SKDAV GOVT.POLYTECHNIC ROURKELA

DEPARTMENT OF CIVIL ENGINEERING

LECTURE NOTES

Year & Semester: 2ND Year, IV Semester
Subject Code/Name:
TH-4, HIGHWAY ENGINEERING

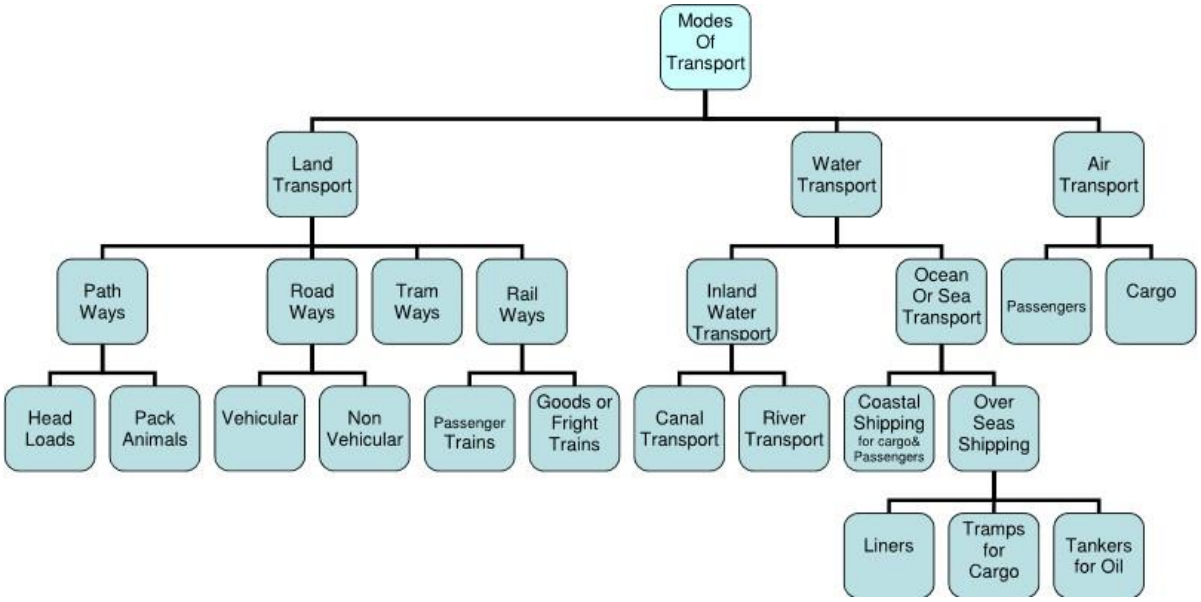
HIGHWAY ENGINEERING

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



Means of Transport

Advantage and Disadvantage of Road Transport

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 11. 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 Organisation

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

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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Indian Roads Congress (I.R.C.):

The Indian Roads Congress was established by the Central Government in 1934 as per the recommendations of the Jayakar Committee. The I.R.C. was constituted to provide a forum for the regular pooling the technical ideas, experiences and knowhow for the panning of the development of the roads throughout the country. I.R.C. provides the recommended specifications regarding the design and construction of the roads in the country.
IRC has collaborated with the road wing of the ministry of the surface transportation of Govt. of India. It publishes journals, standard specifications and guidelines on various aspects of highway engineering.

Functions of Indian Roads Congress (IRC):

IRC a body of professional highway engineers provides the following services:

(i) It provides a forum for expression of collective opinion of its members for all matters affecting the construction and maintenance of roads in India.

(ii) It promotes the use of the standard specifications and practices.

(iii) It provided with the suggestions for the better methods of planning, designing, construction, administration and maintenance of roads.

(iv) It conducts periodical meetings to discuss technical problems regarding roads.

(v) It makes the laws for the development, improvement and protection of the roads.

(vi) It furnishes and maintains libraries and museums for encouraging the science of road making.

Functions of Central Road Research Institute (CRRI):

CRRI was started by the Central Government in 1950, for the research work in the highway engineering. CRRI is a series of laboratories under the council of scientific and industrial research in India. It offers the following services:

(1) Carries basic and applied research for the design, construction and maintenance of the highways.

(2) Carries research on traffic safety and transport economics.

(3) Carries research on economical utilization of locally available materials for construction and maintenance of roads.

(4) Research for the development of the new machinery, tools equipment and instruments for highway engineering.

(5) To provide technical advice and consultancy services to various organizations.

(6) To provide library and documentation services.

Roads wing of ministry of surface transport:

The roads wing of the ministry of Surface Transport handles the road matters of the Central Govt. It is headed by a Director General.

The Director General is assisted by two additional Director Generals(one for roads and one for bridges), a numbers of Chief Engineers, Superintending Engineers, Executive Engineers and Asst. Executive Engineers. The roads wing has a chief Engineer for the North-East region posted at Guwahati and a Liaison-cum-Inspectorate organization consisting of S.E's and E.E's in the various states. The functions of the roads wing of Surface Transport are:

(a) To control funds approved by Central Government for the development of National Highways.

(b) To control the central road fund.

(c) To prepare plans for development and maintenance of National Highways in consultation with state PWD's.

(d) To oversee technically the quality of works executed by the agencies.

(e) To administer matters regarding road research.

(f) To examine technically the projects of roads and bridges prepared by the PWD's.

(g) To administer the central road program other than National Highways in the Union Territories.

IRC(Indian Roads Congress) has classified the roads in the India in the following 5 categories:
(a)National Highways
(b) State Highways
(c) Major District Roads
(d) Other District Roads
(e) Village Roads

- **National Highways(NH):** National highways are the major arterial roads spanning in the length and breadth of the country and connects the Capital to the various state capitals of the country or with the neighboring countries.

They also connect the famous tourism places of the country. National highways are numbered and written as NH-1, NH-2 etc. They have the highest design specifications.

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Example : NH -1 Delhi-Ambala-Amritsar, NH-21 Chandigarh- Mandi- Manali.

- **State Highways(SH):** State highways are the roads which connect the state capital to other states and to the district headquarters in the state. They have design specifications similar to those of the National Highways because they carry enough traffic.
- **Major District Roads(MDR):** These roads connect the district headquarters to the main town centers in the district, and to the headquarters of the other districts also. They also connect these major town centers to the other state highways of importance. They have lower design specifications as compared to the NH and SH.
- **Other district roads(ODR):** These roads connect the rural areas town centers to the major district roads of higher importance.They provide the facilities for the transportation of the raw materials or the goods mainly of agricultural products from the rural towns to the higher markets and vice-versa.
- **Village Roads(VR):** These roads connect the rural villages with one another and to the nearest higher level road or to the nearest town center.

ROAD GEOMETRICS

Overview

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.

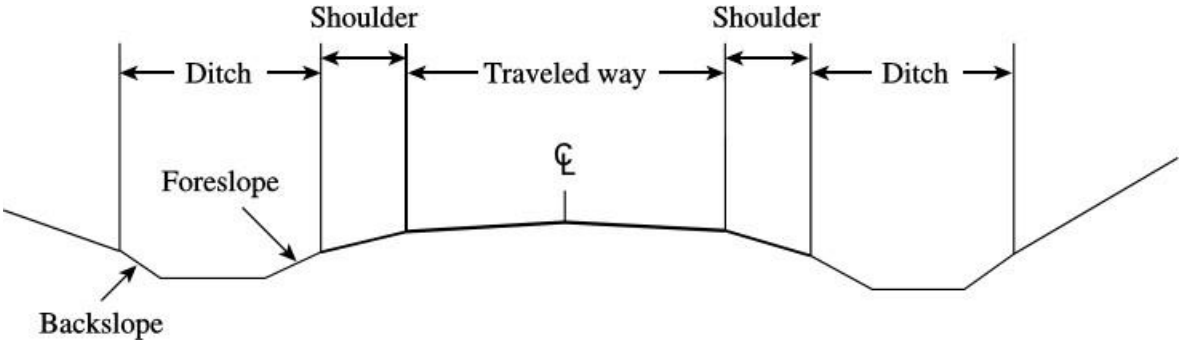
Factors affecting geometric design

- **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.

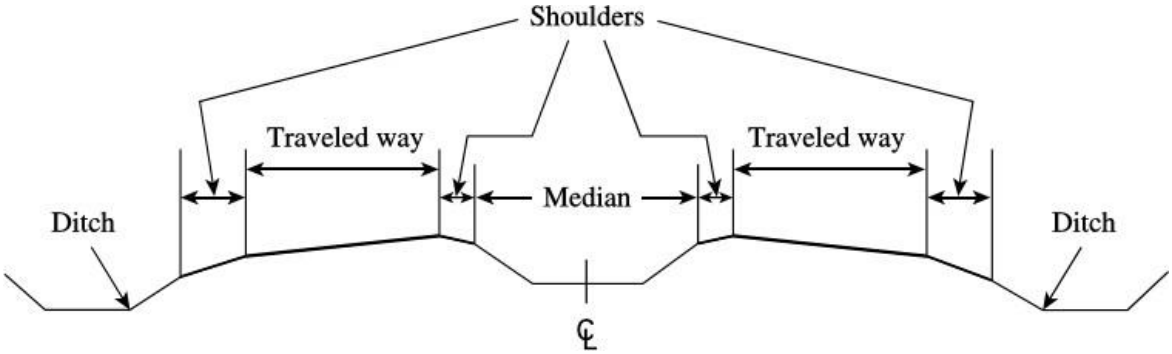
Cross sectional elements

Overview

The primary consideration in the design of geometric cross sections for highways, run-ways, and taxiways is drainage. Details vary depending on the type of facility Highway cross sections consist of traveled way, shoulders (or parking lanes), and drainage channels. Shoulders are intended primarily as a safety feature. They provide for accommodation of stopped vehicles, emergency use, and lateral support of the pavement. Shoulders may be either paved or unpaved. Drainage channels may consist of ditches (usually grassed swales) or of paved shoulders with berms or curbs and gutters. Cross section of various roads are given bellow.



Two-lane highway cross section, with ditches.



Divided highway cross section, depressed median, with ditches.

Pavement surface characteristics

For a safe and comfortable driving four aspects of the pavement surface are important; the friction between the wheels and the pavement surface, smoothness of the road surface, the light reflection characteristics of the top of pavement surface, and drainage to water.

Friction

Friction between the wheel and the pavement surface is a crucial factor in the design of horizontal curves and thus the safe operating speed. Further, it also a ect the acceleration and deceleration ability of vehicles. Lack of adequate friction can cause skidding or slipping of vehicles.

Skidding happens when the path traveled along the road surface is more than the circumferential movement of the wheels due to friction

Slip occurs when the wheel revolves more than the corresponding longitudinal movement along the road. Various factors that a ect friction are:

The frictional force that develops between the wheel and the pavement is the load acting multiplied by a factor called the coe cient of friction and denoted as f . The choice of the value of f is a very complicated issue since it depends on many variables. IRC suggests the coe cient of longitudinal friction as 0.35-0.4 depending on
the speed and coe cient of later friction as 0.15. The former is useful in sight distance calculation and the latter in horizontal curve design.

Unevenness

It is always desirable to have an even surface, but it is seldom possible to have such one. Even if a road is constructed with high quality pavers, it is possible to develop unevenness due to pavement failures. Unevenness a ect the vehicle operating cost, speed, riding comfort, safety, fuel consumption and wear and tear of tyres.

Unevenness index is a measure of unevenness which is the cumulative measure of vertical undulation of the pavement surface recorded per unit horizontal length of the road. An unevenness index value less than 1500 mm/km is considered as good, a value less than 2500 mm.km is satisfactory up to speed of 100 kmph and values greater than 3200 mm/km is considered as uncomfortable even for 55 kmph.

Light refleection

Drainage

The pavement surface should be absolutely impermeable to prevent seepage of water into the pavement layers. Further, both the geometry and texture of pavement surface should help in

draining out the water from the surface in less time.

Camber

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

Overview

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:

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

$$SSD = 1.47\ Vt + \frac{V^2}{30\ (f \pm g)} \qquad \text{(ENGLISH)}$$

where SSD = required stopping sight distance, m or ft.
V = speed, kph or mph
t = perception-reaction time, sec., typically 2.5 sec. for design
f = coefficient of friction, typically for a poor, wet pavement
g = grade, decimal.

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

Overview

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.

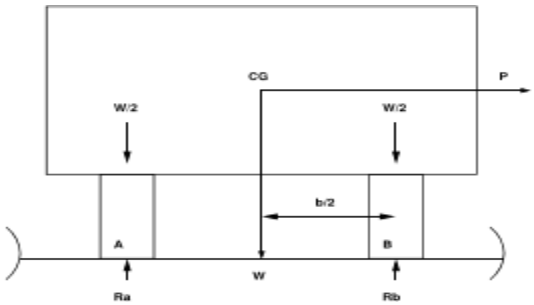
Factors Affecting Alignment

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

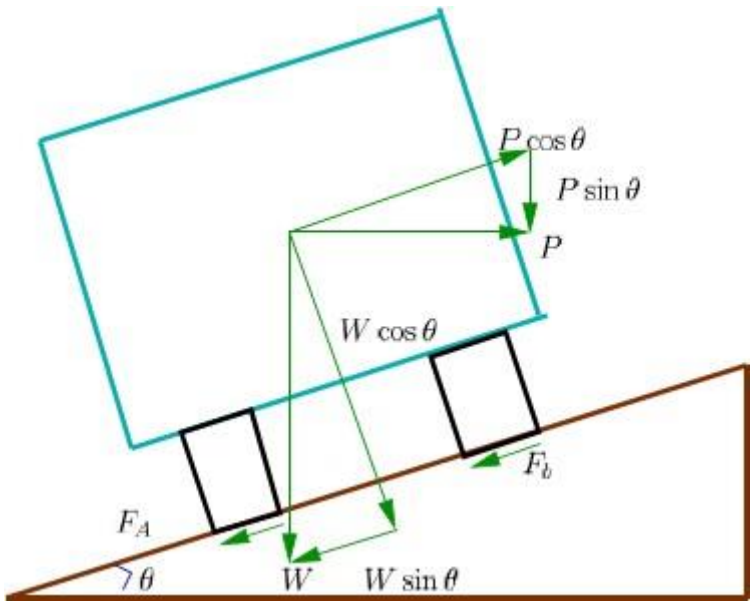
Operating speed is influenced by all other factors so it is the critical factor to consider.

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.



Effect of horizontal curve



Analysis of super elevation

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)

Horizontal alignment II

Overview

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.

$$R_{ruling} = \frac{v^2}{g(e + f)}$$

Ideally, the radius of the curve should be higher than R_{ruling} . However, very large curves are also not desirable. Setting out large curves in the field becomes difficult. In addition, it also enhances driving strain.

Horizontal alignment III

Overview

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.

Curve Resistance

When the vehicle negotiates a horizontal curve, the direction of rotation of the front and the r ear wheels are different. The front wheels are turned to move the vehicle along the curve, whereas the rear wheels seldom turn.

Vertical alignment-I

Overview

The vertical alignment of a transportation facility consists of *tangent grades* (straight lines in the vertical plane) and *vertical curves*. Vertical alignment is documented by the *profile*. Just as a circular curve is used to connect horizontal straight stretches of road, vertical curves connect two gradients. When these two curves meet, they form either convex or concave. The former is called a summit curve, while the latter is called a valley curve.

Gradient

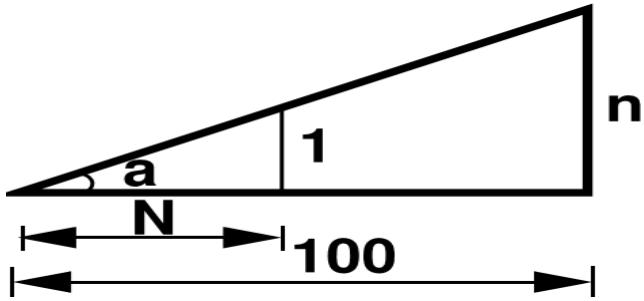
Gradient is the rate of rise or fall along the length of the road with respect to the horizontal. While aligning a highway, the gradient is decided designing the vertical curve. Before nalizing the gradients, the construction cost, vehicular operation cost and the practical problems in the site also has to be considered. Usually steep gradients are avoided as far as possible because of the difficulty to climb and increase in the construction cost. More about gradients are discussed below.

Effect of gradient

The effect of long steep gradient on the vehicular speed is considerable. This is particularly important in roads where the proportion of heavy vehicles is significant. Due to restrictive sight distance at uphill gradients the speed of traffic is often controlled by these heavy vehicles. As a result, not only the operating costs of the vehicles are increased, but also capacity of the roads will have to be reduced. Further, due to high differential speed between heavy and light vehicles, and between uphill and downhill gradients, accidents abound in gradients.

Representation of gradient

The positive gradient or the ascending gradient is denoted as +n and the negative gradient as n. The deviation angle N is: when two grades meet, the angle which measures the change of direction and is given by the algebraic difference between the two grades (n_1 (n_2)) = $n_1 + n_2 = {}_1 + {}_2$. Example: 1 in 30 = 3.33% 2° is a steep gradient, while 1 in 50 = 2% 1° 10^0 is flatter gradient.



Representation of gradient

IRC Specifications for gradients for different roads

Terrain	Ruling	Limitings	Exceptional
Plain/Rolling	3.3	5.0	6.7
Hilly	5.0	6.0	7.0
Steep	6.0	7.0	8.0

Types of gradient

Many studies have shown that gradient upto seven percent can have considerable effect on the speeds of the passenger cars. On the contrary, the speeds of the heavy vehicles are considerably reduced when long gradients as at as two percent is adopted. Although, atter gradients are desirable, it is evident that the cost of construction will also be very high.

Ruling gradient

- Limiting gradient
- Exceptional gradient
- Critical length of the grade
- Minimum gradient
- Summit curve

Summit curves

Summit curves are vertical curves with gradient upwards. They are formed when two gradients meet.

1. when a positive gradient meets another positive gradient
2. when positive gradient meets a at gradient.
3. when an ascending gradient meets a descending gradient.
4. when a descending gradient meets another descending gradient.

Vertical alignment-II

Overview

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.

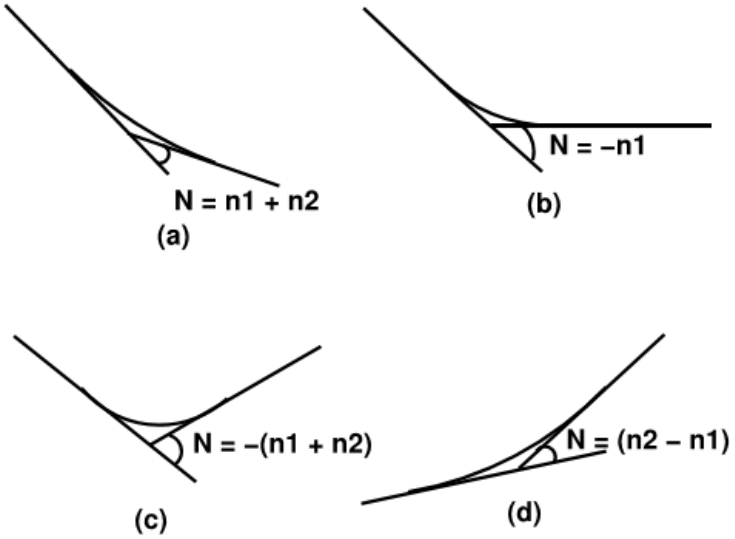
4. When an ascending gradient meets another ascending gradient.

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.



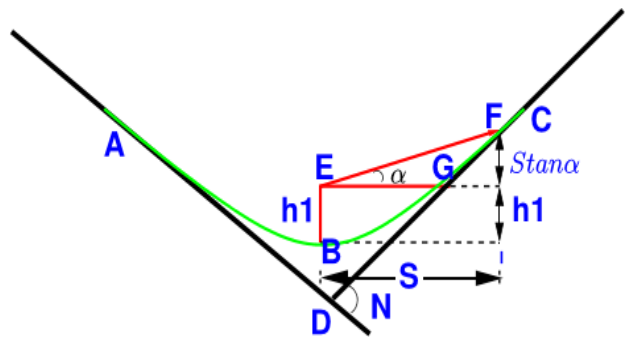
Types of valley curve

Length of the valley curve

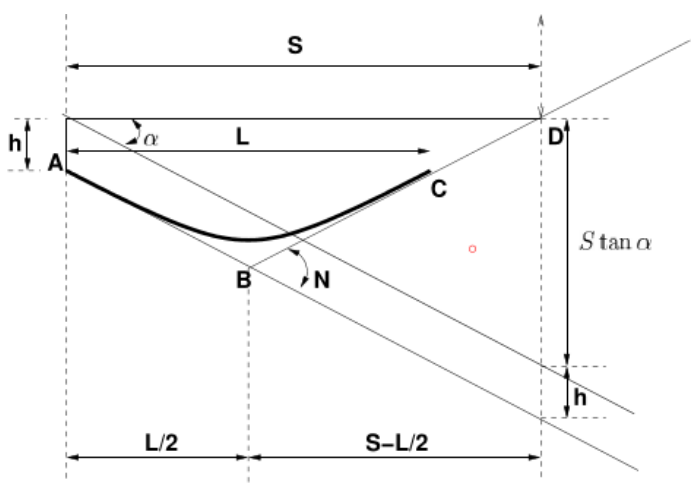
The valley curve is made fully transitional by providing two similar transition curves of equal length The 2N 3 The length of the valley transition curve transitional curve is set out by a cubic parabola y = bx where b = 2 3L is designed based on two criteria:

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.



Valley curve, case1, L > S



Valley curve, case 2, S > L

ROAD MATERIALS

Overview

Pavements are a conglomeration of materials. These materials, their associated properties, and their interactions determine the properties of the resultant pavement.

Sub grade soil

Soil is an accumulation or deposit of earth material, derived naturally from the disintegration of rocks or decay of vegetation, that can be excavated readily with power equipment in the field or disintegrated by gentle mechanical means in the laboratory.

Desirable properties

The desirable properties of sub grade soil as a highway material are

1. Stability
2. Incompressibility
3. Permanency of strength
4. Minimum changes in volume and stability
5. Good drainage
6. Ease of compaction

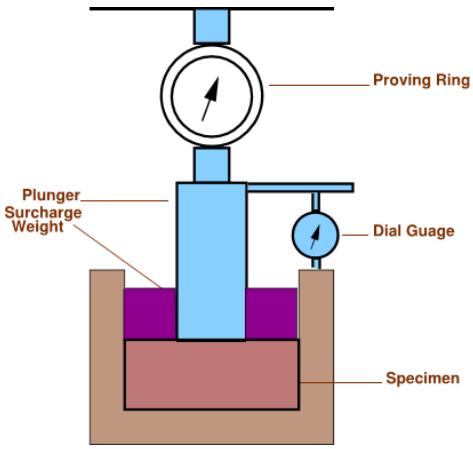
TEST OF SOIL

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

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.
- It is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. to that required for the corresponding penetration of a standard material.



CBR Test

2. Apparatus Required:

- Mould
- Steel Cutting collar
- Spacer Disc
- Surcharge weight
- Dial gauges
- IS Sieves
- Penetration Plunger
- Loading Machine
- Miscellaneous Apparatus

Procedure:

- The top layer of the compacted soil is scratched. Again second layer is filled and process is repeated. After 3rd layer, collar is also attached to the mould and process is continued.
- After fifth layer collar is removed and excess soil is struck off. Remove base plate and invert the mould. Then it is clamped to baseplate.
- Surcharge weights of 2.5kg is placed on top surface of soil. Mould containing specimen is placed in position on the testing machine.
- The penetration plunger is brought in contact with the soil and a load of 4kg(seating load) is applied so that contact between soil and plunger is established. Then dial readings are adjusted to zero.
- Load is applied such that penetration rate is 1.25mm per minute. Load at penetration of 0.5, 1, 1.5, 2, 2.5, 3, 4, 5, 7.5, 10 and 12.5mm are noted.

Standard Load Values for CBR Test

Penetration(mm)	Standard Load(kg)	Unit Standard Load(kg/cm^2)
2.5	1370	70
5	2055	105
7.5	2630	134
10.0	3180	162
12.5	3600	183

Pavement materials

Overview

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.

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.

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 aky 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 a nity with water when compared with bituminous materials, otherwise the bituminous coating on the aggregate will be stripped o 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 at 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.

Aggregate tests-I

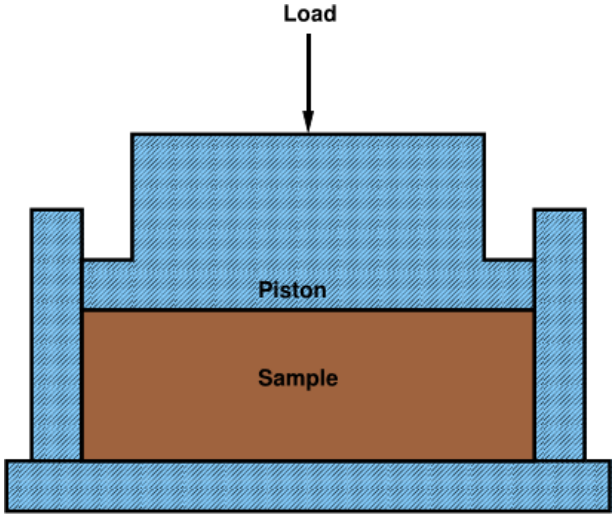
Overview

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

Crushing test

One of the model in which pavement material can fail is by crushing under compressive stress. A test is standardized by IS:2386 part-IV and used to determine the crushing strength of aggregates. The aggregate crushing value provides a relative measure of resistance to crushing



under gradually applied crushing load.

Fig.23.1 Crushing test setup

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).

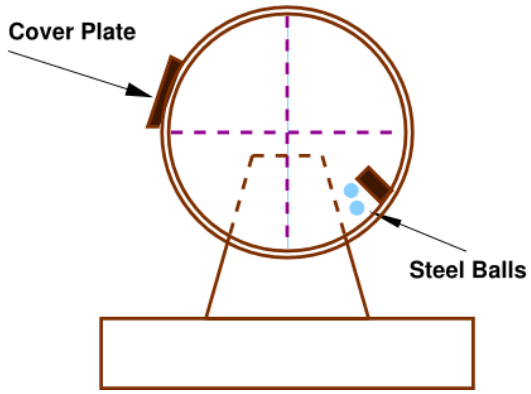


Fig.23.2 Los Angeles abrasion test setup

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.

Soundness test

Soundness test is intended to study the resistance of aggregates to weathering action, by conducting accelerated weathering test cycles. The Porous aggregates subjected to freezing and thawing are likely to disintegrate prematurely. To ascertain the durability of such aggregates, they are subjected to an accelerated soundness test as specified in IS:2386 part-V.

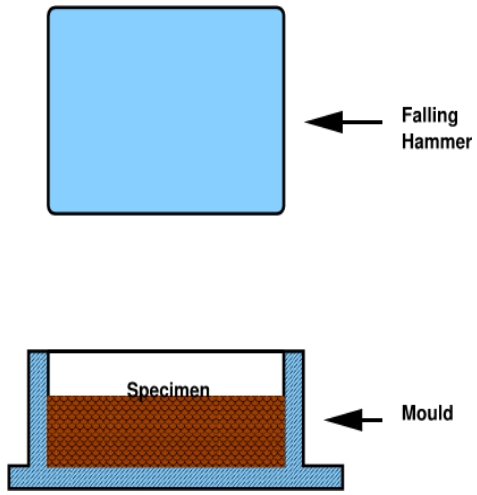


Fig.23.3 Impact test setup

Specific Gravity and water absorption

The Specific gravity and water absorption of aggregates are important properties that are required for the design of concrete and bituminous mixes. The Specific gravity of a solid is the ratio of its mass to that of an equal volume of distilled water at a specified temperature.

- Apparent Specific Gravity
- Bulk Specific Gravity

Water absorption, The difference between the apparent and bulk specific gravities is nothing but the water- permeable voids of the aggregates. The specific gravity of aggregates normally used in road construction ranges from about 2.5 to 2.9. Water absorption values ranges from 0.1 to about 2.0 percent for aggregates normally used in road surfacing.

ROAD PAVEMETS

Types of Pavement – Flexible Pavements and Rigid Pavements

Types of Pavements

There are two types of pavements based on design considerations i.e. flexible pavement and rigid pavement. Difference between flexible and rigid pavements is based on the manner in which the loads are distributed to the subgrade.

Flexible Pavements

Flexible pavement can be defined as the one consisting of a mixture of asphaltic or bituminous material and aggregates placed on a bed of compacted granular material of appropriate quality in layers over the subgrade. Water bound macadam roads and stabilized soil roads with or without asphaltic toppings are examples of flexible pavements.

The design of flexible pavement is based on the principle that for a load of any magnitude, the intensity of a load diminishes as the load is transmitted downwards from the surface by virtue of spreading over an increasingly larger area, by carrying it deep enough into the ground through successive layers of granular material.

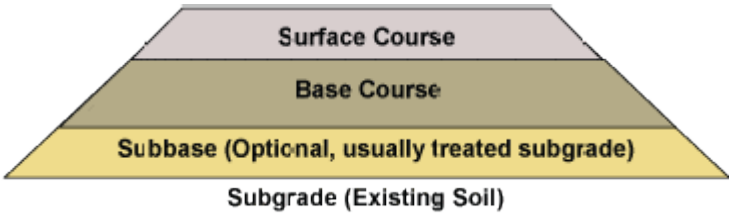


Fig: Flexible Pavement Cross-section

Thus for flexible pavement, there can be grading in the quality of materials used, the materials with high degree of strength is used at or near the surface. Thus the strength of subgrade primarily influences the thickness of the flexible pavement.

Rigid Pavements

A rigid pavement is constructed from cement concrete or reinforced concrete slabs. Grouted concrete roads are in the category of semi-rigid pavements.

The design of rigid pavement is based on providing a structural cement concrete slab of sufficient strength to resists the loads from traffic. The rigid pavement has rigidity and high modulus of elasticity to distribute the load over a relatively wide area of soil.

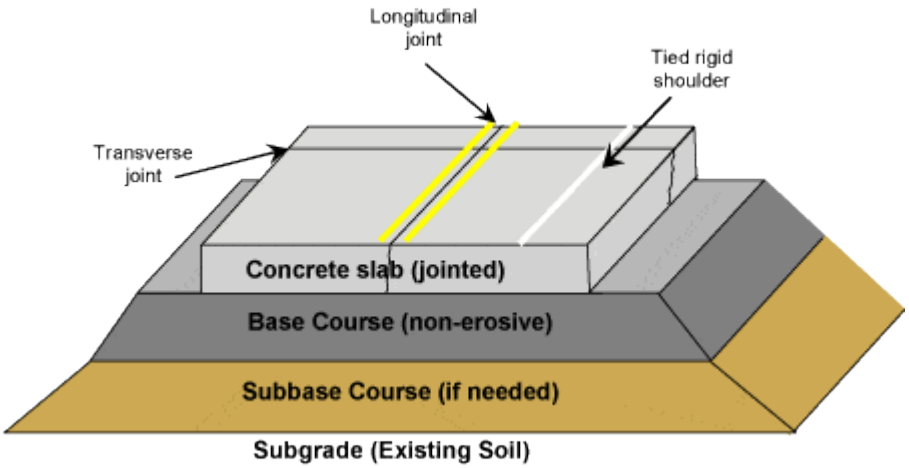


Fig: Rigid Pavement Cross-Section

Minor variations in subgrade strength have little influence on the structural capacity of a rigid pavement. In the design of a rigid pavement, the flexural strength of concrete is the major factor and not the strength of subgrade. Due to this property of pavement, when the subgrade deflects beneath the rigid pavement, the concrete slab is able to bridge over the localized failures and areas of inadequate support from subgrade because of slab action.

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 interlock, particle friction and cohesion.	Its structural strength is provided by the pavement slab itself by its beam action.
4.	Pavement design is greatly	Flexural strength of concrete is a

	influenced by the subgrade strength.	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.

There are four pavement layers:

1. Sub-grade
2. Sub-base
3. Base
4. Surface course

Functions of each layer are described as below:

Sub-Grade :

The load is transferred by the sub-grade effectively to the earth mass. However the locally available earth is used to construct the sub-grade but it becomes necessary that the sub-grade should be of required strength.

Sub-base and base course:

- Base course and sub-base course is used in the flexible pavement to disperse the upcoming loads to large area through a finite thickness, so as to increase the load bearing capacity of the pavement. The material used is the broken stones, or gravels, or bound or unbound aggregates.
- Sometimes the bricks can also be used as the sub-base and base materials. Generally the sub-base layers have the inferior quality of aggregates, than that used in the base course.
- Generally smaller aggregates are used because the larger gravels or aggregates have the tendency to sink to the lose sub-grade soil under the heavy loading.

- The function of the sub-base or the base layer in case of the rigid pavement is to -
  (1) Check the pumping action.
  (2) Protecting the sub-surface against the frost action.

- The basic purpose of the sub-base and base layer is to transfer the load through a dispersed/larger area to the sub-grade. So it must of sufficient strength to do its job. These layers are evaluated using a suitable strength or stability tests like the plate load test, California bearing ratio test, and the Hveem stabilometer test, where each test has its own significance and importance.

Wearing course:

- Top most layer serves as the smooth riding surface for the traffic, and it wears all the abrading forces. The top most layer is constructed with the superior quality of aggregates because it has to wear the maximum intensity of loads.
- It has to be water proof to stop the water penetration to the lower layers, so in case of flexible pavements the bituminous concrete is used and it is well compacted, and in rigid pavements the cement concrete is used and is well compacted so that no water penetration takes place.
- There is no direct test to check the stability of the surface course but the bituminous concrete used in the flexible pavement is checked for its suitability. Marshall stability test is used to determine the optimum content of the bitumen to be used in the aggregate mix, based on the stability density, VMA and VFB of the given grading of the aggregate mixture.

FLEXIBLE PAVEMENT

4.3 Sub base course:

Necessity of sub base: It provides strength and support to the overlying pavement, provides drainage and frost protection, prevents settlements to pavement and slab on grade & be reusable if you decide to change your pavement surface.

Stabilized Sub base: Stabilized base or subbase layers are pavement layers composed of a compacted mixture of aggregate and cementitious material. The binder material is usually lime or cement, though additional pozzolanic materials may also be added. For new construction, the base or subbase materials are mixed with the binder and water if needed, either in place or at a plant, and are then graded and compacted. Stabilized layers provide a strong foundation for both rigid and flexible pavements, though stabilized pavement layers are usually used in flexible pavements.

Purpose of stabilization: Pavement design is based on the premise that minimum specified structural quality will be achieved for each layer of material in the pavement system.
stabilization include better soil gradation, reduction of plasticity index or swelling potential, and increases in durability and strength. Stabilization can increase the shear strength of a soil and/or

control the shrink-swell properties of a soil, thus improving the load bearing capacity of a sub-grade to support pavements and foundations.

There are various methods of stabilization such as following:
i.Mechanical stabilization
ii.Lime stabilization
iii.Fly ash stabilization
iv.Cement stabilization

i.Mechanical stabilization

This technique refers to the application of mechanical energy to enrich the soil properties by compaction. In this practice, the soil stability is improved by mixing the existing soil with the imported soil or aggregates to achieve the required particle size distribution and by compaction of soil mixture to reach the desired density.
This method is commonly adopted for the sub-base and base course construction. It is also applied for the surface course construction of low-cost roads (village roads) when the condition of low traffic and rainfall. The degree of compaction is the parameter in which mechanical stability depends upon. Usually, the compaction is processed at optimum moisture content. The physical structure of the soil could be altered with the method of mechanical stabilization.

Summarize the methods of doing mechanical stabilization as below.

- Compaction–It defines the application of pressure using heavyweight to enhance the soil density.
- Soil reinforcement–Engineered plastic and geo-textiles mesh are designed to trap soils and control the moisture conditions, erosion, and permeability of soil.
- Additions of graded aggregate materials–The engineering soil properties are improved by this method through the addition of certain aggregates that provide the increased strength or reduced plasticity to the soil.
- Mechanical remediation–In this process, the polluted soil is detached and displaced physically to a selected hazardous waste facility that is far from the living area of the population.

ii.Lime stabilization

- Lime-Soil stabilization is the process of adding lime to the soil to improve its properties like density, bearing capacity etc. Various factors affecting lime-soil stabilization are soil type, lime type, lime content used, compaction, curing period and additives which are briefly discussed below.

- The principle involved in lime-soil stabilization is the exchange of ions between lime and soil when added.When clayey soil is treated with lime, Cation exchange takes place between them which increases plastic limit and reduces plasticity index which finally results in increase in stability of soil. If clay contains gravel in it, then lime acts as binding material for clayey gravel.

- Lime-Soil stabilized mix are useful to construct sub-base and base course for pavement. Lime treated soil is more suitable for warm regions where temperature is very high and for colder regions it is not suitable.

- lime soil stabilization is suitable for soils like clay, silty clay, clayey gravel etc. and is not suitable for granular soil or sandy soil.

iii.Fly ash stabilization

Fly ash stabilization is gaining more importance recent times since it has wide spread availability. This method is inexpensive and takes less time than any other methods. It has a long history of use as an engineering material and has been successfully employed in geotechnical applications. Fly ash is a byproduct of coal fired electric power generation facilities; it has little cementations properties compared to lime and cement. Most of the fly ashes belong to secondary binders; these binders cannot produce the desired effect on their own. However, in the presence of a small amount of activator, it can react chemically to form cementations compound that contributes to improved strength of soft soil. However, soil fly ash stabilization has the following limitations
(a) Soil to be stabilized shall have less moisture content; therefore, dewatering may be required.
(b) Soil-fly ash mixture cured below zero and then soaked in water are highly susceptible to slaking and strength loss
(c) Sulfur contents can form expansive minerals in soil-fly ash mixture, which reduces the long term strength and durability
(d) Rice Husk ash Stabilization

iv.Cement stabilization

Soil cement stabilization is soil particles bonding caused by hydration of the cement particles which grow into crystals that can interlock with one another giving a high compressive strength. In order to achieve a successful bond the cement particles need to coat most of the material particles. To provide good contact between soil particles and cement, and thus efficient soil cement stabilization, mixing the cement and soil with certain particle size distribution is necessary. Soil-cement is a highly compacted mixture of soil/aggregate, cement, and water. Soil-cement is sometimes called cement-stabilized base, or cement-treated aggregate base. Soil-cement becomes a hard and durable material as the cement hydrates and develops strength. Cement stabilization is done when the compaction process is continuing. As the cement fills the void between the soil particles, the void ratio of soil is reduced. After this when water is added to the soil, cement reacts with water and goes hard. So, unit weight of soil is increased. Because of hardening of cement shear strength and bearing capacity is also increased. Cement helps decrease the liquid limit and increase the plasticity index and workability of clayey soils. Cement reaction is not dependent on

soil minerals, and the key role is its reaction with water that may be available in any soil.

4.4 Base course

Water Bound Macadam:

The road whose wearing course consists of clean crushed aggregates, mechanically interlocked by rolling and bound together with filler material and water laid on a well compacted base course, is called water bound macadam (W.B.M) road.

Advantages of water bound macadam:

1. Water bound macadam is superior in quality because the materials are carefully graded and the resulting mass is almost void less compacted mass.
2. The interlocking of aggregate particles imparts adequate strength of the materials selected for filling the voids. These ensure non-entry of the plastic materials of the sub-grade into the voids.
3. Water bound macadam is less costly as compared to bituminous base course.

Disadvantages of water bound macadam:

1. The stone pieces used in water bound macadam road are keyed together by means of sand and clay and no other cementing material is used. The binding effects of sand and clay depend upon the pressure and moisture.

2. When a fast moving vehicle passes over a W.B.M. road, the slurry of sand and clay is sucked out by pneumatic wheel tires, the stone pieces get disturbed and finally road surface is disintegrated. Due to this, the W.B.M. roads are not suitable for fast moving vehicles with pneumatic wheels.

3. These roads are only suitable for slow moving iron wheeled traffic such as tongas, bullock carts etc.

4. Constant use of road by iron wheels, the road metal gets crushed. Considering these factors, it may be inferred that a W.B.M road survives only for a short time.

Wet mix macadam:

- This is new method where aggregate are mixed with water before laying and the wet mix is laid and then rolled. Wet mix roads are superior than WBM in all aspects.

- WMM roads are constructed at the faster rate. The consumption of the water is less in case of the WMM roads. Materials used in the WBM are the stone aggregates, screenings and binder material(Stone dust with water) while in WMM material used are only stone aggregates and binders

4.5 surfacing

Surface dressing:

(1) premix carpet:

Premix carpet (PC) is the oldest hot mix in India. It is a good, economical, bituminous wearing course mix to be placed directly on water bound macadam (WBM) of low-volume rural roads. Since such roads are not constructed by mechanical means, the quality of WBM may not be consistent.

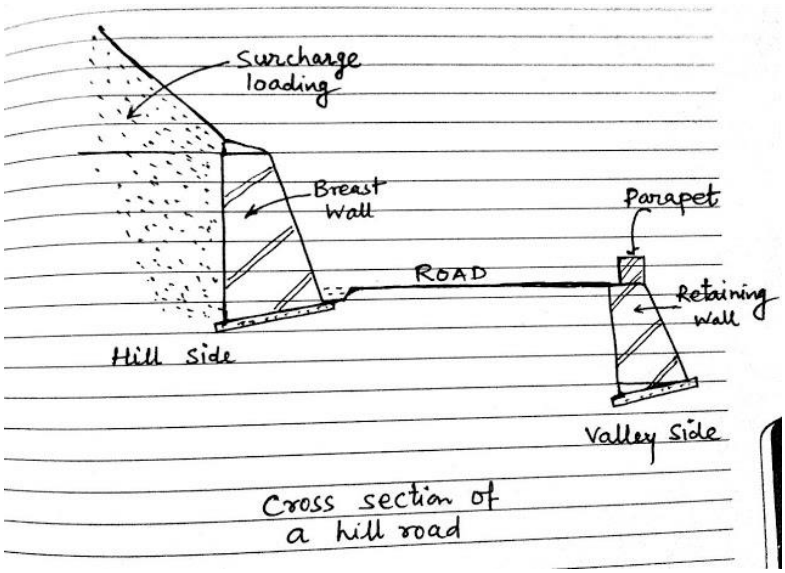
(2) Semi-Dense Bituminous Concrete (SDBC)

- The semi-dense bituminous concrete mixes have neither dense or open graded characteristics. It consists of the so called pessimum voids when they are fully constructed.
- The word is an anonym of optimum. So, it is advised to make the mix get rid of pessimum voids. These tend to capture moisture or water that will later cause stripping.
- When the semi dense bituminous concrete is employed above the bitumen macadam (BM) layer, there is chances for the penetration of rainwater through the SDBC and reach the BM.
- This will create the separation of aggregate and the bitumen in the BM layer. This will cause stripping and the scaling of SDBC. The scaling later with time will result in the potholes on the road.

Bituminous concrete:

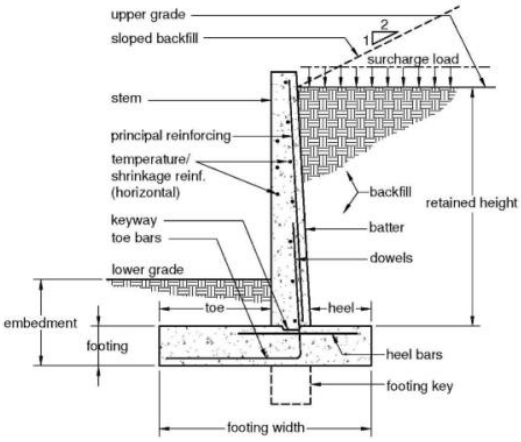
- BC is a Dense Graded Bituminous Mix used as Wearing Course for Heavily Trafficked Roads
- BC Mix consists of Coarse Aggregates, Fine Aggregates, Filler and Binder blended as per Marshall Mix Design
- Quality control operations involved are: Design of mix in laboratory, and control of mixing, laying and rolling temperatures , Density, Marshall Stability, Flow, Air Voids, Retained Stability, Bitumen Content, Gradation of aggregates are controlled Riding quality is a control

HILL ROADS



Retaining walls:

The walls constructed for retaining or supporting earth against their back are called retaining walls. Earth cannot remain vertical but would be in a state of equilibrium when it assumes a natural angle which is called *angle of repose.* If it is desired to be retain the earth vertically, that portion of the earth will have to be supported by a wall called retaining wall. The back of the wall is in the form of steps and the face of the retaining wall may be either vertical or battered. The width at the base will depend upon the height of earth to be retained as the more the height, the greater will be the pressure at the base and the top can be kept 2 bricks thick .



Breast Walls:

A breast wall is constructed to protect the natural sloping ground from the cutting action of natural agents. Breast walls also prevent slides of unreliable soils. The breast walls may be 0’6 m wide at

the top. Weep holes should be provided at regular interval among the length of the wall to relieve the walls of saturated earth pressure. The breast wells are so designed that their line of pressure should be normal to the earth pressure or thrust.

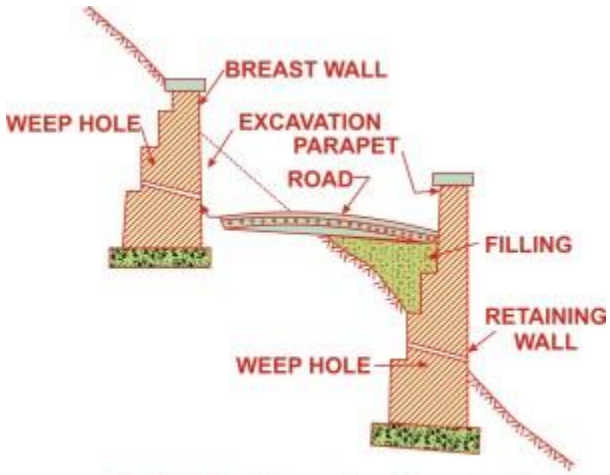
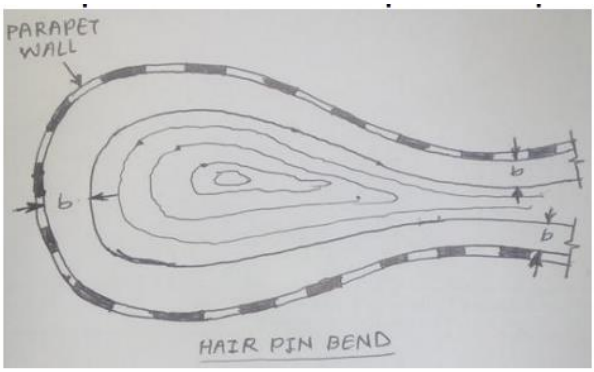


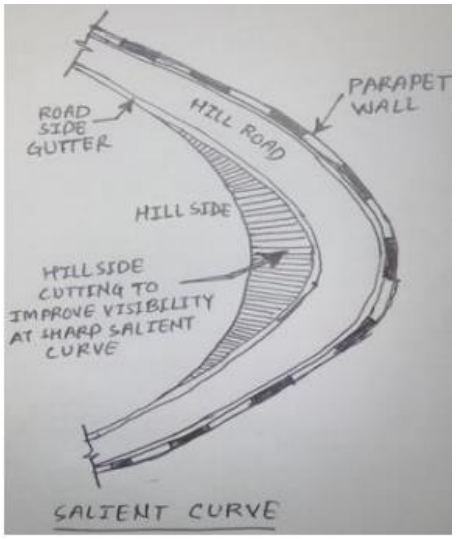
Fig. 2.50. Retaining wall and breast wall.

Types of bends provided on hill road are as follow:

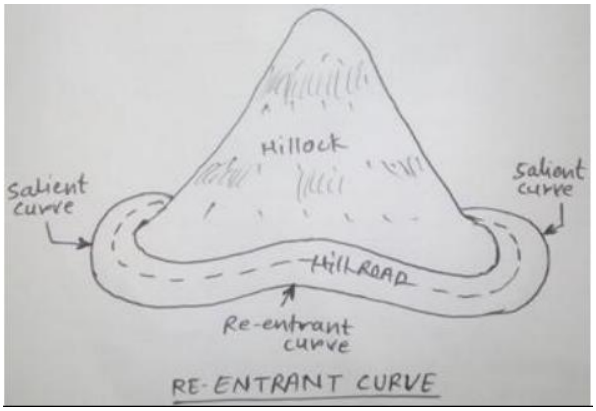
(1) Hair pin bend curve: The curve in a hill road which changes its direction through an angle of 180∘∘ or so, down the hill on the same side is known as hair pin bend curve. This type of curve should be located on a hill side having the minimum slope and maximum stability. It must also be safe from view point of landslides and ground water. Hair pin bends with long arms and farther spacing are always preferred.They reduce construction problems and expensive protection works.



(2) Salient curve: The curves having their convexity on the outer edges of a hill road are called salient curves. The centre of curvature of a salient curve lies towards the hill side. This type of curve occurs in the road length constructed on the ridge of a hill. The bend so formed at the salient curve in a hill road is known as corner bend. Salient curves are very dangerous for fast moving traffic. At such a curve or at corner bend, the portion of projecting hill side is usually cut down to improve the visibility



(3) Re-entrant curve: The curves having their convexity on the inner edge of a hill road are called re-entrant curves. The centre of curvature of a re-entrant curve lies away from the hill side. This type of curve occurs in the road length constructed in the valley of a hill. These curves are less dangerous as they provide adequate visibility to the fast moving traffic. At such curves, the parapet wall is provided only for safety of fast moving traffic.



Highway Drainage

Overview

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.

The three principal types of highway drainage are:

1. Surface drainage
2. Subsurface drainage
3. Cross drainage

1. Surface Drainage:

Surface drainage consists of the arrangements made for the quick and effective draining of water that collects on the pavement surface, shoulders, slopes of embankments and cuttings and adjoining land up to the right of way. This water is let off into natural or artificial channels sufficiently farther away such that the functioning of the highway is not impeded in any manner.

The sources of surface water are precipitation of different kinds such as rain, snow, drizzle, hail and sleet. Waste water from irrigation is also a possible source. Snow fall and melting ice

are common sources in the plains at the foothills of the Himalayas.

2. Subsurface Drainage:

Moisture changes in the subgrade occur due to percolation of rain water and seepage flow, as also due to the phenomenon of capillary rise. The aim of subsurface drainage is to keep the ground water table (GWT) sufficiently below the level of the subgrade – at least 1.2 m.

When the water table is almost at the natural ground surface, the best option is to raise the formation of the roadway on an embankment, such that it is 1.2 m above the ground. If this is not possible for the reason of unfavourable topography, the only option is to lower the ground water table by means of subsurface drainage arrangements. It must, however, be remembered that only gravitational water in the soil can be drained, but not 'held water', which is made up of the moisture film around the grains.

3. Cross Drainage:

Roads have to be aligned often as to cross natural drainage channels, streams and major rivers. Sometimes, the alignment will be across man-made channels like those for irrigation.

In such cases, the need for constructing cross drainage structures arises to ensure that the water flows beneath the road without causing any inconvenience or instability to the highway structure.

Types of Cross-drainage Structures:

1. Culverts (waterway less than 6 m)
2. Minor bridges (waterway from 6-30 m)
3. Medium-sized bridges (waterway from 30-100 m)
4. Major bridges (waterway more than 100 m)
5. Causeways

Side drain:

- The road surface drain is more commonly known as the camber (in some cases super elevation). Side drains are more commonly known as ditches from which the water is led away in mitre drains. Catchwater drains collect and lead away water before it reaches the road.
- It is necessary to provide side drain on one side or both sides, when road is constructed in embankment. The Side drains should be at least 2.0 m away from bottom edge of an embankment. The Depth of side drains is kept 1.0 to 1.5 m to prevent the entry of drain water into the embankment.

HIGHWAY MAINTENANCE

Road maintenance is the one of the most important component of the road system. It involves the assessment of road condition, diagnosis of the problems and adopting the most appropriate maintenance step. Even if the highway are well designed, they may require maintenance due to its less design life. Various types of failures occurs in the pavement which ranges from minor to major distresses.

General causes of pavement failure

1. **Poor soil:-** It is the most common problem in the pavement design. The most common soil problem in the Southeast is a high water table. If not accounted for at the time of construction, a high water table will erode the soil and eventually lead to pavement failure.

2. **Inferior material quality:-** If the material laid on the ground is not good enough, will be leads to severe defects and failures.

3**. Improper geometry:-**

Due to improper geometry of road, lot of factors may arise which keeps the pavement deformation. Continue..

4. Overloading of vehicles:- A vehicle is said to be heavy loaded when it is being loaded more than its carrying capacity. Acc. to IRC, the max. wheel load for standard axle is 80 KN. Due to heavy movement of vehicles or overloaded vehicles or increase traffic volume, severe distresses takes place. **5. Environmental Factors:-** It includes heavy rainfall, soil erosion, high water table, snow fall, frost action etc.

6. inadequate drainage:- Due to improper drainage resulting in stagnation of water in the subgrade which could be the main reason pavement failure in future.

Flexible Pavement failures

i. Surface deformation

- Corrugations
- Rutting
- Shoving
- Settlement and Upheaval

ii. Cracking

- Fatigue Cracking
- Transverse Cracking
- Longitudinal Cracking
- Edge Cracking

iii. Disintegration

- Potholes
- Patches

iv. Surface defects

- Raveling
- Bleeding

Flexible Pavement Failures Alligator cracks:-

It is known as map cracking or crocodile cracking or Fatigue failure. Since it appears similar as alligator skin so it is called as alligator cracks.

- The failure can be due to weakness in the surface, base or sub grade; a surface or base that is too thin; poor drainage or the combination of all three.
- The main reason of this type of failure is the repetitive application of heavy movement of traffic.

Block Cracks

- Block cracks look like large interconnected rectangles (roughly).
- Generally it is caused by shrinkage of the asphalt pavement due to an inability of asphalt binder to expand and contract with temperature cycles.
- This can be because the mix was mixed and placed too dry.
- The size of each rectangle may vary from one foot by one foot to ten foot by ten foot.
- It spreads over a larger area of ground.

Longitudinal Cracks

- Longitudinal cracks are individual and run parallel to the centerline.
- This distress can be considered as either a structural or an environmental distress.
- These can be a result of both pavement fatigue, reflective cracking, and/or poor joint construction.

Patch

- A patch is an area or portion of pavement greater than 0.1 sq.m that has been removed or replaced with new material to repair the existing pavement.
- A patch is considered a defect no matter how well it is performing (a patched area or adjacent area usually does not perform as well as an original pavement section).
- These defects can be improved by taking the measurement in ft^2 or m^2. and filling it with a fresh layer of the bitumen.

Pot holes

- These are small, bowl-shaped depressions in the pavement surface that penetrate all the way through the asphalt layer down to the base course.
- In the Western United States, these are known as chuckhole.
- The pothole can expand to several feet in width and later it leads to the formation of patches. They don’t develop too much in depth.
- The vehicle tires are damaged due to large potholes.
- In cold temperatures, the water trapped in the pothole will carry out the freezing and thawing action that leads to additional stresses and crack propagation.
- Potholes are also repaired by patchwork.

Edge cracking and shoulder drop off

- Edge Cracks travel along the inside edge of a pavement surface within one or two feet.
- The most common cause for this type of crack is poor drainage conditions and lack of support at the pavement edge.
- As a result underlying base materials settle and become weakened.
- Heavy vegetation along the pavement edge and heavy traffic can also be the instigator of shoulder drop off.
- It can be improved by rooting out existing vegetation and by fixing the drainage problem.
- It can be removed by filling the cracks or seal the cracks to prevent further deterioration.

Slippage cracks

- Slippage cracks are crescent-shaped or horse shoe shaped cracks or tears in the surface layer.
- It is the asphalt where the new material has slipped over the underlying course.
- It is caused by a lack of bonding between layers.
- Acceleration, deceleration and sudden brakes on the road are leads to slippage cracks.
- Mostly these cracks show on intersections due to stopping.

Weathering and raveling

- It is the adhesion between the asphalt cement and aggregate.
- Deformation starts with breaking up of fine aggregates in small pieces and leaves small patches over the pavement.
- Later the larger aggregates breaks and leave rough surface.

Rutting

- The depression formed in the surface is called the rutting.
- This is formed in the wheel path surface along the way of road.
- This depression will make the other sides of the wheel to undergo uplift.
- It is caused by insufficient pavement thickness; lack of compaction of the asphalt, stone base or soil, weak asphalt mixes; or moisture infiltration.
- If rutting is minor or if it has stabilized, the depressions can be filled and overlaid. If the deformations are severe, the rutted area should be removed and replaced with suitable material.

Corrugation

- Transverse undulations appear at regular intervals due to the unstable surface course caused by stopand-go traffic.
- The only difference between rutting and corrugation is the direction of distress undulations.

Bleeding

- Excess bituminous binder occurring on the pavement surface causes bleeding.

- Bleeding causes a shiny, glass-like, reflective surface that may be tacky to the touch.
- Usually found in the wheel paths.

Frost heaving or Swelling

- Upheaval is a localized upward movement or the formation of upward bulge in a pavement due to swelling of the subgrade.
- This can be due to expansive soils that swell due to moisture or frost heave (ice under the pavement).

Maintenance of failures

i.Bituminous Surface treatment:-

It is also known as a seal coat or chip seal, is a thin protective wearing surface that is applied to a pavement or base course.

- It is provided to protect the underlying pavements, improved skid resistances etc.

ii. Asphalt Overlay

- Asphalt overlay is a paving method of applying a new layer of asphalt to a deteriorating surface.
- an asphalt overlay project will use the existing layers as a base for the new asphalt pavement.
- Some asphalt surfaces with severe damage like rutting, potholes, large cracks, and expansions will need to be milled before an overlay is applied.

iii. Slurry Seals, Crack Seals

- Slurry seals is a homogenous mixture of emulsified asphalt, water, well-graded fine aggregate and mineral filler that has a creamy fluid-like appearance when applied.
- Slurry seals are used to fill existing pavement surface defects as either a preparatory treatment for other maintenance treatments or as a wearing course.
- Crack seal products are used to fill individual pavement cracks.
- It is used to prevent entry of water or other noncompressible substances such as sand, dirt, rocks or weeds.
- Crack sealant is typically used on early stage longitudinal cracks, transverse cracks, reflection cracks and block cracks.
- Crack filler material is typically some form of rubberized asphalt or sand slurry.

Rigid Pavement Failures

Spalling at the Joint:-

Cracking, breaking or chipping of joint/crack edges or it is the breakdown of the slab near edge of the joint.

- Usually occurs within about 0.6 m (2 ft.) of joint/crack edge.
- Loose debris on the pavement, roughness, generally an indicator of advanced joint/crack deterioration.

Scaling of cement concrete

- Peeling off or flaking off of the top layer or skin of the concrete surface.
- It may be due to by improper design mix, excessive vibration during concrete compaction.
- Performing finishing operation while bleed water is on surface.

Shrinkage cracks

- Formation of hairline shallow cracks on concrete slab is the indication of shrinkage cracks.
- Shrinkage cracks develop on concrete surface during the setting & curing operation.
- These cracks may form in longitudinal as well as in transverse direction.

Warping cracks

- In hot weather, concrete slab tends to expand. Therefore the joints should be so designed to accommodate this expansion.
- When joints are not designed properly, it prevents expansion of concrete slab.
- This leads to development of stresses. This stress causes formation of warping cracks of the concrete slab near the joint edge.

Mud pumping

- When material present below the road slab ejects out through the joints or cracks, it is called pumping.
- When soil slurry comes out it is called mud pumping. Common reasons are:-
- Infiltration of water through the joints, cracks or edge of the pavement forms soil slurry.
- Movement of heavy vehicles on pavement forces this soil slurry to come out causing mud pumping. When there is void space between slab and the underlying base of sub-grade layer.
- When traffic load occurs, it fails to resist the bending and hence cracks formation takes place.

Basic Concept of Traffic Engineering:

Traffic on roads consists of road users including pedestrians, ridden or herded animals, vehicles, streetcars, buses and other conveyances, either singly or together, while using the public way for purposes of travel. Traffic laws are the laws which govern traffic and regulate vehicles, while rules of the road are both the laws and the informal rules that may have developed over time to facilitate the orderly and timely flow of traffic

Traffic is formally organized in many jurisdictions, with marked lanes, junctions, intersections, interchanges, traffic signals, or signs. Traffic is often classified by type: heavy motor vehicle (e.g., car, truck), other vehicle (e.g., moped, bicycle), and pedestrian. Different classes may share speed limits and easement, or may be segregated. Some jurisdictions may have very detailed and complex rules of the road while others rely more on drivers' common sense and willingness to cooperate.

Traffic Signal:

Overview

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 fulfil 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.

CONSTRUCTION EQUIPMENT

Hot Mixing Plant

Asphaltic concrete is a mixture of asphalt, coarse aggregates,fine aggregates & filler material. After mixing, we are heating them up to final product called "HOT MIX". There are two basic types of plants used to manufacture hot mix asphalt:

1. i.Batch type plant
2. ii. Drum(continuous) type plant

The various parts of Batch mix plant are given below as per flow of material:

1. Cold aggregate four-bin feeder.
2. Cold conveyor.
3. Aggregate dryer.
4. Mixing Chamber
5. Asphalt tank.
6. Mineral filler unit.
7. Load-out conveyor.
8. Centralized control panel.

Tipper

A tipper is a heavy duty truck chassis fitted with an open-top body, used for carrying aggregate, crushed rock, soil and other bulk materials to and from construction sites. The body tips up to deposit material, and the hinged tailgate is either one-piece (on aggregate/muckaway tippers) or two-piece (on asphalt tippers). The asphalt tippers have a two-piece tailgate to help control the dropping of asphalt into an asphalt paver hopper, and make sure the remaining asphalt in the body does not cool. The two-piece tailgate is often opened by an air cylinder so the driver does not have to leave his cab on the dangerous construction site.

In the UK tipper trucks are usually 3 or 4 axles. A 4 axle tipper has a total transport weight of 32 tons, and can generally carry about 20tons of soil or stone. The front two axles are steering, and use a different tyre pattern than the rear two axles, which are driving. When purchasing tyres make sure that you get the right tyre tread pattern to get the best performance from your tyres.

Both rear axles are driven to provide better grip on construction sites and off-road areas. This is needed as tipper trucks are often driven up to where excavators or wheel loaders are working, to be loaded, before carrying their load away. MAN Diesel tipper trucks and Mercedes tippers are both popular makes of tipper. For purely off-road use, articulated dumpers give much more performance, as they can carry up to 40tons and all axles are powered to increase traction.

Tipper trucks can also be referred to as 'dump trucks' and 'tip lorries'.

Tractor

A tractor is a versatile earth moving equipment that finds many uses at a construction site. While its primary purpose is to pull or push loads, it is also used as a mount for many types of accessories, such as front-end shovels, bulldozers and others. There are types and sizes to fit almost any job for which they are usable.

Types of Tractors

Tractors may be divided into two major types: Crawler Tractors and Wheel Tractors.

Crawler Tractor

Crawler tractors are usually rated by size or weight and power. The weight is important on many projects because the maximum tractive effort that a unit can provide is limited to the product of weight times the coefficient of traction for the unit and the particular road surface, regardless of the power supplied by the engine.

Wheel Tractor

Wheel tractors are either two-wheel or four-wheel. One of the primary advantages of a wheel tractor compared with a crawler tractor is the higher speed that may exceed (50 km/hr). However, in order to attain a higher speed, a wheel tractor must sacrifice pulling effort.

Wheel Tractors	**Crawler Tractors**
1. Can travel fast	1. Travel slowly
2. Not more powerful and hence used for light duty jobs.	2. Very powerful and hence used for powerful jobs.
3. Less costly	3. Costly due to use of chains
4. Less operation and maintenance cost	4. More operation and maintenance cost
5. Require less skill for their operation because of wheels.	5. Requires more skill for their operation
6. Can be used for roads or pavements.	6. Used for rough ground conditions
7. Self-driven for longer distance hence transportation is easy.	7. Transportation for longer distance required with trailers.
8. Does not have better stability during working	8. Does have better stability during working.

Scraper

A scraper is a machine used for moving or removing dirt, gravel and any other unnecessary material from the surface. There are many earth-moving machines on the market, but the scraper is specialized for scraping and it is the most efficient machine for that task. One advantage over the other earth-moving machines is the capability to remove wet soil from the surface. With other machines, the operators will need to wait for the wet soil to become dry. Also, the scraper performs efficiently on heavier soils and other tough soil conditions. The scraper is a versatile and flexible machine, as it can be used for a variety of tasks.

Today, the demand for scrapers is very high, and different scraper models can be found. This machine is not only used for construction tasks. With all the improvements made, the scrapers are suitable for a variety of mining applications as well. The rough terrains are a real challenge for the scrapers, but they are capable to neglect the heavy impacts and to perform as efficiently as expected. Also, there are plenty of scraper attachments which can be used for other applications.

One big advantage of the scraper is the reduced fuel consumption. With improved transmission, the fuel consumption is reduced up to 30%. Using less fuel than any other earth-moving machine doesn't mean that the productivity is decreased. The scraper is capable to maintain an optimal productivity. It is certainly one of the most cost-efficient earth-moving machines.

The purpose of the scrapers is to give the operators more solutions on the job site. This means that the operators can use scrapers for all types of operations. The scraper is designed to perform even the most demanding construction or mining tasks. Also, the scraper is capable to dig, load, haul and dump. Not so long ago, the operators needed three different machines for these four operations: excavator, truck and loader. With these three machines, the operating costs were very high. Today, the incredible scraper is a four-in-one machine that can do it all.

Bull Dozer

A bulldozer is a tractor equipped with a substantial metal plate (known as a blade) used to push large quantities of soil, sand, rubble, or other such material during construction or conversion work and typically equipped at the rear with a claw-like device (known as a ripper) to loosen densely compacted materials. It is usually a crawler (continuous tracked) tractor.
Bulldozers can be found on a wide range of sites, mines and quarries, military bases, heavy industry factories, engineering projects and farms.
The term "bulldozer" correctly refers only to a tractor (usually tracked) fitted with a dozer blade.

Typically, bulldozers are large and powerful tracked heavy equipment. The tracks give them excellent ground holding capability and mobility through very rough terrain. Wide tracks help distribute the bulldozer's weight over a large area (decreasing ground pressure), thus preventing it from sinking in sandy or muddy ground. Extra wide tracks are known as swamp tracks or LGP (low ground pressure) tracks. Bulldozers have transmission systems designed to take advantage of the track system and provide excellent tractive force.

Because of these attributes, bulldozers are often used in road building, construction, mining, forestry, land clearing, infrastructure development, and any other projects requiring highly mobile, powerful, and stable earth-moving equipment.

Another type of bulldozer is the wheeled bulldozer, which generally has four wheels driven by a 4-wheel-drive system and has a hydraulic, articulated steering system. The blade is mounted forward of the articulation joint, and is hydraulically actuated.

The bulldozer's primary tools are the blade and the ripper.

The word "bulldozer" is sometimes used inaccurately for other similar construction vehicles such as a large front loader.

Dumpers

A dumper is a vehicle designed for carrying bulk material, often on building sites. Dumpers are distinguished from dump trucks by configuration: a dumper is usually an open 4-wheeled vehicle with the load skip in front of the driver, while a dump truck has its cab in front of the load. The skip can tip to dump the load; this is where the name "dumper" comes from. They are normally diesel powered. A towing eye is fitted for secondary use as a site tractor. Dumpers with rubber tracks are used in special circumstances and provide a more even distribution of weight compared to tires. Continuous tracks allow the operator to carry heavier payload on slick, snowy, or muddy surfaces, and are popular in some countries.

Modern dumpers have payloads of up to 10 tonnes (11 short tons; 9.8 long tons) and usually steer by articulating at the middle of the chassis (pivot steering). They have multi-cylinder diesel engines, some turbocharged, electric start and hydraulics for tipping and steering and are usually four-wheel drive. An A-frame known as a ROPS (Roll-Over Protection) frame, may be fitted over the seat to protect the driver if the dumper rolls over. Some dumpers have FOPS (Falling Object Protection) as well. Lifting skips are available for discharging above ground level. In the 1990s dumpers with swivel skips, which could be rotated to tip sideways, became popular, especially for working in narrow sites such as road works. Dumpers are the most common cause of accidents involving construction plant.

Shovels

A power shovel (also stripping shovel or front shovel or electric mining shovel or Electric Rope Shovel [2]) is a bucket-equipped machine, usually electrically powered, used for digging and loading earth or fragmented rock and for mineral extraction.[3] Power Shovels are a type of rope/cable excavator, where the digging arm is controlled and powered by winches and steel ropes, rather than hydraulics like in the more common hydraulic excavators. Basics parts of power shovel including the track system, cabin, cables, rack, stick, boom foot-pin, saddle block, boom, boom point sheaves and bucket. The size of bucket varies from 0.375cu m to 5cu m. Shovels normally consist of a revolving deck with a power plant, driving and controlling mechanisms, usually a counterweight, and a front attachment, such as a crane ("boom") which supports a handle ("dipper" or "dipper stick") with a digger ("bucket") at the end. "Dipper" is also sometimes used to refer to the handle and digger combined. The machinery is mounted on a base platform with tracks or wheels.[4] Modern bucket capacities range from 8 m^3 to nearly 80 m^3.

The shovel operates using several main motions:

- hoist - pulling the bucket up through the bank (i.e. the bank of material being dug)
- crowd - moving the dipper handle out or in to control the depth of cut and when positioning to dump
- swing - rotating the shovel between digging and dumping
- propel - moving the shovel unit to different locations or dig positions

A shovel's work cycle, or digging cycle, consists of four phases:

- digging
- swinging
- dumping
- returning

The digging phase consists of crowding the dipper into the bank, hoisting the dipper to fill it, then retracting the full dipper from the bank. The swinging phase occurs once the dipper is clear of the bank both vertically and horizontally. The operator controls the dipper through a planned swing path and dump height until it is suitably positioned over the haul unit (e.g. truck). Dumping involves opening the dipper door to dump the load, while maintaining the correct dump height. Returning is when the dipper swings back to the bank, and involves lowering the dipper into the track position to close the dipper door.

Grader

A grader, also commonly referred to as a road grader or a motor grader, is a construction machine with a long blade used to create a flat surface during the grading process. Although the earliest models were towed behind horses or other powered equipment, most modern graders contain an engine, so are known, technically erroneously, as "motor graders". Typical models have three axles, with the engine and cab situated above the rear axles at one end of the vehicle and a third axle at the front end of the vehicle, with the blade in between. Most motor graders drive the rear axles in tandem, but some also add front wheel drive to improve grading capability. Many graders also have optional attachments for the rear of the machine which can be ripper, scarifier, blade, or compactor. In certain countries, for example in Finland, almost every grader is equipped with a second blade that is placed in front of the front axle. For snowplowing and some dirt grading operations, a side blade can also be mounted. Some construction personnel refer to the entire machine as "the blade". Capacities range from a blade width of 2.50 to 7.30 m (8 to 24 ft) and engines from 93–373 kW (125–500 hp). Certain graders can operate multiple attachments, or be designed for specialized tasks like underground mining.

Graders are commonly used in the construction and maintenance of dirt roads and gravel roads. In the construction of paved roads, they are used to prepare the base course to create a wide flat surface upon which to place the road surface. Graders are also used to set native soil or gravel foundation pads to finish grade prior to the construction of large buildings. Graders can produce inclined surfaces, to give cant (camber or sideslope) to roads. In some countries they are used to produce drainage ditches

with shallow V-shaped cross-sections on either side of highways.

Dragline

A dragline excavator is a piece of heavy equipment used in civil engineering and surface mining. Draglines fall into two broad categories: those that are based on standard, lifting cranes, and the heavy units which have to be built on-site. Most crawler cranes, with an added winch drum on the front, can act as a dragline. These units (like other cranes) are designed to be dismantled and transported over the road on flatbed trailers. Draglines used in civil engineering are almost always of this smaller, crane type. These are used for road, port construction, pond and canal dredging, and as pile driving rigs. These types are built by crane manufacturers such as Link-Belt and Hyster. The much larger type which is built on site is commonly used in strip-mining operations to remove overburden above coal and more recently for oil sands mining. The largest heavy draglines are among the largest mobile land machines ever built. The smallest and most common of the heavy type weigh around 8,000 tons while the largest built weighed around 13,000 tons. A dragline bucket system consists of a large bucket which is suspended from a boom (a large truss-like structure) with wire ropes. The bucket is maneuvered by means of a number of ropes and chains. The hoist rope, powered by large diesel or electric motors, supports the bucket and hoist-coupler assembly from the boom. The dragrope is used to draw the bucket assembly horizontally. By skillful maneuver of the hoist and the dragropes the bucket is controlled for various operations

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Asphalt Mixer

This machine is used for laboratory mixing of bituminous materials to prepare the specimens to be used for various asphalt tests. Its is widely used in road construction laboratories, Testing laboratories, Research Institutions. The machine mainly consists of a main frame, variable speed mixer, elevating system, heating pot, electrical control box. The variable speed mixer consists of electric motor, gear box and vertical curved blade. The elevating system consists of a motor, worm gear, up right column, guide bar and stopper block. In vertical type of mixer the pot can move up and down and in the horizontal type of mixer the elevating system with agitator assembly moves up and down .

Tar Boilers

These are widely used in road highways construction and development industry. Our Tar Boilers are small in size and are easy to shift. They are operated with electric motors and are capable of producing standardized quality product.

Road Pavers

A paver (paver finisher, asphalt finisher, paving machine) is a piece of construction equipment used to lay asphalt on roads, bridges, parking lots and other such places. It lays the asphalt flat and provides minor compaction before it is compacted by a roller. he asphalt is added from a dump truck or a material transfer unit into the paver's hopper. The conveyor then carries the asphalt from the hopper to the auger. The auger places a stockpile of material in front of the screed. The screed takes the stockpile of material and spreads it over the width of the road and provides initial compaction.

The paver should provide a smooth uniform surface behind the screed. In order to provide a smooth surface a free floating screed is used. It is towed at the end of a long arm which reduces the base topology effect on the final surface. The height of the screed is controlled by a number of factors including the attack angle of the screed, weight and vibration of the screed, the material head and the towing force.

To conform to the elevation changes for the final grade of the road modern pavers use automatic screed controls, which generally control the screed's angle of attack from information gathered from a grade sensor. Additional controls are used to correct the slope, crown or superelevation of the finished pavement.

In order to provide a smooth surface the paver should proceed at a constant speed and have a consistent stockpile of material in front of the screed. Increase in material stockpile or paver speed will cause the screed to rise resulting in more asphalt being placed therefore a thicker mat of asphalt and an uneven final surface. Alternatively a decrease in material or a drop in speed will cause the screed to fall and the mat to be thinner.

The need for constant speed and material supply is one of the reasons for using a material transfer unit in combination with a paver. A material transfer unit allows for constant material feed to the paver without contact, providing a better end surface. When a dump truck is used to fill the hopper of the paver, it can make contact with the paver or cause it to change speed and affect the screed height.