

Professional Foreign Language

(Industrial and Civil Engineering)



**Kharkiv
O. M. Beketov NUUE
2026**

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

**O. M. BEKETOV NATIONAL UNIVERSITY OF URBAN ECONOMY
in KHARKIV**

Professional Foreign Language

(Industrial and Civil Engineering)

Tutorial

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Навчальний посібник з дисципліни «Професійна іноземна мова» розрахований на студентів другого рівня (магістрів) закладів вищої освіти і спрямований на ґрунтовне засвоєння англійської мови за професійним спрямуванням. Посібник складається з 17 юнітів та додаткових текстів, фокус яких визначається відповідністю до вимог навчального плану та нової концепції викладання фахової англійської мови в закладах вищої освіти. Він розроблений таким чином, щоб своєю структурою і проблематикою орієнтувати студентів на системну організацію навчального процесу та бути складовою частиною комплексу навчальних матеріалів з англійської мови для студентів магістрів курсу університету.

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The tutorial on the subject "Professional foreign language" is produced for students (second level) of higher educational institutions and is aimed at a substantive knowledge of English in a professional field. It consists of 17 units and additional texts which are focused and determined in accordance with the requirements of the curriculum and the new concept of teaching professional English in higher education institutions. Its structure and issues guide students to the systematic organization of the educational process and are a part of teaching materials in English for the students of the second level of education.

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PREFACE

This textbook INDUSTRIAL AND CIVIL ENGINEERING (Professional Foreign Language) is designed for Master's degree students majoring in Industrial and Civil Engineering and aims to develop their professional foreign language competence in accordance with modern requirements of higher technical education and the construction industry.

The rapid development of construction technologies, international cooperation, participation in joint engineering projects, and access to global scientific and technical information make English an essential tool for future civil engineers. At the Master's level, students are expected not only to possess general language skills but also to communicate professionally, analyze specialized texts, prepare technical documentation, and participate in academic and professional discussions in English.

The textbook focuses on the formation and improvement of professional communicative competence, including reading and interpreting technical literature; writing reports, abstracts, and project documentation; delivering presentations; and engaging in professional dialogue related to construction processes, materials, structural engineering, project management, sustainability, and safety in construction.

The content of the textbook is structured thematically and includes authentic texts, terminology exercises, communicative tasks, case studies, and problem-solving activities relevant to industrial and civil engineering. Special attention is given to the development of critical thinking, academic writing skills, and the ability to use English in real professional and research contexts.

The textbook can be used for classroom work, guided independent study, and distance learning. It is intended for Master's students of industrial and civil engineering, as well as for postgraduate students, lecturers, and professionals who seek to improve their command of professional English in the field of construction.

UNIT 1

CIVIL ENGINEERING AS A PROFESSION

Civil Engineering is one of the oldest and most vital professions, shaping the world we live in by designing, building, and maintaining the infrastructure that supports modern life.

Civil Engineering is often called the “people’s engineering” because it directly serves society. It is a professional discipline concerned with the design, construction, and maintenance of the built environment – everything from roads, bridges, canals, dams, airports, and railways to water supply systems, sewage networks, and structural components of buildings. They are involved in the planning, construction, and maintenance of all kinds of structures (Figures 1.1. and 1.2.).



Figure 1.1 – Old covered bridge



Figure 1.2 – Gayathri Reservoir in Karnataka, India

Engineering is often defined as the practical application of theoretical sciences, such as physics and chemistry. Creativity is the most important part of their job. Civil engineers plan and construct safe, functional, and sustainable structures. They apply mathematics, physics, and materials science to ensure stability and efficiency. Civil engineers oversee construction from concept to completion, ensuring quality, safety, and cost-effectiveness. Modern civil engineering emphasizes sustainability, reducing environmental impact, and adapting to climate change. Civil engineering is more than just building structures – it is about improving quality of life. Every time you cross a bridge, drink clean water, or travel on a safe road, you benefit from the work of civil engineers. Their role is crucial in urban development, disaster prevention, and sustainable growth.

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 1.3.).



Figure 1.3 – Pont du Gard, southern France

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 18th century engineering became a civilian domain, thereby becoming the profession of the civil engineer.

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 1.4.) 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 1.4 – Eddystone Lighthouse, the English Channel

Civil engineering offers a particular challenge because 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.

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.

Within the field of civil engineering itself there are subdivisions: structural engineering, which deals with permanent structures (Figures 1.5. and 1.6.); 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 1.7.).



Figure 1.5 – Višegrad bridge

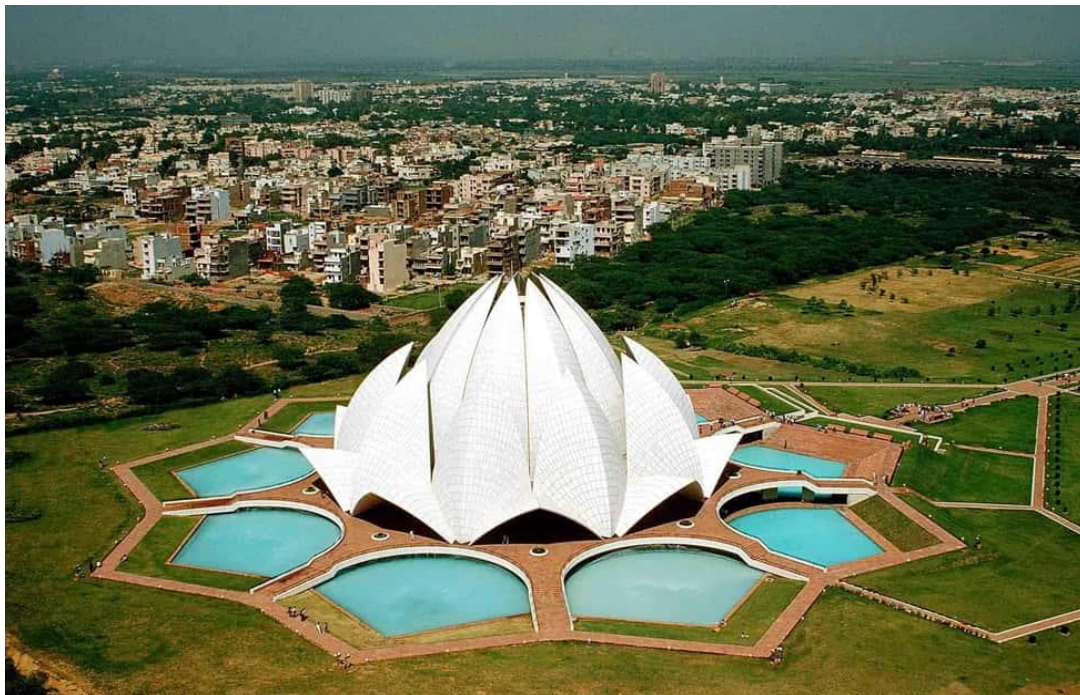


Figure 1.6 – Lotus Temple, a Bahā'ī Faith house of worship designed by Iranian architect Fariborz Sahba, New Delhi



Figure 1.7 – Water treatment plant

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.

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.

LANGUAGE PRACTICE

Answer the questions.

1. Why is civil engineering often referred to as the “people’s engineering”?

2. What types of structures are civil engineers responsible for designing, building, and maintaining?
3. How do modern civil engineers combine theoretical sciences with creativity to ensure safe and sustainable structures?
4. Why have many ancient Roman structures, such as bridges and aqueducts, survived until today despite being built without modern scientific knowledge?
5. What role did military engineers play before civil engineering became a civilian profession in the 18th century?
6. Who is considered the first self-styled civil engineer, and what innovation is he known for?
7. Why is every civil engineering structure or system considered unique, and what challenges does this create for engineers?
8. How have computer technologies such as numerical modelling and virtual reality influenced modern civil engineering design and construction?
9. What advantages do composite materials offer in building larger and stronger structures?
10. Which subdivisions exist within civil engineering, and what does each primarily focus on?
11. Why must engineers continually update their education throughout their careers?
12. How do financial realities influence the way engineers design and implement projects?
13. Why is it important for engineers to consider the social and environmental consequences of their work?

Exercise 1. 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 _

Exercise 2. 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.

Exercise 3. Which of the photographs in the text refer to: a) environmental engineering; b) structural engineering; c) hydraulic engineering?

Exercise 4. 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 _____

Exercise 5. 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.

Exercise 6. 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

Bob: *“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.”*

Daniel: *“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.”*

John: *“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.”

Tom: *“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.”*

Exercise 7. 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."*

Exercise 8. 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 must know something about the environment of the site - that is, is it subject to earthquakes? tornadoes? hurricanes? All 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 must carry out. And the loads are specified by regulation, which are mostly the loads of the occupants and what is going to be placed within the space - tables, chairs, bookshelves, storage cabinets, whatever - hence, the loads of the structure itself. So you must 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 1.8.).

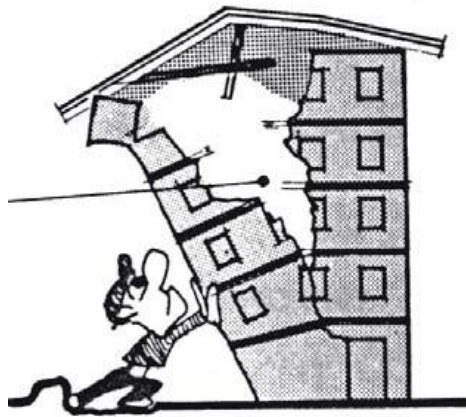


Figure 1.8 – A crack

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 are going to build the structure and what material you are going to use – concrete, steel or wood. That depends very much on where you are building it and how big it is and what its

function is. Then once you know the material that you are 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.

Exercise 9. Complete the definitions of the following terms:

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 _____

UNIT 2

ENVIRONMENTAL ENGINEERING

Environmental engineering is a branch of engineering that focuses on protecting human health and preserving the environment. It combines principles of science, engineering, and sustainability to design solutions that reduce pollution, manage waste, and promote clean resources.

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

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 2.1.).



Figure 2.1 – Entrance into the Cloaca Maxima, Rome

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 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 with a treatment plant.

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.

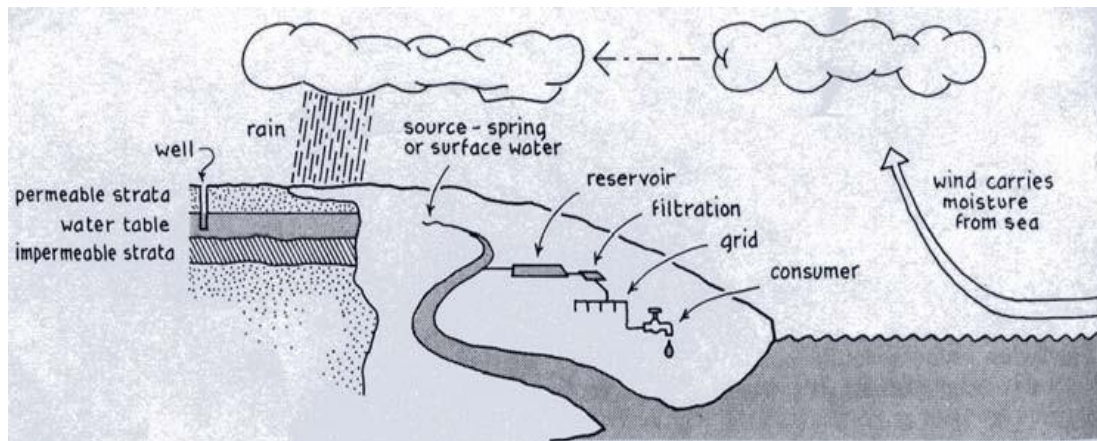


Figure 2.2 – The natural water supply cycle

Another process is aeration (Figure 2.3.). Sprays of water are shot into the air, where sunlight and oxygen help kill bacteria and 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 2.3 – Aeration tank

Today water conservation seeks to lower urban water usage such as using 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.

Terminological Glossary

1. **Environmental engineering** – A branch of engineering focused on protecting human health and the environment through pollution control and sustainable solutions.
2. **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.
3. **Pollution** - The contamination of air, water, or soil by harmful substances.
4. **Sewage treatment** - The process of removing contaminants from wastewater to make it safe for release or reuse.
5. **Sewer network** - A system of underground pipes used to collect and transport wastewater and stormwater.
6. **Sanitary engineering** - A field of engineering concerned with public health, water supply, and waste disposal.
7. **Water supply system** - Infrastructure designed to collect, treat, and distribute clean drinking water.
8. **Wastewater** - Used water containing waste materials from domestic, industrial, or public sources.
9. **Filtration** - A process in which water passes through sand or gravel to remove suspended solids.
10. **Sedimentation** - A treatment process where particles settle out of water under gravity.
11. **Biological treatment** - Water purification using microorganisms to break down pollutants.
12. **Chemical treatment** - The use of chemicals to disinfect or neutralize harmful substances in water.
13. **Chlorination** - A chemical treatment method using chlorine to kill harmful bacteria in water.
14. **Activated-sludge process** - A wastewater treatment method that uses air and microorganisms to purify water.

15. **Aeration** - A process of introducing air into water to remove gases and reduce bacteria.
16. **Aqueduct** - A structure designed to transport water over long distances.
17. **Cloaca Maxima** - An ancient Roman sewer system still partially in use today.
18. **Water conservation** - Practices aimed at reducing water consumption and preventing waste.
19. **Sanitation** - Systems and practices that ensure safe disposal of human waste and clean water access.

LANGUAGE PRACTICE

Answer the questions:

1. What is environmental engineering and what are its main objectives?
2. Which scientific and engineering principles are combined in environmental engineering?
3. What areas and systems are included in the field of environmental engineering?
4. How is environmental engineering connected with sanitary engineering and environmental health?
5. Why are Roman aqueducts and the Cloaca Maxima considered important achievements in environmental engineering history?
6. What was the main function of ancient sewer systems such as the Cloaca Maxima?
7. Why did water supply and sewer systems receive renewed attention in the nineteenth century?
8. What methods are used to remove or neutralize solid wastes in water treatment plants?
9. How do filtration, sedimentation, and the activated-sludge process contribute to water purification?
10. What modern measures are used today to conserve water and improve

sanitation worldwide?

Exercise 1. Match the terms with their definitions.

Term	Definition
1. Environmental engineering	a) Introducing air into water to remove gases and bacteria
2. Sewage treatment	b) A process of removing contaminants from wastewater
3. Filtration	c) Allowing solid particles to settle out of water
4. Sedimentation	d) A branch of engineering focused on environmental protection
5. Aeration	e) Passing water through sand or gravel to remove solids

Exercise 2. Complete the sentences using the following words:

chlorination, aqueducts, wastewater, sustainability, bacteria

1. Roman _____ supplied clean water to ancient cities.
2. _____ is used to kill harmful microorganisms in water.
3. Environmental engineering promotes _____ and public health.
4. Biological treatment uses _____ to purify water.
5. Untreated _____ can cause serious environmental and health problems.

Exercise 3. Decide whether the statements are True (T) or False (F). Correct the false ones.

1. Environmental engineering deals only with modern technologies.
2. The Cloaca Maxima is an ancient Roman sewer system.
3. Filtration and sedimentation are chemical treatment methods.
4. Activated-sludge process accelerates natural purification processes.
5. Water conservation aims to increase urban water consumption.

Exercise 4. Choose the correct answer.

1. Which process uses compressed air to control biological reactions?
a) Filtration b) Sedimentation c) Activated-sludge process
2. What was the main function of ancient sewer systems?
a) Drinking water storage b) Carrying stormwater and wastewater
c) Agricultural irrigation
3. Which method removes unpleasant odours from water?
a) Aeration b) Sedimentation c) Landfilling

Exercise 5. Translate into Ukrainian:

Safe water supply systems, pollution control, biological and chemical treatment, natural purification processes, water conservation measures

Exercise 6. Answer in 2–3 sentences.

1. Why did water supply systems become a priority in the nineteenth century?
2. How does the activated-sludge process work?
3. Why is aeration important in water treatment?

Exercise 7. Choose one topic and prepare a short oral presentation or a written response (150–180 words).

1. The role of environmental engineering in protecting public health.
2. Historical and modern approaches to water supply and sanitation.
3. Water conservation challenges in urban areas today.

Exercise 8. Read the situation and answer the questions.

A growing city experiences water pollution due to outdated sewage treatment facilities.

1. Which environmental engineering methods would you recommend?
2. How can biological and chemical treatment be combined?
3. What water conservation measures could be introduced?

Exercise 9. Give your comment on the following newspaper advertisement (Figure 2.4.).

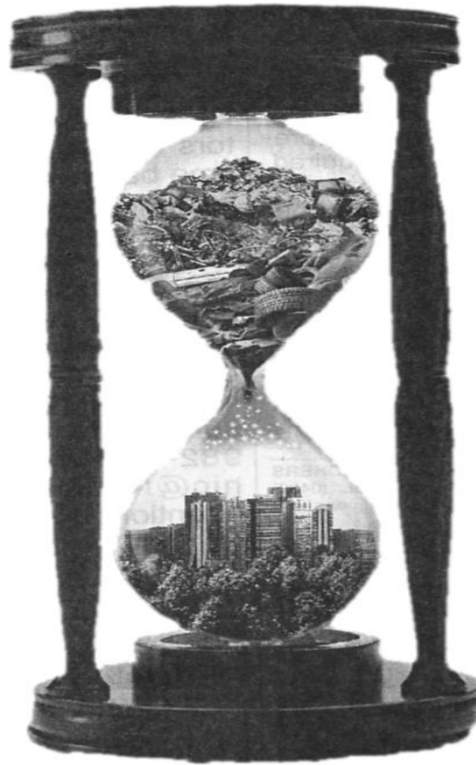


Figure 2.4 – During the 21st century we have continued to create things, then throw them away. To continue this “century of waste” we must quickly create a different way of dealing with our problems

UNIT 3

DISPOSAL OF WASTES IN INDUSTRIAL AND CIVIL CONSTRUCTION

Waste disposal is a critical issue in modern industrial and civil construction due to the rapid growth of urbanization, infrastructure development, and industrial activity. Construction projects generate a significant amount of waste, including concrete debris, metals, timber, plastics, packaging materials, and hazardous substances. Proper waste management is essential to minimize environmental impact, ensure compliance with regulations, and promote sustainable development in the construction industry.

In industrial and civil engineering, waste disposal begins at the planning and design stage. Engineers are expected to apply waste minimization strategies such as

efficient material selection, accurate quantity estimation, and modular construction techniques. These approaches help reduce excess materials and prevent unnecessary waste generation on construction sites.

Construction waste can be classified into non-hazardous and hazardous categories. Non-hazardous waste includes bricks, concrete, soil, glass, and wood, which can often be reused or recycled. For example, crushed concrete may be used as aggregate for road construction, while steel and aluminum can be recycled with minimal loss of quality. Hazardous waste, such as asbestos-containing materials, chemical residues, contaminated soil, and certain types of insulation, requires special handling, storage, and disposal in accordance with environmental and safety standards.

Modern waste disposal methods in construction emphasize recycling, reuse, and recovery rather than landfilling. On-site waste segregation plays a key role in improving recycling efficiency and reducing disposal costs. In addition, digital technologies such as Building Information Modeling (BIM) are increasingly used to optimize material usage and predict waste generation throughout the project lifecycle.

Effective waste disposal in industrial and civil construction contributes to environmental protection, occupational safety, and economic efficiency. Engineers must be familiar with national and international waste management regulations and adopt environmentally responsible practices. By integrating sustainable waste disposal strategies into construction processes, the industry can reduce its ecological footprint and support long-term development goals.

Solid wastes resulting from human and animal activities may 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 (Figure 3.1.) 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.

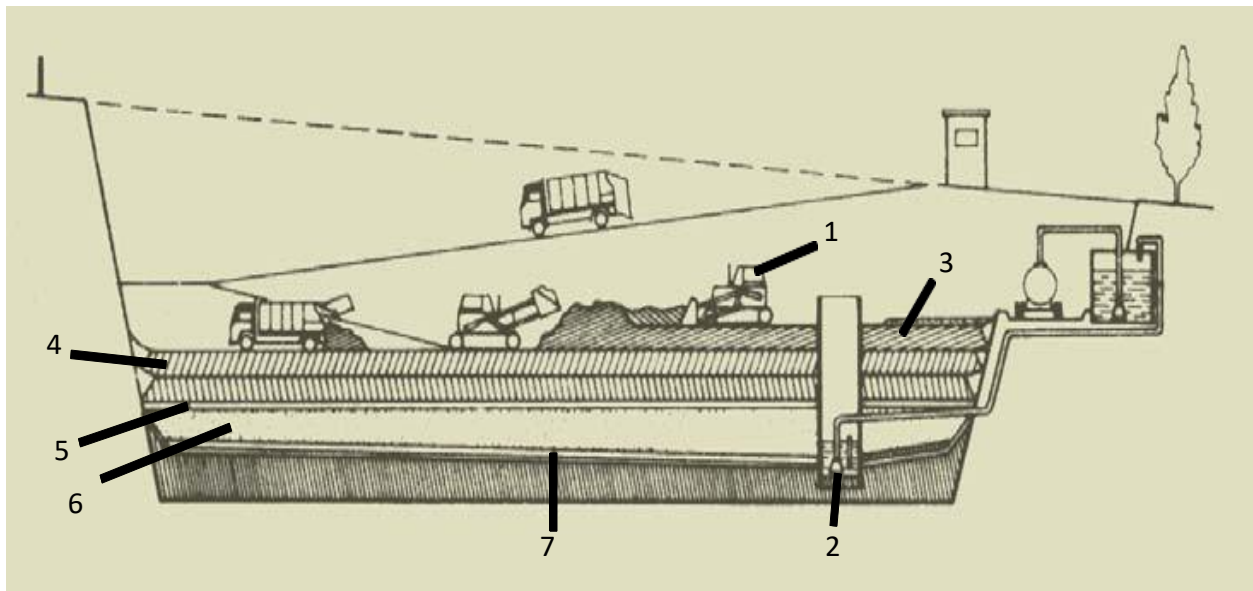


Figure 3.1 – Cross-section of a sanitary landfill: 1-bulldozer for dumping and compacting, 2-waste water pump, 3-porous cover, 4-compacted and decomposed use, 5-gravel filter, 6-moraine filter, 7-drainage layer

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 (Figure 3.2.), huge furnaces that reduce the wastes to ash.



Figure 3.2 – The incinerator

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 these materials can be processed for reuse. In some cases, trash has also been compacted to serve as fuel.

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

Composting of solid wastes accounts for only an insignificant amount (Figure 3.3.). Selecting a disposal method depends entirely on costs, which in turn are likely to reflect local circumstances.



Figure 3.3 – Composting plants for solid wastes

Terminological Glossary

1. **Waste disposal** - The process of collecting, treating, recycling, or safely discarding waste materials.
2. **Construction waste** - Materials generated during construction, renovation,

or demolition activities.

3. **Waste management** - The systematic control of waste generation, handling, storage, and disposal.
4. **Waste minimization** - Strategies aimed at reducing the amount of waste produced at its source.
5. **Non-hazardous waste** - Waste materials that do not pose a significant risk to human health or the environment.
6. **Hazardous waste** - Waste containing substances that are dangerous or harmful and require special handling.
7. **Recycling** - The process of converting waste materials into reusable raw materials.
8. **Landfilling** - The disposal of waste by burying it in designated landfill sites.
9. **On-site waste segregation** - Sorting waste materials at the construction site according to their type for proper disposal or recycling.
10. **Building Information Modeling (BIM)** - A digital technology used to plan, design, and manage construction projects efficiently.
11. **Sustainable development** - Development that meets present needs without compromising the ability of future generations to meet their own needs.

LANGUAGE PRACTICE

Answer the questions:

1. Why is waste disposal considered a critical issue in modern industrial and civil construction?
2. What types of waste are most commonly generated at construction sites?
3. At which stage of a construction project does effective waste disposal begin, according to the text?
4. What waste minimization strategies can engineers apply during the planning and design phase?
5. How is construction waste classified in industrial and civil engineering?

6. Give examples of non-hazardous construction waste that can be reused or recycled.

7. Why does hazardous waste require special handling and disposal procedures?

8. What modern waste disposal methods are preferred over landfilling in construction projects?

9. How can on-site waste segregation improve waste management efficiency?

10. What role do engineers play in promoting sustainable waste disposal practices in the construction industry?

Exercise 1. Match the terms with their definitions.

Term	Definition
1. Waste minimization	a) The disposal of waste by burying it in specially designed sites
2. Hazardous waste	b) Waste that poses a risk to health or the environment
3. Recycling	c) Sorting waste directly at the construction site
4. Landfilling	d) The process of reducing waste generation at its source
5. On-site waste segregation	e) The conversion of waste materials into reusable resources

Exercise 2. Complete the sentences using the following words:

sustainable, hazardous, recycling, engineers, construction waste

1. _____ includes materials such as concrete, metals, wood, and plastics.

2. _____ waste requires special handling and disposal procedures.

3. Modern construction projects focus on _____ rather than landfilling.

4. _____ play a key role in implementing effective waste disposal strategies.

5. Proper waste management contributes to _____ development in the construction industry.

Exercise 3. Decide whether the statements are True (T) or False (F). Correct the false ones.

1. Waste disposal is not a significant concern in civil engineering projects.
2. Waste minimization starts during the planning and design stage.
3. All construction waste must be disposed of in landfills.
4. Hazardous waste can be treated in the same way as non-hazardous waste.
5. BIM technologies can help predict waste generation.

Exercise 4. Choose the correct option.

1. Asbestos-containing materials are classified as:
a) non-hazardous waste b) hazardous waste c) recyclable waste
2. Crushed concrete can be reused as:
a) insulation material b) aggregate for road construction
c) chemical additive
3. On-site waste segregation helps to:
a) increase waste volume b) improve recycling efficiency
c) eliminate waste completely

Exercise 5. Translate the following word combinations into Ukrainian:

Environmental impact, waste management regulations, reuse and recovery, construction project lifecycle, occupational safety

Exercise 6. Discuss the following questions in pairs or write a short answer (120–150 words).

1. Why should waste disposal be considered a priority in industrial and civil construction?
2. Which waste management practices are most realistic for construction projects in Ukraine?
3. How can digital technologies improve waste disposal in the construction industry?

Exercise 7. Read the situation and answer the questions.

A large residential construction project generates significant amounts of concrete debris, metal waste, and packaging materials. The project manager wants to reduce disposal costs and comply with environmental regulations.

1. What waste disposal strategies would you recommend?
2. Which materials can be reused or recycled?
3. How can on-site waste segregation be organized effectively?

UNIT 4

PRINCIPAL CONSTRUCTION MATERIALS

Construction materials play a fundamental role in the design, durability, and safety of buildings and civil engineering structures. Throughout history, builders have selected materials based on their availability, strength, and resistance to environmental conditions. Today, the most widely used principal construction materials include masonry, cement, concrete, steel, timber, and modern composite materials.

In early construction, wood and masonry were the dominant materials. These materials were valued for their durability and compressive strength and were commonly used in walls, foundations, and load-bearing structures. Masonry includes brick, stone, clay, and tile, which are bonded together using mortar – a mixture of cement or lime, sand, and water (Figure 4.1.). 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 4.1 – 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 key binding material in modern construction. Cement is a material that binds together the mixture. When mixed with water, cement undergoes a chemical reaction known as hydration, forming a hardened mass. Unlike lime mortar, cement hardens without contact with air and is therefore classified as a hydraulic binder. The most common type used today is Portland cement, produced by heating limestone and clay and grinding them into a fine powder.

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 4.2.) 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 4.2 – 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 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 4.3.) 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.

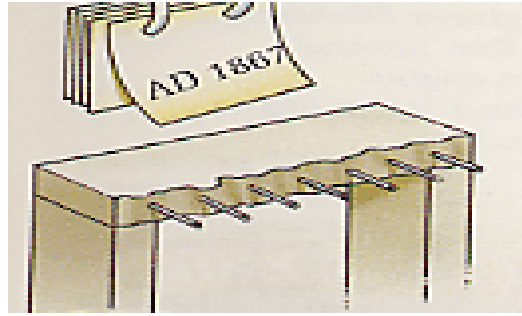


Figure 4.3 – Steel embedded into concrete in the form of bars

Steel is one of the most important construction materials due to its high strength, durability, and versatility. As an alloy of iron and carbon, steel exhibits excellent tensile properties and is widely used in frames, bridges, and industrial structures. Steel and concrete work effectively together because they have similar rates of thermal expansion and contraction. In addition, the alkaline environment of concrete protects steel from corrosion.

Modern construction increasingly relies on a combination of traditional and advanced materials to achieve structural efficiency, sustainability, and economic feasibility. Understanding the properties and applications of principal construction materials is essential for civil and industrial engineers involved in the design and construction of safe and long-lasting structures.

Terminological Glossary

1. **Masonry** - a building material such as stone, clay, brick, or concrete.
2. **Tile** - a thin, medium-sized square, or a rectangle of finishing or covering material made to fit together with others in a regular format.
3. **Mortar** - a mixture of sand, cement and water that sets hard within a few hours to form a thick, rigid mass.
4. **Concrete** - a mixture of water, sand, small stones, and a grey powder called cement.
5. **Aggregate** - gravel or sand, crushed rock or similar materials, which form a large part of roads.
6. **Shuttering** - a structure generally made of timber in which liquid

concrete is placed, compacted, and allowed to harden.

7. **Limestone** - a type of rock that contains calcium.
8. **Compression** - a pressing force that squeezes a material together.
9. **Tension** - a stretching force that pulls on a material.
10. **Steel** - an alloy of iron and carbon that is hard, strong, and malleable.
11. **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
12. **Beam** - a rigid, usually horizontal, structural element

LANGUAGE PRACTICE

1. Answer the questions:

1. What were the main construction materials used in earlier times?
2. How are tiles used in building construction, according to the text?
3. What is mortar and what materials is it made of?
4. How did the Greeks and Romans strengthen their buildings?
5. What was pozzolana and why was it important in Roman construction?
6. What is cement and why is it described as a hydraulic binder?
7. How is concrete produced and what are its main components?
8. Who invented Portland cement concrete and when was it invented?
9. Why do concrete and steel work well together in construction?
10. What advantages make steel one of the most widely used construction materials?

Exercise 1. Match the terms with their definitions.

Term	Definition
1. Mortar	a) A mixture of small stones, sand, or gravel used in concrete

2.	Pozzolana	b) Concrete with embedded steel rods to resist tension
3.	Cement	c) Material that binds together sand, lime, and water to hold bricks or stones
4.	Aggregate	d) A hydraulic cement made by mixing volcanic powder with lime, sand, and water
5.	Reinforced concrete	e) A material that hardens when mixed with water to bind construction elements

Exercise 2. Complete the sentences using words from the box.

(compression, tensile, Portland cement, shuttering, versatile, alkaline)

- Concrete has great strength under _____.
- Steel has excellent _____ strength, making it ideal for reinforcement.
- The most common type of concrete used today is _____.
- Fresh concrete is poured into a form called _____ before it hardens.
- Concrete is a very _____ material; it can be poured, pumped, or sprayed.
- Concrete protects embedded steel because it has an _____ chemical reaction.

Exercise 3. Decide whether the statements are True (T) or False (F). Correct the false ones.

- Tiles can be used both for floors and roofs.
- Portland cement is a natural material found in volcanic rocks.
- Concrete and steel have the same rate of contraction and expansion.
- Steel embedded in concrete will rust quickly because of the moisture.
- Mortar is used to hold bricks or stones together.

Exercise 4. Choose the correct answer.

- Who invented Portland cement concrete?

a) Joseph Aspdin

b) Roman engineers

c) Greeks

2. What is the main advantage of reinforced concrete?
 - a) It only resists compression.
 - b) It resists both tension and compression.
 - c) It does not require water to harden.
3. Which property makes concrete and steel complement each other in buildings?
 - a) Both are light in weight.
 - b) Both have the same tensile strength.
 - c) Both have the same rate of contraction and expansion.
4. Which material did Romans add to cement to make it waterproof?
 - a) Iron
 - b) Pozzolana
 - c) Sand

Exercise 5. Answer in 2–3 sentences.

1. What materials were commonly used in ancient masonry construction?
2. Why is Portland cement called a hydraulic binder?
3. How does reinforced concrete combine the advantages of steel and concrete?
4. What role do aggregates play in concrete?

Exercise 6. Translate the following terms into Ukrainian:

Reinforced concrete, hydraulic binder, mortar, shuttering (formwork), alkaline chemical reaction.

Exercise 7. Choose one topic and write 150–180 words or discuss orally.

1. Advantages and applications of reinforced concrete in modern construction.
2. Historical development of cement and concrete from Roman times to today.
3. Comparison of tensile and compressive strengths in steel and concrete.

Exercise 8. Read the situation and answer the questions.

A new high-rise building requires a strong structural system capable of resisting heavy loads and seismic activity. The architect wants to use concrete and

steel effectively.

1. Which materials would you recommend for the load-bearing structure?
2. How would you design reinforced concrete beams to resist tension?
3. What proportions of cement, aggregate, and water might affect concrete strength?

UNIT 5

THE BIRTH OF MODERN STRUCTURES AND IMPROVED MATERIALS

The birth of modern structures is closely connected with technological progress and the development of improved construction materials. During the late nineteenth and early twentieth centuries, rapid industrialization transformed traditional building methods and introduced new structural systems capable of supporting greater loads and spanning longer distances. This period marked a shift from masonry-based construction to modern engineering solutions based on steel, reinforced concrete, and later, composite materials.

One of the most significant innovations was the widespread use of structural steel. 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. Unlike traditional masonry walls, steel structures allowed for thinner walls, larger windows, and greater flexibility in architectural design. 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. 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 5.1.).



Figure 5.1 – The curtain wall of Mies van der Rohe’s Seagram Building, New York City

In the earlier steel frame building, the curtain walls were 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 5.2.).



Figure 5.2 – Riveted structure

The protruding end of the rivet is flattened by being hammered flat. Rivetting has now largely been replaced by welding (Figure 5.3.), the joining together of pieces of steel by melting a steel material between them under high heat.



Figure 5.3 – Welding

At the same time, reinforced concrete emerged as a revolutionary construction material. By combining concrete's high compressive strength with steel's tensile strength, engineers were able to design durable and economical structures. Reinforced concrete enabled the construction of bridges, industrial buildings, and residential blocks with complex shapes and improved resistance to fire and environmental impact. The ability to mold fresh concrete into almost any form significantly expanded architectural possibilities.

An improved form of reinforcement - a prestressed concrete was introduced in the twentieth century. It is produced in the following way: prestressing tendons - high tensile steel bars or cables are embedded in the concrete (Figure 5.4.).



Figure 5.4 – 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 5.5.).

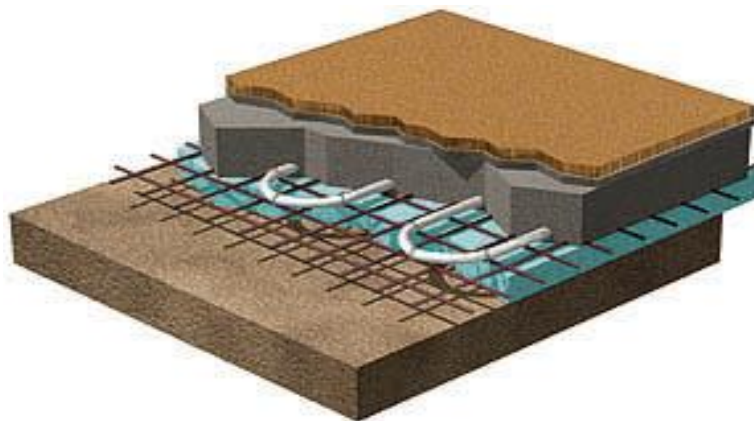


Figure 5.5 – Reinforced slab

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.

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 new structural method are constantly being developed (Figure 5.6.).



Figure 5.6 – Kylesku prestressed concrete bridge, Scotland

Advances in material science also led to the improvement of cement, glass, and later, aluminum and synthetic materials. High-performance concrete, prestressed and post-tensioned systems, and improved insulation materials enhanced structural efficiency and energy performance. These innovations contributed to longer service life, reduced maintenance costs, and increased sustainability of buildings. 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. And can be divided into two main groups: fibres and plastics.

The birth of modern structures was not only a technological breakthrough but also a response to social and economic changes. Urban growth, industrial demands,

and the need for safe infrastructure required new engineering approaches. Today's civil and industrial engineers continue to build on these foundations, using advanced materials and digital design tools to create resilient, sustainable, and efficient structures for the future.

Terminological Glossary

1. **Modern structures** - buildings and engineering works based on steel, concrete, and advanced materials rather than traditional masonry.
2. **Bearing wall** - a wall that supports the weight of a building.
3. **Curtain wall** - façade cladding with sheets of glass, or other materials held in a metal frame.
4. **Girder** - a horizontal, main structural member that supports the vertical loads of a building.
5. **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.
6. **Span** - the distance a bridge extends between two supports; (v.) to traverse a specific distance.
7. **Welding** - a method of joining metal parts by melting them together under high heat.
8. **Framework** (stru.) - a load bearing frame may be of timber, metal, reinforced concrete or other composite material.
9. **Frame building** - a structure in which the load is carried by a steel or concrete skeleton.
10. **Structural steel** - steel used for load-bearing elements such as beams and columns.
11. **Reinforced concrete** - concrete strengthened with embedded steel bars or mesh.
12. **Compressive strength** - the ability of a material to resist being compressed. **Tensile strength** - the ability of a material to resist being pulled apart. **Prestressed concrete** - concrete in which internal stresses are introduced to

improve performance under load.**Prestressing tendons** - high-strength steel bars or cables used to prestress concrete.**Grout** - a thin mortar or binding material used to bond tendons to concrete.**High-performance concrete** - concrete with enhanced strength, durability, and resistance.**Composite materials** - materials made from two or more different substances with improved properties.

LANGUAGE PRACTICE

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

Exercise 1. Match the terms with their definitions.

Term	Definition
1. Curtain wall	a) A non-load-bearing exterior wall
2. Prestressed concrete	b) Joining metal parts by melting them together
3. Rivet	c) Concrete strengthened by internal tension
4. Structural steel	d) A metal pin used to fasten steel plates
5. Welding	e) Steel used for load-bearing structures

Exercise 2. Complete the sentences using the following words:

frame, tensile, curtain walls, industrialization, prestressing

1. Rapid _____ transformed traditional building methods.
2. Modern buildings often use a steel or concrete _____ to carry loads.
3. Concrete has low _____ strength without reinforcement.
4. Exterior walls that do not support the structure are called _____.
5. _____ allows concrete beams to span longer distances.

Exercise 3. Decide whether the statements are True (T) or False (F). Correct the false ones.

1. Early tall buildings relied mainly on very thick bearing walls.
2. Curtain walls support the structural weight of modern buildings.
3. Welding has largely replaced riveting in steel construction.
4. Prestressed concrete is mainly used for very small spans.
5. Aluminium has similar properties to steel but weighs less.

Exercise 4. Choose the correct answer.

1. What made skyscrapers possible in the nineteenth century?
a) Brick masonry b) Steel frames and elevators
c) Timber structures
2. Which property of concrete is improved by steel reinforcement?
a) Compressive strength b) Tensile strength
c) Thermal insulation
3. Prestressed concrete is especially economical for:
a) Short spans b) Decorative elements
c) Long spans and shallow beams

Exercise 5. Answer in 2–3 sentences.

1. Why did frame construction replace bearing-wall construction?
2. How do curtain walls differ from traditional masonry walls?

3. What advantages does prestressed concrete offer in bridge construction?

Exercise 6. Translate into Ukrainian:

Masonry, alloy, shuttering, grind, pour, embed, bind, acid, strength, drill.

Steel frame building, non-load-bearing wall, high tensile steel bars, long-span structures, advanced construction materials/

Exercise 7. Write 150–180 words or discuss orally.

1. The role of steel and reinforced concrete in the development of modern architecture.
2. Advantages of prestressed concrete in contemporary construction.
3. How improved materials contribute to sustainability and energy efficiency.

Exercise 8. 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...

Exercise 9. Explain the difference between a load bearing wall and a non-bearing wall (Figures 5.7. and 5.8.).

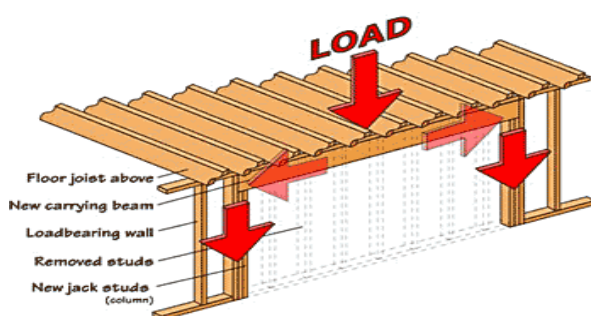


Figure 5.7 – Load bearing wall



Figure 5.8 – Non-bearing walls

UNIT 6

UP IN THE AIR

Both steel and cement, the two most important construction materials of modern times, were introduced in the nineteenth century. Until that period, steel was produced by slow and expensive methods, which limited its use to special applications such as weapons, tools, and decorative elements. The situation changed dramatically after the invention of the **Bessemer process** in 1856, which made it possible to produce steel in large quantities at relatively low cost. This technological breakthrough opened the way for steel to become the primary structural material of modern construction. (Figure 6.1.).



Figure 6.1 – Henry Bessemer and his converter

The enormous advantage of steel lies in its **tensile strength** – the ability to resist forces that tend to pull a material apart. Unlike many traditional materials, steel maintains its strength under carefully calculated tension. In addition, steel is highly versatile: it can be rolled into sheets or bars, shaped into beams of various profiles, or drawn into thin wires. To protect steel from corrosion, it is often coated with zinc in a process known as **galvanizing**, which significantly extends its service life.

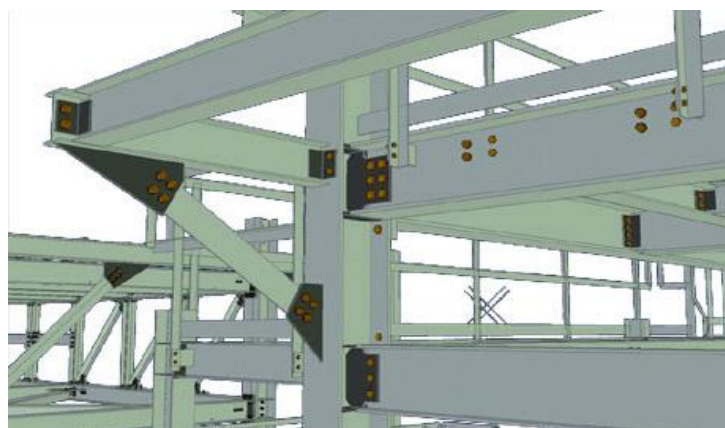


Figure 6.2 – A 3D model of a steel structure

The introduction of steel made possible an entirely new type of building – the **skyscraper**. The first tall building supported by a steel skeleton of vertical columns and horizontal beams was the ten-storey **Home Insurance Building** in Chicago. This innovative structural system transferred the weight of the building from thick masonry walls to a steel frame, allowing buildings to rise higher than ever before.

Modern skyscrapers are not only architectural landmarks but also remarkable achievements of engineering and organization. Long before construction begins, engineers carefully design every structural element and coordinate the production and delivery of all components, from massive girders to the smallest fixtures (Figure 6.3.). A single skyscraper may weigh as much as several large ocean liners, which makes the design of its foundations critically important.

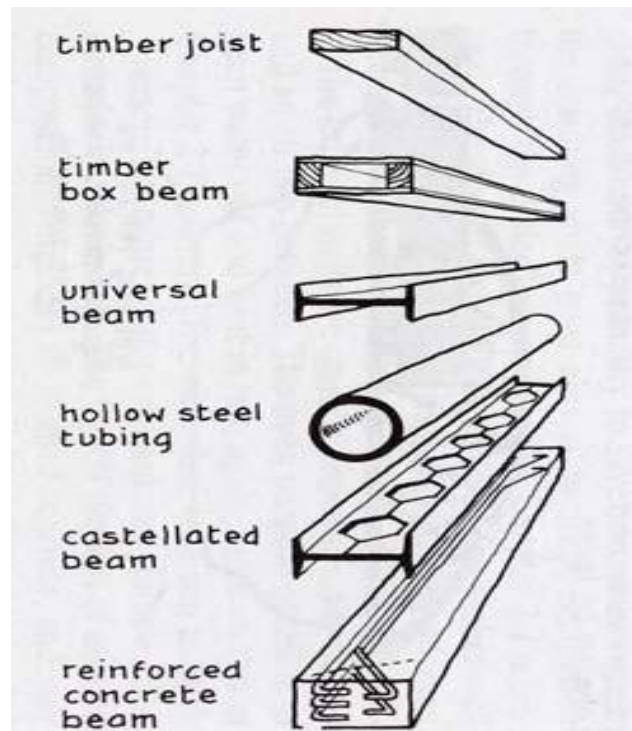


Figure 6.3 – Some beam types used in building

To support such enormous loads, deep and robust foundations are required. Typically, a large excavation is made and filled with reinforced concrete, which hardens to form a solid base. In many cases, buildings are supported by **piles** – long concrete or steel columns driven deep into the ground to reach stable soil layers. Some skyscraper designs include a **central concrete core**, which plays a key structural role. This central core usually contains elevators, staircases, and service shafts. In addition to housing vertical transportation systems, the core provides

stiffness and helps prevent the building from swaying under wind loads. Around the core, a steel frame of columns and girders is erected using tower cranes. This frame supports the floors and exterior walls of the building.

The outer walls of modern high-rise buildings are generally made of lightweight materials, most commonly glass, forming **curtain walls** that do not carry structural loads but protect the interior from weather and allow natural light to enter. Floors are constructed by placing steel decking between the girders, laying reinforcing steel rods on top, and pouring concrete over the assembly. Once hardened, this composite system combines the compressive strength of concrete with the tensile strength of steel.

After the main structural elements are completed, contractors install electrical systems, plumbing, heating, ventilation, air-conditioning equipment, and fire protection systems such as sprinklers. The result is a complex, highly integrated structure that rises high above the ground – a true symbol of modern engineering made possible by steel, concrete, and advanced construction technologies.

Terminological Glossary

1. **Steel** – a strong metal alloy made primarily of iron and carbon, widely used as a structural material in modern construction.
2. **Cement** – a binding material that hardens when mixed with water and is used to produce concrete.
3. **Bessemer process** – a nineteenth-century method of steel production that enabled the mass manufacture of steel at relatively low cost.
4. **Structural material** – a material used to carry loads and ensure the stability of a building or structure.
5. **Tensile strength** – the ability of a material to resist forces that attempt to pull it apart.
6. **Versatility** – the property of a material that allows it to be formed and used in many different ways.
7. **Beam** – a horizontal structural element that supports loads and transfers them

to columns or walls.

8. **Profile** – the cross-sectional shape of a structural element such as a beam or girder.
9. **Galvanizing** – the process of coating steel with zinc to protect it from corrosion.
10. **Service life** – the length of time a material or structure remains functional and safe for use.
11. **Steel frame (steel skeleton)** – a structural system composed of steel columns and beams that supports the entire building.
12. **Masonry wall** – a wall built from bricks or stones, traditionally used as a load-bearing element.
13. **Foundation** – the lowest part of a structure that transfers its weight to the ground.
14. **Reinforced concrete** – concrete strengthened with embedded steel reinforcement to improve its tensile capacity.
15. **Pile** – a long column of concrete or steel driven deep into the ground to support heavy structures.
16. **Concrete core** – a central reinforced concrete structure that provides stiffness and contains elevators and staircases.
17. **Stiffness** – the resistance of a structure to deformation under applied loads.
18. **Wind loads** – forces exerted on a building due to wind pressure.
19. **Tower crane** – a tall construction crane used for lifting heavy materials during high-rise construction.
20. **Curtain wall** – a lightweight exterior wall that does not carry structural loads and serves as weather protection.
21. **Steel decking** – profiled steel sheets used as a base for concrete floors.
22. **Reinforcing steel rods** – steel bars placed in concrete to improve its strength under tension.
23. **Compressive strength** – the ability of a material to withstand forces that reduce its size.

24. **Composite system** – a construction system combining different materials to achieve improved structural performance.
25. **Fixture** – a small but essential component used to fasten or support building elements.
26. **HVAC systems** – systems for heating, ventilation, and air conditioning that control indoor climate.
27. **Sprinkler system** – an automatic fire protection system that releases water when a fire is detected.

LANGUAGE PRACTICE

Answer the questions:

1. Why were steel and cement not widely used in construction before the nineteenth century?
2. What was the significance of the Bessemer process for the development of modern construction?
3. What is tensile strength and why is it an important property of steel?
4. How can steel be shaped and protected from corrosion?
5. Which building is considered the first modern skyscraper and why?
6. How did steel frame construction change the design of tall buildings?
7. Why do skyscrapers require deep and strong foundations?
8. What role do piles and central concrete cores play in high-rise buildings?
9. How are the floors of modern skyscrapers constructed?
10. What construction stages follow after the main frame, floors, and walls are completed?

Exercise 1. Match the terms with their definitions.

Term	Definition
1. Tensile strength	a) A non-load-bearing external wall
2. Galvanizing	b) The ability of a material to resist pulling forces
3. Steel frame	c) Long concrete or steel columns driven deep into the ground

4. Piles	d) A protective coating of zinc to prevent corrosion
5. Curtain wall	e) A structural system of columns and beams

Exercise 2. Complete the sentences using the following words:

Bessemer process, foundations, girders, core, skyscraper

1. The _____ made mass production of steel possible.
2. A tall modern building is commonly called a _____.
3. Heavy buildings require deep and strong _____.
4. The steel frame is made up of columns and _____.
5. Elevators and stairs are usually placed in the central _____ of a building.

Exercise 3. Decide whether the statements are True (T) or False (F). Correct the false ones.

1. Steel was widely used in construction before the nineteenth century.
2. Galvanizing helps protect steel from rust.
3. The Home Insurance Building was supported by thick masonry walls.
4. Curtain walls carry the main structural load of a building.
5. The central core helps prevent buildings from swaying in the wind.

Exercise 4. Choose the correct answer.

1. What property of steel allows it to resist pulling forces?
a) Compressive strength b) Tensile strength
c) Thermal resistance
2. What is the main function of a tower crane?
a) Mixing concrete b) Lifting structural elements
c) Excavating foundations
3. What material is commonly used for the outer walls of skyscrapers?
a) Brick b) Glass c) Concrete blocks

Exercise 5. Answer in 2–3 sentences.

1. Why are steel frames essential for high-rise buildings?
2. How do piles improve the stability of skyscrapers?
3. Why is concrete poured over steel rods in floor construction?

Exercise 6. Put the construction stages in the correct order.

- a) Installation of electrical and plumbing systems
- b) Erection of the steel frame
- c) Excavation and concreting of foundations
- d) Construction of floors
- e) Installation of curtain walls

Exercise 7. Explain the principal stages of erecting a high-rise building.

Exercise 8. 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 _____.

Exercise 9. Exercise 8 as you noticed, contains three grave mistakes concerning the building process. Make a note of them and correct them.

Exercise 10. Choose one topic and write 150–180 words or discuss orally.

1. Why steel and concrete are indispensable in modern high-rise construction.
2. Engineering challenges in building skyscrapers.
3. The role of technology in the development of modern structures.

TRANSPORTATION ENGINEERING

here is nothing more remarkable than the fact that, over the last two thousand years, since the Romans began to develop an extensive network of roads, the fundamental principles of road construction have changed very little. Many Roman roads, built with exceptional precision and durability, still exist today and continue to influence modern transportation engineering. Their longevity demonstrates the effectiveness of careful planning, solid foundations, and proper drainage systems. (Figure 7.1.).

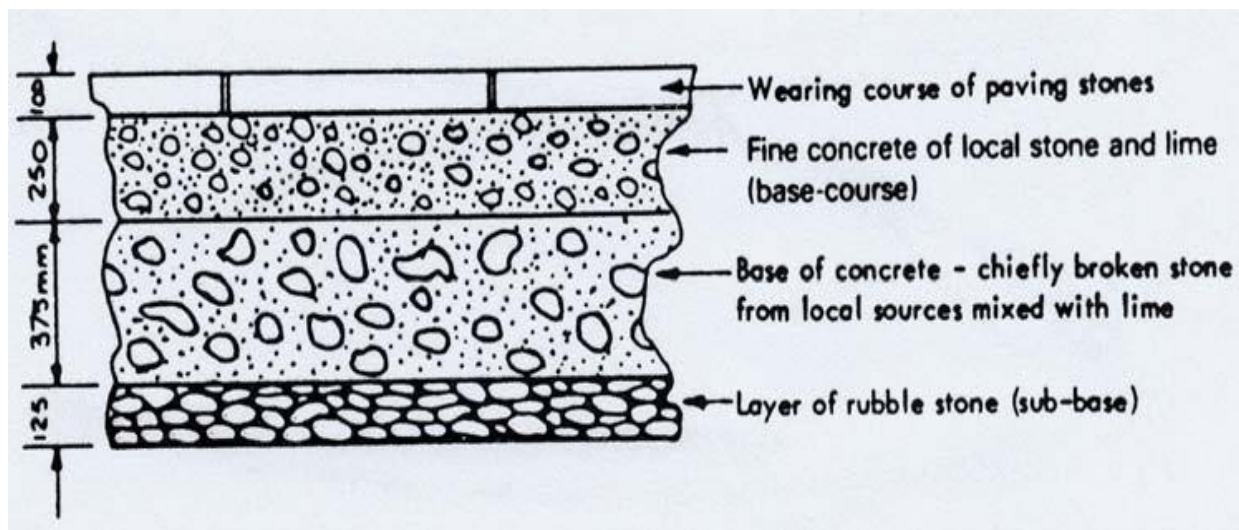


Figure 7.1 – Roman road structure

The durability of Roman roads resulted from the enormous effort invested in their design and construction. Roman engineers constructed multilayer road structures consisting of a well-prepared subgrade, a thick stone foundation, and a durable surface layer. These roads enabled rapid communication, efficient movement of troops, and reliable transportation of goods between Rome and the distant provinces of the empire. As a result, the Roman highway system played a crucial role in political control, economic development, and cultural integration across vast territories.

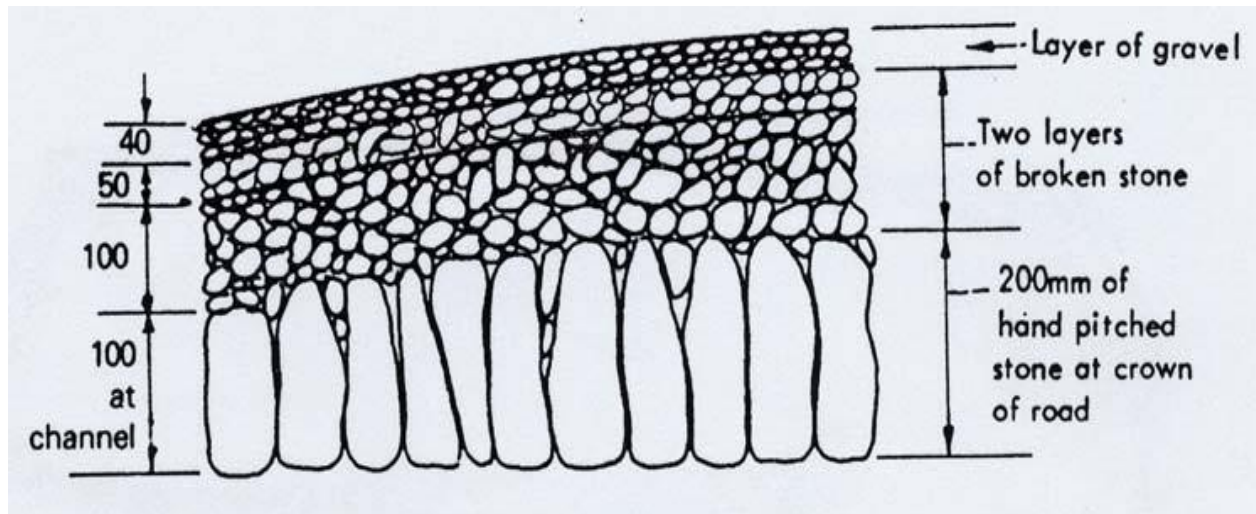


Figure 7.2 – Telford's road structure

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 7.2.), and a Scot, John L. MacAdam whose name has passed into English in the words macadam and macadamize (Figure 7.3.).

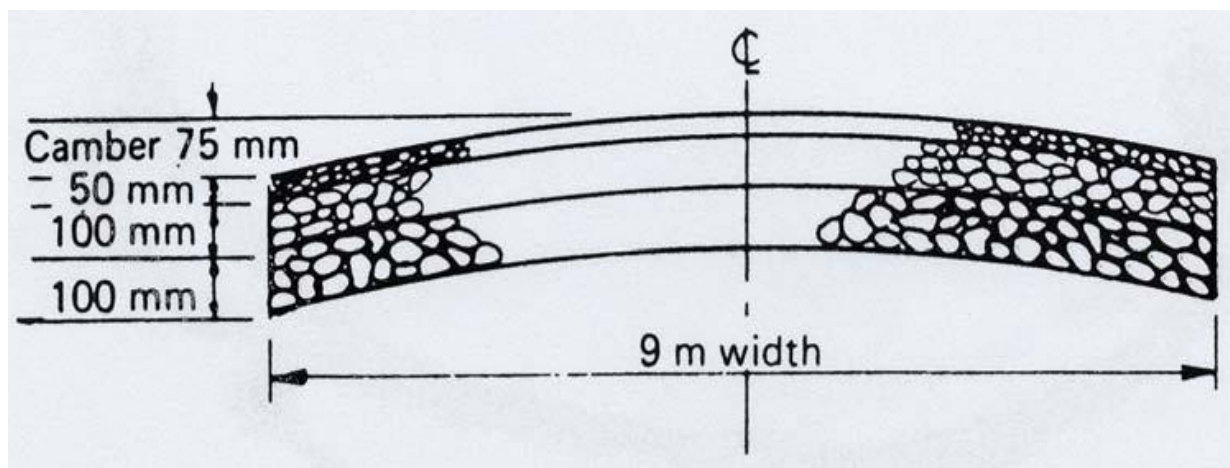


Figure 7.3 – MacAdam's road structure

Tresaguet and Telford emphasized the importance of a firm **subgrade**, which serves as the foundation on which the entire pavement structure rests. They also recognized the necessity of effective drainage to keep the road dry and stable. Their road designs included several layers: a base course of large broken stones, followed by layers of smaller aggregates, and finally a **wearing surface**, which is the top layer exposed to traffic. The wearing surface protects the underlying layers from wheel abrasion and prevents water from penetrating the pavement structure. To improve drainage, roads were constructed with a slight convex shape, known as a **crown**,

allowing rainwater to run off the surface.

McAdam introduced a more economical and innovative approach to road construction. He demonstrated that, if properly compacted and kept dry, the natural soil could support traffic loads without the need for a massive stone foundation. His method involved placing layers of crushed stone directly on a compacted subgrade. Over time, the pressure of iron wheels compressed and polished the stone surface, creating a relatively smooth and watertight pavement. These **macadam roads** were well suited to the transportation needs of the nineteenth century, when vehicles were lighter and equipped with iron or steel wheels.

However, the introduction of the automobile at the beginning of the twentieth century brought new challenges. Motor vehicles were significantly heavier and faster than horse-drawn carriages, and their rubber tires exerted different stresses on road surfaces. As a result, traditional macadam roads began to deteriorate rapidly. To address this problem, engineers developed **bound surfaces** by mixing crushed stone with tar or bitumen, creating what is now known as **bituminous or asphalt pavement**. This innovation greatly increased the strength, durability, and waterproofing of road surfaces.

Today, millions of kilometres of roads around the world are constructed using these principles. Modern transportation engineering continues to evolve by incorporating advanced materials, mechanized construction techniques, and digital design tools. Nevertheless, the core ideas introduced by Roman engineers and later refined by Tresaguet, Telford, and McAdam remain central to the design of safe, durable, and efficient road networks.

Terminological Glossary

1. **Transportation engineering** – a specialized branch of civil engineering focused on the design, analysis, and management of transportation systems, including roads, highways, and traffic infrastructure, to optimize safety, efficiency, and durability.
2. **Roman roads** – advanced ancient roadways engineered by the Romans with

multilayered construction, effective drainage, and durable surfaces, many of which have endured for centuries.

3. **Road structure (pavement structure)** – a multi-layered engineering system comprising subgrade, base, and surface layers designed to distribute loads, resist deformation, and ensure long-term performance.
4. **Subgrade** – the prepared native soil or engineered layer that provides the foundational support for all overlying pavement layers and distributes traffic loads to the ground.
5. **Foundation (base layer)** – the structural layer directly above the subgrade that stabilizes the pavement, reduces settlement, and transfers loads uniformly.
6. **Base course** – a mechanically compacted layer of aggregates or granular material placed above the subgrade or footing to enhance load distribution and structural stability.
7. **Aggregate** – inert granular material, such as crushed stone, gravel, or sand, used in pavement layers to improve strength, stiffness, and durability.
8. **Wearing surface (surface course)** – the topmost layer of a pavement system designed to resist traffic-induced abrasion, environmental degradation, and provide a smooth, durable, and safe riding surface.
9. **Drainage system** – an engineered arrangement of features and structures (such as slopes, channels, and pipes) to remove water from the pavement and subgrade, preventing structural damage and loss of performance.
10. **Crown (camber)** – a controlled transverse curvature of the pavement surface designed to ensure rapid and effective runoff of surface water.
11. **Compacted soil** – soil that has been densified through mechanical means to increase its density, stiffness, and load-bearing capacity.
12. **Macadam road** – a historical type of pavement consisting of compacted layers of crushed stone, often bound by natural fines, designed to provide a smooth, stable surface for traffic.
13. **Macadamize** – the process of constructing a road using successive layers of compacted crushed stone, relying on interlocking and mechanical consolidation for

stability.

14. **Crushed stone** – mechanically fractured rock used as an aggregate in pavement construction, forming part of the base or surface layers.
15. **Footing** – the engineered support layer or structural base beneath a pavement that ensures uniform load distribution and prevents excessive settlement.
16. **Wheel abrasion** – the progressive wear and polishing of the pavement surface caused by repeated contact and friction with vehicle tires.
17. **Bitumen** – a viscous, petroleum-derived binder used to coat aggregates and produce a cohesive, durable, and waterproof pavement surface.
18. **Tar-bound or asphalt surface** – a pavement surface in which crushed stone or aggregates are bound together with bituminous materials to enhance strength, flexibility, and water resistance.
19. **Pavement engineering** – the applied science and technology of designing, constructing, and maintaining road surfaces and associated layers to meet structural, functional, and environmental requirements.

LANGUAGE PRACTICE

Answer the questions:

1. Why are Roman roads considered remarkable even by modern engineering standards?
2. What design features contributed to the durability of Roman roads?
3. How did the Roman road network influence communication and administration in the empire?
4. Which engineers laid the foundations of modern road construction in the eighteenth and nineteenth centuries?
5. What is a subgrade and why is it important in road construction?
6. What is the function of the wearing surface in a pavement structure?
7. How did Tresaguet and Telford design their road layers?
8. What innovation did John L. McAdam introduce to road construction?
9. Why did traditional macadam roads become inadequate with the arrival of

automobiles?

10. How did the use of tar or bitumen improve road surfaces?

Exercise 1. Match the terms with their definitions.

Term	Definition
1. Subgrade	a) A road constructed with compacted crushed stone layers
2. Wearing surface	b) The foundation layer on which the pavement rests
3. Drainage	c) A material used to bind crushed stone and waterproof the surface
4. Macadam road	d) The system that removes excess water from the road structure
5. Bitumen	e) The top layer of pavement exposed to traffic

Exercise 2. Complete the sentences using the following words:

durability, aggregates, crown, automobiles, compacted

1. Roman roads are famous for their exceptional _____.
2. Roads were built with a slight _____ to allow water to run off.
3. Tresaguet and Telford used layers of broken stones and _____.
4. McAdam showed that _____ soil could support road traffic.
5. The appearance of _____ created new challenges for road engineers.

Exercise 3. Decide whether the statements are True (T) or False (F). Correct the false ones.

1. Roman roads consisted of a single layer of stone.
2. Drainage was an important element in early modern road design.
3. McAdam's roads required heavy stone foundations.
4. Macadam roads were suitable for iron-wheeled vehicles.
5. Bituminous surfaces improved the strength and waterproofing of roads.

Exercise 4. Choose the correct answer.

1. Who emphasized the importance of a firm subgrade and layered construction?
a) Roman architects only b) Tresaguet and Telford
c) Modern highway engineers
2. What caused early macadam roads to deteriorate?
a) Heavy rainfall b) Motor vehicles c) Poor drainage
3. What material was added to crushed stone to strengthen modern road surfaces?
a) Cement b) Lime c) Tar or bitumen

Exercise 5. Answer in 2–3 sentences.

1. Why is drainage essential for road durability?
2. How did road construction methods change after the introduction of automobiles?
3. Why can Roman road principles still be seen in modern highways?

Exercise 6. Translate into Ukrainian:

Road pavement structure, effective drainage system, crushed stone base, waterproof wearing surface, modern highway network.

Exercise 7. Choose one topic and prepare a short oral presentation or a written response (150–180 words).

1. The influence of Roman engineering on modern transportation systems.
2. The evolution of road construction from macadam to asphalt pavements.
3. Challenges facing transportation engineering in the twenty-first century.

Exercise 8. 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.

UNIT 8

CONSTRUCTION OF A ROAD

The construction of a road is a complex and carefully engineered process that ensures strength, durability, and safety for traffic loads. Roads are typically built as a multi-layered structure, collectively called the pavement, designed to distribute loads from vehicles to the ground and resist environmental damage over time. A standard pavement consists of several layers: the subgrade (natural or prepared soil), the sub-base (optional, depending on soil quality), the base course, and the wearing course or top surface.

Types of Pavements

Pavements are generally classified into two main types: **rigid pavements** and **flexible pavements**. Rigid pavements (Figure 8.1) are constructed with **Portland Cement Concrete (PCC)** and aggregates. The **wearing surface** is a concrete slab, which provides high compressive strength, durability, and resistance to deformation under heavy traffic loads. Rigid pavements are commonly used on highways, industrial areas, and high-traffic urban roads where long-term performance is critical.

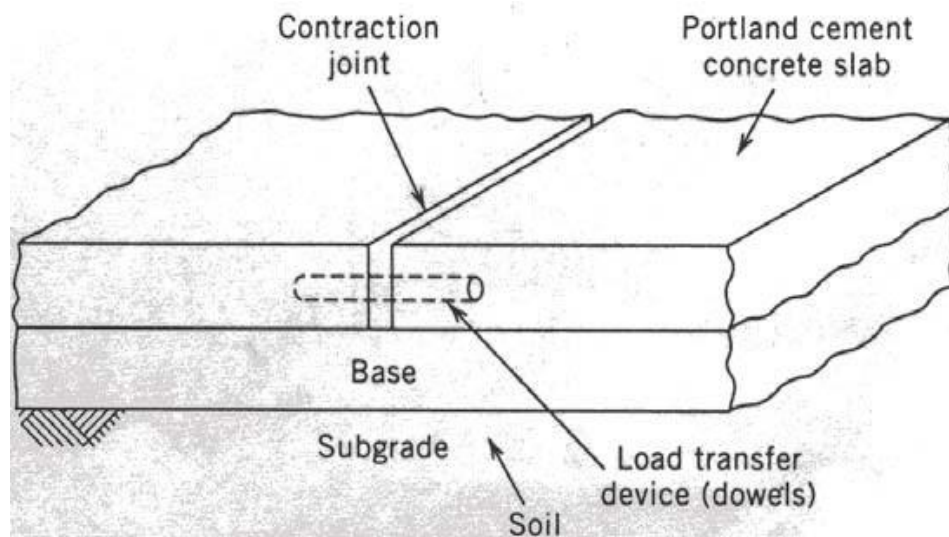


Figure 8.1 – Rigid pavement

Flexible pavements (Figure 8.2) typically have a **wearing surface of asphaltic concrete**, a mixture of **asphalt cement** and aggregates. The asphaltic layer provides flexibility, allowing the pavement to distribute loads gradually over the base and subgrade. Flexible pavements are widely used on urban streets, secondary roads, and areas with variable traffic loads.

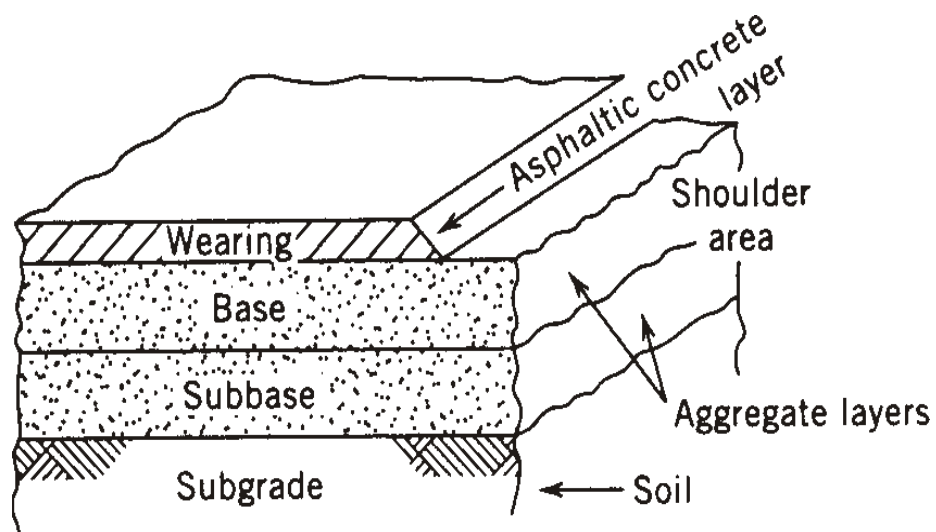


Figure 8.2 – Flexible pavement

Ground Preparation and Earthworks

Before construction begins, the **ground must be leveled and compacted**. Heavy machinery such as **bulldozers** (Figure 8.3) push and spread soil along the designated route to achieve a uniform grade. **Excavators** (Figure 8.4) are used to dig, cut, and move soil, while simultaneously creating ditches for drainage systems along the road edges.



Figure 8.3 – Bulldozer pushes and spreads earth



Figure 8.4 – Excavator digs and moves earth

In many cases, the **subgrade soil must be stabilized** to improve its load-bearing capacity. Stabilization can involve mixing soil with lime, cement, or other additives, a technique guided by the principles of **soil mechanics**. Soil mechanics classifies soils based on texture, cohesion, and compressibility, and relates these properties to the expected performance of the pavement under traffic loads. Proper soil preparation is essential to prevent future settlement, cracking, or deformation 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.

An important economic consideration in road construction is the balance of **cut and fill**. The volume of earth removed from a cut should ideally equal the volume needed for nearby embankments, minimizing the cost of transporting soil over long distances.

Layer Construction

After the subgrade is prepared, **soil compactors** move slowly over the surface to ensure proper density and stability. The next step involves placing the **sub-base and base layers**, usually consisting of crushed stones or aggregates transported to the site by **loaders** (Figure 8.5). These layers distribute vehicle loads and provide structural support for the top pavement.



Figure 8.5 – Loader collects crushed stones

The **wearing surface** is then laid on top of the base. For rigid pavements, this consists of concrete slabs, while for flexible pavements, **hot asphalt** is spread and flattened using **road rollers**. The wearing surface is designed to be **waterproof**, resistant to abrasion, and durable under high traffic loads. Proper compaction and

finishing of the top layer are critical to ensure a smooth, safe, and long-lasting road.

Drainage and Sustainability

Effective **drainage systems** are essential in road construction. Rainwater must be efficiently drained away from the pavement to prevent erosion, weakening of subgrades, and long-term pavement damage. Culverts, side ditches, and stormwater drains are incorporated to maintain the structural integrity of the road. Modern road engineering also emphasizes **sustainable practices**, such as recycling construction materials, reducing earthworks where possible, and using high-performance asphalt and concrete mixtures to extend the lifespan of pavements.

This process demonstrates that road construction is not only a matter of laying materials but involves careful planning, material selection, earthwork management, and quality control. Each layer serves a specific purpose in load distribution, stability, and durability, ensuring that roads can safely support traffic while remaining functional for decades.

Terminological Glossary

1. **Sub-base** – an optional layer of granular material placed above the subgrade to improve load distribution and stability.
2. **Base course** – a compacted layer of aggregates that supports the wearing surface and distributes loads.
3. **Wearing surface (surface course)** – the top layer of the pavement that directly contacts traffic and provides durability and waterproofing.
4. **Rigid pavement** – pavement constructed with Portland cement concrete and aggregates, providing high compressive strength.
5. **Flexible pavement** – pavement with a wearing surface made of asphaltic concrete, allowing load distribution through flexibility.
6. **Soil compactor** – machinery used to increase soil density and stability by mechanical compaction.
7. **Bulldozer** – heavy equipment used to level and move soil along a construction site.

8. **Excavator** – machinery used for digging, cutting, and moving large amounts of soil.
9. **Asphaltic concrete** – mixture of asphalt binder and aggregates used in flexible pavements.
10. **Road roller** – heavy machinery used to compact asphalt or soil to create a smooth, durable surface.
11. **Soil stabilization** – methods of improving the load-bearing capacity of soil, often using additives like cement or lime.
12. **Cut and fill** – the process of removing soil from elevated areas (cut) and using it to fill low areas (fill) in road construction.
13. **Earthworks** – the engineering processes of moving and shaping soil and rock to prepare the site for construction.
14. **Compacted soil** – soil mechanically densified to increase strength and support pavement layers.

LANGUAGE PRACTICE

Answer the questions.

1. What is the complete multi-layered structure of a road called?
2. Name the main layers of a pavement in order from bottom to top.
3. What is the difference between rigid and flexible pavements?
4. What materials are used in the wearing surface of rigid and flexible pavements?
5. Why is subgrade preparation essential before road construction?
6. What machinery is typically used to level and move soil for a new road?
7. How can soil be stabilized if it is not strong enough to support traffic loads?
8. Explain the importance of cut and fill balance in road construction.
9. What is the role of the wearing surface in a road pavement?
10. Why are drainage systems critical in road construction?

Exercise 1. Match the terms with their definitions.

Term	Definition
1. Subgrade	a) Top layer of the road that resists traffic and environmental wear
2. Wearing surface	b) Prepared soil that supports all pavement layers
3. Base course	c) Compacted layer of aggregates supporting the wearing surface
4. Asphaltic concrete	d) Flexible mixture of asphalt binder and aggregates
5. Soil stabilization	e) Methods used to improve soil strength and load-bearing capacity

Exercise 2. Complete the sentences with the following words:

roller, bulldozer, excavator, cut, fill, drainage

1. A _____ is used to level the ground along the road route.
2. Huge amounts of soil are moved by an _____.
3. The road is compacted using a heavy _____.
4. The process of removing soil from high areas is called _____.
5. Soil removed from a cut may be used in a _____.
6. Proper _____ ensures that rainwater does not damage the road.

Exercise 3. Mark statements as True (T) or False (F). Correct the false ones.

1. Flexible pavements are made of concrete slabs.
2. Drainage is essential to prevent erosion and pavement damage.
3. The wearing surface is placed directly over the subgrade in all cases.
4. Soil compaction improves load-bearing capacity.
5. Asphaltic concrete is used only in rigid pavements.

Exercise 4. Choose the correct answer.

1. Which layer directly supports vehicle loads and distributes them to lower

layers?

- a) Wearing surface b) Subgrade c) Base course
- 2. What is the main function of a bulldozer in road construction?
 - a) Compaction of soil b) Leveling and spreading earth
 - c) Pouring asphalt
- 3. Why is soil stabilization sometimes necessary?
 - a) To reduce water runoff b) To improve load-bearing capacity
 - c) To create decorative surfaces

Exercise 5. Answer in 2–3 sentences.

- 1. What are the main layers of a road pavement, and what is the function of each?
- 2. How do machinery like bulldozers, loaders, and rollers contribute to road construction?
- 3. Why is proper drainage essential in road engineering?

Exercise 6. Write 150–180 words or discuss orally:

- 1. Compare rigid and flexible pavements in terms of materials, strength, and durability.
- 2. Explain the role of soil mechanics in modern road construction.
- 3. Discuss the importance of planning cut and fill operations in highway construction.

Exercise 7. 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 8.6.). The earth (smooth) and (flatten) by rollers.



Figure 8.6 – Tipper truck

UNIT 9

TUNNELS

Tunnels are essential structures in civil and transportation engineering, allowing roads, railways, pipelines, and utilities to pass through obstacles such as mountains, rivers, or urban areas. The concept of tunnelling dates back to ancient times, when tunnels were primarily constructed for irrigation, drainage, and water management. Early tunnels were usually hand-dug and relatively short, designed to transport water from one place to another or to drain excess water from fields.

Over the centuries, tunnels were increasingly constructed for canals, providing a navigable route through difficult terrain. The canal tunnels of the 18th and 19th centuries represented significant engineering achievements, as they had to accommodate boats, maintain water levels, and ensure structural stability in variable soil and rock conditions.

The advent of railways in the 19th century greatly increased the importance and scale of tunnelling. Railway tunnels needed to be longer, more stable, and capable of supporting heavy loads while providing sufficient clearance for trains. This period also saw the development of new tunnelling techniques, including the

use of explosives to excavate hard rock and the introduction of lining methods to ensure tunnel stability.

Today, the construction of tunnels depends on multiple factors, including the type and condition of the ground or rock, the tunnel's purpose, and its length. Modern tunnelling methods vary from conventional drill-and-blast techniques in hard rock to mechanized tunnelling using tunnel boring machines (TBMs) for softer soils or long underground passages. The choice of method also depends on environmental conditions, safety requirements, and economic considerations.

Tunnels may be lined with reinforced concrete, steel segments, or shotcrete, depending on ground conditions and design requirements. Ventilation, lighting, drainage, and waterproofing systems are critical in modern tunnel engineering to ensure structural safety and usability. Long tunnels, such as those used for high-speed railways or metro systems, often require advanced geotechnical investigations before construction to assess soil and rock behavior under excavation.

Underwater and Rock Tunnels

The first underwater tunnel, the Thames Tunnel, was completed in 1843. Designed by Marc Brunel and Isambard K. Brunel, it faced floods, financial losses, and human hazards. Marc Brunel invented the tunnelling shield (Figure 9.1.), which protected workers while digging through clay and mud.



Figure 9.1 – M. Brunel's tunneling shield

Shields have since evolved into steel tubes and are now used with tunnel boring machines (TBMs) or micro-tunnelling machines (Figure 9.2.). The Thames Tunnel is still part of the London Underground.

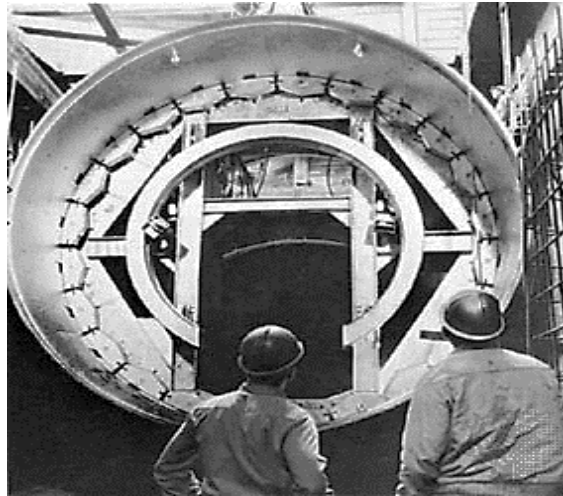


Figure 9.2 – Tunneling shield for San Francisco subway

The Seikan Tunnel in Japan, completed between 1971–1988, is the world's longest underwater rail tunnel at 55 km, running under volcanic rock between Honshu and Hokkaido. It was more difficult and costly 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.

The **Channel Tunnel**, a 49 km rail link between England and France, was built using TBMs with rotating cutting heads moved by hydraulic jacks. It has three tunnels: two for trains and one for ventilation and service. 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. (Figure 9.3.).

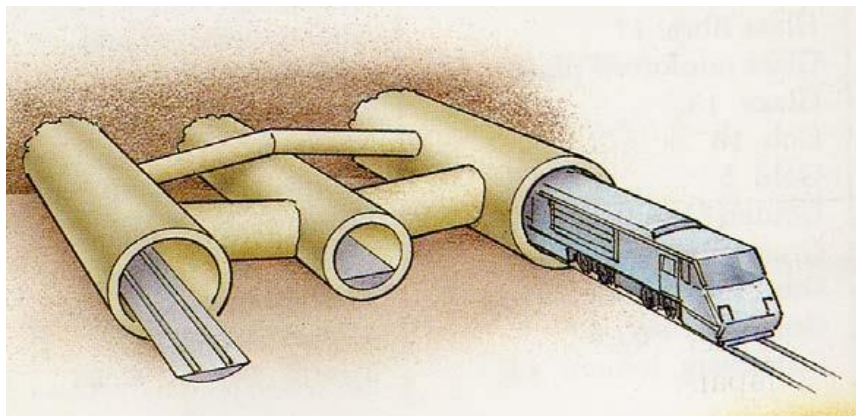


Figure 9.3 – The Channel Tunnel

Another method for underwater tunnels is the **immersed tube system**, used since the early 20th century. Steel tube segments are floated into a dredged trench, sunk, joined underwater, pumped dry, and covered with material.

Rock tunnels are mainly used for railways or roads through mountains. Historic examples, such as the Simplon Tunnel, were built by blasting with dynamite (Figure 9.4.). Modern tunnels use TBMs (“moles”) advancing up to 76 m per day depending on diameter and rock type.

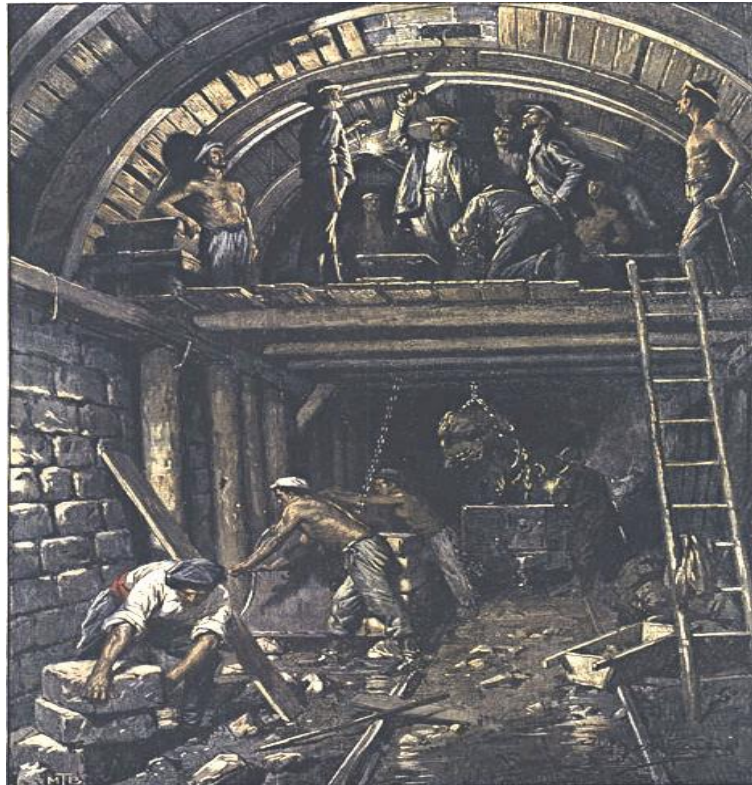


Figure 9.4 – Simplon Tunnel under construction

The first major tunnel built through rock was the **Mont Cenis Tunnel** (Figure 9.5.) in the Alps between France and Italy. It is fourteen kilometres long and it was built around the middle of the 19th century. Initial progress was slow (22 cm/day) until **G. Sommelier** introduced the **pneumatic drill**, increasing speed to 2 m/day (Figure 9.5.). He also pioneered rail-mounted drill carriages and construction camps for workers.



Figure 9.5 – Construction of Mont Cenis Tunnel

Today, drilling and blasting are being replaced by TBMs or heavy hydraulic hammers. TBMs are safer than explosives, preserve ground stability, and are used in both hard and soft ground, but they are expensive and inflexible.

Tunnelling is not only a technical challenge but also a strategic engineering solution, allowing efficient transportation and utility systems in regions where surface routes are impractical. Advances in material science, geotechnical engineering, and construction technology continue to expand the possibilities for safe and economical tunnel construction, enabling engineers to build increasingly long, complex, and environmentally sustainable underground structures.

Terminological Glossary

1. **Tunnelling** – the engineering process of designing, excavating, and supporting a tunnel.
2. **TBM (Tunnel Boring Machine)** – mechanized equipment used for excavating long tunnels in soft soils or rock.
3. **Drill-and-blast method** – traditional technique for excavating hard rock

using drilling and controlled explosives.

4. **Shotcrete** – sprayed concrete used to support tunnel walls and prevent collapse.
5. **Lining** – structural layer installed inside a tunnel for stability and waterproofing.
6. **Mechanized tunnelling** – excavation using advanced machines like TBMs instead of manual labor or explosives.
7. **Irrigation tunnel** – a tunnel constructed to convey water for agricultural purposes.
8. **Structural stability** – the ability of a tunnel to maintain its shape and support loads without collapse.

LANGUAGE PRACTICE

Answer the questions.

1. What were the primary purposes of tunnels in ancient times?
2. How were tunnels used for canals in the 18th and 19th centuries?
3. Why did the advent of railways increase the importance of tunnelling?
4. What are the main factors that determine how a tunnel is constructed today?
5. Name two modern tunnelling techniques and the types of ground they are used in.
6. What materials are commonly used to line tunnels?
7. Why are ventilation, lighting, drainage, and waterproofing important in tunnels?
8. How does geotechnical investigation influence tunnel construction?
9. What are the main differences between conventional drill-and-blast tunnelling and mechanized TBM tunnelling?
10. Why is tunnelling considered a strategic engineering solution in modern infrastructure?
11. How has tunnelling technology evolved from ancient irrigation tunnels to modern metro systems?

12. What challenges do long tunnels present compared to shorter tunnels?
13. How does soil or rock condition affect the choice of tunnelling method?
14. What role does material science play in modern tunnel construction?
15. How does tunnelling contribute to environmental and urban planning solutions?

Exercise 1. Match the terms with their definitions.

Term	Definition
1. Tunnel	a) Sprayed concrete used for tunnel support
2. TBM	b) Mechanized machine for excavating tunnels
3. Drill-and-blast method	c) Underground passage for transportation or utilities
4. Lining	d) Structural layer providing stability and waterproofing
5. Shotcrete	e) Excavation using drilling and controlled explosives

Exercise 2. Complete the sentences with the following words:

geotechnical, ventilation, excavation, lining, reinforced concrete, irrigation

1. Modern tunnels are often lined with _____ for stability and durability.
2. Before construction, engineers perform _____ studies to evaluate soil and rock conditions.
3. Ancient tunnels were mostly used for _____ purposes.
4. Safe tunnel operation requires proper _____ and drainage systems.
5. The first step in creating a tunnel is _____ of soil or rock.
6. Tunnel linings are often made of _____ to withstand high loads.

Exercise 3. Mark statements as True (T) or False (F). Correct the false ones.

1. TBMs are used mainly in hard rock tunnels.
2. Drill-and-blast is a conventional method for soft soil tunnels.
3. Shotcrete provides temporary or permanent support to tunnel walls.
4. Geotechnical investigation is unnecessary if the tunnel is short.

5. Ventilation and drainage systems are critical for tunnel safety and durability.

Exercise 4. Choose the correct answer.

1. What determines the method of tunnel construction?
 - a) Ground type, tunnel length, and purpose
 - b) Color of rock and tunnel depth
 - c) Only the tunnel's length
2. Why is reinforced concrete used for tunnel linings?
 - a) It is cheaper than steel
 - b) It provides structural stability and resistance to loads
 - c) It allows faster excavation
3. Which modern equipment allows tunnelling in long soft soil passages?
 - a) Excavator
 - b) TBM
 - c) Bulldozer

Exercise 5. Answer in 2–3 sentences.

1. Explain the difference between conventional and mechanized tunnelling.
2. Why is geotechnical investigation crucial for long tunnels?
3. How do ventilation and drainage contribute to tunnel safety and longevity?

Exercise 6. Write 150–180 words or discuss orally:

1. Compare ancient irrigation tunnels with modern metro or railway tunnels in terms of engineering complexity.
2. Discuss how soil and rock conditions influence tunnel design and method choice.
3. Explain the importance of modern materials like reinforced concrete and shotcrete in tunnel construction.

UNIT 10

BRIDGES

Bridges are among the earliest and most essential structures in human engineering, providing safe passage over obstacles such as rivers, valleys, and roads. The simplest early bridges were constructed from materials readily available in nature, such as logs, ropes, stones, and timber. These primitive structures were limited in span and load-bearing capacity, yet they formed the foundation for more advanced engineering techniques.

The Romans were the first great master builders of bridges. They developed the arch bridge, a design that allowed for longer spans and greater durability. Roman engineers also applied these principles to the construction of aqueducts, enabling the transport of water over long distances. Many Roman bridges and aqueducts, such as the Pont du Gard in France, have survived for nearly two millennia, demonstrating the effectiveness of their engineering methods.

Modern bridges must meet several critical engineering requirements. A bridge must support its own weight (dead load), the weight of traffic crossing it (live load), and resist dynamic stresses such as those caused by wind, earthquakes, and thermal expansion. Advanced materials, including reinforced concrete, structural steel, and composite materials, allow engineers to design longer, stronger, and more flexible bridges.

Bridges are also classified according to their structural systems, including **beam bridges, arch bridges, suspension bridges, cable-stayed bridges, and truss bridges**. Each type distributes loads differently and is chosen based on factors such as span length, environmental conditions, aesthetic requirements, and economic considerations.

The beam or girder bridge (Figure 10.1.) 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.



Figure 10.1 – The Bridge of Croatian Defendants over Riječina, Rijeka

The arch bridge (Figure 10.2.) 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 18th century were built of masonry.



Figure 10.2 – Krk Bridge

The truss bridge (Figure 10.3.) 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 built of steel, concrete, light alloy or timber as they are also widely used in the construction of roofs.



Figure 10.3 – 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 10.4.) 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 exceedingly difficult to build, because it is across what is open sea, with strong tides.



Figure 10.4 – Brooklyn Bridge, New York

The movable bridge (Figure 10.5.) 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 10.5 – Tower Bridge, London

The cable-stayed bridge (Figure 10.6.) 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.



Figure 10.6 – Dubrovnik Bridge

Terminological Glossary

1. **Dead load** – the weight of the bridge structure itself.
2. **Live load** – the weight of vehicles, pedestrians, or other traffic crossing the bridge.
3. **Dynamic stresses** – forces acting on a structure due to wind, seismic activity, or vibration.
4. **Arch bridge** – a bridge with a curved structure distributing weight through compression.
5. **Beam bridge** – a bridge supported by beams spanning between piers or abutments.
6. **Suspension bridge** – a bridge in which the deck is hung from cables under tension.
7. **Cable-stayed bridge** – a bridge in which cables are attached directly from the towers to the deck.
8. **Truss bridge** – a bridge whose structure is composed of interconnected triangular units.
9. **Fatigue** – weakening of a material due to repeated stress or load cycles.
10. **Corrosion** – degradation of materials, especially metals, due to environmental reactions.
11. **Seismic activity** – movement of the earth's crust that can produce forces acting on structures.

LANGUAGE PRACTICE

Answer the questions.

1. What were the simplest forms of early bridges made from?
2. Which civilization is considered the first master builder of bridges?
3. What is the main structural principle used in Roman bridges and aqueducts?
4. Name one surviving Roman bridge or aqueduct.
5. What are the primary loads that a bridge must support?
6. How do dynamic stresses affect bridge structures?

7. List some modern materials used in bridge construction.
8. Name at least three types of modern bridges based on structural systems.
9. How do structural systems affect load distribution in bridges?
10. Why is durability and maintenance important in bridge engineering?
11. How do engineers account for environmental factors such as wind, earthquakes, or thermal expansion?
12. Give examples of modern bridges that combine engineering and architectural innovation.
13. What role does material selection play in bridge design?
14. How has bridge engineering evolved from Roman times to modern times?
15. What factors influence the choice of bridge type in a particular location?

Exercise 1. Match the terms with their definitions.

Term	Definition
1. Dead load	a) Concrete strengthened with steel for improved structural performance
2. Live load	b) Weight of vehicles or pedestrians crossing a bridge
3. Arch bridge	c) Weight of the bridge itself
4. Suspension bridge	d) A bridge with a curved structure transferring loads through compression
5. Reinforced concrete	e) A bridge deck supported by cables hung from towers

Exercise 2. Complete the sentences with the following words:

dynamic stresses, material selection, truss bridge, aqueducts, thermal expansion, cable-stayed bridge

1. Roman engineers used arches to build bridges and _____.
2. Modern engineers account for _____ caused by wind, earthquakes, or vibrations.

3. _____ is a structural system where cables run directly from towers to the deck.
4. Choosing the right _____ ensures durability and safety of the bridge.
5. A _____ consists of interconnected triangular units to distribute forces efficiently.
6. Bridges must tolerate _____, which occurs due to temperature changes.

Exercise 3. Mark statements as True (T) or False (F). Correct the false ones.

1. Live load includes the weight of the bridge structure itself.
2. Roman aqueducts demonstrate the durability of arch design.
3. Fatigue and corrosion are not major concerns in modern bridges.
4. Beam bridges span between piers or abutments.
5. Suspension bridges transfer deck load to towers through cables.

Exercise 4. Choose the correct answer.

1. Which material allows bridges to have longer spans and flexibility in design?
a) Wood b) Structural steel c) Stone
2. Which factor is critical when designing a bridge in a seismic zone?
a) Traffic signs b) Dynamic stresses c) Color of paint
3. What is the primary purpose of an arch in bridge construction?
a) Decoration b) Transfer loads through compression
c) Reduce material cost

Exercise 5. Answer in 2–3 sentences.

1. Explain why Roman bridges have survived for thousands of years.
2. How do engineers account for both live and dead loads in bridge design?
3. What is the difference between a suspension bridge and a cable-stayed bridge?

Exercise 6. Write 150–180 words or discuss orally.

1. Compare ancient and modern bridge construction in terms of materials, structural systems, and durability.
2. Discuss how modern bridges combine engineering efficiency with architectural aesthetics.
3. Explain the importance of accounting for environmental factors such as wind, seismic activity, and thermal expansion in bridge design.

UNIT 11

HOW ARE BRIDGES BUILT?

Bridge construction often presents significant engineering challenges. Each type of bridge – whether beam, arch, suspension, or cantilever – has its own unique construction difficulties. One of the most critical aspects of bridge construction is the foundation, which must support not only the weight of the bridge itself but also the dynamic loads from traffic, wind, and seismic activity. In many cases, foundations must rest on bedrock, often located below rivers or other bodies of water.

One traditional technique for constructing foundations underwater is the use of a **cofferdam** (Figure 11.1.). Cofferdams were first developed by the Romans and consist of a temporary enclosure built around the construction area. Water is pumped out, allowing workers to access the riverbed or seabed safely. Modern cofferdams are often constructed from interlocking steel plates driven into the ground. These structures are generally effective down to depths of 10 meters, beyond which more

advanced methods are required.



Figure 11.1 – A cofferdam

For deeper foundations, engineers use **pneumatic caissons** (Figure 11.2.), large watertight structures in which air pressure is used to prevent water and soil from entering the working chamber. Workers can excavate the foundation material under controlled conditions, and the caisson is gradually sunk into place until it reaches the required depth.

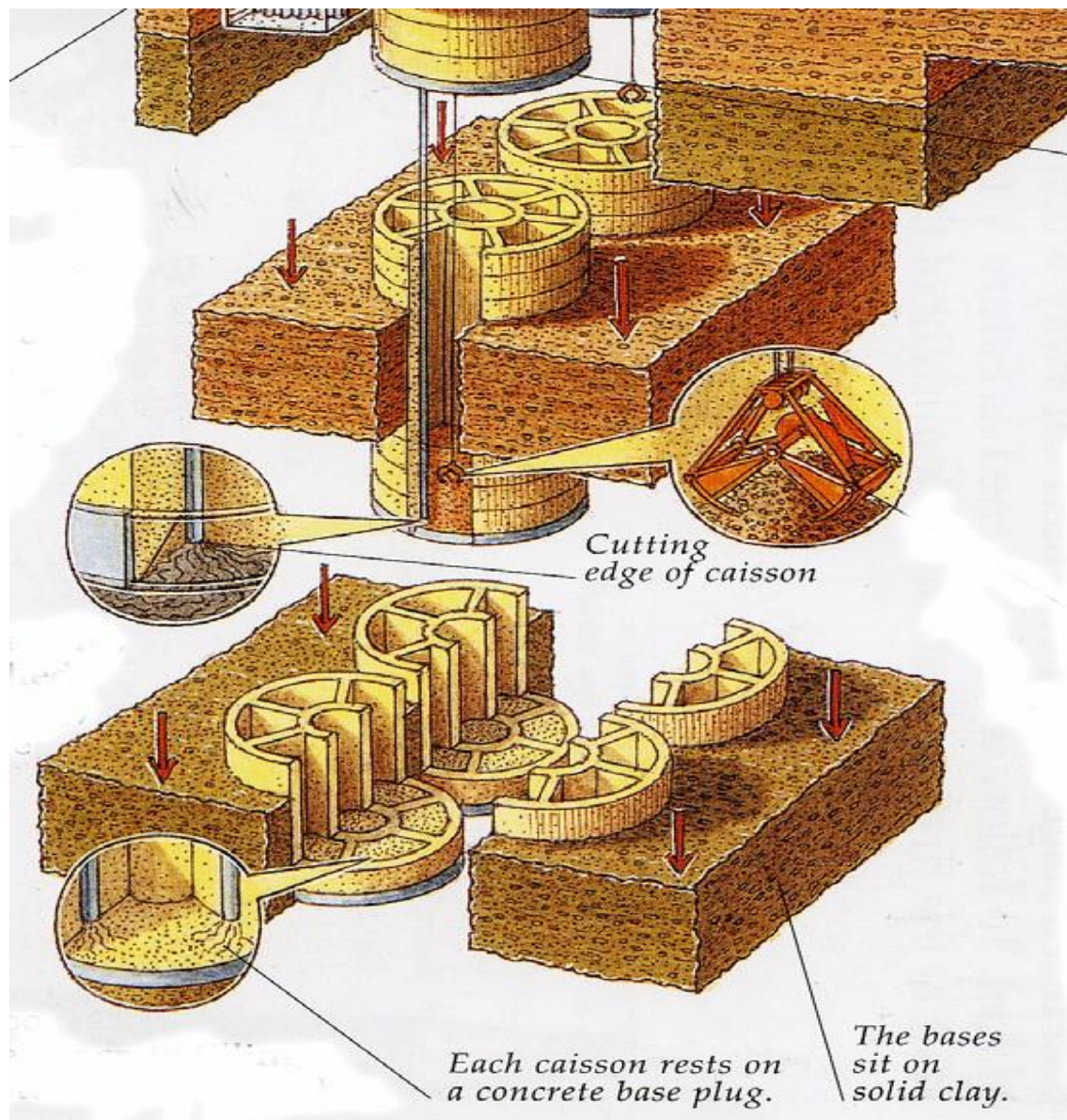


Figure 11.2 – A part of a caisson

In the late 19th century, as engineers sought to span longer distances, the **cantilever bridge** was developed (Figure 11.3.). The cantilever is an extension of the beam, consisting of a bracket anchored at one end and free at the other. Cantilever bridges often have two independent cantilever arms projecting toward each other, joined by a **suspended central span**. In the most common three-span configuration, the central span rests on the cantilever arms, while the outer spans are anchored to the shore and extend into the central span. Cantilever construction allows large spans to be built without the need for temporary scaffolding in the middle of the river or valley.



Figure 11.3 – Cantilevering of a bridge

Arch bridges present a different challenge. The arch structure is inherently unstable until both sides meet at the crown. Traditionally, engineers used a method called centering, in which a temporary wooden framework supported both halves of the arch until they were connected at the top. In modern arch bridge construction, the span can be floated or lifted into position after the piers have been built and then raised using hydraulic jacks or cranes (Figure 11.4.). This allows for efficient construction over rivers, deep valleys, or urban obstacles where scaffolding is impractical.

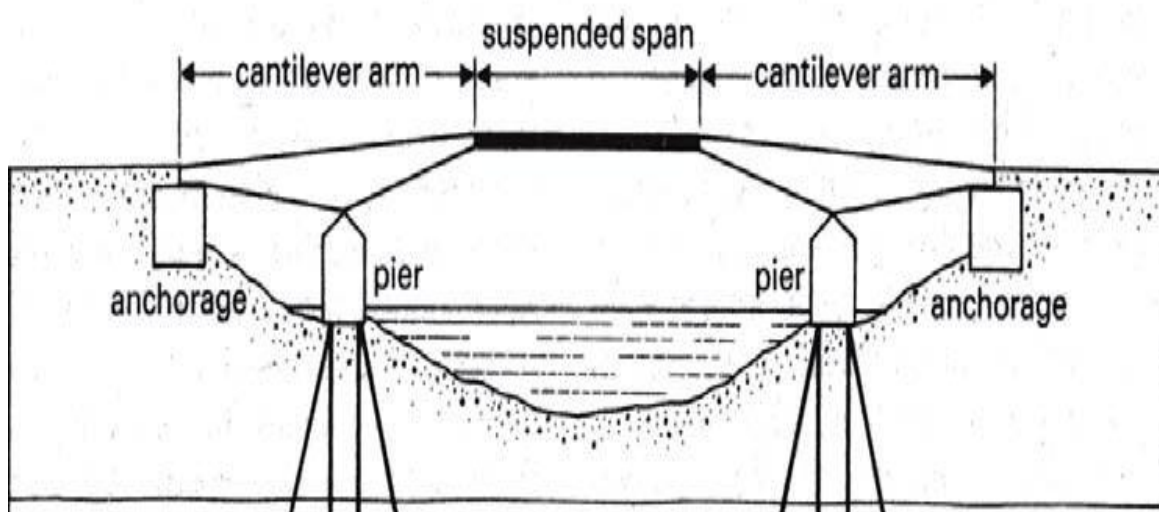


Figure 11.4 – Structural parts of a bridge

Bridge construction combines advanced structural analysis, material science, and construction management. Modern engineers must carefully plan each stage, considering not only structural stability during construction but also long-term durability, load distribution, and environmental impacts. The integration of reinforced concrete, structural steel, and composite materials has expanded the possibilities for bridge design, allowing longer spans, more complex shapes, and safer construction techniques.

Terminological Glossary

1. **Bridge pier** – a vertical support that carries the load of a bridge between spans.
2. **Foundation** – the structural base that transfers the load of the bridge to the ground.
3. **Cofferdam** – a temporary enclosure built to allow construction of foundations under water.
4. **Pneumatic caisson** – a watertight structure using compressed air for deep underwater foundations.
5. **Cantilever bridge** – a bridge where beams project from fixed supports, often joined by a central suspended span.
6. **Suspended span** – the portion of a cantilever bridge resting on cantilever arms, connecting two independent cantilevers.
7. **Centering** – temporary wooden or steel framework supporting an arch until it becomes self-supporting.
8. **Hydraulic jack** – a mechanical device used to lift heavy structures like bridge spans.
9. **Scaffolding** – temporary structures supporting construction activities above ground or water.
10. **Structural stability** – the ability of a structure to maintain its shape under applied loads.
11. **Construction management** – planning, coordinating, and supervising

construction processes efficiently.

LANGUAGE PRACTICE

Answer the questions:

1. What are the main challenges in bridge construction?
2. Why are foundations critical for bridge stability?
3. What is a cofferdam and how does it work?
4. Up to what depth are cofferdams generally effective?
5. What is a pneumatic caisson and when is it used?
6. How does a cantilever bridge differ from a simple beam bridge?
7. Describe the three-span configuration of a cantilever bridge.
8. Why are arch bridges unstable until the spans meet at the crown?
9. What is the traditional centering method in arch bridge construction?
10. How are modern arch spans positioned without full centering?
11. What materials are typically used in modern bridge construction?
12. Why is the cantilever method useful for building bridges over deep rivers or valleys?
13. What role do hydraulic jacks or cranes play in arch bridge construction?
14. How do engineers ensure structural stability during bridge construction?
15. How has material science expanded the possibilities for modern bridge design?

Exercise 1. Match the terms with their definitions.

Term	Definition
1. Cofferdam	a) A bridge portion resting on cantilever arms connecting two independent cantilevers
2. Pneumatic caisson	b) Temporary framework supporting an arch until it becomes self-supporting
3. Cantilever bridge	c) A watertight structure using compressed air for underwater foundations

4. Centering	d) Temporary enclosure to exclude water for foundation construction
5. Suspended span	e) A bridge with beams projecting from fixed supports

Exercise 2. Complete the sentences with the following words:

hydraulic jack, reinforced concrete, scaffolding, central span, bedrock, load distribution

1. Foundations must often rest on solid _____ to ensure stability.
2. The _____ connects two cantilever arms in a cantilever bridge.
3. Modern bridges often use _____ to combine tensile and compressive strength.
4. Engineers use _____ to lift arch spans into position.
5. Temporary _____ supports construction above water or ground.
6. Proper _____ is critical for structural safety during bridge construction.

Exercise 3. Mark statements as True (T) or False (F). Correct the false ones.

1. Cofferdams are used only for foundations on land.
2. Cantilever bridges can be built without temporary support in the central section.
3. Centering was a method used since Roman times for arch bridges.
4. Pneumatic caissons are necessary for deep-water foundations.
5. Reinforced concrete is rarely used in modern bridge construction.

Exercise 4. Choose the correct answer.

1. What is the main purpose of a cantilever bridge?
 - a) To minimize material cost
 - b) To span long distances without central scaffolding
 - c) To create decorative shapes
2. Why are arch bridges unstable until completion?

- a) The materials are weak
 - b) The structure relies on compression, which is incomplete until the crown meets
 - c) They are supported only by cables
3. Which method allows workers to build underwater foundations safely?
- a) Cantilevering b) Cofferdam c) Centering

Exercise 5. Answer in 2–3 sentences.

1. Explain how cofferdams and caissons differ in underwater foundation construction.
2. Describe how a cantilever bridge is built step by step.
3. Why is centering necessary for traditional arch bridges?

Exercise 6. Write 150–180 words or discuss orally.

1. Compare modern and traditional methods of building bridges over water.
2. Discuss the advantages of using cantilever construction for long spans.
3. Explain how modern materials and machinery have changed bridge construction compared to ancient techniques.

Exercise 7. 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 the distance 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.

Exercise 8. Name each of the following bridges and define its characteristics.



Figure 11.5

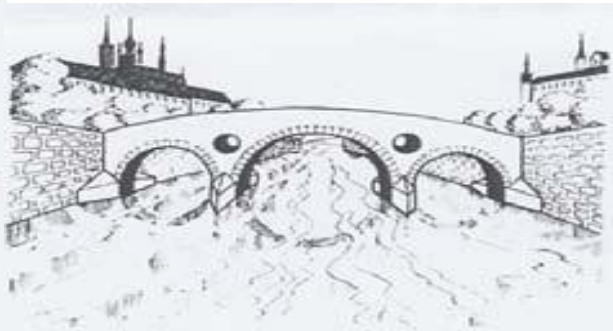


Figure 11.6

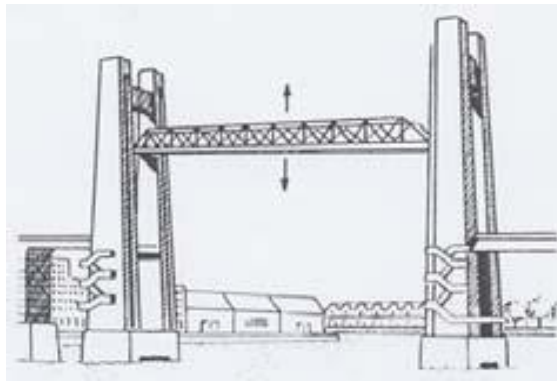


Figure 11.7

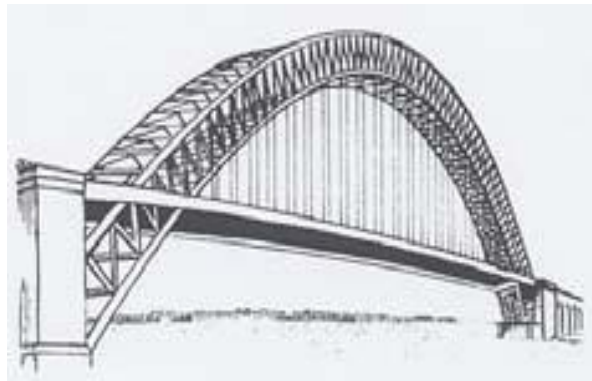


Figure 11.8

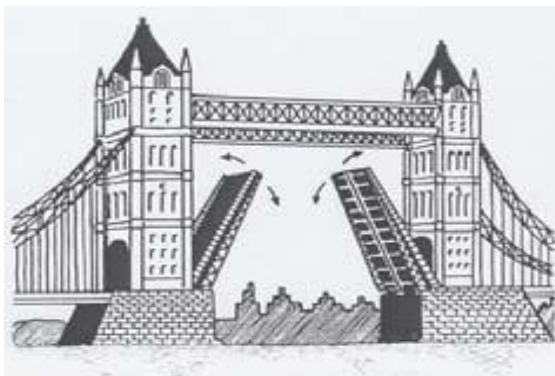


Figure 11.9

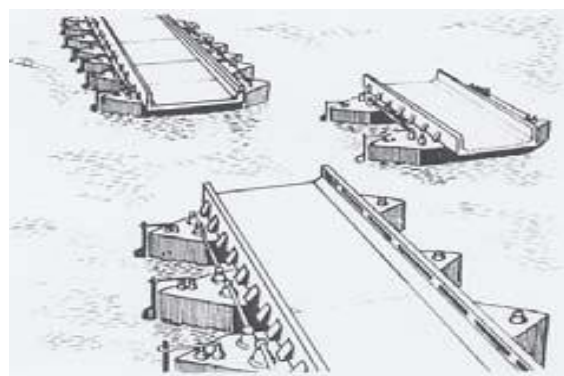


Figure 11.10

UNIT 12

DOMES

A **dome** is a curved roof or vault, one of the oldest and most significant structural forms in architecture. Its origins can be traced back to circular **mud-brick**

huts in Mesopotamia approximately 6,000 years ago. In Europe, similar constructions were created by the Mycenaean Greeks in the 14th century BC. They built **stone tombs** consisting of blocks arranged in superimposed concentric circles (Figure 12.1.).



Figure 12.1 – Mycenae, Tomb of Agamemnon, Greece

The **Romans** were the first to develop the masonry dome in its purest form and on a monumental scale. Their expertise culminated in the **Pantheon**, a temple commissioned by Emperor Hadrian in the 2nd century AD (Figure 12.2.).



Figure 12.2 – The Pantheon, Rome

The monolithic dome of the rotunda behind the portico measures 43.2 m in diameter. To illuminate the interior, engineers incorporated a circular opening at the apex, called the **oculus**, 8.5 m in diameter. Because of the dome's immense weight, they also created **coffers**, recessed panels along the interior, to reduce the overall mass. The size and longevity of the Pantheon demonstrate the Romans' mastery of concrete chemistry and large-scale construction techniques.

During the early Middle Ages, **Byzantine engineers** further advanced dome construction. In **Constantinople**, a succession of large domed churches reached its pinnacle with **Hagia Sophia** in the 6th century (Figure 12.3.).



Figure 12.3 – Hagia Sophia, Istanbul

Hagia Sophia features a shallow dome ringed with windows at its base and supported on four **pendentives** – curved triangular segments that transition a square base into a circular support for the dome. These pendentives are reinforced by massive exterior piers and semi-domes, creating a complex and stable structural system.

Following Hagia Sophia, **Islamic architecture** widely adopted domes. One of the earliest examples is the **Dome of the Rock** (691) in Jerusalem (Figure 12.4.), which features a double dome of timber construction set on a pillared arcade.



Figure 12.4 – The Dome of the Rock, Jerusalem

A major transformation in dome construction occurred during the Renaissance with **Filippo Brunelleschi's** octagonal dome of the **Florence Cathedral** (15th century) (Figure 12.5.). Measuring 39 m in diameter and 91 m high, it consists of an outer roof protecting an inner masonry shell. The dome is reinforced by eight primary ribs and sixteen secondary ribs, forming a tightly interlocked masonry framework.



Figure 12.5 – The cathedral, Florence

St. Peter's Basilica in Rome represents a further evolution in engineering sophistication (Figure 12.6.). Its multi-ribbed dome became a model for domes worldwide. 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 12.6 – St. Peter's Basilica, Rome

The 20th century introduced revolutionary developments in dome design. **Buckminster Fuller** patented the **geodesic dome** in 1947 (Figure 12.7.). It consists of a lattice of interlocking **tetrahedrons and octahedrons** made of lightweight materials such as steel, fiberglass, plastic, or reinforced concrete.



Figure 12.7 – Geodesic dome by B. Fuller

Geodesic domes require no internal structural supports, making them ideal for large open spaces such as **sports arenas** and **botanical gardens** (Figure 12.8.). Their strength, lightness, and adaptability have made them an enduring architectural and engineering solution. The geodesical domes have found many uses as botanical gardens and sports-arenas.



Figure 12.8 – Biosphère, Sainte-Hélène, Montreal

Terminological Glossary

1. **Dome** – a curved roof or vault, often hemispherical, used in architecture for large enclosed spaces.
2. **Oculus** – a circular opening at the top of a dome allowing natural light to enter.
3. **Coffer** – a recessed panel in a dome or ceiling that reduces weight and adds decorative effect.
4. **Pendentive** – a triangular segment of a spherical surface that transitions a square base to support a dome.
5. **Rotunda** – a circular building or room, often topped with a dome.
6. **Ribbed dome** – a dome reinforced with structural ribs to provide additional support.
7. **Tension ring** – an iron or steel ring used to prevent a dome from spreading or cracking.
8. **Geodesic dome** – a lightweight spherical structure composed of a lattice of interlocking triangles.
9. **Tetrahedron** – a polyhedron with four triangular faces used in geodesic dome construction.
10. **Octahedron** – a polyhedron with eight triangular faces, part of geodesic dome geometry.
11. **Pillared arcade** – a series of columns supporting arches, often forming a base for a dome.
12. **Semi-dome** – a half-dome used to support or transition to the main dome structure.
13. **Masonry shell** – the inner structural layer of a dome, carrying most of the compressive load.
14. **Architectural cage** – a system of interlocking ribs or supports forming a stable structural framework.

LANGUAGE PRACTICE

Answer the questions.

1. What is a dome, and where did it originate?
2. How did the Mycenaean Greeks use domes in their architecture?
3. Which Roman building is considered the pinnacle of masonry dome construction?
4. What is the purpose of the oculus in the Pantheon?
5. How did Roman engineers reduce the weight of large masonry domes?
6. What structural innovation did Byzantine engineers use in Hagia Sophia?
7. Define a pendentive and explain its function.
8. How did Islamic architects incorporate domes in early buildings like the Dome of the Rock?
9. What innovation did Filippo Brunelleschi introduce in the Florence Cathedral dome?
10. How are the ribs of Brunelleschi's dome arranged, and what is their purpose?
11. What engineering solution was used to prevent the collapse of St. Peter's Basilica dome?
12. Who invented the geodesic dome, and when?
13. What is the structural principle of a geodesic dome?
14. Why are geodesic domes ideal for large open spaces?
15. What materials are commonly used in modern geodesic domes?

Exercise 1. Match the terms with their definitions.

Term	Definition
1. Oculus	a) Triangular section that allows a dome to sit on a square base
2. Pendentive	b) Lightweight spherical structure composed of interlocking triangles
3. Coffer	c) Circular opening at the top of a dome
4. Geodesic dome	d) Iron or steel ring used to prevent structural spreading
5. Tension ring	e) Recessed panel in a dome to reduce weight

Exercise 2. Complete the sentences with the following words:

rotunda, ribs, pendentives, masonry, tetrahedron, pillared arcade

1. Hagia Sophia's dome is supported on four _____.
2. Brunelleschi's dome features eight primary and sixteen secondary _____.
3. The Pantheon is a monumental _____ topped with a massive dome.
4. A geodesic dome uses a lattice of interlocking _____.
5. The Dome of the Rock rests on a _____ base of columns and arches.
6. Roman engineers mastered the use of _____ for large-scale domes.

Exercise 3. Mark statements as True (T) or False (F). Correct the false ones.

1. The oculus in the Pantheon is purely decorative.
2. Pendentives are used to transition a circular dome onto a square base.
3. Brunelleschi's dome of Florence Cathedral has no ribs.
4. St. Peter's Basilica dome required tension rings to maintain structural stability.
5. Geodesic domes eliminate the need for internal support structures.

Exercise 4. Choose the correct answer.

1. What is the main advantage of coffers in Roman domes?
a) Decoration only b) Reduce the weight of the structure
c) Increase height
2. What innovation allowed Renaissance engineers to build larger domes?
a) Geodesic triangles b) Ribbed masonry shells
c) Pendentives
3. Geodesic domes are ideal for:
a) Small residential houses b) Large open spaces like arenas
c) Only religious buildings

Exercise 5. Answer in 2–3 sentences.

1. Explain the purpose of pendentives in dome construction.
2. How did Brunelleschi's rib system improve dome stability?
3. Why are geodesic domes considered a modern engineering breakthrough?

Exercise 6. Write 150–180 words or discuss orally.

1. Compare the structural principles of Roman, Byzantine, Renaissance, and geodesic domes.
2. Explain how advancements in materials and engineering techniques allowed domes to span larger spaces.
3. Discuss how the aesthetics and functionality of domes evolved over 6,000 years.

UNIT 13

WHAT HOLDS A DOME TOGETHER?

The fundamental structural system that supports a dome is the **arch-and-vault system** (Figure 13.1.). A **dome** is essentially a hemispherical vault that rests on a circular base wall, distributing weight and forces evenly around the structure. Until the 19th century, arches and vaults represented the primary alternative to the simpler **post-and-beam construction**. A **vault** is an arch-shaped structure, usually made of masonry, used as a ceiling or roof over any enclosed space. Vaults allow for larger spans than simple beams while transferring loads efficiently to supporting walls.

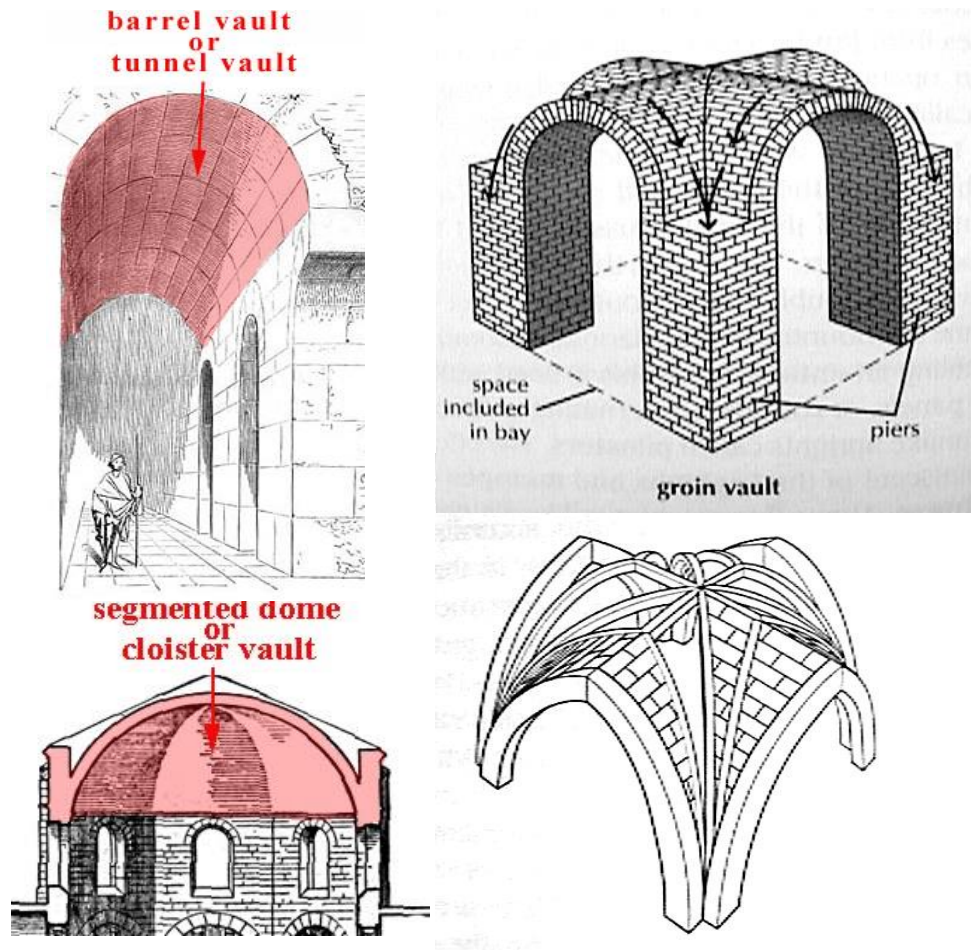


Figure 13.1 – Different vault shapes

The Romans extensively used the semicircular arch in structures such as amphitheatres and aqueducts. However, many Roman temples retained the rectangular post-and-beam form of Greek temples, with a few vaulted exceptions, such as the Pantheon in Rome. Understanding the forces acting on different types of domes is essential for assessing their stability and designing effective reinforcements.

Monolithic Domes: Forces

In a **monolithic dome**, the curved walls at the top push inward toward the centre, creating a self-stabilizing compressive force (Figure 13.2.). This inward pressure ensures that the dome maintains its rigid, stable form. **Ribs** are often integrated into the vault to subdivide the inner surface into independent arches, enhancing structural support and distributing loads more evenly across the dome.



Figure 13.2 – Monolithic Dome

Ringed Dome Forces

A **ringed dome** consists of heavier components arranged in concentric rings. The weight of these components generates outward thrust at the base of the dome. Consequently, the base must be engineered to resist both the downward compressive forces and the outward lateral thrust (Figure 13.3.). In older domes, cracks often appear along the bottom due to these forces. Engineers can reinforce the base by installing tension rings, usually made of iron or steel, which encircle the dome and counteract the outward pressure.

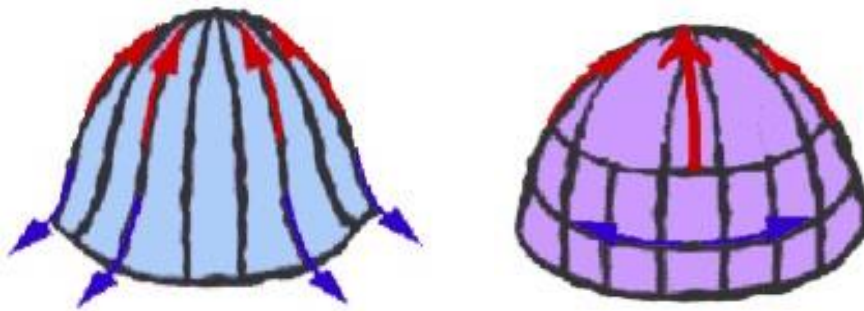


Figure 13.3 – Ringed dome

Geodesic Dome: Forces

The **geodesic dome** represents a modern evolution of the dome form, based on the triangle – the most stable geometric shape. Triangles are widely used in engineering because they are inherently rigid and efficiently distribute forces. In a geodesic dome, **compression at one joint is balanced by tension along the opposite side** (Figure 13.4.).



Figure 13.4 – Geodesic dome

This arrangement allows geodesic domes to be extremely lightweight, enclosing a maximum volume of space using minimal material. Their reduced surface area also minimizes heat loss, making them energy-efficient structures suitable for modern architectural applications such as sports arenas, botanical gardens, and exhibition halls.

Mini activity: Human Dome

This activity demonstrates dome forces in a simple, interactive manner:

1. **Form a human dome:** Stand in a circle around a soccer ball. Place your fingertips on the ball and lift it while leaning inward toward the centre, sliding your feet back (Figure 13.5.). Each participant represents a “rib” of the dome.



Figure 13.5

2. **Simulate load distribution:** Push gently down on the ball from the centre. Observe where the dome requires additional support. Adding seated participants at the base of each “rib” acts as **buttresses**, countering the outward thrust and helping the dome bear more compression (Figure 13.6.).

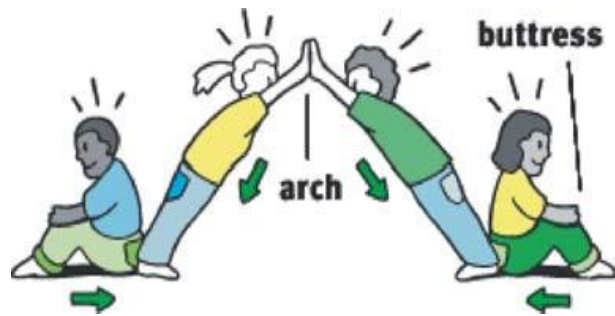


Figure 13.6

Explanation: Similar to an arch, the buttresses exert an inward force along the sides of the dome. This inward force balances the **outward thrust** generated by the weight pressing down on the top of the arch. This principle illustrates why domes, whether masonry, ringed, or geodesic, can achieve remarkable stability and span large spaces without internal supports.

Terminological Glossary

1. **Vault** – an arch-shaped ceiling or roof, usually made of masonry, spanning an enclosed space.
2. **Arch-and-vault system** – a structural system where arches and vaults bear and transfer loads.
3. **Post-and-beam construction** – a structural system using vertical posts and horizontal beams.
4. **Monolithic dome** – a dome formed from a single continuous structure, often reinforced with ribs.
5. **Rib** – a supporting arch embedded in a vault or dome to subdivide the surface and carry loads.
6. **Ringed dome** – a dome constructed in concentric rings that exert outward thrust at the base.
7. **Tension ring** – a metal ring encircling a dome to resist outward lateral forces.
8. **Outward thrust** – lateral force exerted at the base of an arch or dome due to weight above.
9. **Compression force** – a force that pushes material together.

10. **Geodesic dome** – a dome composed of interlocking triangles, distributing forces efficiently.
11. **Triangle (structural element)** – the most rigid geometric shape, used to resist deformation.
12. **Buttress** – a supporting structure that counteracts outward forces on arches or domes.

LANGUAGE PRACTICE

Answer the questions.

1. What structural system underlies the construction of a dome?
2. How is a vault different from a post-and-beam system?
3. What are the main forces acting on a monolithic dome?
4. How do ribs contribute to the stability of a dome?
5. Why do ringed domes exert outward thrust at the base?
6. How can engineers prevent cracks in a ringed dome?
7. What is the function of a tension ring?
8. Why is a triangle considered a stable shape in geodesic domes?
9. How are compression and tension balanced in a geodesic dome?
10. What makes geodesic domes lightweight yet strong?
11. Explain why geodesic domes are energy-efficient.
12. In the human dome activity, what do the participants' fingertips represent?
13. How do buttresses help support a dome?
14. Which type of dome relies primarily on inward forces at the apex?
15. Why are geodesic domes suitable for large open spaces?

Exercise 1: Match the terms with their definitions:

Term	Definition
1. Ribs	a) A lateral force at the base of a dome or arch
2. Tension ring	b) Arch-shaped ceiling or roof used to span an enclosed space.

3. Vault	c) A supporting element that divides a dome into independent arches.
4. Buttress	d) A structure that counteracts outward forces at the base.
5. Outward thrust	e) A metal ring resisting lateral outward forces in a dome.

Exercise 2: Complete the sentences with the following words:

monolithic, geodesic, compression, ribs, outward, buttresses, vault

1. A _____ dome is made as a single continuous structure.
2. In a _____ dome, triangular elements distribute forces evenly.
3. The inner arches of a monolithic dome are called _____.
4. The base of a ringed dome experiences _____ thrust.
5. _____ exert inward force to counteract lateral pressure.
6. A _____ is an arch-shaped roof or ceiling that transmits weight to supporting walls.
7. A force that pushes material together is called _____.

Exercise 3: Mark statements as True (T) or False (F). Correct the false ones.

1. Monolithic domes rely on inward forces at the apex for stability.
2. Geodesic domes are inefficient because they require heavy materials.
3. Tension rings are used to counteract outward thrust in ringed domes.
4. Buttresses are placed at the top of a dome to support the apex.
5. Ribs in a dome subdivide the surface into independent load-bearing arches.

Exercise 4: Choose the correct answer:

1. The primary function of ribs in a dome is to:
 - a) Decorate the interior
 - b) Subdivide the dome surface and support loads
 - c) Reduce the dome height
2. Outward thrust in a ringed dome is resisted by:
 - a) Compression at the apex
 - b) Buttresses or tension rings

- c) Reducing the dome diameter
- 3. Geodesic domes are especially suitable for:
 - a) Small houses
 - b) Large open spaces like sports arenas
 - c) Only religious buildings

Exercise 5: Answer in 2–3 sentences:

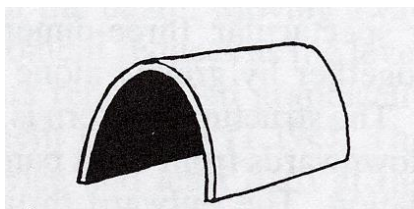
1. Explain how inward and outward forces work in monolithic and ringed domes.
2. Why are geodesic domes considered structurally efficient?
3. Describe the role of ribs and buttresses in maintaining dome stability.

Exercise 6: Write 150–200 words or discuss orally.

1. Compare monolithic, ringed, and geodesic domes in terms of force distribution and material efficiency.
2. How have engineering innovations like ribs, tension rings, and geodesic triangulation expanded the architectural possibilities of domes?
3. Discuss the environmental and energy-efficient advantages of geodesic domes in modern construction.

Exercise 7. Label the drawings with the following words:

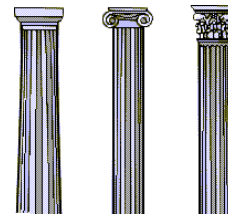
sphere, vault, angle, column, rectangular, inclined, curved:



A



B



C



D



E



F



G

Exercise 8. 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		

Exercise 9. 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 (*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.

UNIT 14

SKYSCRAPERS

The history of skyscrapers can be traced back to ancient times. The Great Pyramid of Cheops, completed around 2580 BC, is regarded as the first predecessor of high-rise buildings. Constructed from more than two million limestone blocks, it remained the tallest man-made structure in the world for nearly 4,000 years. This record was finally surpassed in the 14th century by Lincoln Cathedral in England,

whose spire symbolized the medieval aspiration to reach the heavens. The desire to build higher structures re-emerged during the Middle Ages, particularly with the construction of large Gothic cathedrals in the 12th century (Figure 14.1). These impressive buildings were not only places of worship but also demonstrations of advanced engineering skills for their time. Gothic architecture introduced innovative structural solutions that allowed buildings to grow taller while maintaining stability and elegance.



Figure 14.1 – Notre Dame, Paris

Many Gothic cathedrals are characterized by the use of flying buttresses – external arched supports that extend from the upper walls down to the ground (Figure 14.2). These structures transferred the enormous weight of stone roofs and vaults away from the walls, allowing for thinner walls and larger windows. As a result, cathedrals could be filled with light, creating the distinctive airy interiors typical of Gothic design.



Figure 14.2 – Flying buttress

A true revolution in building height occurred in the late 19th century with the introduction of steel as a primary construction material. The use of steel made possible the construction of the first modern skyscraper in 1884. The first steel-framed building was the ten-storey Home Insurance Building in Chicago, designed

by William Le Baron Jenney (Figure 14.3). Unlike earlier masonry buildings, the steel frame carried the structural loads, eliminating the need for extremely thick walls at ground level and allowing buildings to rise vertically with greater efficiency.



Figure 14.3 – Home Insurance Building, Chicago

Another crucial innovation that contributed to the development of skyscrapers was the invention of the Otis safety lift in the 1850s. Soon known as the elevator, it made upper floors easily accessible and practical for everyday use. Otis's first elevator models were powered by steam, but they quickly evolved as new energy sources became available. Without the elevator, the economic and functional viability of tall buildings would have been impossible.

In the early stages of skyscraper construction, steel structures were assembled using riveted connections. Over time, these were gradually replaced by welded steel constructions, which provided greater strength, flexibility, and speed of assembly. Once exterior walls were no longer required to support the building's weight, architects and engineers gained greater freedom in interior planning. Open floor plans became possible, responding to the needs of offices and commercial spaces.

By the 1920s, European engineers began extending floor slabs beyond the building's vertical supports. These cantilevered floors allowed windows to be suspended from the structure, leading to the development of lightweight curtain walls made largely of glass. This innovation transformed the appearance of skyscrapers, giving rise to the modern glass-clad high-rise buildings that dominate city skylines today.

A major breakthrough in skyscraper engineering occurred in the 1960s with the development of the braced framed-tube structure by structural engineer Fazlur Khan. This system was first applied in Chicago's John Hancock Center (Figure 14.4). By using the building's exterior frame to resist wind forces, the structure achieved unprecedented height and stability while using less material than traditional steel frames.



Figure 14.4 – Hancock Center, Chicago

Today, skyscrapers represent the pinnacle of modern engineering and architectural design. Among the world's tallest buildings are the Taipei Skyscraper,

standing at 508 metres, the Petronas Towers in Malaysia at 450 metres, and the Sears Tower (now Willis Tower) in Chicago at 433 metres (Figure 14.5). The tallest unsupported structure in the world is the CN Tower in Toronto, a television and communications tower reaching a height of 555 metres. These structures demonstrate how advances in materials, structural systems, and construction technologies continue to push the limits of vertical construction.



Figure 14.5 – Petronas Towers, Kuala Lumpur, Malaysia

Terminological Glossary

1. **Skyscraper** – a very tall multi-storey building, typically constructed in urban areas.
2. **High-rise building** – a building with many floors, taller than typical residential or commercial structures.
3. **Predecessor** – an earlier form or model from which something later developed.

4. **Flying buttress** – an external arched support that transfers the weight of a roof or wall to the ground.
5. **Steel frame** – a structural system of steel columns and beams that supports the building's weight.
6. **Load-bearing wall** – a wall that carries structural loads from above.
7. **Riveted construction** – a method of joining steel elements using metal rivets.
8. **Welded structure** – a steel structure in which elements are joined by welding.
9. **Cantilevered floor** – a floor slab that extends beyond its vertical supports.
10. **Braced framed-tube structure** – a structural system that uses the building's exterior frame to resist wind forces.
11. **Unsupported structure** – a tall structure that does not rely on cables or external supports.

LANGUAGE PRACTICE

Answer the questions:

1. Why is the Great Pyramid of Cheops considered a predecessor of skyscrapers?
2. What role did Gothic cathedrals play in the history of tall buildings?
3. How do flying buttresses function in cathedral construction?
4. Why was the Home Insurance Building considered revolutionary?
5. How did steel frames change the design of tall buildings?
6. Why were elevators essential for the development of skyscrapers?
7. What was the difference between riveted and welded steel constructions?
8. How did cantilevered floors influence building design in the 1920s?
9. What is a curtain wall and why is it important?
10. What problem did the braced framed-tube structure solve?
11. Who was Fazlur Khan and why is he important?
12. Which buildings mentioned in the text are among the tallest in the world?

Exercise 1. Match the words with the correct definitions.

Term	Definition
1. Skyscraper	a) A lightweight exterior wall that does not carry structural loads
2. Flying buttress	b) A very tall multi-storey building
3. Steel frame	c) A vertical transportation system for moving between floors
4. Load-bearing wall	d) A structural system that resists wind forces through an exterior frame
5. Elevator	e) An external arched support used in Gothic architecture
6. Riveted construction	f) A wall that supports the weight of a building
7. Welded structure	g) A steel structure in which elements are joined by welding
8. Cantilevered floor	h) A construction method using metal rivets
9. Curtain wall	i) A floor slab extending beyond its vertical supports
10. Braced framed-tube structure	j) A structural system of steel columns and beams

Exercise 2. Complete the sentences using the following words:

skyscraper, steel frame, flying buttresses, elevator, curtain wall, cantilevered, welded

1. The invention of the _____ made high-rise buildings practical for everyday use.
2. Gothic cathedrals used _____ to support heavy stone roofs.
3. The Home Insurance Building was the first _____ supported by a steel structure.
4. Modern buildings often use a _____ made of glass.
5. Floors that extend beyond the supports are called _____ floors.
6. Early steel buildings used rivets, while later ones relied on _____

connections.

7. A _____ allows buildings to rise higher without extremely thick walls.

Exercise 3. Choose the correct answer.

1. The main function of a steel frame is to:
a) decorate the building b) carry structural loads
c) provide insulation
2. Curtain walls are mainly used to:
a) support the building b) resist earthquakes
c) protect the interior from weather
3. Flying buttresses were typical of:
a) modern skyscrapers b) Gothic cathedrals
c) concrete bridges

Exercise 4. Decide whether the statements are true or false:

1. The Great Pyramid remained the tallest structure for almost 4,000 years.
2. Gothic cathedrals used steel as their main construction material.
3. The Home Insurance Building had a steel frame.
4. Elevators made upper floors more accessible.
5. Curtain walls carry the main structural load.

Exercise 5. Answer in 2–3 sentences:

1. Explain why steel was crucial for the development of skyscrapers.
2. How did the invention of the elevator influence the design and use of skyscrapers?
3. Which technological innovation do you think was the most important for the rise of skyscrapers and why?

Exercise 6. Write a short paragraph (80–100 words) on how skyscrapers reflect technological progress.

UNIT 15

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.

The 300 m Eiffel Tower was twice the height of any previous structure (Figure 15.1.).



Figure 15.1 – Eiffel Tower

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 (Figure 15.2.). The graceful form of the tower was constructed to cope with the wind rather than gravity.



Figure 15.2 – 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 (Figure 15.3.), whose construction formed the basis of his ideas for the tower.



Figure 15.3 – 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 (Figure 15.4.). By clustering steel columns and beams in the skyscraper's core (Figure 15.5.), 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.

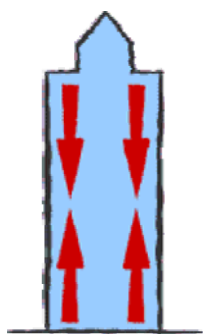


Figure 15.4
Forces



Figure 15.5
Stiff core



Figure 15.6
Hollow tube

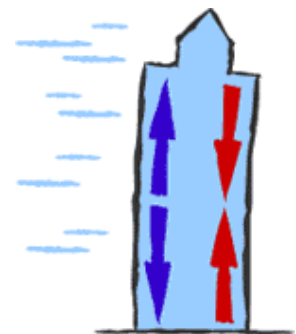


Figure 15.7
Forces

In newer skyscrapers, like the Sears Tower in Chicago, engineers moved the columns and beams from the core to the perimeter (Figure 15.6.), 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 (Figure

15.7.), and the columns on the other side squeeze together.

Terminological Glossary

1. **Steel frame** – a structural system in which steel columns and beams carry the building loads.
2. **Flying buttress** – an external support transferring roof loads away from walls to the ground.
3. **Riveted construction** – steel elements joined using heated metal pins (rivets).
4. **Welded structure** – steel elements joined by melting metal at their connection points.
5. **Cantilevered floor** – a floor slab projecting beyond its vertical supports.
6. **Braced frame-tube structure** – a structural system using exterior bracing to resist lateral loads.
7. **Core structure** – a central stiff element housing elevators and resisting wind forces.
8. **Perimeter tube** – a structural system where columns and beams are placed around the building's outer edge.
9. **Lateral load** – a horizontal force, such as wind pressure, acting on a building.
10. **Equilibrium of forces** – a condition where opposing forces are balanced, ensuring structural stability.
11. **Truss structure** – a framework of interconnected elements forming rigid triangular units.

LANGUAGE PRACTICE

Answer the questions:

1. Who designed the Eiffel Tower, and what was his profession?
2. For what event was the Eiffel Tower built?
3. How tall is the Eiffel Tower, and how did its height compare to previous structures?
4. What type of structural system does the Eiffel Tower use to resist wind?
5. Why does the tower have an open lattice structure?

6. How many wrought iron pieces were used in the Eiffel Tower, and why was each piece unique?
7. What was the purpose of prefabricating sections off-site during construction?
8. How did inclined elevators help during the construction of the Eiffel Tower?
9. What previous project by Gustave Eiffel influenced his design of the tower?
10. How do engineers design skyscrapers to resist wind forces?
11. What role does the inner core of a skyscraper play in wind resistance?
12. How does relocating columns and beams to the perimeter of a skyscraper affect its strength and weight?
13. Explain how columns respond when wind blows on a skyscraper.
14. What is the difference between the Eiffel Tower's approach to wind resistance and traditional towers before it?
15. Why is controlling wind forces important in tall building design?

Exercise 1. Match the term with its definition.

Term	Definition
1. Flying buttress	a) Horizontal force acting on a building
2. Steel frame	b) External support transferring loads from walls
3. Core structure	c) Central stiff structural element
4. Perimeter tube	d) Load-bearing skeleton of steel columns and beams
5. Lateral load	e) Structural system with columns placed along the building edge

Exercise 2. Complete the sentences using the following words:

steel, elevator, wind, core, perimeter, welded, equilibrium

1. The invention of the _____ made tall buildings practical.
2. Modern skyscrapers rely on _____ frames rather than masonry walls.
3. Engineers cluster columns in the _____ to resist wind forces.
4. In tube structures, columns are moved to the building's _____.
5. Forces acting on a skyscraper must be in _____ to ensure stability.

6. _____ loads are among the most critical forces acting on tall buildings.
7. Riveted structures were gradually replaced by _____ ones.

Exercise 3. Mark the statements True (T) or False (F). Correct the false ones.

1. The Eiffel Tower was designed mainly to resist gravity loads.
2. Gothic cathedrals relied on thick walls instead of flying buttresses.
3. Steel framing allows for thinner walls and larger windows.
4. The Sears Tower uses a hollow tube structural system.
5. Prefabrication increased construction time in Eiffel's projects.

Exercise 4. Choose the correct answer.

1. The main advantage of steel in skyscrapers is its:
a) Decorative quality b) Tensile strength
c) Resistance to fire
2. Wind resistance in modern skyscrapers is achieved mainly by:
a) Thick exterior walls b) Balanced structural systems
c) Heavier foundations only
3. The Eiffel Tower's open lattice structure allows:
a) Heat retention b) Wind to pass through
c) Reduced height

Exercise 5: Short Answer (2–3 sentences)

1. Explain how flying buttresses influenced later tall structures.
2. Describe the difference between core and perimeter tube systems.
3. Why is wind considered a critical design factor in skyscrapers?

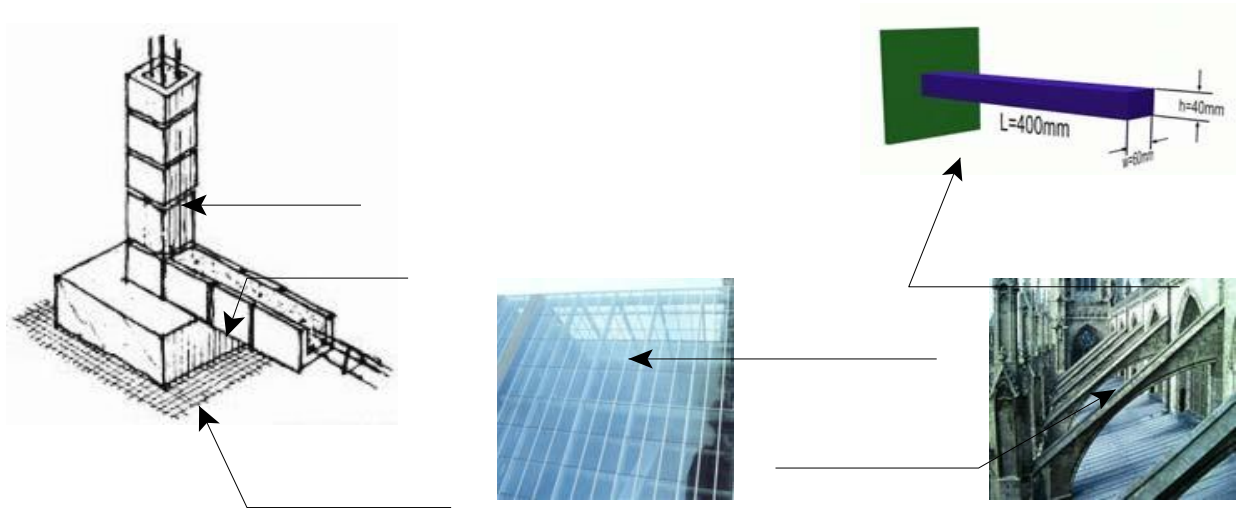
Exercise 6: Write 180–220 words or discuss orally.

1. Compare medieval height-seeking structures (cathedrals) with modern skyscrapers in terms of materials and load transfer.
2. Analyze how wind resistance has influenced the evolution of skyscraper

design.

3. Discuss the importance of structural innovation in enabling vertical urban growth.

Exercise 7. Name the following structural parts of a building.



Exercise 8. 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.

UNIT 16

STRUCTURAL ACTIONS

Civil engineering is concerned with the **designing and construction of stable structures**. Under normal circumstances, these structures should remain intact. If a building sways in the wind, it should do so only to an extent that does not cause discomfort or alarm. All active loads must be **balanced throughout the structure** by the corresponding resistance. Similarly, the loads transmitted from the structure to the foundations must be balanced by opposing resistance. Every structural element and its connections must have **adequate margins of strength and stiffness**.

Loads and their effects

There are several types of loads (Figure 16.1.).

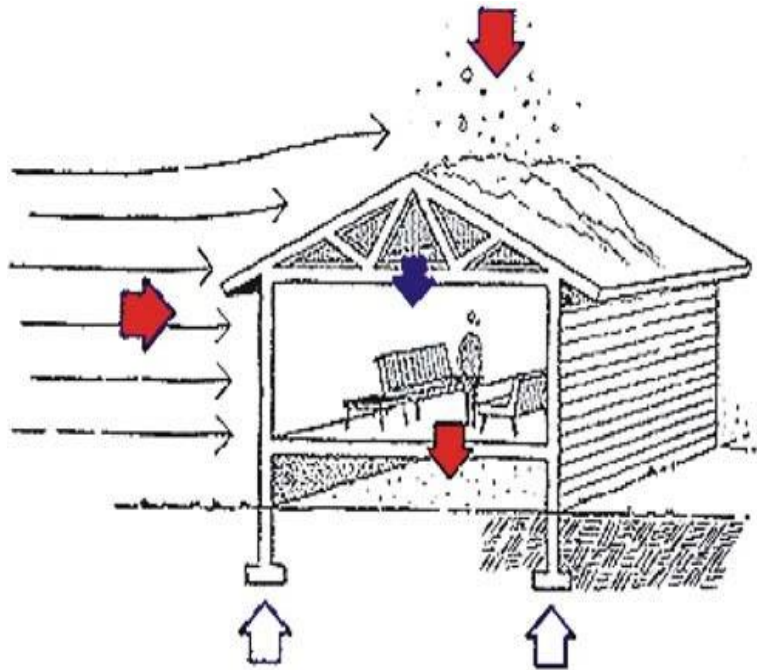


Figure 16.1 – Types of loads

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.

All types of loads tend to produce movement in the direction of their action. Structures resist this movement by providing obstruction. No structural element is completely rigid; each undergoes limited deformation, which generates resistance.

The term **stiffness** denotes the resistance that is developed by a given deformation (Figure 16.2.) and the term **strength** denotes the maximum resistance that can be developed.

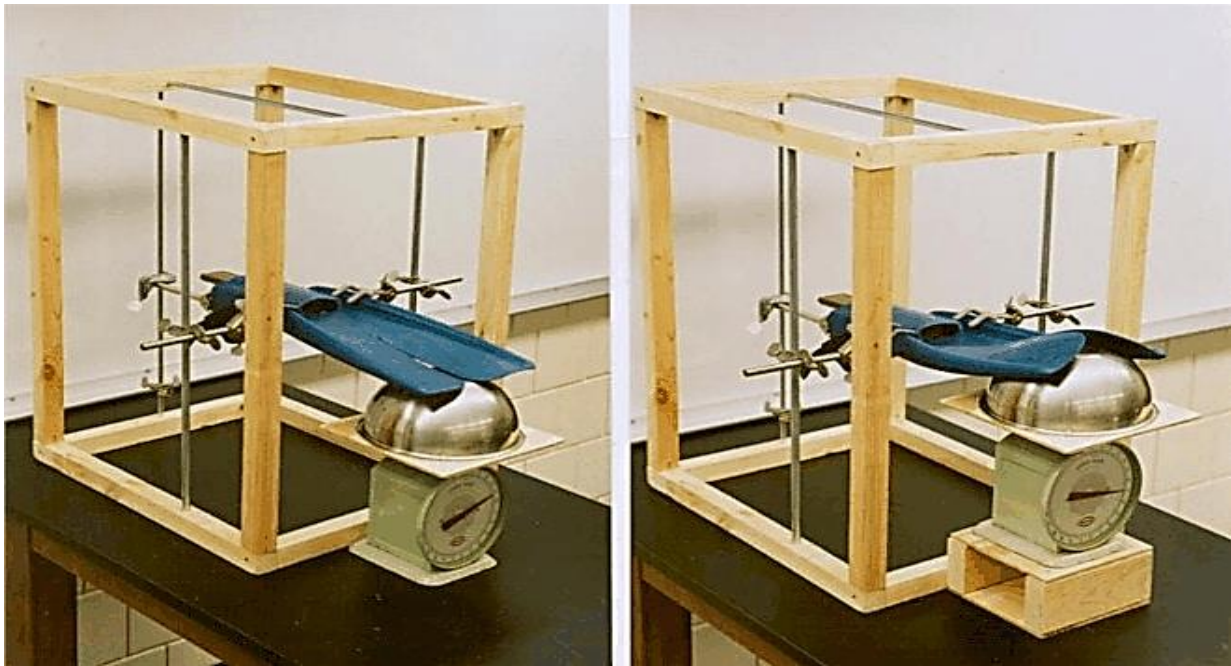


Figure 16.2 – Testing of stiffness

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 (Figure 16.3.). 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 because of very rapid displacement of its foundations.

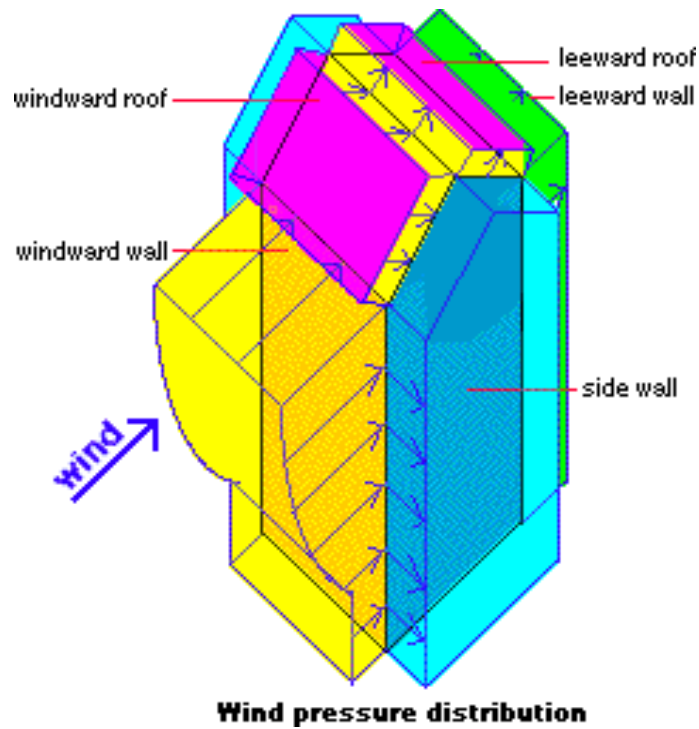


Figure 16.3 – Wind load

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. There is the distinction between **tension**, **compression**, **bending**, **torsion** and **shear** (Figure 16.4. and 16.5.).

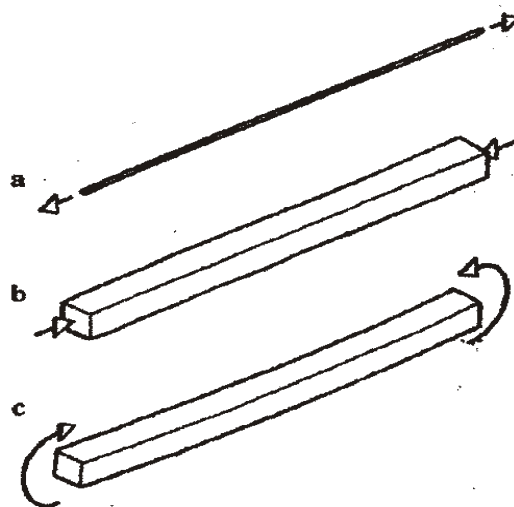


Figure 16.4 – Examples of tension (a), compression (b) and bending (c)

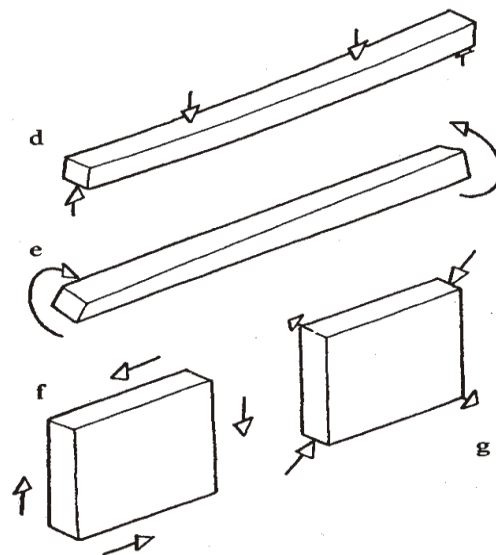


Figure 16.5 – Examples of pure bending (d), torsion (e) and shear (f)

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** (Figure 16.4.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** (Figur. 16.5.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** (Figure 16.5.f and 16.5.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 must 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.

Many great buildings of the past were constructed without detailed knowledge of mathematics and physics. They were built based on experience, observation, and trial and error. These structures often survive because they were over-designed, with strength greater than strictly necessary. The Romans made extensive use of the **arch** (Figure 16.6.) to distribute load more evenly, thus making larger openings possible.

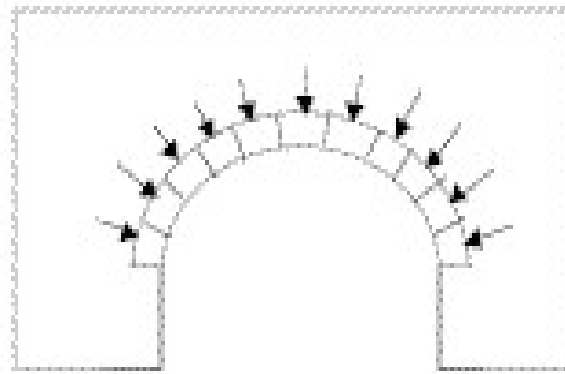


Figure 16.6 – Roman arch

Architects and engineers before the Romans had used a **post-and-beam** construction (Figure 16.7.) with two vertical columns supporting a horizontal beam.

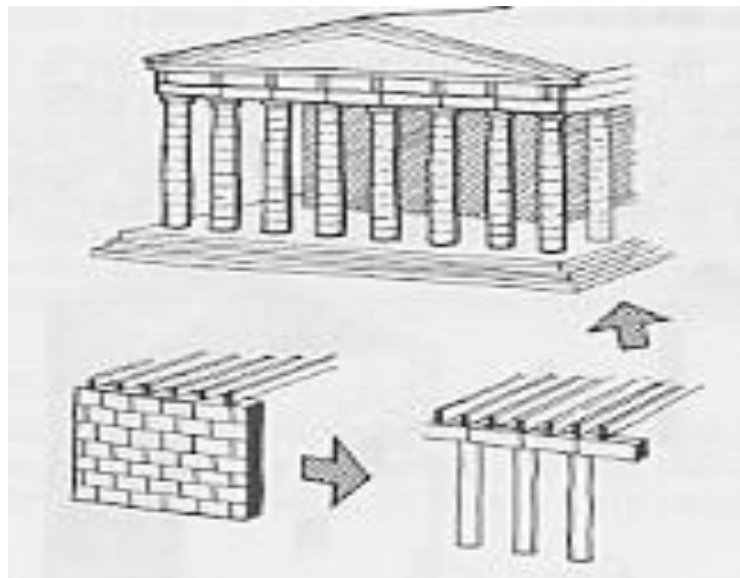


Figure 16.7 – The Parthenon, Greece

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

Terminological Glossary

1. **Load** – a force or weight applied to a structure.
2. **Dead load** – the permanent weight of a structure itself.
3. **Live load** – the weight of people, furniture, vehicles, or other movable objects.

4. **Environmental load** – forces from wind, water, earthquakes, or climate effects.
5. **Stiffness** – resistance developed by a material or structure under deformation.
6. **Strength** – the maximum resistance a material or structure can provide.
7. **Tension** – a pulling force that stretches a material.
8. **Compression** – a pushing force that shortens or squeezes a material.
9. **Bending** – deformation caused by forces applied transversely to a structural element.
10. **Torsion** – twisting force applied to an element.
11. **Shear** – a force causing one part of a material to slide relative to another.
12. **Stress** – force per unit area applied to a material.
13. **Strain** – deformation of a material in response to stress.
14. **Arch** – a curved structure that distributes load evenly.
15. **Post-and-beam construction** – a traditional method using vertical columns and horizontal beams.

LANGUAGE PRACTICE

Answer the questions:

1. What is civil engineering concerned with?
2. Why must a structure remain balanced under wind or other forces?
3. Define dead load and give an example.
4. Define live load and give an example.
5. What are environmental loads?
6. How do structures resist loads despite not being completely rigid?
7. What is the difference between stiffness and strength?
8. What is the main difference between static and dynamic loads?
9. Give an example of a common dynamic load.
10. Explain tension and compression with an example for each.
11. How is bending produced in a structural element?
12. What is torsion and where can it occur?

13. Explain shear with an example.
14. How did Romans use arches in construction?
15. What advantages do modern engineers have compared to ancient builders?

Exercise 1: Match the terms with definitions

Term	Definition
1. Dead load	a) The permanent weight of the structure itself
2. Live load	b) Twisting force applied to an element
3. Torsion	c) Resistance developed by a material under deformation
4. Shear	d) Sliding force between parts of a material
5. Arch	e) Weight of people, furniture, or vehicles
6. Stiffness	f) Curved structure distributing loads evenly

Exercise 2. Complete the sentences with the correct word:

tension, compression, bending, stress, strain, environmental load

1. Wind is an example of an _____ that can act on a building.
2. When a material is pulled apart, it is under _____.
3. When a material is pushed together, it is under _____.
4. A force per unit area applied to a material is called _____.
5. Deformation caused by applied stress is called _____.
6. A beam that curves under transverse forces is experiencing _____.

Exercise 3. 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.

Exercise 4. 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

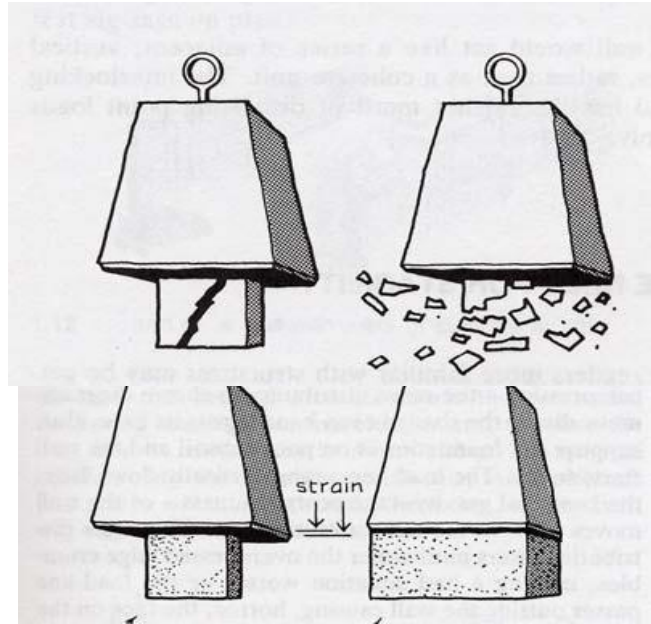
Exercise 5. Mark the statements True (T) or False (F). Correct the false ones.

1. Dead load includes the weight of people inside the building.
2. Dynamic loads occur constantly over time.
3. Shear tends to cause slipping between parts of a structure.
4. Arches were used by Romans to make larger openings possible.
5. Modern engineers rely only on trial-and-error methods.

Exercise 6. Answer in 2–3 sentences:

1. Explain why stiffness is important in a structure.
2. Describe the difference between static and dynamic loads.
3. How do arches distribute weight in a structure?
4. Give an example of tension, compression, and bending in everyday life.

7. Describe the action of forces in Figures 16.8. below.



Figures 16.8

UNIT 17

THE FORCES ACTING ON BRIDGES

Bridges must be designed and built to support their own weight as well as the weight of heavy traffic without collapsing. These downward forces, caused by gravity, must be balanced by upward forces from the supports. In reality, every object is acted on by multiple forces simultaneously. For example, wind exerts a horizontal force when it blows, while gravity pulls everything downward toward the center of the Earth, giving objects their weight.

Bridge designers use the principles of statics to calculate all the loads that a bridge must withstand. The forces that tend to bend the bridge and potentially cause it to collapse must never exceed the forces that keep it straight and stable. Understanding these forces is critical to designing bridges that are both safe and durable.

Types of Bridges and Force Distribution

A beam bridge is one of the simplest types of bridge. In this design, the bridge's weight is supported through upward forces produced by the supports at each end

(Figure 17.1). The combination of the bridge's own weight (dead load) and the live load from traffic causes bending. This bending produces tension along the top surface of the beam and compression along the bottom. In a properly designed beam bridge, these forces are balanced, and the overall mass of the bridge transfers directly downward to the ground beneath.

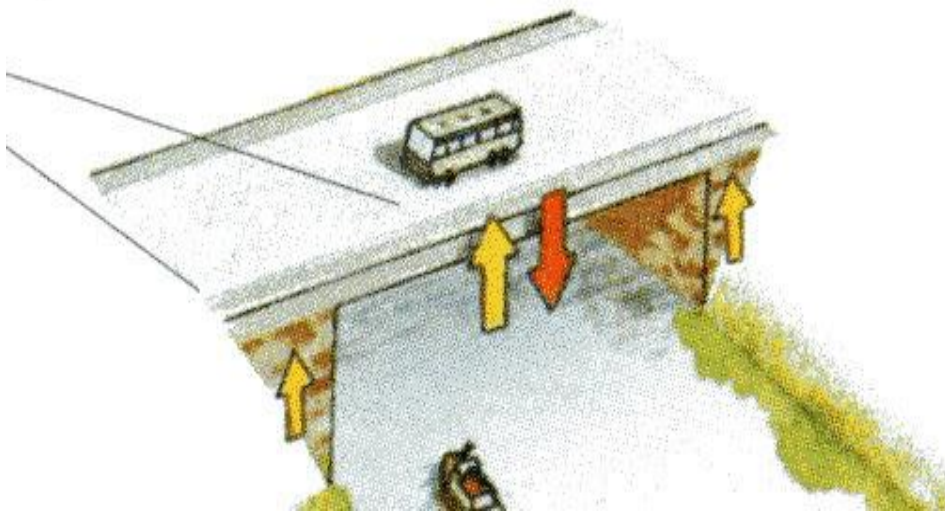


Figure 17.1 – Beam bridge

Beam bridges are effective for short to medium spans and are relatively easy to construct, but they can be limited by material strength when the span increases.

An arch bridge uses the natural strength of a curved structure to transfer loads. The curve of the arch directs the bridge's weight to the supports at each end (abutments), transforming vertical loads into compression along the arch (Figure 17.2). Because the arch is subjected only to compressive forces, materials like stone or concrete are ideal, as they perform well under compression but poorly under tension. Dead and live loads combine to press the arch together, creating a stable, self-supporting structure.

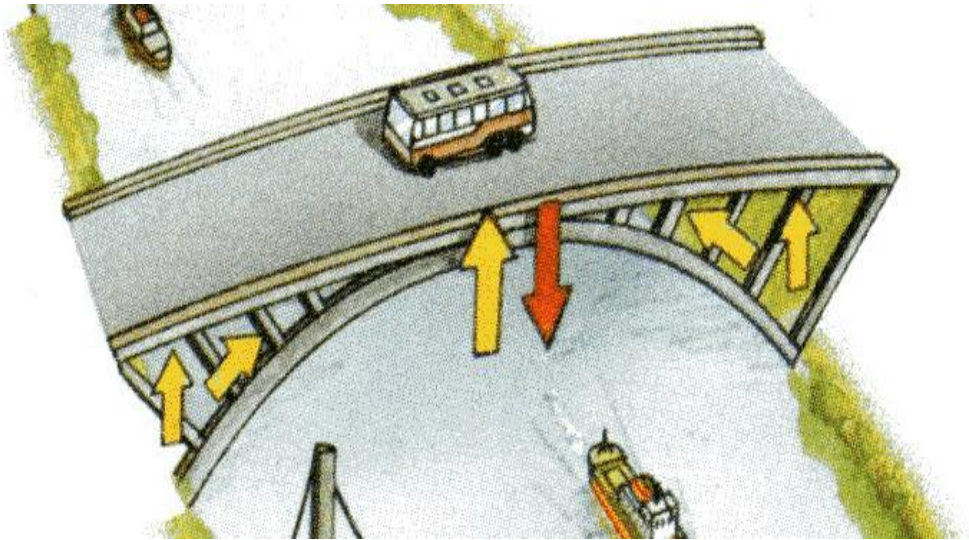


Figure 17.2 – Arch bridge

Arch bridges are often used for medium spans and are valued for both their aesthetic appeal and their ability to carry heavy loads efficiently.

A truss bridge is composed of a framework of diagonal bars connected to form triangles (Figure 17.3). This triangular arrangement ensures that forces are distributed between members in tension and compression, making the structure extremely rigid. A truss cannot be twisted or collapsed without deforming the individual beams. This design is particularly useful for longer spans, as it allows for a lighter structure while maintaining high strength and stability.

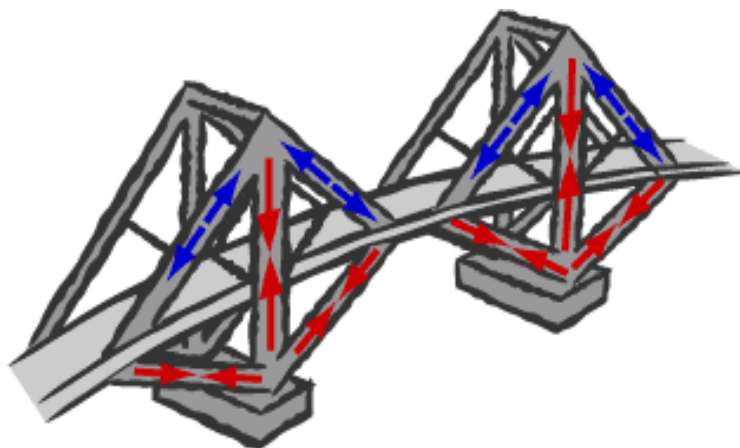


Figure 17.3 – Truss bridge

Truss bridges can be made of steel or timber, and their modular construction allows for prefabrication and faster assembly.

In a suspension bridge, the load is carried by flexible cables, which are supported by towers at each end (Figure 17.4). These towers not only bear the vertical forces but also resist horizontal forces caused by the tension in the cables. Downward loads are transferred via the cables to the towers and then to the foundations.

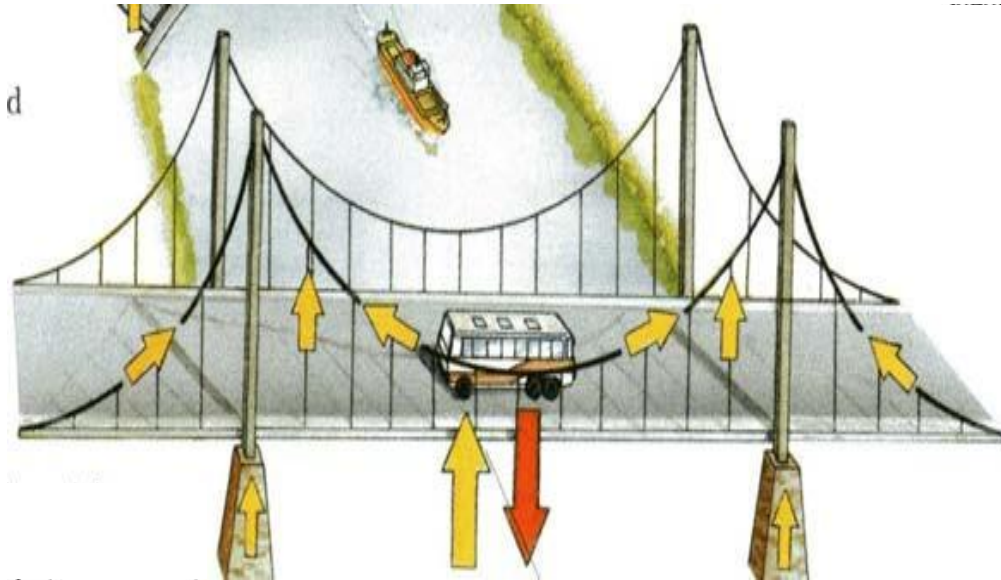


Figure 17.4 – Suspension bridge

Because suspension bridges can sway in strong winds, the roadway is often stiffened with beams or hollow box girders, which reduce flexing and increase stability. Suspension bridges are ideal for very long spans, such as those crossing wide rivers or bays, and are capable of supporting enormous loads with relatively lightweight materials.

Different bridge types resist forces in unique ways:

- Beam bridges rely on tension and compression within the beam itself.
- Arch bridges transfer loads primarily through compression.
- Truss bridges distribute forces efficiently through triangular frameworks.
- Suspension bridges carry loads via cables and towers, often combined with stiffened roadways.

Understanding how forces act on bridges is essential for engineers to design structures that are safe, stable, and durable under all anticipated loads, including traffic, wind, and environmental conditions.

LANGUAGE PRACTICE

Answer the questions

1. Why must bridges be designed to support both dead and live loads?
2. What is the difference between dead load and live load?
3. How do environmental loads affect a bridge? Give an example.
4. In a beam bridge, where are the tension and compression forces located?
5. How does an arch bridge transfer weight to its supports?
6. Why is stone an ideal material for an arch bridge?
7. How does a truss bridge resist twisting and collapsing?
8. What role do cables play in a suspension bridge?
9. How do towers in a suspension bridge resist forces?
10. Why is a stiffened roadway important in a suspension bridge?
11. What is the main principle of statics used in bridge design?
12. How does bending affect a beam bridge under load?
13. What is the main advantage of using a truss structure for long spans?
14. How do suspension bridges differ from beam or arch bridges in handling loads?
15. Why is understanding force distribution critical in bridge engineering?

Exercise 1. Match the terms with definitions

Term	Definition
1. Dead load	a) A curved structure transferring load primarily through compression
2. Live load	b) The permanent weight of the structure itself
3. Compression	c) The weight of people, vehicles, and movable objects
4. Tension	d) A force that stretches a material
5. Arch	e) A framework of triangles distributing loads
6. Truss	f) A horizontal or curved bridge where the deck hangs from cables

7. Suspension bridge	g) A strong, flexible member carrying load in a suspension bridge
8. Cable	h) A force that pushes a material together
9. Stiffened roadway	i) Reinforcement of the bridge deck to resist bending and swaying

Exercise 2. Complete the sentences using the correct words:

beam, arch, truss, cable, tension, compression, live load, dead load, stiffened

1. In a simple _____ bridge, bending creates _____ on the top and _____ on the bottom of the beam.
2. A _____ bridge transfers weight through compression along a curved structure.
3. A _____ bridge uses diagonal members in triangles to resist twisting.
4. A _____ bridge carries the roadway on _____ supported by towers.
5. The weight of vehicles on a bridge is called _____, while the weight of the bridge itself is called _____.
6. Engineers often use a _____ roadway to reduce swaying in suspension bridges.

Exercise 3. Mark the statements True (T) or False (F). Correct the false ones.

1. Beam bridges transfer all loads directly into compression.
2. Truss bridges use triangles to balance tension and compression.
3. Cables in a suspension bridge carry only vertical loads.
4. Arch bridges are ideal for stone construction because they are in compression.
5. Stiffened roadways help suspension bridges resist wind forces.

Exercise 4: Answer in 2–3 sentences.

1. Explain how tension and compression work together in a beam bridge.
2. Why is an arch bridge more efficient with stone than a beam bridge?
3. How do truss bridges resist twisting and bending under load?

4. Describe the role of towers and cables in a suspension bridge.
5. Why is understanding all forces acting on a bridge essential for safety?

Exercise 5. Re-read the text and fill in the boxes according to the headings.

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

Exercise 6. Name the forces:

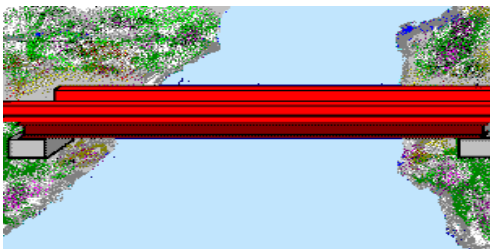
A pushing, squeezing force is called _____.

A pulling force is called _____.

A rotational, twisting force is called _____.

When a straight material gets curved, it is called _____.

Exercise 7. Name each of the following bridges or its structural parts and describe its characteristics:



A



B



C



D

Exercise 8. 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 _____ 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.

ADDITIONAL TEXTS

1. CANALS

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

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 6th century BC (completed AD 1327) and is still in use.

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 to accommodate the supertankers that carry oil from the oil fields on the Persian Gulf.

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 1.1.) are connected by a network of canals that carry a large proportion of the commerce.



Figure 1.1 – Rhein - Main - Danube Canal

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.

LOCKS

Locks (Figure 1.2.) 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.

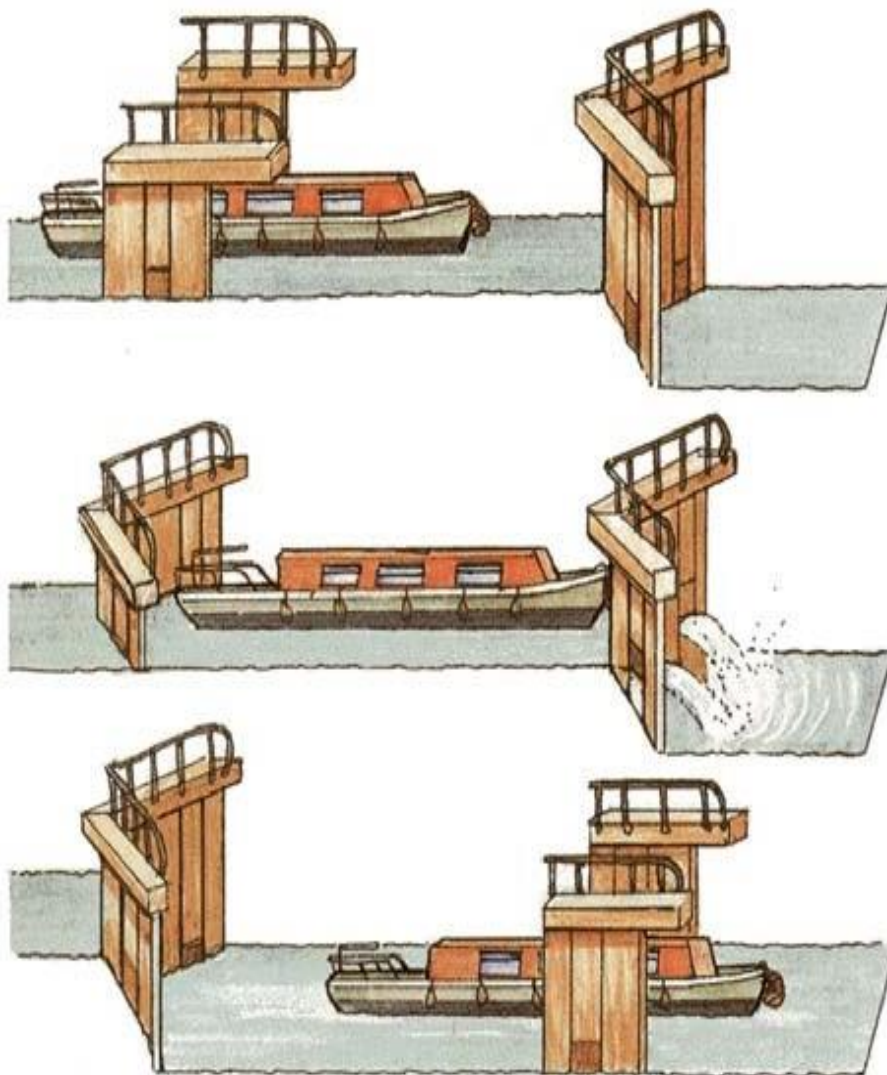


Figure 1.2 – Operation of a lock

2. 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. 2.1.).

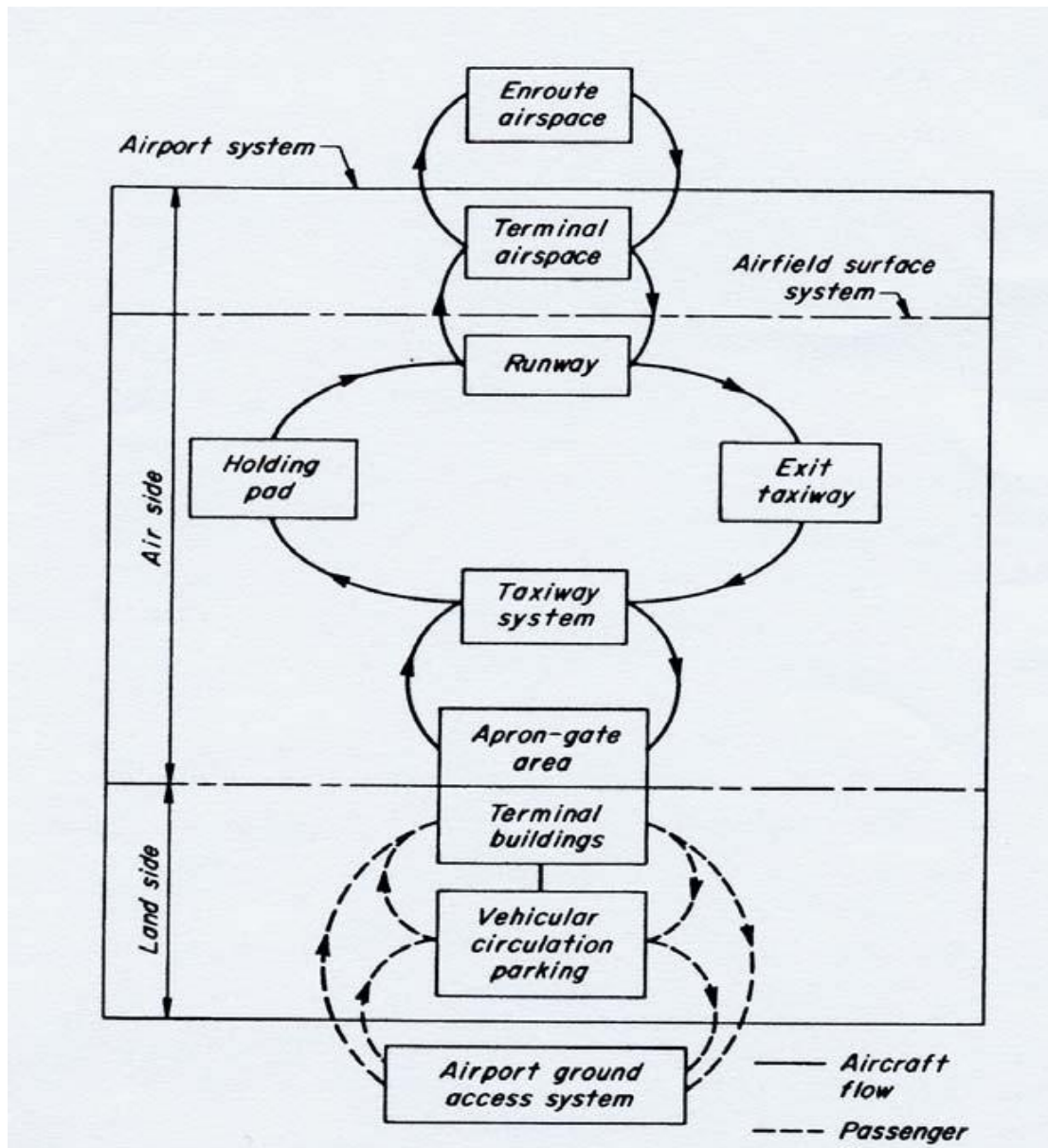


Figure 2.1 – Components of the airport system for a large airport

An airport is divided into two major components, the landside (Figure 2.2.) and the air side.



Figure 2.2 – Kansai Terminal Building

An airport development involves the construction of vast expanses of runways, taxiways, buildings, aprons, and other impermeable surfaces (Figure 2.3.).



Figure 2.3 – Kansai International Airport

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.

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 (1) 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.

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 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).

3. RAIL TRANSPORT

Wooden rail tracks may have been used as early as the 12th 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.

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 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 3.1.) run at up to 210 km/h.



Figure 3.1 – Shinkansen - “bullet train”

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.

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 3.2.). The rail is set on a track. Some monorails straddle the track, others hang beneath it.

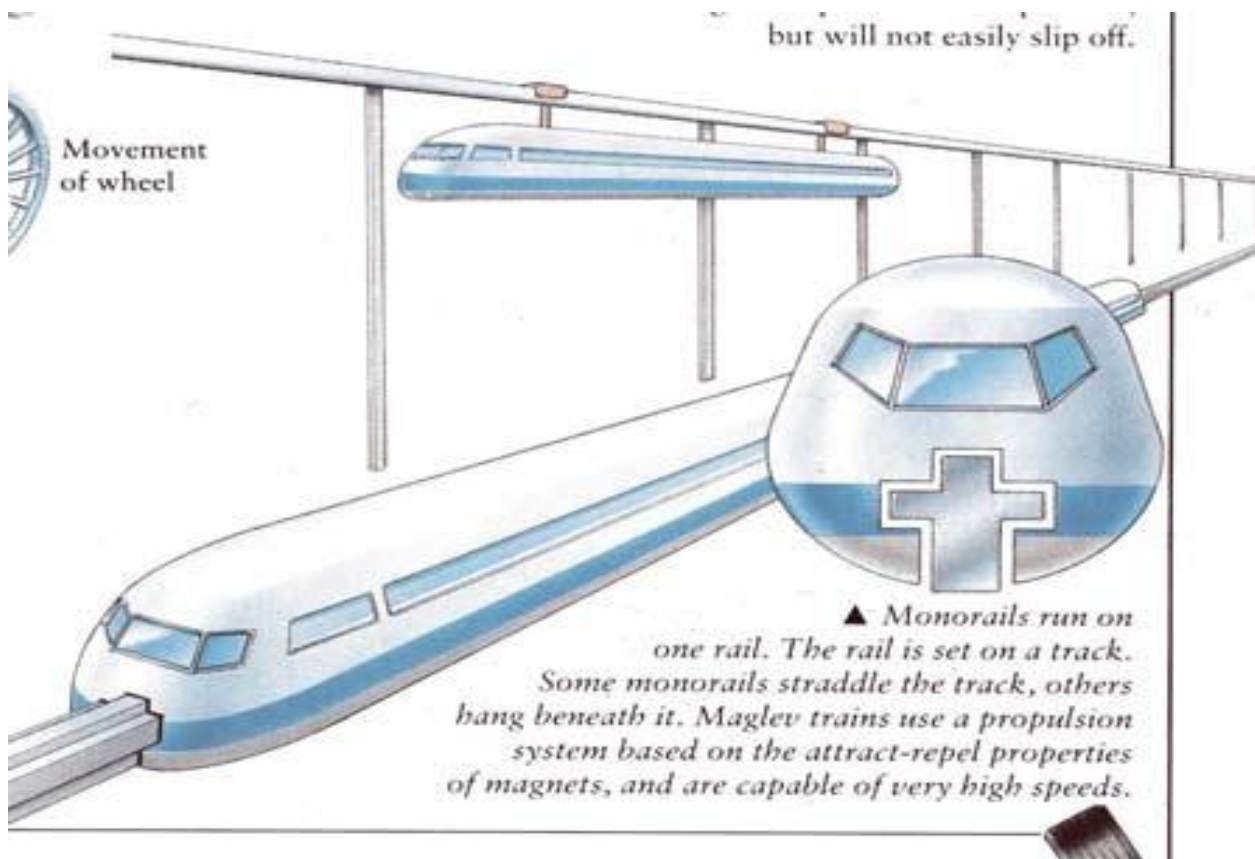


Figure 3.2 – A monorail

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

4. DAMS

Dams are world's biggest structures, transforming nature 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 using 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.

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.

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.

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.

Nowadays there are many huge dams under construction like the Three Gorges scheme on the Chang Jiang 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.

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.

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. 4.1.). 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 can navigate on the Nile much easier since the wild river is more tamed than before.



Figure 4.1 – 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 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.

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 because 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.

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