Tulsiramji Gaikwad-Patil College of Engineering and Technology
Wardha Road, Nagpur-441 108
NAAC Accredited (A+ Grade)
Approved by AICTE, New Delhi, Govt. of Maharashtra & Affiliated to RTM Nagpur University, Nagpur

Civil Engineering

Subject: Transportation Engineering -I

Unit -1 (Highway Planning in India)

INTRODUCTION

Overview

From the beginning of history, human sensitivity has revealed an urge for mobility leading to a measure of Society's progress. The history of this mobility or transport is the history of civilization. For any country to develop with right momentum modern and efficient Transport as a basic infrastructure is a must. **Transport** (British English) or **transportation** (American English) is the movement of people and goods from one place to another. The term is derived from the Latin *trans* ("across") and *portare* ("to carry").

Means of Transport

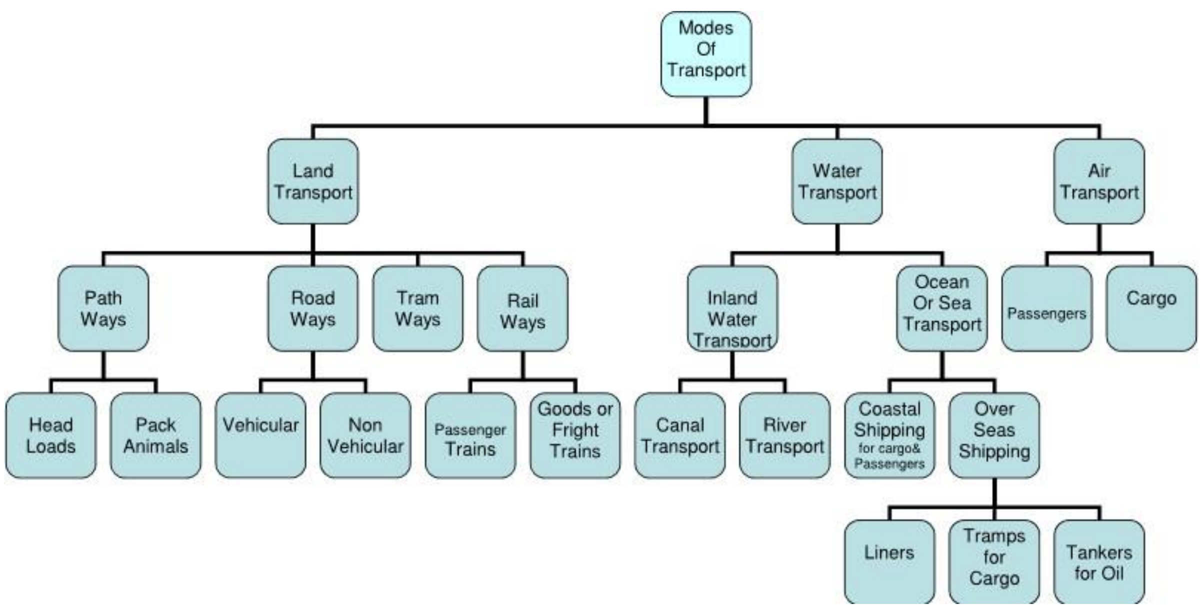

Fig.1.1 Means of Transport

Advantage and Disadvantage Different Modes of Transport

(A) Road Transport

Advantages	Disadvantages
1. Less Capital Outlay 2. Door to Door Service 3. Service in Rural Areas 4. Flexible Service 5. Suitable for Short Distance 6. Lesser Risk of Damage in Transit 7. Saving in Packing Cost 8. Rapid Speed 9. Less Cost 10. Private Owned Vehicles Feeder to other Modes of Transport	1. Seasonal Nature 2. Accidents and Breakdowns 3. Unsuitable for Long Distance and Bulky Traffic 4. Slow Speed 5. Lack of Organization

(B) Railway Transport

Advantages	Disadvantages
1. Dependable 2. Better Organised 3. High Speed over Long Distances 4. Suitable for Bulky and Heavy Goods 5. Cheaper Transport 6. Safety 7. Larger Capacity 8. Public Welfare 9. Administrative Facilities of Government 10. Employment Opportunities	1. Huge Capital Outlay 2. Lack of Flexibility 3. Lack of Door to Door Service 4. Monopoly 5. Unsuitable for Short Distance and Small Loads 6. Booking Formalities 7. No Rural Service 8. Under-utilised Capacity 9. Centralised Administration

(C) Air Transport

Advantages	Disadvantages
1. High Speed 2. Comfortable and Quick Services 3. No Investment in Construction of Track 4. No Physical Barriers 5. Easy Access 6. Emergency Services 7. Quick Clearance 8. Most Suitable for Carrying Light Goods of High Value 9. National Defence 10. Space Exploration	1. Very Costly 2. Small Carrying Capacity 3. Uncertain and Unreliable 4. Breakdowns and Accidents 5. Large Investment 6. Specialised Skill 7. Unsuitable for Cheap and Bulky Goods 8. Legal Restrictions

Elements of transport

The movement of goods or passenger traffic, through rail, sea, air or road transport requires adequate infrastructure facilities for the free flow from the place of origin to the place of destination. Irrespective of modes, every transport system has some common elements:

a) Vehicle or carrier to carry passenger or goods
b) Route or path for movement of carriers
c) Terminal facilities for loading and unloading of goods and passengers from carriers
d) Prime Mover
e) Transit time and cost
f) Cargo

HIGHWAY DEVELOPMENT IN INDIA

Road network provides the arterial network to facilitate trade, transport, social integration and economic development. It facilitates specialization, extension of markets and exploitation of economies of scale. It is used for the smooth conveyance of both people and goods. Transportation by road has the advantage over other means of transport because of its easy accessibility, flexibility of operations, door-to-door service and reliability. Consequently, passenger and freight movement in India over the years have increasingly shifted towards roads vis-à-vis other means of transport.

History of highway engineering

The history of highway engineering gives us an idea about the roads of ancient times. Roads in Rome were constructed in a large scale and it radiated in many directions helping them in military operations. Thus they are considered to be pioneers in road construction. In this section we will see in detail about Ancient roads, Roman roads, British roads, French roads etc.

Ancient Roads

The most primitive mode of transport was by foot. These human pathways would have been developed for specific purposes leading to camp sites, food, streams for drinking water etc. The invention of wheel in Mesopotamian civilization led to the development of animal drawn vehicles. To provide adequate strength to carry the wheels, the new ways tended to follow the sunny drier side of a path. After the invention of wheel, animal drawn vehicles were developed and the need for hard surface road emerged. Traces of such hard roads were obtained from various ancient civilization dated as old as 3500 BC. The earliest authentic record of road was found from Assyrian empire constructed about 1900 BC.

Roman roads

The earliest large scale road construction is attributed to Romans who constructed an extensive system of roads radiating in many directions from Rome. Romans recognized that the fundamentals of good road construction were to provide good drainage, good material and good workmanship. Their roads were very durable, and some still exist. The roads were bordered on both sides by longitudinal drains. A typical corss section is shown in Fig.2.1. This was a raised formation up to a 1 meter high and 15 m wide and was constructed with materials excavated during the side drain construction. This was then topped with a sand leveling course. In the case of heavy traffic, a surface course of large 250 mm thick hexagonal ag stones were provided They mixed lime and volcanic puzzolana to make mortar and they added gravel to this mortar to make concrete. Thus concrete was a major Roman road making innovation.

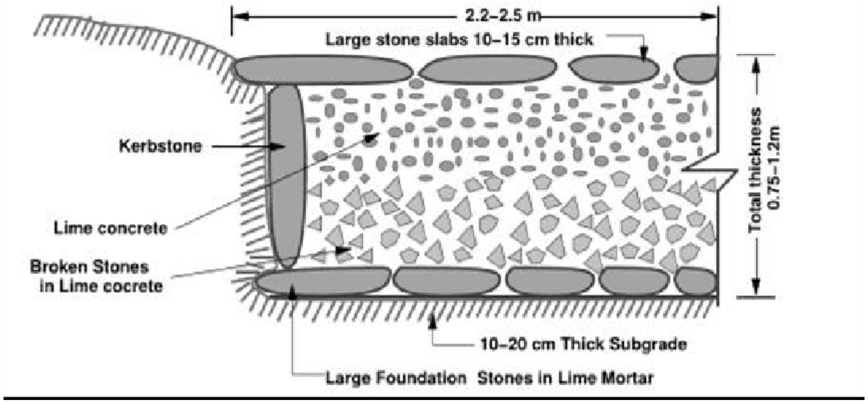

Fig.2.1 Roman roads

French roads

The significant contributions were given by Tresaguet in 1764 and a typical cross section of this road is given in Figure 2.2. He developed a cheaper method of construction than the lavish and locally unsuccessful revival of Roman practice. The pavement used 200 mm pieces of quarried stone of a more compact form and shaped such that they had at least one at side which was placed on a compact formation. Smaller pieces of broken stones were then compacted into the spaces between larger stones to provide a level surface. Finally the running layer was made with a layer of 25 mm sized broken stone. All this structure was placed in a trench in order to keep the running surface level with the surrounding country side. This created major drainage problems which were counteracted by making the surface as impervious as possible, cambering the surface and providing deep side ditches.

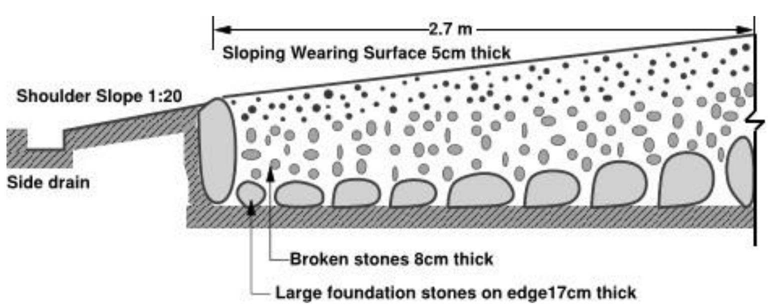

Fig. 2.2. French roads

British roads

The British government also gave importance to road construction. The British engineer John

Macadam introduced what can be considered as the first scientific road construction method. Stone size was an important element of Macadam recipe. By empirical observation of many roads, he came to realize that 250 mm layers of well compacted broken angular stone would provide the same strength a better running surface than an expensive pavement founded on large stone blocks. Thus he introduced an economical method of road construction. A typical cross section of British roads is given in Fig. 2.3.

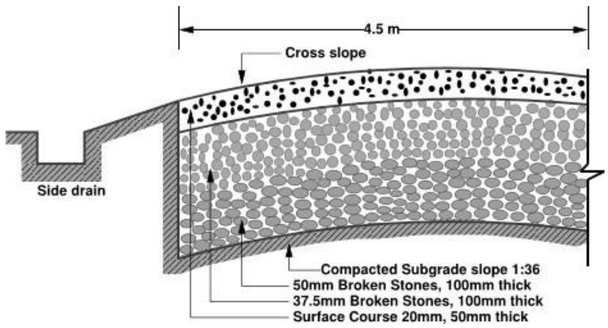

Fig. 2.3. British roads

Modern roads

The modern roads by and large follow Macadam's construction method. Use of bituminous concrete and cement concrete are the most important developments. Development of new equipments helps in the faster construction of roads. Many easily and locally available materials are tested in the laboratories and then implemented on roads for making economical and durable pavements.

Road Development in India

Excavations in the sites of Indus valley revealed the existence of planned roads in India as old as 2500-3500 BC. The Mauryan kings also built very good roads. During the time of Mughal period, roads in India were greatly improved. Roads linking North-West and the Eastern areas through gangetic plains were built during this time. The construction of Grand-Trunk road connecting North and South is a major contribution of the British.

Modern developments

The First World War period and that immediately following it found a rapid growth in motor transport. So need for better roads became a necessity. For that, the Government of India appointed a committee called Road development Committee with Mr.M.R. Jayakar as the chairman. This committee came to be known as Jayakar committee.

Jayakar Committee

In 1927 Jayakar committee for Indian road development was appointed. The major recommendations and the resulting implementations were:

- ✓ Committee found that the road development of the country has become beyond the capacity of local governments and suggested that Central government should take the proper charge considering it as a matter of national interest.
- ✓ They gave more stress on long term planning programme, for a period of 20 years (hence called twenty year plan) that is to formulate plans and implement those plans with in the next 20 years.
- ✓ One of the recommendations was the holding of periodic road conferences to discuss about road construction and development. This paved the way for the establishment of a semi-official technical body called Indian Road Congress (IRC) in 1934
- ✓ The committee suggested imposition of additional taxation on motor transport which includes duty on motor spirit, vehicle taxation, license fees for vehicles plying for hire. This led to the introduction of a development fund called Central road fund in 1929. This fund was intended for road development.
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Nagpur road congress 1943

A twenty year development programme for the period (1943-1963) was finalized. It was the first attempt to prepare a co-ordinated road development programme in a planned manner.

The roads were divided into four classes:

- ➢ **National highways** which would pass through states, and places having national importance for strategic, administrative and other purposes.
- ➢ **State highways** which would be the other main roads of a state.
- ➢ **District roads** which would take traffic from the main roads to the interior of the district. According to the importance, some are considered as **major district roads** and the remaining as **other district roads**.
- ➢ **Village roads** which would link the villages to the road system.

The committee planned to construct 2 lakh kms of road across the country within 20 years. They recommended the construction of star and grid pattern of roads throughout the country. One of the objective was that the road length should be increased so as to give a road density of 16kms per 100 sq.km

Bombay road congress 1961

The length of roads envisaged under the Nagpur plan was achieved by the end of it, but the road system was deficient in many respects. Accordingly a 20-year plan was drafted by the Roads wing of Government of India, which is popularly known as the Bombay plan. The highlights of the plan were:

- It was the second 20 year road plan (1961-1981)
- The total road length targeted to construct was about 10 lakhs.
- Rural roads were given specific attention.
- They suggested that the length of the road should be increased so as to give a road density of 32kms/100 sq.km
- The construction of 1600 km of expressways was also then included in the plan.

Lucknow road congress 1984

Some of the salient features of this plan are as given below:

- This was the third 20 year road plan (1981-2001). It is also called Lucknow road plan.
- It aimed at constructing a road length of 12 lakh kilometers by the year 1981 resulting in a road density of 82kms/100 sq.km
- The plan has set the target length of NH to be completed by the end of seventh, eighth and ninth five year plan periods.
- It aims at improving the transportation facilities in villages, towns etc. such that no part of country is farther than 50 km from NH.
- One of the goals contained in the plan was that expressways should be constructed on major traffic corridors to provide speedy travel.
- Energy conservation, environmental quality of roads and road safety measures were also given due importance in this plan.

Highway Planning

Highway design is only one element in the overall highway development process. Historically, detailed design occurs in the middle of the process, linking the preceding phases of planning and project development with the subsequent phases of right-of-way acquisition, construction, and maintenance. It is during the first three stages, planning, project development, and design, that designers and communities, working together, can have the greatest impact on the final design features of the project. In fact, the flexibility available for highway design during the detailed design phase is limited a great deal by the decisions made at the earlier stages of planning and project development.

The Stages of Highway Development

Although the names may vary by State, the five basic stages in the highway development process are: planning, project development (preliminary design), final design, right of way, and construction. After construction is completed, ongoing operation and maintenance activities continue throughout the life of the facility.

- **Developing a Concept**

A design concept gives the project a focus and helps to move it toward a specific direction. There are many elements in a highway, and each involves a number of separate but interrelated design decisions. Integrating all these elements to achieve a common goal or concept helps the designer in making design decisions.

Some of the many elements of highway design are

a. Number and width of travel lanes, median type and width, and shoulders
b. Traffic barriers
c. Overpasses/bridges

Horizontal and vertical alignment and affiliated landscape.

Test on Highway Materials

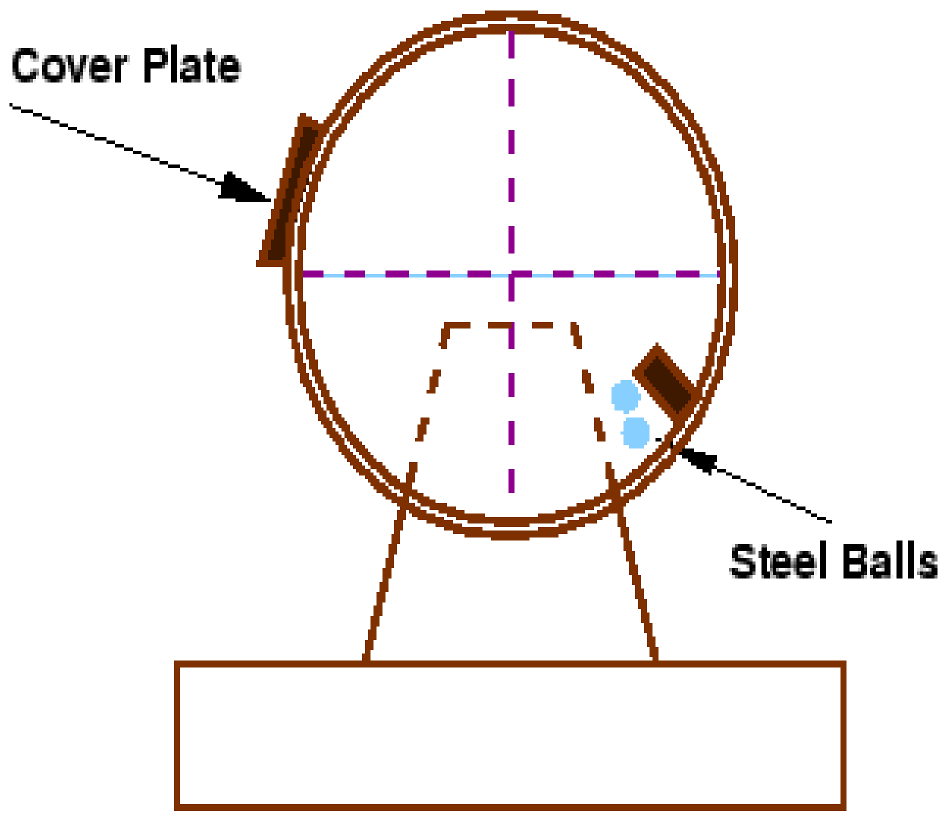
Abrasion test

Abrasion test is carried out to test the hardness property of aggregates and to decide whether they are suitable for different pavement construction works. Los Angeles abrasion test is a preferred one for carrying out the hardness property and has been standardized in India (IS:2386 part-IV). The principle of Los Angeles abrasion test is to find the percentage wear due to relative rubbing action between the aggregate and steel balls used as abrasive charge.

Los Angeles machine consists of circular drum of internal diameter 700 mm and length 520 mm mounted on horizontal axis enabling it to be rotated (see Figure 1). An abrasive charge consisting of cast iron spherical balls of 48 mm diameters and weight 340-445 g is placed in the cylinder along with the aggregates. The number of the abrasive spheres varies according to the grading of the sample. The quantity of aggregates to be used depends upon the gradation and usually ranges from 5-10 kg. The cylinder is then locked and rotated at the speed of 30-33 rpm for a total of 500 -1000 revolutions depending upon the gradation of aggregates.

After specified revolutions, the material is sieved through 1.7 mm sieve and passed fraction is expressed as percentage total weight of the sample. This value is called Los Angeles abrasion value.

A maximum value of 40 percent is allowed for WBM base course in Indian conditions. For bituminous concrete, a maximum value of 35 is specified.



Impact test

The aggregate impact test is carried out to evaluate the resistance to impact of aggregates. Aggregates passing 12.5 mm sieve and retained on 10 mm sieve is filled in a cylindrical steel cup of internal dia 10.2 mm and depth 5 cm which is attached to a metal base of impact testing machine. The material is filled in 3 layers where each layer is tamped for 25 number of blows. Metal hammer of weight 13.5 to 14 Kg is arranged to drop with a free fall of 38.0 cm by vertical guides and the test specimen is subjected to 15 number of blows. The crushed aggregate is allowed to pass through 2.36 mm IS sieve. And the impact value is measured as percentage of aggregates passing sieve to the total weight of the sample .

Bitumen adhesion test

Bitumen adheres well to all normal types of road aggregates provided they are dry and free from dust. In the absence of water there is practically no adhesion problem of bituminous construction. Adhesion problem occurs when the aggregate is wet and cold. This problem can be dealt with by removing moisture from the aggregate by drying and increasing the mixing temperature. Further, the presence of water causes stripping of binder from the coated aggregates. This problems occur when bitumen mixture is permeable to water. Several laboratory tests are conducted to arbitrarily determine the adhesion of bitumen binder to an aggregate in the presence of water. Static immersion test is one specified by IRC and is quite simple. The principle of the test is by immersing aggregate fully coated with binder in water maintained at temperature for 24 hours. IRC has specified maximum stripping value of aggregates should not exceed 5%.

Desirable properties:

Strength

The aggregates used in top layers are subjected to (i) Stress action due to traffic wheel load, (ii) Wear and tear, (iii) crushing. For a high-quality pavement, the aggregates should posses high resistance to crushing, and to withstand the stresses due to traffic wheel load.

Hardness

The aggregates used in the surface course are subjected to constant rubbing or abrasion due to moving traffic. The aggregates should be hard enough to resist the abrasive action caused by the movements of traffic. The abrasive action is severe when steel tyred vehicles moves over the aggregates exposed at the top surface.

Toughness

Resistance of the aggregates to impact is termed as toughness. Aggregates used in the pavement should be able to resist the effect caused by the jumping of the steel tyred wheels from one particle to another at different levels causes severe impact on the aggregates.

Shape of aggregates

Aggregates which happen to fall in a particular size range may have rounded, cubical, angular, flaky or elongated particles. It is evident that the flaky and elongated particles will have less strength and durability when compared with cubical, angular or rounded particles of the same aggregate. Hence too flaky and too much elongated aggregates should be avoided as far as possible.

Adhesion with bitumen

The aggregates used in bituminous pavements should have less affinity with water when compared with bituminous materials, otherwise the bituminous coating on the aggregate will be stripped off in presence of water.

Durability

The property of aggregates to withstand adverse action of weather is called soundness. The aggregates are subjected to the physical and chemical action of rain and bottom water, impurities there-in and that of atmosphere, hence it is desirable that the road aggregates used in the construction should be sound enough to withstand the weathering action

Freedom from deleterious particles

Specifications for aggregates used in bituminous mixes usually require the aggregates to be clean, tough and durable in nature and free from excess amount of flat or elongated pieces, dust, clay balls and other objectionable material. Similarly aggregates used in Portland cement concrete mixes must be clean and free from deleterious substances such as clay lumps, chert, silt and other organic impurities.

Geosynthetic Materials :

Geosynthetics materials are usually made from hydrocarbons and are used with soil or rock in many types of road and trail construction to strengthen weak soil foundations (wetlands). Geosynthetic materials offer alternatives to traditional trail construction and can be more effective in some situations, such as crossing wet soils and stabilizing fill slop

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Geosynthetics materials come in two forms:

- Two-dimensional sheets. The generic name for these sheets is **geofabrics**. Geofabrics have the ability to separate, filter, reinforce, and drain soil.
- Three-dimensional structures. Common geosynthetic materials are **Geoblocks**® or geogrids. These are a series of interlocking, polyethylene paving units that provide vehicular load support. The 20-inch-wide by 40-inch-long by 2-inch-deep sections of geogrids are a commonly used three-dimensional geosynthetic structure. Another three-dimensional structure is a geonet.

The two forms of geosynthetic materials are often used together in conjunction with gravel and perform three major functions:

- Separation.
- Reinforcement.
- Drainage.

All these materials become a permanent part of the trail and must be covered with soil or gravel. If the material is exposed, it can be damaged by trail users.

Here are some considerations for using geosynthetic materials for trail construction:

- The installation of Geoblocks® allows construction of trails on steeper slopes.
- Anchors are necessary to hold Geoblocks® in place.
- Geoblocks® sections can be assembled into 15-foot-long sections and then moved to the final location and dragged into place by an excavator.
- Place fine gravel in the Geoblocks® cells for best results.

Maintenance and Management Considerations

- Inspect for exposed synthetics and the loss of cover (soil, gravel, wood fiber etc.). Replace as needed.
- Snow grooming equipment operators need to be careful not to allow their equipment to catch the edges of Geoblocks®. If not, the Geoblocks® can be pulled out of position and lead to failure.

Prof Sanjay Bhadke

Assistant Professor , Civil Engineering

Unit -03 Pavements

Sub grade soil is an integral part of the road pavement structure as it provides the support to the pavement from beneath. The main function of the sub grade is to give adequate support to the pavement and for this the sub grade should possess sufficient stability under adverse climatic and loading conditions. Therefore, it is very essential to evaluate the sub grade by conducting tests. The tests used to evaluate the strength properties of soils may be broadly divided into three groups:

1. Shear tests
2. Bearing tests
3. Penetration tests

<u>Shear tests</u>

Shear tests are usually carried out on relatively small soil samples in the laboratory. In order to find out the strength properties of soil, a number of representative samples from different locations are tested. Some of the commonly known shear tests:

- Direct shear test,
- Triaxial compression test,
- Unconfined compression test.

California Bearing Ratio (CBR)

This test was developed by the California Division of Highway as a method of classifying and evaluating soil-sub grade and base course materials for flexible pavements.

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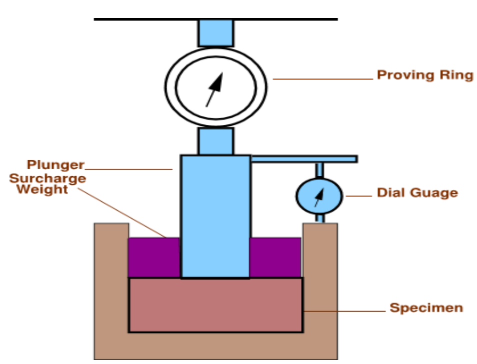


Aggregate is a collective term for the mineral materials such as sand, gravel, and crushed stone that are used with a binding medium (such as water, bitumen, Portland cement, lime, etc.) to form compound materials (such as bituminous concrete and Portland cement concrete). By volume, aggregate generally accounts for 92 to 96 percent of Bituminous concrete and about 70 to 80 percent of Portland cement concrete. Aggregate is also used for base and sub-base courses for both flexible and rigid pavements. Aggregates can either be natural or manufactured.

In order to decide the suitability of the aggregate for use in pavement construction, following tests are carried out:

- ✓ Crushing test
- ✓ Abrasion test
- ✓ Impact test
- ✓ Soundness test
- ✓ Shape test
- ✓ Specific gravity and water absorption test
- ✓ Bitumen adhesion test

Bituminous materials

Asphalts are extensively used for roadway construction, primarily because of their excellent binding characteristics and water proofing properties and relatively low cost.

Production of Bitumen

Bitumen is the residue or by-product when the crude petroleum is refined. A wide variety of refinery processes, such as the straight distillation process, solvent extraction process etc. may be used to produce bitumen of different consistency and other desirable properties.

Vacuum steam distillation of petroleum oils

In the vacuum-steam distillation process the crude oil is heated and is introduced into a large cylindrical still. Steam is introduced into the still to aid in the vaporization of the more volatile constituents of the petroleum and to minimize decomposition of the distillates and residues. The volatile constituents are collected, condensed, and the various fractions stored for further refining, if needed. The residues from this distillation are then fed into a vacuum distillation unit, where residue pressure and steam will further separate out heavier gas oils. The bottom fraction from this unit is the vacuum-steam-re ned asphalt cement.

<u>Different forms of bitumen</u> Cutback
bitumen

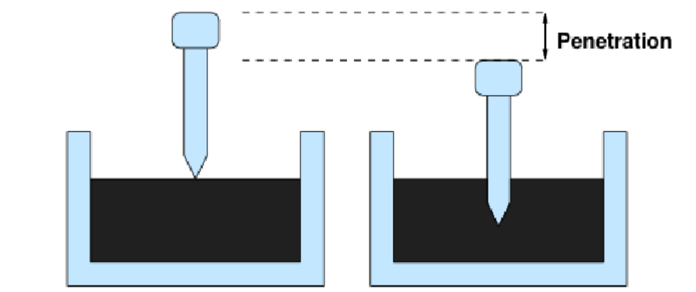
Normal practice is to heat bitumen to reduce its viscosity. In some situations preference is given to use liquid binders such as cutback bitumen. In cutback bitumen suitable solvent is used to lower the viscosity of the bitumen. From the environmental point of view also cutback bitumen is preferred.
There are different types of cutback bitumen like rapid curing (RC), medium curing (MC), and slow curing (SC).

Bitumen emulsion

Bitumen emulsion is a liquid product in which bitumen is suspended in a finely divided condition in an aqueous medium and stabilized by suitable material. Three types of bituminous emulsions are available, which are Rapid setting (RS), Medium setting (MS), and Slow setting (SC). Bitumen emulsions are ideal binders for hill road construction.

Penetration test

It measures the hardness or softness of bitumen by measuring the depth in tenths of a millimeter to which a standard loaded needle will penetrate vertically in 5 seconds. BIS had standardized the equipment and test procedure. The penetrometer consists of a needle assembly with a total weight of 100g and a device for releasing and locking in any position.



Flash and fire point test

At high temperatures depending upon the grades of bitumen materials leave out volatiles. And these volatiles catches fire which is very hazardous and therefore it is essential to qualify this temperature for each bitumen grade.

Float test

Normally the consistency of bituminous material can be measured either by penetration test or viscosity test. But for certain range of consistencies, these tests are not applicable and Float test is used.

Water content test

It is desirable that the bitumen contains minimum water content to prevent foaming of the bitumen when it is heated above the boiling point of water. The water in a bitumen is determined by mixing known weight of specimen in a pure petroleum distillate free from water, heating and distilling of the water.

The bituminous mix design aims to determine the proportion of bitumen, filler, fine aggregates, and coarse aggregates to produce a mix which is workable, strong, durable and economical. The requirements of the mix design and the two major stages of the mix design, i.e dry mix design and wet mix design.

Objectives of mix design

1. Sufficient bitumen to ensure a durable pavement,
2. Sufficient strength to resist shear deformation under traffic at higher temperature,
3. Sufficient air voids in the compacted bitumen to allow for additional compaction by traffic,
4. Sufficient workability to permit easy placement without segregation,
5. Sufficient flexibility to avoid premature cracking due to repeated bending by traffic,and
6. Sufficient flexibility at low temperature to prevent shrinkage cracks.

Constituents of a mix

- Coarse aggregates
- Fine aggregates
- Filler
- Binder

Types of mix

- Well-graded mix
- Gap-graded mix
- Open-graded mix
- Unbounded

Different layers in a pavement

- Bituminous base course
- Bituminous binder course
- Asphaltic/Bituminous concrete

Flexible pavements are so named because the total pavement structure deflects, or flexes, under loading. A flexible pavement structure is typically composed of several layers of materials. Each layer receives loads from the above layer, spreads them out, and passes on these loads to the next layer below. Thus the stresses will be reduced, which are maximum at the top layer and minimum on the top of subgrade.

<u>Design procedures</u>

- Empirical design
- Empirical design

<u>Traffic and Loading</u>

- Fixed traffic
- Fixed vehicle

- Variable traffic and vehicle

Equivalent single wheel load

To carry maximum load with in the specified limit and to carry greater load, dual wheel, or dual tandem assembly is often used. Equivalent single wheel load (ESWL) is the single wheel load having the same contact pressure, which produces same value of maximum stress, deflection, tensile stress or contact pressure at the desired depth.

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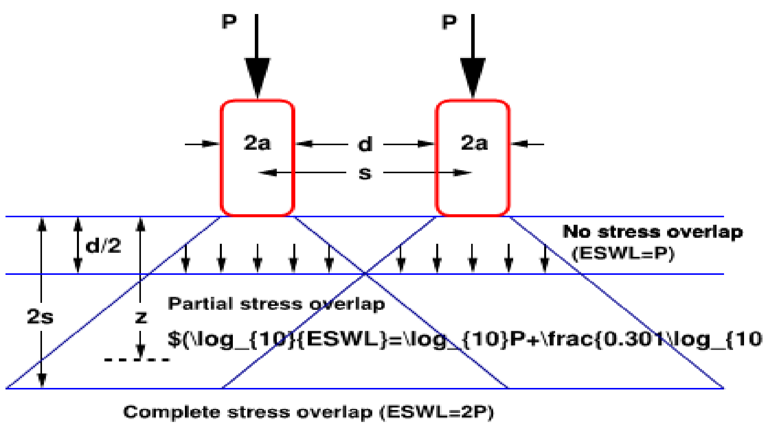
$$\log_{10} ESWL = \log_{10} P + \frac{0.301 \log_{10}\left(\frac{z}{d/2}\right)}{\log_{10}\left(\frac{2S}{d/2}\right)}$$



Indian roads congress has specified the design procedures for exible pavements based on CBR values. The Pavement designs given in the previous edition IRC:37-1984 were applicable to design traffic upto only 30 million standard axles (msa).

Scope

These guidelines will apply to design of exible pavements for Expressway, National Highways, State Highways, Major District Roads, and other categories of roads. Flexible pavements are considered to include the pavements which have bituminous surfacing and granular base and sub-base courses conforming to IRC/ MOST standards. These guidelines apply to new pavements.

Design criteria

- Vertical compressive strain at the top of the sub-grade which can cause sub-grade deformation resulting in permanent deformation at the pavement surface.
- Horizontal tensile strain or stress at the bottom of the bituminous layer which can cause fracture of the bituminous layer.

- Pavement deformation within the bituminous layer.

Failure Criteria

- Fatigue Criteria
- Rutting Criteria

Pavement composition

- Sub-base
- Base
- Bituminous surfacing

Rigid Pavement

As the name implies, rigid pavements are rigid i.e, they do not flex much under loading like flexible pavements. They are constructed using cement concrete. In this case, the load carrying capacity is mainly due to the rigidity ad high modulus of elasticity of the slab (slab action).

Modulus of sub-grade reaction

Westergaard considered the rigid pavement slab as a thin elastic plate resting on soil sub-grade, which is assumed as a dense liquid. The upward reaction is assumed to be proportional to the deflection.

Relative stiffness of slab to sub-grade

A certain degree of resistance to slab deflection is offered by the sub-grade. The sub-grade deformation is same as the slab deflection. Hence the slab deflection is direct measurement of the magnitude of the sub-grade pressure.

Critical load positions

There are three typical locations namely the interior, edge and corner, where differing conditions of slab continuity exist. These locations are termed as critical load positions.

Temperature stresses

Temperature stresses are developed in cement concrete pavement due to variation in slab temperature. This is caused by

(i) Daily variation resulting in a temperature gradient across the thickness of the slab and

(ii) Seasonal variation resulting in overall change in the slab temperature.

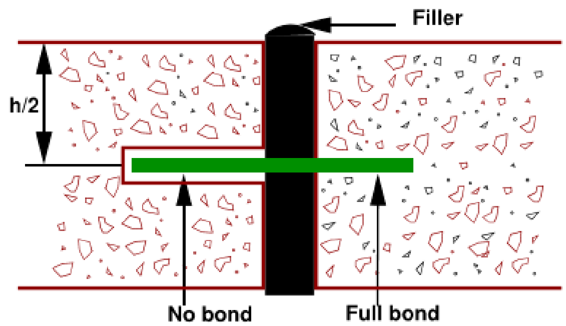
Combination of stresses

The cumulative effect of the different stress give rise to the following thee critical cases

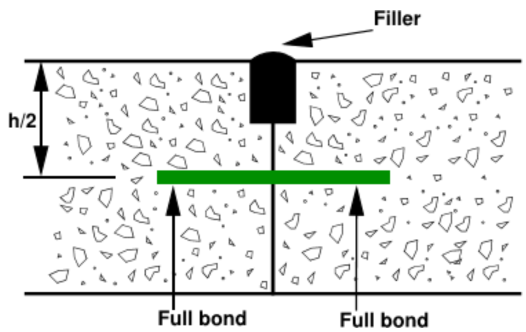
- Summer, mid-day: The critical stress is for edge region
- Winter, mid-day: The critical combination of stress is for the edge region given by
- Mid-nights: The critical combination of stress is for the corner region given

Joints :

The purpose of the expansion joint is to allow the expansion of the pavement due to rise in temperature with respect to construction temperature.



Expansion Joint



Contraction Joint

Dowel bars

The purpose of the dowel bar is to effectively transfer the load between two concrete slabs and to keep the two slabs in same height.

Tie bars

In contrast to dowel bars, tie bars are not load transfer devices, but serve as a means to tie two slabs. Hence tie bars must be deformed or hooked and must be firmly anchored into the concrete to function properly.

Provision for adequate drainage is of paramount importance in road design and cannot be overemphasized. The presence of excess water or moisture within the roadway will adversely affect the engineering properties of the materials with which it was constructed. Cut or fill failures, road surface erosion, and weakened subgrades followed by a mass failure are all products of inadequate or poorly designed drainage. As has been stated previously, many drainage problems can be avoided in the location and design of the road: Drainage design is most appropriately included in alignment and gradient planning.

Importance of Drainage

Water has a number of unhelpful characteristics which impact on highway performance.

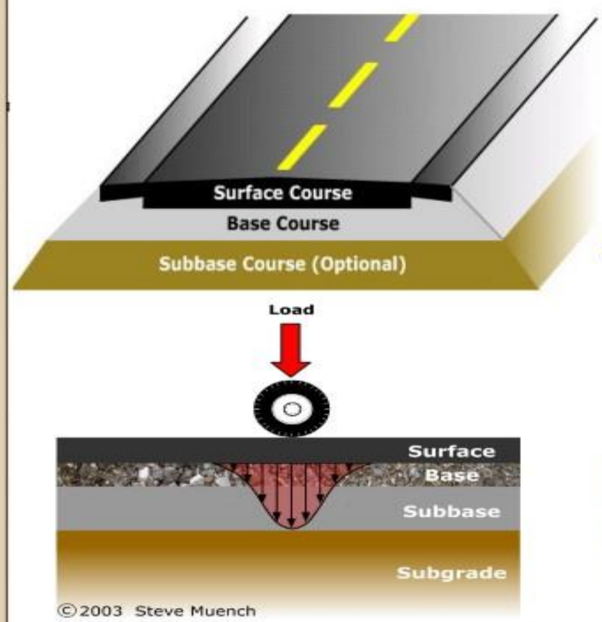
- It is a lubricant reducing the effectiveness of tyre grip on the carriageway wearing surface which can increase stopping distances.
- Spray from rainwater being thrown up by car tyres can reduce visibility which can lead to delays in reacting to events on the carriageway.
- Drag on car tyres from local rainwater ponding can alter the balance of vehicles travelling at speed which can be alarming or cause skidding.
- It is incompressible therefore standing water effectively acts as a jackhammer on the wearing course right through to the sub-base when vehicles pass over head.
- It expands when frozen pulling apart the carriageway construction which then falls apart when it warms up
- In extreme storms, rainwater can simply wash away roads on embankment should the culvert become blocked or lack capacity.

Pavements Comparison

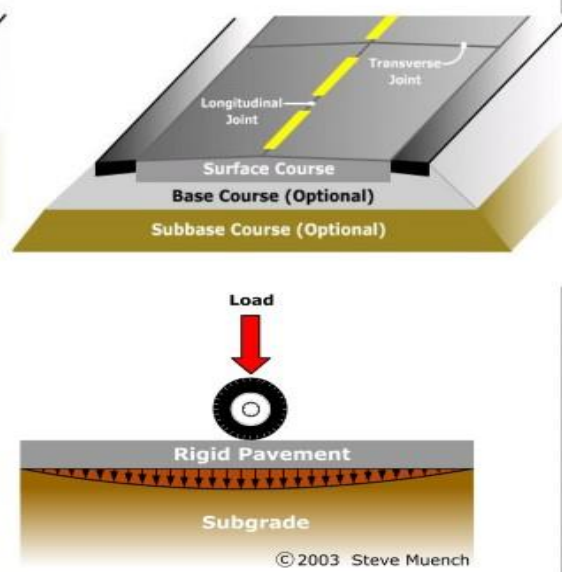
- Heavy vehicles consume less fuel on rigid pavements

- Rigid pavements more economic when considering environmental / life-cycle costing

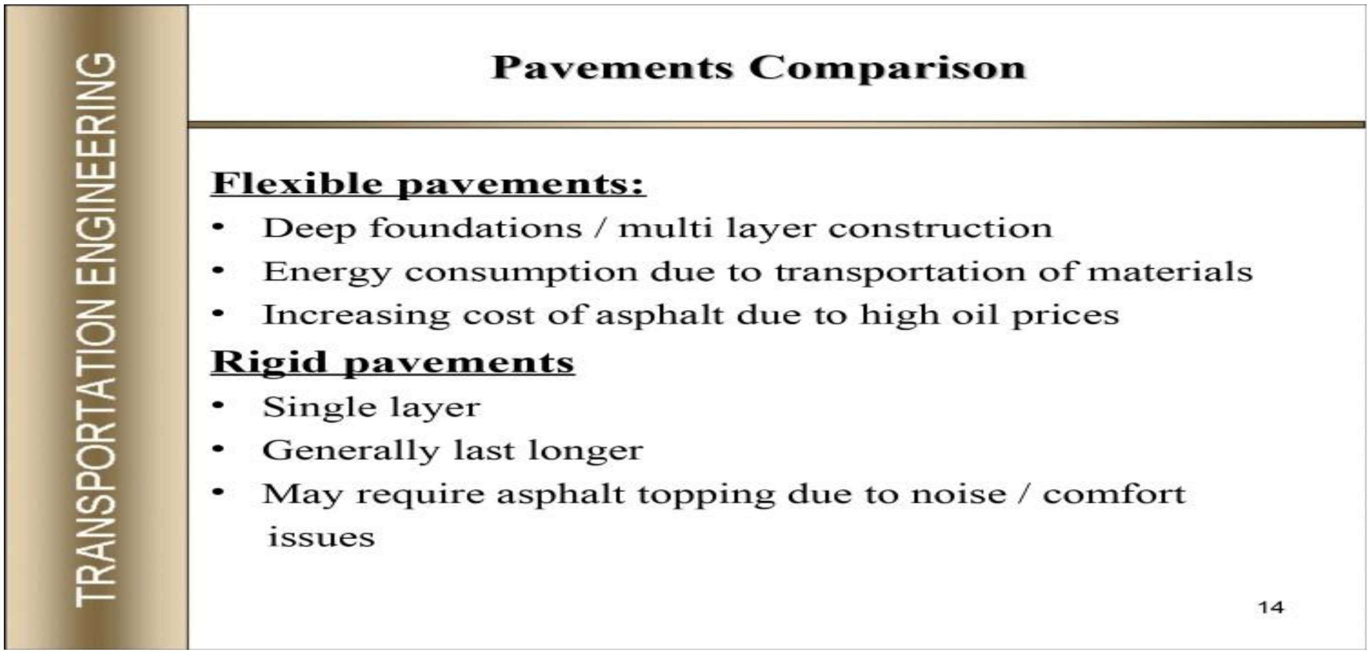
TRANSPORTATION ENGINEERING



Flexible



Rigid



Low Volume Road is considered a road that has relatively low use (an Average Daily Traffic of less than 400 vehicles per day), low design speeds (typically less than 80 kph), and corresponding geometry. Most roads in rural areas are low-volume roads.

Steps

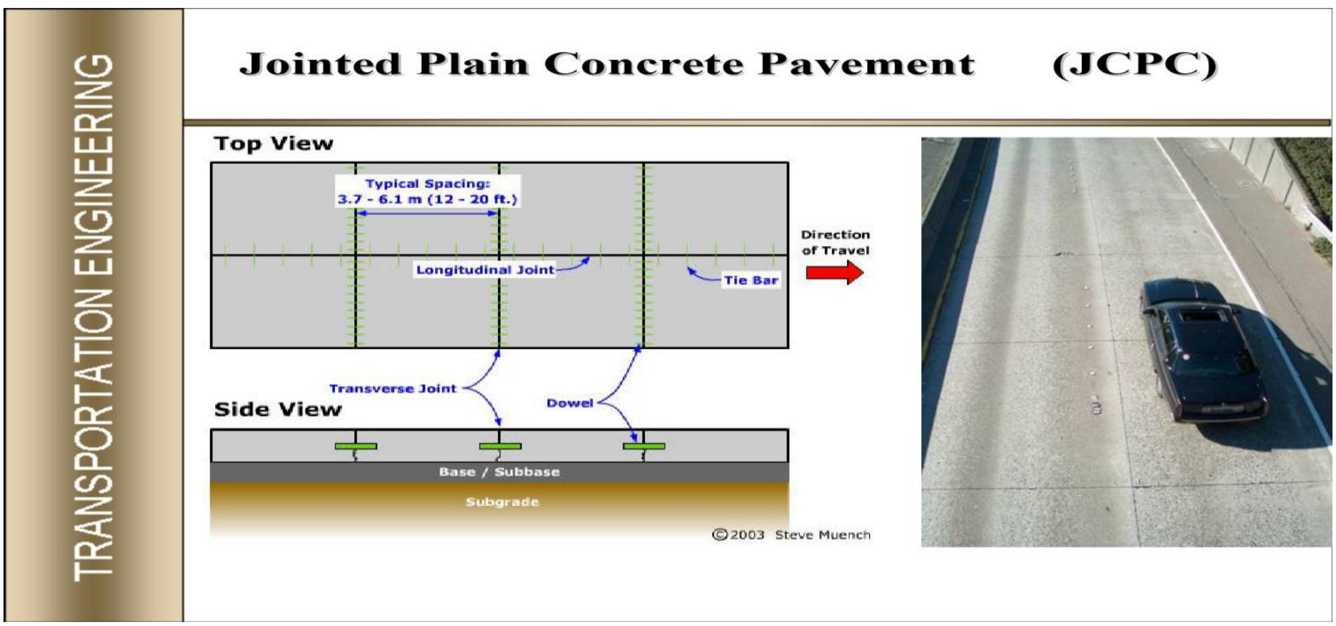
The basic steps of road panning are:

- Planning
- Location
- Survey
- Design
- Construction
- Maintenance

Difference between Flexible Pavements and Rigid Pavements

Sl. No.	Flexible Pavement	Rigid Pavement
1.	It consists of a series of layers with the highest quality materials at or near the surface of pavement.	It consists of one layer Portland cement concrete slab or relatively high flexural strength.
2.	It reflects the deformations of subgrade and subsequent layers on the surface.	It is able to bridge over localized failures and area of inadequate support.
3.	Its stability depends upon the aggregate	Its structural strength is provided by the

	interlock, particle friction and cohesion.	pavement slab itself by its beam action.
4.	Pavement design is greatly influenced by the subgrade strength.	Flexural strength of concrete is a major factor for design.
5.	It functions by a way of load distribution through the component layers	It distributes load over a wide area of subgrade because of its rigidity and high modulus of elasticity.
6.	Temperature variations due to change in atmospheric conditions do not produce stresses in flexible pavements.	Temperature changes induce heavy stresses in rigid pavements.
7.	Flexible pavements have self healing properties due to heavier wheel loads are recoverable due to some extent.	Any excessive deformations occurring due to heavier wheel loads are not recoverable, i.e. settlements are permanent.



Unit -II Geometric design:

For transportation facilities includes the design of geometric cross sections, horizontal alignment, vertical alignment, intersections, and various design details. These basic elements are common to all linear facilities, such as roadways, railways, and airport runways and taxiways. Although the details of design standards vary with the mode and the class of facility, most of the issues involved in geometric design are similar for all modes. In all cases, the goals of geometric design are to maximize the comfort, safety, and economy of facilities, while minimizing their environ-mental impacts. This chapter focuses on the fundamentals of geometric design, and presents standards and examples from different modes.

The geometric design of highways deals with the dimensions and layout of visible features of the highway. The features normally considered are the cross-section elements, sight distance consideration, horizontal curvature, gradients, and intersection. The design of these features is to a great extend influenced by driver behavior and psychology, vehicle characteristics, traffic characteristics such as speed and volume. Proper geometric design will help in the reduction of accidents and their severity. Therefore, the objective of geometric design is to provide optimum efficiency in traffic operation and maximum safety at reasonable cost.

The planning cannot be done stage wise like that of a pavement, but has to be done well in advance. The main components that will be discussed are:

1. Factors affecting the geometric design,
2. Highway alignment, road classification,
3. Pavement surface characteristics,
4. Cross-section elements including cross slope, various widths of roads and features in the road margins.
5. Sight distance elements including cross slope, various widths and features in the road margins.
6. Horizontal alignment which includes features like super elevation, transition curve, extra widening and set back distance.
7. Vertical alignment and its components like gradient, sight distance and design of length of curves.
8. Intersection features like layout, capacity, etc.

Factors affecting geometric design

- **Design speed:** Design speed is the single most important factor that affects the geometric design. It directly affects the sight distance, horizontal curve, and the length of vertical curves. Since the speed of vehicles vary with driver, terrain etc, a design speed is adopted for all the geometric design.
- **Topography:** It is easier to construct roads with required standards for a plain terrain. However, for a given design speed, the construction cost increases multi form with the gradient and the terrain.
- **Traffic factors:** It is of crucial importance in highway design, is the traffic data both current and future estimates. Traffic volume indicates the level of services (LOS) for which the highway is being planned and directly affects the geometric features such as width, alignment, grades etc., without traffic data it is very difficult to design any highway
- **Design Hourly Volume and Capacity:** The general unit for measuring traffic on highway is the Annual Average Daily Traffic volume, abbreviated as AADT. The traffic flow (or) volume keeps fluctuating with time, from a low value during off peak hours to the highest value during the peak hour. It will be uneconomical to design the roadway facilities for the peak traffic flow.
- **Environmental and other factors: -** The environmental factors like air pollution, noise pollution, landscaping, aesthetics and other global conditions should be given due considerations in the geometric design of roads.

_Highway alignment

Once the necessity of the highway is assessed, the next process is deciding the alignment. The highway alignment can be either horizontal or vertical and they are described in detail in the following sections.

Alignment

The position or the layout of the central line of the highway on the ground is called the alignment. Horizontal alignment includes straight and curved paths. Vertical alignment includes level and gradients. Alignment decision is important because a bad alignment will enhance the construction, maintenance and vehicle operating cost. Once an alignment is xed and constructed, it is not easy to change it due to increase in cost of adjoining land and construction of costly structures by the roadside.

Requirements

The requirements of an ideal alignment are:

- The alignment between two terminal stations should be short and as far as possible be straight, but due to some practical considerations deviations may be needed.
- The alignment should be easy to construct and maintain. It should be easy for the operation of vehicles. So to the maximum extend easy gradients and curves should be provided.
- It should be safe both from the construction and operating point of view especially at slopes, embankments, and cutting. It should have safe geometric features.
- The alignment should be economical and it can be considered so only when the initial cost, maintenance cost, and operating cost is minimum.

Factors controlling alignment

We have seen the requirements of an alignment. But it is not always possible to satisfy all these requirements. Hence we have to make a judicial choice considering all the factors.
The various factors that control the alignment are as follows:

- **Obligatory points**: These are the control points governing the highway alignment. These points are classified into two categories. Points through which it should pass and points through which it should not pass. Some of the examples are:
- **Bridge site:** The bridge can be located only where the river has straight and permanent path and also where the abutment and pier can be strongly founded. The road approach to the bridge should not be curved and skew crossing should be avoided as possible. Thus to locate a bridge the highway alignment may be changed.
- **Mountain:** While the alignment passes through a mountain, the various alternatives are to either construct a tunnel or to go round the hills. The suitability of the alternative depends on factors like topography, site conditions and construction and operation cost.
- **Intermediate town:** The alignment may be slightly deviated to connect an intermediate town or village nearby.

These were some of the obligatory points through which the alignment should pass. Coming to the second category that is the points through which the alignment should not pass are:

- Religious places: These have been protected by the law from being acquired for any purpose. Therefore, these points should be avoided while aligning.
- Very costly structures: Acquiring such structures means heavy compensation which would result in an increase in initial cost. So the alignment may be deviated not to pass through that point.
- Lakes/ponds etc: The presence of a lake or pond on the alignment path would also necessitate deviation of the alignment.
- Traffic: The alignment should suit the traffic requirements. Based on the origin-

destination data of the area, the desire lines should be drawn. The new alignment should be drawn keeping in view the desire lines, traffic flow pattern etc.

- Geometric design: Geometric design factors such as gradient, radius of curve, sight distance etc. also governs the alignment of the highway. To keep the radius of curve minimum, it may be required to change the alignment of the highway. The alignments should be finalized such that the obstructions to visibility do not restrict the minimum requirements of sight distance. The design standards vary with the class of road and the terrain and accordingly the highway should be aligned.

Camber or cant is the cross slope provided to raise middle of the road surface in the transverse direction to drain o rain water from road surface.

Too steep slope is undesirable for it will erode the surface. Camber is measured in 1 in n or n% (Eg. 1 in 50 or 2%) and the value depends on the type of pavement surface.

Width of carriage way

Width of the carriage way or the width of the pavement depends on the width of the traffic lane and number of lanes. Width of a traffic lane depends on the width of the vehicle and the clearance. Side clearance improves operating speed and safety.

Kerbs

Kerbs indicate the boundary between the carriage way and the shoulder or islands or footpaths. Di erent types of kerbs are (Figure 12:3):

- Low or mountable kerbs :
- Semi-barrier type kerbs :
- Barrier type kerbs :

Road margins

The portion of the road beyond the carriageway and on the roadway can be generally called road margin. Various elements that form the road margins are given below.

- Shoulders
- Parking lanes
- Bus-bays
- Service roads
- Cycle track

- Footpath
- Guard rails

Sight Distance is a length of road surface which a particular driver can see with an acceptable level of clarity. Sight distance plays an important role in geometric highway design because it establishes an acceptable design speed, based on a driver's ability to visually identify and stop for a particular, unforeseen roadway hazard or pass a slower vehicle without being in conflict with opposing traffic. As velocities on a roadway are increased, the design must be catered to allowing additional viewing distances to allow for adequate time to stop.

Types of sight distance

- Stopping sight distance (SSD) or the absolute minimum sight distance
- Intermediate sight distance (ISD) is the de ned as twice SSD
- Overtaking sight distance (OSD) for safe overtaking operation

The computation of sight distance depends on:

1. Reaction time of the driver
2. Speed of the vehicle
3. Efficiency of brakes

PIEV Process

The perception-reaction time for a driver is often broken down into the four components that are assumed to make up the perception reaction time. These are referred to as the PIEV time or process.

PIEV Process

• Perception	the time to see or discern an object or event
• Intellection	the time to understand the implications of the object's presence or event
• Emotion	the time to decide how to react
• Volition	the time to initiate the action, for example, the time to engage the brakes

Stopping sight distance

Stopping sight distance is defined as the distance needed for drivers to see an object on the roadway ahead and bring their vehicles to safe stop before colliding with the object. The distances are derived for various design speeds based on assumptions for driver reaction time, the braking ability of most vehicles under wet pavement conditions, and the friction provided by most pavement surfaces, assuming good tires. A roadway designed to criteria employs a horizontal and vertical alignment and a cross section that provides at least the minimum stopping sight distance through the entire facility.

The stopping sight distance is comprised of the distance to perceive and react to a condition plus the distance to stop:

$$SSD = 0.278\,Vt + \frac{v^2}{254\,(f \pm g)} \qquad \text{(METRIC)}$$

Overtaking sight distance

The overtaking sight distance is the minimum distance open to the vision of the driver of a vehicle intending to overtake the slow vehicle ahead safely against the traffic in the opposite direction. The overtaking sight distance or passing sight distance is measured along the center line of the road over which a driver with his eye level 1.2 m above the road surface can see the top of an object 1.2 m above the road surface.

The factors that affect the OSD are:

- Velocities of the overtaking vehicle, overtaken vehicle and of the vehicle coming in the opposite direction.
- Spacing between vehicles, which in-turn depends on the speed
- Skill and reaction time of the driver
- Rate of acceleration of overtaking vehicle

Horizontal alignment is one of the most important features influencing the efficiency and safety of a highway. Horizontal alignment design involves the understanding on the design aspects such as design speed and the effect of horizontal curve on the vehicles. The horizontal curve design elements include design of super elevation, extra widening at horizontal curves, design of transition curve, and set back distance.

Design Speed

The design speed as noted earlier, is the single most important factor in the design of horizontal alignment. The design speed also depends on the type of the road. For e.g, the design speed expected from a National highway will be much higher than a village road, and hence the curve geometry will vary significantly.

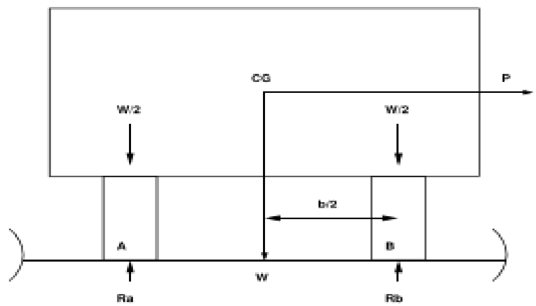
Factors Affecting Alignment

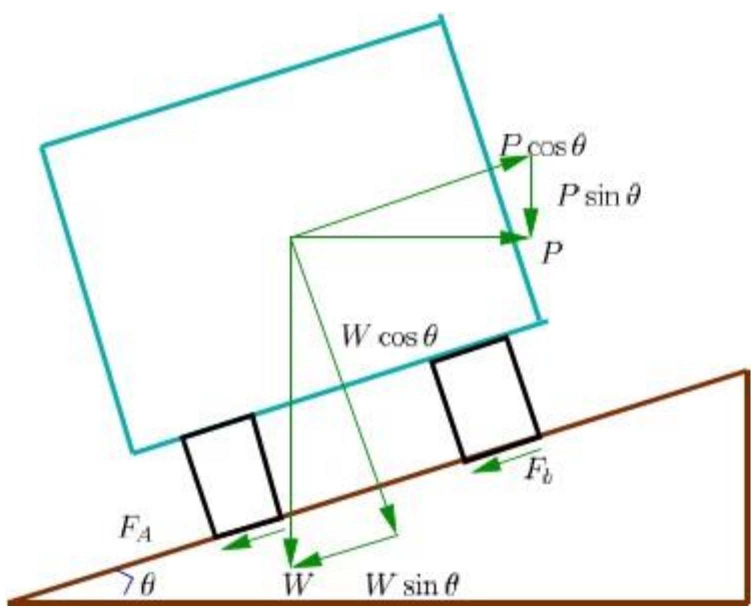
I. Safety
II. Grades
III. Design speed
IV. Cost of resumption of land
V. Construction costs

Operating speed is influenced by all other factors so it is the critical factor to consider.

Horizontal curve

The presence of horizontal curve imparts centrifugal force which is reactive force acting outward on a vehicle negotiating it. Centrifugal force depends on speed and radius of the horizontal curve and is counteracted to a certain extent by transverse friction between the tyre and pavement surface. On a curved road, this force tends to cause the vehicle to overrun or to slide outward from the centre of road curvature. For proper design of the curve, an understanding of the forces acting on a vehicle taking a horizontal curve is necessary





P the centrifugal force acting horizontally out-wards through the center of gravity, W the weight of the vehicle acting down-wards through the center of gravity, and mF the friction force between the wheels and the pavement, along the surface inward. At equilibrium, by resolving the forces parallel to the surface of the pavement we get,

P cos = W sin + F_A + F_B

= W sin + f (R_A + R_B)

= W sin + f (W cos + P sin)

This section discusses the design of superelevation and how it is attained. A brief discussion about pavement widening at curves is also given.

When being applied to the road need to take into account

- Safety
- Comfort
- Appearance
- Design speed
- Tendency for slow vehicles to track towards centre
- Difference between inner and outer formation levels
- Stability of high laden vehicles
- Length of road to introduce superelevation
- Provision for drainage

Design of super-elevation

For fast moving vehicles, providing higher superelevation without considering coefficient of friction is safe, i.e. centrifugal force is fully counteracted by the weight of the vehicle or superelevation. For slow moving vehicles, providing lower superelevation considering coefficient of friction is safe, i.e.centrifugal force is counteracted by superelevation and coefficient of friction .

Maximum Superelevation

- Max range from flat to mountainous of 0.06 – 0.12 respectively but most authorities limit to0.10
- In urban areas limit max values to 0.04-0.05 Minimum Superelevation
- Should be elevated to at least the cross-fall on straights ie 3% (0.03)

Attainment of super-elevation

1. Elimination of the crown of the cambered section by:

    rotating the outer edge about the crown

    shifting the position of the crown:

2. Rotation of the pavement cross section to attain full super elevation by:There are two methods of attaining superelevation by rotating the pavement

    rotation about the center line : rotation
    about the inner edge:

Radius of Horizontal Curve

The radius of the horizontal curve is an important design aspect of the geometric design. The maximum comfortable speed on a horizontal curve depends on the radius of the curve. Although it is possible to design the curve with maximum superelevation and coe cient of friction, it is not desirable because re-alignment would be required if the design speed is increased in future. Therefore, a ruling minimum radius R_{ruling} can be derived by assuming maximum superelevation and coe cient of friction.

v^2

$$R_{ruling} = g(e + f)$$

In this section we will deal with the design of transition curves and setback distances. Transition curve ensures a smooth change from straight road to circular curves. Setback distance looks in for safety at circular curves taking into consideration the sight distance aspects.

Horizontal Transition Curves

A transition curve differs from a circular curve in that its radius is always changing. As one would expect, such curves involve more complex formulae than the curves with a constant radius and their design is more complex.

The need for Transition Curves

Circular curves are limited in road designs due to the forces which act on a vehicle as they travel around a bend. Transition curves are used to introduce those forces gradually and uniformly thus ensuring the safety of passenger.

Transition curves have much more complex formulae and are more difficult to set out on site than circular curves as a result of the varying radius.

- ✓ to introduce gradually the centrifugal force between the tangent point and the beginning of the circular curve, avoiding sudden jerk on the vehicle.This increases the comfort of passengers.
- ✓ to enable the driver turn the steering gradually for his own comfort and security,
- ✓ to provide gradual introduction of super elevation, and
- ✓ to provide gradual introduction of extra widening.
- ✓ to enhance the aesthetic appearance of the road.

The use of Transition Curves

Transition curves can be used to join to straights in one of two ways:

- Composite curves

- Wholly transitional curves

Types of Transition Curve

There are two types of curved used to form the transitional section of a composite or wholly transitional curve. These are:

-The clothoid

-The cubic parabola.

Length of transition curve

The length of the transition curve should be determined as the maximum of the following three criteria: rate of change of centrifugal acceleration, rate of change of superelevation, and an empirical formula given by IRC.

1. Rate of change of centrifugal acceleration
2. Rate of introduction of super-elevation
3. By empirical formula

Setback Distance

Setback distance m or the clearance distance is the distance required from the centerline of a horizontal curve to an obstruction on the inner side of the curve to provide adequate sight distance at a horizontal curve. The setback distance depends on:

1. sight distance (OSD, ISD and OSD),
2. radius of the curve, and
3. length of the curve.

Valley curve Valley curve or sag curves are vertical curves with convexity downwards. They are formed when two gradients meet in any of the following four ways:

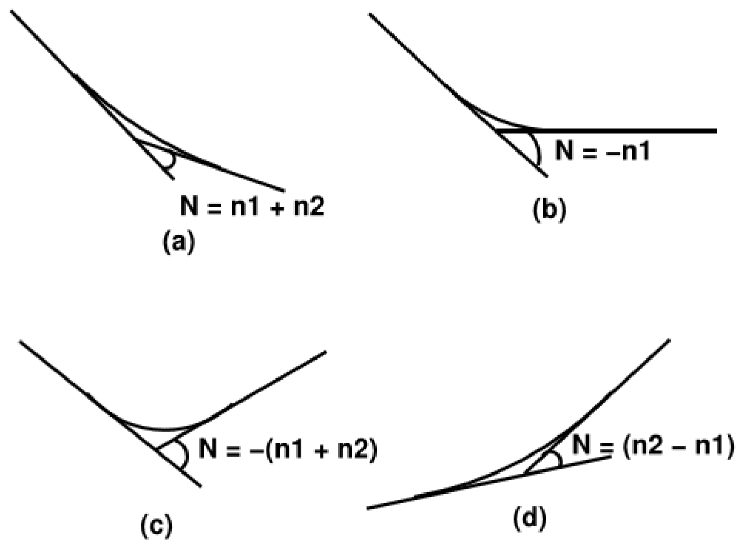
1. When a descending gradient meets another descending gradient.
2. When a descending gradient meets a flat gradient.
3. When a descending gradient meets an ascending gradient.
4. When an ascending gradient meets another ascending gradient.

Design considerations

Thus the most important design factors considered in valley curves are:

(1) impact-free movement of vehicles at design speed and

(2) Availability of stopping sight distance under headlight of vehicles for night driving.

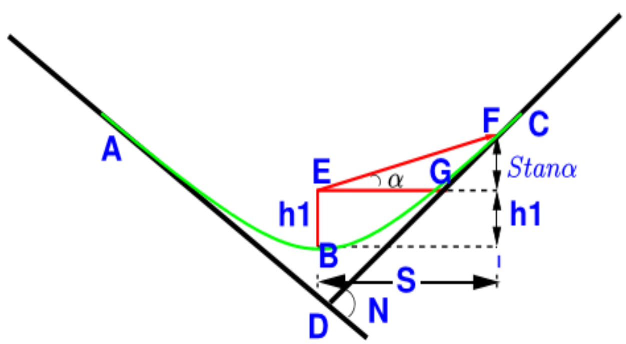


Length of the valley curve

The valley curve is made fully transitional by providing two similar transition curves of equal length The 2N 3 The length of the valley transition curve transitional curve is set out by a cubic parabola y = bx where b = 2 3L is designed based on two criteria:

1. Comfort criteria; that is allowable rate of change of centrifugal acceleration is limited to a comfortable 3 level of about 0.6m/sec.

2. Safety criteria; that is the driver should have adequate headlight sight distance at any part of the country.



Actual Road Curve

Reverse Curve

Extra widening

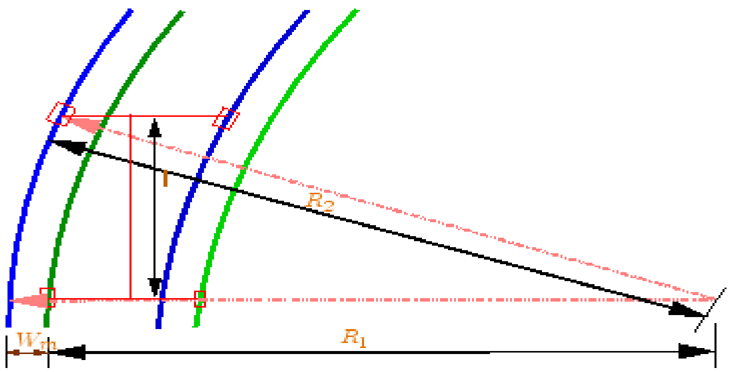
Extra widening refers to the additional width of carriageway that is required on a curved section of a road over and above that required on a straight alignment. This widening is done due to two reasons: the first and most important is the additional width required for a vehicle taking a horizontal curve and the second is due to the tendency of the drivers to ply away from the edge of the carriageway as they drive on a curve. The first is referred as the mechanical widening and the second is called the psychological widening. These are discussed in detail below.

$$W_m = \frac{nl^2}{2R}$$

Psychological widening

Widening of pavements has to be done for some psychological reasons also. There is a tendency for the drivers to drive close to the edges of the pavement on curves. Some extra space is to be provided for more clearance for the crossing and overtaking operations on curves. IRC proposed an empirical relation for the psychological widening at horizontal curves

$$\frac{nl^2}{2R} + \frac{v}{2.64\sqrt{R}} \qquad W_{ps} = \frac{v}{2.64\sqrt{R}}$$



Prof , Sanjay Bhadke
Assistant Prof Civil Engg

Numerical Below:

Numerical on SSD ①

Calculate stopping sight distance (SSD)

$$SSD = v.t + \frac{v^2}{2gf}$$

Where

v = speed in m/sec
t = reaction time of driver
t = 2.5 sec
f = friction factor (0.35)

Q1 Calculate the SSD for design speed of 50 km/hr for two way traffic on two lane Road

SSD = ?

$V = 50$ km/hr

$$v = \text{speed in m/s} = \frac{50 \times 1000}{60 \times 60}$$

$v = 13.89$ m/s

$$SSD = vt + \frac{v^2}{2gf}$$

(2)

$$SSD = 13.89 \times 2.5 + \frac{13.89^2}{2 \times 9.81 \times 0.35}$$

SSD = 62.82 m

ii) Two way traffic on two lane Road. SSD = 62.82 m

Now SSD on slope or on gradient

$$SSD = v.t + \frac{v^2}{2g\left(f \pm \frac{n}{100}\right)}$$

n = % gradient use positive for rising gradient and negative for falling gradient

Q. 2 Calculate the SSD for a road having uniform rising gradient of 1 : 200 for design speed of 60 kmph

$$n = \frac{1}{200} \times 100 = 0.5\%$$

$$\alpha = \frac{1}{200} = 0.005 \text{ in } \% = \frac{0.005}{100} = 0.5\%$$

$V = 60$ kmph

$v = \frac{60}{\cancel{3.6}} = \frac{60 \times 1000}{60 \times 60} = 16.67$ m/s

$$SSD = 16.67 \times 2.5 + \frac{(16.67)^2}{2 \times 9.81 \left[0.35 + \frac{0.5}{100}\right]}$$

$SSD = 81.57$ M

Numerical on Extra Widening

$$W_e = \frac{nl^2}{2R} + \frac{V_{\cancel{kmph}\ km/hr}}{9.5\sqrt{R}}$$

V = is in kmph

Where n = no of lanes

3.5 - 4.m single lane n = 1
7 - 8m double lane n = 2
10.5 - 12m triple lane n = 3

l = length of longest wheel base (taken 7M if not given)

1. Calculate the extra widening required for a road of 7M wide on a horizontal curve of 250m radius with the longest wheel base of the vehicle as 7m and design speed 70 Kkmph.

Extra Widening (W_e)

$$W_e = \frac{nl^2}{2R} + \frac{V_{kmph}}{9.5\sqrt{R}}$$

$$W_e = \frac{2 \times 7^2}{2 \times 250} + \frac{70}{9.5\sqrt{250}}$$

$$\boxed{W_e = 0.662\,M}$$

Overtaking Sight Distance

$$OSD = V_b t + V_b \cdot T + 2S + v \cdot T$$

Where

V_b = overtaken vehicle speed (smaller speed)

v = speed of overtaking vehicle
t = reaction time (2 second)
T = overtaking time

$$T = \sqrt{\frac{4S}{a}}$$

a = acceleration of overtaking vehicle

S = spacing between two vehicle

$$S = 0.7 V_b + 6$$

The speeds of overtaking & overtaken vehicle are 70 & 40 Kmph with acceleration of overtaking vehicle as $0.99 \; m/s^2$

$$v = \frac{70 \times 1000}{60 \times 60} = 19.44 \; M/sec$$

$V_b = 40$

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V_b = smaller speed

$$v_b = \frac{40 \times 1000}{60 \times 60} = 11.11 \text{ m/s}$$

t = 2 seconds

$$S = 0.7 \times 11.11 + 6 = 13.78 \text{ m}$$

$$T = \sqrt{\frac{4S}{a}} = \sqrt{\frac{4 \times 13.78}{0.99}}$$

$$T = 7.46$$

$$\cancel{OSD = V_b T}$$

$$OSD = V_b t + V_b \cdot T + 2S + VT$$

$$OSD = 11.11 \times 2 - 11.11 \times 7.46 + 2 \times 13.78 + 19.44 \times 7.46$$

$$OSD = 278 \text{ m}$$

Unit 4: Traffic Engineering:

Traffic control device is the medium used for communicating between traffic engineer and road users. Unlike other modes of transportation, there is no control on the drivers using the road. Here traffic control devices comes to the help of the traffic engineer. The major types of traffic control devices used are-

1. Traffic signs
2. Road markings
3. Traffic signals
4. Parking control.

Requirements of traffic control devices

The control device should fulfill a need

It should command attention from the road users

It should convey a clear, simple meaning

Road users must respect the signs

The control device should provide adequate time for proper response from the road users

Types of traffic signs

1. Regulatory signs
2. Warning signs
3. Informative signs

Regulatory signs

These signs are also called mandatory signs because it is mandatory that the drivers must obey these signs. If the driver fails to obey them, the control agency has the right to take legal action against the driver.

- Right of way series
- Speed series

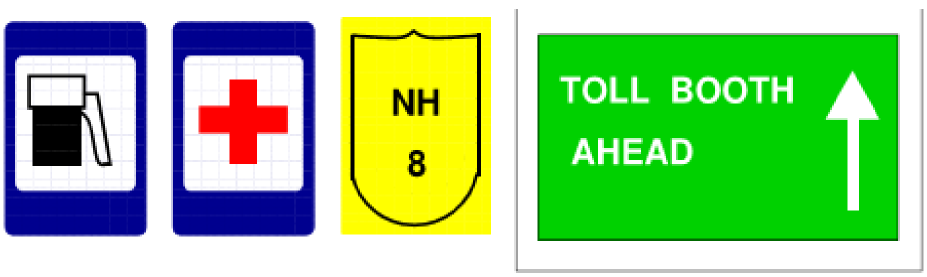
- Movement series
- Parking series
- Pedestrian series
- Miscellaneous

Warning signs

Warning signs or cautionary signs give information to the driver about the impending road condition. They advice the driver to obey the rules.

Informative signs

Informative signs also called guide signs, are provided to assist the drivers to reach their desired destinations. These are predominantly meant for the drivers who are unfamiliar to the place. The guide signs are redundant for the users who are accustomed to the location.



Examples of informative signs

Traffic Sign

The essential purpose of road markings is to guide and control traffic on a highway. They supplement the function of traffic signs. The markings serve as a psychological barrier and signify the delineation of traffic path and its lateral clearance from traffic hazards for the safe movement of traffic. Hence they are very important to ensure the safe, smooth and harmonious flow of traffic.

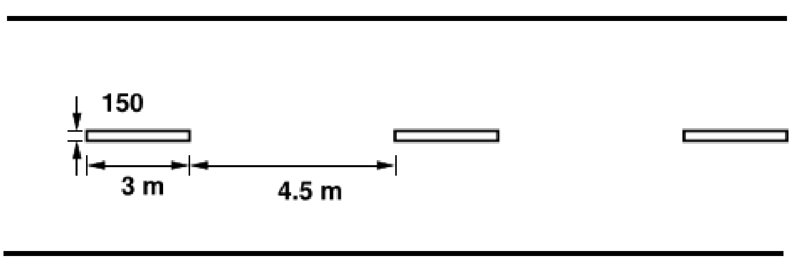
Classification of road markings

The road markings are defined as lines, patterns, words or other devices, except signs, set into applied or attached to the carriageway or kerbs or to objects within or adjacent to the carriageway, for controlling, warning, guiding and informing the users. The road markings are classified as

- Longitudinal markings
- Transverse markings
- Object markings
- Word messages
- Marking for parking
- Marking at hazardous locations

Longitudinal markings

Longitudinal markings are placed along the direction of traffic on the roadway surface, for the purpose of indicating to the driver, his proper position on the roadway.



Centre Line Marking

Centre line

Centre line separates the opposing streams of traffic and facilitates their movements. Usually no centre line is provided for roads having width less than 5 m and for roads having more than four lanes. The centre line may be marked with either single broken line, single solid line, double broken line, or double solid line depending upon the road and traffic requirements.

Traffic lane lines

The subdivision of wide carriageways into separate lanes on either side of the carriage way helps the driver to go straight and also curbs the meandering tendency of the driver.

No passing zones

No passing zones are established on summit curves, horizontal curves, and on two lane and three lane highways where overtaking maneuvers are prohibited because of low sight distance. It may be marked by a solid yellow line along the centre or a double yellow line.

Parking studies

Before taking any measures for the betterment of conditions, data regarding availability of parking space, extent of its usage and parking demand is essential. It is also required to estimate the parking fares also.

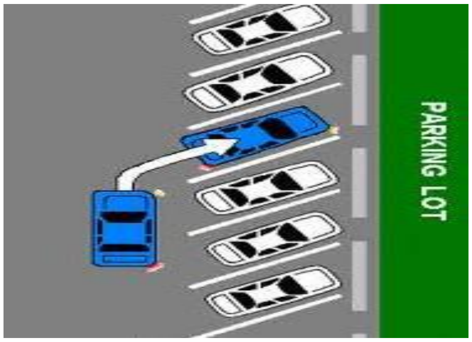
- Parking statistics
- Parking accumulation
- Parking volume
- Parking load
- Average parking duration
- Parking turnover
- Parking index

Parking surveys

- In-out survey
- Fixed period sampling
- License plate method of survey

On street parking

- ✓ Parallel parking
- ✓ 30 parking
- ✓ 45 parking
- ✓ 60 parking
- ✓ Right angle parking



Off street

Parking In many urban centres, some areas are exclusively allotted for parking which will be at some distance away from the main stream of traffic. Such a parking is referred to as off-street parking.

The conflicts arising from movements of traffic in different directions is solved by time sharing of the principle. The advantages of traffic signal includes an orderly movement of traffic, an increased capacity of the intersection and requires only simple geometric design. However the disadvantages of the signalized intersection are it affects larger stopped delays, and the design requires complex considerations.

Definitions and notations

- Cycle
- Cycle length
- Interval
- Green interval
- Red interval
- Phase
- Lost time

Parking

Phase design

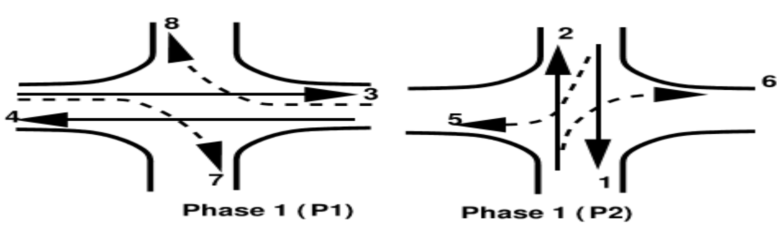
The signal design procedure involves six major steps.

They include the

1. phase design
2. determination of amber time and clearance time
3. determination of cycle length
4. apportioning of green time
5. pedestrian crossing requirements,
6. the performance evaluation

Two phase signals

Two phase system is usually adopted if through traffic is significant compared to the turning movements.



3E's"of Engineering :

The various phase of traffic engineering is implemented with the help of Engineering, Enforcement and Education or "3E's"

Enforcement is usually made through traffic laws, regulations and control.

Education may be possible by sufficient publicity through schools and televisions. It aims at improving the human factor in traffic performance.

Engineering phase is one which is constructive. It deals with improvement of road geometrics, providing additional road facilities and installation of suitably designed traffic control devices.

Traffic Studies

Traffic studies are carried out to analyze the traffic characteristics. These studies helps in deciding the geometric design features traffic control for safe and efficient traffic movement. The various traffic survey studies generally carried out are:

- ❑ Traffic volume study
- ❑ Speed study
- ❑ Spot speed study
- ❑ Speed and delay study
- ❑ Origin and destination study
- ❑ Traffic flow characteristics
- ❑ Traffic capacity study
- ❑ Parking study

  Accident studies

Traffic Volume Study

- ❑ It is the number of vehicles crossing a section of road per unit time at any selected period.
- ❑ It is used as a quantity measure of flow: the commonly units are vehicles/day or vehicles/hour

Object and Uses of Traffic Volume Study:

- ❑ It is generally accepted as a true measure of the relative importance of roads and in deciding the priority for improvement and expansion.
- ❑ It is used in planning, traffic operation and control of existing facilities and also for planning the new facilities.
- ❑ It is used in the analysis of traffic patterns and trends.
- ❑ Useful in structural design of pavement Pedestrian traffic volume study is used for planning side walk, cross walks, subway and pedestrian signals

Manual Method:

counts are typically used to gather data for determination of vehicle classification, turning movements, direction of travel, pedestrian movements, or vehicle occupancy. Most applications of manual counts require small samples of data at any given location. Manual counts are sometimes used when the effort and expense of automated equipment are not justified. Manual counts are necessary when automatic equipment is not available. Manual counts are typically used for periods of less than a day. Normal intervals for a manual count are 5, 10, or 15 minutes. Traffic counts during a Monday morning rush hour and a Friday evening rush hour may show exceptionally high volumes and are not normally used in analysis; therefore, counts are usually conducted on a Tuesday, Wednesday, or Thursday.

Procedure for Manual Method

- No. of observers required depends upon no. of Lanes and type of information required.
- More desirable to record traffic in each direction of travel
  by posting separate observers for each direction.
- For all-day counts, work in three shifts can be arranged.
  Data is recorded by Five- dash system.

Equipment for Manual Method:

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  Data is recorded by Five- dash system.

Talley Sheet:

Recording data onto tally sheets is the simplest means of conducting manual counts. The data can be recorded with a tick mark on a pre-prepared field form. A watch or stopwatch is necessary to measure the desired count interval

Advantage of Manual Method:

- Details such as vehicle classification and no. of occupants can be obtained.
- Records Turning movement data of vehicles at intersections.
- Analysing traffic characteristics in unusual conditions such as adverse weather conditions, traffic breakdowns, temporary closure of any lane of highway etc.
- Comparatively cheaper method of counting. Data accumulated by manual methods are easy to analyse

Automatics Method:

An automatic survey involvesplacing a tube or loop across a road which is connected to a box containing the means for storing the information. In this method, vehicles are counted automatically without any human involvement. There are two techniques of automatic counting: system based on pneumatic mechanical, magnetic

- The CCTV Video and other automatic instrument is used for method The automatic count method provides a means for gathering large amounts of traffic data. Automatic counts are usually taken in 1- hour intervals for each 24-hour period.
- The counts may extend for a week, month, or year. When the counts are recorded for each 24-hour time period, the peak flow period can be identified.
- Automatic counts are recorded using one of three methods: portable counters, permanent counters, and videotape
- ***Portable Counters***
- Portable counting is a form of manual observation. Portable counters serve the same purpose as manual counts but with automatic counting equipment. The period of data collection using this method is usually longer than when using manual counts. The portable counter method is mainly used for 24-hour counts.
- Pneumatic road tubes are used to conduct this method of automatic counts Specific information pertaining to pneumatic road tubes can be found in the users' manual

Passenger Car Unit:

it is a common practice to consider the passenger car as the standard vehicle unit to convert the other vehicle classes and this unit is called **Passenger car unit PCU.**

Factor affecting the Passenger Car Unit

- Vehicle characteristics
- Speed distribution of the mixed traffic stream, volume to capacity
- Roadway characteristics.
- Regulation and control of traffic.
- Environmental and climatic conditions.

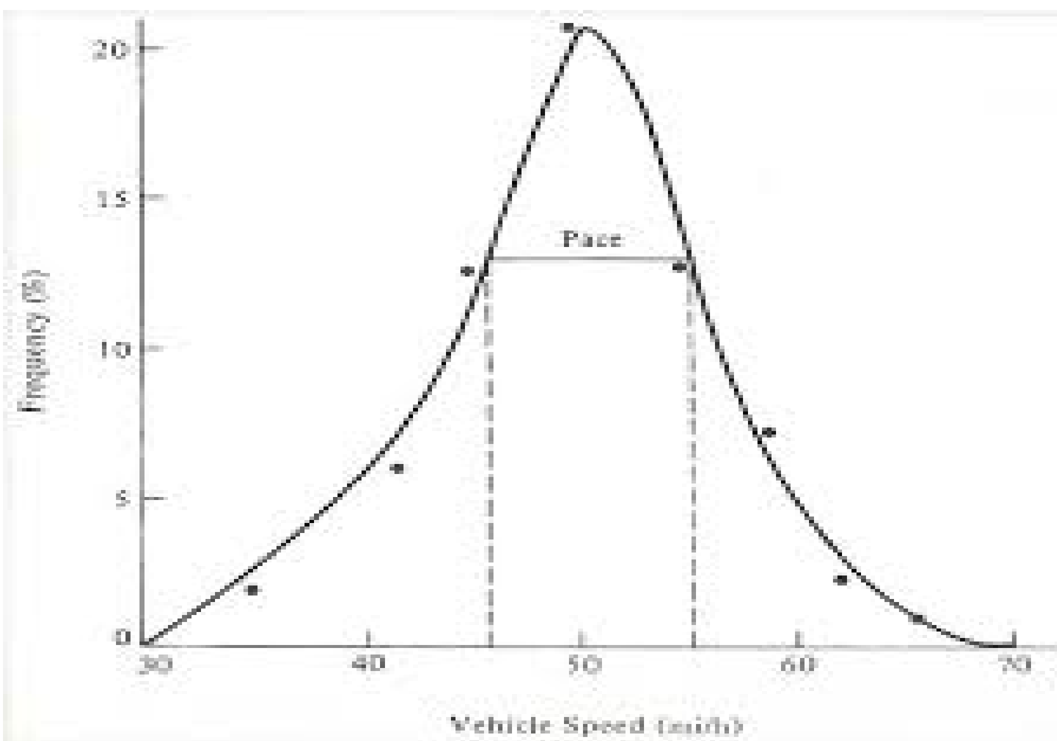
Speed Study:

Speed percentiles are tools used to determine effective and adequate speed limits. The two speed percentiles most important to understand are the 50th and the 85th percentiles. The 50th percentile is the median speed of the observed data set. This percentile represents the speed at which half of the observed vehicles are below and half of the observed vehicles are above. The 50th percentile of speed represents the average speed of the traffic stream. The 85th percentile is the speed at which 85% of the observed vehicles are traveling at or below. This percentile is used in evaluating/recommending posted speed limits based on the assumption that 85% of the drivers are traveling at a speed they perceive to be safe (Homburger et al. 1996). In other words, the 85th percentile of speed is normally assumed to be the highest safe speed for a roadway section. Weather conditions may affect speed percentiles. For example, observed speeds may be slower in rainy or snowy conditions.

Key Steps to a Stopwatch Spot Speed Study A stopwatch spot speed study includes five key steps:

1. Obtain appropriate study length.
2. Select proper location and layout.
3. Record observations on stopwatch spot speed study data form.
4. Calculate vehicle speeds.
5. Generate frequency distribution table and determine speed percentiles.

The city of Cottonwood Glen received a complaint of afternoon traffic speeding in a residential area. The city suspected this was related to students leaving a nearby high school. The first action taken by the city was to quantify the facts by conducting a spot speed study. The city decided to use the stopwatch method because of their limited resources. A location was selected near the intersection of 4th Street and University Avenue, approximately two blocks from the high school and where the city had received multiple speeding complaints from residents. The posted speed limit is 30 mph. The study was conducted on a Wednesday and started at 3:00 p.m. The time was selected to correspond to the period when most high school students leave the school. The study continued until a sample size of 100 vehicles was measured



Unit -05

Classification of Bridges

1. Classification of Bridges (According to form (or) type of superstructures)
•Slab bridge
•Beam bridge
•Truss bridge
•Arch bridge
•Cable stayed (or)suspended bridge

2. Classification of bridges (According to material of construction of superstructure)
•Timber bridge
•Concrete bridge
•Stone bridge
•R.C.C bridge
•Steel bridge
•P.C.C bridge
•Composite bridge
•Aluminum bridge

3. Classification of bridges (According to inter-span relationship)
•Simply supported bridge
•Cantilever bridge
•Continuous bridge

4. Classification of bridges (According to the position of the bridge floor relative to superstructures)
•Deck through bridge
•Half through or suspension bridge

5. Classification of bridges (According to method of connection of different part of superstructures)

•Pinned connection bridge
•Riveted connection bridge
•Welded connection bridge

6. Classification of bridges (According to length of bridge)

•Culvert bridge(less than 6 m)
•Minor bridge(less than 6 m-60m)
•Major bridge(more than 60 m)
•Long span bridge(more than 120 m)

9. Classification of bridges (According to function)

•Aqueduct bridge(canal over a river)
•Viaduct(road or railway over a valley or river)
•Pedestrian bridge
•Highway bridge
•Railway bridge
•Road-cum-rail or pipe line bridge

Bridge scour

It is the removal of sediment such as sand and rocks from around bridge abutments or piers. Scour, caused by swiftly moving water, can scoop out *scour holes*, compromising the integrity of a structure.

In the United States of America, bridge scour is one of the three main causes of bridge failure (the others being collision and overloading). It has been estimated that 60% of all bridge failures result from scour and other hydraulic-related causes. It is the most common cause of highway bridge failure in the United States, where 46 of 86 major bridge failures resulted from scour near piers from 1961 to 1976.

Shallow Foundations:

Foundations provided immediately beneath the lowest part of the structure, near to the ground level are known as shallow foundations. Such foundations are mostly placed on the first hard and firm strata available below the ground level. Shallow foundations are further classified into the following types:

1. Spread footing or open trench foundations
2. Grillage foundations
3. Raft foundations
4. Stepped foundations
5. Inverted arch foundations

Deep Foundation:

The foundation constructed sufficiently below ground level with some artificial arrangements such as piles, wells etc, at their base are called deep foundations. Deep foundation are further classified into the following types;

1. Pile foundation
2. Well foundation
3. Caisson foundation

Abridge can be divided into two major parts:

Superstructure

Substructure

The superstructure of bridge is analogous to a single-story building roof and substructure to that of walls, columns and foundations supporting it.

Classification of Bridge:

Bridges can be classified into various types depending upon the following factors:

Materials used for construction: Under this category, bridges may be classified as timber bridges, masonry bridges, steel bridges, reinforced cement concrete bridges, pre-stressed bridges, composite bridges.

Alignment: Under this category, bridges may be classified as straight or a skew bridge.

Location of Bridge Floor: Under this category, bridges may be classified as deck, semi-through or through bridges.

Purpose: Under this category, bridges may be classified as aqueduct, viaduct, highway bridge, railway bridge, and foot bridge etc. Nature of superstructure action: Under this category, bridges may be classified as Portal frame bridges, truss bridges, balanced cantilever bridges and suspension bridges.

Position of High flood level: Under this category, bridges may be classified as submersible and non submersible bridges.

Life: Under this category, bridges may be classified as permanent and temporary bridges.

Loadings : Road bridges and culverts have been classified by Indian road congress into Class AA, Class A and Class B bridges according to the loadings they are designed to carry.

An ideal bridge meets the following requirements to fulfill the three criteria of efficiency, effectiveness and equity.

It serves the intended function with utmost safety and convenience.

It is aesthetically sound.

It is economical.

Separate numbers are assigned to all culverts and bridges on a highway for their identification by the maintenance and inspection.

Methods of numbering: the culverts and bridges on a road should be numbered in serial order, in each kilometer separately.

The number should be in the form of fraction, numerator denoting the number of kilometer in which the structure is situated and the denominator the kilometer wise serial number of the structure.

The 3rd cross drainage structure in 5th kilometer (i.e. between kilometer stones 4 and 5) should be designated as 5/3, and the 6th structure in 12th kilometer as 12/6.

Bridge Alignment:

Depending upon the angle which the bridge makes with the axis of the river, the alignment can be of two types;

Square Alignment: In this the bridge is at right angle to the axis of river.

Skew Alignment: In This the bridge is at some angle to the axis of river which is not a right angle.

Economic Span of Bridge :

Considering only the variable items, the cost of superstructure increases and that of the substructure decreases with an increase in the span length. Thus most economic span length is that, which satisfies the following i.e

The cost of the superstructure=the cost of the substructure

The derivation for the economic span can be established on the basis of the following assumptions;

The bridge has equal span length. In practice generally equal spans are kept.

The cost of the supporting system of superstructure varies as the square of the span length. This assumption is nearly justified, because the design of supporting system sections of super structure depends upon the bending moment, which in turn varies as square of span length.

Cost of flooring and parapets varies directly as the span, this assumption is justified because as the span increases the quantity of material also increases.

Cost of one pier and its foundation is constant. This is more or less only approximately true, as the depth of foundation is decided by scour considerations, which is constant at a bridge site.

v) Cost of abutments and their foundations is also constant. As the end span length increases the load on the abutment also correspondingly increases requiring costly design.

Let, L= Total length of bridge

i= Span Length

n = The total number of spans

= L / l

P = Cost of one pier with its foundation.

A1 = Cost of one abutment and its foundation

A2 = Cost of one approach

T = Total Bridge Cost

According to ii) and iii) assumptions:

Cost of one span of superstructure = a1l2 + a2l

Here, a1 and a2 are constants of variation

There are (n-1) number of piers and two abutments

The Total Cost of Bridge = Cost of supporting System of superstructure + Cost of two abutments + Cost of (n-1) piers + cost of Approaches, railings and parapets

i.e.

T = n (a1l2 + a2l) +2A1 + 2A2 + (n-1) P

Replacing n = L / l

T = L / l(a1l2 + a2l) +2A1 + 2A2 + (L / l -1) P

= La1l + a2 L + PL/l – P + 2A1 + 2A2

Therefore,

$dT/dl = a1l + 0 - PL/l2$

For T to be minimum

$dT/dl = o$

Or $a1l - PL/l2 = 0$

Or $a1 = P/l2$

Or $P = a1l2$

or Economic Span = l = P/

Scour depth :

When the velocity of stream exceeds the limiting velocity which the erodible particle of bed material can stand, the scour occurs. The normal scour depth is the depth of water in the middle of the stream when it is carrying the peak flood discharge. This can be easily ascertained by actual soundings at or near the site proposed for the bridge during or immediately after a flood before the scour holes have had time to silt up appreciably. Due allowance should be made in the observed depth for increase in scour resulting from;

The designed discharge being greater than the flood discharge during which the scour was observed.

The increase in velocity due to the obstruction in flow caused by construction of the bridge.

Alluvial streams bed and banks are composed of loose granular material, that has been deposited by the stream and can be picked up and transported again by the current during flood.

These streams tend to scour or silt up till it has acquired such a cross-section and more particularly such a slope that the resulting velocity is non silting and non-scouring. When such a stage occurs, the stream becomes stable and tends to maintain the acquired shape and size of its cross section and the acquired slope. Such a stream is known as regime channel.

Afflux :

When a bridge is constructed, the structures such as abutment and piers cause the reduction of the natural waterway area.

This increased velocity gives rise to a sudden heading up of water on the upstream side of the stream. This phenomenon of heading up of water on the upstream side of stream is known as afflux.

Depth of Foundation :

The depth of bridge foundation is determined by consideration of the safe bearing capacity of the soil after taking into account of the effect of scour. In all doubtful cases, the bearing capacity of the foundation soil is ascertained by actual field load test. The bore holes are driven to determine the adequacy of thickness of the foundation bearing layer of the soil. The minimum depth of foundation can be approximately calculated by the following relationship;

$$h = \frac{P}{w}\left(\frac{1-\sin \phi}{1+\sin \phi}\right)^2$$

Where h-the depth of foundation in metres.

P- the bearing capacity of soil in kg/m2

w-specific weight of earth in kg/m2

ø- the angle of internal friction of the soil

Free board

Is the vertical distance between the designed high flood level, allowing for afflux, if any, and the level of the crown of the bridge at its lowest point. it is essential to provide the free board in all types of bridges for the following reasons; Free board is required to allow floating debris, fallen tree trunks and approach waves to pass under the bridge. Free board is also required to allow for the afflux during the maximum flood discharge due to contraction of waterway. Free board is required to allow the vessels to cross the bridge in case of navigable rivers. The value of the free board depends on the type of the bridge

Clearance :

To avoid any possibility of traffic striking any structural part clearance diagrams are specified. The horizontal clearance should be the clear width and the vertical clearance the clear height, available for the passage of vehicular traffic.

A Road causeway is a dip which allows floods to pass over it. It may or may not have openings or vents for low water to flow. If it has vents for low water to flow then it is known as high level causeway or submersible bridge. Otherwise a low level causeway.

Low Level Causeways

It is also known as Irish bridge. The beds of small rivers and streams, which remain dry for most part of the year, are generally passable without a bridge.

This involves heavy earth work in cutting for bridge approaches. Banks of such type of streams are cut down at an easy slope.

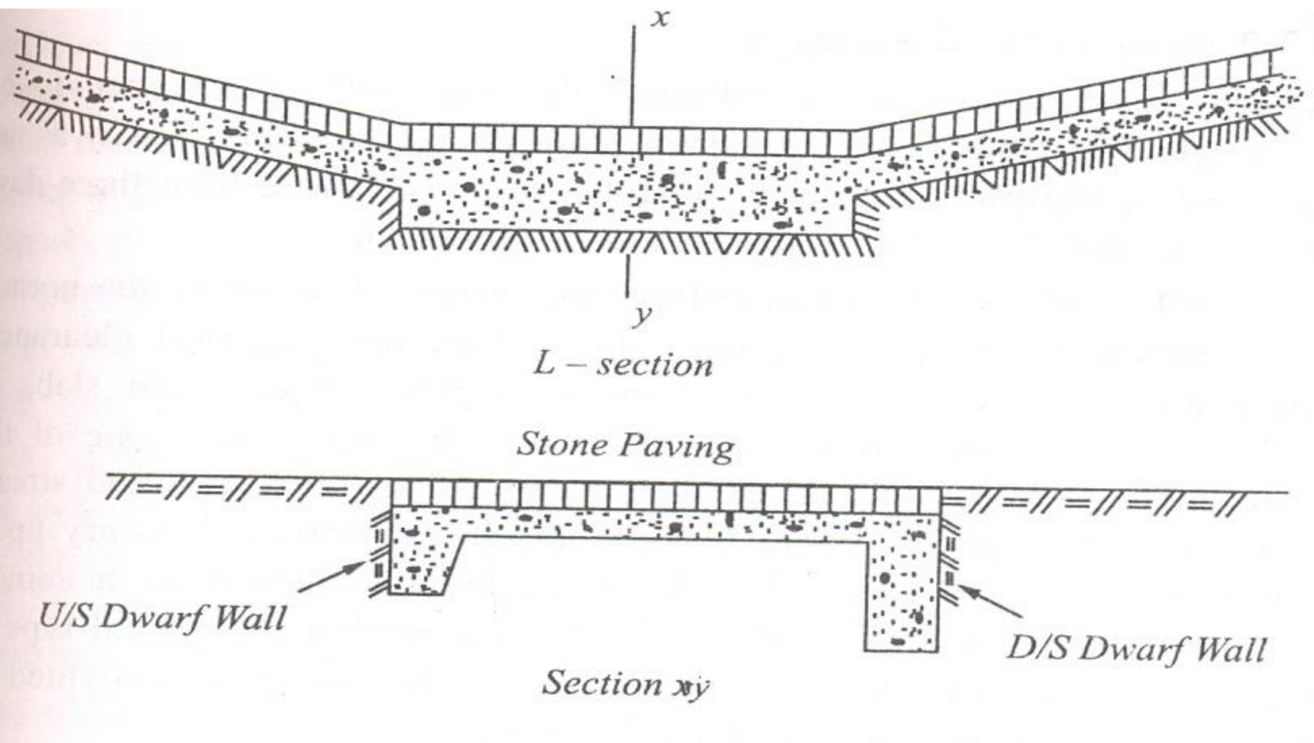
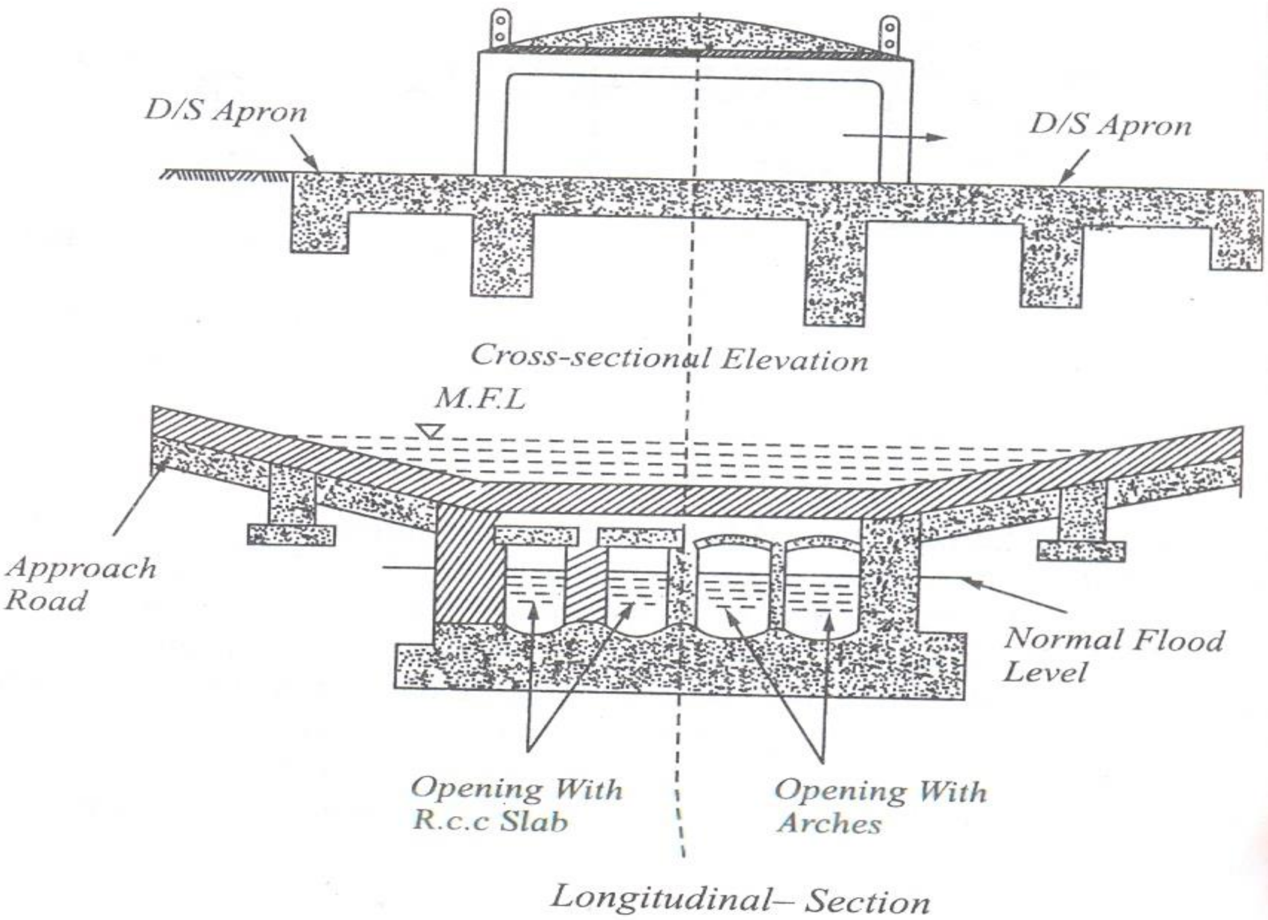


Fig. 5.3.1 Low Levels Causeway.

High Level Causeway

When the velocity is high and stream bed is soft the aprons could be of concrete or harder masonry up to a certain distance. Similarly, the road can be formed of a cement concrete slab or stone blocks set in cement mortar.

A typical type of high level causeway is shown in Fig. If railing are provided on the bridge, they should be of collapsible type.



Unit -06

Bridge Inspection

A culvert is a small bridge for carrying water beneath a road railway. It is used when the linear waterway does not exceed 12 m.

The waterway is provided in 1 to 3 spans, as required. In case of road culvert, span is limited to 5 m in length, whereas in case of railway the span can be as high as 6 m.

The common types of culverts are classified in following four categories:

(i) Arch Culvert.
(ii) Slab Culvert.
(iii) Pipe Culvert.
(iv) Box Culvert.

An arch culvert consists of abutments, wing walls arch, parapets and the' foundations.

The construction materials commonly used are brick work or concrete.

Floor and curtain wall May or may not be provided depending upon the nature of foundation soil and velocity of flow. An oblique view of typical arch culvert is shown in Fig.

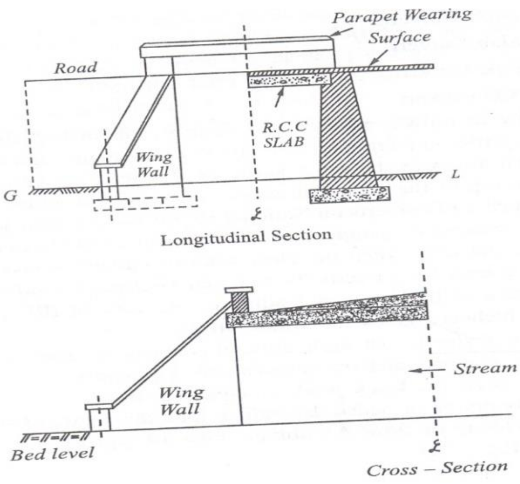
Box Culvert :

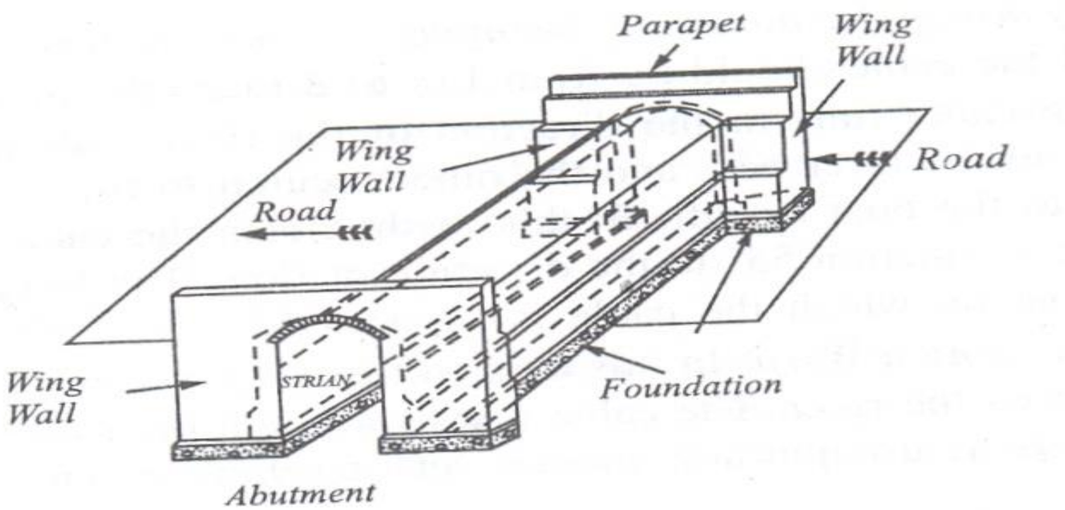
They comprise one or more number of rectangular or square openings. These are provided if soil is Soft and the load has to be spread over a wider foundation area.

Pipe Culvert:

They are provided when discharge of stream is small or when sufficient headway is not available.

Usually one or more pipes of diameter not less than 60 cm are placed side by side.





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Bridge Bearing :

The loads coming from the superstructure of a bridge are transmitted to the substructure through the bearings. The design of the sub-structure and foundation is affected to a considerable extent by the type and method of providing the bearings.

In all bridge of any size, some allowance has to be made for expansion and contraction of their decks on their supports. Generally, this expansion and contraction and the movements which occur under traffic or wind loads are not imposed on the supports of the bridges but on bearings which allow such movements quite freely in relation to the supports.

Requirement

To accommodate maximum expected deck movement and rotation with least possible resisting force.

To perform satisfactorily with minimum maintenance and low friction during the design life of the bridge.

To be able to distribute the superimposed load uniformly on sub-structure giving greater stability to structure.

To be economically viable.

To be compact in size and easy to install and

To be offer excellent resistance to weathering.

The main functions of the bearings can be divided under the following categories:

Function of Bearing:

Longitudinal Movement due to Temperature Variations:

Temperature variations result in expansion or contraction of the members. If one end of a simply supported members is free to move longitudinally, other end being held in position, changes in temperature of concrete lengthens or shortens the member without inducing any stresses in the member itself.

Transference of Horizontal Forces due to Braking: Due to application of brakes to vehicles, the superstructure of a bridge is acted by braking forces. This force can be fully transmitted to the sub-structure only if one of the bearings is fixed and does not permit horizontal movement.

Rotation at Supports due to Deflection of Girders: The deflection of a simply supported girder under load, results in an angular movement over the supports. The bearing at both ends must accordingly rotate to assume a position tangent to the deflected bottom shape of the girder

Vertical movement due to sinking of the support

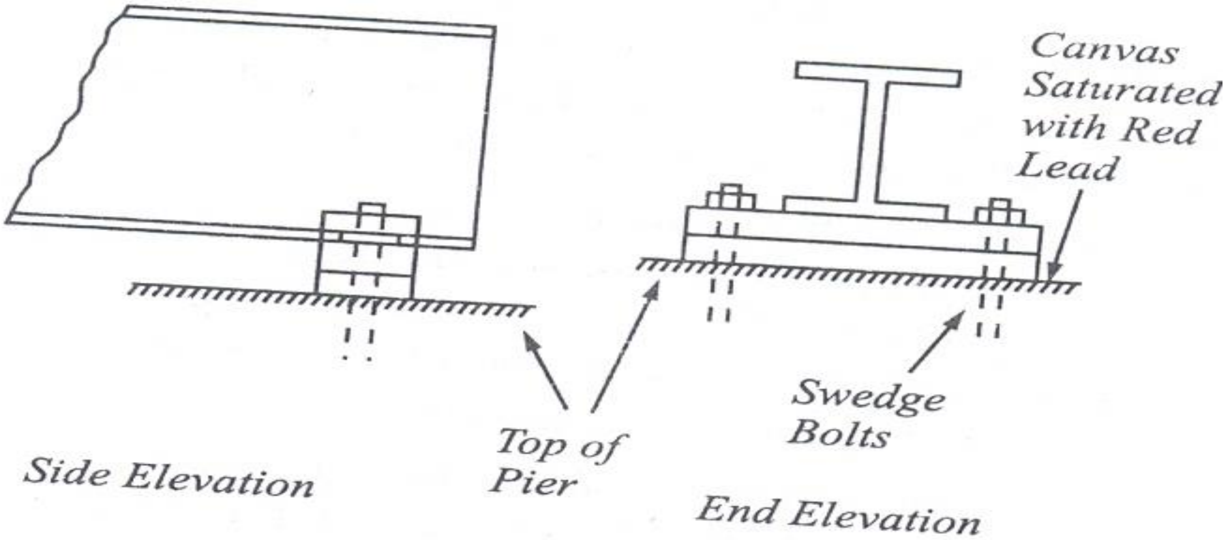
Broadly bearings are classified as follows:

(i) Fixed bearings.

(ii) Expansion bearings.

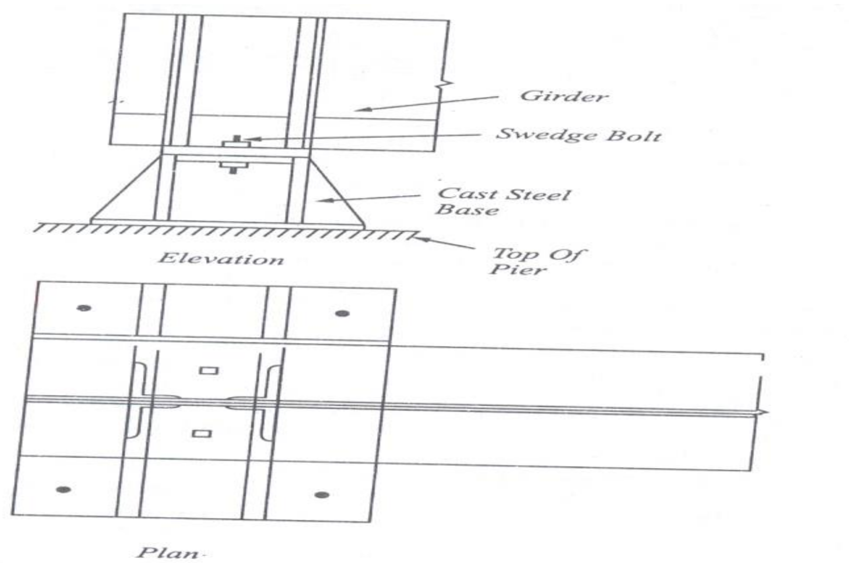
(i) Fixed Bearings: These bearings do not permit any longitudinal movements of the girders. They should be able to allow rotation. The design of a fixed bearing depends upon the type of superstructure, type, of supports and also on span length. In general fixed bearing can be shallow plate bearing, deep base bearing, steel hinge, rocker bearings of steel and reinforced concrete, laminated rubber fixed bearing and cement mortar pad.

Shallow Plate bearing: This comprises a flat rectangular steel plate attached to the under side of the lower flange of the girder. This plate is anchored down with usually two anchors, one on each side of the girder to the top of pier.



Deep Base Bearing: For spans over 12 m a deep cast base, This avoids the concentration of the reaction at the inner edge of the bearing.

(c) Steel Hinge : It consist of a top saddles casting bolted to the underside of the main girders and resting on a knock pin held in position by the bottom casting which is bolted securely to the pier top.



Rocker Bearing: For spans over 20 m carrying heavier loadings rocker bearings are used. In this type the girder is connected to the top inverted shoe resting on a cylindrical rocker pin which in turn rests on bottom shoe. With the deflection of the girder the top shoe rotates over the pin, thereby allowing for free angular movements of the ends of the girder