МИНИСТЕРСТВО ОБРАЗОВАНИЯ РЕСПУБЛИКИ БЕЛАРУСЬ

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Сборник текстов по обучению профессионально-ориентированному чтению на английском языке составлен в соответствии с учебной программой по специальности 1-70 03 01 «Автомобильные дороги».

Тематика текстов позволяет студентам ознакомиться с основными видами деятельности в области строительства автомобильных дорог.

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Chapter I. Building Materials
Unit 1. The Definition and Classification of Building Materials

Building material is any material that can be used for construction purposes. It commonly includes wood, concrete, steel, cement, aggregates, bricks, clay, metal, and so much more. In the olden times, people have been using pure bricks, wood, straw, sand, rocks and even twigs and leaves. Some of these are still widely used in the modern construction scene. However, in this modern age, engineers have learned to mix and match the right materials to come up with higher quality structures. Many man-made materials came out in the previous years and some are synthetic. Although not natural, some are used to make eco-friendly houses like 3D houses that actually pass the green construction standards. All building materials can be used to create a quality structure, but that depends on how they are used in construction. This is why project managers and field engineers need to analyze carefully the material they need in their projects.

Importance of selecting the right building materials

The right building materials have a big impact on the quality of the structure. No matter how proficient a construction team is when the materials are cheap and substandard, the building will still see many problems and won't last long.

Sadly, the selection of right building materials is often overlooked. Many project planners tend to cut corners and push aside the use of the best quality materials. Often, cost is the reason for choosing alternative materials that are not as good as the original choice. However, clients need to consider that they can deliver the highest quality building to their tenants by using the most suitable materials. This also ensures the safety and durability of the building.

Types of construction building materials

1. Natural materials

Building materials can be divided into two general sources – the first is natural and the second one is synthetic.

Natural construction materials refer to those that are not or minimally processed, like lumber or glass. Synthetic construction materials are those that are manufactured and go through a lot of human manipulations. Some examples are plastics and petroleum-based paints.

Apart from lumber, mud, stone, and fibrous plants are three of the most used materials in building homes. Builders usually combine these three, apart from tents and skin to create houses that can withstand local weather conditions.

Generally, the stone is used as the essential building component, while mud is used to fill in the gap between them. In modern construction, the stone serves as the natural counterpart of hollow blocks or bricks, while mud is cement's alternative. Furthermore, mud acts as natural insulation to a structure.

An example of a structure built with natural construction materials is the wattle and daub, where wet soil, sand, clay, straw, and animal dung are used as building components.

2. Mud and clay

As we mentioned earlier, mud and clay are natural construction materials that are still used today. The amount of mud or clay used in construction creates different styles of buildings so if you want flexibility in your design, mud and clay should be used.

The main factor on the amount of each material to choose lies in the quality of soil used in construction. On the one hand, larger amounts of clay can build adobe style houses, on the other hand, a lower amount of clay soil can be used in sod building.

Apart from the soil, the amount of sand/gravel and straw/grass can influence the clay structure you create. Rammed earth is used in creating walls made by compacting clay between planks by hand. Nevertheless, in this modern age, a mechanical pneumatic compressor is used in processing clay to create more intact rammed earth.

One reason why mid and clay are still used today is because of its right thermal mass. Structures made of clay soil tend to be cool during the summer and warm during the colder seasons. Clay can hold heat or cold.

Cob, sod, and adobe houses are very common in the southwest or western and northern parts of Europe. While most of the countries there have wet climate throughout all the year, these house styles surprisingly remain habitable even after hundreds of years. For that reason, some modern sustainable buildings are adapting sod styles.

3. Rock

The use of rock can be traced back to ancient times. In fact, the entire Egyptian civilization, specifically the pyramids, was made of rock. It's one of the longest-lasting materials available so even if you won't see cave-style rock houses these days, rocks are still used as components or other construction materials. The fact that it is also readily available makes it a less expensive material to procure.

There are many types of rock and each of them differs in properties. So, before using rocks in your building, you have to see that you are getting a good quality rock.

Generally, rock is a very dense material, making it a good protective material. Its weight and energy density are considered its biggest drawbacks since it can be difficult to keep stones warm.

In the olden times, a mortar was used to hold stones together, whereas, in this era, cement is what is commonly used.

4. Wood

Wood or lumber is still widely used today. Both are products of big trees where the trunk is usually broken down into portions. Back in the days, wood was used almost unprocessed as logs and then tied or notched in place. However, since architecture and new construction techniques came to play, wood has been cut and pressed into timber boards or planks and is now used on floors, ceilings, and cabinetry.

Wood remains to be a generic material and used in making buildings in about any climates. It's flexible and can bend while keeping its strength.

The quality and durability of wood depend on the species it came from. Some species are more potent than others, but of course, they are more expensive too. This also means that some species are perfect for certain applications in construction.

For example, oak and maple are suitable for flooring and cabinets, while pine and teak are best for walls.

These days, modern western houses still use wood, as it is quicker to put up. It's also classic. Some people design their wooden homes with modern furniture to make space look more elegant and up to date.

5. Brick and block

Bricks are made of kiln-fired material. Typically, clay or shale is used to make bricks. Some others use mud when the funds are insufficient, but of course, the quality isn't that good.

Clay bricks are manufactured by molding clay or by extruding it on a die. They are still widely used these days as people learn to combine wood and bricks, making their houses fire-resistant. Additionally, clay bricks are cheaper than wood.

In the late 20th century, clay blocks got an alternative through cinder blocks. It's made with concrete and, obviously, more durable. Lately, a low-cost variant of brick was introduced. The sandcrete block is now among the options but is generally weaker than clay.

6. Concrete

Most commercial and industrial structures are now made of concrete. It's trendy because of its strength and longevity. It is a composite material produced usually from aggregate and cement.

Portland is the most widely used concrete these days. It uses mineral aggregates like sand and gravel, portland cement, and water for its mixture, which is later hydrated and hardened. The end product is a stone-like building material.

However, concrete has a low tensile strength. It is typically strengthened by enforcing steel rods or rebar. Hence we have the reinforced concrete structures.

Air bubbles are what usually weakens the concrete. This is why concrete pouring in construction should be given extra care. Vibrators are used to eliminate the bubbles formed during the pouring process.

7. Metal

Metal is one of the most essential materials in making modern buildings like skyscrapers. It is also usually used as a wall covering.

Different types of metals are employed in construction. Steel, whose major component is iron, is the most common metal used in construction because of its longevity, strength, and flexibility. However, it can be weakened by corrosion.

Sometimes aluminum alloy is used as an alternative to eliminate the corrosion. It's more costly than steel, but when you need your building put up near the shore, it will be more advantageous to use aluminum.

Other metals used as building materials include brass, titanium, silver, chrome, and gold. Titanium and brass can be used in construction, while the more special metals in decorative details.

Modern building materials

The construction industry in modern times has grown into a multi-billion dollar industry. Construction projects are done left and right and with the employment rate growing in different industries, more constructions are expected to happen.

Following this, the building material harvesting industry is also growing and evolving. To meet the standards of modern buildings, new types of construction materials are being invented.

Since environmental concerns are becoming a worldwide concern, natural building materials like wood are limited. If not, they come with the special condition of the industry planting its trees to harvest.

This led the industry to develop modern alternatives where these new materials production and use won't hurt the environment. 3D printing, for instance, uses construction scraps as raw material.

The choice of building materials greatly affects the success of a construction project. They can make or break your project, so the planners need to analyze which materials will work best for the project during the planning stage.

Answer the following questions:

1. What are building materials?
2. Why is it important to choose the right building materials?
3. What is the difference between natural and synthetic materials?
4. Where can mid and clay be used?
5. What material were Egyptian pyramids made of?
6. How was wood used in the past? How is it used nowadays?
7. What are bricks and cinder blocks made from?
8. What is concrete?
9. Where is metal used? What types of metal do you know?
10. Tell about modern construction industry. What has changed since the last century?

Chapter II. Bridge Building
Unit 1. Bridge Egineering and Bridge Components

A bridge is a construction made for carrying the road traffic or other moving loads in order to pass through an obstacle or other constructions. The required passage may be for pedestrians, a road, a railway, a canal, a pipeline, etc. Obstacle can be rivers, valleys, sea channels, and other constructions, such as bridges themselves, buildings, railways, or roads. Bridges are important structures in modern highway and railway transportation systems, and generally serving as "lifelines" in the social infrastructure systems.

Bridge engineering is a field of engineering (particularly a significant branch of structural engineering) dealing with the surveying, plan, design, analysis, construction, management, and maintenance of bridges that support or resist loads. This variety of disciplines requires knowledge of the science and engineering of natural and manmade materials, composites, metallurgy, structural mechanics, statics, dynamics, statistics, probability theory, hydraulics, and soil science, among other topics. Similar to other structural engineers, bridge engineers must ensure that their designs satisfy given design standard, being responsible to structural safety (i.e., bridge must not deform severely or even collapse under design static or dynamic loads) and serviceability (i.e., bridge sway that may cause discomfort to the bridge users should be avoided). Bridge engineering theory is based upon modern mechanics (rational knowledge) and empirical knowledge of different construction materials and geometric structures. Bridge engineers need to make innovative and high efficient use of financial resources, construction materials, calculation, and construction technologies to achieve these objectives.

Bridge components

Structural components of bridges are based on parametric definitions involving deck types and various bridge properties. Bridge structures are composed of superstructure, bearing, superstructure, and accessories.

1. Superstructure

In general, the superstructure represents the portion of a bridge above the bearings, as shown in Fig. 1.3. Superstructure is the part of a bridge supported by the bearings, including deck, girder, truss, etc. The deck directly carries traffic, while other portions of the superstructure bear the loads passing over it and transmit them to the substructures. In case, the deck was divided as a separate bridge component, and the structural members between the deck and the bearings are called as bridge superstructure.

The superstructure may only include a few components, such as reinforced concrete slab in a slab bridge, or it may include several components, such as the floor beams, stringers, trusses, and bracings in a truss bridge. In suspension and cable-stayed bridges, components such as suspension cables, hangers, stays, towers, bridge deck, and the supporting structure comprise the superstructure.

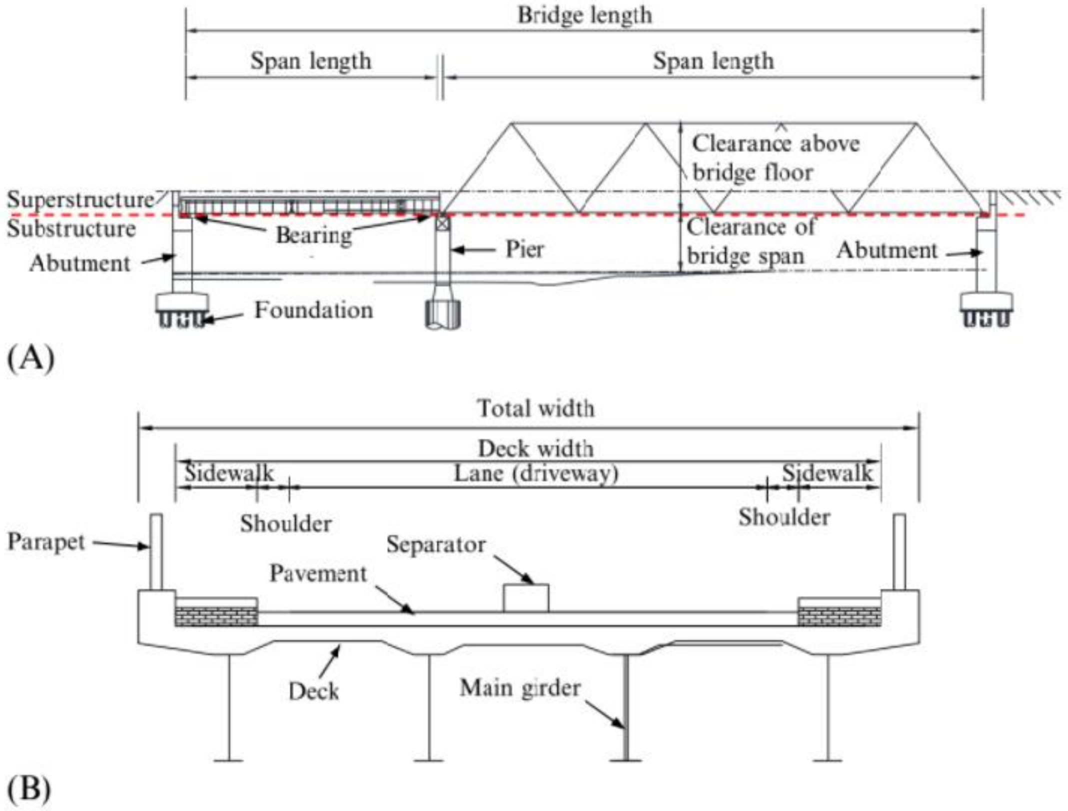


Fig. 1.3 General terminology of bridges. (A) Longitudinal direction. (B) Cross section.

2. Bearings

A bridge bearing is a component of a bridge transmitting the loads received from the deck on to the substructure and to allow controlled movement due to temperature variation or seismic activity and thereby reduce the stresses involved. A bearing is the boundary between the superstructure and the substructure.

3. Substructure

Substructure is the portion of the bridge below the bearing, used for supporting the bridge superstructure and transmits all those loads to ground. In this sense, bridge substructures include abutments, piers, wing walls, or retaining walls, and foundation structures like columns and piles, drilled shafts that made of wood, masonry, stone, concrete, and steel.

Both abutments and piers are vertical structures used for supporting the loads from the bridges bearings or directly from the superstructures and for transmitting the load to the foundation. However, the abutments refer to the supports located at beginning or end of bridge, while the piers are the intermediate supports. Therefore, a bridge with a single span has only abutments at both ends, while multispan bridges also need intermediate piers to support the bridge superstructures.

4. Accessory structures

Bridge accessories are structure members subordinate to the main bridge structure, such as parapets, service ducts, and track slabs. Deadweight of accessory structures must be considered in the design, but their load carrying capacities are generally ignored.

Bridge length, span length, and bridge width

The distance between centers of two bearings at supports is defined as the span length or clear span. The distance between the end of wing walls at either abutments or the deck lane length for bridges without using abut is defined as total bridge length. Obviously, the bridge length is different from the span length. For example, the world's largest bridge (means the span length) is the Akashi Kaikyo¯Bridge in Japan (with the central span of 1991 m), while the longest bridge (means the total length) is the Bridge Engineering Danyang-Kunshan Grand Bridge in China, which is a 164.8-km long viaduct on the Beijing-Shanghai High-Speed Railway.

Deck width is the sum of the carriageway width, sidewalk width, shoulder width, and the individual elements required to make up the desired bridge cross section. The total bridge width not only includes the deck width but also the width of the bridge accessories such as parapets. The lane width is determined according to the bridge design codes, generally with the minimum width of 2.75 m and the maximum width of 3.5 m.

Answer the following questions:

1. What is bridge?
2. What is bridge engineering dealing with?
3. How many components is bridge structure composed of?
4. Does the superstructure represent the portion of a bridge above or below the bearings?
5. Where can bearings be found?
6. What is the main function of the superstructure?
7. What do bridge superstructures include?
8. Should the deadweight of accessory structures be considered in the design?
9. What is the difference between the bridge length and the span length?
10. What information is required to make up the desired bridge?

Unit 2. Bridge Classification

Bridges are generally classified in terms of the bridge's superstructure, and superstructure can be classified according to the following characteristics:

- Materials of construction
- Span length
- Position (for movable bridges)
- Span types
- Deck location
- Usage
- Geometric shape
- Structural form

Beam bridges

Beam bridges (also referred to as Girder Bridges) are the most common, inexpensive, and simplest structural forms supported between abutments or piers. In its most basic form, a beam bridge is just supported at each end by piers (or abutments), such as a log across a creek. The weight of the beam and other external load need to be resisted by the beam itself, and the internal forces include the bending moment and shear force. When subjected a positive bending moment, the top fibers of a beam are in compression (pushed together) while the bottom fibers are in tension (stretched).

This is more complex than a cable only in tension or an arch mainly in compression. Therefore, only materials that can work well for both tension and compression can be used to build a beam bridge. Obviously, both plain concrete and stone are not good materials for a beam because they are strong in compression, but weak in tension. Though ancient beam bridges were mainly made of wood, modern beam bridges can also be made iron, steel, or concrete with the aid of prestressing. Two continuous girder bridges that made of steel and concrete are shown in Figs. 1.16 and 1.17.

Fig. 1.16 Lagan bridge (concrete continuous girder bridge), Belfast.

Fig. 1.17 Queen Elizabeth II Bridge (steel continuous girder bridge), Belfast.

Rigid-frame bridges

A Rigid-Frame Bridge (also known as Rahmen Bridge) consists of superstructure supported on vertical or slanted monolithic legs (columns), in which the superstructure and substructure are rigidly connected to act as a unit and are economical for moderate medium-span lengths.

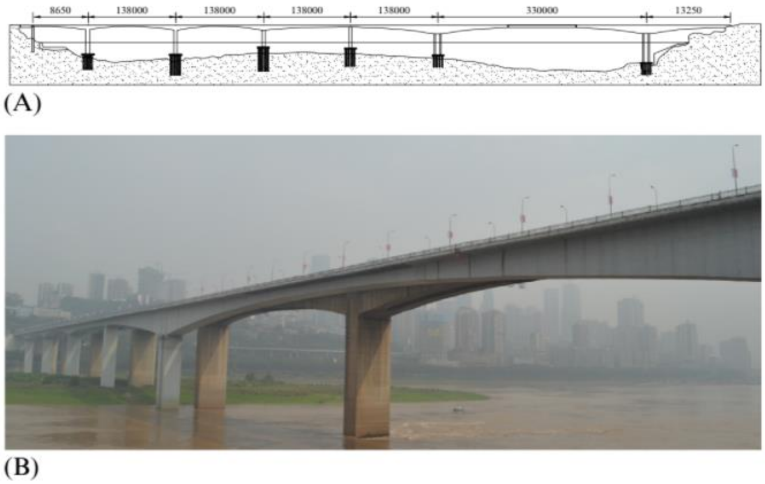


Fig. 1.18 The second Shibanpo Bridge in Chongqing, China. (A) Layout of the bridge. (B) Main span after construction. *(Photos by Yan.)*

The rigid-frame bridges are superstructure-substructure integral structures with the superstructure can be considered as a girder. Bridges of superstructure-substructure integral structure include braced rigid-frame bridges, V-leg rigid-frame bridges, and viaducts in urban areas. The connections between superstructure and substructure are rigid connections which transfer bending moment, axial forces, and shear forces. A bridge design consisting of a rigid frame can provide significant structural benefits but can also be difficult to design and construct. Moments at the center of the deck of a rigid frame bridge are smaller than the corresponding moments in a simply supported deck. Therefore, a much shallower cross section at mid-span can be used. Additional benefits are that less space is required for the approaches and structural details for where the deck bears on the abutments are not necessary. However, as a statically indeterminate structure, the design and analysis is more complicated than that of simply supported or continuous bridges.

Truss bridges

Truss is a structure of connected elements forming triangular units, and a bridge whose load-bearing superstructure is composed of a truss is a truss bridge.

Fig. 1.19 The Toyosu Bridge in Tokyo, Japan. *(Photo by Zheng.)*

Truss bridges are one of the oldest types of modern bridges. In order to simplify the calculation, trusses are generally assumed as pinned connection between adjacent truss members. Therefore, the truss members like chords, verticals, and diagonals act only in either tension or compression. For modern truss bridges, gusset plate connections are generally used, then bending moments and shear forces of members should be considered for evaluating the real performance of the truss bridges, which is achieved by the aid of finite element software. For the design point of view, however, the pinned connection assumption is considered for security concerns and also for simplifying the structural design and analyses. In addition, as the axial forces are generally governs the stress conditions of the members, such assumption generally will not cause large errors between the real bridges and the design models.

According to this assumption, the truss members can be in tension, compression, or sometimes both in response to dynamic loads. Owing to its simple design method and efficient use of materials, a truss bridge is economical to design and construct.

Short-span truss bridges are built as simply supported, while the large span truss bridges are generally built as continuous truss bridges or cantilever truss bridges.

Arch bridges

An arch bridge is a bridge shaped as an upward convex curved arch to sustain the vertical loads. A simple arch bridge works by transferring its weight and other loads partially into a horizontal thrust restrained by the strong abutments at either side. The arch rib needs to carry bending moment, shear force, and axial force in real service conditions. A viaduct (a long bridge) may be made from a series of arches although other more economical structures are typically used today. The current world's largest arch bridge is the Chaotianmen Bridge over the Yangtze River in Chongqing (China) with a span length of 552 m, as shown in Fig. 1.22.

For statically indeterminate arch bridges, the internal forces will occur due to the temperature variation and settlement of supports. For this reason, if the arch bridges are constructed in soft soil foundations, the bridge deck is generally designed to sustain the horizontal forces.

Fig. 1.22 The Chaotianmen Bridge, Chongqing, China. *(Photo by Yan.)*

Cable-stayed bridges

A cable-stayed bridge is a structure with several points in each span between the towers supported upward in a slanting direction with inclined cables and consists of main tower(s), cable-stays, and main girders, as shown in Fig. 1.24. In comparison with the continuous girder bridges, the internal forces due to both dead load and live load are much smaller in cable-stayed bridges. For mechanical point of view, a cable-stayed bridge is a statically indeterminate continuous girder with spring constraints. The cable-stayed bridges are also highly efficient in use of materials due to their structural members mainly works in either tension or compression (axial forces).

Cable-stayed bridges have the second-longest spanning capacity (after suspension bridges), and they are practically suitable for spans up to around 1000 m. The Russky Bridge in Russia has the largest span of 1104 m.

Suspension bridge

A typical suspension bridge is a continuous girder suspended by suspension cables, which pass through the main towers with the aid of a special structure known as a saddle, and end on big anchorages that hold them. Fig. 1.26 shows the essential structural members and elements of typical, including tower, hanger, main girder, and the anchorage. The main forces in a suspension bridge are tension in the cables and compression in the towers.

The deck, which is usually a truss or a box girder, is connected to the suspension cables by vertical suspender cables or rods, called hangers, which are also in tension. The weight is transferred by the cables to the towers, which in turn transfer the weight to the anchorages on both ends of the bridge, then finally to the ground.

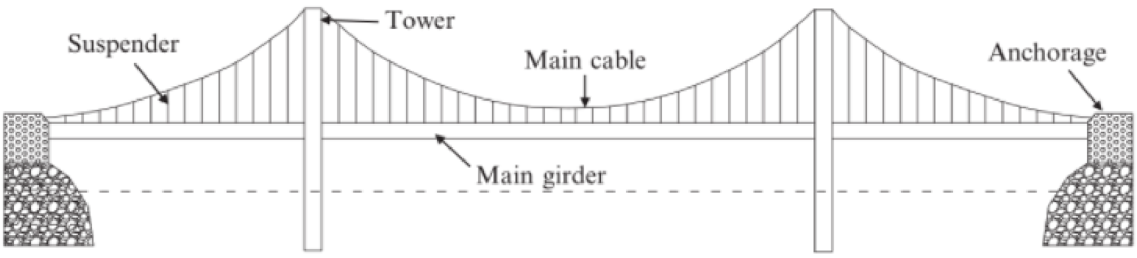


Fig. 1.26 Image of the suspension bridge.

The curve shape of the suspension cables is similar to that of arch. However, the suspension cable can only sustain the tensile forces, which is different from the compressive forces in the arch. Also because of this, the cable will never “buckle” and highly efficient use of high strength steel materials becomes possible. The use of suspension bridges makes longer main spans achievable than with any other types of bridges, and they are practical for spans up to around 2 km or even larger.

The Akashi Kaikyo Bridge (Fig. 1.27) in Japan has the longest central span of any suspension bridge in the world at 1991 m.

Fig. 1.27 The Akashi Kaikyō Bridge (Japan, the longest bridge since 1998).

Selection of bridge types

The selection of the proper type of bridge is determined based on the results of topographic survey, geological survey, traffic survey, geotechnical survey, hydro technical survey, seismic survey, and meteorological survey, etc., as well as the cost, environmental impact, and esthetics. While, the maximum span length (or spanning capability) is generally an important factor that should be considered for designing the bridge superstructure due to the fact that each bridge type has its own scope of application.

Selection of the bridge superstructures is closely related to the use of construction materials. Based on the materials used for superstructure construction, the modern bridges can be roughly divided into concrete bridges and steel bridges, with different structural forms. Benefit by the high strength to weight ratio, steel construction requires less material than other traditional technologies and contributes to reducing a bridge’s environmental impact.

The steel bridges are generally built in large spans such as arch bridges, truss bridges, cable-stayed bridges, and suspensions bridges. Especially for large span bridges, as the dead weight governs the load carry capacity of bridges, the bridge superstructures are built in steel but not concrete. Concrete is a brittle material, like stone, good in compression but weak in tension, so it is vulnerable to crack under bending or twist. Concrete has to be reinforced with steel to improve its ductility; naturally, its emergence follows the development of steel. However, for some structural forms of bridges, concrete will be a perfect material to build, such as the arch bridges whose members are mainly under compression. In addition, concrete bridges are also widely used for short-span bridges due to the relative low cost and less maintenance in service stage. In addition, with the development of the prestressing technique, the prestressed concrete bridges can also be built in medium spans.

The availability of the construction materials should be considered in the selection of the bridge superstructures. The mechanical characteristics of each bridge type are the determinant factor for an appropriate span capacity. Based on the discussion above, the simply supported structure is statically determinate and is simplest to design, and generally is suitable for short-span bridges. When unyielding foundation is attainable, the rigid-frame bridges and arch bridges may provide the most economical solution for span length. For medium-span bridges, the continuous girder bridges, the truss bridges, and the arch bridges can be considered as an alternative. For large span bridges longer than 500 m, the cable-stayed bridge and the suspension bridges are promising solutions. A cable-stayed bridge is the successor to the suspension bridge for spans up to 600 m, and the largest span of cable-stayed bridge 1104 m. However, for super bridges with span length larger than 1000 m, a suspension bridge is still the best choice.

The bridge foundation is another factor that may affect the selection of the bridge superstructures. When unyielding foundation is attainable for building the intermediate piers, then continuous girders supported by independent piers and multispan rigid frames will be good options. When unyielding foundation is available for building the abutments, the arch and rigid-frame bridge can be alternatives. For soft foundations, other bridge types with larger spanning capacity should be selected to avoid the intermediate piers.

To sum up, each bridge type has its own suitable range of application and should be considered in the selection of the bridge superstructures. In addition, other factors such as the cost, environment impact, and esthetics need also to be considered to determine suitable alternatives for bridge superstructures.

Answer the following questions:

1. How can bridge supestructures be classified?
2. What are the advantages of beam bridges?
3. What materials should beam bridges be made of?
4. When did the use of rigid-frame bridges begin?
5. Why is it difficult to design a rigid-frame bridge?
6. What is truss?
7. Is a truss bridge economical to construct?
8. How does a simple arch bridge work?
9. Why are cable-stayed bridges highly efficient in use of materials?
10. What is the longest bridge in the world?

Chapter III. Tunnel Construction
Unit I. Steps of Tunnel Construction

Man has spent tens of thousands of years trying to change the planet at will, to greater or lesser success. Hollowing out earth and rock, initially for mining purposes and later on for building roads and communication links, was one of the first engineering feats in history, almost akin to the invention of the wheel or the discovery of fire.

However, much has changed since the engineer Eupalinos built what is considered to be one of the first tunnels in history – an underground passage over a kilometer in length on the Greek island of Samos – in the 6th century B.C. Today, technical and technological developments allow us to talk of tunnels which cross the seas, such as the 50 km-long English Channel, or join continents, such as the tunnel of Marmaray, in Istanbul. To build a tunnel you should follow the next steps:

1. **Geological evaluation**

The first step is compiling as detailed a report as possible regarding the ground where the tunnel will be built, from both a geological (materials and structure) and a geotechnical (how the affected materials will react to tunneling) perspective.

In order to construct appropriate models, both field and laboratory work is required, including geological mapping, mechanical surveys of the route to be followed by the tunnel, geophysical tests to determine what the surface is like, and laboratory trials on samples selected on site. Then all the data collected must be interpreted and analysed in order to build geological and geotechnical models of the tunnel.

2. **Studying the route**

The chosen route usually has to be accepted, and then the most appropriate construction solution must be applied to ensure success.

There are many factors which may make complying with the chosen route more complicated, nonetheless there are two elements which may really put the whole project at risk: unexpected presence of water or gas. The presence of large volumes of water at the tunnel mouth can cause instability, risk of collapse, landslides.

Classical building methods, where workers directly access the tunnel opening, are the best way of solving this problem. The presence of large tunnel boring machines (TBMs) in such cases is an added problem. Generally, such complications must be detected and solved before large volumes of water can get into the tunnel.

Gas, for its part, whether flammable or not, may put health and safety at risk in the tunnel, and regulations are becoming increasingly stringent. Construction of the Abdalajís tunnels (which are over 7 km long) on the Córdoba-Málaga high-speed rail link required boring through complex geological formations, and excavation works were affected by the presence of methane, something which had apparently not been foreseen at the project stage.

3. **Supports and lining**

The design of supports and linings depends on the construction method chosen for building the tunnel, as well as on a knowledge of the ground. While support is critical for maintaining the infrastructure, the use of certain linings is sometimes called into question, as this can be influenced by other factors, such as reasons of aesthetics or aerodynamics (for example in high-speed rail lines).

However, some terrains also make linings essential. A different approach must be taken in areas of expansive terrain, where changes in humidity make the ground expand and exert pressure on the lining. In such cases, strongly armoured lining sections must be used.

4. Choosing the tunnel construction process

In a world where technological advances seem to dominate everything, it may appear surprising that some methods of tunnel boring have barely changed over the past 200 years. These are the so-called classical methods, still frequently used in urban settings, of which the Belgian or German methods are some examples.

Such methods, which involve workers digging with picks and shovels, require teams of highly qualified and experienced people. Today, when the trend is for such traditional occupations to disappear as a result of tunneling, specialist tunnel borers have to be trained by the actual construction companies.

And how is it possible that such tunneling artists survive in today's day and age? The reason is that, contrary to what might be expected, they are competitive regarding costs. When you commission a TBM, 12 to 15 months may go by before it is assembled and ready to go. In that time, between 800 to 900 metres of tunnel can be bored using classical methods. Which means that for shorter tunnels it is not cost efficient to use a TBM if the ground to be bored (preferably soft soils) allows for manual labour.

Tunnel boring machines

A tunnel boring machine (TBM) is not just any machine. Dulcinea, the TBM used for boring Madrid's M30 ring road by-pass, weighs 4,367 tonnes and is 107 m long. Which means that when deciding to buy or rent one of these machines, a large number of criteria must be taken into account.

1. Geology. Both for soft ground and for rock, available information on factors such as permeability and pressure must be as detailed as possible.

2. Range of TBMs available. The time taken for building and on-site assembly of a TBM is rarely less than a year; this is enough time for excavating shorter tunnels using classical methods.

3. Length and diameter of the tunnel. For tunnels of more than 4.5 km and a regular section, a TBM is the most cost-efficient option.

4. Layout and elevation of the tunnel. Numerous factors come into play here, such as the need to include auxiliary high capacity earth and rubble removal machinery (TBMs create a lot of waste material), the diameter of the tunnel (complications could arise in tunnels with diameters of less than 5 meters) or its slope. TBMs work best at slopes of less than 5%. They can be used on slopes of up to 20%, provided they work upwards.

Answer the following questions:

1. Who built one of the first tunnels?
2. How many steps are in tunnel construction?

3. What information is needed to build geotechnical and geological models of the tunnel?
4. What factors can put the whole project at risk?
5. What is the best way of solving the risk problem?
6. When are supports and linings used?
7. What are classical methods of tunnel boring?
8. Do construction companies still use manual labor while building a tunnel?
9. When use a TBM is not cost effective?
10. When is it better to use a TBM?

Unit 2. Tunnel Construction Methods

The tunnel construction process is costly and time-consuming. However, transport and communication via tunnel networks is extremely efficient and comfortable. Modern machinery has made the excavation and stabilization processes much easier and safer, which is why tunnel networks have become a more popular choice for roads, railways, and even waterways.

There are different tunnel construction methods that are used according to the geology, type of overburden as well as seismic and noise restrictions, as mentioned below.

1. Cut and cover method:

This method is commonly used to construct shallow tunnels. Basically, this method involves the cutting of a trench in the soil, tunnel box elements are installed after which they are covered over to reinstate the surface by a support method that is capable of bearing the load. Early underground metro rail stations in London were built using this method. Some sections of road networks are also built this way when the depth of the required tunnel is relatively shallow (The Marselis Tunnel in Aarhus and the Nordhavnsvej tunnel in Copenhagen are the first Danish cut and cover tunnels).

2. Bored or mined tunnelling:

In this method, the tunnels are built without excavating the ground surface. This method is enabled by the use of Tunnel Boring Machines (TBM's). These allow tunnels to be excavated in a wide variety of ground conditions and beneath towns, cities, rivers and even tall buildings. They do this by maintaining the static pressure of the existing ground to virtually eliminate settlement, thereby avoiding damage to surface buildings or structures. TBM's are also able to install a concrete ring for permanent ground support when the tunnel is in operation. Bored or Mined tunneling can be sub-divided as follows:

3. Soft ground tunnelling:

This would typically be described as tunnelling through non-self supporting materials such as Sand, Marine Clay, or a mixture of both, with MPa levels of around 40 or less. The Netherlands is commonly associated with soft ground tunneling. Examples of tunnels in soft ground can be metro's and road tunnels, such as the Rotterdamsebaan Road Tunnel in The Hague and the Westerschelde Road Tunnel in Southern Holland.

4. Hard rock tunnelling:

As the name suggests, the geology will typically be through hard to very hard rock with MPa levels of greater than 100. Excavation would be done with specially adapted TBM's which can cope with highly abrasive conditions in largely self-supporting geology. In such geology hard rock tunnels can often remain unlined and are used for water transfer or hydro power plants. They can also be used in in mountainous regions such as Switzerland for road tunnels, The Gotthard Road Tunnel in Switzerland runs from Göschenen in the canton of Uri at its northern portal, to Airolo in Ticino to the south, and is 16.9 kilometres long.

5. **Microtunnelling and pipejacking:**

This method is used for relatively short and correspondingly small diameter tunnels, mainly used by the utilities construction sector. This allows for cables and pipes to cross beneath roads, rivers railway lines and even airport taxiways and runways without disrupting any surface traffic. The principal of excavation is based on “State of the Art” full face tunnel boring machines (TBM’s).

Answer the following questions:

1. Where can tunnel networks be constructed?
2. When different tunnel construction methods are used?
3. What method is used to construct shallow tunnels?
4. What are the first cut and cover tunnels?
5. Why do TBM’s avoid damage to surface buildings or structures?
6. How can bored and mining tunneling method be sub-divided?
7. How can soft ground tunneling method be described?
8. Where is it better to use hard rock tunneling method?
9. Where is microtunnelling and pipejacking method used?
10. What are the advantages of microtunnelling and pipejacking method?

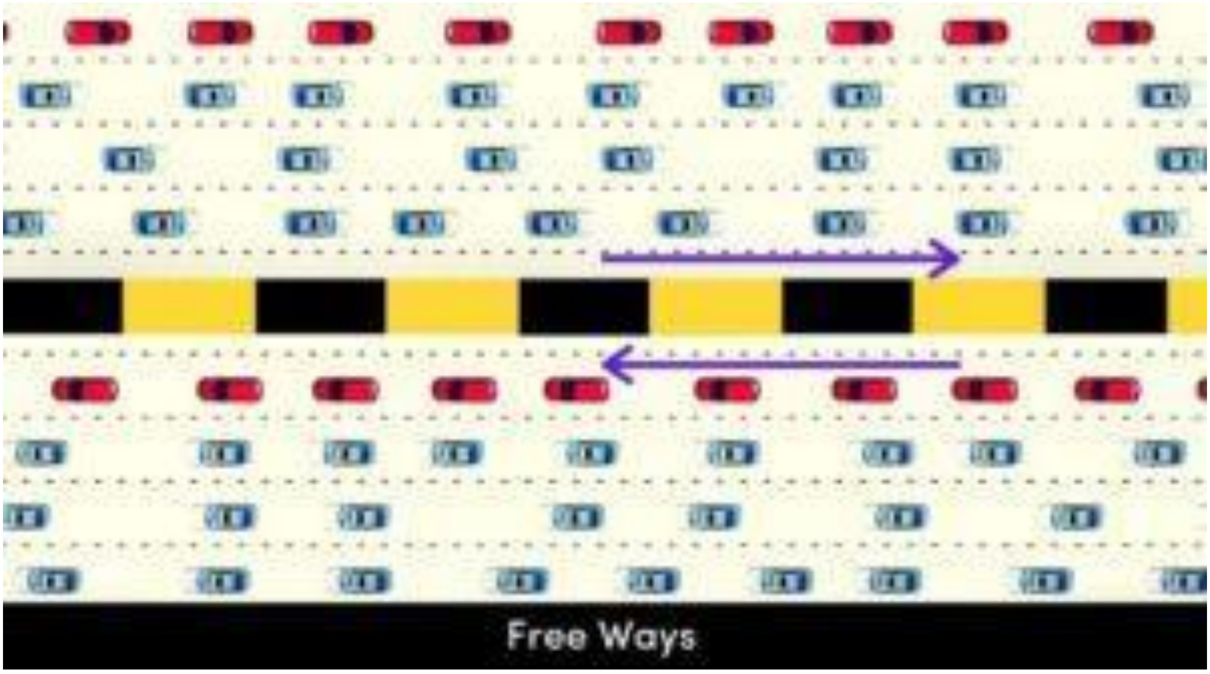
Chapter IV. Road Building
Unit 1. Types of Roads

The road is a wide way leading from one place to another, especially one with a specially prepared surface that vehicles can use. Roads are classifications are based on different criteria; each among them is further classified into different types of roads. Roads are primarily classified as follows:

- **Based on speed and accessibility:**

1. Freeways:

Freeways are wide roads designed for fast-moving vehicles to travel long distances with higher speeds. These are generally designed in four lanes, two lanes in each direction. Traffic movement on freeways is continuous and unhindered because there are no railway or road intersections and no signals. Bridges or underpasses are constructed to create a passage for roads, which cross freeways.



Parking and walking are strictly prohibited on freeways and they don't have footpaths on either side of roads.

The minimum speed limit and maximum speed limit varies from the country by country and it ranges between 45mph to 75mph.

2. Expressways:

Expressways are one of the superior types of access-controlled roadways where the entry and exit of the expressway are fully controlled by ramps.

As the name itself "express" echoing that these are meant for a free flow of very speed traffic. Expressways are designed to travel quickly with great comfort and safety by avoiding sharp curves, busy traffic intersections, railway junctions.

Vehicles with high acceleration are only permitted in expressways. Heavy load vehicles, cargo vehicles, pedestrians are not allowed.

Parking, loading and unloading are strictly prohibited on Expressways.

Express Ways

3. Highways:

Highways connect villages to cities or cities to cities or state to state or the roads connect the state capital to the national capital are called highways. Highways are the roads run through the length and breadth of the country. They are generally laid in two lanes.

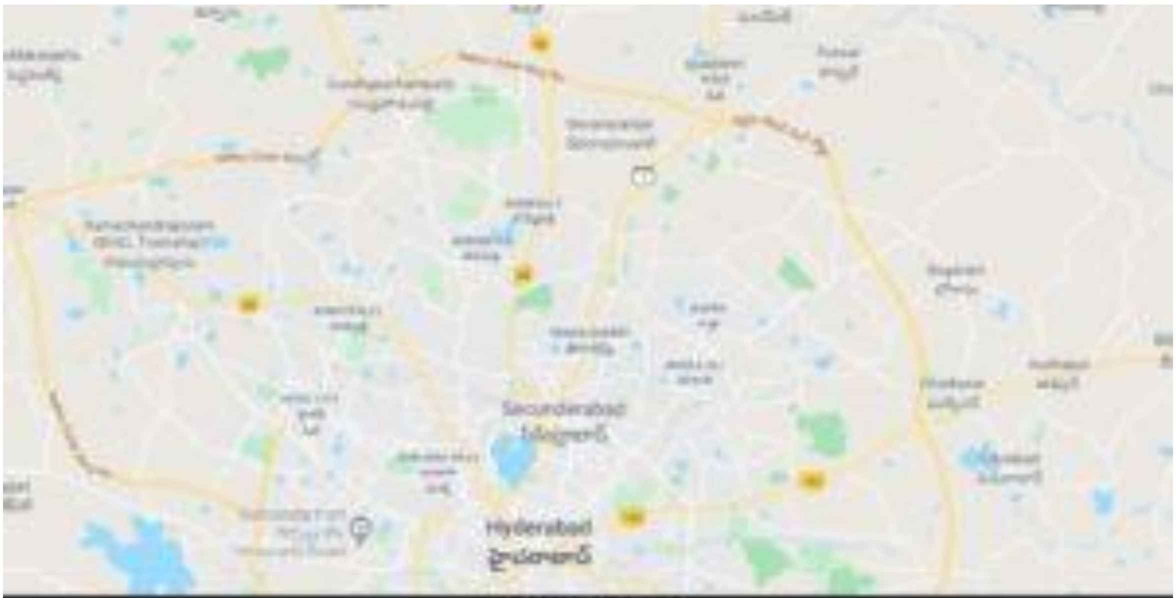
Highways

4. Arterials:

Arterials are the roads laid inside the city or town for the movement high volume of traffic. An arterial road joins the central business point to the outside residential areas. Arterials provide access to the highways.

Pedestrians are allowed to cross the roads only at intersections or at designated pedestrian crossings. The flow of traffic is controlled by a signaling system at intersections.

Parking is not allowed on arterial roads.



Arterials

In the above image, white lanes and yellow lanes denote arterials.

5. Local streets:

Local streets don’t carry a large volume of traffic like arterials. The speed limit is restricted to 30km/h in a local street. Local streets allow you to properties around it.

Local Streets

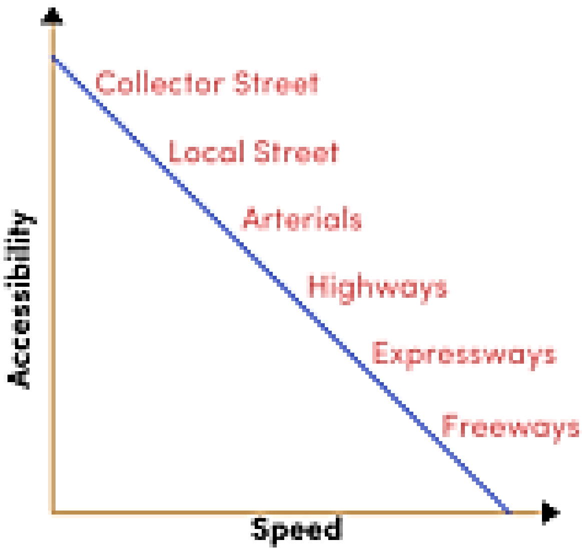
Pedestrians can cross the road at any point in local streets. Unrestricted parking, loading and unloading of vehicles are allowed in local streets. They usually don’t have any divider with boulders but divided with 1m dotted white lines or straight white line.

6. Collector roads:

Collector roads collect and deliver the traffic to and from local streets and arterials. The speed limit usually ranges between 35-55km/hr.

Pedestrians are allowed to cross only at intersections. Parking can be allowed except at peak times.

The below graph represents the speed and accessibility for different types of roads



- **Based on materials used:**

There are different types of roads based on the materials used in the construction of the road.

1. Earthen roads:

The roads that are laid with the available soil at the site are called Earthen Roads. These are the cheapest roads among all the roads. Earthen roads are designed for very low volume traffic.

Available soil is laid in two-three layers and surface of the road is compacted with the rammer to expel the excess voids present in the soil.

It is not recommended to go with Earthen roads in monsoon as the soil may runoff during rain.

2. Gravel roads:

Gravel roads are the second cheapest among all the types of roads and they are also better than Earthen roads.

In this type of roads, the mixture of gravel and earth (available soil at the site) is paved on the surface and compacted. Gravel roads are also called as metal roads. These types of roads are easily built and generally laid in villages.

3. Murram Roads:

Murram is a gravelly lateritic material which is occurred during the disintegration of igneous rocks by weathering agencies. The roads that are laid using Murram as primary material is called as a Murram road. The density of murram is higher than the gravel that also provides good surface finish and compaction than above two types of roads.

Murrom Roads

4. Kankar Roads:

The word Kankar is derived from India, which means an impure form of Limestone. This type of roads usually recommended at places having a good quantity of lime. Kankar road is one of the low-quality roads but better than Earthen roads and gravel roads.

Kankar Roads

5. Bituminous roads:

The bituminous is a black viscous and adhesive material occurred during the distillation of petrol. Bituminous roads are primarily used all over the world that is very easy to lay and provides smooth and good surface finish. The thickness of bitumen road depends upon the subgrade soil at the site. It is always recommended to lay the bitumen roads in two layers.

Bitumen Roads

6. Concrete roads:

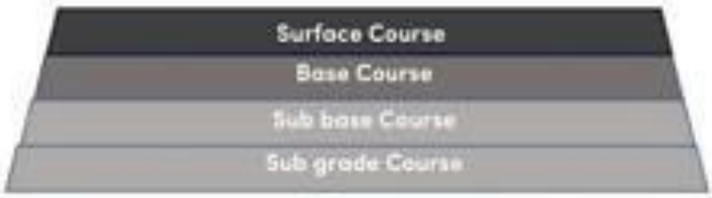
The roads that are laid using the cement concrete material is called concrete roads. These are the costlier roads among all type of roads. This type of roads are recommended at the places of the high volume of traffic and it takes more time to construct the concrete roads, as the concrete requires proper curing. The average life of a concrete road is 40 years whereas bituminous road has an average life of 3 years.

- **Based on rigidity:**

1. Flexible Roads:

The flexible road has four layers; the outer surface layer is topped with bituminous material, which is called as wearing course and an underlying sub-base, base and subgrade course. All these layers make the road flexible. Periodic maintenance is required for flexible roads; otherwise, it can disintegrate easily with heavy traffic.

All roads except cement concrete roads are flexible roads.



Flexible Roads

2. Rigid roads:

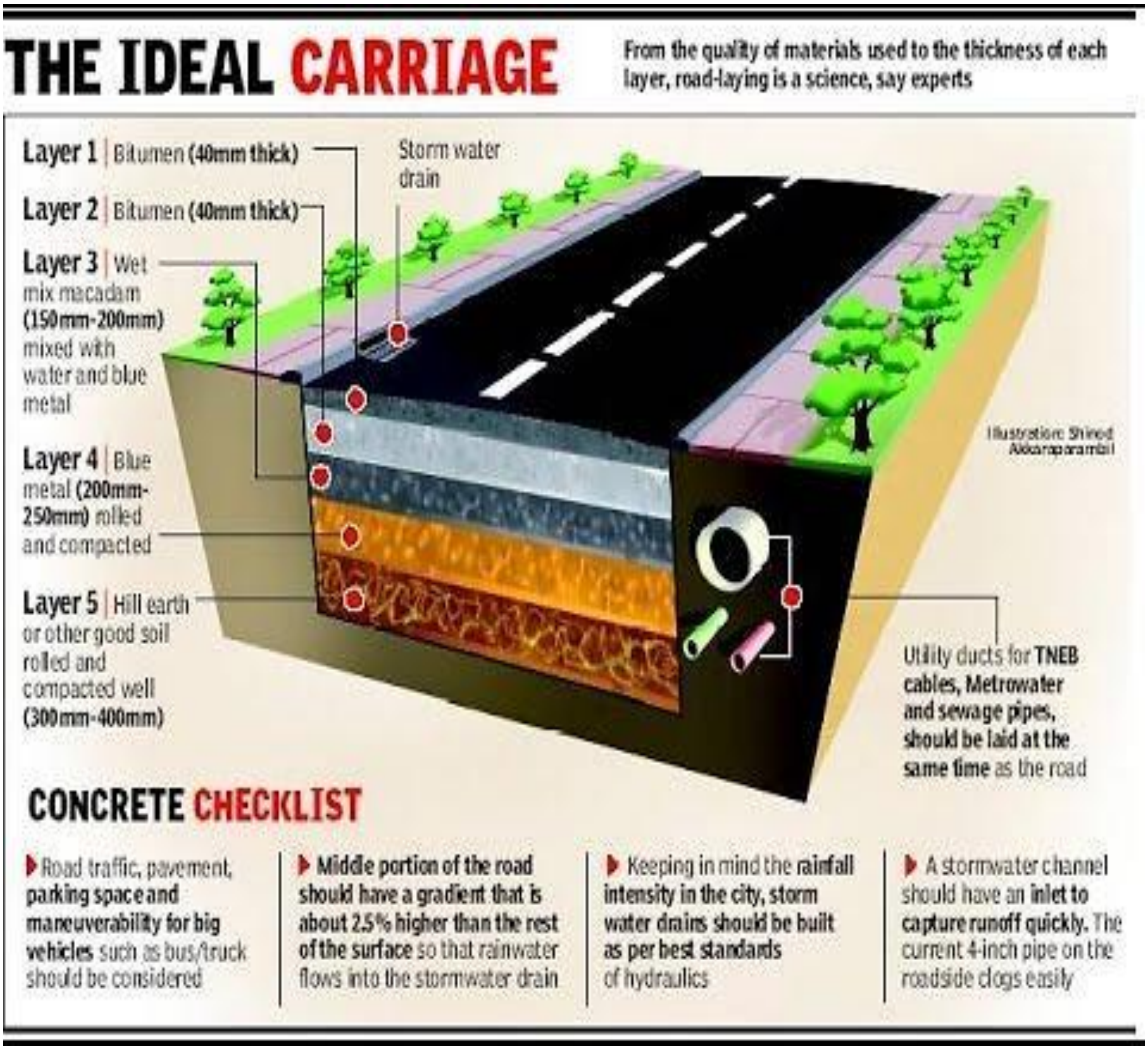
These are the roads with only three layers (Surface course, Base and Subgrade course) makes road non-flexible. Cement concrete road falls under this category.

Flexible roads consist of a flexible layer as a pavement surface, which requires proper maintenance; otherwise, it can be disintegrated easily with heavy traffic. All types of roads except concrete roads fall under this category.

Answer the following questions:

1. What is a road?
2. How can roads classified?
3. What types of roads are there based on speed and accessibility?
4. What vehicles are not allowed on an expressway?
5. What types of roads connect villages to cities?
6. How can the flow of traffic be controlled on arterial roads?
7. Where can pedestrians cross the road in local streets?
8. How can roads be classified based on materials used?
9. What roads are the most expensive?
10. What is the difference between flexible and rigid roads?

Unit 2. Components of Road Structure



A road structure consists of the following components:

1. Sub Grade:

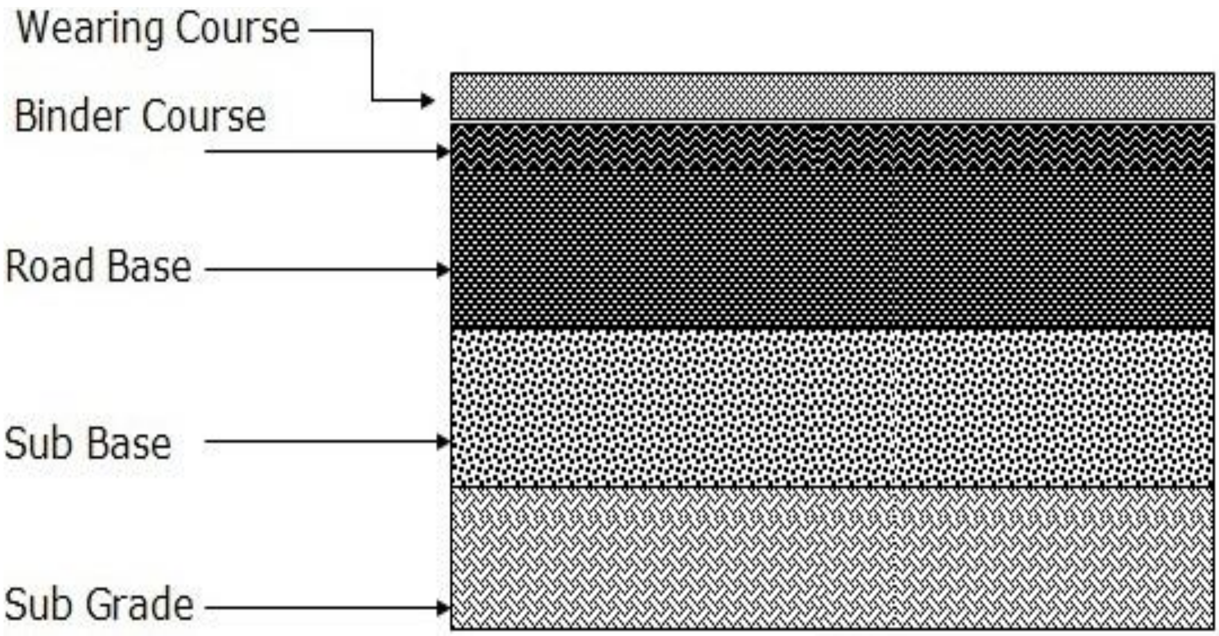
Subgrade is the foundation of the road, thus it's the lowest and most important component of road structure.

Construction:

- If natural surface is above the formation level then the surface is cut down to proposed sub grade surface
- If natural surface is below the formation level then the sub grade will be above the ground level
- It should be constructed at least 60 cm (2ft) high from highest flood level of the area

Function of Sub grade:

- Bears all the load thus acts as a foundation of road
- Transfer load through grain to grain contact



Material:

Material of sub grade should be strong enough to bear the loads, easily accessible and available in the vicinity and cheap.

2. Sub Base:

Consists of:

1. Upper Base Course
2. Sub or Lower Base Course

Construction:

- Constructed above the sub grade
- Not needed if the sub grade is of very high strength
- In case of flexible pavement upper and lower base courses are separated having different materials
- In case of rigid pavement only upper base course is provided
- Thickness varies from 7.5 (3in) to 15cm (6in)

Functions of sub base:

- Prevent rise of water or capillary action

Material:

- Should be better than the material of Sub Grade
- The Upper Base Course is made up of sand, gravel, and stone
- The Lower Base Course is made up of cheaply available material i-e rock and stone fragments

3. Road base:

Due to quality of material used in the road base is divided into

1. Upper Road Base
2. Lower Road Base

Construction:

- Constructed above the Sub Base

Functions of Road Base:

- To avoid the distortion of wearing course due to its sufficient density
- Supports the wearing course

Material:

- In case of Upper Road Base the material is of high quality as the load intensity is high
- In case of Lower Road Base the material is of high quality as the load intensity decreases

4. Surfacing:

It is the upper most layer of road cross section. It can be provided in one or two layers:

Construction:

Constructed usually in two layers

- Binder Course
- Wearing Course (It is the layer which is in direct contact with the tires of the vehicle)

Functions of surfacing of road:

- Prevent penetration of water in to the pavement
- Binder Course binds the Wearing Course with the Road Base
- Wearing Course provide a smooth riding
- Saves the lower layers from abrasion and weathering effects of the moving vehicles

Material:

- Made up of bituminous material
- For Flexible Pavement asphalt concrete is used
- For Rigid Pavements Reinforced Cement Concrete (RCC) is used.

Answer the following questions:

1. What components does a road structure consist of?
2. What is the lowest and most important component of road structure?
3. Where is sub base constructed?
4. What are the functions of sub base?
5. Where is road base constructed?
6. What are the functions of road base?
7. Why should the material be of high quality in case of upper and lower road base?
8. How many layers can surfacing be provided in?
9. What are the functions of surfacing?
10. What materials are used for flexible and rigid pavements?

Unit 3. Road construction process

Pre-construction activities.

The type of construction adopted for a particular road depends on:

- the volume and nature of traffic,
- the nature of available materials,
- the topography,
- foundation conditions,
- type and availability of construction equipment,
- financing arrangements and timing.

There are many steps in the road construction process. They involve many teams of people and much organization from the use of a surveying company to handle land surveys to project managers. The steps must be carefully followed to ensure a successful project is completed. These steps can be summarized as:

1. planning;
2. design;
3. earthworks;
4. pavement construction;
5. open to traffic.

Step I: Planning

A road project begins with evaluating the transportation system, taking into account statewide priorities, including strategic plans for the state's transportation system. Department of Transportation collects and maintains information about our roads, including road and bridge conditions, traffic volumes, and accident statistics.

Using this data, transportation planners, engineers, environmentalists, landscape architects, soil scientists and others identify trends that determine what and how to build.

Step II. Design

A survey of the area is step two. Recently, Global Positioning Systems, laser surveys, and other technology have sped up the process and improved accuracy. Many factors influence designs, including location, terrain and soil properties, drainage capabilities, traffic volume, the ratio of cars to trucks and buses, possible future development in the area, effects on the environment or nearby residents.

Step III. Earthwork

Earthwork is one of the most important elements in road construction because it establishes a stable foundation. The aim of the earthworks phase of the construction is to position the subgrade underlying the pavement layers in the right location and at the correct level and to provide drainage.

First, embankments are built. Next, a grader or bulldozer levels the screened dirt. Leveling bumps and filling in dips creates a surface that will support a road for decades. The screened dirt is sprayed with water and compacted to its maximum density. During this stage, drains and sewers are installed. The center of the road must be higher than the edges so water will run off into the storm sewers. Drainage is a critical element because improper drainage will greatly reduce the new pavement's life expectancy. All of this work must pass strict inspections before the project can continue. To complete the earthwork, workers place gravel in 12-inch layers on the road bed, then moisten and compact each layer. Layers are added and compacted until the road bed reaches the height called for in the design.

The earthwork is often the largest task in the road building process and therefore careful planning and organization are essential. Speed and efficiency depend very much upon the quantity and types of earthmoving plant available.

Answer the following questions:

1. What does the type of road construction depend on?
2. How many steps are there in the road construction process?
3. What specialists are involved in planning a road?
4. What factors influence design?
5. Who collects information about roads?
6. What technologies have sped up the road construction process and improved accuracy?
7. Why is earthwork one of the most important elements in road construction?
8. What steps should be followed during earthwork stage?
9. Why is drainage a critical element in the road construction?
10. What is the largest task in the road construction?

Unit 4. Roadway Materials

Roadway materials, and particularly roadway surfacing materials, such as aggregate or paving, can be half the cost of a road. Selection of materials directly affects the function, structural support, rider comfort, environmental impact and safety of the road and user. Materials and quality control of those materials are needed in the following:

- In roadway surfacing materials.
- In the road subgrade.
- In structural fill embankments.
- In quarries and borrow pits.

The driving surface

On low-volume roads, a variety of surfacing options exist. The most common surfacing types, shown on Figure 12.1, are:

- Native Soil
- Crushed Aggregate
- Cobblestone or Concrete Block
- Bituminous Seal Coats
- Asphalt Concrete

Selection of surfacing materials depends on availability of materials, their cost, and road use (weight and amount of traffic). Native soil is the least expensive and often poorest material.

Crushed aggregate is the most common improved surfacing material. Asphalt concrete is the best, smoothest, and most expensive surface.

Dust palliatives may be used to reduce dust. Common palliatives are water, lignins, chlorides, and oils. Use depends on product costs, soils, and pattern of road use.

Subgrade reinforcement

On low-volume roads, subgrade reinforcement (to achieve a strong structural section) is often achieved using a layer of crushed aggregate placed over a weaker in-place subgrade soil.

Compaction

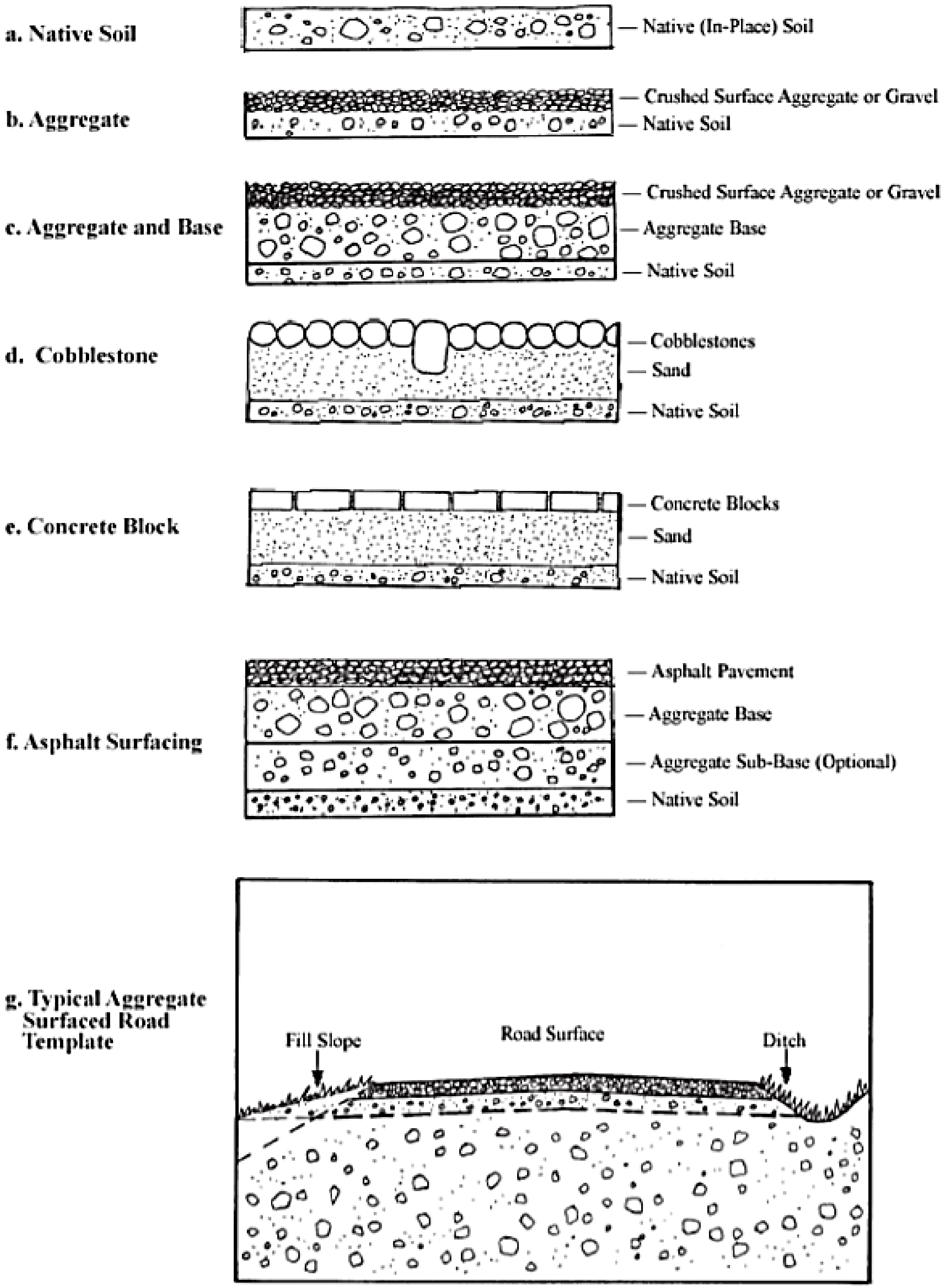
Compaction is the single most efficient and cost effective way to improve a soil's properties, including density, strength, moisture resistance, and reduced swell potential.

- First representative soil samples are obtained.
- Soil compaction tests are run on the samples or Modified Proctor tests to determine the Maximum Density and Optimum Moisture Content.
- The appropriate target density is specified for field compaction (to produce the needed or maximum soil strength).
- Field compaction is best achieved near the Optimum Moisture Content with a number of passes using appropriate compaction equipment. For granular soils,

a vibratory compactor is best. In clay soils a kneading compactor, such as a sheepsfoot roller is used. Vibratory rubber tire rollers are all-purpose.

- Field density is determined during construction using a “nuclear gauge”, sand cone, or balloon density measuring equipment.

Figure 12.1 Commonly used low-volume road surfacing types and structural sections.



Soil improvement or reinforcement methods

- Compact native soils (as outlined above).
- Remove and replace with Select Material.
- Drain the road subgrade (underdrains/filter blankets).
- Use Geotextiles plus aggregate cover.
- Limit road use during wet periods.
- Improve the native soil in-place by mixing with cement, lime, asphalts, resins, chemicals, enzymes, etc. (Each soil additive has particular requirements for use and effectiveness).

Quality control/sampling and testing

Quality control of materials being used in a project includes guaranteeing that the material has appropriate properties, such as durability, hardness, strength, compaction, or gradation. Such control is kept through selection of representative samples of the material and testing to insure that they meet the appropriate materials properties.

Reject or modify materials that do not meet specifications. You get what you inspect, not what you expect.

Answer the following questions:

1. What does the selection of materials affect?
2. Where is control needed?
3. What are the most common surfacing types?
4. What does selection of surfacing materials depend on?
5. What is the most expensive surface?
6. When are dust palliatives used?
7. What can compaction improve?
8. What compactor is best for granular soils?
9. What methods are used for soil improvement and reinforcement?
10. What properties should the material have?

Chapter V. Road Maintenance
Unit 1. Road Maintenance Components and Methods

Preserving and keeping each type of roadway, roadside, structures as nearly as possible in its original condition as constructed or as subsequently improved and the operation of highway facilities and services to provide satisfactory and safe transportation, is called road maintenance or maintenance of highways.

Road maintenance components

The various road maintenance function includes:

1. Surface maintenance
2. Roadside and drainage maintenance

3. Shoulder and approaches maintenance
4. Snow and ice control
5. Bridges maintenance
6. Traffic service

Highway maintenance is closely related to the quality of construction of original road. Insufficient pavement or base thickness or improper construction of these elements soon results in expensive patching or surface repair. Shoulder care becomes a serious problem where narrow lanes force heavy vehicle to travel with one set of wheels off the pavement.

Improperly designed drainage facilities, mean erosion or deposition of material and costly cleaning operation or other corrective measures. For regular highways maintenance and repair sharp ditches and steep slopes require manual maintenance as compare to cheap repair of flatter ditch and soil by machine.

In snowy country, improper location extremely low fills and narrow cuts leave no room for snow storage, creating extremely difficult snow removal problems.

Pavement maintenance and rehabilitation programs restore the riding quality and maintain the structural integrity of the pavement over its full design life.

Methods of surface treatment for road maintenance

The surface treatment may be single or multiple. Although the best type of surface course is pre-mix carpet for roads maintenance. The surface treatment methods are employed when:

1. Intensity of traffic is not very high.
2. The pro-mix mixers are not easily available due to long transportation or technical reasons.
3. When the cost is high.

In highway maintenance**,** for good surface treatment it is necessary that:

- Base course is well prepared to its profile and is made more free from pot holes and ruts.
- Excellence of surface dressing depends upon the correct proportion of binder aggregate.
- Before laying that first surface dressing coat, the base should be made free from all dust loose soil etc.

In all bituminous construction it is necessary that the newly surface posses a bond with the existing base at the interface. It is also necessary that the base is nearly impervious.

- For maintenance of gravel roads blading and occasional resurfacing is required.
- For surface treatments of low type bituminous surface in maintenance of roads; Patching, seal coating or possible loosening oiling, re mixing and relaying are involved.
- For high type bituminous concrete and Portland cement concrete, the Removal and replacement of failure areas and resurfacing are approximate treatment methods for highway maintenance.
- Use same material and methods for road surface maintenance as far as possible.
- Maintenance and repairs of roads must be planned for rapid performance and to cause least possible disruption or hazard to traffic.

Roadside and highway drainage maintenance

Depends on the characters of roadside where the roadside is grassy it must be mowed; cutting, ploughing or spraying with weed killer must be done.

If there is dry grass fire hazard burning, plowing must be done in road maintenance. To improve visibility and increase the sight distance and clearance of road trimming should also be done. It’s important to note that side slope erosion by mulching, seeding etc. should be checked and controlled as and where required to ensure slope and shoulder stability. Furthermore, picking up litter, thrown or blown along roadside or wayside area should be a routine work.

Drainage of Highways: Keeping ditch, culvert and other drainage structure, clean and ready to carry next flow water. Sediments deposited during period of heavy flow must be removed badly eroded channel and dikes properly protected to prevent recurrence.

Shoulders maintenance

The maintenance of shoulders depend on the surface character of the area where the maintenance and repair is performed.

SOD shoulders (Sod shoulders are earth shoulders on which a solid turf has been established. Normally they require very little maintenance and holes, ruts, and settlements should be repaired with sod or stabilized material.) must be moved and occasionally bladed down to the level of the roadway so that water is not trapped in the traveled way. Grass must be kept in good condition. In maintenance of roads shoulders protected by bituminous blankets have surface treatments same as for roadway surface.

Gravel and earth shoulders that leaves a drop off at the pavement edges creates a serious accident hazard, hence, should be corrected by reconstruction, resurfacing or other appropriate means. Due to continuous wetting and drying of shoulder, edge joints result between lane and shoulder, which may cause settlement of pavement due to entrance of water in sub grade soil. It can be repaired by filling the joint with sand and asphalt concrete

Snow and ice control

Ice forming on the roadway reduces coefficient of friction between tires and surface, which makes vehicle control almost impossible. In repair of roads, we can apply abrasive to heavily traveled roadway and street. Suitable materials that can be used are clean and sharp sand, cinders and washed stone screening.

Bridge maintenance

Bridges maintenance is a major part of roads maintenance. Bridges can be maintained in good condition by following the below guidelines:

- Exposed steel work must be cleaned by sand blasting flame or other means followed by repainting.
- Deck joint may extrude or become filled with dirt so that cleaning and resealing is necessary.
- Out of control vehicle, causing damage to guard rail, must be repaired and strengthened.
- If bridge deck become rough resurfacing is required
- Remedial measures to correct serious scour around and under piers and abutments.

Traffic services

Include stripping, sign repair and maintenance (particularly needed for repair after stormy weather).

Factor affecting roads maintenance

Generally, following factors affect the maintenance of pavements:

1. Increase in the intensity of traffic.

There is increase in road transport per year about 8%. This is the most important factor, which affects the maintenance of roads.

2. Inadequate thickness of pavement.

Adequate thickness of pavement is essential. If the adequate thickness is not provided, it will result frequent pavement failure, unevenness and heavy patches.

3. Effect on no of lanes.

The road research laboratory has established pavement by experiments that concentration of road is almost 4 times larger on a single lane than a double lane pavement section. Thus, the road distress and maintenance on single lane pavement are higher than double lane pavements.

Answer the following questions:

1. What is road maintenance?
2. What functions does road maintenance include?
3. What can insufficient pavement lead to?
4. Where does shoulder care become a problem?
5. What do improperly designed facilities mean?
6. Why are pavement maintenance and rehabilitation programs important?
7. When are the surface treatment methods employed?
8. What is necessary in highway maintenance?
9. How can bridges be maintained?
10. What factors affect the maintenance of pavement?

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