# 1. CIVIL ENGINEERING AS A PROFESSION

**Civil Engineering** is a branch of engineering dealing with social, commercial, and industrial infrastructure that sustains a modern society. Civil engineers build roads, bridges, tunnels, public buildings, sewer systems etc. They are involved in the planning, construction, and maintenance of all kinds of structures (Figures 1.2. and 1.4.). Creativity is the most important part of their job.

**Figure 1.1.** Pont du Gard, southern France

Engineering is often defined as the practical application of theoretical sciences, such as physics and chemistry.

Many of the early branches of engineering, however, were based not on science but on empirical information, that is, on information that depended on observation and experience rather than theoretical knowledge. Many of the structures that have survived from ancient times, such as the bridges, arenas and aqueducts of Rome, exist because they were built with greater strength than modern standards require (Figure 1.1.).

Historically, military engineers were responsible for the design and construction of roads, fortifications, bridges, and the destruction of enemy facilities by tunnelling and explosives. Eventually, in the 18$^{th}$ century engineering became a civilian domain, thereby becoming the profession of the civil engineer.

**Figure 1.2.** Old covered bridge

The first school of civil engineering, the École National des Ponts et Chaussées in Paris, was founded in 1747. John Smeaton who developed new waterproof pozzolanic cements to construct a lighthouse in the English Channel in the late 18th century (Figure 1.3.) is considered as the first self-styled civil engineer. The Institution of Civil Engineers, formed in London in 1828, was the world's first engineering society.

**Figure 1.3.** Eddystone Lighthouse, the English Channel

Civil engineering offers a particular challenge because almost every structure or system that is designed or built by civil engineers is unique. One structure rarely duplicates another exactly.

The civil engineer must therefore always be ready and willing to meet new challenges. Opportunities for innovation in design and construction follow many important recent technological advances.

Numerical modelling and analysis, and virtual reality techniques, to assist design and construction, have been made possible by the rapid growth in computer technology. Composite materials are increasingly chosen by civil engineers to meet structural needs for ever bigger structures, such as stronger bridges with bigger spans, or to accommodate seismic and dynamic forces, improve fire resistance, or meet environmental standards.

**Figure 1.4.** Peruča dam

Undergraduate teaching for civil engineers is in mathematics, physics, mechanics, hydraulics, materials science, structural design and analysis, geology and geotechnics, surveying, construction technology, planning and financial management, computer technology, health and safety.

LANGUAGE PRACTICE

**I. Answer these comprehension questions with reference to the text.**

1. How is engineering defined?
2. Why did civil engineering develop from military engineering?
3. Why does civil engineering offer a particular challenge?
4. Which skills should a civil engineer combine?
5. Why is an engineers's education never really finished?
6. What must an engineer consider in his or her work?

**II. Complete the sentences:**

a) Civil engineers apply ________________________________________

b) The first professional civil engineer is considered to be ___________

c) The first civil engineering university was established _____________

d) The first civil engineering association was founded _______________

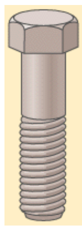
e) Modern civil engineering is aided by ___________________________

**WORD CHECK**

**III. Find the English translation of the following terms in the text:**

kanalizacijski sistem, održavanje, primjena znanosti, sila, građevinski projekt, gradilište, ekološki standardi, promatranje terena, prilagoditi ideje, zahtjevi projekta, dodiplomski studij, diplomirani inženjer

**IV. Translate:**



"*Snimajući filmove o povijesnim građevinama želio bih ljudima pomoći da razumiju na koji način kupole, mostovi i tuneli, brane i neboderi ostaju čvrsto na mjestu gdje su izgrađeni. Htio bih odgovoriti na pitanje tko ih je izgradio, zašto su izgrađene i zašto stoje uspravno. Ove građevine nisu se pojavile samo odjednom. Postoji metoda i sustav kako nastaju. Smatram izazovnim da i sam to razumijem. Pretpostavljam da bi me snimajući takvu seriju sve više zanimali vijci i zakovice. Zašto ovaj oblik, a ne drugi? Zašto čelik umjesto betona ili kamena? Zašto staviti gredu ovdje, a ne tamo? Takva su pitanja početak procesa projektiranja. Svaka je građevina rezultat logičnog i stoga razumljivog niza događaja.*"

# 2. WHAT’S COOL ABOUT BEING AN ENGINEER

Within the field of civil engineering itself there are subdivisions: structural engineering, which deals with permanent structures (Figures 2.1. and 2.2.); hydraulic engineering, which is concerned with systems involving the flow and control of water or other fluids; sanitary or environmental engineering, which involves the study of water supply, purification and sewer systems (Figure 2.3.).

**Figure 2.1.** Višegrad bridge

Many of these specialties overlap. A water supply system may involve dams and other structures as well as the flow and storage of water. Engineers must be willing to undergo a continual process of education.

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 officials who are very cost conscious. Therefore engineers must accommodate their ideas to the financial realities of a project.

**Figure 2.2.** Interior of the box type girder, Bajer

Second, the public in general has become much more aware of the social and environmental consequences of engineering projects. In other words, engineers do not work in a scientific vacuum. They must consider the social consequences of their work.

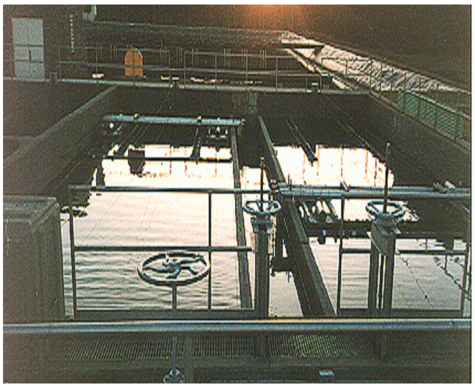


**Figure 2.3.** Water treatment plant

## LANGUAGE PRACTICE

**I. Which of the following headings match the descriptions:**
A) Structural Engineering, B) Construction management,
C) Environmental Engineering

1) Civil engineers coordinate the entire construction process - from initial planning and foundation work through to the final coat of paint. Being a construction manager requires organization, attention to detail,

ability to persuade, and an understanding of all aspects of the construction process.

2) These engineers plan, design, and supervise the construction of facilities essential to modern life. They investigate the behaviour and design of all kinds of structures, including dams, domes, tunnels, bridges, and skyscrapers, to make sure they are safe and sound for human use.

3) The engineers design systems to provide safe drinking water and to prevent pollution in water, in the air, and on the land. Environmental engineers are involved in water supply systems, wastewater treatment facilities, sewage treatment plants, clean - up of toxic waste sites, recycling, reduction of air pollution, and pesticide control.

**II. You may be interested in the advice that some long experienced experts would give you: read it and summarize the gist of his/her message.**

A: "*Concentrate on math, science, and writing courses. You could be the greatest engineer in the world, but if you can't convey your ideas to somebody else, it's useless. Your ability to communicate your ideas to somebody else becomes a big part of what you're doing. It was lacking in me originally, and it's something that I think all engineers have to develop. Even though you're going to be a technical person, you need to have the writing background to be able to communicate your ideas to other people*." (A dam expert)

B: "*Primarily students have to sharpen their basic skills, which are the skills in mathematics and physics. And then also read a lot. Especially read about what other people are doing in architecture and structures. Math and physics are really the keys to engineering, especially engineering structures, because physics tells you how structures behave when you push against them, when you pull against them, and how they will react in the wind and under earthquakes and under the load of occupants. Mathematics is the tool that you use to calculate the physical effects. So you use both mathematics and the physical sciences*." ( A general civil engineer )

C: "*Be aware of your surroundings - look at buildings and structures, and try to figure out how they work. Think creatively about problem solving*." (C.E.)

**III. List all the requirements of an engineering design.**

**IV. Which of the photographs in the text refer to:**
a) environmental engineering; b) structural engineering; c) hydraulic engineering?

**V. Complete the sentences:**
1. Environmental engineering includes ___________________________
2. An engineering project should include __________________________
3. Basic subjects in civil engineering are __________________________
4. Key problems in civil engineering are __________________________
5. Creativity in engineering is___________________________________
6. You need writing skills in engineering because __________________
7. The social consequences of an engineer' s work involve ___________

**VI. Find synonyms or explanations for the following words:** issue, investigate, hydro engineering, load, workable, purification, occupant.

**VII. COMPOUND NOUNS**
**Complete the sentences with a compound noun formed with either WATER, ENVIRONMENTAL, COMPOSITE, HYDRAULICS or RESISTANCE**
1. New materials such as concrete reinforced with fibreglass or plastics is called a _______ material.
2. A system of providing or storing water is called _______ supply.
3. The main aim of testing is to estimate the _____ of building elements.
4. _______ engineering refers to the sewage treatment while _______ concerns mainly the flow of water, water supply, dam building, irrigation and drainage.

**WORD CHECK**

**VIII. Find in the text English equivalents for the following terms:**
konstruktorsko inženjerstvo, organizacija građenja, zaštita okoliša, hidrotehnika (vodogradnja), konstruktor

# 3. GO WHERE THE ACTION IS

**I. Look at the photographs and make predictions: In which field of civil engineering do the following persons work?**

a) transportation civil engineering,
b) environmental engineering,
c) consulting structural engineering,
d) structural engineering,

**Figure 3.1.** Bob

**A:** *"I deal with water supply and wastewater treatment projects. Water comes from streams, rivers and lakes. I'm looking at ways of getting the water to the people and quality issues that go along with that: if the water needs to be treated or filtered. We are concerned with issues to meet the current environmental regulations and to have generally good drinking water."*

**Figure 3.2.** Daniel

**B:** "*I deal with underground structures used for highways and railroads. I am currently involved in the seismic design of such structures. The way we build them depends primarily on technology available, the* *type and condition through which they must pass, and their ultimate length. While their initial costs may be high, well-designed and well-built structures may last indefinitely and require relatively little maintenance. We often take such structures for granted.* "

**Figure 3.3.** John

**C:** **"***From a design point of view, what I deal with is to try to organize the other designers who are working on a project, give them tasks that they have to carry out, numerical calculations that they have to make, and drawings that they have to prepare. I meet with the other members of the design team – the architects, the mechanical engineers, who provide the air conditioning, ventilation, lighting, and plumbing – and we try to coordinate our tasks so that the building contains all of these elements in the right place and they don't interfere with each other."*

**Figure 3.4.** Tom

**D:** **"***What I do first is to come up with preliminary drawing of what type of structure is going to be selected in the site. Then I go to the final design process where you design details. During the construction we* *assist the client or the contractor in reviewing drawings and clarifying various technical issues that might come up. My job also involves bridge inspection, rehabilitation and maintenance.”*

**II. Match each person with the passages A, B, C, or D!**

**III. Which of the mentioned engineers might have said the following?**

**A:** *"The most fun thing about my job is seeing something you've designed being constructed or people using the facilities after construction. Seeing ... something on site that gets torn down and replaced with new construction is a very satisfying part of this job."*

**B:** *” It's a great feeling to know that you're contributing to the health of the community and the environment."*

**C:** *"Whether you're a structural or electrical or civil engineer or whatever, it's just solving problems, in whatever field it may be. And in my case, it's building various facilities. I'm just solving all the problems of how to build buildings."*

**D:** *“I enjoy applying problem-solving skills to solve real-life problems, visiting job sites and seeing my designs transformed from paper to real life. It is pretty safe to say that only an engineer could love such structures."*

**IV. Here is a jumbled version of the text that tells you about several phases in the process of building. The passages include SITE, LOADS, MATERIALS AND OUTLOOKS. Put them into the right order:**

a) Choose a suitable title for each section: Material, Site, Load, Force
b) Put the sections in the correct order to show the stages of a design process. Number them from 1 to 4.
1. __________, 2. __________, 3. ___________, 4. __________

**A:** You have to know something about the environment of the site - that is, is it subject to earthquakes? tornadoes? hurricanes? All of these extreme cases become cases of loads that are going to act on the building that you want to put on that site. So load determination is one of the early tasks that you have to carry out. And the loads are specified by regulation, which are mostly the loads of the occupants and what is actually going to be placed within the space - tables, chairs, bookshelves, storage cabinets, whatever - hence, the loads of the structure itself. So you have to calculate what the weight of all of these parts is, and you have to calculate what the **forces** are that all of these external effects are going to impose on the structure – an earthquake, the wind, etc (Figure 3.5.).

**Figure 3.5.** A crack

**B:** And then you can begin to lay out the orientation of the structure – what the structure is going to look like. Once you know that, then you begin to calculate how big each of the members that constitutes that structure has to be.

**C:** Obviously there has to be a place, so you have a site where it will actually be built. And you have to know something about that site, especially what kind of soils exist below the surface of the site. So you have to have probes made, which are essentially holes that are dug in the ground that will tell you what kind of materials exist at what levels below the ground and also where the water level exists below the ground level, and if you hit rock, where the rock is.

**D:** Once you know these, then the next step is to decide how you're going to build the structure and what material you're going to use – concrete, steel or wood. That depends very much on where you're building it and how big it is and what its function is. Then once you know the material that you're going to use, you can begin to lay out the building, which the architect usually does and you help him with, and you lay out points where you will provide supports.

**V. Complete the definitions of the following terms (use a dictionary to help you):**

1. **to design** means to develop and draw ___________________________
2. **load** is something ___________________________________________
3. **force** is a natural or physical __________________________________
4. **wastewater treatment** is a procedure ___________________________
5. **site requirements** are _________________________________________

**Figure 3.6.** Building site

# 4. ENVIRONMENTAL ENGINEERING

Environmental engineering includes sewage treatment, sewer networks and prevention of pollution by gases or other “insults to the environment”. It includes as well providing clean and safe water supply system for towns, cities, and rural areas. It is also concerned with disposing of excess water and waste materials by means of sewer systems. Sanitary engineering has also links with environmental health, pollution control, and river protection.

**Figure 4.1.** Entrance into the Cloaca Maxima, Rome

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 supply. Rome also had a sewer, the Cloaca Maxima, part of which is still used today (Figure 4.1.). 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 late 19th century. In the Middle Ages in Europe water came from streams and wells. 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.

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 a treatment plant.

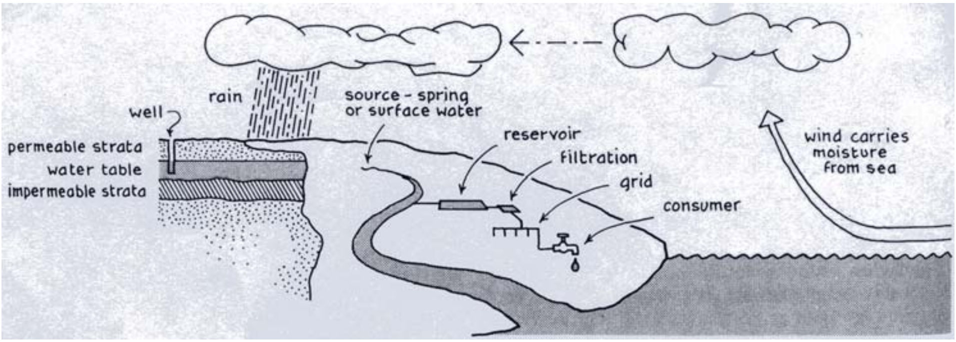



**Figure 4.2.** The natural water supply cycle

One of the processes 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 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 speed up natural purification processes so that the water that is finally released from them is essentially harmless.

Another process is **aeration** (Figure 4.3.). Sprays of water are shot into the air, where sunlight and oxygen help kill bacteria and also remove gases with an unpleasant odour or taste; or air is bubbled into or through the water. A method that involves treatment with chemicals, usually chlorine, to kill harmful bacteria is known as **chlorination**.

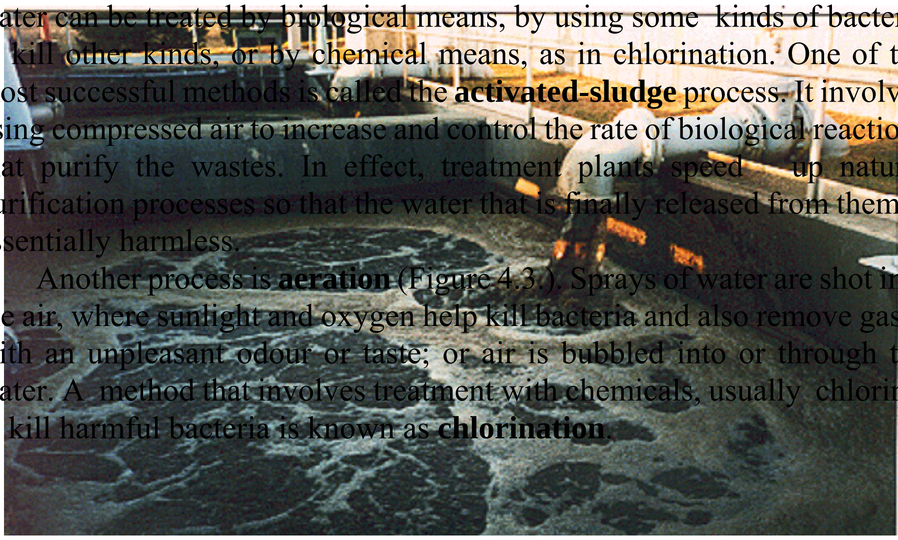


**Figure 4.3.** Aeration tank

Today water conservation seeks to lower urban water usage such as through the use of toilets with low flush volume, to introduce domestic re-use of water, and bring clean drinking water and adequate sanitation to communities in developing countries.

## LANGUAGE CHECK

**I. Comprehension questions:**

1. What is environmental engineering concerned with?
2. To what other branch of engineering are many aspects of sanitary engineering directly related?
3. What evidence do we have of the existence of Roman water supply systems?
4. What kind of sewer system did Rome have? What kind of waste was it not used for?
5. What was done about water supply and waste disposal in the Middle Ages in Europe?
6. Why did cities and towns all over the world begin building safe water supply systems in the nineteenth century?
7. What problems must water supply systems deal with?
8. What are some of the water purification techniques that are currently used?

## WORD CHECK

**II. Find expressions in the text for the following terms:**
kruti otpad, pročišćenje, uređaj za pročišćavanje vode, opskrba vodom, kanalizacijski sustav, odvodnja, postrojenje za pročišćavanje vode

**III. Put the following sentences into passive:**

1. Certain impurities in water can spread diseases.
2. We use several techniques for purification.
3. In filtration we remove solid particles from the water.
4. In aeration we shoot sprays of water into the air.
5. Sunlight and oxygen kill bacteria.
6. In the past engineers piped sewage back into rivers and today they mix it with air and decompose it by bacteria into harmless products.

**IV. Describe how water is made safe and clean in water treatment plant.**

**V. Make a list of the ways of saving water!**

**Figure 4.4.** Los Angeles Water Department Aqueduct

**VI. Describe the Los Angeles Water Department Aqueduct (Figure 4.4.)!**

## 5. DISPOSAL OF WASTES

Solid wastes resulting from human and animal activities my be classified as follows: garbage, industrial wastes, agricultural wastes. Vast amounts of trash have posed many problems in disposal. Much of it has been used as **landfill** (Fig. 5.1.) by dumping in swampy areas or in shallow water so that the area can be made useful. Disposal of solid wastes on land is by far the most common method.

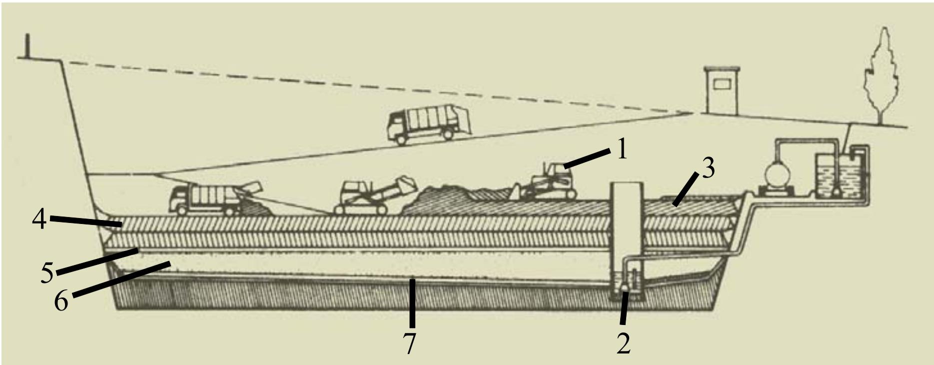



**Figure 5.1.** Cross-section of a sanitary landfill: 1-bulldozer for dumping and compacting, 2-waste water pump, 3-porous cover, 4-compacted and decomposed use, 5-gravel filter, 6-moraine filter, 7-drainage layer

Refuse is spread in thin layers, each of which is compacted by a bulldozer before the next is spread. When about 3 m of refuse has been laid down, it is covered by a thin layer of clean earth, which also is compacted.

Pollution of surface and groundwater is minimized by lining and contouring the fill, compacting and planting the cover, selecting proper soil, diverting upland drainage, and placing wastes in sites not subject to flooding or high groundwater levels. A great deal of it has also been burned in **incinerators** (Fig. 5.2.), huge furnaces that reduce the wastes to ash. Incinerators, however, are out of fashion today because they release harmful fumes into the air.

One modern method of disposing of trash and domestic wastes is **recycling,** which simply means using the waste material again. 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.

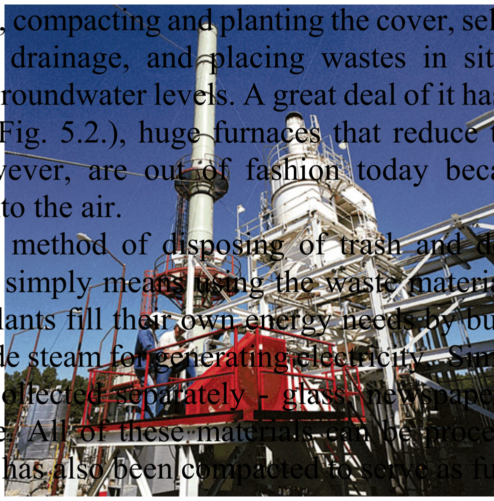


**Figure 5.2.** The incinerator

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.

**Figure 5.3.** Composting plants for solid wastes

**Composting** of solid wastes accounts for only an insignificant amount (Figure 5.3.). Selecting a disposal method depends almost entirely on costs, which in turn are likely to reflect local circumstances.

## LANGUAGE CHECK

### I. Comprehension questions:

1. Name one aspect of providing a safe water supply. Why has this problem become acute?
2. What has happened as a result of the large amount of waste?
3. What methods have been employed to dispose of trash?
4. Why are incinerators out of fashion today? What is being done about this?
5. What is one modern method of disposing of trash and domestic wastes? How can some of this waste be used again?

**WORD CHECK**

**II. Translate the following key words:**
podzemna voda, palionica, potrošnja, kruti otpad, odlagati otpad, uklanjanje otpada, nabijanje, štetni otpad

**III. Turn the following sentences into the active voice. Where no agent is mentioned one must be supplied.**

1. Waste from the garden does not have to be thrown away.
2. It may be reused as a compost.
3. A compost pile may be built up by layering different kinds of waste in a bin.
4. Nitrogen is added to the pile in the form of meal or greenery to generate heat.
5. Once the pile is slightly dampened, it is covered.
6. Tests were made on mortar containing stone, brick and tile dust.
7. After different mixtures of the mortar ingredients had been tested, Smeaton estimated their cost.
8. The results of cement testing in hydraulic compression machine were published in 1847.
9. Already in 1848 Portland Cement was being made by several companies in England.

**IV. Find in the text the words that mean:**
to clean, to supply, grown, throw away, huge, rework, reuse, release, shallow, efficiently, to dump

**V. Give your comment on the following newspaper advertisement (Figure 5.4.). Explain the way you deal with the problem of waste**

**disposal.**

**Figure 5.4.** During the 21st century we have continued to create things, then throw them away. In order to continue this "century of waste" we must quickly create a different way of dealing with our problems.

# 6. PRINCIPAL CONSTRUCTION MATERIALS

The major construction materials of earlier times were wood and **masonry**: brick, stone, clay, tile, and similar materials (Figure 6.1.). A tile is a flat square piece of baked clay or other material used for covering floors or baths. As a thin curved piece of baked clay it is used for covering roofs. Bricks or stones were held together with a mixture of cement or lime, sand and water called mortar.

**Figure 6.1.** Masonry products

The Greeks and Romans sometimes used iron rods to strengthen their buildings. The columns of the Parthenon in Athens, for example, have holes drilled in them for iron bars that have now rusted away. The Romans developed an excellent waterproof cement called pozzolana, made by mixing water, lime and sand with a fine powder ground from volcanic rock found near Pozzuoli (hence the name).

**Cement** is a material that binds together the mixture. It reacts with water, becoming cementitious, and is termed hydrated cement in this state. In contrast to traditional lime mortar, cement does not need contact with the air in order to harden off. Cement is therefore a hydraulic binder.

**Concrete** is really an “artificial stone”. Consisting of a dense medium of cement, water and aggregates such as sand or gravel, it is poured into **shuttering** or formwork (Figure 6.2.) and is compacted by agitating and pressing down. Fresh concrete sets and becomes hardened concrete. The commonest concrete in use today is Portland cement concrete. It was invented in 1824 by a bricklayer called Joseph Aspdin.

**Figure 6.2.** The shuttering

Portland cement 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. Whereas steel has great tensile strength, concrete has great strength under compression. Thus, the two substances 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** (Figure 6.3.) in concrete beams or structures where tension will develop. Concrete with steel reinforcement is a versatile material widely used in the loadbearing structure of buildings. Still another advantage is that steel does not rust in concrete. Acid corrodes steel, whereas concrete has an alkaline chemical reaction, the opposite of acid.

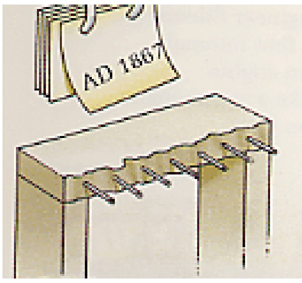



**Figure 6.3.** Steel embedded into concrete in the form of bars

Steel as a very tough and strong metal has many useful applications in a wide range of constructions. The best building materials are strong, durable and easily obtainable. **Steel**, an alloy of iron and carbon, is the most commonly used alloy in industry.

## LANGUAGE PRACTICE

**I. Comprehension questions:**

1. Which are the oldest building materials?
2. What is pozzolana?
3. What are the properties of cement and concrete?
4. What is Portland cement?
5. What enormous advantage does steel have as a construction material?
6. How can rust be prevented?

## WORD CHECK

**II. Find in the text English equivalents for:**

stup, žbuka, hrđanje, šipka, vapno, vapnenac, legura, oplata, usitnjavati (mljeti), mnogostran, ugraditi, četvrtast oblik

**III. Form complete sentences, making all the changes and additions necessary to produce the definitions of stress, cement, alloy and rod:**

1. exerted / deformation / stress / resulting in / on / stress / force / and / body / strain / or

   ______________________________________________

2. making / cement / widely / used / limestone / is / construction / lime / in / and

   ______________________________________________

3. material / with / two / alloy / is / metals / more / mixture / nonmetallic / metal / or

   ______________________________________________

4. plastic / narrow / wood / cylindrical / rod / metal / length / usually / of / or

   ______________________________________________

**IV. Translate into Croatian:**

masonry, alloy, shuttering, grind, pour, embed, bind, acid, strength, drill

**V. Make new words or grammar categories from the words:**

Example: bond - bondage - bound

concrete (n), tension, expand, deform, stone

**VI. Write the definition of the underlined words:**

1. This is a three- storey building.
2. Concrete molds to any shape.
3. Concrete cracks with temperature changes.
4. It is fireproof and weatherproof.
5. Steel bars are hidden in concrete.
6. Steel is iron with a touch of carbon.

**VII. Sort out the following categories from T. S. Eliot's poem "The Rock":**

*In the semi-darkness the voices of WORKMEN are heard chanting*
*In the vacant places*
*We build with new bricks*
*There are hands and machines*
*And clay for new brick*
*And lime for new mortar*
*Where the bricks are fallen*
*We build with new stone*
*Where the beams are rotten*
*We build with new timbers*
*Where the word is unspoken*
*We will build with new speech*
*There is work together*
*A Church for all*
*And a job for each*
*Every man to his work*

Materials: ______________________________________________

Structural elements: ______________________________________

Verbs denoting action: _____________________________________

**VIII. Choose the right meaning:**

1. *property is:* a) a special quality or characteristic; b) one of the parts of the whole;
2. *lightweight is:* a) easy to lift or move; b) made of thinner material and weighing less than average;
3. *moderately is:* a) not very, quite; b) average, in the middle; c) to an unusually great extent;
4. *rust is:* a) stop work; b) decay naturally and gradually; c) a substance that forms on iron or steel;

**Figure 6.4.** Excavation of pozzolana nera, Italy

# 7. THE BIRTH OF MODERN STRUCTURES AND IMPROVED MATERIALS

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 buildings have a skeleton of steel or concrete that bears the weight of the structure.

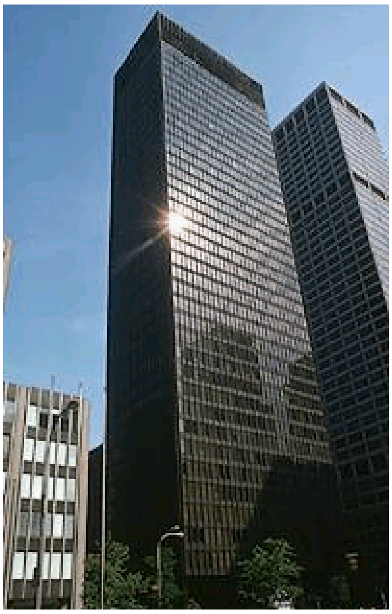


**Figure 7.1.** The curtain wall of Mies van der Rohe's Seagram Building, New York City

**Figure 7.2.** Riveted 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. 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 (Figure 7.1.).

**Figure 7.3.** Welding

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, aluminium, or plastic, in various combinations. Another advance in steel construction is the method of fastening together the beams. For many years metal girders and plates in a building were joined only by screws, nuts, bolts and rivets. Rivets are metal pins, which are heated, and then driven through two or more plates (Figure 7.2.). The protruding end of the rivet is flattened by being hammered flat. Rivetting has now largely been replaced by welding (Figure 7.3.), the joining together of pieces of steel by melting a steel material between them under high heat. An improved form of reinforcement - a prestressed concrete was introduced in the twentieth century. It is produced in the following way: prestressing tendons - usually high tensile steel bars or cables are embedded in the concrete (Figure 7.4.).

**Figure 7.4.** Prestressed beams launched and reinforcement diaphragm tied

The tendons may be tensioned either before or after the concrete has hardened. They are 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 bars. When the bars are run through the channels or "prestressing beds", they are then bonded to the concrete by filling the channels with grout, a thin mortar or binding agent (Figure 7.5.).

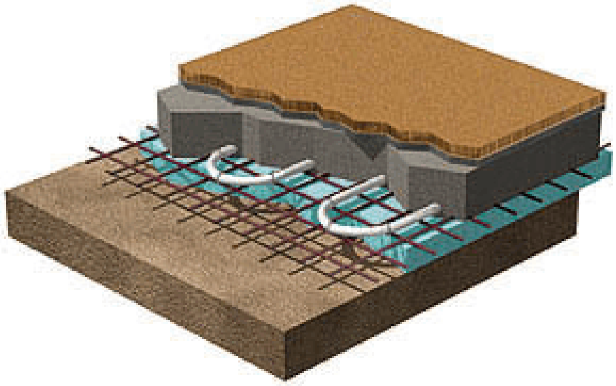


**Figure 7.5.** Reinforced slab

In the other (and more common) method, the prestressed tendons 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. This technique has been increasingly used in bridge engineering.

**Figure 7.6.** Kylesku prestressed concrete bridge, Scotland

Prestressed concrete is economical for spans which are large or where the beam depth must be reduced to a minimum. Prestressed concrete has made it possible to develop buildings with unusual shapes, like some of the modern sports arenas, with large spaces unbroken by any obstructing supports. The uses for this relatively new structural method are constantly being developed (Figure 7.6.). The current tendency is to develop lighter materials. Aluminium, for example, weighs much less than steel but has many of the same properties. Aluminium beams have already been used for bridge construction and for the framework of buildings.

Attempts are also being made to produce concrete with a lighter weight but with the same strength under compression. One system that claims to cut concrete weight by a quarter to a third uses polymers, which are long chain-like compounds. Polymers are divided into two main groups: fibres and plastics.

## LANGUAGE PRACTICE

**I. Comprehension questions:**

1. What method of construction have steel and concrete made possible?
2. What is the difference between the walls in a building built with and without steel or concrete frames? Give an example!
3. What is the function of curtain walls? What kind of materials do they often use today?
4. What kind of structures has it been possible to build with prestressed concrete?
5. What kind of materials are currently being developed?

## WORD CHECK

**II. Translate:** natezni kabel, raspon, prednapinjanje, oplata, armatura, zakivanje, zavarivanje, zakovica

**III. Write the definition of the underlined words. Use your dictionary to help you:**

1. Different fibres are often mixed to give a <u>composite</u> material.
2. Concrete can <u>withstand</u> heavy weights and <u>extremes</u> of weather.
3. Reinforced concrete is made with metal <u>rods</u> <u>embedded</u> in it.
4. Corrosion is a chemical <u>reaction</u> caused by air or other chemicals on the <u>surface</u> of a metal.
5. Prestressed concrete is <u>cast</u> over cables under <u>tension</u>.
6. <u>An external skin</u> of glass saves weight and space.

**IV. Find synonyms in the text for the following words. The first letter of each synonym is given.**

soil = e..., g... ; bar = r... ; base = f... ; solid = f... ; carry = b... ; weight = l... ; stony = m... ; structure = f... ; fasten = f...

**V. Translate the questions:**

1. Kad je konstrukcija izgrađena? Koliko je trajala gradnja?
2. Je li tijekom gradnje bilo kakvih problema?
3. Koliki su bili troškovi gradnje?
4. Kako je mjesto na kojem se gradi izgledalo prije gradnje?
5. Kako je gradnja promijenila područje na kojem je nastala? Je li imala neočekivanih učinaka na zajednicu?
6. Koliko je građevina važna za zajednicu?

**VI. Explain the difference between a load bearing wall and a non-bearing wall (Figures 7.7. and 7.8.).**

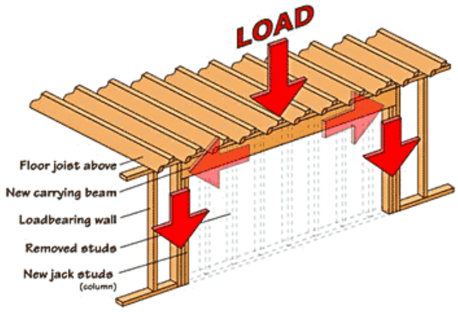



**Figure 7.7.** Load bearing wall

**Figure 7.8.** Non-bearing walls

**VII. Put the following into the passive, mentioning the agent where necessary.**

a) The patents of Hennebique gave rise to an international enterprise.
b) J. Monier patented his system of reinforced concrete.
c) Turner and Maillart had developed the first slab construction.
d) Engineers direct much of the study of cement at the improvement of mortar.
e) Mechanization caused workers to move to cities, seeking employment in factories.
f) In England, the machines had significantly influenced national life.

g) The Association of engineers chose John Smeaton to direct the rebuilding of Eddystone lighthouse.
h) The experts had made Smeaton a Fellow of the Royal Society .
i) The archeologists found much iron within Greek walls.
j) The Romans used iron as dowels (moždanici) and cramps (klanfe) in their masonry.
k) Rods between piers and columns stabilize the work.

**Figure 7.9.** Steel frame

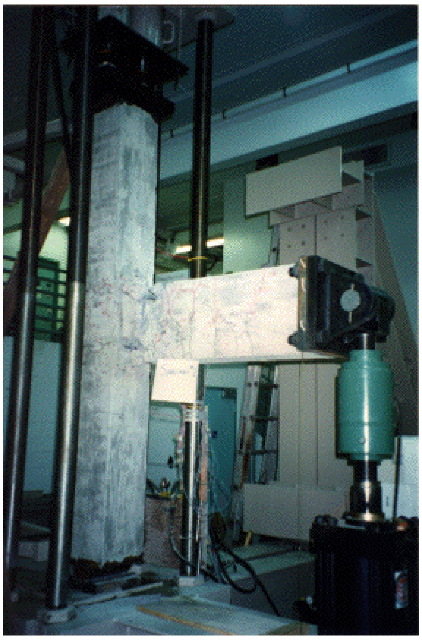


**Figure 7.11.** Test setup for high strength concrete frame connections

**Figure 7.10.** Grout in the road-making

# 8. UP IN THE AIR

Both steel and cement, the two most important construction materials of modern times, were introduced in the nineteenth century. Steel had been made up to that time by a labourious process that restricted it to such special uses as sword blades.

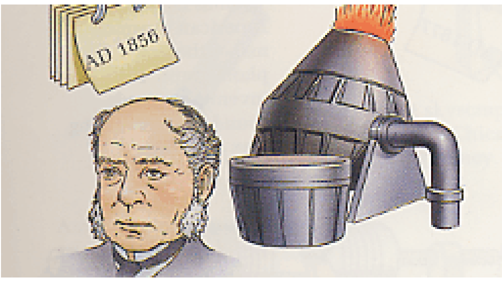



**Figure 8.1.** Henry Bessemer and his converter

After the invention of the Bessemer process in 1856, steel was available in large quantities at low prices (Figure 8.1.).

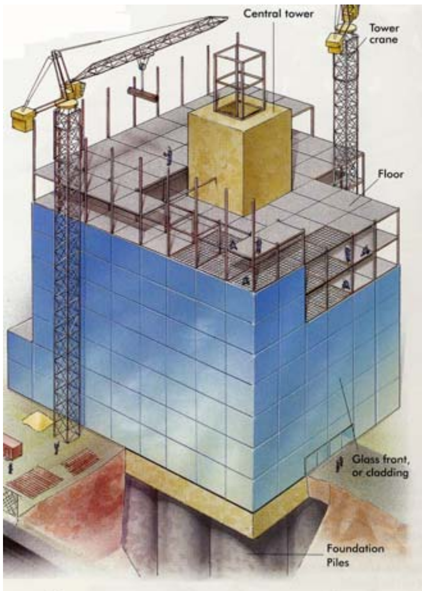



**Figure 8.2.** Construction of a skyscraper

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 tends to pull apart many materials. Steel can be rolled into sheets or bars, or drawn into thin wires. Rust can be prevented by coating the steel with zinc ( a process called "galvanizing"). The first modern skyscrapers came with steel.

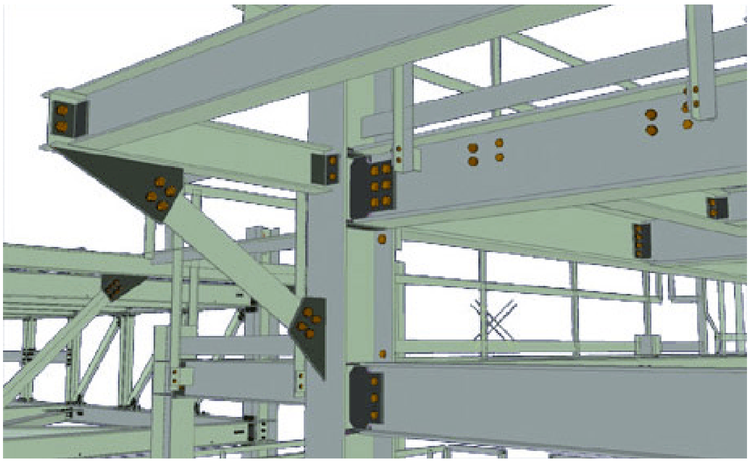


**Figure 8.3.** A 3D model of a steel structure

The first tall building supported by a steel skeleton of vertical columns and beams was the ten-storey Home Insurance Building in Chicago. Modern buildings are miracle of engineering - and feats of organization, too. Before work starts, engineers design each detail and order every part, from the largest girder (Figure 8.4.) to the "welcome" doormat at the front door. A skyscraper can weigh as much as four large ocean liners. To bear the great weight, the underground foundations need to be strong. To make the foundations, a large pit is dug and filled with concrete. The concrete sets hard and forms a solid base for the building. Some skyscrapers are supported by legs, called piles, of concrete or steel. The piles go deep into the ground. In one skyscraper design, there is a hollow central tower made of concrete. The elevators and stairs are built inside the tower or the core. The core stops the building swaying in the wind. A tower crane lifts girders and wall sections up to the top of the building. A frame of steel girders is built

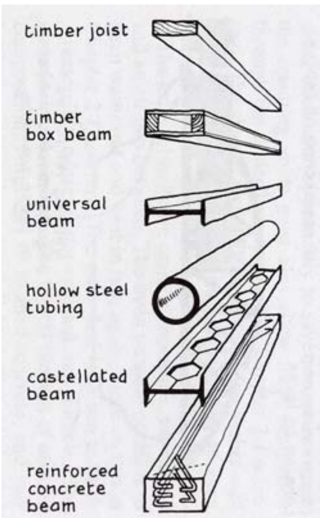



**Figure 8.4.** Some beam types used in building

around the tower. The frame supports the floors and walls. The outer walls are made of lightweight materials, often glass. The floors are made by bolting a steel sheet between the girders. Next, thin steel rods are laid over the sheet, and concrete poured on. The steel rods strengthen the concrete. The frame, floors and walls being in place, contractors can fit the electrical, plumbing, and air-conditioning equipment, and install fire sprinklers.

## LANGUAGE PRACTICE

**I. Draw a rough sketch of a skyscraper: foundation; piles; floors; skeleton frame; curtain walls and label each element.**

**II. Explain the principal stages of erecting a high-rise building.**

## WORD CHECK

**III. Translate the following:**
izvođač, zasunjivanje, greda, okvir, jezgra, vlačna čvrstoća, nosač, ploča, temelj, pilot, glavna noseća greda

**IV. Write down the definition of a PILE, as used in construction.**

**V. Divide the paragraphs of the text according to the following headings and summarize each paragraph using two or three sentences.**

1. Going higher
2. Building a skyscraper
3. A strong base
4. The frame construction
5. Finishing work

**VI. Find expressions in the text that mean:**
steel skeleton, steel beams, reinforcing bars, central core, swaying top, earth, base, carry, weight

**VII. In the following summary there are some gaps to be filled in:**
To ___________ a firm base, cranes dig soil away. Workers build the _________ using concrete and steel. If there is no ____ to mix the

concrete on site, special cars bring it from a concrete plant. Steel _____arrive cut to exact lengths. ____the steel frame is complete, workers add floors. The workers pour steel over ____ bars. The core contains ____services such as_____.The exterior of the building is called ____.

**VIII. Exercise VII. as you noticed, contains three grave mistakes concerning the building process. Make a note of them and correct them.**

**IX. Choose the word that is the odd man out and say why it is different.**

**Example: a dam, a tunnel, a bridge, a dome, *a car***

1. Stone, rock, wood, gravel
2. Column, ceiling, girder, beam
3. Top, pit, pile, foundation
4. Aluminium, glass, steel, plastic
5. Shear, thrust, compression, rust

**X. Find synonyms in the text:**

move _______; necessity ________; beam _______;
discard ________; base ______; accomplishment _______;
complete ________; commerce ________; provide _______

# 9. TUNNELS

In ancient times tunnels were used extensively for irrigation. Over the centuries, tunnels were built mostly for the canals, but the coming of the railways made tunnelling very important. The way tunnels are built today depends primarily on the technology available, the type and condition of material through which they must pass, and their ultimate length.

**Underwater tunnels**

The first tunnel under water - the **Thames Tunnel** was completed in 1843. It was the first in a series of railway and foot tunnels to be built under the Thames.

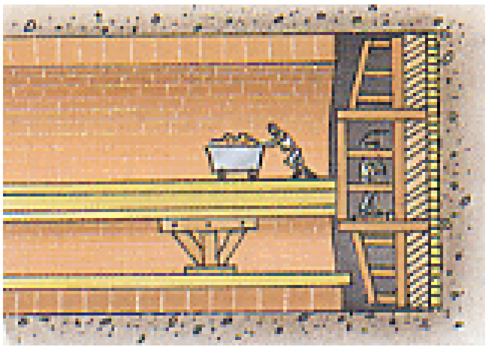


**Figure 9.1.** M. Brunel's tunneling shield

In building it Marc Brunel and Isambard K. Brunel had to overcome considerable difficulties. It was a triumph of ingenuity and perseverance in the face of floods, financial losses and human disaster. Huge floods delayed the work and so Marc Brunel pioneered the method by which many road, rail, sewer and other tunnels would be constructed up to the present day.

He designed a tunnelling shield (Figure 9.1.) which made the work possible. The shield offered the workers protection while they dug out clay and mud in the faces of the shields. The shields were then moved by jacks so that the process could be repeated. The Thames tunnel is still used by the London Underground Railway System today.

Since then, the shields have been developed as steel protective tubes used in soft ground (Figure 9.2.). Instead of miners in the shield there is a tunnel boring machine (TBM), or in a small tunnel, a micro-tunnelling machine.

**Figure 9.2.** Tunneling shield for San Francisco subway

**The Seikan Tunnel**, the world' s longest underwater rail tunnel (1971-1988) runs between the islands of Honshu and Hokkaido in Japan. 55 km long and with a minimum depth of 84 metres below the seabed it was far harder to build than the Channel Tunnel. The rock was volcanic, full of fissures and cracks that allowed water through, and digging took twice as long and cost ten times more than the initial estimate.

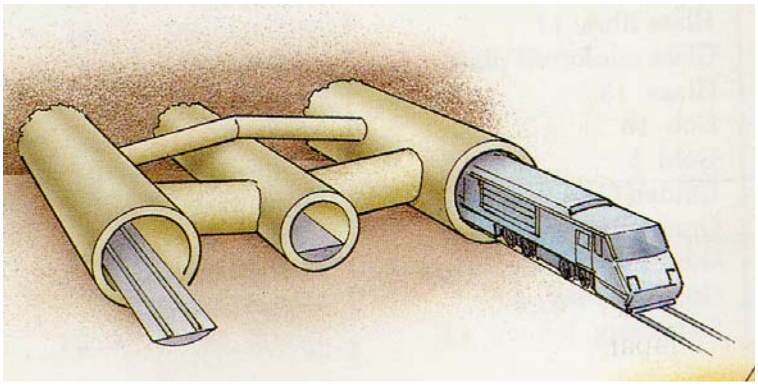


**Figure 9.3.** The Channel Tunnel

**The Channel Tunnel** (Fig. 9.3.) was a dream for nearly 200 years. It is a rail link between England and France, bored by heavy tunnelling machines(TBM). The rotating cutting heads were moved forward by hydraulic jacks. It consists of three separate tunnels, two to take railway lines and the third to provide ventilation, access for service vehicles and an escape route for passengers. Of the total length of 49 km, 38 km lies under the sea, drilled through chalk below the seabed. The tunnel was bored from both sides of the Channel at the same time, using laser beams to keep the machines on course and ensuring that both sides met exactly.

Another method which has been used for underwater tunnels is since the beginning of the 20th century an immersed tube system. A trench is dredged in the riverbed, the segments of steel tubes are floated into position, and sunk; the segments are locked together by divers and water is pumped out and then covered with excavated material.

**Rock tunnels** are mainly used as railways or roadways through mountains. Years ago, building St Gothard or the Simplon (Fig. 9.4.) Tunnel, engineers were forced to blast through mountains with dynamite.

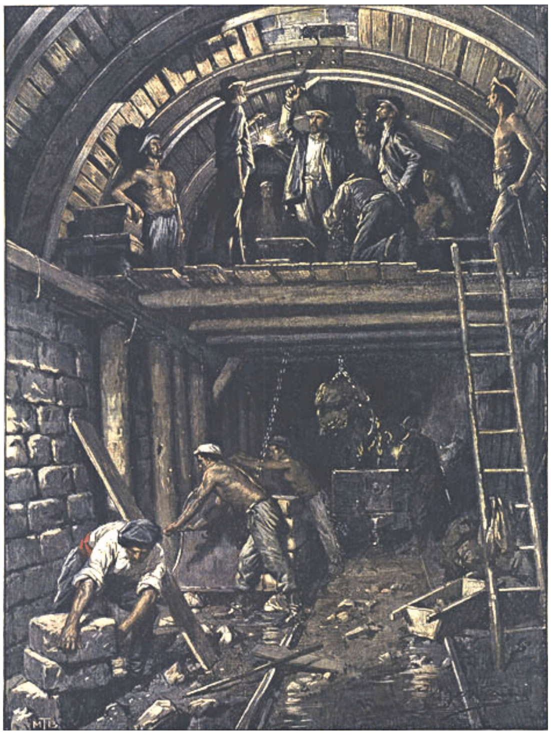


**Figure 9.4.** Simplon Tunnel under construction

Today they rely on enormous tunnel boring machines (TBM), sometimes called moles. A mole can advance about 76 m a day, depending on the diameter of the tunnel and the type of rock being bored.

The first major tunnel built through rock was the **Mont Cenis Tunnel** (Fig. 9.5.) in the Alps between France and Italy. It is fourteen kilometres long and it was built around the middle of the 19$^{th}$ century. When the construction began on it, progress was only twenty-two centimetres a day. Fortunately, the pneumatic drill, which uses compressed air to bore holes in rock, was invented by G. Sommelier a few years later. It increased the tunnelling speed to two metres a day.

**Figure 9.5** Construction of Mont Cenis Tunnel

Sommelier introduced not only hydraulic ram air compressors but also many other pioneering techniques, including rail-mounted drill carriages, construction camps for workers complete with dormitories, family housing, schools, hospitals, and a recreation building. Like most tunnels, the Mont. Cenis was bored from two different headings, one in France and one in Italy, which met in the middle.

Drilling and blasting, formerly the only method in hard rock, is giving way either to a fullface TBM or to a heavy hydraulic hammer of up to 3500 kg in weight. TBMs do not weaken the surrounding ground as explosives, but they are a heavy investment. TBMs have also been successful in soft ground but they are inflexible and generally suitable only for the type of rock they are designed for.

## LANGUAGE PRACTICE

### I. Passive constructions

The Passive voice is formed by using the auxiliary verb to be and the past participle of the respective verb. An active construction may be turned into a passive one by making the object of the active verb the subject of the Passive voice.

*Active construction: The London Underground Railway System still uses the Thames River Tunnel.*

*Passive: The Thames River Tunnel is still used by the London Underground Railway System.*

**Turn the following active sentences into passive:**

1. The French engineer Sommelier invented the pneumatic drill.
2. The miners bored Mont. Cenis from two different headings.
3. Miners fill the holes with an explosive.
4. A pilot tunnel or a heading often provides ventilation.
5. The English government opened the Thames Tunnel as a pedestrian route, and sold it to a railway company in 1865.
6. Engineers shaped the world of the $19^{th}$ century.

### II. Make sentences using the following:

- tunnels in the ancient and modern world
- major rock tunnels
- major underwater tunnels
- pioneering machines in tunnelling

### III. Match the following terms with their definitions:

| | | |
|---|---|---|
| 1. | Tunnelling shield = | a) A tunnelling machine that can bore through hard rock |
| 2. | Heading = | b) A large cylinder with a cutting edge that can be moved forward by jacks. |
| 3. | Blasting = | c) Any small tunnel used for excavating small sections of a long tunnel to make the roof safe before the bulk excavation |
| 4. | Jack = | d) Blowing up of rock |
| 5. | TBM = | e) A piece of equipment for raising heavy loads from below |

**IV. Fill in each of the blanks in the following sentences with the appropriate word or phrase referring to the text. The verbs are to be put into the correct tense: vary, detonate, waterlog, drive, propellers, place, soil, provide, clear, detonate, tunnelling shield.**

1. Most tunnels in soft ground are ______ by shields.
2. Huge ____ ventilate the tunnel to _____ air to the workers below ground.
3. It is common practice today to use ____ _______ for tunnelling through silt, sand or gravel.
4. Blasting material is __________into the holes, the area _______ and the explosives_________.
5. Tunnelling methods _____ with the hardness of the _____, the ____ of the tunnel and whether the ground is ______.

**WORD CHECK**

**V. Translate:**

tunelski štit, iskopati, teret, ispitati, dno rijeke, dizalica, potopiti, spojiti, jarak (rov), bageriranje, mikrotunel, plovni objekt

# 10. TUNNELLING TOOLS AND TECHNIQUES THROUGH THE CENTURIES

Throughout the ages, people have developed all kinds of tools and techniques for digging tunnels. Some were more successful than others!

**FIRE-SETTING** (Figure 10.1.)

An ancient technique in which the tunnel wall is heated with fire, then cooled with water. In the right conditions, the temperature change causes the wall to break off in chunks. It was first used in a tunnel around 2000 BC, to mine copper and gold from Egyptian mountains. Roman slaves built the enormous Cloaca Maxima, one of Rome's oldest sewer tunnels, using the fire-setting technique. The tunnel was so huge and impressive, the Emperor Augustus was rumoured to have toured it in a ship. Thousands of slaves died in the tunnel from the toxic fumes and intense heat, but fire-setting remained the standard tunnel digging method for well over 2,000 years!

**Figure 10.1.**Fire-Setting

**HAND TOOLS** (Figure 10.2.)

Before there were explosives and tunnel-digging machines, workers used hand tools to carve tunnels. Hand tools were first used in a tunnel around 2000 BC, to mine copper, gold, and salt from mountains in Belgium, France, and Portugal.

**Figure 10.2.**Hand Tools

**EXPLOSIVES** (Figure 10.3.)

Gunpowder, nitroglycerin, and dynamite allowed tunnel diggers to blast through mountains much faster than ever before. Gunpowder was first used in 1679, to build an underground section of the Canal du Midi, a canal connecting the Atlantic Ocean and the Mediterranean Sea. The tunnel was 157 metres long. In 1867 Swedish physicist Alfred Nobel patented another blasting explosive called dynamite. Dynamite is based on nitroglycerin but is much safer to handle than nitroglycerin alone. One of the first tunnels to be excavated with gunpowder was the Harcastle Canal Tunnel in England in the 1700s - and it was an absolute disaster. Gunpowder blasts struck springs, which flooded the tunnel and delayed construction. To save

**Figure 10.3.** Explosives

time and money, the chief engineer built a very small and narrow tunnel. The tunnel was so tiny (2.2 metres wide by 3.6 metres high), barges had to be "legged" from end to end. This meant that men lay on their backs on the barge deck and pushed the barge through by walking their feet along the tunnel roof!

**Figure 10.4.** Compressed Air Drill

**COMPRESSED AIR DRILL** (Figure 10.4.) is an earsplitting drill that can rip through rock with ease. It was first used in the mid-19$^{th}$ century. When the construction on the Mont Cenis Tunnel began progress was only twenty-two centimetres a day. Fortunately, the pneumatic drill, which uses compressed air to bore holes in rock, was invented a few years later after construction began. Thereafter, the tunnelling speed increased to two metres a day. The drill was safe and three times more effective than gunpowder. In the choking dust, the drills also had a welcome side effect. Air blew out of the end of the drills and actually provided some fresh air. Before the compressed air drill, workers toiled in hot, steamy tunnels without any ventilation!

**Figure 10.5.** Tunnel Shield

**TUNNEL SHIELD** (Figure 10.5.) is an internal frame, or shield, used to support loose earth in a tunnel while digging. It was first used in a tunnel in 1825, to excavate the **Thames Tunnel,** London, England. The inspiration for the tunnel shield was a bizarre creature called the helmet-headed shipworm. While in prison for debt, an engineer named Marc Brunel watched the worm bore through wood, using the hard shell on its head as a shield. As it tunneled into the wood, the worm excreted a substance that formed a rigid lining behind it. Brunel figured out a way to copy this idea on a large scale. He used a large iron frame to keep the unstable sides of a tunnel up while masons lined the inside with brick.

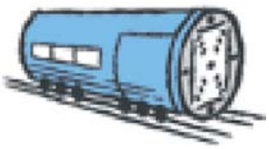


**Figure 10.6.** Tunnel Boring Machine

**TUNNEL BORING MACHINE (TBM )** (Figure 10.6.) is a 200-ton rock-chewing machine designed to carve through rock. It was first used in a tunnel in 1957 to carve a sewer tunnel through shale and limestone in Toronto, Canada. Tunnel boring machines (TBMs) are very selective about the rocks they chew through. This is why the rock must be monitored at the head of every tunnel. On good days, TBMs can bore through rock at a rate of 80 m a day. But when TBMs bite into rocks they are not suitable for, they grind to a halt. Many tunnel engineers have been forced to abandon their TBMs because they can't back them out of the tunnel!

LANGUAGE PRACTICE

**I. Comprehension**

1. Which is in your opinion, the most creative feat in the history of tunnel constructions?
2. Describe the tiniest tunnel in the 19$^{th}$ century.

**II. List the advantages and drawbacks of each of the tunnelling methods mentioned in the text.**

**III. Match these verbs to their definitions:**

*excavate, patent, delay, monitor, back out*

a) to watch or listen to something carefully over a certain period of time for a special purpose
b) to move to a later time
c) to fail to fulfil a plan
d) to make a hole by digging
e) to obtain a legal document giving the right to make or sell a new invention

**lV. Define the underlined words. Use a dictionary to help you.**

1. It is important <u>to determine</u> the geological features of the rock.
2. Ventilation is one of <u>the major problems</u> in tunnelling operations.
3. The Thames Tunnel was <u>dug out</u> of the clay.
4. The Channel Tunnel is one of the greatest civil engineering <u>achievements.</u>
5. Today many <u>phases</u> of the tunnelling process can be performed by machines.

**V. Fill in with the appropriate word or phrase in the text:**

1. When holes have been bored in hard rock, they are filled with an _________ which is then detonated.

2. A pilot tunnel is often bored in advance of the main tunnel in order to determine _________features that will be encountered.
3. A _________ is a new type of machine that can bore through hard rock.
4. When a tunnel is being excavated through _______, a shield with compressed air, a kind of caisson, is ordinarily used.
5. The face of a tunnelling shield has a larger ________than its tail.
6. A tunnelling shield is moved forward by _________.

**Figure 10.7.** Banquet in the Thames Tunnel

**VI. Turn the following sentences into the active voice.**

1. The banquet was organized by the young Marc Brunel with the aim to restore confidence in the Tunnel project.
2. The banquet is considered as one of the more bizarre episodes in the Story of the Thames Tunnel and added considerably to the notoriety of both Brunel and the Tunnel.
3. After the first major flood in 1827 a banquet was held in the Thames Tunnel itself.
4. The Tunnel was extensively prepared by Marc Brunel for the occasion.
5. The floor was swept and carpeted, and red velvet was hung on the walls.
6. Tables were taken down into the tunnel and covered with cloths.
7. The tunnelling shield was cleaned and gas candelabra were hung.

# 11. CANALS

Until the advent of the railway (1827), water transportation was the most efficient means of carrying goods and people over long distances.

**Figure 11.1.** Rhein - Main - Danube Canal

Canals date from a period long before the Christian era and served as a means of navigation and communication for the Assyrians, Egyptians, Hindus, and Chinese. The 1,600-km-long Grand Canal of China was begun in the $6^{th}$ century BC (completed AD 1327) and is still in use.

**Figure 11.2.** Derivation canal of Danube hydro-power plant

The Age of Canals started in the seventeenth century in England due to the necessity of transporting coal, iron, bricks, timber and other types of industrial goods for the growing network of factories.

The completion of the Canal du Midi in 1681, linking the Mediterranean to the Atlantic, was the first important canal of the modern age. The most famous accomplishments of modern hydraulic engineering are the three great international ocean canals: the Suez Canal in Egypt that connects the Mediterranean Sea with the Red Sea, providing a passageway between Europe and Asia. This 169 km long canal eliminates the voyage around Africa. The Suez Canal has been widened and deepened in order to accommodate the supertankers that carry oil from the oil fields on the Persian Gulf.

**Figure 11.3.** Corinthian Canal, Greece

**Figure 11.4.** Computer simulation of future Vukovar port

The second most important is the Panama Canal joining the Atlantic and Pacific oceans across the Isthmus of Panama. Running from an arm of the Caribbean Sea, to Balboa, on the Gulf of Panama, the canal is slightly more than 64 km long.

The St Lawrence Seaway half-artificial canal completed in 1959 permits ocean-going vessels to sail from the Atlantic Ocean to such Great Lakes ports as Chicago and Duluth.

Sometimes freight can be carried by water much more cheaply than on land; therefore, canal-building has continued up to the present time despite the attention given to railways in the nineteenth century and to highways in the twentieth.

Most of the rivers of Europe (Figure 11.1.) are connected by a network of canals that carry a large proportion of the commerce.

**INLAND WATERWAYS**

Navigable rivers are used for navigation as natural or canalized rivers. If a natural river bed can not accommodate the vessels due to lack of depth, the river can be trained by dredging and construction of water facilities. If the river is not deep enough it should be canalized. A dam with a weir and lock is built across the water course and dikes are built at the sides of the river. The water within the dikes is raised above the level of the adjoining terrain to increase the depth of water for navigation. It results in dividing a river into reaches separated by locks and weirs to help ships or irrigation, or control flooding.

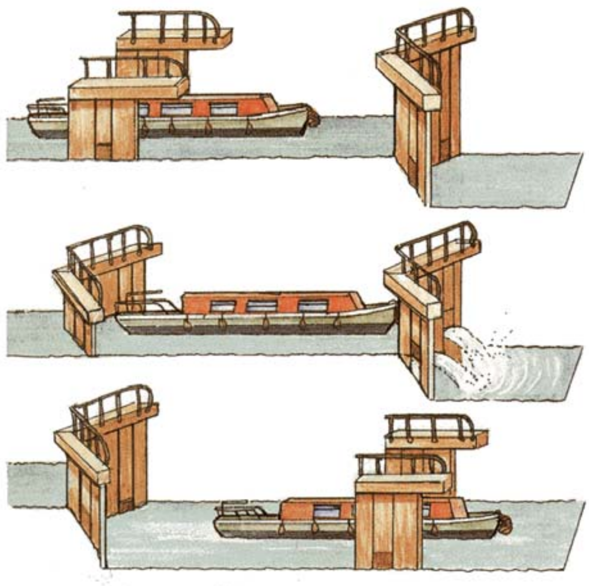


**Figure 11.5.** Operation of a lock

**LOCKS**

Locks (Figure 11.5.) are the most distinctive feature of a waterway. A lock is a concrete chamber, closed by iron lock gates at both ends, in which the water level can be raised or lowered by means of sluices to match the level in the upper or lower reach, as desired; when the levels are the same, the corresponding water gate is opened to permit a vessel to enter or leave the lock.

## LANGUAGE PRACTICE

**I. Comprehension questions**

1. When did the new age of canal-building begin in Europe?
2. Why has canal-building continued despite competition from railways and highways?
3. What does the canalization of a river include?
4. Name some of the world's most important canals.

## WORD CHECK

**II. Translate**:

drvena građa (tehničko drvo), hidrotehnika (vodogradnja), krak, vodna stepenica, preljevna brana, reguliranje rijeke, nasip, komora, plovila, vodni tok, teret, vodna građevina, brodska prevodnica, plovidba

**III. Rephrasing: Rewrite the following replacing the words in bold with their definitions.**

1. Early **proposals** for a canal included extending the navigability of the flood-**prone** Chagres River into the Panamanian isthmus.
2. By 1811 the German scientist Humboldt **identified** nine possible locations that would provide **unobstructed** water passage between the Atlantic and Pacific.
3. In the early years of its **operation** the canal was plagued with landslides, but after each slide the channel was methodically **dredged open** again.
4. Even if **superceded**, the Panama canal will remain one of the greatest engineering achievements of all time.
5. Its more recent history has been **dominated** by political rather than technical **considerations.**

**IV. Translate the following text:**

*Ustave koje se grade na kanalima s više razina imaju nekoliko loših obilježja; često su neisplative zbog troškova građenja i rukovanja njima. Ako je promet gust, teško je održati opskrbu vodom za najviši vodostaj. Zbog toga, da bi se izbjegla gradnja ustava, kanali se katkad grade uz depresije na nasipima, preko rijeka na akveduktima te kroz planine u tunelima.*

**V. Find synonyms in the text for the following words and expressions:**

move ________, necessity __________, provide __________,
commerce _______, complete ______, accomplishment ________,
discard _________, solid _________, base _________,
soil __________, bar __________, dredge ________,
river bed ________, passageway ________, carry_____________
eliminate _________, goods _________, in favour __________

**VI. a) Turn the following sentences into the active voice. Where no agent is mentioned one must be supplied.**
**b) Translate the sentences in active voice into Croatian.**

a) After Smeaton' s experiments there were many trials and errors made by practical men.
b) The construction of the bridge across the Dordogne river was directed by a French military engineer.
c) J. Aspdin's company had been moved from London to Newcastle, where fuel and wages cost less.
d) Ingredients are added to produce a Portland cement of the desired quality.

# 12. TRANSPORTATION ENGINEERING

There is nothing more remarkable than the fact that, over the last two thousand years, since the Romans started to spread the network of roads, the world has not been able to make any essential improvements in road making (Figure 12.1.).

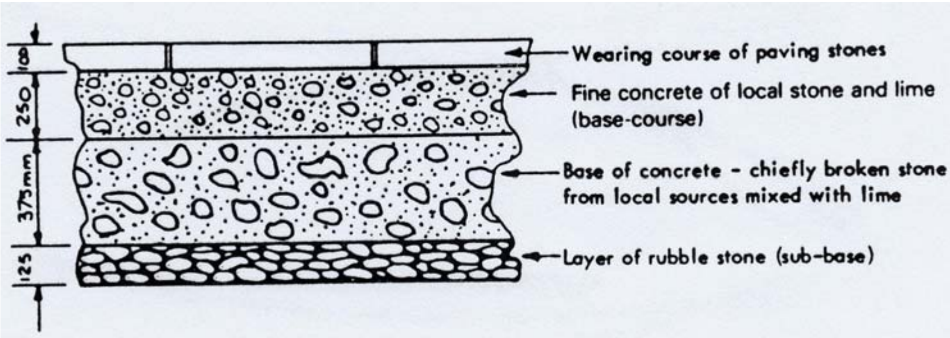



**Figure 12.1.** Roman road structure

The reason why the Roman roads are so durable is because of the great amount of effort that was put into the design and construction. The Roman highway system made possible a rapid communication between Rome and the provinces of the empire.

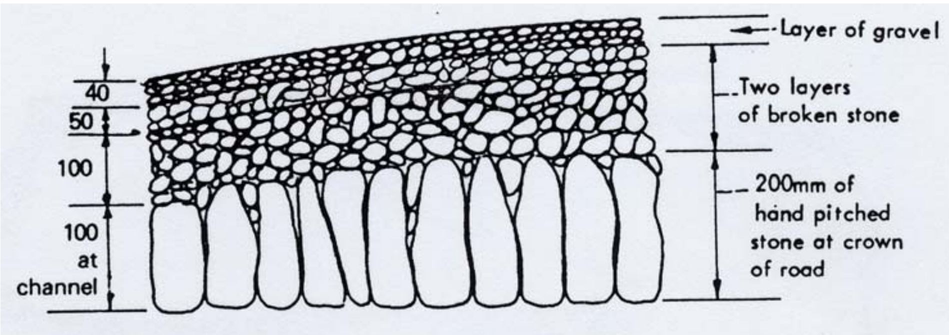



**Figure 12.2.** Telford’s road structure

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 Thomas Telford (Figure 12.2.), and a Scot, John L. MacAdam whose name has passed into English in the words macadam and macadamize (Figure 12.3.).

These men designed the first modern roads that had a firm sub-grade, the surface on which the foundation rested. Their roads also included good drainage and a wearing surface. The top layer of a pavement is referred to as a wearing surface.

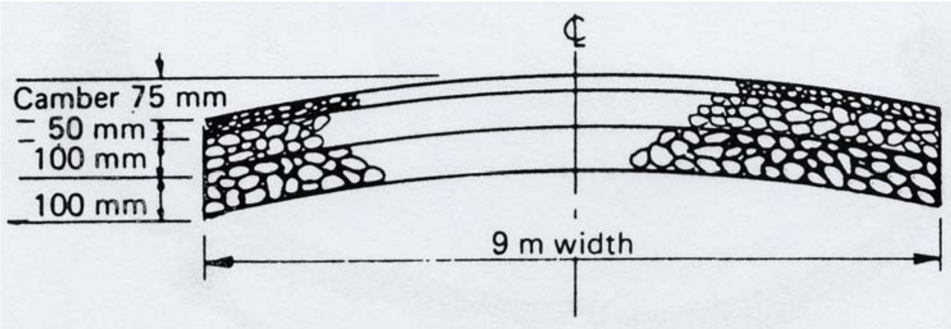



**Figure 12.3.** MacAdam's road structure

The purpose of the wearing layer is to protect the base layer from wheel abrasion and to waterproof the entire pavement structure. Both Tresaguet and Telford used broken stones, on top of which a base course of aggregates of smaller size and a wearing surface of still smaller stones were built up. Their roads were also slightly curved in a crown so that the water would run off.

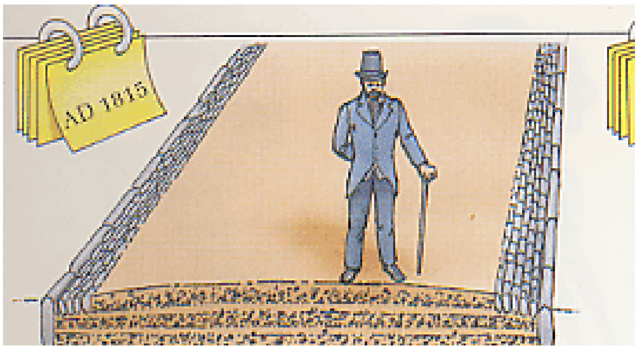



**Figure 12.4.** John L. MacAdam

MacAdam (Figure 12.4.) 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 the weight of the automobiles broke up the smooth surfaces. Therefore, the top layer was bound together more firmly by mixing the crushed rock with tar or bitumen. Millions of kilometres of roads throughout the world today have this kind of surface.

## LANGUAGE PRACTICE

**I. Complete the sentences with reference to the text:**

1. Engineers whose principles of road-building are still applied to the building of modern highways are_____________________________
2. The roads designed by MacAdam differ from those designed by Tresaquet and Telford in ___________________________________
3. MacAdam's roads became inadequate in the twentieth century because
   ____________________________________________________
4. The layer that directly receives the wear of traffic is called
   ____________________________________________________

## WORD CHECK

**II. Translate:**

agregat, gazeći sloj, kolnik, posteljični sloj, trajna konstrukcija, konstrukcija otporna na vodu, zbijanje zemlje

**III. Fill in the gaps with the most suitable phrasal verbs: put off, let in for, sort out, feed into, call in, interested in**

Transport engineering is very nearly the hidden face of civil engineering of which it is a specialisation. Transport engineers are a)_______ e.g. to b)_______ a junction that is not working. It c)_____ many a graduate _____" straight" civil engineering, having no idea what they d)_____ themselves ____. Transport engineers are e) ______ transportation modelling and traffic engineering. Results of the research are f)_______ the computers.

**IV. Underline the passive structures and then re-write the passive using active voice.**

Computer models are used to predict the amount of traffic. Interviewing people about the start and the finish of their journeys is involved in preliminary surveys. After looking at problems a new range of options is developed. A new signalling sequence or a roundabout may be included. Enormous scope for specialisation is offered in this field. A social value is contained in transportation engineering as well.

**V. Translate:**

*Oksfordski rječnik engleskog jezika definira "građenje makadama" kao proces kompaktiranja malih kamenčića u čvrstu masu na konveksnoj, dobro osušenoj posteljici ceste. Naziv potječe od imena Johna MacAdama, čovjeka čijoj je slavi inženjera u Engleskoj konkurirao samo njegov suvremenik Thomas Telford. MacAdamovo ime postalo je sinonimom za proces građenja puteva, a njegovo čvrsto i financijski isplativo oblikovanje ceste nadopunjavalo je sustav kanala koji su izgrađeni na Britanskim otocima za vrijeme industrijske revolucije. 1830 francuska vlada preuzela je MacAdamovo načelo izgradnje cesta.*

## 13. CONSTRUCTION OF A ROAD

Roads need to be strong, so they are built up from several layers. The whole construction of a road is called pavement, and consists of the sub-grade (soil), then the sub-base if any, the base and finally the wearing course. Distinction should be made between **rigid** pavements (Figure 13.1.) that are constructed with Portland cement concrete (PCC) and aggregates.

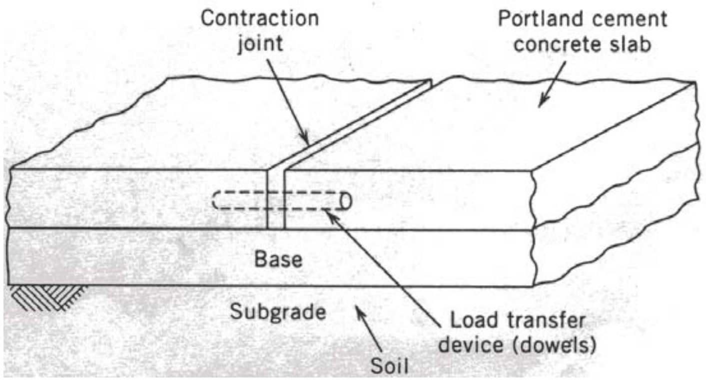



**Figure 13.1.** Rigid pavement

The top layer or wearing surface is the Portland cement concrete slab. The wearing surface of the **flexible** pavement (Figure 13.2.) is usually made of asphaltic concrete, which is a mixture of asphalt cement and aggregates.

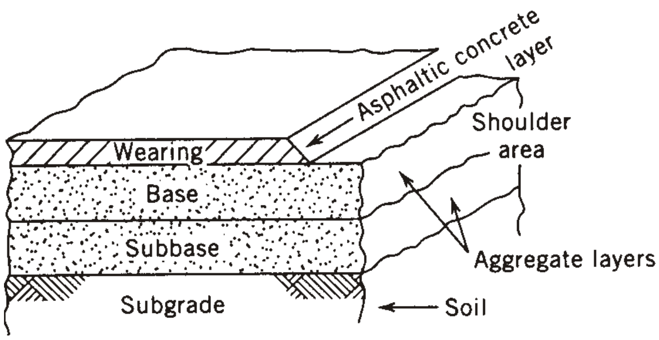



**Figure 13.2.** Flexible pavement

Before a new road can be built, the ground has to be made flat and compacted. Huge earth-moving machines called bulldozers (Figure 13.5.) level the ground along the designated route. Giant excavators (Figure 13.3.)

dig, cut and move the soil for the new road. In many cases, however, the soil must be stabilized by mixing some other material with it. 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 excavators also make ditches for drains along the side of the road. When the road is finished, rain will run off the road into the drains. The amount of earth to be moved, both in cutting 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.


**Figure 13.3.** Excavator digs and moves earth

Next a soil compactor moves slowly over the ground to make it compacted and flat. A loader (Figure 13.4.) collects a mixture of crushed stones and takes it to the site. This mixture forms a sub-base of the road or base layers.

**Figure 13.4.** Loader collects crushed stones

A top or wearing surface is laid over the base layer. This can be made of concrete slabs or asphalt. It provides a waterproof and long-lasting road. A heavy road roller flattens the hot asphalt.

## LANGUAGE PRACTICE

**I. Read the following statements carefully and indicate whether they are true (T) or false (F) according to the information in the text:**

1. Bulldozers are used to compact soil.
2. Soil stabilization means mixing soil with some other substances.
3. After a time, traffic wears out the surface of the road.
4. Loaders dig and move earth.
5. Improper drainage results in deformation of the road surface.
6. Soil mechanics is used to identify particular soils and their properties.

**II. Fill in the gaps to complete the questions using passive and active forms.**

1. How can the soil __ stabilized?
2. What ___ soil stabilization techniques depend __?
3. What are the base course and the wearing surface of modern

highways usually ___?
4. Why must a concrete surface ____ in segments?
5. What two methods ____ to lay a reinforced concrete surface?
6. What machines are used for ________ the concrete slabs of a highway?

**Figure 13.5.** Bulldozer pushes and spreads earth

**III. Complete the sentences with reference to the text.**

1. The basic problem in road making is to obtain __________________
2. The need for efficient roads has resulted in _____________________
3. Excavators dig and ________________________________________
4. Loaders use their buckets ____________________________________
5. Rigid and flexible pavements differ in __________________________

**IV. Re-write the text using either passive or active forms with the verbs in brackets:**

Often jackhammers and other small machines are used ( make) repairs. Excavators (run) on caterpillar tracks over rough ground without (get) (stick). Graders (make) sure the whole road (be) the same level. Hot asphalt ( tip) slowly out of the tipper truck (Figure 13.6.). The earth (smooth) and (flatten) by rollers.

**Figure 13.6.** Tipper truck

## WORD CHECK

### V. Translate

usjek, nasip, krut, kruta kolnička konstrukcija, fleksibilna kolnička konstrukcija, bager jaružalo, utovarivač, mehanika tla, stabilizacija tla

# 14. BRIDGES

Bridges were among the earliest structures. The simplest were log or rope bridges across rivers built of what nature had provided - stone and wood. The first great master builders of bridges were the Romans. They used the arch to create bridges and aqueducts, many of which have survived to this day. A bridge must support its own weight, the weight of the traffic crossing it, and withstand stresses caused by high winds.

**Figure 14.1.** The Bridge of Croatian Defendants over Riječina, Rijeka

**The beam or girder bridge** (Figure 14.1.) is basically a giant log placed across a stream. The beam stretches from bank to bank, and can be supported by piers buried deep in the river bed. A span is the distance between the supports of a bridge. Beam bridges are limited in span because of the strength of their girders.

**The arch bridge** (Figure 14.2.) may have one or more arches. The arch is immensely strong, so long as its ends are fixed. The roadway - a deck - is built either on top of the arch or beneath it. The arch takes the whole weight of the structure and therefore it can span greater distances than any unsupported beam. Most arch bridges until the late 18$^{th}$ century were built of masonry.

**Figure 14.2.** Krk Bridge

**The truss bridge** (Figure 14.3.) is made of a series of triangles. The triangle is not only used in bridges but also in buildings, domes and towers because of its strong rigid shape. Nowadays the frames are generally built of steel, concrete, light alloy or timber as they are also widely used in the construction of roofs.

**Figure 14.3.** Newburgh-Beacon Bridge, New York

**Suspension bridges** are hung by steel cables from tall towers. The cables are held by anchor blocks or solid rock behind the towers. The cables can carry huge loads and a single span over 1000 m is possible. The first modern suspension bridge was the Brooklyn Bridge (1883) built by John and Washington Roebling (Figure 14.4.) with a span of 486 meters. The world's most famous bridge is the Golden Gate in San Francisco, which stretches 1280 meters across San Francisco Bay. The bridge was very difficult to build, because it is across what is virtually open sea, with strong tides.

**Figure 14.4.** Brooklyn Bridge, New York

**Figure 14.5.** Tower Bridge, London

**The movable bridge** (Figure 14.5.) dates deep into history as a drawbridge of medieval castles, which was raised to protect its occupants against attackers. The swing bridge swings on a vertical pivot at its center, to allow vessels to pass. Other types include lift bridge, used usually for long spans, with the towers that raise the entire span between them.

**Figure 14.6.** Dubrovnik Bridge

**The cable-stayed bridge** (Figure 14.6.) is a bridge with straight cables from masts connected directly to the deck girders without suspenders. In the 30s it was realized that the stiffness and stability could be achieved if the cables were made of high-strength wires under stress.

## LANGUAGE CHECK

**I. Comprehension questions:**

a) Which bridges have the shortest spans, which have the longest?
b) What kind of bridges were constructed in ancient times?
c) What affects the length of the span?

## WORD CHECK

**II. Translate:**

gredni most, lučni most, ovješeni most, viseći most, rešetkasti most, korito rijeke, stup, krutost, vješalica, stožer, sidro, toranj, raspon, nosač, kolnička ploča

**III. With reference to the text insert the missing verb. Be careful to use the appropriate form of the verb: exert, become, avoid, begin, construct, last, span, stop, develop, make.**

The sudden expansion in transportation system that (a)_________ in the eighteenth century, and still (b)________ in our own day, (c) *Pres.Perfect* enormously _______ the need for bridges as a part of highways and railroads. Better understanding of the forces that (d) *Pres.Passive* on structures and improved materials that (e)_______ available in the nineteenth century (f) *Pres.Perfect* it possible (g) *Infinitive* increasingly longer and stronger bridges. With the ability (h)______ greater distances, the damlike effect of masonry arch bridges with several heavy piers that (i)_______ the flow of stream can be largely (j)_______.

**IV. Mini-activity: Toothpick truss**

*Truss - a skeleton-like structure composed of struts (short straight pieces), some in compression and some in tension, joined to form a series of triangles.*

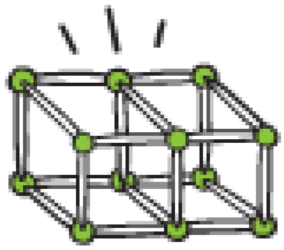


**Figure 14.7.** Rectangular box

1. Construct a rectangular box as shown here (Figure 14.7.) by joining toothpicks with small white beans, soaked overnight before the activity, or gumdrops. Test its stability by pressing down on it and wiggling it. Strengthen the box. You will probably find that you can stabilize the box by adding cross-pieces of toothpicks.
2. Add more materials to it and triangular braces, as in the example shown here (Figure 14.8. ).
3. Extend the trusses and see how wide a gap they can cross. Explain to a classmate how you constructed the truss. Define truss in your own words.

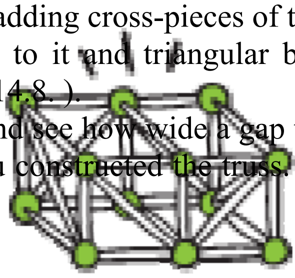


**Figure 14.8.**

**V. Translate:**

*Često su mostovi najspektakularnija građevinska ostvarenja. Impozantni mostovi iz dalekih vremena sačuvani do danas su masivne lučne konstrukcije obično od kamena ili cigle. Još i danas teče promet preko Fabriziovog mosta nad rijekom Tiber u Rimu izgrađenim 62. g. pr. Krista i nazvanog po njegovom graditelju (Slika 14.9.).*

**Figure 14.9.** Fabrizius Bridge, Rome

*Kao i mnoge druge rimske mostove, mostove Fabrizius i Sant Angelo podupire niz lukova koji sežu do čvrste podloge. U starim izvorima spominju se i pontonski mostovi, obično u vezi s vojnim operacijama. Pontonski je most šuplji bubanj koji može plutati; niz pontona usidrenih u riječnom koritu može nositi cestu. Inke iz pretkolumbijskog Perua izgradile su izvanredne viseće mostove koje su podržavale žice od prirodnih vlakana, premošćujući tako vodotoke u planinskim područjima.*

Remember: čvrsta podloga (temeljna stijena) = bedrock, pontonski most = pontoon bridge, vlakno = fibre

# 15. HOW ARE BRIDGES BUILT?

Bridge construction can present great difficulties. Each type of bridge presents special construction problems. 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** (Figure 15.1.) which was originally used by the Romans.

**Figure 15.1.** A cofferdam

They developed a method of constructing foundations within a temporary enclosure from which the water is excluded thus giving access to an area called cofferdam. Cofferdams are used down to 10 m below water level. Nowadays 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.

For greater depths a **pneumatic caisson** is needed (Figure 15.2.). 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. Workers can only stay in the compression chamber for short periods of time. If they come up to normal atmospheric pressure too rapidly, they are subject to the caisson disease, which is a crippling or even fatal condition.

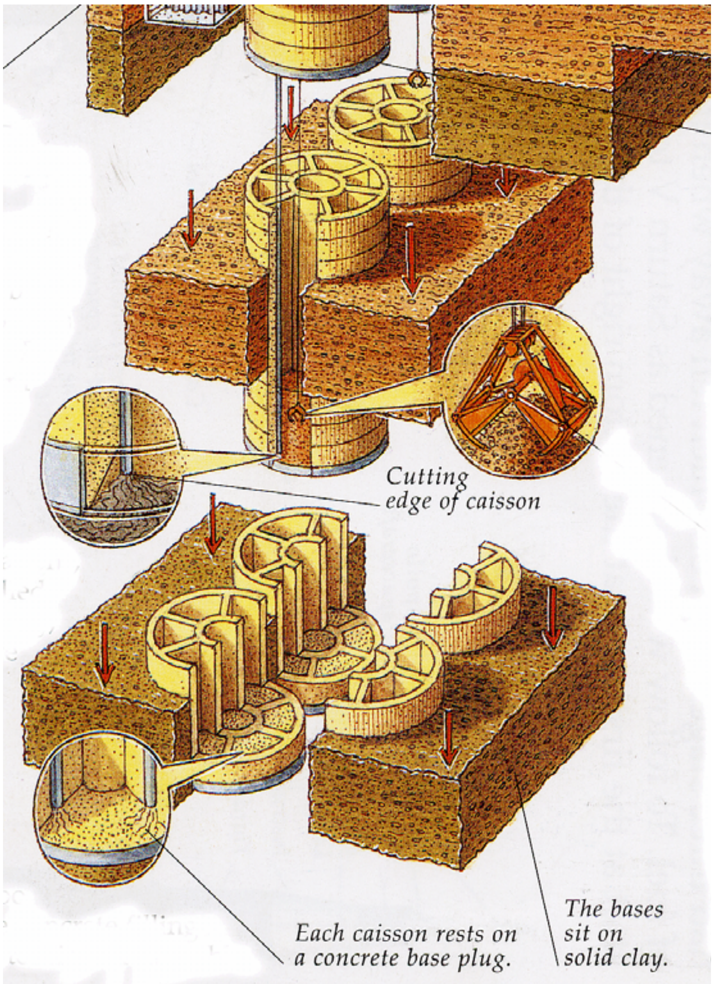



**Figure 15.2.** A part of a caisson

In search for longer spans the engineers of the late $19^{th}$ century devised the **cantilever (**Figure 15.3.). It is a development of the beam. It consists of a bracket with one end fixed and the other end hanging free. The simplest cantilever bridge has a beam supported on two opposite cantilevers. Cantilever bridges have two independent cantilever beams projecting towards each other that are joined by a central span. In the most common type, which is a three-span bridge, the suspended span, resting on the cantilever arms, occupies the remaining one third of the central span. Each of the outer spans is anchored down at the shore and overhangs into the central span.

**Figure 15.3.** Cantilevering of a bridge

**How are arch bridges built?**

Building an arch bridge can be quite tricky, since the structure is completely unstable until the two spans meet in the middle.

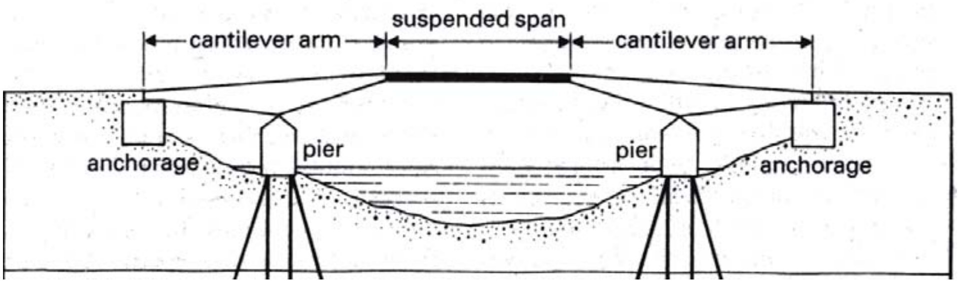



**Figure 15.4.** Structural parts of a bridge

Since Roman times engineers used a technique called centering, in which a wooden form supported both spans until they locked together at the top. In modern arch bridges the span is floated into position after the piers have been erected and then raised into the place by means of *jacks* or *cranes*.

## LANGUAGE WORK:

**I. Find words and expressions in the text that mean:**

a) the distance between two supports of a bridge = __________

b) a bridge supported by cables that are usually hung from towers = ______

c) a type of structure in which a horizontal beam extends beyond its support = ________

d) the roadway or traffic - bearing surface of a bridge = __________

e) a device that moves and lifts heavy weights = ___________

f) a temporary form over which an arch or vault is built= __________

g) a watertight enclosure made of piles or steel sheets sunk into a water bed = _______

**WORD CHECK**

**II. Translate**

komora, konzolna greda, konzola, zagat, privremen, prepust, usidriti, izumiti (pronaći), temeljna stijena, most na podizanje, centriranje

**III. Write down the definition of the following terms using complete sentences. These key words will help you.**

DECK: traffic-bearing surface
STAY: supporting cable/ deck/ diagonal/ suspension bridge
LIFT BRIDGE: movable/ elevators/ raised
TRUSS BRIDGE: structure/ diagonal/ bars/ triangle/form
CRANE: lift/device/weight
ANCHORAGE: support/concrete/terminal/block/cables/suspension bridge

**IV. Name each of the following bridges and define its characteristics.**

**Figure 15.5.**

. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

**Figure 15.6.**

. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
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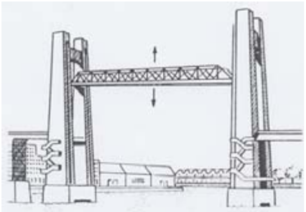


Figure 15.7.

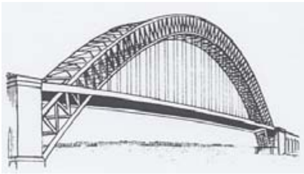


Figure 15.8.

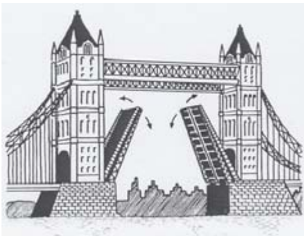


Figure 15.9.

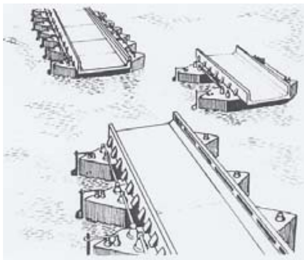


Figure 15.10.

## V. Mini - activity: Arm Cantilever

Cantilever: A projecting structure supported at only one end, such as a shelf bracket or diving board.

Figure 15.11.

1. Place a heavy book in a bag with straps.
   **Do you think you could support this weight with one arm?**
2. First place the bag straps over your arms near the shoulder (Fig. 15.11.), and then over the tips of your fingers (Fig. 15.12.).

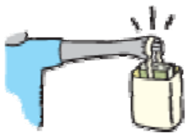


Figure 15.12.

**Is it equally easy to support the weight in both places?**

It is much easier to support the bag close to the shoulder, near the fixed base of the cantilever, than at the unsupported fingertip end. Cantilevers support loads by bending. A cantilever can support more weight closer to its fixed end. Examples of cantilevers in structures include balconies and awnings.

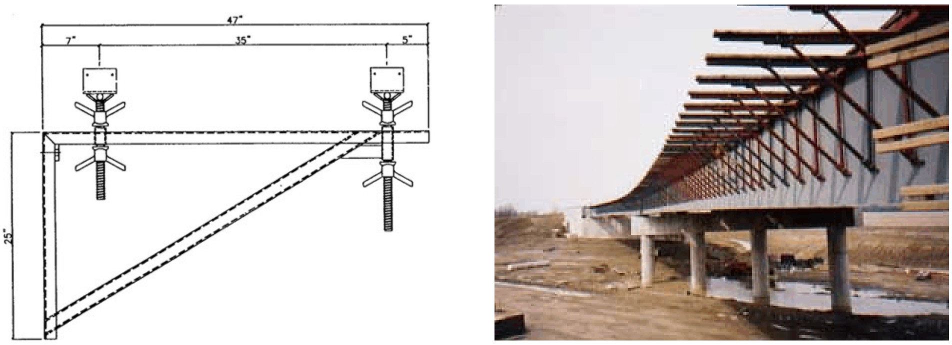


**Figure 15.13.** Bridge overhang bracket

**VI. Match the words on the left with the correct definition on the right:**

1. Span — a)___A frame, generally nowadays of steel to carry a roof or a bridge built up wholly from members in tension and compression
2. Pontoon bridge — b)___The distance between the supports of a bridge, truss, arch or a girder
3. Pier — c)___A temporary or permanent bridge which floats on the water
4. Truss — d)___A wide column or a short wall of masonry or reinforced concrete for carrying heavy loads
5. Suspender — e)___A timber, steel, reinforced or prestressed concrete post driven into the ground
6. Cable-stayed bridge — f)___An overhanging beam fixed at one end and free at the overhanging end
7. Cantilever — g)___Any bridge with straight cables from masts connected directly to deck girders without suspenders
8. Pile — h)___ A vertical hanger in a suspension bridge by which the road is carried on the cables

# 16. DESIGNING AN AIRPORT

The planning of an airport is such a complex process that the analysis of one activity without regard to its effect on other activities will not provide acceptable solutions (Fig. 16.3.). An airport is divided into two major components, the landside (Fig. 16.4.) and the air side.

**Figure 16.1.** Kansai International Airport

An airport development involves the construction of vast expanses of runways, taxiways, buildings, aprons, and other impermeable surfaces (Fig. 16.1.). The location of an airport will be influenced by the following factors:

1. Type of development of the surrounding area which is an extremely important factor from the standpoint of noise. Proximity to residential areas and schools should be avoided whenever possible.
2. Atmospheric conditions like the presence of the fog, haze and smoke that reduce visibility.

3. Accessibility to ground transport required by both passengers and other users of airport such as employees and truck freight.
4. Availability of land for expansion to accommodate new facilities.
5. Presence of other airports in the general area.
6. Surrounding obstructions.
7. Economy of construction.

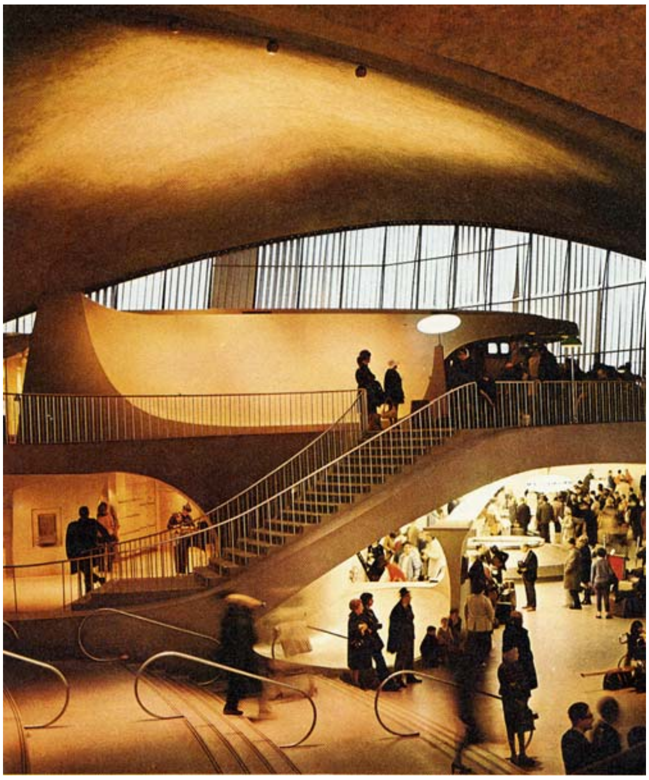


**Figure 16.2.** The J.F.Kennedy Airport, New York

The landing area includes the runways, the interconnecting taxiways, and the taxiways leading to the terminal area. Airport runways must be designed to carry the heavy load of big modern jumbo jets, as well as to withstand enormous blasts of heat from the engines. The impact factor is much greater with aeroplanes than with automobiles. The number of runways and their pattern depend on (l) the volume and character of traffic,
(2) wind direction, and (5) noise abatement. An adequate drainage system for the removal of surface water is vital for the safety of aircraft and for the

longevity of the runway pavement.

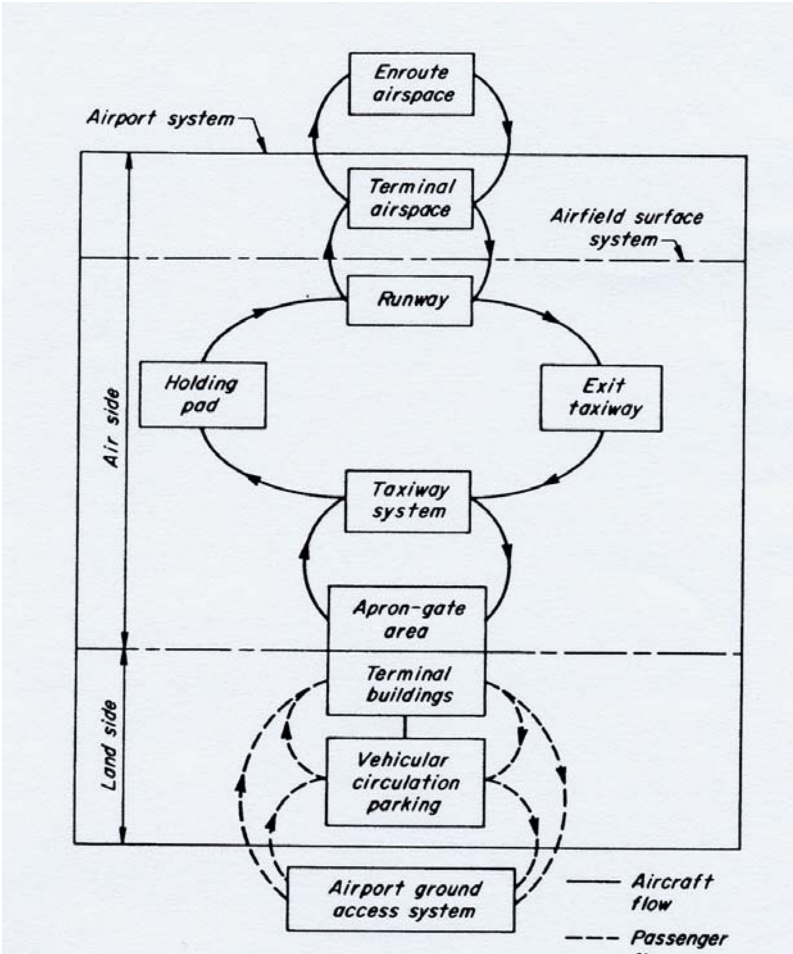



**Figure 16.3.** Components of the airport system for a large airport

The principal function of taxiways is to provide access from the runways to the terminal area and service hangars. Taxiways should be arranged so that aircraft which have just landed do not interfere with aircraft taxiing to the takeoff point. The aircraft is unloaded, loaded, and serviced on the terminal apron, which is usually in the proximity to the passenger air aide gates. The apron serves two functions: it is an area for parking airplanes and for performing servicing and minor maintenance work.

The terminal building (Fig. 16.2. and Fig. 16.4.) covers as well airline operations, facilities for the convenience of passengers, offices for airport management, aeronautical functions of the government, and functions of the government (post office department, passport and customs control).

## LANGUAGE PRACTICE

**I. Comprehension questions**:

1. List the factors influencing the location of an airport.
2. What does the size of an airport depend on?
3. Describe the main elements of an airport: the landing area, the terminal area and the terminal air traffic control.
4. What is the principal function of taxiways and how are they arranged?
5. What services does the terminal building provide?

## WORD CHECK

**II. Translate:**

slijetanje, polijetanje, površinske vode, objekti na aerodromu, odvodnja, gustoća prometa, smanjivanje buke, prepreke u okolici, stajanka, udar, održavanje objekta

**III. Rewrite the text replacing the underlined words with their synonyms.**

1. Engineers are <u>called upon</u> to design and build a <u>suitable</u> infrastructure.
2. In addition to building <u>improved</u> runways, engineers <u>devise</u> effective systems for <u>maintaining</u> aircraft and for <u>handling</u> passengers and cargo.
3. An <u>on-going</u> construction is a <u>testament</u> to the growing volume of passengers and <u>freight</u> these days.
4. It <u>represents</u> the ever-present need for engineers to handle the increasing air travel.

**IV. Match the definition with the correct word:**

aerodrome, terminal, traffic control, impermeable

1. Not permitting passage through its substance =__________
2. A building where air passengers arrive and depart =________
3. A defined area on land or water used for takeoff or landing of aircraft =_________
4. Procedure governing the air traffic in the air space =_________

## V. Match the words on the left with their definitions on the right:

| | | |
|---|---|---|
| 1. | RUNWAY | ___ a very large area of water, sky, land etc. |
| 2. | TAXIWAY | ___a large building in which aircraft are kept or repaired |
| 3. | TAXI | ___parking area for planes |
| 4. | APRON | ___path used by taxiing aircraft |
| 5. | HANGAR | ___a paved strip on which aircraft land or take off at an airport |
| 6. | EXPANSE | ___move aircraft on ground |

**Figure 16.4.** Kansai Terminal Building

## VI. Find a sentence in the text that means the same as:

1. An airport encompasses a wide range of activities which have different and often conflicting requirements.
2. The aircraft gates at the terminal buildings form the division between the two components.
3. Improper drainage results in the formation of puddles on the pavement surface which can be hazardous to aircraft taking off and landing.

4. The principal services to be supplied on the apron are: electrical supply and aircraft fuelling facilities.

## 17. RAIL TRANSPORT

Wooden rail tracks may have been used as early as the $12^{th}$ century in German mines. In 1803 Richard Trevithick put the steam car on iron rails. There was much less friction between iron wheels and rails than between wheels and the ground. Running on rails, steam-driven vehicles had sufficient traction power to pull long lines of heavily loaded wagons. Not only people but also enormous quantities of goods and raw materials could now be transported rapidly and cheaply, making the railroad the keystone of the entire economic infrastructure.

**Figure 17.1.** The first railway to carry passengers in South Wales, Great Britain, 1807

The introduction of iron and Portland cement as building materials changed civil engineering design. Before this, the only available materials had been stone, brick and timber. Now engineers like G. Stephenson "the father of the first steam locomotive" (1825) and I. K. Brunel had much more scope for design as they planned the railways that were to run the length and breadth of Britain and other countries.

As steam locomotives did not operate efficiently at a grade of more than 2 percent this fact resulted in a great deal of bridge and tunnel construction in order to keep the lines from rising at too steep an angle. As automobiles came into increasingly wider use in the twentieth century the emphasis shifted to highway construction. Today, however, there is a renewed interest in railroads. The Japanese high-speed "bullet" trains (Figure 17.5.) run at up to 210 km/h. The construction of railway lines is undertaken only after an extensive survey of the route. Every phase of the project must be studied in minute detail. The curves also had to have a longer radius than is necessary for an automobile road. Railroad curves are always banked, with the outer rail raised above the inner one. This is known as superelevation, and it is also a principle in road design. In the last few decades, 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.

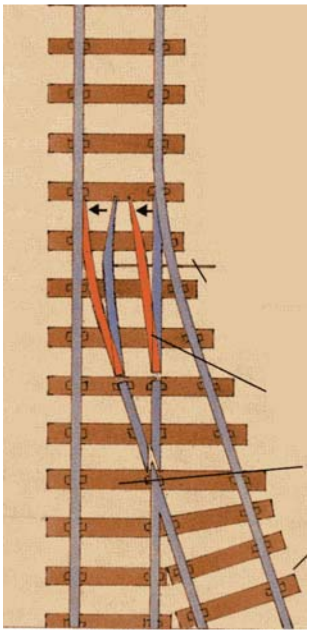


**Figure 17.2.** A track

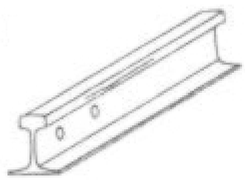


**Figure 17.3.** A rail

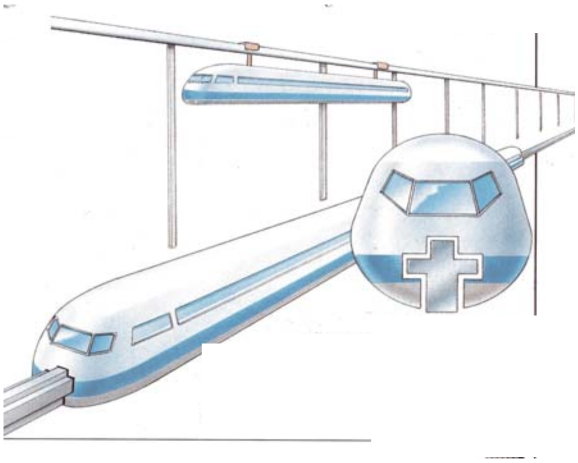


**Figure 17.4.** A monorail

Prestressed concrete sleepers that have been designed to replace the conventional wooden ones are being tested, and welded rails replace jointed rails. All these developments permit higher speeds and a smoother ride.

Experiments are being carried out with monorails. Monorails run on one rail (Figure 17.4.). The rail is set on a track. Some monorails straddle the track, others hang beneath it.

**Figure 17.5.** Shinkansen - “bullet train”

The automobile has proved to have many 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.

## LANGUAGE PRACTICE

### I. Comprehension questions:

1. What must be done before construction of a railroad line can begin?
2. At what grade did steam locomotives stop operating efficiently? What did this result in?
3. What special considerations were necessary in designing curves on railroad lines?
4. What technological advances have taken place in railroad construction

in the last few decades? What do these permit?

## WORD CHECK

**II. Translate the key words**:
tračnica, nagib, kolosijek, zavoj, trenje, krivina, vuča, snimanje terena, nadvišenje, mehanika tla, temelj, željeznički prag

**III. Say whether these statements are true (T) or false (F), and if they are false correct them**.

1. The first railroad featured steam-powered locomotives.
2. The first locomotives pulled cars along iron rails.
3. Iron rails minimized resistance between the wheels and the road surface.
4. Railroad curves are never banked.
5. Elevated highways should solve traffic problems in cities.

**IV. Translate the following text:**
*Prvu električnu željeznicu velikih brzina Japanci su uveli 1964. godine. Ti putnički vlakovi, zvani "metak", dosezali su brzinu od 210 kilometara na sat, što je u to vrijeme bio svjetski rekord. Ali najviše novaca željezničke kompanije zarađuju prometom dobara i tereta.*
*Teretne vlakove često pokreću lokomotive na dizelsko gorivo odterećujući na taj način promet na cestama.*
*Najduži teretni vlak na svijetu u Južnoj Africi ima 660 vagona, a dugačak je više od 7 kilometara!*

**V. Insert suitable words:**
The steam railway _______ combined medieval technology (wheels on metal ____) with the new ____ of steam. First public steam railway ____ in 1825 in England. The first steam trains ______ a top speed of 20 - 40 km/h. _________high-speed electric trains _____ at 200 km/h.

**VI. Summarize the text using these headings.**

1. Advantages of railway transport
2. Technological advances in railroad building

3. Renewed interest in railroads
4. Some principles in railway building
5. Make a list of all the materials used for building tracks throughout the centuries

## 18. STRUCTURAL ACTIONS

Civil engineering is concerned with the designing and building of stable structures. In normal circumstances the structures should stay intact. If the whole structure sways in the wind it must not do so to an extent that causes discomfort or alarm. The active loads should be balanced throughout the structure by the resistance opposed to them. The loads passed on by the structure as a whole to the foundations are similarly balanced by the opposed resistance. In all structural elements and their interconnections there must be adequate margins of **strength** and **stiffness**.

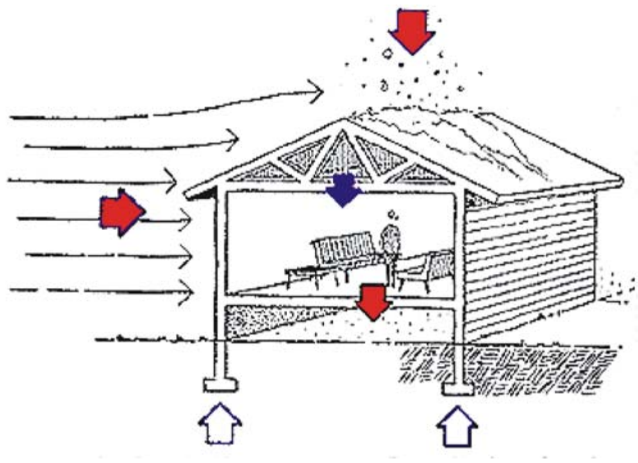


**Figure 18.1.** Types of loads

### Loads and their effects

There are several types of loads (Fig. 18.1.). Always present is gravitational self-weight. This is unchanging, and is known as the **dead load** which is the weight of the structure itself. It depends on the materials of which it is made. An engineer 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. Imposed or **live loads** are imposed either by its users or its environment. An **environmental load** is imposed by external forces, such as wind, water or earthquakes. Changes in temperature or humidity and even the setting of cement can also produce loads.

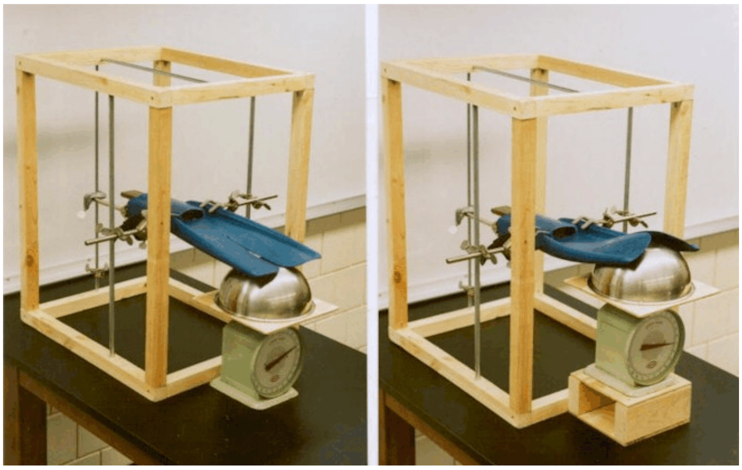


**Figure 18.2 .** Testing of stiffness

All types of loads tend to produce movement in the direction in which they act. The structure - or any part of it including the earth on which it stands - resists simply by being there as an obstacle in the path of the movement. No structural element is completely rigid. Each gives way to some extent and it is through this limited giving-way or deforming that the resistance is developed.

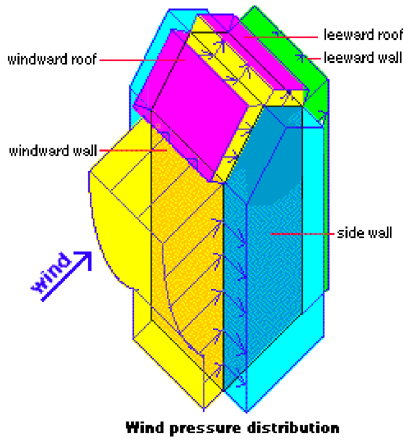



**Figure 18.3.** Wind load

The term **stiffness** denotes the resistance that is developed by a given deformation (Figure 18.2.) and the term **strength** denotes the maximum resistance that can be developed**.** Static loads that remain constant or change only slowly are the most important ones for most structures. Dynamic and periodic loads are usually of sporadic and infrequent occurrence. The commonest dynamic load is that of the wind (Fig. 18.3.). Much less common are the dynamic loads due to slight earth shakings which are usually considered to act horizontally. They are inertial loads acting on all parts of a structure above the ground as a result of very rapid displacement of its foundations.

**LANGUAGE PRACTICE**

**I. Comprehension questions:**

1. What actions on the materials that are used must an engineer understand?
2. Why might a material fracture? What force causes this kind of fracture?
3. What are the loads that can act on (or within) a structure?
4. How must these factors work in relation to each other?
5. *"Statics is a question of balance."* Explain the statement.

**WORD CHECK**

**II. Find equivalents in the text for:**

opterećenje, krutost, čvrstoća, pomak, pojava, otpornost, pojačanje, mrtvi teret (opterećenje vlastitom težinom), korisni teret, nametnuti

**III. Find in the text a word with a similar meaning for:**

inflexibility______, rigid______, undamaged_______, yield________, constant ________, vibrate_______, inconvenience _______, opposition ________, unstable_______,contain________, dislocation_________, moisture ________, contrary ________, influence (v) ________, solidifying _____ _______.

**IV. Choose a suitable word and insert it in the gap: create, affect, dead, compression, attached, loads, act**!

The forces and actions _____________ structures. When a material is in __________ it tends to be shorter. Forces that ____ on structures are called ____________. Anything permanently ____ to the structure is called ____ load. Loads ____ vibrations that can become dangerous over a period of time.

**V. Write some sentences including these key words:**
INTACT, DISCOMFORT, DISPLACEMENT, INFREQUENT, GIVE WAY, EXTERNAL, COMMON

**VI. Word formation**

| VERB | NOUN | ADJECTIVE |
|---|---|---|
| work | | |
| restrict | | |
| introduce | | |
| fail | | |
| consider | | |
| exploit | | |
| extend | | |

**VII. Translate:**

*Tko je zapravo građevinski inženjer? Definicija u rječniku opisuje ga kao inženjera čije obrazovanje ili zanimanje jest projektiranje i građenje, osobito u javnim radovima, s ciljem da unaprijedi ljudski život.*
*Građevinu možemo opisati kao znanost koja mudro koristi ograničene izvore prirode za dobrobit čovječanstva, štiteći istovremeno okoliš.*
*Ipak, građevina je mnogo više od toga. Građevinar stvara ikone, a ljudi iz cijelog svijeta dolaze ih vidjeti. Stoljećima su se ljudi obraćali građevinskim inženjerima da riješe probleme s kojima se društvo suočava.*
*Ako su građevine dobro izgrađene, izazvat će divljenje, stoga*

*građevinski inženjer mora biti oprezan u radu. Ako pogriješi, prouzrokovat će nered i smrt.*

## 19. INTERNAL ACTIONS

Engineers design buildings so that the forces on the walls and foundations are in equilibrium, otherwise the buildings would collapse. When dealing with static loading let us consider the possible types of action on individual structural elements.

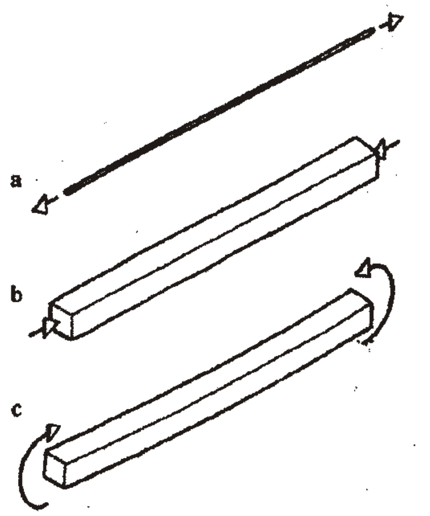



**Figure 19.1.** Examples of tension (a), compression (b) and bending (c)

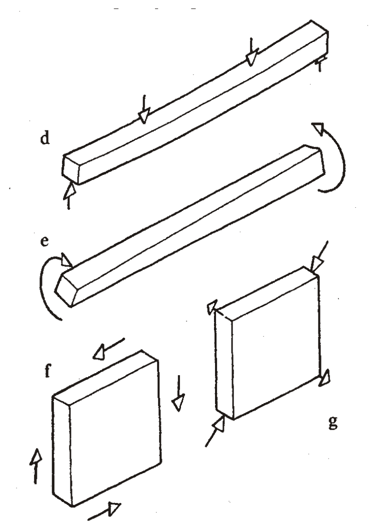



**Figure 19.2.** Examples of pure bending (d), torsion (e) and shear (f)

There is the distinction between **tension, compression, bending, torsion** and **shear** (Fig. 19.1. and 19.2.) . In compression the material is pressed or pushed together; in tension the material is pulled apart or stretched, like a rubber band. The simplest kind of **bending** (Fig. 19.1.c) is the action which results from applying equal and opposite couples in its own plane to an element. In other words, it is the making of a curve in a straight material under loading. It is also the principal action resulting from applying transverse forces to such an element at some distance from its supports. **Torsion** (Fig. 19.2.e) is the twisting action which results from applying equal and opposite couples to the ends of a similar element in planes at right angles to its axis. **Shear** (Fig. 19.2.f and 19.2.g) is an action tending to cause slipping of one part of the element on another.

**Stress** is load divided by area, a measure of how hard the material has to work. When a stress is applied to a body a corresponding **strain** is produced and the ratio of stress to strain is a characteristic constant of the body. In other words, strain is the linear distortion in response to stress.

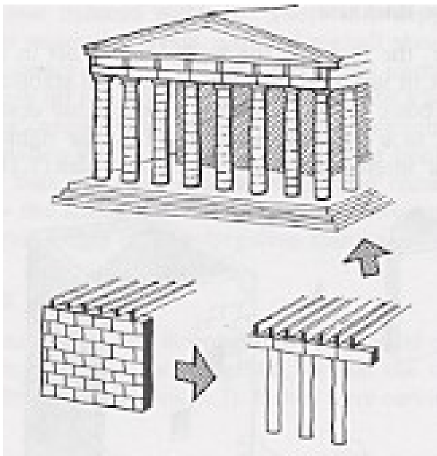


**Figure 19.3.** The Parthenon, Greece

The great buildings of the past 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 than necessary in most cases.The Romans made extensive use of the **arch** (Fig. 19.4.) to distribute load more evenly, thus making larger openings possible. Architects and engineers before the Romans had used a **post-and-beam** construction (Fig. 19.3.) for the most part, with two vertical columns supporting a horizontal beam.

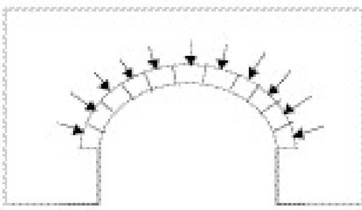


**Figure 19.4.** Roman arch

Today, an engineer has the advantage not only of empirical information, but also of scientific data. When an engineer plans a structure, he takes into account the total weight of all its component materials. Every structure uses the properties of its material to overcome and exploit the forces that it is subjected to.

**WORD CHECK**

**I. Translate:**
podužna deformacija, luk, stup i greda, ploha (ravnina), naprezanje, savijanje, torzija, uvijanje, posmik, osovina (os),par sila (spreg), tlačno naprezanje, vlačno naprezanje, ravnoteža

**II. Find a similar example of trial and error on the first page of UNIT 1.**

**III. Complete the sentences and name the forces:**

1. pulling-apart ____________________
2. the force on a member divided by the area, which carries the force____________________
3. pushing-together ____________________
4. the tendency to fracture or break along the lines of the stress ____________________
5. a change in length caused by a force applied to a piece ____________________
6. the twisting effect of a force____________________
7. a curved structure above a door or a window ____________________
8. a balance between different forces, so that none is stronger than the other ____________________

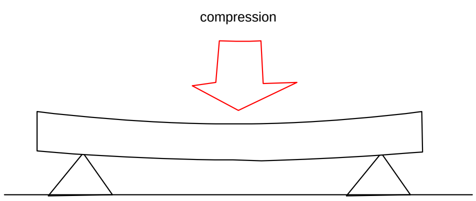



**Figure 19.5.** Bending of a beam under lateral force

**IV. Translate the following passage:**
*Vlak rasteže, a tlak, koji je njegova suprotnost, skuplja materijal.*

*Posmik je rezajuća ili posmična sila, a torzija je sila zaokretanja. Različite čvrstoće materijala, kao što su otpornost na vlak i otpornost na tlak mjere se otpornošću na te četiri sile. Kamen ima znatnu otpornost na tlak, ali ne i otpornost na vlak, a vinova loza i užad imaju otpornost na vlak, ali ne i otpornost na tlak. Razne vrste drveta ujedinjuju otpornost na vlak i otpornost na tlak u različitim omjerima. Deblo čvrstog hrastova drveta gotovo je jednako otporno na vlak kao i kamen, ali ima znatno veću čvrstoću na tlak. Ipak, kao i svi prirodni materijali, ono je, kako bi to inženjer nazvao, slabo u posmiku - može puknuti na pola.*

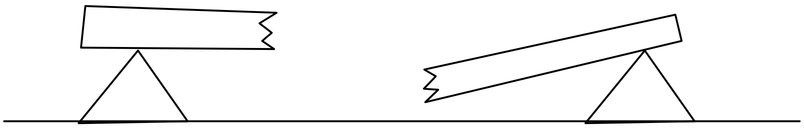


**Figure 19.6**. Failure due to overloading of a beam

*Isto tako mogu puknuti vinova loza i uže, no oni su znatno otporniji na torziju (rotirajuću silu) nego drvo i kamen. Željezo i čelik kvalitetniji su od prirodnih materijala zbog četverovrsne otpornosti, a armirani beton ujedinjuje visoku vlačnu silu s tlačnom silom betona.*

## VI. Describe the action of forces in Figures 19.7. and 19.8. below.

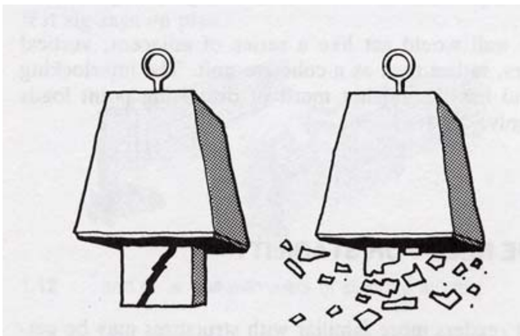


**Figure 19.7.**

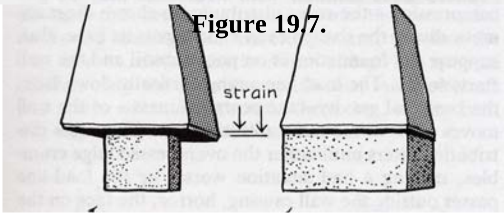



**Figure 19.8.**

## 20. DOMES

A dome is a curved roof or vault (Fig. 21.1.). It seems to have developed as roofing for circular mud-brick huts in Mesopotamia about 6,000 years ago. In Europe such constructions were built by Mycenaean Greeks in the 14th century BC who buried their dead in tombs, stone chambers that consisted of blocks arranged in superimposed concentric circles (Fig. 20.1.).

**Figure 20.1.** Mycenae, Tomb of Agamemnon, Greece

**Figure 20.2.** The Pantheon, Rome

The Romans were first to develop the masonry dome in its purest form and on a massive scale. Their skills culminated in the Pantheon, a temple built by the Emperor Hadrian in the 2nd century AD (Fig. 20.2.). The monolithic dome of the rotunda behind the portico is 43.2 m in diameter. To let the light in the engineers created a round opening at the top, called the oculus 8.5 m in diameter.

As the masonry dome of the Pantheon was very heavy the engineers hollowed out special shapes, called coffers, along the walls to reduce the weight of the enormous structure. The size and longevity of the dome prove that the Romans mastered the chemical processing and manufacturing technology of concrete to a very high extent. In the early Middle Ages Byzantine engineers proved to be most inventive in their construction of domes. In the Byzantine capital of Constantinople, a succession of large domed churches reached its height in Hagia Sophia, in the $6^{th}$ century (Fig. 20.3.).

**Figure 20.3.** Hagia Sophia, Istanbul

It has a shallow dome, ringed with windows at its base and supported on four pendentives. The pendentives are portions of hemispherical vaults, or curved triangles, placed in the corners of a square to form a circular base for the dome above. These spherical triangles are backed by immense exterior piers and by a series of semi-domes.

After the construction of Hagia Sophia a great number of Islamic domed buildings started. The Dome of the Rock (691) in Jerusalem is one of the earliest examples (Fig.20.4.). It has a double dome of a timber construction set on a pillared arcade.

A new epoch in the construction of domes was initiated by F. Brunelleschi ($15^{th}$ century) with his octagonal dome of the Florence

Cathedral (Fig. 20.5.). The immense structure, 39 m in diameter and 91 m high consists of an outer roof shielding an inner masonry shell. The 8 primary ribs and 16 secondary ribs form a tightly interlocked masonry cage.

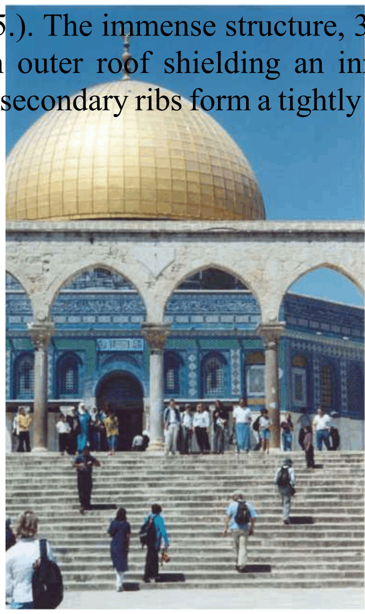


**Figure 20.4.** The Dome of the Rock, Jerusalem

St. Peter's Basilica in Rome represented a step forward in engineering skillfulness (Fig. 20.6.). Its multiribbed dome became the prototype for domes throughout the world.

**Figure 20.5.** The cathedral, Florence

When it began cracking in the early 18th century, Vatican engineers tied several iron rings, called tension rings, around the structure to prevent it from collapsing.

**Figure 20.6.** St. Peter's Basilica, Rome

The technological developments of the 20th century have significantly changed the concept and construction of the dome. The geodesic dome was patented by the American inventor Buckminster Fuller in 1947 (Fig.20.7.). It is composed of a lattice of interlocking tetrahedrons and octahedrons made of lightweight materials.

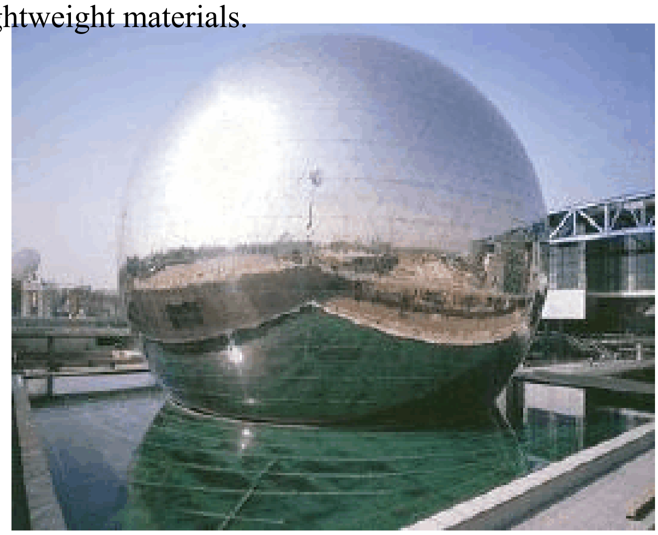


**Figure 20.7.** Geodesic dome by B. Fuller

The interior is left free of structural support which makes it an ideal structure for holding large groups of people (Fig. 20.8.).

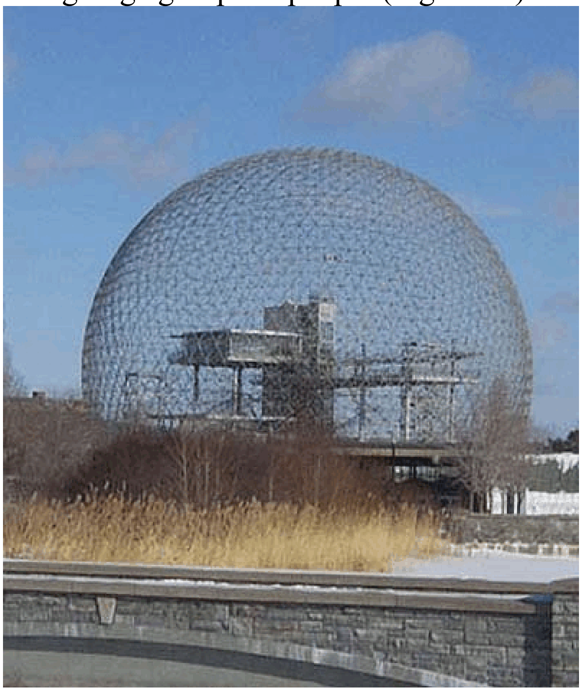


**Figure 20.8.** Biosphère, Sainte-Hélene, Montreal

The geodesical domes have found many uses as botanical gardens and sports-arenas. The materials include steel, fibreglass, plastic or reinforced concrete.

## LANGUAGE PRACTICE

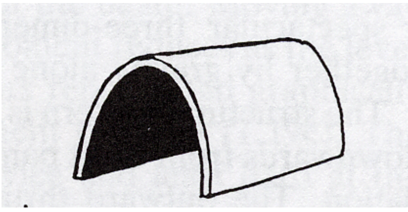
### I.a) Match the words with their definitions:

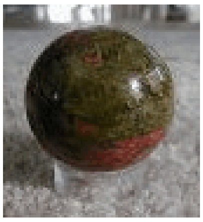
1. RECTANGLE, 2. SQUARE, 3. CURVE, 4. ARCH, 5. RIB

a)__a line that bends smoothly and regularly from being straight or flat,
like part of a circle or sphere
b)__a ridge or moulding on the underside of a vault or arched ceiling
c)__shape with four sides and four right angles
d)__the shape resembling an inverted U
e)__a geometric figure with four right angles and four equal sides

**b) With reference to the text give opposites of:**
monolithic, assemble, interlocking, curved, superimpose, crack, hollow out, culminate

**II. Label the drawings with the following words:**
SPHERE, VAULT, ANGLE, COLUMN, RECTANGULAR, INCLINED and CURVED:


A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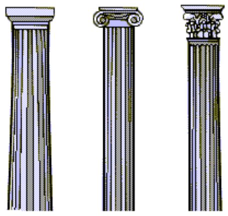
C


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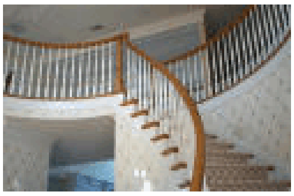
E


F


G

**III. Summarize the text using the key words below:**
curved, structures, masonry dome, tension rings, double dome design, iron rib, geodesic dome

**IV. Fill in the table in the chronological order of the development of domes:**

| **PLACE** | **STRUCTURE** (innovation) | **MATERIAL** | **FAMOUS BUILDING** |
|---|---|---|---|
| Mesopotamia | | | |
| | monolithic dome | | Pantheon |
| | pendentives | | |
| Florence | | | |

| | | | |
|---|---|---|---|
| | | | St. Peter's Basilica |
| | partial sphere | | |

**WORD CHECK**

**V. Translate the following key words of the text:**
vlačni prsten, kugla, svod, pandantiv, rebrasta kupola, potisak

**VI. Write down the superlatives of the following adjectives:**
heavy, light, different, tight, lightweight

**VII. Read this summary about development of a dome, and fill in the missing words. These need not be the actual words used in the text, but any which are suitable English.**
The __________ used domes but, moving ___________to the 6th century, the great Santa Sophia in Istanbul _________ the compression dome near _________ practical limits. Domes, like arches ______ to spread at their _______. Much latter, engineers like Wren at St Paul's, London, ________ restraining chains _________ dome bases to ________ the need for side buttressing. At Santa Sophia, the Byzantines _________ auxiliary half domes and massive side arches to ________ the main dome _______ the nave. The ________ was a column-free enclosure 69 m x 33 m and 55 m high, as large as anything ________ the steel-framed industrial _________ and railway _______ of the late 18th century.

## 21. WHAT HOLDS A DOME TOGETHER?

The fundamental construction system that underlies the dome structure is the arch and vault system (Fig. 21.1.). A dome is a hemispherical vault resting on a circular base wall. Until the 19th century arch and vault were the only alternative to the simpler post-and-beam system. A vault is an arch-shaped structure, usually of masonry, used as the ceiling of any enclosed space, such as the roof of a building.

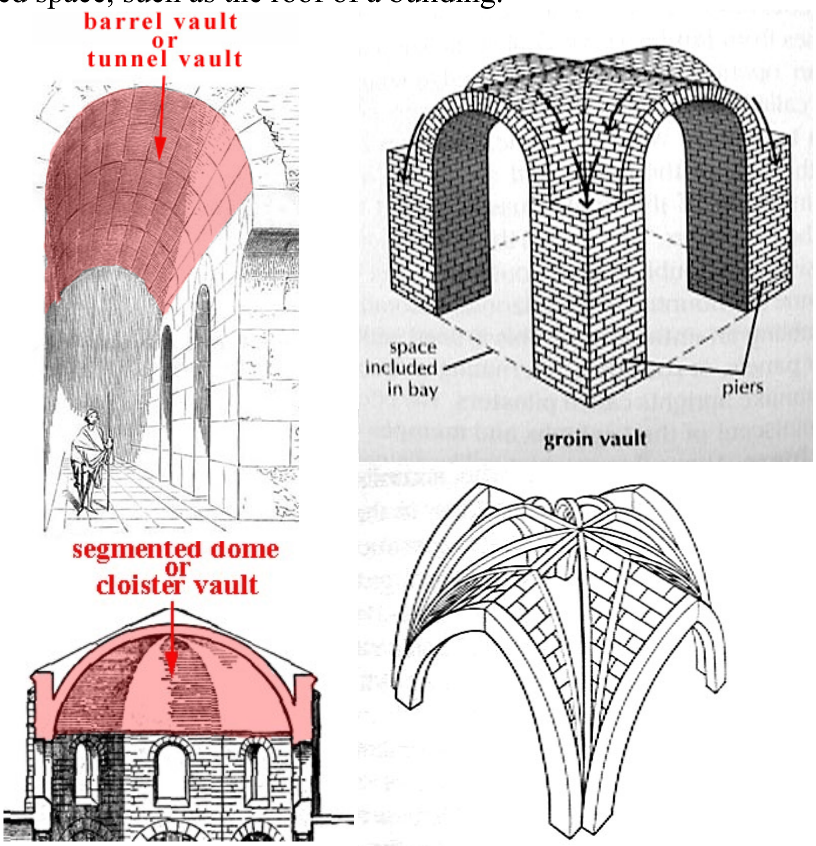



**Figure 21.1.** Different vault shapes

The Romans used the semicircular arch in structures such as amphitheatres and aqueducts, but their temples usually had the rectangular post-and-beam construction of Greek temples. The few vaulted exceptions include the Pantheon in Rome. Let us see what are the forces that act on the three principal shapes of the domes!

**Monolithic Domes: Forces**

At the top of a dome, the curving walls push inward toward the centre. This force holds the dome in a rigid, stable shape (Fig. 21.2.). The vaults usually include ribs, which means that the inner vault surface is subdivided by a number of independent supporting arches.

**Figure 21.2.** Monolithic Dome

**Ringed Dome: Forces**

Because of the combined pressure of heavy components, such a structure exerts an outward pressure at its base, and the base must be so constructed as to withstand the outward as well as the downward thrust of the arch (Fig 21.3). Therefore cracks can appear throughout the bottom portion of the structure. Repair can be accomplished by using iron rings, called tension rings, around the base of the dome.

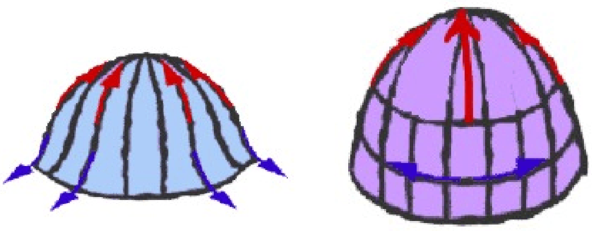


**Figure 21.3.** Ringed dome

**Geodesic Dome: Forces**

The basic form of a geodesic dome is a triangle, which is a very stable shape. The triangle is often used in buildings, bridges and domes because of its strong rigid shape.

The forces act equally in all directions (Fig.21.4). Compression at one joint is balanced by tension along the opposite side. Geodesic domes are lightweight enclosing the most amount of space with the least amount of material. Since they have less area to lose heat from, they are also very energy-efficient.

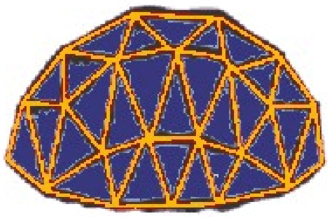


**Figure 21.4.** Geodesic dome

**Mini activity: Human Dome**

Dome: A curved roof enclosing a circular space; a three-dimensional arch

1. Stand in a circle around a soccer ball. Place your fingertips on the ball and lift it, leaning in toward the centre of the circle and sliding your feet back.(Fig. 21.5.) **Who represents the "ribs"?**

**Figure 21.5.**

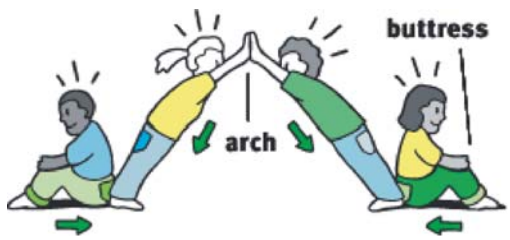



**Figure 21.6.**

2. Reach into the centre and push down gently on the ball. **Where could the dome use more support?** Adding seated students as buttresses at the base of each "rib" of the dome will help the dome support more compression (Fig.21.6.).
   Explanation: As in an arch, the buttresses exert an inward force on the sides of the dome that balances the outward force created by the load pressing down on the top of the arch.

**LANGUAGE PRACTICE**

**I. Comprehension questions:**

1. Name three basic types of domes.
2. What is the difference between an arch and a vault?

3. Give a definition of the forces mentioned in the text.
4. What is the difference between a rib and a buttress?
5. Explain the function of buttresses - what sort of force do they exert?

**II. Complete the sentences:**

1. The _________ provides the only source of light for the interior of the Pantheon.
2. The strongest shape to build with is _______.
3. ___________ are made of standardized interlocking shapes that can be quickly assembled and taken apart.
4. A series of arches inside a dome is called ________.
5. A masonry floor or roof in the form of an arch is called _______.
6. A hemispherical vault is a ______.
7. A structure of stone or brick built against a wall to support it is ______.
8. A building that represents the transition from a square to a circle; i.e. the raising of a circular dome over a square base is _____________.

**Figure 21.7.** The interior of Hagia Sophia, Istanbul

**III. Active or passive? Put the verbs in brackets into the correct tense, and indicate if it is active(A), infinitive (I) or passive (PA).**

(*Consider)* the finest example of Byzantine architecture in the world, the church of Hagia Sophia (Fig. 21.7.) (*construct*) on a scale unprecedented in human history. Under the rule of Justinian the Emperor, and with a force of 10,000 workers, the dome atop the church of Hagia Sophia *(build*) in record time: it (*take*) just five years

(*complete*).
In 559A.D. an earthquake *(tumble*) the dome of Hagia Sophia. It ( *rebuild*) to a smaller scale, and the whole church ( *reinforce)* from the outside. After the Turkish conquest of Constantinople, Hagia Sophia *(become*) a mosque, and the ornate interior mosaics (*obscure*) by layers of plaster and painted ornament. Today, all plaster (*remove*), Hagia Sophia *(be*) a museum of Byzantine Art.

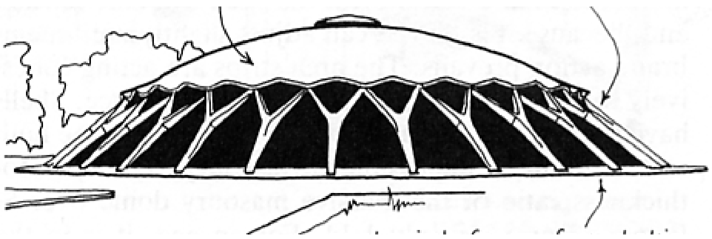


**Figure 21.8.** Palazzeto dello Sport, Rome Olympics 1960

## IV. Translate:

*Kontrafor (Sl. 21.8.) jest potporanj sa strane koji djeluje suprotno od vanjske gurajuće sile. Djeluje na isti način kao što potpornji za knjige djeluju da bi ih zadržali da ne kliznu na polici. Kontraforima se često podupiru strane lukova i zidovi visokih katedrala, gdje djeluju suprotno vanjskom potisku.*

## WORD CHECK

## V. Find English equivalents for the following terms:

kontrafora, zidarski radovi, rebrasta kupola, pandantiv, svod, potisak luka, kružni oblik, kruti oblik

## VI. Form the adjectives from the following nouns:

sphere, rectangle, angle, square, circle, pillar, vault, mason

## 22. THE FORCES ACTING ON BRIDGES

Bridges should be built so that they support their own weight and the weight of heavy traffic without collapsing. These downward forces must be balanced by upward forces. The objects are acted on by more than one force. The wind exerts a force when it blows: gravity is a force that pulls everything down towards the center of the Earth and gives objects their weight. Bridge builders use statics to calculate the loads that will be supported by the bridge. The forces tending to bend the bridge and make it collapse must never exceed the forces tending to keep the bridge straight.

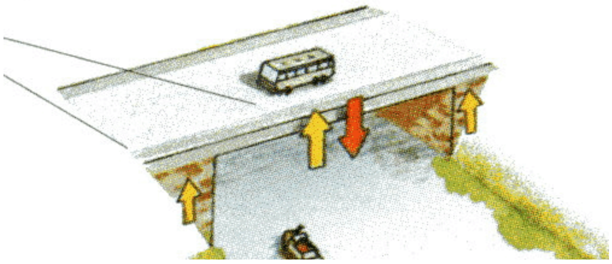


**Figure 22.1.** Beam bridge

**Beam bridge:** In a simple beam bridge the weight is supported through upward forces produced by the supports (Fig.22.1.)**.** The combination of the bridge's own weight (dead load) and traffic across it (live load) will tend to make it bend. The result will be tension along its top surface and compression along the bottom. In the beam, the compressive and tensile forces are balanced, while the overall mass of the bridge bears directly downwards on the ground beneath.

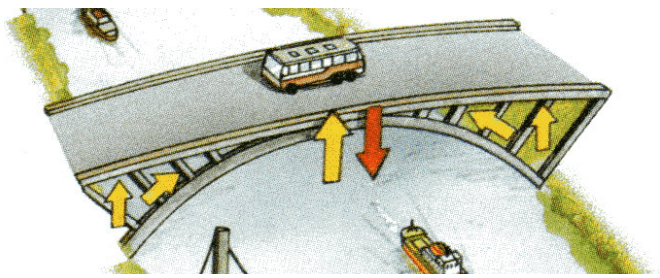


**Figure 22.2.** Arch bridge

**Arch bridge:** In an arch bridge, the curve of the bridge structure transfers the weight to the supports at each end (Fig. 22.2.). Dead and live load combine to force the material of the arch together in compression. Because the arch is in compression only, stone makes an ideal construction material, as it is not subjected to any tensile force.

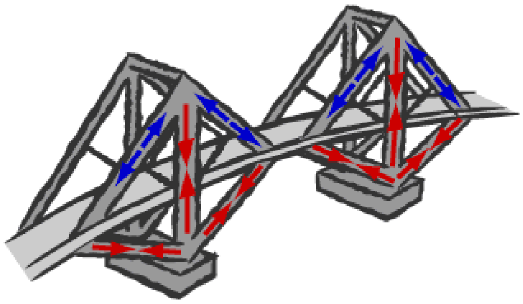


**Figure 22.3.** Truss bridge

**Truss bridge** consists of frames of diagonal bars to carry the bridge (Fig.22.3.). Frames are built up wholly from members in tension and compression. A structure made of beams connected together in triangles cannot be twisted or collapsed without deforming the beams.

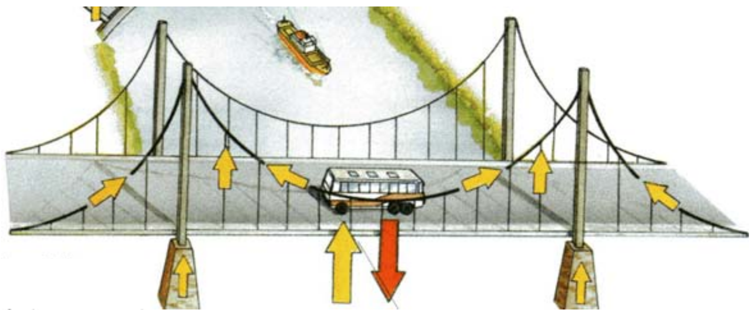


**Figure 22.4.** Suspension bridge

**Suspension Bridge:** In a suspension bridge the load is borne by flexible cables, which are in turn supported by towers at each end (Fig.22.4.). The towers pull some of the weight sideways as well as supporting it vertically. Weight pushing down is supported by upward forces. These towers are built to withstand extremely strong forces. Since this kind of bridge can tend to sway in strong winds, the road is often stiffened with a beam or a girder shaped like a hollow box.

## LANGUAGE CHECK

**I. Re-read the text and fill in the boxes according to the headings.**

| Type of a bridge | Material | Forces cause: |
|---|---|---|
| | | b............. |
| | | t..................... |
| | | c.................... |
| | | t....................... |

**II. Name the forces:**

A pushing, squeezing force is called __________.
A pulling force is called _______________.
A rotational, twisting force is called __________.
When a straight material gets curved, it is called ___________.

**III. Question formation: write an appropriate question to these answers:**

a. ____________________________________________?
The bridge spans a distance of 1900 metres.

b. ____________________________________________?
A pontoon bridge is supported by hollow drums that can float.

c. ____________________________________________?
A beam bridge consists of a rigid beam between two supports.

d. ____________________________________________?
A suspension bridge is supported by cables usually hung from towers.

e. ____________________________________________?
A structure in which a horizontal beam extends beyond its support is called a cantilever.

f. ____________________________________________?
Truss is a framework strengthened by diagonal beams that form triangles.

g. ____________________________________________?
A pile is a sunken support for building: a vertical wood, metal, or concrete support for a building or other structure that is driven into the ground.

**IV. Name each of the following bridges or its structural parts and describe its characteristics:**

1. ____________________________________________
____________________________________________
____________________________________________
____________________________________________

2. ____________________________________________
____________________________________________
____________________________________________
____________________________________________

3. ____________________________________________
____________________________________________
____________________________________________
____________________________________________

4. ____________________________________________
____________________________________________
____________________________________________
____________________________________________

**V. Here are some sentences using words from the previous units and the text about bridges. Decide on the most suitable words to put into the sentences.**

Bridges should be built so that they _____ their own weight and the ______ of heavy traffic without collapsing. These downward ______ must be balanced by upward forces. The objects are _____ on by more than one force. The wind ____ a force when it blows: gravity is a force that _____ everything down towards the center of the Earth and gives objects their _____. Bridge builders use ______ to calculate the loads that will be supported by the bridge. The forces tending to_____ the bridge and make it _____ must never exceed the forces tending to keep the bridge straight.

# 23. SKYSCRAPERS

**A**

The great Pyramid of Cheops completed in 2580BC is regarded as the first predecessor of high buildings. With more than two million blocks of limestone it was the world's tallest building for almost 4000 years until overtaken in the 14th century by Lincoln cathedral in England.

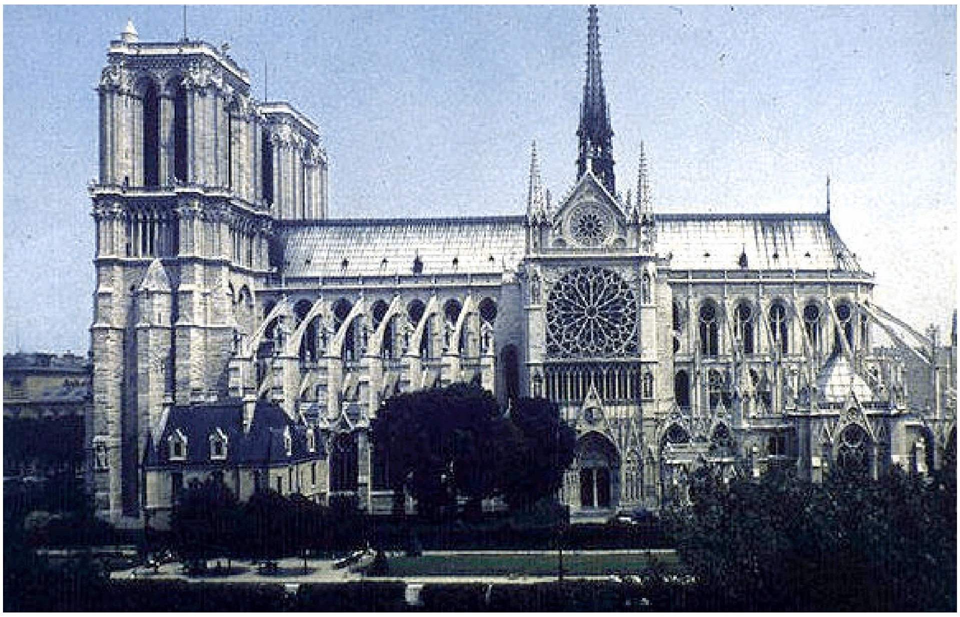


**Figure 23.1.** Notre Dame, Paris

The striving for heights emerged again in the Middle Ages with the building of great Gothic cathedrals in the $12^{th}$ century (Fig.23.1.). Many cathedrals have flying buttresses - structures that reach out from the outer walls and down to the ground (Fig.23.2.). They help the walls to support the huge weight of the roof.

**B**

The use of steel in building made possible the first skyscraper in 1884. The first steel framed building was the 10-storey Home Insurance Building in Chicago, built by William Jenney (Fig.23.3.). The steel is supported without needing extremely thick walls at ground level. The Otis safety lift developed in the 1850s, soon known as the elevator, made it possible to reach high floors easily. Otis's first model was powered by steam.

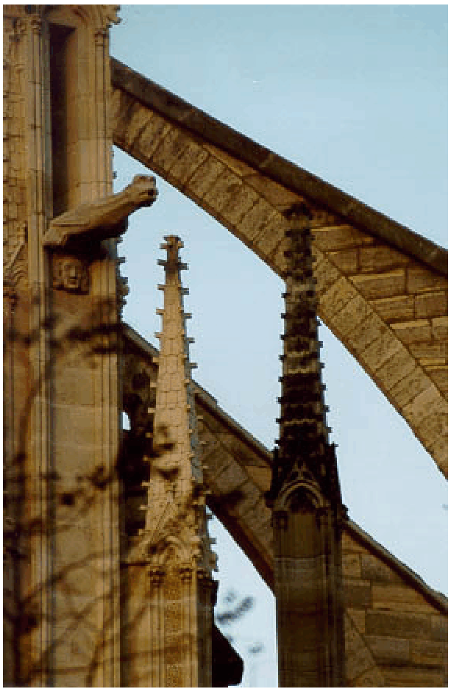


**Figure 23.2.** Flying buttress

**Figure 23.3.** Home Insurance Building, Chicago

**C**

Riveted steel constructions gradually gave way to welded steel structures. Once exterior walls were no longer necessary to support a structure, engineers were free to create open interiors. By the 1920s European engineers extended the floor slabs beyond the building' s vertical supports. Windows were hung from these cantilevered floors built mostly of glass.

**D**

In the 1960 steel framing took a giant leap forward with the braced framed- tube structure engineered by Fazlur Kahn for Chicago' s Hancock Center (Fig.23.4.).

**E** (See next page, exercise II.)

As a building__________ in height, it is proportionally _________ to intense wind pressure. To reduce the ______ of sway caused by wind, counterweights or dampers are _______ at the top of the building. There are also buildings with _______ pendulum counterweights at its apex.

**Figure 23.4.** Hancock Center, Chicago

**Figure 23.5.** Petronas Towers, Kuala Lumpur, Malaysia

**F**

The world's tallest buildings are the Taipei Skyscraper at 508 metres, the Petronas towers in Malaysia at 450 metres and the Sears Tower in Chicago, at 433 metres (Fig.23.5.). The tallest unsupported structure is the CN Tower, a TV tower in Toronto at 555 metres.

## LANGUAGE CHECK

**I. Comprehension:**

1. What made the building of a skyscraper possible?
2. Which was the first steel-framed building?
3. What did the first skyscraper design eliminate?
4. Which was the first skyscraper with over 100 floors?

**II. Here are the words missing from the previous text (E). Read the text again and fill in the gaps with the most suitable word:**
DEGREE, INCREASES, EXPOSED, HIDDEN, SUBJECTED

**III. Skim for the KEY WORDS and PHRASAL VERBS and underline them.**
**E.g: riveted Phrasal verb: give way**

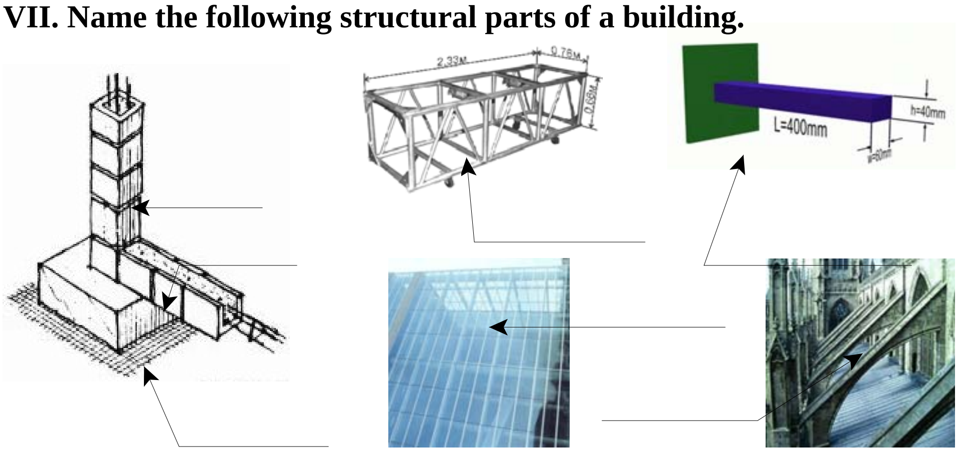
**IV. a) Make a question with each interrogative word on the left and one of the verb forms on the right. Add other words to complete the question referring to the texts A to F.**
**b) Ask other students to answer your questions.**

| | | |
|---|---|---|
| 1. | When...........? | Build |
| 2. | What..........? | Be |
| 3. | When.........? | Start |
| 4. | Which........? | Be |
| 5. | What.........? | Enable |
| 6. | How many...? | Must |
| 7. | Which........? | Be |

**V. Summarize the paragraphs A to F into one text, using the phrases listed below at the beginning of each sentence:**
AFTER THIS, IN THE PAST, SUBSEQUENTLY, AT THIS STAGE, FINALLY, EVENTUALLY, IN THE MIDDLE
E.g. The tallest buildings **in the past** were church towers. **In the middle** of the 19th century...........

**VI. Give headings to passages: A, B, C, D, E and F.**

**VII. Name the following structural parts of a building.**




**VIII. Translate:**
kontrafor, zavarivanje, ploča, čelični okvir, razupora, skeletna konstrukcija, lebdeći upornjak, noseći zid, protuuteg, prigušivač, klatno, konzolni strop

## 24. HOW TO RESIST WIND

The Eiffel Tower was built as the triumphal gateway to the famous Paris Exhibition of 1889. Engineers reveled in it as a prestigious showcase of France's industrial innovations. Before the tower Gustave Eiffel had built great stations and bridges, and devised the structure for the Statue of Liberty in New York harbor.

**Figure 24.1.** Eiffel Tower

The 300 m Eiffel Tower was twice the height of any previous structure (Fig.24.1.). It is a web of intersecting three-dimensional iron girders giving maximum strength for minimum weight. These pieces form an open lattice through which the wind can blow (Fig. 24.2.). The graceful form of the tower was constructed to cope with the wind rather than gravity.

**Figure 24.2.** Truss structure of the Eiffel Tower

Gustave Eiffel tackled his engineering challenge with a combination of mathematics, precision and patience. Everything was thought out and foreseen. Because of the tower' s odd angles and curves, each of its 12, 000 wrought iron pieces was designed independently to reflect variable inclinations and to bear different loads. Each piece was riveted and the rivet holes had to match exactly when placed on top of one another. To save time Eiffel had the sections prefabricated off-site.

Visitors reached the top of the tower by elevators that ran on inclined tracks. Those tracks were initially used in the construction for the climbing cranes, another example of the economy of Eiffel's working method. For the first time abstract engineering forms were the goal of a tower builder. Before then the function of towers was dictated by religion or military concerns.

Gustave Eiffel defined the tower's function as its maximum load-bearing capacity. He was a structural engineer whose mastering of iron made him the most celebrated builder of bridges, notably the great viaduct at Garabit (Fig.24.3.), whose construction formed the basis of his ideas for the tower.

**Figure 24.3.** Garabit Viaduct, France

**How do engineers design skyscrapers to resist wind?**

Engineers design skyscrapers so that the forces on the walls and foundations are in equilibrium, otherwise the building would collapse (Fig.24.4.). By clustering steel columns and beams in the skyscraper's core (Fig.24.5.), engineers create a stiff backbone that can resist tremendous wind forces. The inner core is used as an elevator shaft, and the design allows lots of open space on each floor.

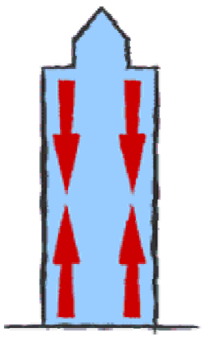


**Figure 24.4.** Forces

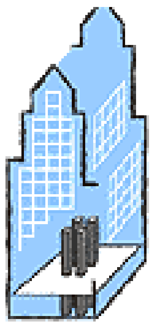


**Figure 24.5.** Stiff core

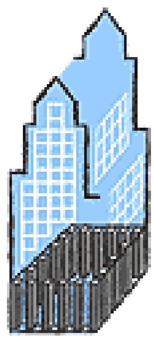


**Figure 24.6.** Hollow tube

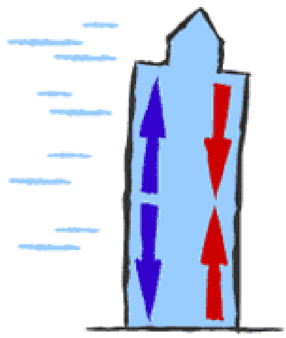


**Figure 24.7.** Forces

In newer skyscrapers, like the Sears Tower in Chicago, engineers moved the columns and beams from the core to the perimeter (Fig. 24.6.), creating a hollow, rigid tube as strong as the core design, but weighing much less.

When the wind blows, the columns on the windy side stretch apart (Fig.24.7.), and the columns on the other side squeeze together.

## LANGUAGE PRACTICE

**I. a) Here are some notes for a talk about the Eiffel Tower. They are in random order. Put the points in the order in which they might logically be spoken in a speech.**

A The elevator was the main attraction for the first visitors to the Eiffel Tower .

B The Eiffel Tower was built for the Paris World Exhibition.

C The French government ordered already well known engineer Gustave Eiffel to build the tower.

D It was made of tons of wrought iron.

E With the completion of the Tower Eiffel he earned the name "the magician of iron".

F All the parts of the tower were prefabricated to save time.

**b) Decide which sentences (A-F) are active and passive. Then convert them to the opposite voice.**

**II. Find words and expressions in the text that mean**:

a) off-site______________

b) foresee _________

c) become wider _____________

d) press firmly together ____________

e) criss-cross framework _______________

f) members joined by intersecting diagonal bars _____________

**III. Rewrite these sentences with an opposite meaning as indicated:**

**E.g:**

Critics called Eiffel's design an eyesore. However it turned out ______.

It turned out to be a great success!

1. Critics predicted that the tower would cost too much to build.
   It proved that ___________
2. Eiffel was one of the first engineers to recognize the importance of wind forces on tall structures.
   Since Eiffel built his tower ________________

3. Elevator ticket sales in the tower recovered the entire cost of the structure.
   It is curious that ________________________.
4. In the past towers were mainly built for religious purposes
   In the late 19th century towers ________________________________

**Figure 24.8.** A lattice: a criss-cross framework made by criss-crossing strips of wood, metal or plastic to form a pattern

**IV. Find these sentences in the text and write the definitions of the words in bold.**

1. The Eiffel Tower was built **to commemorate** the French revolution.
2. The Tower was constructed as an **open lattice** of light trusses.
3. Eiffel ‘s crew **assembled** thousands of pieces of iron.
4. The columns on the windy side **stretch apart**.
5. The inner core is used as an elevator **shaft.**
6. The construction is a **network of beams and bars**.
7. The iron bars are structured as **criss-crossing strips of metal**.

**V. Write a short description of two main designs in the construction of a skyscraper.**

**WORD CHECK**

**VI. Translate:**

rešetkasta konstrukcija, izumiti, nosač, projektirati, kosina, ravnoteža, montažni svežanj stupova, jezgra

**Figure 24.9.** Commerzbank, Frankfurt am Main

## VII. Translate:

*Dvadeseto stoljeće donijelo je veliki napredak u uporabi većine materijala u građevinskim projektima. Uvodi se ljuska od armiranog betona, primijenjena primjerice u aerodromu J. F. Kennedy. Primjenom čelika je trodimenzionalni sustav za jednaku raspodijeljenost opterećenja u svim smjerovima dosegao znatne raspone; oblikovan u kuglu postaje geodezijska kupola.*

*Da bi odolio teretu vjetra na velikim visinama, tradicionalni čelični skelet razvio je hibridne oblike poput čvrste jezgre, poprečnog zida i razupora na fasadi, pa zgrada zapravo djeluje kao vertikalna konzola.*

## 25. DAMS

Dams are world's biggest structures, transforming nature in order to generate electricity and provide irrigation.  Dams were built some 5000 years ago to control river waters. Methods of building dams were much improved in the 1800s by the use of steel-reinforced concrete, and by a more exact knowledge of the stresses and loads that such massive structures must withstand. Wherever possible, a dam is built at the mouth of a gorge or valley to force the waters of a river to pile up behind it to form a lake.

**Figure 25.1.** Kardeh arch dam, Iran

**Arch dams** are curved so that the weight of water is directed into the sides of the valley. They are usually built on rock, as yielding ground would cause the dam to fail. It may be built of stone, brick or concrete.

**Buttress dams** have a series of buttresses or triangular walls built to support the deck. They are usually made of reinforced concrete slabs spanning the spaces between the buttresses. Such dams are often built at sites with poor underlying soil conditions.

**Figure 25.2.** Daniel-Johnson Dam, Canada

**Embankment dams** are made of a mass of earth and rock with a thin concrete skin. Compared to an all-concrete dam the embankment dam is higher, more massive and cheaper, and it does not need to be braced against the sides of a river valley. In a typical embankment dam, a tunnel carries the water from behind the dam to turbines in the power house.

**Figure 25.3.** Peruča dam, Croatia

**Gravity dams** are the simplest of concrete dams. The weight of concrete holds back the water. They are usually built on bedrock, and if they are high they are very heavy and expensive. Therefore other types are preferred where possible.

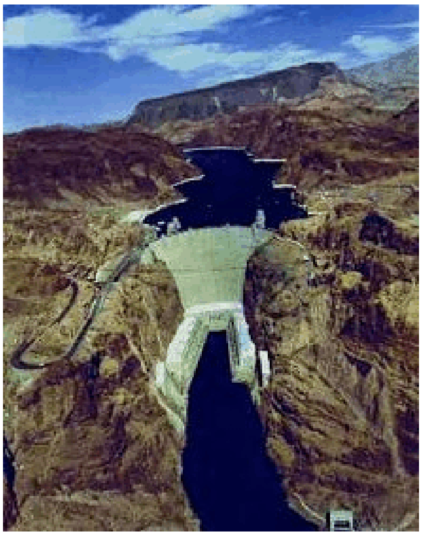


**Figure 25.4.** Hoover Dam, Colorado

Nowadays there are many huge dams under construction like the Three Gorges scheme on the Yangtze River in China. The dam will provide flood control, improved navigation and power generation, but on the other hand, the 600 kilometre long reservoir will flood some 1,300 archeological sites.

**Figure 25.5.** The Three Gorges Project: demolition efforts, China

It will cause a huge resettlement - more than a million people will be displaced from their homes. Such projects generate controversy because of their effects on the environment and on local people (Fig. 25.5). But dams are a cheap and effective source of electricity, and now provide about a fifth of the world's demand.

## LANGUAGE PRACTICE:

**I. Answer the questions with reference to the text.**

1. Which are usually the most massive dams?
2. Which  are the most expensive to build?
3. Which dams are usually the cheapest ones?
4. Which are the largest dams in the world?
5. Which dams do you know in Croatia?

## WORD CHECK

**II. Translate:**

obuzdati, nasuta brana, raščlanjena betonska brana, preljev, procjeđivanje, lučna brana, raseliti, nagomilati

**III. Re-read the text and underline all the superlative forms in the text; then make a list of the comparative form of each one.**

**IV. Fill in the boxes under each heading referring to the text.**

| TYPE | SHAPES | MATERIALS |
|---|---|---|
| | | |
| | | |
| | | |

**V. Underline the passive constructions and then rewrite the passage in active voice:**

When a site is being considered for construction of a dam, earthquake hazards must be taken into account as part of a thorough geologic analysis. In addition it must be determined whether the natural foundations are subject to seepage and whether they have the strength to support the weight of the dam and the water that will be backed behind.

**VI. Match each of the dams 1,2 or 3 with its corresponding adjectives**

**and illustration.**

1. embankment
2. arch
3. buttress

Adjectives: most common, solid look, curved.

A B C

**VII. Reread the text and complete the boxes as indicated:**

| ADJECTIVES | SYNONYMS | ANTONYMS |
|---|---|---|
| | | |
| | | |
| | | |

**VIII. Fill in each of the blanks in the following sentences with an appropriate word or a phrase from the text.**

Dams are world's ___________, transforming nature in order to _________ and provide _______. Dams were built some 5000 years ago to _________. Methods of building dams were much improved in the 1800s by the use of _________, and by a more exact knowledge of the _______ and _______ that such massive structures must withstand. Wherever possible, a dam is built ________________ or valley to force the waters of a river to pile up behind it to form a lake.

## 26. ASWAN HIGH DAM - A SUCCESS OR A FAILURE?

The Aswan Dam in Egypt built in 1970 is an example of humans' attempt to win the war against nature (Fig. 26.1.). It is a huge embankment ( rockfill) dam that captures the Nile in the world's third largest reservoir, Lake Nasser. The goals of the dam are to supply water, to generate energy, to prevent catastrophic floods, to provide perennial irrigation and year - round navigation on the Nile. Anglers are able to navigate on the Nile much easier since the wild river is more tamed than before.

**Figure 26.1.** Aswan High Dam, Egypt

The dam provides irrigation and electricity for the whole of Egypt. The resulting lake created by the dam (Fig. 26.2.), Lake Nasser provides area for recreation activities, like fishing and of course water for agriculture. Undoubtedly, the Nile is the life source for Egypt.

However, the Aswan High Dam has produced several negative side effects. The number of fish the Egyptian fishermen catch is ultimately reduced because the dam eliminates the annual flood. Furthermore, the loss in the catch compounds the problem of protein deficiency in the diet of the Egyptian people.

**Figure 26.2.** Aswan Dam, Lake Nasser, Egypt

Throughout time, the Egyptians have depended on the gifts of the Nile for their livelihood. Although farmers are now able to plant crops throughout the year, the fertile soil is entrapped behind the dam. This consequence forces farmers to use artificial fertilizers.

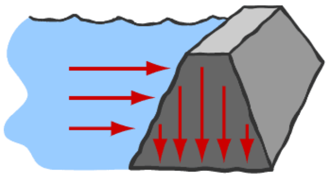
In the course of time several problems have become evident, such as water loss through evaporation and water seepage, silt deprivation, salinisation, and the erosion of the Nile Delta. Also, displaced residents of the construction site, the Egyptian Nubians, resent the loss of their homes as a result of the Egyptians' gain.

The building of the dam forced the relocation of whole towns. Ancient temples and monuments in the area are covered for most of the year. Most of Egypt's amazing past has been sacrificed for the dream of a better future.

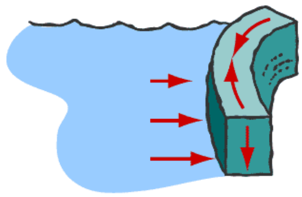
## LANGUAGE PRACTICE

### Revision of dam types

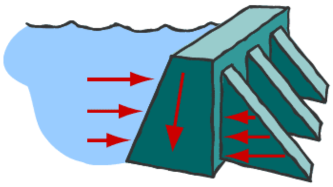
**I. Match the drawings of dams with the appropriate dam type (A, B, C or D).**



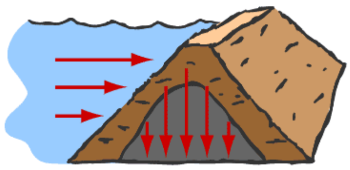
**A**



**B**



**C**



**D**

a) **Arch Dam = ___. Forces**
The arch squeezes together as the water pushes against it. The weight of the dam also pushes the structure down into the ground.

b) **Buttress Dam = ___. Forces**
Water pushes against the buttress dam, but the buttresses push back and prevent the dam from toppling over. The weight of the buttress dam also pushes down into the ground.

c) **Gravity Dam = ___. Forces**
Water pushes against the gravity dam, but the heavy weight of the dam pushes down into the ground and prevents the structure from falling over.

d) **Embankment Dam = ___. Forces**
Water pushes against the embankment dam, but the heavy weight of the dam pushes down into the ground and prevents the structure from falling over.

**II. Fill in the gaps using a suitable VERB from the text.**
The Aswan High Dam________ floodgate during rainy seasons and____________ the water during times of drought. The dam

also_______ enormous amounts of electric power - more than 10 billion kilowatt-hours every year. That's enough electricity to _____ one million colour televisions for 20 years!
Since the dam _____ in 1970, the fertility of Egypt's farmland has gradually ______. Today, more than half of Egypt's soil is ____ medium to poor.
Unfortunately, the dam ___ also _____ several negative side effects. In order to build the dam, 90,000 Egyptian peasants ___ to ____. To ____ matters worse, the rich silt that normally _____ the dry desert land during annual floods is now _____ at the bottom of Lake Nasser!
Farmers _____ ____ ______ to use about one million tons of artificial fertilizer as a substitute for natural nutrients that once ____ the arid flood plain.

**WORD CHECK**

**III. Translate:**

neprekidan, procjeđivanje, plovidba, isparavanje, ukinuti, premještanje

**IV. Paraphrase the words underlined in the following sentences:**

**E.g.** The dam <u>captures</u> the mighty river in the reservoir.
The dam holds the river's water in the reservoir.

1. The Nile River <u>overflowed</u> its banks.
2. The river <u>deposited</u> tons of nutrient rich <u>silt</u> on the valley floor.
3. The dam <u>generates</u> a huge amount of electric power.
4. Artificial fertilizers <u>substitute</u> natural nutrients.
5. The dam <u>submerged</u> temples from the Greco- Roman period.
6. The creation of the reservoir <u>necessitated</u> the costly relocation of ancient temples.
7. The Aswan Dam <u>yields</u> enormous benefits to the economy of Egypt.

**V. a) Comment on the following statements:**

1. *"The Aswan Dam is a circle of cause and effect, success and failure, progress and lost".*
2. *"The sailboats on the clear water hide the poor quality of the soil."*
3. *"The Aswan Dam wipes out the existence of the Sudanese Egyptians and historical monuments."*
4. *"Controlling the Nile helps and hurts farmers at the same time"*

**V. b) Make a list of the benefits and drawbacks of the Aswan High Dam as indicated:**

| advantages | disadvantages |
|---|---|
| | |
| | |
| | |

**VI. What do the following technical abbreviations stand for:**

R.C. = ______________________

P.C.C. = ____________________

C.I. = ______________________

C.E. = ______________________

MEng = _____________________

## GLOSSARY

**Abutment** - the outermost end supports on a bridge, which carry the load from the deck

**Aggregate** - gravel or sand, crushed rock or similar materials, which form a large part of roads

**Aide** - (n) someone whose job is to help somebody who has an important job

**Alloy** - a metal that consists of two or more metals mixed together

**Aluminium** - a lightweight chemical element (Al); the most abundant metallic element in the Earth's crust

**Anchorage** - a secure fixing, usually made of reinforced concrete to which the cables are fastened

**Aqueduct** - a bridge-like structure or channel for conveying water, usually over long distances

**Arch** - a curved structure that converts the downward compression force of its own weight, into a force along its curve

**Arch Bridge** - a curved structure that converts the downward force of its own weight, and of any weight pressing down on top of it, into an outward force along its sides and base

**Arch Dam** - a dam with an arched shape that resists the force of water pressure; requires less material than a gravity dam for the same distance

**Awning** - a roof like cover extending over or if front of a place as a shelter

**Barge** - large low flat-bottomed boat used mainly for carrying heavy goods

**Beam** - a rigid, usually horizontal, structural element

**Beam Bridge** - a simple type of bridge, composed of horizontal beams supported by vertical posts

**Bedrock** - the solid rock layer beneath sand or silt

**Bend** - (v.) to curve; bending occurs when a straight material becomes curved; one side squeezes together in compression, and the other side stretches apart in tension

**Bends** - (n.) see caisson disease

**Blueprint** - a photographic print of building plans, with white lines on a blue background

**Brace** - (n.) a structural support; (v.) to strengthen and stiffen a structure to resist load's brace

**Bracket** - a projecting support usually fixed to a wall or column

**Brittle** - characteristic of a material that fails without warning; brittle materials do not stretch or shorten before failing

**Bucket** - a container, usually cylindrical in shape with an open top, used for catching or holding liquids or solids

**Buckle** - to bend under compression

**Bulldozer** - a powerful vehicle used for moving earth and rock

**Buttress** - a support that transmits a force from a roof or wall to another supporting structure

**Buttress Dam** - a gravity dam reinforced by structural supports

**Cable** - a structural element formed from steel wire bound in strands; the suspending element in a bridge; the supporting element in some dome roofs

**Cable-Stayed Bridge** - a bridge in which the roadway deck is suspended from cables anchored to one or more towers

**Caisson** - a watertight, dry chamber in which people can work underwater

**Caisson Disease** - an affliction developed by people moving in and out of caissons quickly;
also called “the bends“ or decompression sickness

**Cantilever** - a projecting structure supported only at one end, like a shelf bracket or a diving board

**Cap** - (v.) to cover the top of a structure

**Carve** - to cut into a special shape

**Cast Iron** - a brittle alloy with high carbon content; iron that has been melted, then poured into a form and cooled; can be made into any shape desired

**Chamber** - an enclosed space, esp. in a body or a machine

**Cement** - a binding material, or glue, that helps concrete harden

**Clog** - to become blocked so that movement is very difficult

**Cluster** - to gather or grow together

**Coin** - to invent a word or phrase

**Compact** - to press something together so that it becomes more solid
**Compound** - (v.) to make something more extreme or intense by adding something to it
**Contractor** - a person or company that agrees to do work for payment within a specified time
**Core** - the hard central part
**Coffer** - a sunken panel in a ceiling
**Cofferdam** - a temporary dam built to divert a river around a construction site so the dam can be built on dry ground
**Column** - a vertical, structural element, strong in compression
**Compact** - to press something together so that it becomes smaller or more solid
**Composite materials** - different materials used together, such as steel beams in reinforced-concrete floors
**Compressed-Air Chamber** - the space at the bottom of a caisson into which air is introduced under pressure to exclude water so that excavation can take place
**Compression** - a pressing force that squeezes a material together
**Concrete** - a mixture of water, sand, small stones, and a grey powder called cement
**Construction Manager** - a person who coordinates the entire construction process - from initial planning and foundation work through to the structure's completion
**Counteract** - to reduce or oppose the effect by opposite action
**Continuous Span Beam Bridge** - a simple bridge made by linking one beam bridge to another; some of the longest bridges in the world are continuous span beam bridges
**Core** - central region of a skyscraper; usually houses an elevator and the stairs
**Couple** - two equal and opposite parallels, but not co-linear, forces acting upon a body.
**Crack** - (v.) break without dividing into separate parts
**Curtain wall** - façade cladding with sheets of glass, or other materials held in a metal frame
**Cut and Cover** - a method of tunnel construction that involves

digging a trench, building a tunnel, and then covering it with fill

**Damper** - 1. a flat metal plate or any device to control a flow of air or gas,
2. a device to slow a moving part

**Deck** - supported roadway on a bridge

**Design** - 1. to create a detailed plan of something; to work out or create the form or structure of something
2. to plan and make something; to plan and make something in a skilful or artistic way

**Devise** - to plan or invent, especially cleverly

**Ditch**- a long narrow hole dug at the side of a road

**Diversion Channel** - a bypass created to divert water around a dam so that construction can take place

**Diving board** - a board fixed at one end, especially high off the ground off which people dive into water

**Dome** - a curved roof enclosing a circular space; a three-dimensional arch

**Drainage** - the process or system by which water or waste liquid flows away

**Dredge** - to clear mud from the bottom of a canal or river using a special machine, i.e. a dredger

**Dynamite** - a blasting explosive, based on nitroglycerin, but much safer to handle than nitroglycerin alone

**Embankment Dam** - a dam composed of a mound of earth and rock;

**Envelope** - anything that covers or surrounds

**Environmental Engineer** - an engineer who designs and operates systems to provide safe drinking water and to prevent and control pollution in water, in the air, and on the land

**Excavator** - a large machine that digs and moves earth and soil

**Fissure** - deep crack, especially in rock or earth

**Fibre** - strands of glass, plastics or wood to reinforce hard, brittle materials

**Forensic** - related to or used in the law and the tracking of criminals
**Force** - any action that tends to maintain or alter the position of a structure
**Formwork** - anything that holds fresh in-situ concrete in place until it hardens
**Framework** - (stru.) a load bearing frame may be of timber, metal, reinforced concrete or other composite material

**Geodesic Dome** - a dome composed of short, straight pieces joined to form triangles; invented by Buckminster Fuller
**Geotechnical Engineer** - an engineer who evaluates and stabilizes foundations for buildings, roads, and other structures
**Girder** - a horizontal, main structural member that supports the vertical loads of a building
**Grader** - earth leveller, a machine with a wide blade that levels earth, used in road construction
**Graduate** - someone who has completed a univeristy degree
**Glass fibre** - tough fibres made by drawing and rapidly cooling molten glass used often for heat insulation
**Gravity Dam** - a dam constructed so that its great weight resists the force of water pressure
**Grind** - crush into small pieces
**Grout** - a thick mixture of cement, sand and water, used for fixing components in place
**Gunpowder** - any of several low-explosive mixtures used as a blasting agent in mining and tunneling; the first such explosive was black powder, which consists of a mixture of potassium nitrate, sulfur, and charcoal

**Haul** - (v.) to pull something with effort or difficulty
**Helmet** - a hard hat to protect the head

**Impermeable** - not allowing liquids or gases to pass through
**Improper** - illegal, morally wrong
**Iron** - a chemical element (Fe); one of the cheapest and most used metals
**Isthmus** - a narrow piece of land with water on both sides that

connects two larger areas of land

**Jackhammer** - a large powerful tool used to break hard materials such as the surface of the road

**Joint** - a device connecting two or more adjacent parts of a structure; a roller joint allows adjacent parts to move controllably past one another; a rigid joint prevents the adjacent parts from moving or rotating past one another

**Lattice** - an open girder or beam built up from members joined by intersecting diagonal bars

**Layout** - a drawing showing the general arrangement of proposed construction

**Leak** - to let in or out of a hole or a crack

**Lime** - a white substance obtained by burning limestone, used for making cement, marking sports fields, ets.

**Limestone** - a type of rock that contains calcium

**Load** - weight distribution throughout a structure; loads caused by wind, earthquakes, and gravity, for example, affect how weight is distributed throughout a structure

**Lock** - a short section of a canal with gates at each end and a mechanism for letting water in and out

**Log** - a thick piece of wood from the trunk or large branch of a tree

**Mason** - a person whose job is cutting stone into shape for building

**Masonry** - a building material such as stone, clay, brick, or concrete

**Microtunelling machine** - a machine for driving a tunnel smaller than a person can work in

**Monolithic Dome** - a dome composed of a series of arches, joined together with a series of horizontal rings called parallels

**Moraine** - a mass of earth or pieces of rock moved along by a glacier and left in a line at the bottom of it

**Mortar** - a mixture of sand, cement and water that sets hard within a few hours to form a thick, rigid mass.

**Movable Bridge** - a bridge in which the deck moves to clear a navigation channel; a swing bridge has a deck that rotates around a centre point; a drawbridge has a deck that can be raised and lowered; a bascule bridge has a deck that is raised with counterweights like a drawbridge; and the deck of a lift bridge is raised vertically like a massive elevator

**Necessitate** - to force or to oblige somebody to do something
**Nitroglycerine** - an explosive compound made from a mixture of glycerol and concentrated nitric and sulphuric acids, and an important ingredient of most forms of dynamite

**Overhang** - a structure that hangs over something else

**Panel** - a flat, rectangular part, serves as a part of a structure, such as a door or a wall
**Pavement** - 1. the whole construction of a road including stabilized soil and the surface
2. A hard surface or path at the side of a road for people to walk on
**Perimeter** - the distance around the outside of a shape, or the border round any flat space
**Pendentive** - a triangular shape that adapts the circular ring of a dome to fit onto a flat supporting wall
**Pier** - a bridge support: a vertical structural support between two spans of a bridge
**Pierce** - to make a hole in or through something with a point
**Pile** - a long, round pole of wood, concrete, or steel driven into the soil by pile drivers
**Pile Driver** - a noisy machine that repeatedly drops a heavy weight on top of a pile until the pile reaches solid soil or rock or cannot be pushed down any farther
**Pillar** - a column or pier of stone or cast iron
**Pivot** - a central point on which something balances or turns
**Plaster** - a mixture of lime, water, and sand which hardens when dry and is used on walls
**Plastic** - a synthetic material made from long chains of molecules;

has the capability of being molded or shaped, usually by the application of heat and pressure

**Precast concrete** - concrete beams, piles, and parts of floors and walls which are cast and partly matured on the site or in a factory before being lifted into their position in a structure

**Prefabricated** - to make in sections that can be assembled later

**Pressure** - a force applied or distributed over an area

**Probe** - a long thin metal instrument, used to search inside of something

**Proximity** - nearness in distance or time

**Pylon** - a tall vertical structure forming part of a building or a construction

**Rage** - to spread or continue with great violence e.g. epidemic or blizzard or forest fires raged

**Reach** - one stretch of water between two locks

**Reinforced Concrete** - concrete with steel bars or mesh embedded in it for increased strength in tension; in pre-tensioned concrete, the embedded steel bars or cables are stretched into tension before the concrete hardens;
in post-tensioned concrete, the embedded steel bars or cables are stretched into tension after the concrete hardens

**Reliable** - that may be trusted; dependable

**Retractable** - to draw back or in

**Revel in** - to enjoy something very much

**Rib** - a curved piece of wood or metal that is used as part of a structure

**Richter Scale** - used to measure the magnitude of an earthquake; introduced in 1935 by the seismologists Beno Gutenberg and Charles Francis Richter

**Rigid** - (adj.) ability to resist deformation when subjected to a load; rigidity (n.) the measure of a structure's ability not to change shape when subjected to a load

**Rivet** - a fastening in the form of a short metal rod with a head. The shaft is passed through holes in materials and flattened into a second head on the other side

**Rock Tunnel** - a passage constructed through solid rock

**Seep** - to make its way gradually through small openings

**Sewer** - a large pipe under the ground for carrying away waste material

**Shaft** - a long passage, usually in an up-and-down or sloping direction

**Sheet** - a thin flat material, usually metal or glass produced by rolling or pressing,

**Shear** - a force that causes parts of a material to slide past one another in opposite directions

**Shear-walls** - solid concrete walls that resist shear forces; often used in buildings constructed in earthquake zones

**Shipworm** - a burrowing marine insect

**Shuttering** - a structure generally made of timber in which liquid concrete is placed, compacted, and allowed to harden

**Silt** - 1. sediment particles ranging from 0.004 to 0.06 mm (0.00016 to 0.0024 inch) in diameter
2. loose sand, mud, soil carried in running water

**Sink** - to go down below a surface, out of sight

**Skyline** - the outline of buildings, trees, hills etc. seen against the sky.

**Slab** - a thick flat piece of a hard material such as stone

**Soft-Ground Tunnels** - a passage constructed through loose, unstable, or wet ground, requiring supports to keep the walls from collapsing

**Span** - (n.) the distance a bridge extends between two supports;
(v.) to traverse a specific distance

**Spillway** - an overflow channel that allows dam operators to release lake water when it becomes high enough to threaten the safety of a dam

**Stable** - (adj.) ability to resist collapse and deformation;
stability (n.) characteristic of a structure that is able to carry a realistic load without collapsing or deforming significantly

**State-of-the-art** - the level of development (as of a device, technique) reached at the present time as a result of the most modern method

**Statics** - the science dealing with the forces that produce balance in objects that are not moving

**Steel** - an alloy of iron and carbon that is hard, strong, and malleable

**Stiff** - (adj.) ability to resist deformation;
stiffness (n.) the measure of a structure's capacity to resist deformation

**Straddle** - to sit or stand with legs on either side of something

**Strike** - to hit forcefully

**Strength** - the measure of a structure's ability to carry a realistic load

**Structural** - concerned with strength, e.g., the parts of a building which carry loads in addition to their own weight

**Structural Engineer** - an engineer who investigates the behaviour and design of all kinds of structures, including dams, domes, tunnels, bridges, and skyscrapers, to make sure they are safe and sound for human use

**Sub-base** - a bed of suitable material such as gravel laid sometimes under a base course to strengthen it

**Sub-grade** - the natural ground below a road

**Survey** - 1. to make a detailed map of an area of land
2. to inspect a building in order to determine its structural soundness or assess its value

**Suspend** - hang something from above; especially so that it can swing freely

**Suspender** - a vertical hanger in a suspension bridge, by which the road is carried on cables

**Suspension Bridge** - a bridge in which the roadway deck is suspended from cables that pass over two towers; the cables are anchored in housings at either end of the bridge

**Sustain** - to make something continue to exist or happen for a period of time

**Sustainable** - able to continue without causing damage to the environment

**Tension** - a stretching force that pulls on a material
**Tension Ring** - a support ring that resists the outward force pushing against the lower sides of a dome
**Thrust** - a forceful forward movement or push
**Tile** - a thin, medium-sized square, or a rectangle of finishing or covering material made to fit together with others in a regular format
**Timber** - a wooden beam forming part of a structure
**Tipper truck** - a lorry built so that the front of the platform carrying the load can be raised to allow the load to slide off
**Torsion** - an action that twists a material
**Tower** - the vertical structure in a suspension bridge or cable-stayed bridge from which cables are hung; also used as a synonym for the term skyscraper
**Truss** - a rigid frame composed of straight pieces joined to form a series of triangles or other stable shapes
**Tuned Mass Damper** - a mechanical counterweight designed to reduce the effects of motion, such as the swaying of a skyscraper in the wind or in an earthquake
**Tunnel Boring Machine (TBM)** - a mechanical device that tunnels through the ground
**Tunnel Shield** - a cylinder pushed ahead of tunnelling equipment to provide advance support for the tunnel roof; used when tunnelling in soft or unstable ground

**Under budget** - less than the planned cost
**Unobstructed** - unblocked

**Vault** - a roof or ceiling that consists of several arches joined together
**Vessel** - a ship or a boat, especially a large one

**Wearing course** - the top visible layer of a road
**Weir** - a wall built across the full width of a stream with a

horizontal crest over which water flows

**Withstand** - be resistant to something: to be strong enough to stand up to somebody or remain unchanged by something such as extremes of heat or pressure

**Wood** - a common natural material strong in both compression and tension

**Wrought Iron** - a pure form of iron, which is hammered or beaten into shape, less brittle than cast iron

**Yield** - 1. to give way;
2. to produce something

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