МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
ВІННИЦЬКИЙ ДЕРЖАВНИЙ ТЕХНІЧНИЙ
УНІВЕРСИТЕТ

# ENGLISH FOR CIVIL ENGINEERING CAREER

Вінниця ВДТУ 2000

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**Англійська мова для студентів 3-4 курсів інженерно-будівельних спеціальностей**



Затверджено Ученою радою Вінницького державного технічного університету як навчальний посібник з англійської мови для студентів інженерно-будівельних спеціальностей.

Протокол №6 від 27 січня 2000р.

Вінниця ВДТУ 2000

УДК 4И (англ) (075):69

English for Civil Engineering Career. Навчальний посібник з англійської мови для студентів 3 - 4 курсів інженерно-будівельних спеціальностей. /Л.С.Степанова, О.Р.Яковець - Вінниця: ВДТУ, 2000. - 67с. Англ. мова/

Бібліограф. 5 найм.

Рецензенти: С.Д.Чугу к. філол. н. ВДПУ
В.В.Кириленко к. психол. н. ВДПУ
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Зміст

# Пояснювальна записка

Даний навчальний посібник направлений на розвиток лексичних та граматичних навичок, необхідних для читання і перекладу текстів науково-технічного характеру головним чином із спеціальностей "Цивільне будівництво" та "Містобудування".

Основна мета посібника - познайомити студентів із особливою термінологією, вільне володіння якою є складовою частиною університетського курсу іноземної мови. Підібрані із оригінальних джерел та частково адаптовані тексти - це, в основному, опис різних фаз цивільного будівництва (топографічні виміри, будування мостів, підземних споруд і т.п.), а також обговорення проблем, що можуть виникати при виконанні даних будівельних робіт.

Посібник вимагає певного рівня знань студентів. Іншими словами, студент, що використовує даний посібник як навчальний, має вже бути знайомий із основними структурними частинами англійської мови. Автори старались спрямувати всі види робіт (дотекстові, післятекстові) на розширення словникового запасу і покращення комунікативних навичок студентів. Враховуючи вищесказане, підручник може бути використаний для роботи зі студентами старших курсів факультету цивільного будівництва.

Кожен розділ починається зі словника спеціальних термінів, де дано визначення кожного слова англійською мовою. За тлумачним словником йдуть вправи, направлені на засвоєння нової лексики (студентам треба відповісти на запитання, і саме відповіді і допоможуть засвоїти використання спеціальних термінів). В тексті, що займає значну частину розділу, ці терміни використовуються знову - у контекстному каркасі. За кожним текстом йде цілий ряд питань для дискусії, що дає студентові можливість застосувати новий лексичний матеріал в комунікативній ситуації.

Автори сподіваються, що даний посібник збільшить цікавість студентів у отриманні інформації, що стосується будівництва, а також покращить їх вміння спілкуватися англійською мовою по темах, що безпосередньо зв'язані із майбутньою спеціальністю.

# *UNITE ONE*
# *THE ENGINEERING PROFESSION*

## *Special terms*

**Engineering**: The practical application of the findings of theoretical science so that they can be put to work for the benefit of mankind. An engineer is a member of the engineering profession, although this term is also used to refer to someone who operates or maintains certain kinds of equipment - a railroad locomotive engineer, for example. In the latter context, the profession referred to is a technician rather than a professional engineer.

**Profession**: An occupation, such as law, medicine, or engineering, that requires specialized education at the university level.

**Empirical information**: Information that is based on observation and experience rather than theoretical knowledge.

**Civil engineering**: The branch of engineering that deals with the design and construction of structures that are intended to be stationary, such as buildings, dams, and bridges. Among its subdivision are structural engineering, dealing with permanent structures; hydraulic engineering, dealing with flow of water and other fluids; and environmental/sanitary engineering, dealing with water supply, water purification, and sewer systems, as well as urban planning and design.

**Aqueduct**: A structure that is used for transporting water over long distances.

**Stress**: Physical pressure or others forces exerted on an object. The force of gravity, the natural pull of the earth, for example, is one of the stresses that acts on an object.

**Environmental impact study**: A study that shows the effect a proposed structure will have on its surroundings: the ear, water, human, animal, and plant life, for example. Such studies are now required for most major construction projects in many countries.

## *Vocabulary Practice*

1. What does an engineering mean?
2. What is a profession? Give some examples.
3. How does a railroad locomotive engineer differ from a professional engineer ?
4. What is empirical information ?
5. What does a civil engineer deal with ?
6. What are some of the subdivisions of civil engineering ? With what is each of them concerned ?
7. What is an aqueduct ?
8. Define stress.
9. What is an environmental impact study concerned with ?

# *THE ENGINEERING PROFESSION*

Engineering is one of the oldest occupations in the history of mankind. Indeed, without the skills that are included in the field of engineering, our present-day civilization could never have evolved. The first toolmakers who chipped arrows and spears from rock were the forerunners of modern mechanical engineers. The craftsmen who discovered metals in the earth and found ways to process and refine them were the ancestors of mining and metallurgical engineers. And the skilled technicians who devised irrigation systems and erected the great buildings of ancient world were the civil engineers of their time. One of the earliest names that has come down to us in history is that of Imhotep, the designer of the stepped pyramids at Sakkara in Egypt about 3,000 B.C.

Engineering is often defined as the practical application of theoretical sciences, such as physics or chemistry, for the benefit of mankind. Many of the early branches of engineering, however, were based not on science but on empirical information, that is, information that depended on observation and experience rather than theoretical knowledge. Many of the structures that have survived from ancient times, such as the aqueducts of Rome, exist because they were built with greater strength than modern standards require. But at least the Roman engineers were sure that their buildings would last for a long time. Probably the oldest text in engineering is the work of a Roman architect and engineer named Vitruvius Pollio, who wrote a book in the first century B.C. about the engineering practices of his day. Many of the problems encountered by Vitruvius Pollio were similar to those that modern engineers still must confront.

The term civil engineering originally came into use to distinguish it from military engineering. Civil engineering dealt with permanent structures for civilian use, whereas military engineering dealt with temporary structures for military use. An example of the latter is the bridge built across the Rhine in 55 B.C. that is described in Julius Caesar's Commentaries on the Gallic War. A more appropriate definition of civil engineering is that it deals with the design and construction of objects that are intended to be stationary. In practice, this definition includes buildings and houses, dams, tunnels, bridges, canals, sanitation systems, and the stationary parts of transportation systems - highways, airports, port facilities, and roadbeds for railroads.

Since the beginning of the modern age in the sixteenth and seventeenth centuries, there has been an explosion of knowledge in every scientific field: physics and chemistry, astronomy and physiology, as well as recently evolved disciplines like nuclear and solid state physics. The eighteenth century witnessed the beginning of what is usually called the Industrial Revolution, in which machines began to do more and more of the work that previously had been done by human beings or animals. In the nineteenth century and in our own day, both scientific research and the practical applications of its results have progressed rapidly. They have given the civil engineer new and stronger materials; the mathematical formulas which he can use to calculate the stresses that will be encountered in a structure; and machines that make possible the construction of skyscrapers, dams, tunnels and bridges that could never have been built before.

Another result of the explosion of knowledge was an increase in the number of scientific and engineering specialties. Within the field of civil engineering itself, there are nowdays subdivisions: structural engineering, which deals with permanent structures; hydraulic engineering, which is concerned with systems involving the flow and control of water or other fluids; and sanitary or environment engineering, which involves the study of water supply, purification, and sewer systems. Obviously, many of these specialties overleap. A water supply system, for example, may involve dams and other structures as well as flow and storage of water.

Many different kinds of engineers often work on large projects, such as space exploration or nuclear-power development. In the space program, for example, the launching pads and the rocket assembly and storage building at Cape Canaveral, Florida - the largest such structure in the world - are primarily the work of civil engineers. In a nuclear power plant, civil engineers are responsible for the design and construction of the plant itself, as well as the protective shielding around the nuclear reactor. In both these cases, however, the civil engineers work with specialists in aerospace, nuclear, and electrical engineering. In projects of this kind, the engineer is a member of a team hat is often headed by a systems engineer who coordinates the contributions of all members of the team. Because teamwork is necessary in so many engineering projects nowadays, an important qualification for engineers is the ability to work successfully with other people.

The word engineer is used in two ways in English. One usage refers to the professional engineer who has a university degree and an education in mathematics, science, and one of the engineering specialties. Engineer, however, is also used to refer to a person who operates or maintains an engine or machine. An excellent example is the railroad locomotive engineer who operates a train. Engineers in this sense are essentially technicians rather that professional engineers.

Engineers must be willing to undergo a continual process of education and be able to work in other disciplines. They must also adapt themselves to two requirements of all engineering projects. First, the systems that engineers produce must be workable not only from a technical but also from an economic point of view. This means that engineers must cooperate with management and government official who are very cost-conscious. Therefore, engineers must accommodate their ideas to the financial realities of a project.

Second, the public in general has become much more aware, especially in the last ten years or so, of the social and environmental consequences of engineering projects. For much of the nineteenth and twentieth centuries, the attitude of the public could be summed up by the phase «Science is good». The most visible part of science was the engineering work. No one can avoid seeing the great dams, the bridges, the skyscrapers, and the highways that have created an impressive, engineered environment around us.

Nowadays, however, the public is more conscious of the hidden or delayed hazards in new products, processes, and many other aspects of civil engineering systems. For instance, new highways in many countries as the United States are no longer approved routinely; instead, highways and other similar projects must now undergo environmental impact studies to assess the project's effect on air pollution other environmental concerns.

A resent news story which reported that the Egyptian government now permits public criticism of the Aswan High Dam underlines this concern. The Aswan Dam is one of the engineering wonders of modern times, but several undesirable effects have been noted. The dam has, for instance, blocked the flow of silt down the Nile, so that the fertility of the land below the dam has decreased. Nutrients that were once carried down the river have been held back by the dam, and consequently schools of fish that once thrived around the Nile Delta have gone elsewhere. Still another reported effect of the dam has been the increase of the salinity of the soil which is irrigated by the water behind the dam. These and other problems might have been prevented by more thorough studies before construction was undertaken.

In other words, engineers do not work in a scientific vacuum. They must consider the social consequences of their work. We have, after all, described engineering as a profession that makes practical application of the findings of theoretical science. Successful engineers must include on their definition of practical the idea that the work is also desirable and safe for society.

Name the word-building elements (suffixes, prefixes) and the part of speach of each word. Translate them into Ukrainians:

*civil - civilian - civilize - civilized - uncivilized - civilization;*
*engine - engineering - engineer;*
*to depend - dependence - dependent - independent;*
*to develop - developed - undeveloped - development;*
*to vary - variation - variety -*
*to use - use - useful - useless;*
*to invent - inventor - invention;*
*to utilize - utilization.*

## *DISCUSSION*

1. Who were the forerunners of modern mechanical, mining and metallurgical, and civil engineers ?
2. Who was Imhotep ?
3. How do the buildings that have survived from ancient times compare with those built by modern standards ?
4. How does civil engineering differ from military engineering ? What is a classical example of a structure built for military purposes ? Can you think of any modern examples ?
5. Why does civil engineering offer a particular challenge ? What consequence does this have for civil engineers ?

6. What began in the eighteenth century ? Has this movement continued up to the present ?
7. What are some of the subdivisions within the field of civil engineering ?
8. Why is an engineer's education never really finished ?
9. What has the general public become aware of in the last ten years or so ? What was the public attitude prior to this period ?
10. What must an engineer consider in his or her work ?

# *UNIT TWO*
# *SURVEYING*

## *Special Terms*

**Surveying**: Measuring the earth's surface. Plane surveying measures surfaces as though they were flat, without taking into account the earth's curvature, whereas geodetic surveying includes calculations for the curvature. A surveyor is the person who makes a survey.

**Horizontal Plane**: Perpendicular to the force of gravity.

**Vertical plane**: In line with the direction of gravity.

**Chain**: A device 66 feet long (surveyor's chain) or 100 feet long (engineer's chain) for measuring distance.

**Transit**: A telescopic device that can be used for measuring distances and horizontal and vertical angles.

**Theodolite**: A special kind of transit that gives more accurate readings of angles that a standard transit.

**Stadia Hairs**: Lines in a transit that are used in determining distances. Stadia is the plural of stadion, a Greek word for a measure of distance, about 607 feet.

**Control Lines**: The lines on a map that indicate points of equal elevation (height).

**Geological Survey**: Determining underground conditions, such as types of soil and rock beneath the surface.

**Boring**: The process of bringing up samples of subsurface soil and rock by means of a hollow drill. Each sample is also called a boring.

**Gravimeter**: A device that measures the earth's gravitational pull.

**Seismograph**: A device that measures the strength of vibrations (seismic waves) within the earth.

## *Vocabulary Practice*

1. What is surveying ?

2. What is the difference between plane surveying and geodetic surveying ?
3. What is the difference between a horizontal plane and vertical plane ?
4. What is a chain ? What has replaced it nowadays ?
5. What are transits and theodolites ?
6. What are stadia hairs ? Where does the word stadia come from ?
7. What are contour lines ?
8. Is a geological survey the same as a geodetic survey ? If not, what is it?
9. What does boring mean ?
10. What does a gravimeter measure ?
11. What does a seismograph measure ?

## *SURVEYING*

Before any civil engineering project can be designed, a survey of the site must be made. Surveying mans measuring - and recording by means of maps - the earth's surface with the greatest degree of accuracy possible. Some engineering projects - highways, dams, or tunnels, for example - may require extensive surveying in order to determine the best and most economical location or route.

There are two kinds of surveying: plane and geodetic. Plane surveying is the measurement of the earth's surface as though it were a plane (or flat) surface without curvature. Within areas of about 20 kilometers square - meaning a square, each side of which is 20 kilometers long - the earth's curvature does not produce any significant errors in a plane survey. For larger areas, however, a geodetic survey, which takes into account the curvature of the earth, must be made.

The different kinds of measurements in a survey include distances, elevations (heights of features within the area), boundaries (both man-made and natural), and other physical characteristics of the site. Some of these measurements will be in a horizontal plane; that is, perpendicular to the force of gravity. Others will be in a vertical plane, in line with the direction of gravity. The measurement of gravity. The measurement of angles in either the horizontal or vertical plane is an important aspect of surveying in order to determine precise boundaries or precise elevations.

In plane surveying, the principal measuring devise for distance is the steel tape. In English - speaking countries, it has replaced a rule called a chain, which was either 66 or 100 feet long. The 66-foot-long chain gave speakers of English the acre, measuring ten square chain or 43,560 square feet as a measure of land area. The men who hold the steel tape during a survey are still usually called chainmen. They generally level the tape by means of plumb bobs, which are lead weights attached to a line that give the direction of gravity. When especially accurate results are required, other means of support, such as a tripod - a stand with three legs - can be used. The indicated length of a steel tape is in fact exactly accurate only at a temperature of 20° centigrade, so temperature readings are often taken during a survey to correct distances by allowing for expansion or contraction of the tape.

Distances between elevations are measured in a horizontal plane. In the diagram alongside, the distance between the two hills is measured from points A to B rather that from points A to C to D to B. When distances are being measured on a slope, a procedure called breaking chain is followed. This means that measurements are taken with less than the full length of the tape.

Lining up the tape in a straight line of sight is the responsibility of the transitman, who is equipped with a telescopic instrument called a transit. The transit has plates that can indicate both vertical and horizontal angles, as well as leveling devices that keep it in a horizontal plane. Cross hairs within the telescope permit the transitman to line up the ends of the tape when he has then in focus.

Angles are measured in degrees of arc. Two different systems are in use. One is the sexagesimal system that employs 360°, each degree consisting of 60 minutes and each minute of 60 seconds. The other is the centesimal system that employs 400 grads, each grad consisting of 100 minutes and each minute of 100 seconds. A special telescopic instrument that gives more accurate readings of angles that the transit is called a theodlite.

In addition to cross hairs, transits and theodolites have markings called stadia hairs (stadia is the plural of the Greek word station, a measure of distance). The transitman sights a rod, which is a rule with spaces marked at regular intervals. The stadia hairs are fixed to represent a distance that is usually a hundred times each of the marks on the rod. That is, when the stadia hairs are in line with a mark on the rod that reads 2.5, the transit is 250 meters from the rod. Stadia surveys are particularly useful in determining contour lines, the lines on a map that enclose areas of equal elevation.

Contour maps can be made in the field by means of a plane-table alidade. The alidade is a telescope with a vertical circle and stadia hairs. It is mounted on a straight-edged metal plate that can be kept parallel to the line of sight. The surveyor can mark his readings of distances and elevations on a plane (or flat) table that serves as a drawing board. When the marks representing equal elevations are connected, the surveyor has made a contour map.

Heights or elevations are determined by means of a surveyor's level, another kind of teleskope. A bubble-leveling device parallel to the telescope. A bubble level, which is similar to a carpenter's level, is a tube containing a fluid that has an air bubble in it. when the bubble is centered in the middle of the tube, the devise is level. The surveyor sights a rule called a level rod through the telescope. The rod is marked off to show units of measure in large, clear numbers. The spaces between the marks usually are alternately black and white in order to increase visibility. The number that the surveyor reads on the level rod, less the height of his or her instrument, is the vertical elevation.

Heights are given in relation to other heights. On maps, for example, the usual procedure is to give the elevation above sea level. Sea level, incidentally, can be determined only after averaging the tides in a given area over a definite period. A survey carried out by level and rod often gives the elevation in relation to a previously measured point that is called a bench mark.

Approximate elevations can also be measured with an altimeter, which is a device that takes advantage of changes in atmospheric pressure. Readings taken with an altimeter are usually made at two, and sometimes three, different points and then averaged. The readings must be corrected for humidity and temperature, as well as the weight of the air itself.

Modern technology has been used for surveying in instruments that measure distance by means of light or sound waves. These devices direct the waves toward a target that reflects them back to a receiver at the point of origin. The length of time it takes the waves to go to the target and return can then be computed into distance. This surveying method is particularly useful when taking measurements over bodies of water.

Aerial photography is another modern method of surveying. A photograph distorts scale at its edges in proportion to the distance the subject is from being in a direct vertical line with the lens of the camera. For this reason, the photographs for an aerial survey are arranged to overlap so that the scale of one part joins the scale of the next. This arrangement is called a mosaic, after the pictures that are made from hundreds of bits of colored stone or glass.

Geodetic surveying is much more complex that plane surveying. It involves measuring a network of triangles that are based on points on the earth's surface. The triangulation is then reconciled by mathematical calculations with the shape of the earth. This shape, incidentally, is not a perfect sphere but an imaginary surface, slightly flattened at the poles, that represents mean sea level as though it were continued even under the continental land masses.

In addition to measuring surfaces for civil engineering projects, it is often necessary to make a geological survey. This involves determining the composition of the soil and rock that underlie the surface at the construction site. The nature of the soil, the depth at which bedrock is located, and the existence of faults or underground streams are subsurface factors that help civil engineer determine the type and size of the structural foundations or the weight of the structure that can rest on them. In some areas, these can be critical factors. For example, Mexico City rests on a lakebed with no bedrock near the surface it is also located in an earthquake zone. The height and weight of buildings must therefore be carefully calculated so that they will not exceed the limits that are imposed by the site.

Geological samples are most often obtained by borings, in which hollow drills bring up cores consisting of the different layers of underground materials. Other devices that are used in geological surveys are gravimeters and magnetometers. the gravimeter measures the earth's gravitational pull heavier rocks like granite exert a stronger pull that lighter ones like limestone. The magnetometer measures the strength of the earth's magnetic field. Again, the denser the rock, the more magnetic force it exerts.

A third instrument is the seismograph, which measures vibrations, or seismic waves, within the earth. It is the same instrument that is used to detect and record earthquakes. In a geological survey, it is used by setting off small, man-made earthquakes. The waves created by a blast of dynamite buried in the ground reflect the different kinds of rock under the surface hard or dense rocks reflect the waves more strongly that soft or porous rock.

## *DISCUSSION*

1. What may some engineering projects require? For what reason ?
2. What kind of survey measures the earth's surface as though it were flat? What kind of survey takes into account the curvature of the earth?
3. Name several different kinds of measurement that are included in a survey?
4. How long was a chain? What was it used for? What is used in modern surveying instead of a chain? How is it leveled?

5. How are angles measured? What two different systems are in use?
6. What special telescopic instrument gives more accurate readings of angles that a transit ?
7. What can be used to make contour maps in the field? What does the surveyor use to make his sightings? Where does he mark his readings? What has he made when he connects the marks representing equal elevations?
8. How are heights or elevations given on maps? How is sea level in a given area determined?
9. What device can be used to determine approximate elevations? What does this device take advantage of?
10. How can distances be measured by means of light or sound waves? Where is this method particularly useful?
11. Why are pictures in an aerial survey arranged to overlap in a mosaic? Where does the word mosaics come from?
12. What does geodetic surveying involve?
13. What is the shape of the earth?
14. What other kind of survey is often necessary for civil engineering projects? What does this involve?
15. What others devices are used in surveying? Describe them.

# *UNIT THREE*
# *MODERN BUILDINGS AND STRUCTURAL MATERIALS*

## *Special Terms*

**Thrust**: The pressure or force exerted by each part of a structure on the other parts.

**Post-and-lintel**: A type of construction in which a horizontal beam rests on two vertical supports.

**Shear**: The tendency of a material to fracture or break along the lines of stress, the force that strains or deforms a structure or its parts.

**Flying Buttress**: A support for walls or pillars that absorbs their outward and downward thrust. They were used in building the Gothic cathedrals.

**Dead Load**: The total weight of all the materials in a structure; in other words, the weight of the structure itself.

**Live Load:** The weight that will be added to a structure as a result of its use-people, furniture, cars, machines, and so on.

**Impact**: The force at which the live load will be exerted on a structure. Cars have a greater impact that people, but airplanes have a greater impact than cars.

**Compression**: The force that presses or pushes two or more materials together.

**Tension**: The force that stretches or pulls apart a material.

**Neutral Plane**: The place in a material where there is neither tension nor compression.

**Masonry**: Building materials such as rock, brick, or tile, often bound together by mortar or cement.

**Pozzolana**: A natural cement used by the Romans.

**Bitumen**: A binding agent made from natural tars.

**Tensile Strength**: The ability of a material to retain its strength under tension.

**Fatigue**: The tendency of a material to weaken as a result of continual changes in stress.

**Steel**: An alloy or mixture of iron with a small amount of carbon or some other substance that increases its strength. Steel has great tensile strength.

**Portland Cement**: A mixture of limestone and clay< which is then heated and ground into a powder.

**Aggregate**: Small stones or gravel or crushed rock used as a building material.

**Concrete**: A mixture of cement, aggregate, sand, and water. It is the most important material for masonry construction in modern times. It has great strength and resistance to shearing forces.

**Reinforced Concrete**: Concrete with steel rods embedded in it to increase its tensile strength and resistance to shearing forces.

**Bond**: A union between two materials.

**Prestressed Concrete**: A variety of reinforced concrete in which the steel rods are pulled tight in advance before pouring concrete to give the material the greatest strength possible.

**Curtain Wall**: A wall supported by a steel or concrete structure of a building. A curtain wall does not have any support function itself, as does a bearing wall.

**Riveting**: The process of fastening together pieces of metal with rivets that do not have threads.

**Welding**: The process of fastening together pieces of metal by melting a bonding metal between similar metals.

**Polymers**: Long chainlike compounds of elements, principally hydrogen and carbon. They are the basis for many plastics and are now being used to produce concrete with more strength and durability. Accordingly, they help cut concrete weight to some extent.

## *Vocabulary Practice*

1. What in thrust?
2. What does post-and-lintel construction indicate?
3. What kind of buildings used flying buttresses? What was their purpose?
4. What is the difference between dead load and live load?
5. What is the difference between compression and tension?
6. What is masonry made of?
7. What is tensile strength?
8. What is Portland cement?
9. What is aggregate?
10. What materials are combined to form concrete?
11. How is the strength of prestressed increased?
12. What is the difference between a curtain wall and a bearing wall?
13. What is the difference between riveting and welding?
14. What are polymers? Why are they now being mixed with concrete?
15.

# *MODERN BUILDINGS AND STRUCTURAL MATERIALS*

Many great buildings built in earlier ages are still in existence and in use. Among them are the Pantheon and the Colosseum in Rome, Hagia Sopia in Istambul, the Gothic churches of France and England, and the Renaissance cathedrals, with their great domes, like the Duomo in Florence and St. Peter's in Rome. They are massive structures with thick stone walls that counteract the thrust of their great weight. Thrust is the pressure exerted by each part of a structure on its other parts.

All of these buildings and many others represent engineering solutions to challenging problems. The Romans made extensive use of the arch to distribute thrust more evenly, thus making larger openings possible. Architects and engineers before the Romans had used a post-and-lintel construction for the most part, with two vertical columns supporting a horizontal beam. If the beam is too long, or if it has to support too much weight, it is subject to shear, the tendency to fracture or break along the lines of stress. Stress is the force or pressure that tends to strain or deform a structure or its various parts.

In the Gothic cathedrals, stone pillars that had comparatively thin walls between them were raised to great heights. The cathedral at Beauvais, France, reached a height of 157 feet, bout the same as a modern building of fifteen floors. The vault collapsed on the first attempt to raise it to such a height, but it was later rebuilt and still stands. The great stone ribs of the Gothic cathedrals were supported by flying buttresses that absorbed the outward and downward thrust. In great domed structures like Hagia Sophia or St. Peter's, the thrust was distributed by a series of arches or half-arches that were supported by enormous piers (vertical supports).

These great buildings were not the product of knowledge of mathematics and physics. They were constructed instead on the basis of experience and observation, often as the result of trial and error. One of the reasons they have survived is because of the great strength that was built into them - strength greater that necessary in most cases. But the engineers of earlier times also had their failures. In Rome, foe example, most of the people lived in insulae, great tenement blocks that were often ten stories high. Many of them were poorly constructed and sometimes collapsed with considerable loss of life.

Today, however, the engineer has the advantage not only of empirical information, but also of scientific data that permit him to make careful calculations in advance. When a modern engineer plans a structure, he takes into account the total weight of all its component materials. This is known as the dead load, which is the weight of the structure itself. He must also consider the live load, the weight of all the people, cars, furniture, machines, and so on that the structure will support when it is in use. In structures such as bridges that will handle fast automobile traffic, he must consider the impact, the force at which the live load will be exerted on the structure. He must also determine the safety factor, that is, an additional capability to make the structure stronger that the combination of the three other factors.

The modern engineer must also understand the different stresses to which the materials in a structure are subject. These include the opposite forces of compression and tension. In compression the material is pressed or pushed together; in tension the material is pulled apart or stretched, like a rubber band. In the diagram alongside, the top surface is concave, or bent inward, and the material in it is compression. The bottom surface is convex, or bent outward, and the material in it is in tension. When a saw cuts easily through a piece of wood, the wood is in tension, but when the saw begins to bind, the wood is in compression because the fibers in it are being pushed together.

In addition to tension and compression, another force is at work, namely shear, which we defined as the tendency of a material to fracture along the lines of stress. The shear might occur in a vertical plane, but it also might run along the horizontal axis of the beam, the neutral plane, where there is neither tension nor compression.

Altogether, three forces can act on a structure: vertical - those that act up or down: horizontal - those that act sideways: and those that act upon it with a rotating or turning motion. Forces that act at an angle are a combination of horizontal and vertical forces. Since the structures designed by civil engineers are intended to be stationary or stable, these forces must be kept in balance. The vertical forces, for example, must be equal to each other. If a beam supports a load above, the beam itself must have sufficient strength to counterbalance that weight. The horizontal forces must also equal each other so that there is not too might pull the structure around must be countered with forces that pull in the opposite direction.

One of the most spectacular engineering failures of modern times, the collapse of the Tacoma Narrows Bridge in 1940, was the result of not considering the last of these factors carefully enough. When strong gist of wind, up to sixty-five kilometers an hour, struck the bridge and also a lateral motion that caused the roadway to fall. Fortunately, engineers learn from mistakes, so it is now common practice to test scale models of bridges in wind tunnels for aerodynamic resistance.

The principal construction materials of earlier times were wood and masonry - brick, stone, or tile, and similar materials. The courses or layers were bound together with mortar or bitumen, a tarlike substance, or some other binding agent. The Greeks and Romans sometimes used iron rods or clamps to strengthen their buildings. The columns of the Parthenon in Athens, for example, have holes drilled in them for iron bards that have now rusted away. The Romans also used a natural cement called pozzolana, made from volcanic ash, that became as hard as stone under water.

Both steel and cement, the two most important construction materials of modern times, were introduced in the nineteenth century. Steel, basically an alloy of iron and a small amount of carbon, had been made up to that time by a laborious process that restricted it to such special uses as sword blades. After the invention of the Bessemer process in 1856, steel was available in large quantities at low prices. The enormous advantage of steel is its tensile strength: that is, it does not lose its strength when it is under a calculated degree of tension, a force which, as we have seen, tends to pull apart many materials. New alloys have further increased the strength of steel and eliminated some of its problems, such as fatigue, which is a tendency for it to weaken as a result of continual changes in stress.

Modern cement, called Portland cement, was invented in 1824. It is a mixture of limestone and clay, which is heated and then ground into a powder. It is mixed at or near the construction site with sand, aggregate (small stones, crushed rock, or gravel), and water to make concrete. Different proportions of the ingredients produce concrete with different strength and weight. Concrete is very versatile; it can be poured, pumped, or even sprayed into all kinds of shapes. And whereas steel has great tensile strength, concrete has great strength under compression. Thus, the two substantces complement each other.

They also complement each other in another way: they have almost the same rate of contraction and expansion/ They therefore can work together in situations where both compression and tension are factors. Steel rods are embedded in concrete to make reinforced concrete in concrete bars or structures where tension will develop. Concrete and steel also form such a strong bond-the force that unites them-that the steel cannot slip within the concrete. Acid corrodes steel, whereas concrete has an alkaline chemical reaction, the opposite of acid.

Prestressed concrete is an improved form of reinforcement. Steel rods are bent into the shapes to give them the necessary degree of tensile strength. They are then used to prestress concrete, usually by one of two different methods. The first is to leave channels in a concrete beam that correspond to the shapes of the steel rods. When the rods are run through the channels, they are then bonded to the concrete by filling the channels with grout, a thin mortar or binding agent. In the other (and more common) method, the prestressed steel rods are placed in the lower part of a form that corresponds to the shape of the finished structure, and the concrete is poured around them. Prestressed concrete uses less steel and less concrete. Because it is so economical, it is a highly desirable material.

The availability of steel and concrete, together with the elevator, which was also developed in the nineteenth century, have made possible the most characteristic kind of modern structure: the steel or concrete frame building. Not only towering modern skyscrapers, but also many less gigantic and spectacular building have a skeleton of steel or concrete that bears the weight of the structure. Until this type of construction became possible, the exterior walls - called bearing walls - had to carry the weight of the building. This meant that the walls on the lower floors of a tall building had to be tremendously thick. The old Pulitzer Building in New York , for example, built about the same time as the first steel-frame building, the Home Insurance Building in Chicago, and about the same height, had walls that were nine and one-half feet thick at the base.

Since the weight of modern structures of this type is carried by the steel or concrete frame, the walls do not support the building. They have become curtain walls, which keep out the weather and let in light. In the earlier steel frame building, the curtain walls were generally made of masonry; they had the solid look of bearing walls. Today, however, curtain walls are often made of lightweight materials such as glass, aluminum, or plastic, in various combinations.

Another advance in steel construction is the method of fastening together the beams. For many years the standard method was riveting. A rivet is a bolt with a head that looks like a blunt screw without threads. It is heated, placed in holes through the pieces of steel, and a second head is formed at the other end by hammering it to hold it in place. Riveting has now largely been replaced by welding , the joining together of pieces of steel by melting a steel material between them under high heat.

Prestressed concrete has made it possible to develop buildings with unusual shapes, like some of the modern sports arenas, with large spaced unbroken by any obstruction supports. The uses for this relatively new structural method are constantly being developed.

The current tendency is to develop lighter materials. Aluminum, for example, weighs much less that steel but has many of the same properties. Aluminum beams have already been used for bridge construction and for the framework of a few buildings.

Attempts are also being made to produce concrete with more strength and durability, and with a lighter weight. One system that helps cut concrete weight to some extent uses polymers, which are long chainlike compounds used in plastics, as part of the mixture.

## *DISCUSSION*

1. What are some of the buildings built in earlier ages that are still in existence and in use ?
2. What is thrust? How did the Romans solve the problem of thrust?

3. How was thrust distributed in great domed structures like Hagia Sophia or St. Peter's ?
4. Why have these buildings from earlier times survived? What is an example of engineering failure in ancient times?
5. What advantage do the engineers of modern times have over those of earlier days?
6. What four factors must an engineer take into account when he plans a structure?
7. What are the three forces that can act on a structure? How must these three forces work in relation to each other?
8. What was one of the most spectacular engineering failures of modern times? What happened?
9. What has been the result of this failure?
10. What were the principal construction materials of earlier times?
11. How did the Greeks and Romans use iron? Give an example.
12. What kind of cement did the Romans use?
13. When were steel and cement introduced?
14. Why had steel been restricted to special uses prior to 1856?
15. What enormous advantage does steel have as a construction material?
16. How have new alloys of steel increased its strength?
17. What is modern cement made from? How is it used to make concrete?
18. What are the advantages of concrete as a construction material?
19. In what ways do steel and concrete complement each other? How do these factors work together in reinforced concrete?
20. What are two methods for prestressing concrete? Why is prestressed concrete highly desirable?
21. What is the difference between the walls in buildings built with and without steel or concrete frames? Give an example.

# *UNITE FOUR*
# *TRANSPORTATION SYSTEMS*

## *Special Terms*

**Footing**: The surface on which a foundation rests.

**Wearing surface**: The top level of a road that receives the wear of traffic.

**Base coarse**: The level of a road between the footing and the wearing surface; it is usually made of crushed rock.

**Compacting**: Pressing down in order to make a material like sand and soil denser and firmer.

**Cloverleaf Interchange**: An intersection between two roads designed like a four-leaf clover. It permits cars to change from one highway to another without interrupting the flow of traffic.

**Soil mechanics**: A new science that deals with the classification of different kinds of soil according to density, stability, and so on. Soil stabilization techniques are used for making soils denser and firmer.

**Bulldozer; Vibrating Roller**: Earth-moving machines. The bulldozer pushes the earth aside; the vibration roller compacts earth.

**Concrete Train**: A group of machines that are used together to carry out the different steps in laying a concrete wearing surface for a highway.

**Urban Rapid Transit Systems**: Public transportation systems in cities. They include subways, elevated railways, and bus and trolley lines. Each system is designed for and operated at higher speeds.

**Superelevation**: Raising the outer edge of a road or railroad line above the inner edge en a curve; in other words, banking the curve.

**Ballast**: Crushed rock used on top of the footing of a roadbed for a railway line.

## *Vocabulary Practice*

1. What does footing mean?
2. What is the wearing surface of the road?
3. What is the base course of the road?
4. What does compacting the soil mean?
5. What is cloverleaf interchange?
6. What does soil mechanics deal with? What are soil stabilization techniques used for?
7. What do bulldozers and vibration rollers do?
8. What do urban rapid transit systems include?

# *TRANSPORTATION SYSTEMS*

Transportation has always been one of the most important aspects of civil engineering. One of the greatest accomplishments of the Roman engineers was the highway system that made rapid communication possible between Rome and the provinces of the empire. The first school that offered training specifically in engineering was the Ecole des Ponts et Chaussees, the School of Bridges and Highways, established in France in 1747. And in England, Thomas Telford, a road builder, become the first president of the Institution of Civil Engineers in 1820.

Modern highways are still built according to the principles laid down in the eighteenth and early nineteenth centuries by a Frenchman, Pierre Tresaguet., the Englishman Telford, and a Scot, John L. McAdam. These men designed the first modern roads that had a firm footing, the surface on which the foundation rested. Their roads also included good drainage and wearing surface - the top level that directly receives the wear of traffic - that could not be penetrated by water. Both Tresagued and Telford used a heavy foundation of stones, on top of which a base course of lighter crushed stones and a wearing surface of still smaller stones were built up. Their roads were also slightly curved in a crown or camber so that the water would run off. McAdam realized that the soil itself could bear the weight of the road when it was compacted or pressed down, as long as it remained dry. He was able therefore to eliminate the heavy cost of the stone foundation by laying a base course of crushed stone on top of a compacted footing. The iron wheels of the carriages of his day ground the stones of the top level into a continually smoother and more watertight surface.

These roads were adequate during the nineteenth century when wagons and carriages had tires made of iron or steel. When the automobile appeared at the beginning of the twentieth century, however, its rubber tires broke up the smooth surfaces. Therefore, the top layer was bound together more firmly by mixing the crushed rock with tar or asphalt. Millions of kilometers of roads throughout the world today have this kind of surface.

Basically, roadbuilding has improved in only two ways in the twentieth century. The first improvement in only two ways in the twentieth century. The first improvement involves the use of concrete for the wearing surface. The other is traffic engineering, the design of highways for high-speed, heavy-volume traffic, highways that are economical to build and safe for vehicles and their passengers. Traffic engineering has produced the modern express highway, or freeway, that has only limited access and maximum safety controls. The angular intersections common on older roads have been eliminated in factor of cloverleaf interchanges or other with even more complicated designs. Modern freeways usually have special lanes where traffic can either slow down before exiting or speed up upon entering. Extreme curves or steep slopes are minimized so that the traffic can continue to move without slowing down. Since monotony has proved to be a safety hazard, traffic engineering even includes the landscaping of the borders of the road.

When construction on a new highway begins, huge earth-moving machines called bulldozers level the ground along the designated route. The amount of earth to be moved, both in leveling and filling, has been previously calculated. Wherever possible, the amount in a cut where earth is being removed should be equal to the amount needed for a nearby fill.

Moving earth from a distant point is extremely expensive, and economy is a critical aspect of an engineer's work.

After the earth has been moved and shaped according to the design of the road, other machines prepare the footing. The most important of these is probably a vibrating roller, which compacts the earth until it can bear the weight of the base course and wearing surface that will rest on it. In many cases, however, the soil must be stabilized by mixing some other material with it. This may be bitumen or a grout of concrete or some other substance. The new and complex science of soil mechanics classifies soils and relates those classifications to their load-bearing capacity in a number of different ways.

The base course, which is made of either crushed stone or a layer of thinly-mixed concrete, comes next; the wearing surface, which may be a layer of asphalt or a series of reinforced concrete slabs, is then laid. A concrete surface must be laid in segments separated by joints to allow for expansion and contraction under differing weather conditions. One method of laying a reinforced concrete wearing surface is to put down the steel rods, usually in the form of a grill or mesh, after a certain proportion of the concrete has been poured. The top level must be poured within twenty minutes of the pouring of the bottom level to assure proper bonding. Another method is to pour the entire thickness of concrete and then force the steel mesh down into it to a predetermined level.

A group of machines collectively called a concrete train usually perform these operations at a rate of about three-fourths of a meter per minute. A single new machine called a slipform paver can perform all the different jobs of a concrete train except laying the reinforcing mesh. However, a technique has been worked out in which the mesh is held in place before the machine passes over it and pours concrete around it. The slipform paver can operate at a rate of about two meters per minute.

It huge concrete freeways are the transportation phenomenon of this century, then the railroads were the transportation phenomenon of the nineteenth century. Transportation by rail was not unknown before the invention of the steam lokomotive in 1829, but rail lines had been limited to the short distances over which horses or other draft animals pulled the load. Most of the lines were built in conjunction with mining operations. After the steam locomotive became a practical machine, a surge of railroad construction rapidly spread a network of railroads across the face of the world

By 1920 the great age of railroad building generally seemed to be over. As automobiles came into increasingly wider use, the emphasis shifted to highway construction. Except for a few improvements such as electrification, railroads were neglected. Now, however, there is a renewed interest in railroads. The Japanese, for example, have recently opened the Tokaido line between Tokyo and Osaka, with express trains that average 166 kilometers per hour and reach speeds as high as 210 kilometers per hour in normal operation. Even in the United States where many of he railroads are in deplorable condition, especially in the eastern part of the country, there is an increased interest in providing better service. There is also considerable inter- east-not only in the United States but in many other countries as well – in urban rapid transit systems. New subway (underground) lines have opened in Montreal, Mexico City, and San Francisco, and at this writing, lines are under construction in Washington, D.C.

In the last few years, important technological advances in railroad building have taken place. Soil mechanics and soil stabilization techniques have been used in the construction of footings for railroad lines as well as for other kinds of construction. Prestressed concrete sleepers that have been designed to replace the conventional wooden ones are being tested, and welded rails have begun to replace jointed rails. All these developments permit higher speeds and a other new concepts. One revolutionary proposal is for a railroad between Washington and Boston in which the trains would be pushed through a vacuum tube by means of atmospheric pressure.

The automobile has many advantages, but it has also proved to have disadvantages – air pollution and a high energy consumption are probably the most serious. These two negative factors are behind the increased effort to find new and improved methods for mass transportation systems.

## DISCUSSION

1. Whose principles of road-building are applied to the building of modern highways?
2. What elements were included in the roads that these men designed?
3. How did the roads designed by McAdam differ from those designed by Tresaguet and Telford?
4. Why were McAdam's roads adequate in the nineteenth century but inadequate in the twentieth?
5. How was the surface of such roads first improved to handle automobile traffic?
6. In what two ways was road-building improved in the twentieth century?
7. What kind of roads has traffic engineering produced?
8. What is the first step in the construction of a new road?
9. Why should the civil engineer carefully calculate the amount of earth to be moved?
10. What kind of machine is probably used to prepare the footing for the road? What does it do?
11. How can the soil be stabilized? On what do soil stabilization techniques depend?
12. What are the base course and the wearing surface of modern highways usually made of?
13. Why must a concrete surface be laid in segments?
14. What two methods are used to lay a reinforced concrete surface?
15. What machines are used for laying the concrete slabs of a highway? How is the reinforcing mesh laid with the second machine? How quickly do they work?
16. When was the steam locomotive invented? What rail lines were in existence before that time?

17. Why did the great age of railroad building generally seem to be over by 1920? What is one example of the renewed interest in railroad building?

18. In what other kind of transportation system is there considerable interest?

19. What technological advances have taken place in railroad construction in the last few years? What do these permit?

20. What are some experimental or proposed forms of rail transportation systems?

21. What disadvantages does the automobile have that have caused an increased interest in new mass transportation system?

# *UNITE FIVE*
# *BRIDGES*

## *Special Terms*

**Span**: The distance between two supports of a bridge. Span is also used as a verb, as in: The bridge spans a distance of 200 meters.

**Masonry Arch Bridge**: A bridge of masonry with arches between piers. Today the term usually refers to bridges made of stone.

**Pontoon**: A hollow drum that can float. Pontoons are used as supports for a pontoon bridge.

**Beam bridge**: The simplest kind of bridge. It consists of a rigid beam between two supports.

**Suspension Bridge**: A bridge supported by cables that are usually hung from towers.

**Truss**: A framework strengthened by diagonal beams that form triangles with horizontal and vertical beams. Trusses are used to strengthen beam bridges.

**Cantilever**: A type of structure in which a horizontal beam extends beyond its support. A cantilever bridge is a type of beam bridge.

**Steel arch bridge**: A bridge with an arch made with steel beams.

**Deck**: The roadway or traffic-bearing surface of a bridge.

**Stay**: A cable that runs at a diagonal from the main supporting cable to the deck of a suspension bridge.

**Concrete Arch Bridge**: A bridge with an arch made of reinforced concrete. It is really a kind of masonry arch bridge, but in can span a much greater distance that a stone arch.

**Lift Bridge**: A movable bridge with a span that is raised by elevators.

**Swing Bridge**: A movable bridge with a span that swings open parallel to the channel. It is also known as a pivot bridge.

**Pneumatic Caisson**: A cylinder with a cutting edge that can be sunk into the water bed. Water is forced out by compressed air.

**The Bends**: A crippling or fatal condition, caused by excess nitrogen in the blood, that can result from working in compressed air. It is also known as caisson disease.

**Keying**: Extending the piers of a bridge into bedrock instead of simply resting them on top of the rock.

**Crane**: A device that moves and lifts heavy weights. It is also called a jack.

## *Vocabulary Practice*

1. What is a span? Use the word as a verb.
2. What does the term masonry arch bridge usually refer to today?
3. What is a pontoon? How is it used in connection with bridges?
4. What is a beam bridge?
5. What kind of bridge is a suspension bridge?
6. What is a cantilever?
7. What is a steel arch bridge?
8. What does deck refer to in connection with a bridge?
9. How does a concrete arch bridge differ from other masonry arch bridges?
10. What is a lift bridge?
11. What is a swing bridge? What is another term for a swing bridge?
12. What are the bends? What is another name for this condition?
13. What does keying mean?
14. What is a crane?

# *BRIDGES*

Bridges are among the most important, and often the most spectacular, of all civil engineering works. The imposing bridges that have survived from ancient times are arched structures of heavy masonry, usually stone or brick. Herodotus, the greek historian of the fifth century B.C., however, mentions a wooden bridge across the Euphrates River at Babylon. In Rome, the bridge of Fabricius, built in 62 B.C. and named for its engineer, still carries traffic across the Tiber River, as does the Sant' Angelo Bridge, built in about 136 A.D. Both of these bridges, and many other Roman bridges, have a series of arches supported by heavy piers that extend down to bedrock. Ancient sources also mention pontoon bridges, usually in connection with military operations. A pontoon is a hollow drum that can float; a series of pontoons anchored to a riverbed can support a roadway. The Incas of pre-Columbian Peru built remarkable suspension bridges, supported by cables of natural fibers, that crossed many of the deep gorges in their mountainous country.

The sudden expansion in transportation systems that began in the eighteenth century, and still continues in our own day, has enormously increased the need for bridges as a part of highways and railroads. Better understanding of the forces that are exerted on structures and the improved materials that became available in the nineteenth century have made it possible to build increasingly longer and stronger bridges. With the ability to span greater distances, the domelike effect of masonry arch bridges with several heavy piers that block the flow of a stream can be largely eliminated.

The simplest type of span is a beam bridge, consisting of a rigid beam between two supports. Today most simple beam bridges are strenghened by a truss, which is based on the triangle. Diagonal beams that extend between the horizontal and vertical beams give support against both compression and tension. Many early truss bridges were built of wood; one that was erected across the Susquehanna River in Pennsylvania in 1815 had a span of 110 meters. Iron and then steel were later used in the construction of truss bridges, still further increasing their strength. Trusses are not only strong but also light, because all unnecessary material has been eliminated in their design.

Another type of beam bridge is the cantilever, in which a horizontal beam extends beyond its support. Cantilever bridges, like trusses, had also been built before iron and steel became available. Most cantilever bridges have two arms of truss structure that meet or support a section between them. Cantilevers enabled bridge builders to span longer distances than truss bridges. During the nineteenth century, cantilevers were frequently used to build railroad bridges. The Quebec Bridge, which crosses the St.Lawrence River in Canada, is the longest cantilever bridge in the world, with a span of 540 meters. It was completed in 1917, and until 1929 it was the longest bridge of any type in the world.

A third type of modern bridge is the steel arch bridge, which can carry a roadway either above or below its arch of steel beams. An arch exerts strong downward and diagonal thrusts, so the piers that support it must be especially strong. Probably the most famous steel arch bridge is the Sydney Harbor Bridge in Australia, with a span of 495 meters. The Bayonne Bridge between New Jersey and Staten Island in New York has a span one meter longer.

Suspension bridges span even longer distances that other types of bridges. The longest bridge of any type is the Verrazano-Narrows Bridge in New York, with a span of 1,280 meters. The deck or roadway of a suspension bridge is suspended from steel cables that are supported by massive towers. The first modern suspension bridges used linked chains made of wrought iron. Some of them survived for many years, like one across the Danube River in Budapest, Hungary. It was completed in 1849 and destroyed during World War II, nearly a hundred years later.

When steel became available, cables of steel wires replaced chains of wrought iron. Several suspension bridges built in this manner collapsed, however, as a result of storms or the movement created by the rhythm of the loads moving across them. It was later discovered that these failures were caused by the lack of truss supports for the deck. The first major cable-type suspension bridge to overcome these faults was designed by John A.Roebling at Niagara Falls. Its span of 250 meters was strengthened by trusses between the two decks. Roebling also used stays, inclined cables that ran from the main supporting cables to the deck, to stabilize the bridge. Roebling went on to design the Brooklyn Bridge in New York, which was completed in 1883 by his son, George Washington Roebling. The Brooklyn

Bridge, with a span of 486 meters, is one of the most important – and one of the most esthetically satisfying – bridges ever built. The method devised by the Roeblings for laying – bridges ever built. The method devised by the Roeblings for laying the component wires that make up the cables for the Brooklyn Bridge is essentially the same technique used today.

The development of reinforced and prestressed concrete has given engineers other important materials for bridge building. Concrete has been used particulary for relatively short-span bridges that are a part of freeway systems. These bridges often use precast concrete beams. Many arch bridges have also been constructed of concrete. Currently, the longest concrete arch bridge is the Gladesville Bridge in Sydney, Australia. It has a span of 305 meters, and its deck is above the arch. This is another example of an esthetically pleasing bridge.

Many bridges that pass over rivers or canals must be movable so that shipping can pass under them. One type is the lift bridge, with towers that can raise the entire span between them by means of counterbalances and electric motors. Another type is the swing or pivot bridge, which pivots the span on a pier so that the bridge can swing open parallel to the river or canal. A third type is the bascule bridge, which has one or two arms that can open upward at an angle by means of counterweights. A bascule with one arm is a single-leaf bridge, and with two arms it is a double-leaf bridge.

Bridge construction can present extraordinary difficulties. Usually the foundations for the piers must rest on bedrock, and often under water. One technique for working in these conditions is by means of a cofferdam. Piles usually made of interlocking steel plates are driven into the water bed. The water is then pumped out from within the area that has been enclosed.

Another technique is the use of the pneumatic caisson. The caisson is a huge cylinder with a bottom edge that can cut into the water bed. When compressed air is pumped into it, the water is forced out. Caissons must be used with extreme care. For one thing, workers can only stay in the compression chamber for short periods of time. For another, if they come up to normal atmospheric pressure too rapidly, they are subject to the bends, or caisson disease as it is also called, which is a crippling or even fatal condition caused by excess nitrogen in the blood. When the Eads Bridge across the Mississippi River at St.Louis was under construction between 1867 and 1874, at a time when the danger of working in compressed air was not fully understood, fourteen deaths were caused by the bends.

When extra strength is necessary in the piers, they are sometimes keyed into the bedrock – that is, they are extended down into the bedrock. This method was used to build the piers for the Golden Gate Bridge in San Francisco, which is subject to strong tides and high winds, and is located in an earthquake zone. The drilling was carried out under water by deep-sea divers.

Where bedrock cannot be reached, piles are driven into the water bed. Today, the piles in construction are usually made of prestressed concrete beams. One engeniours technique, used for the Tappan Zee Bridge across the Hudson River in New York, is to rest a hollow concrete box on top of a layer of piles. When the box is pumped dry, it becomes buoyant enough to support a large proportion of the weight of the bridge.

Each type of bridge, indeed each individual bridge, presents special construction problems. With some truss bridges, the span is floated into position after the piers have been erected and then raised into place by means of jacks or cranes. Arch bridges can be constructed over a falsework, or temporary scaffolding. This method is usually employed with reinforced concrete arch bridges. With steel arches, however, a technique has been developed whereby the finished sections are held in place by wires that supply a cantilever support. Cranes move along the top of the arch to place new sections of steel while the tension in the cables increases.

With suspension bridges, the foundations and the towers are built first. Then a cable is run from the anchorage – a concrete block in which the cable is fastened – up to the tower and across to the opposite tower and anchorage. A wheel that unwinds wire from a reel runs along this cable. When the reel reaches the other side, another wire is placed on it, and the wheel returns to its original position. When all the wires have been put in place, another machine moves along the cable to compact and to bind them. Construction begins on the deck when the cables are in place, with work progressing toward the middle from each end of the structure.

## DISCUSSION

1. How were the bridges that have survived from ancient times constructed? What two Roman bridges still exist?
2. What other kinds of bridges do ancient sources mention?
3. What kind of bridges did the Incas of pre-Columbian Peru build?
4. What has enormously increased the need for bridges?
5. What has made it possible to build longer and stronger bridges? What advantage does a longer span give?
6. What is the simplest type of span?
7. How are most beam bridges strengthened today? What advantage in addition to strength does this construction give to a bridge?
8. What is another type of beam bridge? Are all bridges of this type built from iron or steel?
9. What is the longest cantilever bridge in the world? When was it built?
10. What is another type of modern bridge? Why must the piers that support this type of bridge be especially strong? What are two examples of this type of bridges?
11. What kind of bridge can span longer distances that other types of bridges? What is the longest bridge in the world?
12. How is the deck of a suspension bridge supported? What other system was once used? Give an example.
13. What happened to some of the earlier suspension bridges that had steel cables? What caused these failures?
14. How did John A. Roebling overcome the difficulties in steel cable suspension bridges? What two bridges did he design?

15. What two types of bridges are often built today with reinforced concrete? What is the longest concrete arch bridge?
16. Why must some bridges be movable?
17. What are three types of movable bridges? How do they differ from each other?
18. Where do the foundations for a bridge usually rest?
19. What is one technique used in the construction of the foundations for the piers of a bridge?
20. What is another technique that is used for working on foundations below water?
21. Why must great care be taken when caissons are used? What happened during the construction of the Eads Bridge in St.Louis?
22. What is sometimes done when extra strength is necessary in the piers? Why did this have to be done for the Golden Gate Bridge?
23. What technique is used when bedrock cannot be reached?
24. What special technique was used for the Tappan Zee Bridge in New York?
25. How is the span sometimes raised into place with truss bridges?
26. What is the usual construction method for concrete arch bridges?
27. What method has been developed for the construction of steel arch bridges?
28. What is built first for a suspension bridge?
29. How are the cables put in place on a suspension bridge?
30. What part of the bridge is constructed after the cables are in place?

# *UNIT SIX*
# *TUNNELS*

## *Special Terms*

**Tunneling Shield:** A large cylinder with a cutting edge that can be moved forward by jacks. It is used when tunneling through clay or soft rock.

**Tail:** The back part of a shied. The lining for a tunnel is usually assembled in the tail.

**Pneumatic Drill:** A compressed air machine that is used to make holes in rock.

**Heading:** The point from which work progresses on a tunnel. Most tunnels are bored from two headings.

**Pilot Tunnel:** A small exploratory tunnel bored in advance a tunnel project along the same route. It provides geological information, as well as ventilation.

**Immersed Tube:** A tunnel made of prefabricated sections that are sunk into position.

**Cut-and-cover:** A tunneling technique. A trench is excavated and the tunnel lining assembled in it. The trench is then filled in.

**Dredging:** Pumping silt or sand usually from the bottom of a body of water such as a river or a harbor.

**Duct:** A tube or channel that carries something, as an aqueduct carries water. A system of ducts is used for ventilation in most tunnels.

**Mole:** A tunneling machine that can bore through hard rock.

## *Vocabulary Practice*

1. What is a tunneling shield ? When is it used?
2. What is usually assembled in the tail of a tunneling shield?

3. What is a pneumatic drill ?

4. What is the heading of a tunnel ? How many headings are tunnels usually bored from ?

5. What is a pilot tunnel ? What are its purpose ?

6. What is an immersed tube ?

7. Describe the cut-and-cover tunneling technique.

8. What does dredging mean?

9. What is a duct? What are ducts used for in tunnels ?

10. What does the term mole refer to in tunneling ?

# *TUNNELS*

Most of the tunnels before the great age of railroad construction were built in connection with mines, water supply systems, or canals. The maximum grade at which a steam locomotive could operate efficiently was 2 percent. This fact encouraged the construction of a great many tunnels. As more tunnels were built, many significant technical advances were made in boring both through underwater clay and through rock.

One of the most remarkable tunnel building feats was the construction of the first tunnel under the Thames River in London. This tunnel is still used by the London Underground Railway System. It was dug out of clay beneath the riverbed between 1825 and 1843 under the direction of Sir Marc Brunel, who had designed a tunneling shield that made the work possible. The shield offered the workers protection while they dug out clay and mud in the face of the shield. It was then moved forward by jacks so that the process could be repeated.

One of the first major tunnels built through rock was the Mont Ccenis Tunnel in the Alps between France and Italy. It is fourteen kilometers long and was built between 1857 and 1871. When construction began on it, progress was only twenty-two centimeters a day. Fortunately, the pneumatic drill, which uses compressed air to bore holes in rock, was invented a few years after construction began. Thereafter, the tunneling speed was increased to two meters a day. Like most tunnels, the Mont

Cenis was bored from two different headings, one in France and one in Italy, which met in the middle.

Another tunnel under the Alps, the Simplon, remains a major engineering accomplishment. It runs for a distance of nineteen kilometers, and at one point, it is more than 2,100 meters under the crest of a mountain. It was built between 1898 and 1906, and extraordinary difficulties had to be overcome: extremely high temperatures, rock that burst off the walls because of the pressure, springs of both cold and hot water, and layers of soft stone that required special supports. It remains the deepest tunnel ever constructed.

The usual technique for tunneling through hard rock is to drill holes in the face of the heading. The holes are filled with an explosive that is detonated after the workers and equipment are withdrawn to a safe distance. After fumes and rock dust have settled, the rock brought down by the explosion is removed, often on conveyor belts. In many projects, like the Simplon, for example, a small pilot tunnel is driven before the full diameter of the tunnel is excavated. This technique helps engineers to determine the geological features of the rock through which the tunnel is passing so that many difficulties can be anticipated. In some cases, work on the main tunnel progresses a few meters behind the pilot tunnel so that the latter provides ventilation, always a major problem in tunneling operations.

Shields that are modifications of the one that Brunel developed for boring the Thames Tunnel are used in excavating through clay or soft rock. A shield has a sharp edge that is driven into the tunnel face by hydraulic jacks. The top edge of the shield projects for a short distance in order to protect the workers. Behind the cutting edge is the tail, which has a smaller diameter. The permanent lining of the tunnel is assembled in this area. The space between the lining and the larger diameter that has been excavated by the forward part of the shield is filled with a grout that is pumped in under pressure. Modern shields are highly mechanized so that many phases of the tunneling process can be performed almost completely by machine.

Silt, the soft mud that is typical of riverbeds and other underwater tunneling sites, presents difficult problems. In Brunel's Thames Tunnel, water broke through on several occasions, and the tunnel had to be pumped dry. In addition, Brunel had loads of clay dumped into the riverbed to make it more impervious to water. Modern engineers, of course, have developed and now use more sophisticated soil stabilization techniques when they tunnel through silt, sand, or loose material such as gravel. Most underwater tunnel construction through these materials utilizes shields with compressed air, similar to the caissons we described in the previous unit. The same precaution must be taken to protect workers from being exposed to the dangers of extreme pressure.

Another technique that has come into wide use in recent years is the immersed-tube system. In this technique a channel is dredged along the line of the tunnel; in other words, silt is pumped out of the water bed. Piles are then driven along the channel, and prefabricated section of the tunnel are lowered into place onto the piles. The tunnel sections are closed by temporary feces that are removed after all the sections have been assembled. The joints between the sections are also made watertight at this stage of construction. Finally, the channel is filled in to give the tunnel greater stability. The Maas River Tunnel at Rotterdam is an immersed tube. Another is the recently opened tube between San Francisco and Oakland, California, for the Bay Area Rapid Transit System.

A technique that is often used for subway construction is the cut-and-cover method. Workers excavate a trench, inside of which the lining for the tunnel is built. It is then covered over with the earth or other fill that was originally removed. The cut-and-cover method obviously can only be used when the tunnel is immediately beneath the surface. One difficulty is that normal street traffic must often be beams or steel plates are laid down to cover the excavation.

Ventilation is a major problem in all tunnels, but particularly in those to be used by automobile traffic. The exhaust fumes of automobiles contain carbon monoxide, a deadly gas. Most automobile tunnels therefore have two systems of ducts. Huge fans pump in fresh air through one of them, while polluted air is sucked out through the other.

A good example of the complexity of engineering a modern highway system can be illustrated by the Chesapeake Bay Bildge-tunnel. This crossing between Maryland and Virginia over one of the principal waterways in the United States is twenty-eight kilometers long. Most of the highway is supported on concrete piles with short spans between them. It was also necessary, however, to leave four ship channels. Two of these are spanned by bridges, but the other two are provided by tunnels. The entrances to the two tunnel sections are from man-made islands in the bay. The tunnels themselves are steel tubes which were placed in a channel that had been dredged in the bay bottom.

Another great engineering project that is still in the process of construction is the Seikan Railroad Tunnel in Japan. This tunnel, thirty-six kilometers long, will connect the islands of Honshu and Hoccaido, passing 100 meters under the surface of the strait between them; the strait itself is 140 meters at its deepest point. The route is now being explored by a pilot tunnel in order to determine the geological formations and types of rock through which the tunnel must be bored. The Japanese are also experimenting with new types of machines called moles, which can bore through hard rock by mechanical means.

## *DISCUSSION*

1. Before the great age or railroad construction, in what connection were most tunnels built ?
2. What fact encouraged the construction of many tunnels ? What other result did increased tunnel construction bring about ?
3. When was the first tunnel built under the Thames River in London ? Under whose direction ?
4. What made the construction of Brunel's Thames Tunnel possible ?

5. What was one of the first major tunnels built through rock ? How long is it ? When was it built ?
6. How rapid was progress at the beginning ? What increased the speed of construction ?
7. From how many headings was the Mont Cenis Tunnel bored ? Is this a usual practice ?
8. How long is the Simplon Tunnel ? How far is it beneath the surface at one point ?
9. What difficulties had to be overcome in excavating the Simplon Tunnel ?
10. What is the usual technique for tunneling through hard rock ?
11. What is sometimes excavated in advance of the main tunnel ? What purposes does this serve ?
12. Describe a tunneling shield.
13. Why is there a space between the excavated space and the tunnel lining?
How is it filled ?
14. What is silt and where is it often encountered ?
15. How did Brunel deal with the problem of water in his tunnel ?
16. How is tunneling through silt accomplished today ?
17. How is a tunnel constructed by the immersed-tube technique ? What are some examples of tunnels built by this method ?
18. What technique is often used for subway construction ?
19. What condition is necessary when employing the cut-and-cover method ? What is one difficulty with this method, and how is it overcome ?
20. Why is ventilation a major problem in automobile tunnels ?
21. How is it dealt with in most automobile tunnels ?
22. Describe the Chesapeake Bay Bridge-tunnel .
23. What major tunnel is now under construction in Japan ? How long will this tunnel be ? How far under sea level will it pass ?
24. What are the Japanese experimenting with in the construction of this tunnel ?

# *UNITE SEVEN*
# *CAREERS IN CIVIL ENGINEERING*

## *Special Terms*

**Statistics**: A branch of mathematics that deals with gathering, classifying, and using numerical data (pieces of information).

**Probability**: A branch of statistics that deals with what may happen when different factors can change the result of a problem.

**Research**: Looking for basic facts or principles (basic research) or for ways to apply such knowledge (applied research).

**To Design**: To prepare or work out the plan for some kind of work; civil engineers work out the design for projected structures.

**Feasibility Study**: A study to determine whether a project is practicable or not. The study must consider not only structural features, but also economic factors and possible alternatives, or other choices.

**Consulting Engineers; Consultants**: Engineers or other specialists who offer their services to a number of different customers on a job-by-job basis. They usually work for relatively short periods of time to solve specific problems for their customers.

**Systems Engineers**: Engineers who understand and have experience in several different fields of engineering so that they can coordinate work on systems or projects that involve two or more engineering specialties.

**Construction**: The actual work of building a project. From an engineering viewpoint it includes such activities as scheduling and supervising the work.

**Maintenance:** Keeping existing systems, structures, or equipment in working order.

**Sales:** The selling of construction equipment, an area in which some civil engineers specialize.

**Management:** The establishment and carrying out of policies for an organization. Some civil engineers work in management of corporations; others form companies of their own. A knowledge of administration and finance is essential.

## *Vocabulary Practice*

1. What does statistics deal with?
2. What does probability deal with?
3. What is the difference between basic research and applied research?
4. What is design?
5. What does a feasibility study determine? What are some of the things that it must consider?
6. What does a consulting engineer or consultant do?
7. What is a systems engineer?
8. What is construction? What does it include from an engineering viewpoint?
9. What is maintenance?
10. What kind of sales work do some civil engineers specialize in?
11. What is management? How are some civil engineers involved in it?

# *CAREERS IN CIVIL ENGINEERING*

As it was noted in the first unit, engineering is a profession, which means that an engineer must have a specialized university education. Many government jurisdictions also have licensing procedures which require engineering graduates to pass an examination, similar to the bar examinations for a lawyer, before they can actively start on their careers.

In the university, mathematics, physics, and chemistry are heavily emphasized throughout the engineering curriculum, but particularly in the first two or three years. Mathematics is very important in all branches of engineering, so it is greatly stressed. Today, mathematics includes courses in statistics, which deals with gathering, classifying, and using numerical data, or pieces of information. An important aspect of statistical mathematics is probability, which deals with what may happen when there are different factors, or variables, that can change the results of a problem. Before the construction of a bridge is undertaken, for example, a statistical study is made of the amount of traffic the bridge, variables such as water pressure on the foundations, impact, the effects of different wind forces, and many other factors must be considered.

Because a great deal of calculation is involved in solving these problems, computer programming is now included in almost all engineering curricula. Computers, of course, can solve many problems involving calculations with greater speed and accuracy that a human being can. But computers are useless unless they are given clear and accurate instructions and information – in other words, a good program.

In spite of the heavy emphasis on technical subjects in the engineering curriculum, a current trend is to require students to take courses in the social sciences and the language arts. We have already discussed the relationship between engineering and society; it is sufficient, therefore, to say again that the work performed by an engineer affects society in many different and important ways that he or she should be aware of. An engineer also needs a sufficient command of language to be able to prepare reports that are clear and, in many cases, persuasive. An engineer engaged in research will need to be able to write up his or her findings for scientific publications.

The last two years of an engineering program include subjects within the student's field of specialization. For the student who is preparing to become a civil engineer, these specialized courses may deal with such subjects as geodetic surveying, soil mechanics, or hydraulics.

Active recruiting for engineers often begins before the student's last year in the university. Many different corporations and government agencies have competed for the services of engineers in recent years. In the science-oriented society of today, people who have technical training are, of course, in demand. Young engineer may choose to go into environmental or sanitary engineering, for example, where environmental concerns have created many openings; or they may choose construction firms that specializes in highway work; or they may prefer to work with one of the government agencies that deals with water resources. Indeed, the choice is large and varied.

When the young engineer has finally started actual practice, the theoretical knowledge acquired in the university must be applied. He or she will probably be assigned at the beginning to work with a team of engineers. Thus, on-the-job training can be acquired that will demonstrate his or her ability to translate theory into practice to the supervisors.

The civil engineer may work in research, design, construction supervision, maintenance, or even in sales or management. Each of these areas involves different duties, different emphases, and different uses of the engineer's knowledge and experience.

The civil engineer may work in research, design, construction supervision, maintenance, or even in sales or management. Each of these areas involves different duties, different emphases, and different uses of the engineer's knowledge and experience.

Research is one of the most important aspects of scientific and engineering practice. A researcher usually works as a member of a team with other scientists and engineers. He or she is often employed in a laboratory that is financed by government or industry. Areas of research connected with civil engineering include soil mechanics and soil stabilization techniques, and also the development and testing of new structural materials.

Civil engineering projects are almost always unique; that is, each has its own problems and design features. Therefore, careful study includes a survey both of topographical and subsoil features of the proposed site. It also includes a consideration of possible alternatives, such as a concrete gravity dam or an earth-fill embankment dam. The economic factors involved in each of the possible alternatives must also be weighed. Today, a study usually includes a consideration of the environmental impact of the project. Many engineers, usually working as a team that includes surveyors, specialists in soil mechanics, and experts in design and construction, are involved in making these feasibility studies.

Many civil engineers, among them the top people in the field, work in design. As we have seen, civil engineer work on many different kinds of structures, so it is normal practice for an engineer to specialize in just one kind. In designing buildings, engineers often work as consultants to architectural or construction firms. Dams, bridges, water supply systems, and other large projects ordinarily employ several engineers whose work is coordinated by a systems engineer who is in charge of the entire project. In many cases, engineers from other disciplines are involved. In a dam project, for example, electrical and mechanical engineers work on the design of the powerhouse and its equipment. In other cases, civil engineers are assigned to work on a project in another field; in the space program, for instance, civil engineers were necessary in the design and construction of such structures as launching pads and rocket storage facilities.

Construction is a complicated process on almost all engineering projects. It involves scheduling the work and utilizing the equipment and the materials so that costs are kept as low as possible. Safety factors must also be taken into account, since construction can be very dangerous. Many civil engineers therefore specialize in the construction phase.

After the structure has been completed, it must be kept from falling into disrepair; therefore many engineers specialize in maintenance. This is often a function of the privately owned utility or governmental agency that will ultimately be responsible for the completed structure. A large system like the California State Water Project obviously requires a large maintenance staff under the supervision of qualified engineers.

Some engineers also work in sales. Companies that supply products or equipment for construction often employ civil engineers as part of their sales staffs. The customers are engineers themselves, and so they must be given the opportunity to communicate with salespeople who can understand the same technical specifications. A few engineers may also go into management – the establishment or carrying out of the policies of the companies that employ them. Construction companies are often headed by civil engineers; indeed, some of these companies were founded by engineers. No matter what the part into management may be, these engineers must have administrative as well as technical skills.

Many civil engineers work for government agencies; many others work as consultants, providing their knowledge and experience to solve problems in their field on a job-to-job basis. Since the building of a structure is ordinarily a unique endeavor, consulting is a particularly common practice among civil engineers. A successful consulting engineer must have a wide range of experience and knowledge, as well as the ability to work easily with other people, such as real estate developers, government officials, or ordinary citizens whose lives will be affected by a project.

Much of the work of civil engineers is carried on outdoors, often in rugged and difficult terrain or under dangerous conditions. Surveying is as outdoor occupation, for example, and dams are often built in wild river valleys or gorges. Bridges, tunnels, and skyscrapers under construction can also be dangerous places to work. In addition, the work must also progress under all kinds of weather conditions. The prospective civil engineer should be aware of the physical demands that will be made on him or her.

## *DISCUSSION*

1. What does the fact that engineering is a profession mean to someone who is interested in becoming an engineer?
2. What do many licensing procedures require?
3. What kinds of courses are stressed in the first two or three years of an engineering curriculum in a university?
4. What mathematics subject is included in the course? What is an important aspect of this subject? Why is this important?

5. Why is computer programming included in engineering courses? Only in what circumstances can a computer do an accurate job?
6. What courses besides technical ones are included in the engineer curriculum?
7. Why does an engineer need to take courses in social sciences and language arts?
8. When will an engineering student probably begin to take courses in his or her own field of specialization? What might some of these courses be for a student of civil engineering?
9. What are some of the fields of civil engineering in which a graduate engineer might specialize?
10. What are some of the kinds of work in which a civil engineer may specialize? What does each of these involve?
11. Where is a researcher often employed?
12. What are some of the areas of research connected with civil engineering? What are some others that are not mentioned in the reading?
13. Why is careful study given to each civil engineering project before design work begins?
14. What are some of the things that are included in such a study?
15. Who is involved in making such studies? What are they called?
16. Why don't all civil engineers specialize in the design of all kinds of different structures?
17. What kind of engineer would be in charge of a large project involving several different engineering fields? What engineers besides civil engineers would be employed on a dam project? In what kind of project would civil engineers be brought in as consultants?
18. Why is construction a complicated process?
19. Why must safety factors be taken into consideration in construction?
20. Who may employ engineers who specialize in maintenance?
21. What kind of companies often employ civil engineers on their sales staff? Why?

22. How do some engineers get into management? What kinds of skills must these engineers have?

23. Why is consulting a particularly common practice among civil engineers?

24. What special ability must a consulting engineer have?

25. What kinds of physical demands may be made on a civil engineer?

# UNIT EIGHT
# ENVIRONMENTAL / SANITARY ENGINEERING

## Special Terms

- **Environmental/Sanitary Engineering**: The branch of civil engineering that deals with water supply, drainage, and waste disposal systems.
- **Sewer**: A duct or pipe for carrying off waste material (known as sewage) or excess water.
- **Cesspool**: A well or hole in the ground used for waste disposal.
- **Sewage Treatment Plant**: A plant where harmful substances are removed from sewage.
- **Reservoir**: An artificial body of water created to store water/
- **Filtration**: Process of purifying water by passing it through sand or gravel to remove solids.
- **Aeration**: Process of purifying water by either shooting sprays of water in the air, where sunlight helps to kill bacteria, or bubbling air into or through the water.
- **Chlorination**: Process of purifying water by treating it with chlorine, which kills bacteria.
- **Sedimentation**: A purification process in which wastes are allowed to settle until they become solid enough to be removed.
- **Activated-**sludge Process: Treating wastes with compressed air in order to encourage biological reactions that destroy harmful order to encourage biological reactions that destroy harmful bacteria.
- **Trash**: waste material such as paper, cans, bottles, and so on.
- **Landfill**: Disposal of trash in wet areas for the purpose of reclaiming them, or the use of trash to build up new land.
- **Incinerator**: A furnace in which trash is burned.
- **Recycling**: Reclaiming some kinds of trash-aluminum cans, for example-so that the material in them can melted down and reused.

## *Vocabulary Practice*

1. What does environmental/sanitary engineering deal with?
2. What is a sewer? What is waste material known as?
3. What is a cesspool?
4. What is a sewage treatment plant?
5. What is a reservoir?
6. What is filtration?
7. What is aeration?
8. What is chlorination?
9. What is sedimentation?
10. What is the activated-sludge process?
11. What is trash?
12. How is trash used for landfill?
13. What is an incinerator?
14. What does recycling mean?

# *ENVIRONMENTAL/SANITARY ENGINEERING*

Environmental/Sanitary engineering is concerned with providing clean, safe water supply systems for towns, cities, and rural areas. It is also concerned with disposing of excess water and waste materials by means of sewer systems. Many aspects of environmental/sanitary engineering are directly related to hydraulic engineering; indeed;, some of the projects that we discussed in the previous unit are parts of water supply systems. The Hoover Dam, for example, supplies water to the city of Los Angeles, with which it is connected by a series of canals, tunnels, and aqueducts across the deserts and mountains of the southwestern United States.

A great deal of archeological evidence has revealed the importance of water supply systems in the ancient world. Probably the most impressive systems were built by the Romans, whose aqueducts still stand in modern Italy, Spain, France, and Turkey. Rome itself had a water estimated at 50 million gallons a day, or about 50 gallons a day for each resident of the city. The water was delivered to fountains, where people collected it in pots and then carried it to their homes; only a few buildings and residences had connections to the main pipelines. Rome also had a sewer, the Cloaca Maxima, part of which is still used today. Like other sewer systems of ancient times, it was intended to carry off the water from storms or the waste water from the public baths. There were penalties for disposing of solid wastes in it.

After the fall of the Roman Empire, water supply and sewer systems received relatively little attention until modern times. In the Middle Ages in Europe, water came from streams and wells, while wastes were disposed of in cesspools or even returned to the same streams from which the water was taken. After the connection between water supply and certain diseases such as typhoid was established in the nineteenth century, cities and towns all over the world built safe water supply systems. The experience of three American cities illustrates some of the engineering problems – and economic and legal problems as well – in constructing large water supply systems.

Chicago grew from a tiny trading post on Lake Michigan to a great metropolis in only a few decades. Providing water for the fast growing population was a problem from the city's earliest days. The primary source was the lake that bordered the city, but the water was frequently polluted by discharge of water from the Chicago River, which acted as a sort of open sewer during the city's early years. After storms or floods, the pollution was especially severe, and not even moving the pumps for the water farther from the shore was an adequate solution. It was finally decided to reverse the flow of the Chicago River so that it discharged not into the lake but into the Illinois River, a tributary of the Mississipi. After this had been done by means of the Chicago Sanitary and Ship Canal, however, there were cries of outrage, followed by lawsuits, from people in towns and cities downstream from Chicago because their water supply sources were being polluted by wastes from Chicago. Finally, the city was forced to build several large sewage treatment plants to remove harmful substances from waste water before it was resealed into the Chicago River.

New York City has had to construct a system that brings water to the city from considerable distances. As the city has grown, it has been necessary to range farther and farther away to find new sources. At present, much of New York's water comes from the watershed of the Delaware River, northwest of the city, across the Hudson River and beyond the Catskill Mountains. It is delivered to the city's system of holding reservoirs through the longest tunnel in the world, the Delaware Aqueduct, which extends for the most part through bedrock for a distance of 169 kilometers. At some points the aqueduct reaches a depth of 750 meters. The New York system delivers an average supply of approximately 1,3 billion gallons a day – considerably more that 100 gallons a day for every person in the city.

Los Angeles is located in an area of low rainfall. When the population of the city began to grow rapidly, water was brought in from the Colorado River, more that 350 kilometers away, across deserts and mountains. The Colorado River Aqueduct, supplying water to Los Angeles and other southern California communities, is 1,081 kilometers long. An even more ambitious project now under construction will divert water from rainy northern California to the drier central and southern portions of the state. The Oroville Dam, a great earth-fill embankment dam, is part of the overall California State Water Project. When the project is completed, it will deliver water for both irrigation systems and town and city systems from San Francisco and Sacramento in the central part of the state to Los Angeles and areas even farther south. The main aqueduct and its principal branches will be several hundred kilometers long, some of it in concrete lines canals and some of it in pipes and tunnels. High capacity pumping stations will raise the water over intervening mountain ranges.

In addition to transporting water over long distances, modern water supply systems also use several techniques for purification. One of them is filtration. The water is passed through a filter that consists of a bed of sand or gravel, which removes a large proportion of the solids that might otherwise contaminate the supply. Another process is aeration. Sprays of water are shot into the air, where sunlight and oxygen help kill bacteria and also remove gases with an unpleasant odor or taste; or air is bubbled into or through the water. A third method involves treatment with chemicals, usually chlorine, to kill harmful bacteria. The process is known as chlorination.

Part of providing a safe water supply is disposing of liquid and solid wastes. This problem has become acute in recent years not only because of world-wide population growth, but also because of the vast amount of waste created by industrial processes and by the great mountains of trash that are the by-product of increased consumption.

A large number of modern drainage systems use the same sewers to dispose of domestic wastes and runoff water from storms. Many of these systems were designed to empty into streams or other bodies of water where nature itself purified the water over a period of time. Now, however, the amount of waste has become so great that many streams and lakes and even the seas have become polluted. More and more treatment plants are being built to purify water before it is released back into the environment. Therefore, the modern trend is to build separate drainage systems for storm runoff and for domestic wastes so that the treatment plants do not have to process the runoff water, which is relatively unpolluted. There are a number of different methods by which solid wastes can be removed or rendered harmless. Several of them are ordinarily used in combination in treatment plants. One of the process is filtration. Another is sedimentation, in which wastes are allowed to settle until they become solid or semisolid and can be removed. There are also techniques in which water can be treated by biological means, by using some kinds of bacteria to kill other kinds, or by chemical means, as in chlorination. One of the most successful methods is called the activated-sludge process. It involves using compressed air to increase and control the rate of biological reactions that purify the wastes. In effect, treatment plants speedup natural purification processes so that the water that is finally released from them is essentially harmless. Present-day concern over environmental pollution has increased the demand that waste water should be treated to the fullest degree possible before it is returned to the environment.

Vast amounts of trash have also posed problems in disposal. Much of it has been used as landfill by dumping in swampy areas or in shallow water so that the area can be made useful. A great deal of it has also been burned in incinerators, huge furnaces that reduce the wastes to ash. Incinerators, however, are out of fashion today because they release harmful fumes into the air. Many of them are being redesigned to control these emissions more effectively; at the same time other solutions are being sought.

One modern method of disposing of trash and domestic wastes is recycling, which simply means using the waste material again. The wastes from treatment plants, for example, can be used as fertilizer. It can also be used as fuel. In fact, some treatment plants fill their own energy needs by burning their waste products to provide steam for generating electricity. Similarly, some kinds of trash can be collected separately – glass, newspapers, and aluminum cans, for example. All of these materials can be processed for reuse. In some cases, trash has also been compacted to serve as fuel.

The concern for a cleaner environment together with the need to conserve and reuse our resources has created a challenge for which sanitary engineers, working with environmentalists, will be called upon to find new solutions over the next few years.

## *DISCUSSION*

1. What is environmental/sanitary engineering concerned with?
2. To what other branch of engineering are many aspects of environmental/sanitary engineering directly related? Give an example.
3. What evidence do we have of the existence of Roman water supply systems?
4. What kind of water supply system did Rome have?

5. What kind of sewer system did Rome have? What kind of waste was it not used for?
6. What was done about water supply and waste disposal in the Middle Ages in Europe?
7. Why did cities and towns all over the world begin building safe water supply systems in the nineteenth century?
8. Where is Chicago located? What is its primary source of water?
9. What problem did Chicago have with its water supply?
10. What solution was decided on? What was the result of this?
11. What was Chicago finally forced to do?
12. What has been necessary regarding New York City's water supply as the city has grown?
13. Where does much of New York's water currently come from?
14. How is it delivered to the city? How long is the Delaware Aqueduct? How deep is it at some points?
15. How much water is delivered to New York each day?
16. What is the basic water supply problem of Los Angeles?
17. How was water supplied for the city when the population began to grown rapidly?
18. What project now under construction will supply water to Los Angeles and other parts of California? What will this system consist of?
19. What other problem must water supply systems deal with?
20. What are some of the water purification techniques that are currently used?
21. What is part of providing a safe water supply? Why has this problem become acute?
22. What two purposes do a large number of modern drainage systems serve?
23. Why were sewer systems designed to empty into streams or other bodies of water?
24. What has happened as a result of the large amount of waste?

25.What steps are being taken to overcome the problem of water pollution from the release of wastes?

26.What are some of the different methods by which solid wastes can be removed or rendered harmless?

27.What demand has present-day concern over environmental pollution increased?

28.What poses another problem in disposal?

29.What two methods have been employed to dispose of trash?

30.Why are incinerators out of fashion today? What is being done about this?

31.What is a modern method of disposing of trash and domestic wastes? How can some of this waste be used again?

32.What challenge has concern for the environment created?

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МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
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Фортмат 29.7 x 1/4
Гарнітура Times New Roman
Друк різографічний
Зам. № 2000-0051
Тираж 39 прим.

Віддруковано в комп'ютерному інформаційно-видавничому центрі ВДТУ
м. Вінниця, Хмельницьке шосе, 95, ВДТУ, ГНК, 9-й поверх.
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