of Directors of the BART District. In 1967 Westinghouse was awarded the contract to design and construct an Automatic-Train Control system (ATC) for BART. The actions of three electrical engineers of BART in 1971–72 became a classical case of engineering ethics and was detailed in the book entitled *Divided loyalties: Whistleblowing at BART,* by Robert M. Anderson, Robert Perucci, Dan E. Schendel, and Leon E. Trachtman, Science and Society: A Purdue University Series in Science, Technology, and Human Values. Trachtman Leon, editor. Vol. 4. West Lafayette (IN): Purdue University, 1980. The following much abridged description is an attempt to show only those events that are key to the whole case. The three engineers are Roger Hjortsvang, Robert Bruder, and Max Blankenzee.

1. Hjortsvang wrote an unsigned memo in November of 1971 to all levels of BART management including the general manager that summarized the problems he perceived with the ATC.
2. In January 1972, the three engineers contacted several members of the BART board of directors when their concerns were not being taken seriously by lower levels of management.
3. The three engineers consulted an external expert who wrote a report with a conclusion similar to the concerns of the three engineers. When BART tried to identify the engineers behind the unsigned memos and interviewed engineers, the three engineers denied they were the authors of the memos.
4. One of the Board of Directors, Dan Helics listened to the engineers sympathetically and took the engineer's unsigned memos and the report of the consultant and distributed them to other members of the board. Without warning the engineers he also released them to a local newspaper.
5. In February 1972, Helics convinced the engineers to appear before the whole Board of Directors but the Board was not convinced that the engineers' concerns were serious.

6. In March 1972, the three engineers were asked by BART to resign or face termination. They refuse to resign and were fired on the ground of insubordination, lying to their superiors and failing to follow organizational procedures.
7. Hjortsvang could not find full time employment for 14 months, Bruder for eight months, and Blankenzee for five months.
8. In 1974, the three engineers sued BART for damage in the amount of $875,000. The Institute of Electrical and Electronics Engineers (IEEE), the counterpart to ASCE, filed friend of the court brief supporting the three engineers' "professional duty to keep the safety of the public paramount," and citing IEEE's code of ethics that the engineers must "notify the proper authority of any observed conditions which endanger public safety and health." IEEE considered the 'public' as the 'proper authority.'
9. The attorney of the engineers advised them before the case went to trial that they could not win because they had lied to their employer. They settled out of court for $75,000.

Several things can be learned from this case. When the engineers brought the case to the Board of Directors, the case became 'Internal Whistle blowing' because they jumped the chain of command but still acted within the organization. When Helics released the documents to the local newspaper, he, not the three engineers committed an act of external whistle blowing because it became public. When the engineers denied being the authors of the memos, they lied to the employer and saw the seed for weakening their legal case later. While the whistleblowers suffered economically and mentally they were able to gain employment eventually. The BART did improve the ATC system and maintained a good safety record since 1972.

2.7 The Collapse of the Kansas City Hyatt Regency Walkway

The Structure. The Kansas City Hyatt Regency Hotel was opened in 1980. The hotel has a 40-story tower, a function block and a large open atrium approximately 117 ft (36 m) by 145 ft (44 m) in plan and 50 ft

(15 m) high. There were three suspended walkways connecting the tower and the function block: The second and fourth floor walkways on the west side and the third floor walkway on the east side.

The report is based on the original investigative paper published in the July 1982 issue of *Civil Engineering* magazine by the same author. The following description is an abbreviated account of what was described in this report, the *Civil Engineering* paper and other open sources.

The Event. On July 17, 1981 while there was a tea dance in progress in the hotel atrium, two suspended walkways, from the second and fourth floor on the west side of the atrium of the hotel collapsed. The collapse resulted in the second floor walkway falling to the ground and the fourth floor walkway piled up on top of the second floor walkway. The third floor walkway on the opposite side of the atrium was not involved in the accident. The total casualty: 114 dead and 185 injured most from the people on second floor and the ground floor under the walkway.

The Investigation. In the aftermath of the incident, the Mayor of Kansas City requested an independent investigation by the National

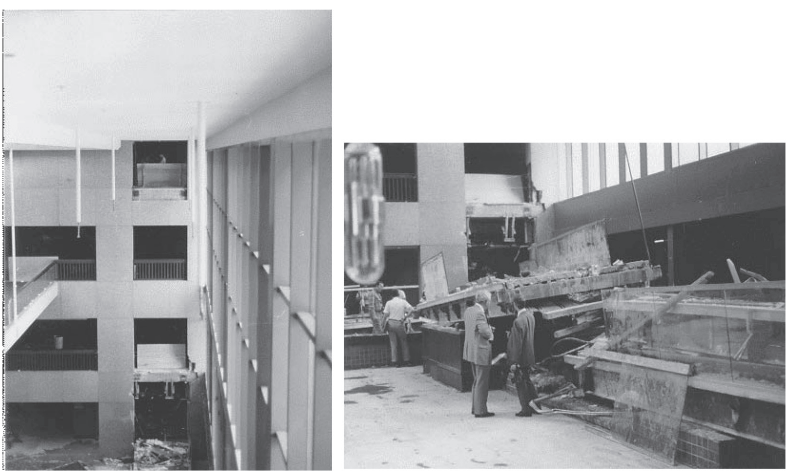

Figure 2.1 The Suspended Walkways Disappeared (Left) and the Disaster (Right)

Source: http://en.wikipedia.org/wiki/File:Hyatt_Regency_collapse_end_view.PNG. Copyright in the Public Domain.
Source: http://en.wikipedia.org/wiki/File:Hyatt_Regency_collapse_floor_view.PNG. Copyright in the Public Domain.

Bureau of Standards (NBS, known as National Institute of Standards and Technology since 1988) for the cause of the collapse.

The NBS team did on site inspection, gathered walkway debris, all relevant documents relating to the design and construction of the hotel (in service about one year), and photographs, videotapes and records available from the media. NBS also did extensive laboratory tests on material strength from the debris and similar material and conducted analytical studies on the as-built capacity of the walkways and the estimated load at the time of the incident. Fortunate for the NBS team a TV crew was videotaping the tea dance and the tape included a segment on the second floor walkway and the people on it just ten minutes before the incident. This piece of tape gave the NBS team a reliable means to estimate the number of people on the two walkways and in turn a realistic estimate of the live load at the time of the collapse. In the course of the investigation it was discovered that the original design of the suspension rod and box-beam connection by the engineers of the firm Jack D. Gillum and Associates was altered during the construction by the contractor Havens Steel. We draw the as-built configuration and the original design configuration of the connection at the 4th floor walkway below, Figure 2.2, based on the schematics and descriptions of the report.

The local details of the walkway connector are shown in Figure 2.3.

This change in the hanger rod design essentially doubled the load on the nut connecting the top hanger rod at the 4th floor to the floor beam as it carried not only the weight on the 4th floor walkway coming from

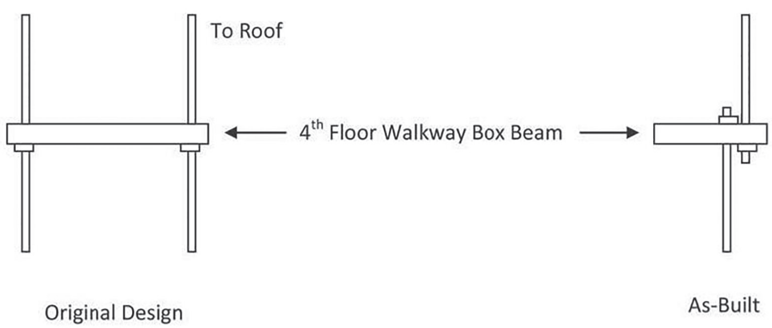

Figure 2.2 Schematics of the Walkway.

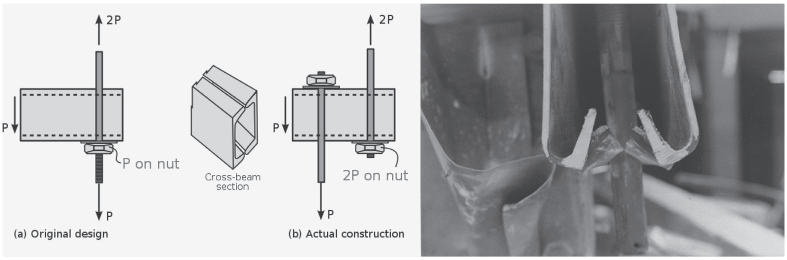

Figure 2.3 Details of the As Built and Original Hanger Rod Arrangement of the Walkway (Left) and the Damage (Right)

Source: http://en.wikipedia.org/wiki/File:HRWalkway.svg. Copyright in the Public Domain.
Source: http://en.wikipedia.org/wiki/File:Hyatt_Regency_collapse_support.PNG. Copyright in the Public Domain.

the floor beam but also that on the second floor walkway coming from the hanger rod below. A detailed analysis by the NBS team revealed other problems as well.

The Findings. The NBS team's findings were published in the July 1982 issue of the Civil Engineering magazine by Dr. Edward Pfrang. Only the major conclusions are described below.

1. The estimated load at the 4th floor connections exceeded the capacity of the connections at all the connection locations. Any of the connection could have initiated the collapse.
2. The as-built connection and the fourth floor hanger rod did not satisfy the design provisions of the Kansas City Building Code.
3. If the original design were used, the connection would have the capacity to resist the estimated load at the time of the collapse.
4. The connection capacity in the original design was only 60% of that of required in the Kansas City Building Code.

In other words, even the original design was flawed although it would have resisted the load at the time of the collapse. Furthermore, the design change was approved by the engineers at the firm of Jack D. Gillum and Associates apparently without a thorough review.

Aftermath. The engineers at the firm who approved the final drawings eventually were convicted by the Missouri Board of Architects, Professional Engineers, and Land Surveyors of 'gross negligence, misconduct, and unprofessional conduct in the practice of engineering' and their professional engineer licenses were revoked. The firm Jack D. Gillum and Associates was cleared of criminal negligence but lost its license as an engineering firm.

2.8 The Collapse of the I-35W Bridge in Minnesota

The Structure. The I-35W Bridge in Minneapolis, Minnesota is a fourteen-span 1,907 feet (580 m) long eight-lane bridge spanning the Mississippi River, opened in 1967. The bridge runs approximately south-north at the river crossing. The three main spans are of the deck truss type, 1,064 feet (304.3 meter) long. The other eleven spans are steel girder type. The bridge was designed by the engineering consulting firm of Sverdrup & Parcel and Associates, Inc., of St. Louis, Missouri, which was acquired in 1999 by Jacobs Engineering Group, Inc. The bridge design was certified by the Sverdrup & Parcel project manager on March 4, 1965 and approved by the Minnesota Department of Transportation on June 18, 1965. The design was based on the 1961 American Association of State Highway Officials (AASHO) *Standard Specifications for Highway Bridges* and 1961 and 1962 *Interim Specifications*, and on the *1964* Minnesota Highway Department *Standard Specifications for Highway Construction*. By August 1, 2007 an ongoing repair and renovation project closed four of the eight travel lanes (the two outside lanes northbound and the two inside lanes southbound) to traffic.

The Event. On 6:05 p.m., August 1, 2007 while the traffic was bumper-to-bumper on the bridge, the main spans suddenly collapsed and fell to the river and the south and north river banks. A total of 111 vehicles were on the collapsed spans. The collapse's casualty: 13 people died, and 145 people injured. The following photos are copied from the Accident Report Collapse of the I-35W Highway Bridge, Minneapolis, Minnesota, August 1, 2007, National Transportation Safety Board, NTSB/HAR-08/03, PB2008-916203. (http://www.dot.state.mn.us/i35wbridge/ntsb/finalreport.pdf)

The Investigation. Representatives of the National Transportation Safety Board (NTSB) and the Federal Highway Administration (FHWA) performed extensive investigative work themselves but made the consulting firm Wiss, Janney, Elstner Associates Inc. (WJE) part of the investigative team. WJE is known for its expertise in construction technology and failure evaluation. According to Howard Hill, director of technical operations and a principal of WJE (see the 12/30/2008 issue of the Engineering News Record), on site investigation by him and NTSB and FHWA experts quickly led to the gusset plates at the truss node U10, mainly because "1) that the 3-span structure separated rather cleanly along two symmetric lines, which coincided with the U10 nodes; 2) that the U10 gusset plates at all four locations … came apart in similar ways and 3) that the positions of the U10 node elements were such that it would have been difficult for them to have sustained damaged as a result of the collapse."

The numbering system for the nodes uses U for upper chord and L for lower chord and designates the southernmost node the node number zero and progresses by one going north. In the meantime, because of symmetry, the mirror image numbering is used for the northern half but with a prime (') attached.

Because the gusset plate connects the top chord members to each other and to the web members on both sides of the members, there are two gussets plates at the west side of the bridge deck and two at the east side, with a total of four at node U10.

Figure 2.4 The collapsed main span of the I-35 W Bridge

Figure 14, Highway Accident Report: Collapse of I-35W Highway Bridge, Minneapolis, Minnesota, August 1, 2007, National Transportation Safety Board. Copyright in the Public Domain.

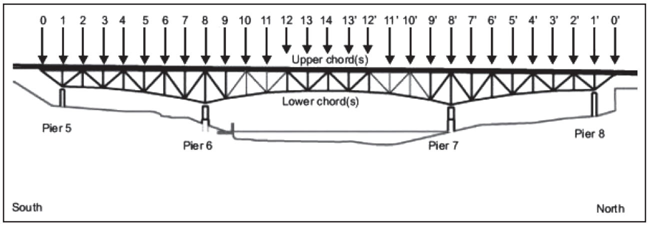

Figure 2.5 The Numbering System of the Members of the I-35W Bridge

Figure 8, Highway Accident Report: Collapse of I-35W Highway Bridge, Minneapolis, Minnesota, August 1, 2007, National Transportation Safety Board. Copyright in the Public Domain.

Although the U10 gusset plates were suspect at the beginning of the investigation, the NTSB team did an exhaustive study on all aspects and possibilities. It reviewed the three renovations of the bridge and the effects on the load: The 1977 Renovation increased deck thickness resulting in an increase of dead load by 3 million pounds or 13.4 percent; the 1998 renovation resulting in an increase by about 1.13 million pounds, or 6.1 percent; the ongoing 2007 renovation brought on deck some equipment but some 250,000 pound of concrete was already milled away from the center span deck. The NTSB team examined documents from a 1999 inspection and discovered photos showing 'bowing' of the gusset plates at node U10, a distortion of the gusset plates (See Figure 2.6).

The team performed finite element analysis of the truss structure as well as the detailed deformation of the gusset plates. The team performed material testing on the truss members and gusset plates and confirmed that the gusset plates used were of 50,000 pound per square inch (psi) capacity. The team's study all ruled out other factors such as corrosion damage found on the gusset plates at the L11 nodes and elsewhere, fracture of a floor truss, preexisting cracking in the bridge deck truss or approach spans, temperature effects, or shifting of the piers, as causes for the collapse. The investigation was concluded and NTSB published a report on November 14, 2008, entitled 'Collapse of I-35W Highway Bridge, Minneapolis, Minnesota, August 1, 2007.'

Some of the major findings in addition to what have already been mentioned above are selectively reproduced below (see http://www.dot.state.mn.us/i35wbridge/ntsb/finalreport.pdf).

U10W looking north **U10E looking north**

Figure 2.6 Two Views of the U10 Gusset Plates

Detail from: Figure 19, Highway Accident Report: Collapse of I-35W Highway Bridge, Minneapolis, Minnesota, August 1, 2007, National Transportation Safety Board.

1. The initiating event in the collapse of the I-35W bridge was a lateral shifting Instability of the upper end of the L9/U10W diagonal member and the subsequent failure of the U10 node gusset plates on the center portion of the deck truss.
2. The gusset plates at the U10 nodes, where the collapse initiated, had inadequate capacity for the expected loads on the structure, even in the original as-designed condition.
3. Because the bridge's main truss gusset plates had been fabricated and installed as the designers specified, the inadequate capacity of the U10 node gusset plates had to have been the result of an error on the part of the bridge design firm.
4. Even though the bridge design firm knew how to correctly calculate the effects of stress in gusset plates, it failed to perform all necessary calculations for the main truss gusset plates of the I-35W bridge, resulting in some of the gusset plates having inadequate capacity, most significantly at the U4 and U4 , U10 and U10 , and L11 and L11 nodes.
5. The design review process used by the bridge design firm was inadequate in that it did not detect and correct the error in design of the gusset plates at the U4 and U4 , U10 and U10 , and L11 and L11 nodes before the plans were made final.
6. Neither Federal nor State authorities evaluated the design of the gusset plates for the I-35W bridge in sufficient detail during the design

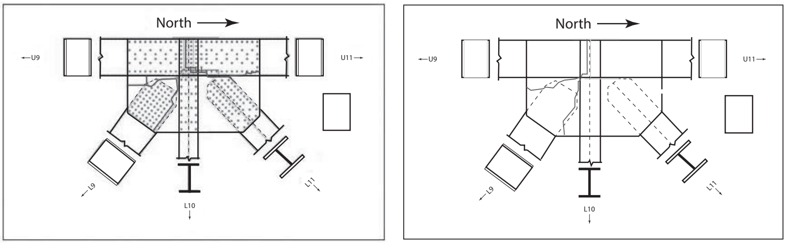

Figure 2.7 The Fracture Patterns of the U10 Gusset Plates

Figure 20A, Highway Accident Report: Collapse of I-35W Highway Bridge, Minneapolis, Minnesota, August 1, 2007, National Transportation Safety Board. Copyright in the Public Domain.

and acceptance process to detect the design errors in the plates, nor was it standard practice for them to do so.

7. Current Federal and State design review procedures are inadequate to detect design errors in bridges.
8. The loading conditions that caused the failure of the improperly designed gusset plates at the U10 nodes included substantial increases in the dead load from bridge modifications and, on the day of the accident, the traffic load and the concentrated loads from the construction materials and equipment; if the gusset plates had been designed in accordance with American Association of State Highway Officials specifications, they would have been able to safely sustain these loads, and the accident would not have occurred.

The report gave the following 'probable cause':

"The National Transportation Safety Board determines that the probable cause of the collapse of the I-35W bridge in Minneapolis, Minnesota, was the inadequate load capacity, due to a design error by Sverdrup & Parcel and Associates, Inc., of the gusset plates at the U10 nodes, which failed under a combination of (1) substantial increases in the weight of the bridge, which resulted from previous bridge modifications, and (2) the traffic and concentrated construction loads on the bridge on the day of the collapse. Contributing to the design error was the failure of Sverdrup & Parcel's quality control procedures to ensure that the appropriate main truss gusset plate calculations were performed for the I-35W bridge and

> the inadequate design review by Federal and State transportation officials. Contributing to the accident was the generally accepted practice among Federal and State transportation officials of giving inadequate attention to gusset plates during inspections for conditions of distortion, such as bowing, and of excluding gusset plates in load rating analyses."

The report also made recommendations on a bridge design quality assurance/quality control program to approve final design, modifications on bridge inspection training, and including gusset plate as a structural element for design review and inspection.

A new replacement bridge at the same location, named The I-35W Saint Anthony Falls Bridge, was opened on September 18, 2008, three months ahead of schedule. The bridge is wider with ten lanes and is a box girder bridge constructed with high strength concrete.

Highway Accident Report: Collapse of I-35W Highway Bridge, Minneapolis, Minnesota, August 1, 2007, National Transportation Safety Board. Copyright in the Public Domain.

CHAPTER 3

Is there life beyond the BSCE Degree?

3.1 Overview

Receiving a BSCE degree is a major milestone in your career. It by no means signals the end of learning. To the contrary, it simply signals the beginning of a pathway to a rewarding career, which in all likelihood requires lifelong learning to keep yourself up to date on new development and expand the portfolio of your skill set. In other words you are expected to continue your professional development throughout your career. Most new BSCE degree recipients are eager to get into the real world and gainful employment. The opportunities in civil engineering for a BSCE degree holder are described first in this chapter. Other career paths and higher degree programs are to follow. But first, one must know how to look for a job that requires a BSCE degree.

3.2 The First Job

In seeking employment, one question comes up often: should one looking for work in the private sector or in the public sector. That is a question difficult to answer. In terms of salary, generally private companies pay higher but some government agencies pay very well too and with better benefit and job security. Initial salary should not be a major concern although one should always know the salary range for employee of the organization and potential for promotion. For a new BSCE degree holder it is important to consider future career development opportunities beyond the first job. The questions to ask are whether there are potential exposures to a variety of different projects so that a new engineer can gain extensive experience from the work and what the career advancement opportunities within the organization are.

Whether one can relocate is a major factor in potential job opportunities. Obviously willingness to relocate broadens the prospect of choices. Ultimately, it is one's personal preference and the availability of opportunities that determine the first job.

No matter what is one's preference, job opportunities do not just appear. One must look for them. There are three types of resources one can explore while still in school:

1. **Career office.** Most universities have a career office or placement office serving graduating seniors and alumni. Many employers contact career offices for job posting or to participate in university's job fair during which many employers set up stations to highlight their job needs and accept applications on site. Staffs in career offices also give seminars on resume preparation and job interview techniques. Some even offer to review one's resume and conduct mock interviews. Most career offices also subscribe to online job search networks which maybe more useful than some free online resources. The career office is a great resource for students and one should get in touch with the office as early as possible, but certainly no later than six months before graduation.
2. **Professors.** In job hunting nothing is better than an inside track. Many professors practice engineering consulting and have extensive contact with potential employers. They may know job opportunities even before the opening is made public. Their recommendations carry a lot of weight. The relationship with one or more professors is not something to be developed just before one begins to think of jobs. In Chapter 2 the importance of professors has already been pointed out. Good grades and good interaction in and out of classroom is the key to being on the good side of a professor. Some BSCE programs hire practicing engineers as part-time instructors. They may be more important as far as job recommendations go. Certainly they have firsthand knowledge of the job market and specific job openings.

   After getting the first job, the most important thing is to keep and do well on the first job. While most civil engineers may change jobs several times in their whole career, a soured experience on the first job is damaging to the prospect of a rewarding career. In addition to the usual professionalism expected of civil engineers: punctual, honest, diligent, willing to work hard or over time, etc., one should observe the culture of the workplace: how people dress, how people interact, and how team work functions. It is advisable to have a mentor, a more senior colleague, who is willing to offer advices. One can ask the direct supervisor to recommend a mentor/advisor. A new employee is not expected to be a leader immediately in any team, but that does not prohibit you from taking initiative and request additional work assignment to assert your abilities. If and when one decides to leave the first job for career advancement, it is important to leave on friendly terms with all colleagues. They may be one's best referees for future career advancement opportunities.

3. **Personal Network.** Virtually all civil engineering or engineering related student organizations on campus have industrial advisors. If one has been an active member of a student organization or even has served on one or more officer positions, one must have already developed a relationship with the industrial advisors. Such a relationship can also be developed with practicing engineers when they are lecturing on campus in seminars or student organization activities. The more practicing engineers one knows and has a good relationship with the better opportunities one has when it comes to job hunting.

3.3 Some Major Companies

There are literally tens of thousands of engineering companies that hire BSCE degree holders. Briefly described below in alphabetic order are just a few who have broad ranges of engineering services and offices worldwide.

AECOM. The company describes itself as "a global provider of professional technical and management support services to a broad range of markets, including transportation, facilities, environmental and energy. With more than 43,000 employees around the world, AECOM is a leader in all of the key markets that it serves. AECOM provides a blend of global reach, local knowledge, innovation and technical excellence in delivering solutions that enhance and sustain the world's built, natural and social environments. A *Fortune 500* company, AECOM serves clients in more than 100 countries and had revenue of $5.9 billion during the 12-month period ended March 31, 2009." It has offices worldwide and in 42 states and D.C., Puerto Rico and Guam in the United States. It is headquartered in Los Angeles, CA with 56 other locations in California alone.

Black & Veatch. The professional services offered by Black & Veatch include asset, management, climate change solutions, construction, design—build/ engineering, procurement and construction, engineering consulting, engineering & design, infrastructure planning, management consulting, procurement, program management, smart utility, and water and wastewater refurbishment. Its market fields include energy, water, telecommunications, management consulting, federal, and environmental. Its 9,600 professionals work in 100 offices worldwide. In the United States, it has 65 offices in 29 states. It is headquartered in Overland Park, Kansas.

Bechtel. Bechtel offers services in Construction, Development & Financing, Engineering & Technology, Procurement, Project Management, Safety, and Sustainability & Environment. Its wide range projects include works on rail, road, bridges, tunnels, airport, ports, wireless and other communication infrastructure, defense, space, energy management, environmental restoration and remediation, mining and metals, oil, gas, petrochemical, liquefied natural gas, pipelines, industrial facilities, and fossil and nuclear power plants. Headquartered in San Francisco, California, it has nine other offices in Unites States and 25 offices in 24 other countries.

CH2M Hill. Known initially for its leadership in environmental engineering, CH2M Hill's services now cover markets in chemicals, manufacturing, electronics and advanced technology, mining, energy, nuclear, enterprise management solution, power, environmental, transportation, government and commercial facilities, water, wastewater and water resources and life sciences.

It has 25,000 employees in 40 countries. In the United States it has more than 100 project and area offices.

FLUOR. Founded as a construction company in 1912, FLOUR's services now include engineering, procurement, construction, maintenance (EPCM), and project management. FLOUR is a *Fortune 500* company with global reach. The range of markets FLOUR services includes energy and chemicals, industrial and infrastructure, government, power, and global services. Headquartered in Irving Texas, it has 41 offices outside of the Unite States and 22 offices in 12 states and Puerto Rico in the United States.

JACOBS. A broad-based technical professional consulting firm, JACOBS offers services in architecture/engineering, construction, **environmental, health and safety, planning, management, m**odular fabrication**,** and technology. Its market covers aerospace and defense, automotive and industrial, buildings, chemicals and polymers, consumer and forest products, environmental programs, infrastructure, oil and gas, pharmaceuticals and biotechnology, refining, and technology. It has 123 offices in 37 states and D.C. in the United States and 160 offices in over 26 countries.

KBR. A technology-driven engineering, procurement and construction (EPC) company, KBR is headquartered in Houston, Texas, the energy capital of the world. It supports the energy, petrochemicals, government services and civil infrastructure markets. KBR has the following business units: downstream, government and infrastructure, services, technology, upstream, and ventures. It has offices in Asia, Europe, Australia, North America and South Africa.

PARSONS. An engineering and construction company, PARSONS offers services in asset management, commissioning, qualification, validation, condition assessment, construction, data management, design, development and fabrication, disaster response, intelligent/security. Operations and maintenance, planning, project management and construction management. Its market covers communications, education, energy, environment, facilities, federal government, health care, infrastructure, transportation, vehicle inspection, and water and wastewater. Its projects in 34 states in United States and 15 other countries worldwide.

PARSONS BRINCKERHOFF. A firm in the development and operations of infrastructure, Parsons Brinckerhoff provides services in strategic consulting, planning, engineering, and program and construction management in multiple market sectors, including transportation, power, buildings/facilities, water/ wastewater, environmental, and urban/community development. It has offices in Australia, Asia, Middle East, Africa, Europe, South America and North America. In the United States, it has offices in 64 cities, with its headquarters in New York City, New York.

URS. A global, fully integrated engineering, construction and technical services firm, URS offer s professional planning, design, environmental, construction, program and construction management, operations and maintenance, management and specialized technical services. Its market includes transportation, power, industrial infrastructure and process, environmental and nuclear management, facilities, water/wastewater, mining, and defense and security programs. It has more than 300 offices and job sutes in major cities in 31 countries in the Americas, Asia-Pacific, the Middle East and Europe. URS has offices in every state of the United States.

The above are a sample of companies with wide range of services in civil engineering and other fields. There are many other companies specialize in one or two technical areas in civil engineering serving global, regional or local markets. These can be searched on internet or the database in career offices.

3.4 Some Major Federal and State Agencies

Virtually every federal or state agency hires civil engineers but some agencies hire more because their responsibilities are closely related to civil engineering. A sample of four of these agencies is given below. Their responsibilities and operations cover most of the civil engineering technical areas.

Army Corps of Engineers. The United States Army Corps of Engineers (USACE) is one of the oldest federal agencies established by the Congress. Its mission is to "provide vital public engineering services in peace and war to strengthen our Nation's security, energize the economy, and reduce risks from disasters." Today it "is the Nation's number one federal provider of outdoor recreation, owns and operates more than 600 dams, operates and maintains 12,000 miles of commercial inland navigation channels, dredges more than 200 million cubic yards of construction and maintenance dredge material annually, maintains 926 coastal, Great Lakes and inland harbors, restores, creates, enhances or preserves tens of thousands of acres of wetlands annually under the Corps' Regulatory Program, provides a total water supply storage capacity of 329.2 million acre-feet in major Corps lakes, owns and operates 24 percent of the U.S. hydropower capacity or 3 percent of the total U.S. electric capacity, supports Army and Air Force installations, provides technical and construction support to more than 100 countries, manages an Army military construction"

USACE serves the public and the military but it also serves private firms by providing engineering and technical support to U.S. firms competing for contracts for overseas projects on cost reimbursement basis. It commands approximately 37000 civilian and military employees working in over 70 countries worldwide. In the United States its offices spread geographically in ten Divisions and 37 Districts.

Environmental Protection Agency. The mission of the United States Environmental Protection Agency (USEPA) is "to protect human health and the environment," and to "lead the nation's environmental science, research, education and assessment efforts." Although it is a regulatory agency, its science and technology laboratories and research centers hire civil and environmental engineers. Its more than twenty laboratories and centers are located in 16 states.

Each state has its own Environmental Protection Agency charged with developing, implementing and enforcing the state's environmental protection laws. They also hire civil and environmental engineers.

Department of Transportation. The mission of the United State Department of Transportation (USDOT) "is to serve the United States by ensuring a fast, safe, efficient, accessible and convenient transportation system that meets our vital national interests and enhances the quality of life of the American people, today and into the future." Of its 12 federal agencies at least the following eight are closely related to civil engineering and hires BSCE degree holders: Federal Aviation Administration (FAA), Federal Highway Administration (FHWA), Federal Railway Administration (FRA), Federal Transit Administration (FTA), Maritime Administration (MARAD), National Highway Traffic Safety Administration (NHTSA), Research and Innovation Technology Administration (RITA), and Saint Lawrence Seaway Development Corporation (SLSDC).

Many more job and career opportunities are in each state's department of transportation (DOT) or equivalent (e.g. Caltrans for California). Most state DOTs carry out design, construction and maintenance themselves although more and more they also subcontract out their work. In Chapter 5 the funding for the interstate highway system was described.

The funding is allocated to the state level annually, making the state DOTs one of the most stable and reliable employers for BSCE degree holders.

Bureau of Reclamation. The US Department of Interior's Bureau of Reclamation (USBR) is charged with managing the water resources in the west part of United States. The 16 western states are covered by five regions under USBR: Great Plains, Lower Colorado, Upper Colorado, Mid-Pacific and Pacific Northwest. A total of 30 offices and the D.C. headquarters house administrators and engineers. The USBR's activities cover building seismic safety, canal safety, dam safety, desalination, fisheries and wildlife resources, flood hydrology, geotechnical engineering, hydroelectric research and technical services, infrastructure services, land and water surfaces use, materials engineering and research, national irrigation water quality, recreation, remote sensing and GIS, river systems and meteorology, sedimentation and river hydraulics, stream corridor restoration, water conservation, water operations, water resources research, and water resource services.

Many cities and counties, especially those in major population centers, have engineering offices with a large professional staff. The water and wastewater treatment is the responsibility of local governments, so is solid waste collection and disposal. While some local governments contract out these services to private companies, many also create semi-public entities to manage water supply and wastewater treatment. These entities hire many civil engineers.

3.5 PE Exam

Beyond the BSCE degree the next personal milestone for a civil engineer is the licensing as a professional engineer. The licensing of professional engineer is regulated by each state. The last hurdle for a civil engineer to obtain the professional engineer license is to pass the Principle and Practice of Engineering (PE) exam. It generally cannot be taken right after the BSCE degree. In fact application to take the exam requires the passing of the FE exam a BSCE degree (or any engineering degree from an ABET accredited program), and four years of practice under the supervision of professional engineers. The four years of practice after the BSCE degree is considered as internship for an engineer-in-training period. For Master's degree holders most state cuts the 4-year requirement to two. A study of the passing rate of the PE exam from between October 2005 and October 2008 by the National Council of Examiners for Engineering and Surveying (NCEES) reveals that the passing rate is the highest for exam takers with four and five years of experience (70 and 68%, respectively). This was reported in the June 2009 NCEES newsletter *Exchange* in a leading article entitled 'PE pass rate demonstrate importance of experience.'

While the PE exam can be taken by any qualified engineering degree holders, the content of the exam is discipline specific. For civil engineers, the one to take is the PE Civil exam. The PE exam is similar to the FE exam only in the length of the exam; four hours of morning session and four hours of afternoon session separated by a one hour lunch break. The morning session of the PE Civil exam emphasizes the breadth and includes the follow five basic areas of civil engineering: Construction, Geotechnical, Structural, Transportation, and Water Resources and Environmental. The afternoon session emphasizes depth. Exam takers are to choose only one of the above five areas. The breadth exam and the depth exam contain 40 multiple-choice questions each. Only the topical content of all five areas of the breadth exam is reproduced from the NCEES web-publication below:

> Depending on whether your BSCE curriculum requires all the above five technical areas, you may be wise to take some elective courses in areas not required by your program. It should be emphasized herein that the most important thing is the practical experience gained in the four years of working as a civil engineer. That is the fundamental difference between the FE and the PE exams.

All PE exams are open book. The PE Civil exam takers can also bring their own design standards/ handbooks. The PE Civil passing rate for the October 2012 exam was 65% for first-time exam takers and only 27% for repeat takers (http://ncees.org/exams/pe-exam/).

3.6 Master's and Ph.D. Degrees

The body of knowledge in modern civil engineering is expanding significantly because of the rapid changes in globalization, information technology, diversity in society, emerging technology, public awareness of engineering impact and the needs in civil infrastructure renewal. ASCE in 2010 made a policy statement to 'support the concept of Master's degree or Equivalent as a prerequisite for licensure and the practice of civil engineering at a professional level.' (Policy Statement 465—Academic Prerequisites for Licensure and Professional Practice(2).) While the state boards in charge of professional engineer licensing has yet to embrace this concept, it is unmistakable that ASCE's policy points to the importance of a Master's degree in combination with a BSCE degree as a fundamental prerequisite to practice civil engineering. In the same policy statement, ASCE also mentioned the importance of lifelong learning, which will be discussed later in this chapter.

There are two types of Master's degrees: Master of Science and Master of Engineering. The former emphasizes theory and the latter emphasizes practice. In reality, however, most universities offer Master of Science degrees which may also emphasize practice. In general, the Master of Engineering degree is considered a terminal degree for practicing engineers. The Master of Science degree may be considered as a stepping stone to a Doctor of Philosophy (Ph.D.) degree, although many programs allow the study of a Ph.D. degree directly after a B.S. degree without a Master of Science degree. The programs for advanced degrees are indeed set up in a variety of ways in different universities.

Many universities offer a Master of Science program in general civil engineering. The program usually requires taking courses in three or more technical areas in civil engineering; some of the courses are required, some elective. Thus it expands the breadth as well as depth of the civil engineering education. Many universities offer Master of Science degree in one of the civil engineering technical areas or allowing a student to concentrate on one area. One example is the Master of Science in Environmental Engineering degree programs. While very few B.S. in Environmental Engineering degree programs are offered, many M.S. in Environmental Engineering degree programs are, especially if a department is named as civil and environmental engineering. After all a B.S. education is supposed to be broad-based, and a Master's education is to be in-depth and concentrated on a technical area in civil engineering.

Normally a Master of Engineering program in civil engineering or one of the technical areas requires an in-depth design project on a very practical subject in addition to ten to twelve courses. A Master of Science program, on the other hand, may require a thesis worthy of the equivalent of two courses in addition to ten to twelve courses. There are programs that require only course work without project or thesis. In that case if one studies full time, it is possible to graduate within two semesters or three quarters. In case of a project or thesis requirement a student is required to have an advisor or a project director to supervise the student and more often than not to assign a topic for the project or thesis.

If a Master's program of choice is offered in a university near a population center, then it is possible to study part-time while working full time as a civil engineer. The advantage of studying part-time while working is the benefit of the synergistic relationship between work and study. The work may help focus the study on courses that have immediate impact on the work. The study may open up new opportunities in present and future work. Many companies and government agencies have generous reimbursement programs that pay full or partial cost of the Master's degree. If one studies part-time, then usually it is too demanding to take more than two courses at the same time. Taking two courses a term allows one to graduate within two to three years. Some universities offer teaching or research assistantship (TA/RA) to full time Master's students with required work load up to 20 hours per week.

Pursuing a Ph.D. degree is a very different matter. The degree is not normally required by most government agencies or private firms, although both sometimes hire Ph.D. degree holders for special purposes or programs. The degree is however a prerequisite for a teaching career in higher education, which is to be described in the next section.

A Ph.D. degree program in civil engineering or specialty technical areas is designed to produce experts or specialists. In addition to course requirements, which vary greatly from one institution to another, a dissertation is required. An advisor is required too to supervise not only the dissertation research but also in general the course of study. A successful dissertation must contain new ideas, new approaches or elements of new solutions to a new or existing problem in one of the specialty technical areas in civil engineering. The advisor simply advises but may not assign a specific topic for dissertation research. The new ideas must come from the Ph.D. degree candidate. Not only a written dissertation must be produced, the candidate for the degree must successfully defend the dissertation in an oral presentation and question-and-answer meeting, which may last for hours. There usually is a committee of three to five or even more faculty members sitting on the committee. In addition to the dissertation advisor, some universities require at least one or more members from a different department to be included in the committee. They vote to decide whether the defense is successful or not.

Rarely a Ph.D. student in civil engineering supports oneself completely. The TA/RA financial assistance is usually available to Ph.D. students. Some universities even offer fellowships or scholarships to Ph.D. students that require no work. Because of the uncertainty in the time needed to complete a Ph.D. dissertation, the financial burden would be high if without any forms of financial assistant. It is also rare that a Ph.D. student work full time and study only part-time. The research on the dissertation is too demanding to spend only part-time on it; few, if any, advisors would take on a part-time Ph.D. student.

Most universities require the test score of the GRE (Graduate Records Examination) for admission to Masters or Ph.D. degree programs. It should be mentioned that some universities also offer a Doctor of Science (Sc. D.) degree program instead of a Ph.D. degree program to emphasize the practical aspect of the study.

3.7 A Teaching Career in Higher Education

There are two different types of higher education institutes that hire Ph.D., degree holders in civil engineering or related fields: one that offers Ph.D. degrees and one offers up to Master's degrees. While both require teaching, research and services, the extent and depth of the requirement in each of the three categories are very different. Since Ph.D. programs are inseparable with research, those offering Ph.D. degree programs are inevitably research oriented and value research achievements in their faculty members. Each of the three categories of expected activities on faculty is briefly described below.

Teaching. The first responsibility of any higher education institute is to teach students. Teaching is conducted by full-time and part-time instructors. Part-time instructors usually are practicing engineers and teach one or two courses per term in areas they practice. Full-time instructors are often tenured or tenure-track faculty who teaches whatever amount of courses required of them in their areas of expertise. The teaching 'load' is usually one to two courses per semester in a Ph.D. degree granting institute and three to four in a Master degree granting institute. For first time teachers, it takes a lot of time to prepare for a course. A useful rule of thumb is at least three hours of preparation for every hour of classroom time. Then, there are office-hour requirements for off classroom interaction with students: usually at least one hour for every three hours of classroom time. The making of exam problems and the grading of exam papers also take time. Most exams in civil engineering programs are essay type problems that require careful grading. Teaching assistants may grade homework assignments but usually are not involved in making exam problems and grading exam papers.

The above is a sketch of the time requirement on teaching, but it does not address the increasing demand on the quality of teaching. The classical teaching method is to lecture the course content straightforwardly. Today the lecturing maybe aided by modern audiovisual tools but more importantly teaching becomes more than just lecturing the course content. Because of the diversity in students' background and preparedness, it is increasingly important to motive and inspire students and make the lecturing interactive and easier to accept. The classical 'sink or swim' attitude toward students is no longer acceptable and the instructor is more in a partnership with the learning student than just playing judge and giving out a grade at the end of a term. All these may need the instructor to become a student again to attend teaching workshops to learn the teaching skills necessary to succeed as a teacher in a higher education institute. In Ph.D. granting universities, advising successfully Ph.D. students is valued as part of the teaching responsibilities, which takes mentorship and excellent advising and supervision.

Research. Research is measured by the scholarship exhibited through peer-reviewed publications. A new faculty member may be able to publish off the Ph.D. dissertation work with the advisor at the beginning but ultimately must exhibit the ability to conduct research independently from the previous advisor. While it is possible to conduct some civil engineering research by oneself without research assistants or laboratory work, most research work do need some form of assistant. That means funding or research grants are needed to support the assistants.. The ability to acquire funding from external sources is highly valued in any university, but especially in research oriented universities. The benefits of research grants also include the ability for the faculty to attend technical and professional meetings and conferences without having to rely on university funding for travel and related expenses. Abundance of research grants without adequate research output in terms of publications, however, is viewed negatively in internal peer review. It signals the weakness in not being able to complete promised research and produce quality results that are publishable.

Services. Most universities have faculty governance policies that require the participation of faculty in many aspects and levels of operations and decision-making. The faculty participation is in the form of committee membership at the department, college, and university levels. The demand on faculty's time varies from committee to committee. New faculty members are expected to serve at the department level and gradually move to college and university levels progressively. Some committee membership is by election and some by appointment, depending on the culture of faculty governance of the institute. Serving on committees are both an obligation and an honor.

Getting Tenured. The tenure system in higher education institutes in the simplest terms means that a tenured faculty cannot be fired without cause. Most universities now also have a post-tenure review system to ward off criticism that the tenure system rewards. For all practical purposes, a tenured faculty is guaranteed a lifetime employment at the institute. Thus, getting tenured is a major milestone in a teaching career.

When a new faculty is hired at the lowest faculty rank of assistant professor, he/she is given a seven-year probation period. At the end of the sixth year, the university must make a decision, unofficially called 'up or out', on either to promote the faculty to associate professor with tenure or terminate the employment at the end of the seventh year. The decision is made jointly with faculty peers and administrators according to some established procedures, which vary from one institute to another. The decision is made based on the faculty's record and peer evaluation on teaching, research and services, and sometimes external review on research and scholarship. Student evaluation of teaching effectiveness factors significantly in the decision. Even research orientated universities are reluctant to grant tenure to a faculty who could not teach effectively.

While the tenure decision is a grave one, most universities have interim reviews so that the final decision would not be abrupt and take the faculty by surprise.

Getting Promoted. The promotion from assistant professor to associate professor is usually granted at the time of tenure but some institute may promote someone and grant tenure later in a separate evaluation process. The promotion to full professor is another milestone in a teaching career. In a research oriented university it typically requires achieving a national or even international reputation in one's chosen field of expertise. The full professorship is normally at the top of the academic ladder, although some universities create another rank above full professor to reward the most productive and respected faculties. Another way of honoring respected faculties is to grant them chair or endowed professorships. These professorships are not another rank but are titles that carry tangible and intangible privileges.

While a teaching career seems attractive, especially considering the tenure system and flexible working hours, it by no means is an easy career. The tenure and promotion process is demanding and competitive. The flexible hours does not translate into less working hours. It is not uncommon to find a full faculty parking lot on weekends in a research oriented university. The pay is normally below that of the private companies but some nationally reputable universities have a salary structure that is very competitive. After all, to pursue a teaching career one must have a heart in teaching and enjoy the challenge in creating new knowledge through research and scholarship.

3.8 Lifelong Learning

The need for continuously learning new skills and knowledge in civil engineering is the same as the need to have a Master's degree as ASCE suggested. The knowledge base is changing continuously, the code and specifications governing design and construction practices are modified periodically and with shorter intervals, and the theater of application is changing from mostly domestic to international. Lifelong learning becomes necessary just to 'keep up' in the field of civil engineering. Furthermore, for a licensed professional engineer, many states now require periodical certification of continuing education credits to maintain the license. There are many forms of lifelong learning that are officially acceptable to the state boards. But in its most basic meaning, lifelong learning is the desire and the practice of self renewal in the professional sense. It may take the form of studying professional journals and reading textbooks on one's own on an advanced subject. Some of the more popular and recognized forms of lifelong learning is briefly described below.

Attending Professional Seminars. Most professional societies such as ASCE, ACI, AISC conduct frequent technical seminars around the country. Local chapters of professional societies also conduct technical seminars during their regular meetings and special seminars when they host prominent visitors. These seminars serve to bring the most recent developments in the profession to the local professionals.

Attending Technical Workshops. Professional societies sponsor technical workshops around the country when there are changes in design or construction codes and specifications. These workshops are usually very detailed with design examples using the new practice. Attending these workshops is not only helpful in one's daily practice but necessary.

Attending Professional Society Conferences. Professional societies held conferences once or twice annually. A variety of technical meetings are organized and participants can select the most relevant ones to attend.

Attending Classes in Local Universities. Sometimes it is advantageous to come back to school again and take one course to learn something new, usually a graduate level course. The rigor of a graduate level course benefits all attendants.

Lecturing and Making Presentations. Reporting on engineering projects in technical meetings that contain new elements of practice is another form of learning. Lecturing at undergraduate or graduate level regularly or on special occasions is also a form of lifelong learning.

3.9 Career Development—Management and Leadership Positions

Sooner or later opportunities present themselves for a civil engineer to move into management and leadership positions. Management is different from leadership but both require some similar personal skills and qualities.

Management means a clear goal or mission is given from the leadership within an organization and the manager's clear mandate is to carry out the mission and achieve the goal. Leadership often entails the creation of a new direction or mission for a group or an organization. The required abilities for a manager and a leader are briefly described below and numbered continuous from those for a manager to those for a leader to emphasize most of the required abilities of a manger may also apply to a leader.

I. **A Manager's Abilities**

1. **Ability to Plan Ahead:** As in problem solving, a plan to achieve the given goal need to be worked out in broad outlines. This requires the understanding of the technical issues and to be up-to-date on available technical tools, and know what is possible and what is not.
2. **Ability to Organize a Team and Other Resources:** To carry out a plan, it takes people to work together as a team. The manager must know the capabilities of each team member and assign responsibilities accordingly. The manager must also know any other resources within and without the team, such as additional funding, equipment, or even personnel, and get the authority from upper management to utilize these resources. Getting additional resources is always much appreciated by team members.
3. **Ability to Articulate the Plan and Team Responsibilities Clearly:** The manager must use all the communication skills to make sure everyone on the team understands what is expected of each of them and how their responsibilities fit in the overall plan.
4. **Ability to Monitor the Progress and Change Course:** To make sure the plan is carried out timely a manager must establish milestones and monitor the progress closely but not give the impression of overbearing on the team members. Lack of progress requires the manager's attention to troubleshot and to remedy either by re-assignment of personnel or even by modifying the plan.
5. **Ability to Share Credit and Glory:** When the goal is achieved, the manager must be generous in sharing the credit with all members and should take any opportunities to promote the contribution and reputation of team members. This approach goes a long way to ensure continuous success in future goals and projects.

II. **A Leader's Abilities**

6. **Ability to Have a Clear Vision of Direction:** Whether it is for a group or the entire organization, a leader must be able to see the strengths, weaknesses, the opportunities, and the competition of the organization and establish a vision and mission for the future.
7. **Ability to Create Practical Strategies:** To achieve the vision and mission, a broad outline of the strategies must be created. This requires a complete knowledge of all the resources of the organization and potential resources gained from being in partnership with other organizations. These resources are to be utilized in specific ways to achieve the vision and mission.
8. **Ability to Inspire and Motivate Colleagues:** A superb communication skill is a necessary condition to inspire and motivate but must be applied in combination with a clear vision and strategy to achieve results. A leader's ability to inspire and motivate tends to bring out the best from everyone.
9. **Ability to Manage the Managers:** To successfully carry out the strategies it is necessary to organize the managers and their groups to the optimum state, i.e. utilize their strengths to the fullest and avoid their weaknesses. This requires the knowledge the personal qualities of the top managers and properly put them to use.
10. **Ability to Make Timely Decisions:** Not all things turn out well all the time. Mid-course adjustment of strategies may become necessary. Only a leader can make decisions to change and the decision must be made at the most opportune time in order to have the most effect.

In addition to the above abilities, there are important qualities for a leader described below.

11. **Impeccable Personal Integrity:** A leader sets the standard of conduct of all members of an organization.
    The so-called 'moral authority' is derived from the daily behavior of the leader. Honesty in informing members of good and bad news is appreciated by all and the upholding of professional ethical standards to the highest degree sets the tune for the whole organization.

12. **Optimism and Positive Attitude:** if a leader does not believe in the vision and mission and the strategies designed and put forth by himself/herself, how can one expects others to believe? A leader's attitude is contagious. Positive attitude toward the outcomes of the strategies inspires others to work to achieve the outcomes.
13. **Creativity:** Find new directions and ways to achieve a mission requires 'out of the box' thinking. To see others do not see and invent new approaches is a winning quality in a leader.
14. **Fairness:** One of the central responsibilities of a leader is the periodical evaluation of performances of subordinates. Rewarding outperformers and inspiring underperformers are the necessary duties of the leader. Whatever the decision the leader makes in performance evaluation, it will be well received if it is carries out fairly and without ambiguity.
15. **Empathy:** The ability to feel and understand the emotion of others is a great asset in a leader. It helps establish a good relationship between two human beings and helps promote a healthy workplace atmosphere.
16. **Respect Others:** One of the most important attributes of a good leader is the ability to respect others. Everyone needs respect and performs the best if one feels respected.

3.10 Non-Civil Engineering Careers

A BSCE degree does not restrict the degree holder to a civil engineering career. As described in Chapter 1, there are several related disciplines that a civil engineering degree holder can get into. For example, a civil engineer with structural engineering interest and abilities can be hired by automobile companies, offshore platform design and construction companies, and even space industry to design structures. One can also choose to pursuit a completely different career after a BSCE degree. Some of the possibilities are described below.

1. **Medical Career.** A BSCE degree holder is qualified to apply to medical schools. Most medical schools require the test score of the Medical College Admission Test (MCAT). If admitted, the study period is normally four years. After the medical degree, there is typically

a 3-5 year residency/internship depending on the specialty, and 1-3 years of fellowship for further sub-specialization if desired. Then, one needs to pass a Board exam regulated by each state to practice medicine.

While the pay for a medical doctor is normally much higher than that of a civil engineer, considering the ten or more years required before one can begin to practice medicine and the usually demanding hours in practice, pay incentive cannot be the deciding factor in choosing a medical career. Besides, the tuition and fees for the four-year medical school study is very high and many students have to go into debt and accumulate more than $100,000 of debt in at the time of graduation. One must feel very strongly about helping people and relieving patients of the agony and suffering brought upon by illness to actually pursue a medical career.

2. **Law Career.** A BSCE degree holder is qualified to apply to law schools. The test to take is the Law School Admission Test (LSAT). If admitted, the study period is normally three years. Depending on the reputation of the law school, summer internship maybe readily available to law school students. To practice law, one must first to pass the bar examination; the difficulty to pass has been the subject of many movies and fictions. The public perception is lawyers make good money, but surprisingly the average income of lawyers is actually lower than that of civil engineers. That is because to every high profile and successful lawyer there may be ten struggling lawyers. For civil-engineer-turned-lawyers, however, there is a niche market: patent law. A patent lawyer assists inventors to apply for patent right and also assists patent holders to protect their patent right.
3. **Business Career:** After a BSCE degree one may choose to pursue a business career either by entering the business world directly or apply to enter a Master of Business Administration (MBA) degree program. The test to take is GMAT (Graduate Management Admissions Test). Some MBA programs accept previous GRE (Graduate Records Examination) test results in lieu of the GMAT score. The degree requirements vary from one program to another but it generally requires two-years of full time study or three to four years of part-time study. A combination of BSCE-MBA is very attractive to many corporations

and many large civil engineering firms. Success in a business career is never guaranteed with a MBS degree, however, as there are many MBA degree holders and the business world is just as competitive if not even more competitive than the civil engineering world.

4. **Any Other Careers:** The education of a BSCE program empowers the degree holder to pursue whatever career path one chooses to follow. The many abilities and qualities needed for a civil engineering career are equally useful for any other career. In the end it is a personal choice and we encourage you to follow your heart to make career choices but use your mind to ensure success.

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MOMENTUM PRESS ENGINEERING

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

ISBN 978-1-60650-712-4
90000
9 781606 507124