PNS SCHOOL OF ENGINEERING & TECHNOLOGY

NISHMANI VIHAR , MARSHAGHAI, KENDRAPARA-754213

SUBJECT-HIGHWAY ENGINEERING (4THthSemester)

Prepared by Er Sudeepta Mishra

DEPARTMENT OF CIVIL ENGINEERING

CHAPTER-1

Introduction

They provide people and vehicles to commute a wide range of locations and help them to reach their destination without any hiccups.

Road transport is the process of transporting goods or people from one destination to the other via roads.

A highway is **a busy road with many lanes**. Highways are usually the quickest route for driving between one city and another. Highways were originally built to connect cities and towns, and since they're wide and have high speed limits, they decreased the travel time.

Highway engineers **strive to predict and analyze all possible civil impacts of highway systems**. Some considerations are the adverse effects on the environment, such as noise pollution, air pollution, water pollution, and other ecological impacts.

Their advantages include **high speed, greater safety, comfort and convenience for drivers and passengers, and lower vehicle operating costs**. Many of these new express highways, especially in the United States, are toll roads, but that is an incidental, not an essential, feature.

The basic components of the highway are the **road width, cross slope, pavement, road margins, traffic separators, and curbs**. These geometric elements are designed and influenced by the psychology of the driver, the characteristics of the vehicle and the traffic of the region.

Indian Roads Congress

IT is the premier technical body of highway engineers which was formed in 1934 as India's national body for laying down and designing standards for roads and highway construction and provides a stage for exchanging expertise and latest research developments relating to it.

The Indian Road Congress was formed as the apex body for Engineering in Highway construction in India in the year 1934 with 73 members[2] with the main objective for development of roads and helping to provides a stage for exchanging expertise and latest research developments relating to it are shared.[3] The association is a group of experts from various fields of Civil Engineering laying down road safety norms in India.[4] It was set up after the recommendation of Jayakar Committee also known as Indian Road Development Committee. Currently the association has 13,500 members from various fields of engineering consisting of varied ranks in Border Roads Organisation,state and Central

governments, engineering services in Army,Institutes in Road Research, engineering colleges, local bodies and private enterprises.[2]

FUNCTIONS OF I.R.C.

The Indian Road Congress (I.R.C.), a body of professional highway engineers, has the following important functions :

(1) To providing a platform for expression of collective opinion of its members for all the matters affecting the construction and maintenance of roads in India.

(2) To suggest improve method of planing, design, construction and maintenance of roads in India.

(3) To promote thee use of standard specification and practices for roads construction, roads materials and designed of roads.

(4) To Make Laws for the development, improvement and protection of roads.

(5) To conduct periodical meeting to discuss technical issues regarding road construction.

(6) To publish journals, research publication, Standard specifications and other guidelines on various aspects of highway engineering.

CSIR-Central Road Research Institute (CRRI), a premier national laboratory established in 1952, a constituent of Council of Scientific and Industrial Research (CSIR)(link is external) is engaged in carrying out research and development projects on design, construction and maintenance of roads and runways, traffic and transportation planning of mega and medium cities, management of roads in different terrains, improvement of marginal materials, utilization of industrial waste in road construction, landslide control, ground improvements environmental pollution, road traffic safety and analysis & design, wind, fatigue, corrosion studies, performance monitoring/evaluation, service life assessment and rehabilitation of highway & railway bridges.

The institute provides technical and consultancy services to various user organizations in India and abroad. For capacity building of human resources in the area of highway Engineering to undertake and execute roads and runway projects, Institute has the competence to organize National & International Training Programmes continuing education courses since 1962 to disseminate the R&D finding to the masses.

IRC(Indian Roads Congress)

IT has classified the roads in the India in the following five 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.

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. They have lower design specifications and many of them are not even metaled.

State Highways Development Programme (SHDP)

State Highways play major role in economic development of the people as it connects major & important places of the State as well as neighboring States. Also, development of these roads will improve tourism activities in the State as it connects major tourist places. The Left Wing Extremism activities in the State have become a threat for development. The improved roads in these areas are strategically significant since it would provide better connectivity, resulting in efficient handling of law and order situation and thereby reduce Left Wing Extremism activities. Moreover, due to increase in industries and mining activities, day by day increase in traffic intensity requires rehabilitation and augmentation of the State Highways in order to provide good roads. Due to inadequate funding in other

continuing Schemes & considering importance of the State Highways in improving the socio-economic condition of the people, this scheme has been taken up for development of these roads. With a view to improve all State Highways in a time bound manner & considering its contribution in uplifting the socio-economic condition of the people of the State, this scheme has been envisaged with a target of improving and widening of all State Highways to 2-Lane corridors from its existing Single/ Intermediate Lane carriageway.

During the year 2013-14, Government has introduced a new scheme "State Highways Development Programme (SHDP)" for development of existing 2158Km of Single/ Intermediate Lane carriageway State Highways in the State with scheme outlay of Rs.3000.00Crore. The projects costing more than Rs.50.00Crore under the scheme are executed as per EPC contract & up to Rs.50.00Crore in P1 Mode of Contract. Up to end of 2016-17,1213.00Km road length has been developed to 2-Lane standard with expenditure of Rs.2004 Crore & 532Km is in progress. During,2017-18, there is budget provision of Rs.500.00Crore for development of another 500.00Km & to take up balance length of 413Km for 2-lanning.

QUESTIONS

1. WHAT IS HIGHWAY ENGINEERING ?
2. WHAT ARE THE IMPORTANT OF HIGHWAY ENGINEERING ?
3. WHAT IS NATIONAL HIWAY ?
4. WHAT IS STATE HIGHWAY ?
5. WHAT IS VILLAGE ROAD ?

LONG QUESTIONS

1. DEFINE IRC & ITS FUNCTIONS ?
2. WRITE ABOUT CLASSIFICATION OF ROAD CONGRESS ?

\

CHAPTER–2

HIGHWAY GEOMETRICS

The emphasis of the geometric design is to address the requirement of the driver and the vehicle such as safety, comfort, efficiency, etc. The features normally considered are the **cross section elements, sight distance consideration, horizontal curvature, gradients, and intersection.**

The geometric design of roads is the branch of highway engineering concerned with the positioning of the physical elements of the roadway according to standards and constraints. The basic objectives in geometric design are to **optimize efficiency and safety while minimizing cost and environmental damage**.

Horizontal Curves are one of the two important transition elements in geometric design for highways (along with Vertical Curves).

The most important factor affecting the geometric design of the highway is the **design speed**. The design speed parameter affects the: Length of the vertical curves. The horizontal curves.

right of way

IT is a public path across private land. When someone who is driving or walking along a road has right of way or the right of way, they have the right to continue along a particular road or path, and other people must stop for them.

formation width,

It is the sum of the widths of pavements or carriageways including separators and shoulders. This does not include the extra land of formation/cutting.

- it is the sum of with pavement or carriageway including separator (if any) and the shoulder.
- Roadways width is the top of highway embankment or bottom width of highway cutting excluding the side drain.

road margin,

The portion of the road beyond the carriageway and on the roadway can be generally called road margins. Different elements of road margins are shoulder, parking lanes, bus bays, cycle track, footpath and guard rails.

1.5m should be the minimum width.

It is **the sum of the pavement width including separators and the width of shoulders on either side**.

road shoulder

The shoulder is a strip of pavement outside an outer lane; it is provided for emergency use by traffic and to protect the pavement edges from traffic damage.

The term "shoulder" refers to the graded or surfaced area of the roadway, on the side of and adjacent to the pavement, which **gives lateral support to the road surface** and can be used by traffic in an emergency.

carriage way,

A **carriageway** (British English)[1] or **roadway** (North American English)[2] consists of a width of road on which a vehicle is not restricted by any physical barriers or separation to move laterally. A carriageway generally consists of a number of traffic lanes together with any associated shoulder, but may be a sole lane in width (for example, a highway offramp).

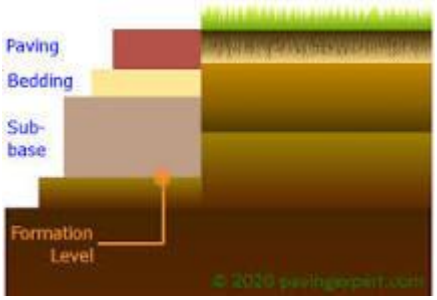
side slopes

Side slope means that area outside of the ditch or road shoulder that is graded to a uniform slope in order to stabilize the soil between the ditch or shoulder and the native, undisturbed ground.

If a roadside is not flat, a motorist who leaves the roadway will encounter a **fill slope, a cut slope, a transverse slope, or a drainage ditch**. Fill slopes, also known as fore slopes, result from construction of a roadway above the original ground level.
Pavement is typically laid at a cross-slope of **2%, or ¼" of fall per horizontal foot of road width measured from the centerline toward the ditch**. On unpaved surfaces, the recommended cross-slope is between 4% and 6%, or ½" to ¾" of fall per horizontal foot of width from the centerline toward the ditch.
Side slope means that area outside of the ditch or road shoulder that is graded to a uniform slope in order **to stabilize the soil between the ditch or shoulder and the native, undisturbed ground**.

Slopes come in 4 different types: **negative, positive, zero, and undefined**. as x increases. The slope of a line can also be interpreted as the "average rate of change". It tells us how fast y is changing with respect to x.

What is formation level in highway?



The sub-grade layer of a pavement is, essentially, the underlying ground. It is also known as the "Formation Level", which can be defined as **the level at which excavation ceases and construction starts**

Kerb

it is the component of a road or highway, it is also called a curb. Kerbs are edges where a raised sidewalk meets the other road. This road can be pedestrian or street. It creates barriers between vehicles and pedestrians.

(i) They **provide strength to the sides of road pavements and avoid lateral displacement of carriageway due to traffic loads**.

(ii) In terms of road safety, they serve as a separation line between footway and carriageway and aid car drivers in driving safely.

Roads are not flat but are designed and constructed to assist in the drainage of water. This is known as a camber. The surface is angled to stop rain water and snow melt gathering into puddles.

The main objective of providing camber will be **to drain off rainwater from the road surface, as quickly as possible**. As rest options are the ultimate result of the quick drainage of water from the pavement.

road gradient

it is a longitudinal slope provided to the formation level of a road along its alignment. "Gradient of Road is defined as the rate of rising or falls along the length of the road with respect to the horizontal alignment".

The gradient is a vector operation which operates on a scalar function to produce a vector whose magnitude is the maximum rate of change of the function at the point of the gradient and which is pointed in the direction of that maximum rate of change.

Gradient: It is **the slope provided to the surface of the road in the longitudinal direction for the vertical alignment of the road**. In other words, Gradient is the rise or fall along the length of road with respect to horizontal. It is expressed as 1 in n (1 vertical to n horizontal) or n% i.e. n in 100.

In April 2018, the Union Ministry of Road Transport and Highways fixed the maximum speed limit on expressways at 120 km/h, for national highways at 100 km/h, and for urban roads at 70 km/h for M1 category of vehicles.

Design speed is defined as the highest continuous speed at which an individual vehicle can travel with safety on the highway when weather conditions are favorable. It is the most important factor while designing a highway. It depends on **the topography, type of road, and the nature of traffic**.

The minimum design speed adopted where hairpin bends are provided at hill roads is **20 Kmph**.

It should have a speed limit of 120 kmph on the expressway and **100 kmph** as per national highway rules and 60 kmph on other roads and lanes.

stopping and passing sight distance

Stopping sight distance (SSD) is the minimum sight distance available on a highway at any spot having sufficient length to enable the driver to stop a vehicle traveling at design speed, safely without collision with any other obstruction.

This is done using the equation D = VT from physics. Since George's brake reaction time was 0.9 seconds and his velocity was 25 m/sec (90 km/h), the distance he traveled during his brake reaction time was 22.5 meters.

The safe spacing 'S' to be kept between vehicle 'A' (fast moving) and vehicle B (slow moving) is given by expression. **S = (V2 × 0.7) + length of vehicle 'A'** (assume 6m) = 0.7 V2 + 6. The value of t0 is obtained by the following equation, $t0 = 2\sqrt{S/a}$, here a = acceleration in m/sec^2.

Passing Sight Distance (PSD) is the minimum sight distance that is required on a highway, generally a two-lane, two-directional one, that will allow a driver to pass another vehicle without colliding with a vehicle in the opposing lane. This distance also allows the driver to abort the passing maneuver if desired.

To do this, we simply assume that the driver's eyes are at a height of 3.5 ft from the road surface and the opposing vehicle is 4.25 ft tall. The actual passing sight distance is **the length of roadway ahead over which an object 4.25 ft tall would be visible, if your eyes were at an elevation of 3.5 ft**.

The distance D4 is the final component of the passing sight distance and is defined as the distance the opposing vehicle travels during 66% of the time that the passing vehicle is in the left lane. This distance is computed using **D=VT, where V = 88 ft./sec. (60 mph) and T = 3.7 seconds (5.7*66%)**

Importance of curves in highway

Gradual change in direction or orientation in the alignment can be made by providing the curves. Road curves are provided so as to get comfort to the passengers.
Gradual change in the direction or orientation in the alignment can be made by providing the curves.

A highway curve is an arc which connects two straight lines which are separated by some angle called deflection angle.
This situation occurs where the alignment of a roadway or railway changes its direction because of unavoidable objects or conditions. There are two types of curves in highway construction which range from horizontal curve and vertical curve.
Curves are provided whenever a road changes its direction from right to S (vice versa) or changes its alignment from up to down (vice versa).
Curves are a critical element in the pavement design. They are provided with a maximum speed limit that should be followed very strictly.
Following the speed limit becomes essential as the exceed in speed may lead to the chances of the vehicle becoming out of control while negotiating a turn and thus increase the odds of fatal accidents.
Also,
it is very necessary that appropriate safety measures be adopted at all horizontal and vertical curves to make the infrastructure road user friendly and decrease the risks of hazardous circumstances.

- If there is a sudden obstruction in the mid way of the highway such as mountains, Rocks etc.. which are impossible to move so a gradual curvature is provided to move forward towards the destination.
- Highways are generally straight roads for longer lengths so there may be a higher chance of occurring accidents due to overspending, or drowsy driving.
- If the curvature is provided the driver gets conscious and controls his speed and drowsiness while driving.

- Drowsiness is the main cause of accidents on highways, if curve is provided on the highway the driver becomes alert and respond to the curvature
- Gradual change in direction or orientation in the alignment can be made by providing the curves.
- Road curves are provided so as to get comfort to the passengers.
- Gradual change in the direction or orientation in the alignment can be made by providing the curves.
- Curves are provided so as to get easy turning in case of road and track.

- Different types of highway curves
- There are two types of curves – Horizontal and Vertical curves. Each of them comes with various subcategories, each of them is explained below.
- Horizontal curves
- The curve provided in the horizontal plane of ground or earth is called a horizontal curve. It connects two straight lines which are in the same level but having different or the same directions. There are different types of horizontal curves, each of them is explained below.
- *Simple circular curve*
- It is a curve consisting of a single arc with a constant radius connecting the two tangents. It is a type of horizontal curve used most in common. A simple arc provided in the road or railway track to impose a curve between the two straight lines is the simple circular curve. The smaller is the degree of curve, the flatter is the curve and vice versa. The sharpness of a simple curve is also determined by radius R. Large radius are flat whereas small radius are sharp. A simple curve is normally represented by the length of its radius or by the degree of curve
- *Compound curve*
- It is a curve made up of two or more circular arcs of successively shorter or longer radii, joined tangentially without reversal of curvature, and used on some railroad tracks and highways as an easement curve to provide a less abrupt transition from tangent to full curve or vice versa. Since their tangent lengths vary, compound curves fit the topography much better than simple curves. These curves easily adapt to mountainous terrain or areas cut by large, winding rivers. However, since compound curves are more hazardous than simple curves, they should never be used where a simple curve will do.

- Horizontal curves
- *Reverse curve*
- A reverse curve is composed of two or more simple curves turning in opposite directions. Their points of intersection lie on opposite ends of a common tangent, and the PT of the first curve is coincident with the PC of the second. This point is called the point of reverse curvature (PRC).

- A reverse curve is composed of two arcs of equal or different radii bending or curving in opposite directions with common tangent at their junction, their centers being on opposite sides of the curve.
- *Track transition curve*
- A track transition curve, or spiral easement, is a mathematically-calculated curve on a section of highway, in which a straight section changes into a curve. It is designed to prevent sudden changes in lateral In plane (viewed from above), the start of the transition of the horizontal curve is at infinite radius, and at the end of the transition, it has the same radius as the curve itself and so forms a very broad spiral. At the same time, in the vertical plane, the outside of the curve is gradually raised until the correct degree of bank is reached.
- *Spiral curve*
- Spiral curves are generally used to provide a gradual change in curvature from a straight section of road to a curved section. They assist the driver by providing a natural path to follow. Spiral curves also improve the appearance of circular curves by reducing the break in alignment perceived by drivers. The use of a spiral is about making the road or track follow the same form that the vehicle naturally takes. In a car, you don't go directly from going straight to fully turning. There is a transition area where you slowly turn the steering wheel. On highways, the lanes are wide enough that you can drive a spiral just by moving from one side of the lane to the other.
- Vertical curves
- These curves are provided to change the slope in the road and may or may not be symmetrical. They are parabolic and not circular like horizontal curves. Identifying the proper grade and the safe passing sight distance is the main design criterion of the vertical curve, crest vertical curve the length should be enough to provide safe stopping sight distance and in sag vertical curve the length is important as it influences the factors such as headlight sight distance, rider comfort and drainage requirements. There are two types of vertical curves discussed below/
- *Valley/ Sag Curve*
- Valley curves or sag curves are vertical curves with convexity downwards. In valley curves, the centrifugal force will be acting downwards along with the weight of the vehicle, and hence impact to the vehicle will be more. This will result in jerking of the vehicle and cause discomfort to the passengers. Thus the most important design factors considered in valley curves are- impact-free movement of vehicles at design speed and availability of stopping sight distance under headlight of vehicles for night driving. The valley curve is made fully transitional by providing two similar transition curves of equal length.

- Vertical curves
- *Summit curve*

- Summit curves are vertical curves with gradient upwards. Sight distance requirements for the safety is most important on summit curves. The stopping sight distance or absolute minimum sight distance should be provided on these curves and where overtaking is not prohibited, overtaking sight distance or intermediate sight distance should be provided as far as possible. When a fast moving vehicle travels along a summit curve, there is less discomfort to the passengers. This is because the centrifugal force will be acting upwards while the vehicle negotiates a summit curve which is against the gravity and hence a part of the tyre pressure is relieved. Also if the curve is provided with adequate sight distance, the length would be sufficient to ease the shock due to change in gradient.

- Conclusion

- The curves play a vital role in the geometric design of highway alignments, so it must be properly designed so as to provide safety, comfort and convenience at the time of driving the vehicles or train on road curves. The design of the curve is dependent on the intended design speed for the roadway, as well as other factors including drainage and friction.

  Superelevation is the banking of highway horizontal curves to assist the driver by counteracting the lateral acceleration produced by tracking the curve. Superelevation is expressed as a decimal, representing the ratio of the pavement slope to width, and ranging from 0.04 to 0.12.

Method of Obtaining Superelevation & Radius of Horizontal Curve...

- Method of Obtaining Superelevation: i) Elimination of crown of the cambered section. ii) Rotation of pavement to attain full super-elevation.
- Radius of Horizontal Curve. 1.Ruling Minimum Radius(RMR) 2.Absolute Minimum Radius(AMR)

1. Elimination of The Crown of The Cambered Section

In this method, the outer half of the camber is gradually decreased. This may be done by two methods.

In the first method, the outer half of the camber is rotated about the crown at the desired rate such that the surface falls on the same plane as the inner half.

In the second method, the crown is progressively shifted outwards. This method is not usually adopted.

2. Rotation of Pavement To Attain Full Superelevation

In this stage, super elevatioN is gradually provided over the full width of the carriageway so that the required superelevation is available at the beginning of the circular curve. The different method employed for attaining the superelevation is as follows:

A. Revolving Pavement About The Center Line

In this method the surface of the road is rotated about the center line of the carriageway, gradually lowering the inner edge and rising the upper edge. The level of

C. Revolving Pavement About The Outer Edge

In this method, the surface of the road is rotated about the outer edge depressing the center and inner edge.

QUESTIONS

1.WHAT IS HIGHWAY GEOMETRIC ?

2. WHAT IS FORMATION WIDTH ?

3.WHAT IS SHOUILDER ?

4. WHAT IS ROAD MARGIN ?

5.WHAT IS CARRIAGE WAY ?

5. WHAT IS CAMBER &GRADIENT ?

LONG QUESTIONS

1. **WHAT IS CURVE & WHAT ARE THE CHARACTERSTICKS IN HIGHWAY ENGINEERING ?**
2. **WHAT IS SUPER ELEVATION AND EXPLAIN IN DETAILS ?**

CHAPTER-3
Road Materials

Materials Used for the Construction of Roads: Methods, Process, Layers and Road Pavement!

A wide variety of materials are used in the construction of roads these are soils (naturally occurring or processed), aggregates (fine aggregates or coarse aggregates obtained from rocks), binders like lime, bituminous materials, and cement, and miscellaneous materials used as admixtures for improved performance of roads under heavy loads and traffic.

Soil constitutes the primary material for the foundation, subgrade, or even the pavement (for low-cost roads with low traffic in rural areas). When the highway is constructed on an embankment at the desired level, soil constitutes the primary embankment material; further, since all structures have to ultimately rest on and transmit loads to 'mother earth', soil and rock also serve as foundation materials.

Soil is invariably used after some process of stabilisation such as compaction and strengthening by adding suitable admixtures for improving the performance of the road. Mineral aggregates obtained from rocks form the major component of the sub-bases and bases of highway pavements of almost all types.

A detailed study of their properties is therefore essential. Binder materials such as bitumen and cement mixed with appropriate types and proportions of aggregates are used for the construction of superior types of roads that are characterised by their durability and load-carrying capacity. Thus, base courses, sub-base courses and even the surface or wearing courses require the use of these materials.

1. Soil:

Soils can be studied effectively if they are classified according to certain principles into a definite system. A system is an ordered grouping of certain elements in a discipline according to pre-defined principles. Just as classification or grouping is practised in scientific disciplines such as chemistry, zoology and botany, it is used in Geotechnical Engineering as well.

A soil classification system may be defined as a fundamental division of the various types of soil into groups according to certain parameters such as its physical properties, constituents or

texture, field performance under load, presence of water and so on. There are a few field identification tests have been developed for preliminary identification in the field.

Need for Soil Classification:

Soil deposits in nature are never homogenous in character; wide variations are observed in their properties and behaviour. Soils that exhibit similar average properties may be grouped as a class. Classification of soil is necessary to obtain an appropriate and fairly accurate idea of the properties and behaviour of a soil type.

A classification system is usually evolved with a view to assessing the suitability of a soil for specific use as a construction material or as a foundation material. In view of the wide variations in engineering properties of several soils, it is inevitable that in any system of classification, there will be borderline cases which may fall into groups that appear to be radically different under different systems of classification.

Hence, classification is taken only as a preliminary requirement to study the engineering behaviour of a soil; special tests may become necessary in any project of importance.

Requirements of a Soil Classification System:

The general requirements of an ideal soil classification system are:

(i) It should have a scientific basis.

(ii) It should be relatively simple and objective in approach.

(iii) The number of groupings and properties used as the criteria should be limited.

iv) The properties considered should be relevant to the purpose of classification.

(v) A generally accepted uniform soil terminology should be used.

(vi) It should indicate the probable performance of the soil to a satisfactory degree of accuracy.

(vii) Group boundaries should be drawn as closely as possible where significant changes in soil properties occur.

(viii) It should be acceptable to all engineers.

These are rather ambitious requirements and cannot be expected to be met by any system, primarily because of the complex nature of soil, which does not lend itself to a simple classification. Therefore, a soil classification system is probably satisfactory only for the specific engineering application for which it was developed.

Although several classification systems have been developed, some being relatively more elaborate and exhaustive than others, the following systems only will be considered:

(a) Textural classification

(b) PRA system of classification (Group index method)

(c) Unified soil classification System

(d) Indian Standard Soil classification system

(a) Textural Classification:

Textural or grain size classification of soil is based on the particle size of the soil. Terms such as gravel, sand, silt and clay are used to indicate the ranges of grain size. Natural soil is invariably a mixture of particles of various sizes.

Although several textural classifications have been proposed, including the PRA system, the MIT classification and the IS textural classification are considered here in view of their wider acceptance.

MIT Textural Classification:

This was developed by the Massachusetts Institute of Technology, USA. The ranges of grain sizes in this scale, along with the soil designations, are given below (Fig. 6.7).

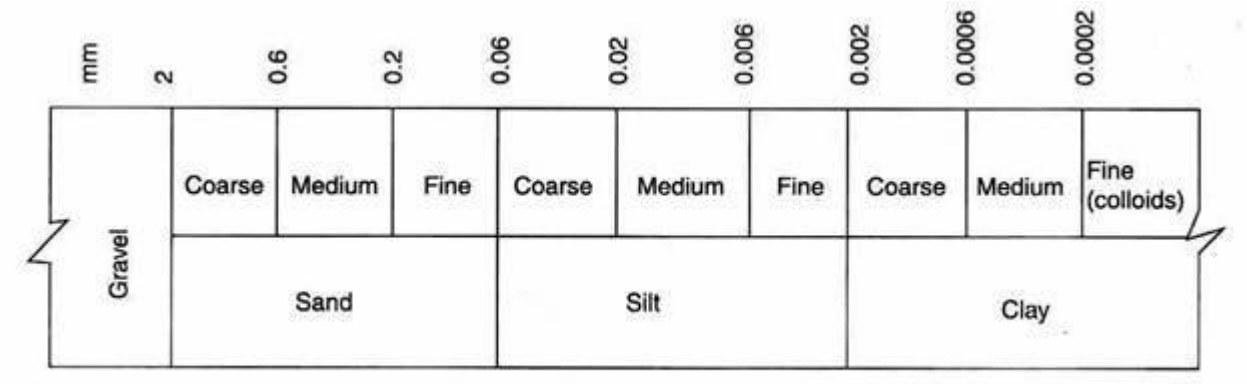


FIG. 6.7 *MIT Textural classification*

IS Textural Classification:

The ranges of sizes in the IS textural classification scale, along with the soil designations, are given below (Fig. 6.8).

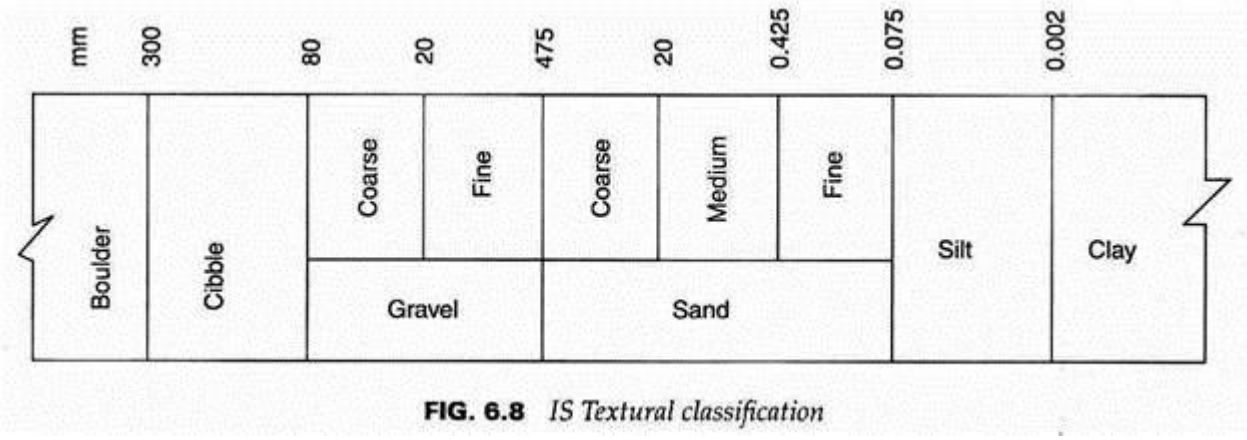


FIG. 6.8 *IS Textural classification*

This forms part of the Indian Standard Soil Classification System. In general, textural classifications are inadequate primarily because plasticity characteristics do not find any place in them.

(b) PRA System of Classification (Group Index Method):

The US Bureau of Public Roads developed a classification system, called the Public Roads Administration (PRA) classification system in 1931, specifically meant for use in road construction. This was revised several times, and the one given here is that revised in 1945 by the American Association of State Highway and Transport Officials (AASHTO). This system is based on both particle size and plasticity characteristics.

According to this system, soils are classified into eight groups—A-1 to A-8, the last one being Peat. Some groups contain a few subgroups. Soils within each group are evaluated according to the group index (GI), calculated from the following empirical formula –

$$GI = 0.2\,a + 0.005\,ac + 0.01\,bd \quad \ldots (6.55)$$

Here,

a = that part of the percent passing US Sieve No.200 (IS-75 μm) greater than 35, and not exceeding 75, expressed as a positive whole number (1 to 40);

b = that part of the percent passing US Sieve No.200 (IS-75 μm) greater than 15, and not exceeding 55, expressed as a positive whole number (1 to 40);

c = that part of the liquid limit greater than 40, and not greater than 60, expressed as a positive whole number (1 to 20); and,

d = that part of the plasticity index greater than 10, and not exceeding 30, expressed as a positive whole number (1 to 25).

The group index value should be rounded off to the nearest integer; in case any of the above values is less than the minimum limit, it should be taken as zero.

In general, the greater the group index value, the less desirable the soil is for highway construction within that subgroup.

The details of the groups and subgroups are set out in Table 6.1.

Table 6.1 PRA System of Soil Classification (AASHTO, 1945)

General classification	Granular materials (35% or less passing US No.200 sieve)				Silt-clay materials (More than 35% passing US No. 200 sieve)						
Group classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1a	A-1b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5 A-7-6
Sieve analysis Percent passing US No (2 mm) US No 40. (450 μm) US No. 200 (75 μm)	50 max 30 max 15 max	50 max 25 max	51 min 10 max	35 max	35 max	35 max	35 min	36 min	36 min	36 min	36 min
Characteristics of fraction passing US No.40 (420 μ) Liquid limit Plasticity index	6 max		Non-plastic	40 max 10 max	41 min 10 max	40 max 11 min	41 min 11 min	40 max 10 max	41 min 10 max	40 max 11 min	41 min 11 min
Group index	0		0	0	4 max			8 max	12 max	16 max	20 max
Usual types of significant constituent materials	Stone fragments Gravel and Sand		Fine sand	Silty or clayey gravel and sand				silty soils		clayey soils	
General rating as subgrade	Excellent to good							Fair to poor			

Note: A-8 is identified by visual examination; so it is not shown in the table. Classification procedure: Proceeding from left to right in the chart the correct group will be found by elimination. The first group from the left, consistent with the test data is the correct classification.

A-7 group is subdivided into A-7-5 and A-7-6, depending on the plastic limit. For A-7-5, $\omega_p \geq 30$; for A-7-6, $\omega_p < 30$.

Unified Soil Classification System:

This system was originally developed by Arthur Casagrande and adopted by the US Corps of Engineers in 1942 as 'Airfield Classification'. It was later revised for universal use and re-designated as the Unified Soil Classification in 1953.

In this system, soils are classified into three broad categories:

(i) Coarse-grained soils with up to 50% passing No.200 American Standard Testing Service (ASTM) Sieve (75 μm-IS sieve).

(ii) Fine-grained soils with more than 50% passing No.200 ASTM Sieve (75 μm-IS sieve).

(iii) Organic soils.

The first two categories can be distinguished by their plasticity characteristics. The third can be easily identified by its colour, odour and fibrous nature.

Each soil component is assigned a symbol as follows:

Gravel – G

Silt: M (from the Swedish word, 'mo' for silt)

Organic – O

Sand – S

Clay – C

Peat – Pt

Coarse-grained soils are further sub-divided into well-graded (W), and poorly-graded (P) varieties, depending upon the uniformity coefficient (U) and the coefficient of curvature (C_c) –

Well-graded gravel, $U > 4$

Well-graded sand, $U > 6$

Well-graded soil, $C_c = 1$ to 3.

Fine-grained soils are subdivided into those with low plasticity (L), with $\omega_L < 50\%$, and those with high plasticity (H), with $\omega_L > 50\%$. The plasticity chart devised by Casagrande is used for the identification of fine-grained soils (Fig 6.9) –

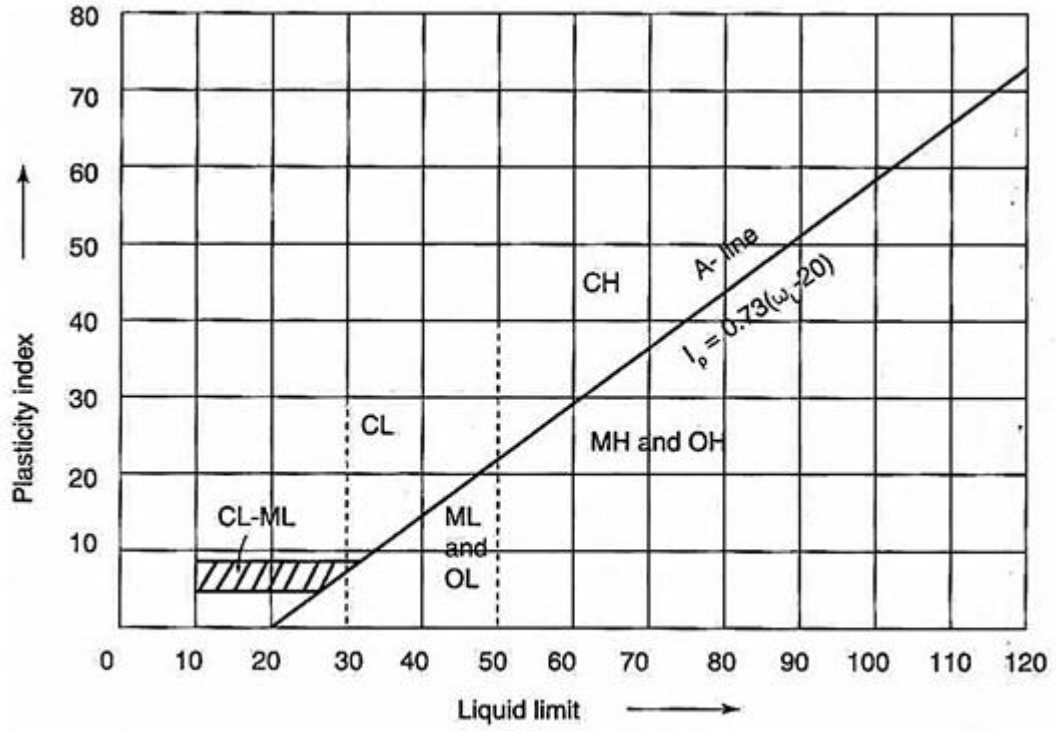


FIG. 6.9 *Plasticity Chart (Unified soil classification)*

Indian Standard Soil Classification System:

The relevant Indian Standard is "IS: 1498-1970, classification and identification of soils for engineering purposes (First Revision.)".

The significant provisions of this system are given below:

Soil shall be broadly divided into three divisions:

(1) Coarse-grained soil – More than 50% of the total material by weight is larger than 75 μm IS sieve size.

(2) Fine-grained soil: More than 50% of the total material by weight is smaller than 75 μm IS sieve size.

(3) Highly Organic Soil and Other Miscellaneous Soil Materials:

These soils contain large percentages of fibrous organic matter such as peat and particles of decomposed vegetation.

In addition, certain soils containing shells, cinders and other non-soil materials in sufficient quantities are also grouped in this division.

Coarse-grained soils shall be divided into (a) gravels and (b) sands.

(a) Gravels – More than 50% of coarse fraction (+75 μm) is larger than 4.75 mm IS sieve size.

(b) Sands – More than 50% of coarse fraction (+75 μm) is smaller than 4.75 mm IS sieve size. Fine-grained soils can be subdivided into

(i) Silts and clays of low compressibility – Liquid limit less than 35% (L).

(ii) Silts and clays of medium compressibility – Liquid limit greater than 35% and less than 50% (I).

(iii) Silts and clays of high compressibility – Liquid limit greater than 50% (H).

Coarse-grained soils shall be further subdivided into eight basic soil groups, and the finegrained soils into nine basic soil groups; highly organic soils and other miscellaneous soil materials shall be placed in one group.

The Plasticity Chart used in IS system of soil classification is shown in Fig. 6.10.

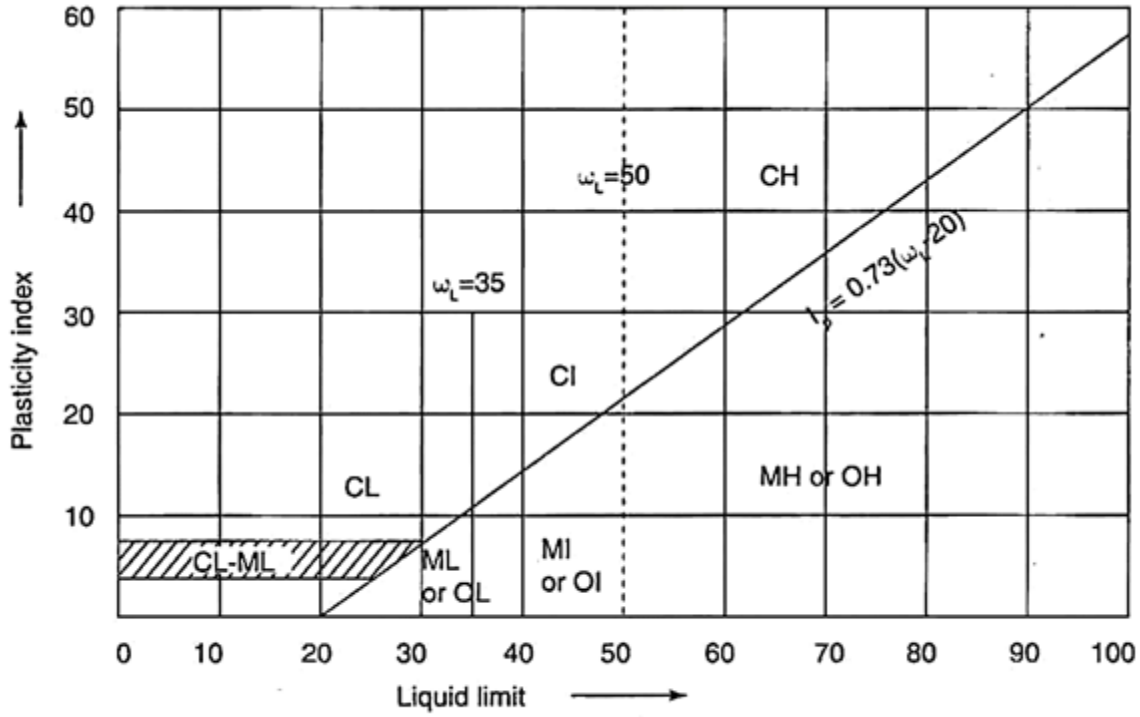


FIG. 6.10 *Plasticity chart (IS soil classification)*

Classification Criteria for Fine-Grained Soil:

Based on laboratory tests and the results in the form of consistency limits, the plasticity chart forms the basis for the classification of fine-grained soils.

Organic silts and clays are distinguished from inorganic soils which have the same position on the plasticity chart, by odour and colour. In case of doubt, the material may be oven-dried, remixed with water, and retested for liquid limit. The plasticity of fine-grained organic soils is considerably reduced on oven-drying.

Oven-drying affects the liquid limit of inorganic soils also, but only to a small extent. A decrease in liquid limit on oven-drying to a value-less than three-fourths of that before oven-drying is a positive identification of organic soils.

Black-Cotton Soils:

These are inorganic clays of medium to high compressibility. They are characterised by high shrinkage and swelling characteristics. When plotted on the plasticity chart, they lie mostly along a band above the A-line. For some, the band may lie below the A-lie also.

Kaolin behaves like inorganic silt and usually lies below the A-line; this shall be classified as such (ML, MI and MH), although it is clay from mineralogical stand point. The classification criteria for coarse-grained soils are given in Table 6.4.

Table 6.4 Classification criteria for coarse-grained soils

Group Symbol	Laboratory classification criteria		
GW	U greater than 4 C_c = 1 to 3		Determine the percentage of gravel and sand from grain-size distribution curve. Depending upon the percentage of fines (fraction smaller than 75μm IS sieve), coarse-grained soils are classified as follows: Less than 5%: GW, GP, SW, SP. More than 12%: GM, GC, SM, SC. 5% to 12%: Border-line case requiring the use of dual symbols. Uniformity coefficient $U = D_{60}/D_{10}$ Coefficient of curvature $C_c = \frac{(D_{30})^2}{D_{60} \times D_{10}}$ where D_{60} = 60% finer size $D3_0$ = 30% finer size D_{10} = 10% finer size
GP	Not meeting all the gradation requirements for GW		
GM	Atterberg limits below A-line or $I_p < 4$	Limits plotting above A-line with I_p between 4 and 7 are border-line cases requiring the use of dual symbols.	
GC	Atterberg limits above A-line with $I_p > 7$		
SW	U greater than 6 C_c = 1 to 3		
SP	Not meeting all the gradation requirements for SW.		
SM	Atterberg limits below A-line or $I_p < 4$	Limits plotting above A-line with I_p between 4 and 7 are border-line cases requiring the use of dual symbols.	
SC	Atterberg limits above A-line with $I_p > 7$		

Boundary Classification for Coarse-Grained Soils:

Coarse-grained soils with 5% to 12% fines are considered border-line cases between clean and dirty gravels or sands-for example, GW-GC, or SP-SM. Similarly, border-line cases might occur in dirty gravels and dirty sands, where I_p is between 4 and 7- for example, GM-GC, or SM-SC. It is, therefore, possible to have a border-line case of a border-line case. The rule for correct classification in such cases is to favour the non-plastic classification.

For example, gravel with 10% fines, a U-value of 20, a C_c -value of 2.0, and I_P of 6 would be classified GW-GM, rather than GW-GC.

Note – Even separate flow-charts may be shown for coarse-grained and fine-grained soils.

Relatively Suitability for General Engineering Purposes:

The characteristics of the various soil groups pertinent to roads and airfields-value as subgrade, sub-base and base material, compressibility, drainage characteristics, compaction characteristics, dry unit weight, CBR-value, and subgrade modulus are all tabulated in "IS: 1498-1970 – classification and identification of soils for general engineering purposes".

It also includes characteristics pertinent to embankments and foundations-values as embankment material, compaction characteristics, value as foundations material, requirements for seepage control, ranges of permeability and dry unit weight. Characteristics pertinent to suitability for canal sections compressibility, workability as a construction material and shearing strength when compacted and saturated are also given in relative terms or qualitative terms.

The information provided in IS: 1498-1970 serves the purpose of a guideline or an indication of the suitability of a soil based on the IS classification system. However, important and large projects need detailed investigation of the soil properties and engineering behaviour for good design.

2. Stone Aggregates:

Stone aggregate, or mineral aggregate, as it is called, is the most important component of the materials used in the construction of roads. These aggregates are derived from rocks, which are formed by the cementation of minerals by the forces of nature.

Stone aggregates are invariably derived by breaking the naturally occurring rocks to the required sizes. They are used for granular bases, sub-bases, as part of bituminous mixes and cement concrete; they are also the primary component of a relatively cheaper road, called water-bound macadam.

A study of the types of aggregates, their properties, and the tests to determine their suitability for a specific purpose is of utmost importance to a highway engineer. Properties such as strength and durability of aggregates are generally influenced by their origin of occurrence, mineral constituents and the nature of the bond between the constituents.

Geological Classification of Rocks:

Geologically speaking, rocks are classified into the following categories:

(a) Igneous Rocks:

These are formed by the cooling, solidification and crystallisation of molten rock on the earth's crust at different depths. The minerals, their proportions and the rate of cooling of the magma have a bearing on the strength characteristics of the rock.

Igneous rocks are, in general, stronger than the other two types. Granite, diorite and gabbro are intrusive rocks which form at deep layers in the earth's crust. Basalt (or trap), andesite, rhyolite and dolerite are extrusive rocks which from at the top layers of the earth's crust.

(b) Sedimentary Rocks:

Fine material or rock fragments and particles transported by water or wind and deposited in layers, get hardened in course of time to form sedimentary rocks (the time required is on geologic scale). They consist of a layered structure; the rock beds are stratified, they may be porous, and have relatively low strength.

Examples of siliceous variety are sandstone and argellite; those of calcareous variety are limestone and dolomite.

(c) Metamorphic Rocks:

These are formed by the modification and re-crystallisation of igneous rocks and sedimentary rocks by geological and natural agents such as temperature, pressure, moisture, humidity, and movement of rock beds.

Major changes occur in geologic time and form foliations. This kind of foliated structure makes these rocks comparably weaker than igneous rocks. Popular examples of metamorphic rocks are gneiss (from granite), slate (from shale) and schist.

Examples of un-foliated types are marble (from limestone) and quartzite (from sandstone). (Marble and gneiss are used for flooring and face work in buildings.)

Desirable Properties of Sand Aggregates:

The following properties are desirable in soil aggregates used the construction of roads:

(i) Strength:

It is the resistance to crushing which the aggregates used in road construction, especially in the top layers and wearing course, have to withstand the stresses due to wheel loads of the traffic in addition to wear and tear.

(ii) Hardness:

It is the resistance to abrasion of the aggregate at the surface. The constant rubbing or abrading action between the tyres of moving vehicles and the exposed aggregate at the road surface should be resisted adequately.

(iii) Toughness:

This is the resistance to impact due to moving traffic. Heavily loaded trucks and other vehicles cause heavy impact loads on the road surface while moving at high speeds, and while accelerating and decelerating. Even steel-typed vehicles, though moving slow, cause heavy impact on the aggregates exposed at the surface. Hence, resistance to such impact forces is a desirable quality.

(iv) Durability:

It is the resistance to the process of disintegration due to the weathering action of the forces of nature. The property by virtue of which the aggregate withstands weathering is called soundness. This is also a desirable property.

(v) Cementation:

It is the ability of the aggregate to form its own binding material under traffic, providing resistance to lateral displacement. Limestone and laterite are examples of stones with good cementing quality. This becomes important in the case of water-bound macadam roads.

(vi) Appropriate Shape:

Aggregates maybe either rounded, cubical, angular, flaky, or elongated. Each shape is appropriate for a certain use. Too flaky and too elongated aggregates have less strength and durability; so they are not preferred in road construction.

Rounded aggregates are good for cement concrete because of the workability such aggregates provide. Cubical or angular aggregates have good interlocking properties; since flexible pavements derive their stability due to interlocking, such aggregates are the preferred type for construction. Thus, the appropriate shape for a particular use is also a desirable property.

(vii) Adhesion with Bitumen:

The aggregates used in bituminous pavements should have less affinity to water than to bitumen; otherwise, the bituminous coating on the surface of the aggregate will get stripped off in the

presence of water. So, hydrophobic characteristic is a desirable property for aggregates to be used in the construction of bituminous roads.

(viii) Attrition:

This is mutual rubbing of aggregates under traffic; adequate resistance to attrition is a desirable property.

(ix) Texture:

This is a measure of the degree of fineness or smoothness of the surface of the aggregate.

Gravels from river beds are fairly smooth; as a rule, fine grained rock is highly resistant to wear and is preferred for surface courses.

3. Bituminous Materials:

Bitumen was used as a bonding and water-proofing agent thousands of years ago. However, the use of bitumen for road-making picked up only in the nineteenth century. As the quest for fuels like petroleum to run automobiles grew and the distillation of crude oil emerged as a major refining industry, the residues known as bitumen and tar found increasing use in constructing bituminous surfaces, which provided superior riding surface.

The definition for the term, bitumen, given by the American Society for Testing Materials (ASTM) runs thus:

"Bitumen is a hydrocarbon material of natural or pyrogenous origin, which is in a gaseous, liquid, semi-solid, or solid state, and which is completely soluble in carbon disulphide (CS_2)."

Of course, bitumen is found to be soluble to a large extent in carbon tetrachloride (CCl_4) also. Bitumen is a complex organic compound and occurs either as such in nature or can be obtained during the distillation of petroleum; it is generally non-volatile and resistant to most acids, alkalis and salts.

Bitumen occurring in nature as rock intrusions invariably contains inert inorganic materials or minerals; in such a case it is called asphalt. It is also found in lakes (as in Trinidad), in which case it is called lake asphalt. However, in American terminology, bitumen itself is termed asphalt, irrespective of whether it contains inorganic/mineral matter or not. In India, the British terminology is used for the terms bitumen and asphalt.

Important Properties of Bitumen:

1. Predominantly hydrocarbons, with small quantities of sulphur, nitrogen and metals.

2. Mostly (up to 99.9%) soluble in carbon disulphide (CS_2), and insoluble in water.

3. Softens on heating and gets hardened on cooling.

4. Highly impermeable to water.

5. Chemically inert and unaffected by most acids, alkalis and salts.

6. No specific boiling point, melting point or freezing point; a form of 'softening point' is used in their characterisation.

7. Although generally hydrophobic (water repellent), they may be made hydrophilic (water liking) by the addition of a small quantity of surface-active agent.

8. Most bitumens are colloidal in nature.

Desirable Properties of Bitumen as a Road Material:

1. Workability – Bitumen should be fluid enough at the time of mixing so that the aggregates are fully coated by the binder. Fluidity is achieved either by heating or by cutting back with a thin flux or by emulsifying the bitumen.

2. Durability – There should be little change in viscosity within the usual range of temperatures in the locality.

3. Volatile constituents in bitumen should not be lost excessively at higher temperatures to ensure durability.

4. It should have enough ductility to avoid brittleness and cracking.

5. Strength and adhesion – The bitumen should have good affinity to the aggregates and should not be stripped off in the continued presence of water.

6. Cost-effectiveness.

A few more terms relating to bitumen/asphalt are:

Straight-Run Bitumen:

Bitumen derived from the refining of petroleum for which the viscosity has not been adjusted by blending with flux oil or by softening with any cut-back oil or by any other treatment. It generally has high viscosity.

Asphalt Cement:

A binder consisting of bitumen, or a mixture of lake asphalt and bitumen or flux oils, specially prepared as per prescribed quality and consistency for direct use in paving, usually in the hot condition.

Oxidised or Blown Bitumen:

Bitumen obtained by further treatment of straight-run bitumen by running it, while hot, into a vertical column and blowing air through it. In this process, it attains a rubbery consistency with a higher softening point than before.

Cut-Back Bitumen:

Asphalt/bitumen dissolved in naphtha or kerosene to lower the viscosity and increase the workability.

Emulsified Bitumen:

A mixture in which asphalt cement, in a finely dispersed state, is suspended in chemically treated water.

Liquid Bitumen:

Include cut-backs in naphtha and kerosene, as also emulsified asphalts.

Flux-Oil:

A bituminous material, generally liquid, used for softening other bituminous materials.

Bitumen from Petroleum Refining:

The main source of bitumen is petroleum crude. Refining of petroleum crude involves fractional distillation. The crude oil is heated in a tube-still to about 200°C to 400°C and injected into a

fractionating column. As the pressure is suddenly reduced, the volatile fractions with low boiling points get vaporised and go up the column, from where they are carried through condensers.

Gasoline, kerosene, diesel oil, and lubricating oils, constituting the light, medium and heavy distillates with gradually increasing boiling points, thus get collected. The heavy residue left at the bottom is collected as bitumen. Steam is injected into the fractionating column to help in the separation process of the fractions. The steam and vacuum distillation process is only a physical process and does not involve any chemical changes.

In modern refining processes, the distillation is carried out in stages. In the first stage, the temperature in the tube-still is kept relatively low (say 300°C to 350°C) and the light and medium fractions are separated in the fractionating column operating at atmospheric pressure.

The crude left is then passed through another still for subsequent transfer to another column operating under vacuum and injected with steam. The latest process dispenses with steam and relies on dry vacuum only, thus enabling a wide range of bitumen to be produced.

Paraffinic crudes yield, on distillation, an undesirable wax-like residue. Naphthenic crudes yield practically wax-free bitumen; crude from middle-east yields good bitumen. The heavy residue may be blown with air at high temperature in a converter to produce air-blown or oxidised bitumen.

They are stiff even at high atmospheric temperatures. Such bitumen are not used for pavements, but are good as roofing materials and water-proof paints. It is also used as filler material for cracks and joints in concrete pavements.

The **sub grade** soil and its properties are important in the design of pavement structure. 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.

Tests on soil

Sub grade soil is an integral part of the road pavement structure as it provides the support to the pavement from beneath. The sub grade soil and its properties are important in the design of pavement structure. 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:

- Shear tests
- Bearing tests
- Penetration tests

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

Bearing tests are loading tests carried out on sub grade soils in-situ with a load bearing area. The results of the bearing tests are influenced by variations in the soil properties within the stressed soil mass underneath and hence the overall stability of the part of the soil mass stressed could be studied.

Penetration tests may be considered as small scale bearing tests in which the size of the loaded area is relatively much smaller and ratio of the penetration to the size of the loaded area is much greater than the ratios in bearing tests. The penetration tests are carried out in the field or in the laboratory.

California Bearing Ratio Test

California Bearing Ratio (CBR) 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. CBR test, an empirical test, has been used to determine the material properties for pavement design. Empirical tests measure the strength of the material and are not a true representation of the resilient modulus. It is a penetration test wherein a standard piston, having an area of 3 in (or 50 mm diameter), is used to penetrate the soil at a standard rate of 1.25 mm/minute. The pressure up to a penetration of 12.5 mm and it's ratio to the bearing value of a standard crushed rock is termed as the CBR.

In most cases, CBR decreases as the penetration increases. The ratio at 2.5 mm penetration is used as the CBR. In some case, the ratio at 5 mm may be greater than that at 2.5 mm. If this occurs, the ratio at 5 mm should be used. The CBR is a measure of resistance of a material to penetration of standard plunger under controlled density and moisture conditions. The test procedure should be strictly adhered if high degree of reproducibility is desired. The CBR test may be conducted in re-moulded or undisturbed specimen in the laboratory. The test is simple and has been extensively investigated for field correlations of flexible pavement thickness requirement.

Test Procedure

- The laboratory CBR apparatus consists of a mould 150 mm diameter with a base plate and a collar, a loading frame and dial gauges for measuring the penetration values and the expansion on soaking.
- The specimen in the mould is soaked in water for four days and the swelling and water absorption values are noted. The surcharge weight is placed on the top of the specimen in the mould and the assembly is placed under the plunger of the loading frame.
- Load is applied on the sample by a standard plunger with dia of 50 mm at the rate of 1.25 mm/min. A load penetration curve is drawn. The load values on standard crushed stones are 1370 kg and 2055 kg at 2.5 mm and 5.0 mm penetrations respectively.
- CBR value is expressed as a percentage of the actual load causing the penetrations of 2.5 mm or 5.0 mm to the standard loads mentioned above. Therefore,

- Two values of CBR will be obtained. If the value of 2.5 mm is greater than that of 5.0 mm penetration, the former is adopted. If the CBR value obtained from test at 5.0 mm penetration is higher than that at 2.5 mm, then the test is to be repeated for checking. If the check test again gives similar results, then higher value obtained at 5.0 mm penetration is reported as the CBR value. The average CBR value of three test specimens is reported as the CBR value of the sample.

What is the importance of soil in highway engineering?

Soil compaction is a crucial part of the construction process as it **provides a strong working platform**. A strong soil base is the foundation and all other parts of the project depend on its strength and performance, both during construction and once the pavement structure is in place.

What are Tests on Aggregates?

Aggregates are crucial in the construction industry and can be utilized for a variety of projects. Aggregates are a key component in the production of concrete and provide various advantages. Their principal application is to reinforce concrete, hence strengthening its structure and reducing cracking.

As a result, before using aggregates for construction, they must be examined and evaluated for quality. Many types of aggregate studies show that aggregate quality has a significant impact on the quality of concrete and, eventually, the building.

Crushing test of aggregate

A pavement is bound to fail under compression of load it cannot handle, which may lead to public disaster and can definitely prove to be hazardous.

Therefore, an aggregate crushing test is conducted to ascertain the aggregate's structural soundness and crushing strength. The aggregate crushing value gives a comparative indication of the resistance to crushing under a crushing load that is applied gradually. The recommended value of a crushing test should ideally be 30% for roads and pavements and 45% for other projects.

Abrasion test

The abrasion test focuses primarily on the hardness of the aggregate and helps decide whether a certain aggregate is suitable for use in construction or not. The Los Angeles abrasion test is the most preferred form of abrasion test of aggregates and has been standardised as the test for aggregate hardness in India.

Impact test

The impact test of aggregates helps in determining the resistance of an aggregate to impact forces.

Soundness test

The soundness test is conducted to determine the resistance of aggregates to wear and tear due to weather forces. This is done through a simulation of weather cycles. Porous aggregates that are exposed to freezing and thawing over and over again are more likely to disintegrate prematurely. To increase the durability of such aggregates, they are exposed to a series of soundness tests in order to select the highest quality aggregate.

Shape tests

An aggregate, whether naturally occurring or artificially manufactured, has flaky or elongated parts in it. These flaky components help determine the flakiness of the aggregate. Aggregates with a higher

number of flakes seem to be detrimental to higher workability and the stability of mixes. This is known as the flakiness index.

Another metric that helps determine the stability of an aggregate is the elongation index of an aggregate. The elongation index of an aggregate is defined as the percentage index by weight particles whose greatest dimension is 1.8 times their mean dimension. This test is only applicable to aggregates larger than 6.3mm.

Specific gravity and water absorption test

The design of concrete and bituminous mixes must take into account an aggregate's specific gravity and water absorption. A solid's specific gravity is determined by how much mass it has in relation to an equivalent amount of distilled water at a given temperature. There is a possibility of the aggregates containing water-permeable voids. Hence, to avoid this, two measures of the specific gravity of aggregates are used, which are known as apparent specific gravity and bulk specific gravity.

Whereas, apparent specific gravity is calculated on the basis of the net volume of aggregates or the volume of aggregates excluding the water-permeable voids.

Bulk-specific gravity, on the other hand, is calculated on the basis of the total volume of aggregates, including the water-permeable voids.

Bitumen adhesion test

Bitumen is a well-known compound that is widely used in construction. When picking the ideal aggregate for a given use case, it's crucial to consider bitumen's adherence in cold and wet conditions. This test is conclusive of the adhesion of aggregate when wet and cold.

LONG QUESTIONS

1.WHAT ARE THE DIFFERENCE TYPE OF MATERIALS USED IN HIGHWAY ENGINEERING ?
2. EXPRESSED CBR TEST ?
3.WAHAT ARE THE TEST OF AGGREGREAD ?

CHAPTER-4
Road Pavements

A highway pavement consists of layers of processed materials above the natural soil subgrade, whose primary function is to distribute the applied vehicle loads to the sub-grade. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favorable light reflecting characteristics, and low noise pollution. It has to be constructed based on the traffic requirements, climatic conditions of the area, terrain, etc.

Requirements of highway pavement

The primary function of a pavement is to transmit loads to the sub-base and underlying soil. Modern flexible pavements contain sand and gravel or crushed stone compacted with a binder of bituminous material, such as asphalt, tar, or asphaltic oil. Such a pavement has enough plasticity to absorb shock. Rigid pavements are made of concrete, composed of coarse and fine aggregate and portland cement, and usually reinforced with steel rod or mesh. An ideal pavement should meet the following requirements:

- Right thickness to distribute the wheel load stresses to a safe value on the sub-grade soil
- Durable to withstand all types of stresses imposed upon it
- Adequate coefficient of friction to prevent skidding of vehicles,
- Smooth surface to provide comfort to road users
- Impervious surface, so that sub-grade soil is well protected
- Long design life with low maintenance cost
- Thickness should be adequate to transmit the applied loads and distribute them on to a larger area of the soil below
- Hard wearing surface so as to resist the abrasion caused by vehicle tyres.

Structural layers of highway pavement

Base course

It is below the surface course and its function is to distribute the stresses transmitted through the surface course evenly onto the layers below. Invariably, it consists of granular or bituminous material, and acts as a structural part of the pavement. The base course is the most important layer of a road

structure which transfers the stresses developed due to traffic impacts through the wearing course. The base course layer provides the required foundation stiffness and structural strength.

Surface Course

It is the topmost layer; its function is to provide a smooth, strong, abrasion-resistant and reasonably impervious course. Since it is directly in contact with the vehicle tyres, it has to resist the imposed wheel loads and transmit them safely to the layer below. The material may be granular, bituminous or cement concrete depending upon the nature of the construction. For flexible pavements, the bituminous surface is the wearing course whereas in rigid pavement the concrete surface act as the base course cum wearing course.

Sub-Base Course

Sub-Base Course

It is just below the base course and provides additional help to the courses above it in distributing the loads. It also helps in preventing soil grains of the subgrade from intruding into the base course above, and counteracts frost action, if any. It may consist of stabilised soil or soil aggregate mixes, which facilitate drainage of free water from the pavement. It comes between the base course and subgrade. The material used for this layer shall satisfy the specifications in terms of gradation, strength, and plastic characteristics. This layer is necessary if the subgrade is of poor quality.

Subgrade

It is the compacted natural soil immediately below the pavement layers; this act as a foundation for the highway. The top surface of the subgrade is called the formation level. Based on the alignment and the nature of the terrain, a roadway may be constructed over an embankment or a cutting, or at or nearly at the natural ground level. The formation of level, therefore, has to be properly decided to suit these conditions. It serves as the foundation and acts as a uniform support to pavements. Subgrades bear the entire load of the payments along with the service load of traffic.

Different types of highway pavements

Flexible pavements

Flexible pavements have base courses of broken stone pieces either compacted into place together with bitumen to form asphalt. These can be either in the form of pavement surface treatments (such as a bituminous surface treatment (BST) generally found on lower volume roads) or, HMA surface courses (generally used on higher volume roads such as the Interstate highway network). These types of

pavements are called “flexible” since the total pavement structure “bends” or “deflects” due to traffic loads. A flexible pavement structure is generally composed of several layers of materials which can accommodate this “flexing”. The vertical compressive stress is maximum on the pavement surface directly under the wheel load and is equal to the contact pressure under the wheel. The lower layers of pavement have to take up only lesser magnitudes of stresses and there is no direct wearing action due to traffic loads and weathering action due to environmental factors. Therefore inferior materials with lower cost can be used in the lower layers. The top layer has to be the strongest as the highest compressive stresses are to be sustained by this layer, in addition to the wear and tear due to the moving traffic and varying factors due to weather.

Types of Flexible Pavements

- Conventional layered flexible pavement
- Full – depth asphalt pavement
- Contained rock asphalt mat (CRAM).

Rigid pavements

Rigid pavements are those which possess noteworthy flexural strength of flexural strength or flexural rigidity. The basic design of rigid pavement is very simple. A surface layer, made up of slabs of Portland cement concrete (PCC), sits on top of a handful of sub-layers. The layer directly under the PCC is more flexible than the concrete, but still quite rigid. This layer provides a stable base for the PCC as well as assists in drainage. Some roads have a second sublayer under the first that is even more flexible, while some simply have the existing soil.

Types of Rigid Pavements

- Jointed plain concrete pavement (JPCP)
- Jointed reinforced concrete pavement (JRCP)
- Continuous reinforced concrete pavement (CRCP)
- Prestressed concrete pavement (PCP).

Semi-rigid pavement

A semi-rigid pavement is intermediate between the flexible and the rigid types. The semi-rigid pavement is a composite pavement material consisting a porous asphalt concrete (PAC) with air voids which is filled or flooded by a special formulated high performance polymer modified cement mortar grouting material. It is the combination the characteristics of Porous Asphalt Concrete (PAC) and Portland cement concrete (PCC) pavement. The semi-rigid pavement consists of two main components which are porous asphalt concrete (PAC) and the high performance polymer modified cement mortar grouting material.

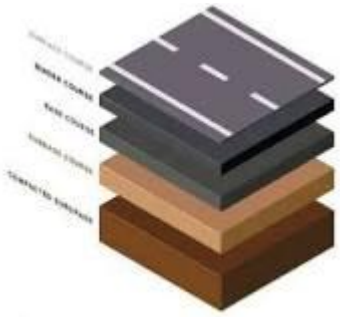
Composite pavement

A composite pavement is a type of pavement that utilizes both asphalt and concrete. Typically, a concrete base layer provides structural capacity while an asphalt surface layer provides a wearing surface course. This pavement type can also be used in conjunction with roller-compacted concrete (RCC) pavements, where the RCC pavement provides the structural capacity that the conventional concrete pavement base would.

Conclusion

The performance of the highway pavement depends on the correct usage of structural layer as per fitted with pavement types as discussed above. Pavement performance is an important issue in the operation and planning of highway engineering. There are several factors that affect pavement performance, such as traffic, soil, environmental, economic and stress distribution factors. Go for an experienced pavement engineer to meticulously manage the operation efficiency desired from highway pavement.

subgrade in flexible pavement



Subgrade is **the bottom most layer which is nothing but natural soil layer compacted up to required depth generally about 150 to 300 mm to receive the loads coming from top layers**. This layer is termed as foundation for the pavement system

The purpose of subgrade preparation

The subgrade must be able to **support loads transmitted from the pavement structure**. This load bearing capacity is often affected by degree of compaction, moisture content, and soil type. A subgrade that can support a high amount of loading without excessive deformation is considered good.

Although a pavement's wearing course in a highway/ road is most prominent, the success or failure of a pavement is more often dependent upon the underlying subgrade – the material upon which the pavement structure is built. Subgrades be composed of a wide range of materials although some are much better than others. This post discusses a few of the aspects of subgrade materials that make them either desirable or undesirable and the typical tests required to characterize subgrades.

A subgrade's performance generally depends on three of its basic characteristics (all of which are interrelated) as under:

Load bearing capacity

The subgrade must be able to support loads transmitted from the pavement structure. This load bearing capacity is often affected by degree of compaction, moisture content, and soil type. A subgrade that can support a high amount of loading without excessive deformation is considered good.

Moisture content

Moisture tends to affect a number of subgrade properties including load bearing capacity, shrinkage and swelling. Moisture content can be influenced by a number of things such as drainage, groundwater table elevation, infiltration, or pavement porosity (which can be assisted by cracks in the pavement). Generally, excessively wet subgrades will deform excessively under load.

Shrinkage and/or swelling

Some soils shrink or swell depending upon their moisture content. Additionally, soils with excessive fines content may be susceptible to frost heave in colder climates. Shrinkage, swelling and frost heave will tend to deform and crack any pavement type constructed over them.

Poor Subgrade

Poor subgrade should be avoided if possible, but when it is necessary to build over weak soils there are several methods available to improve subgrade performance:

Removal and replacement (over-excavation)

Poor subgrade soil can simply be removed and replaced with high quality fill. Although this is simple in concept, it can be expensive. Table in right shows typical over-excavation depths recommended by the Colorado Asphalt Pavement Association (CAPA).

Stabilization with cement or asphaltic binder

The addition of an appropriate binder (such as lime, Portland cement or emulsified asphalt) can increase subgrade stiffness and/or reduce swelling tendencies.

Additional base layers

Marginally poor subgrade soils may be compensated for by using additional base layers. These layers (usually of crushed stone – either stabilized or un-stabilized) serve to spread pavement loads over a larger subgrade area. This option is rather perilous; when designing pavements for poor subgrades the temptation may be to just design a thicker section with more base material because the thicker section will satisfy most design equations. However, these equations are at least in part empirical and were usually not intended to be used in extreme cases. In short, a thick pavement structure over a poor subgrade will not necessarily make a good pavement.

Strength & Stiffness of Subgrade Soil

Subgrade materials are typically characterized by their resistance to deformation under load, which can be either a measure of their strength (the stress needed to break or rupture a material) or stiffness (the relationship between stress and strain in the elastic range or how well a material is able to return to its original shape and size after being stressed). In general, the more resistant to deformation a subgrade is, the more load it can support before reaching a critical deformation value. Three basic subgrade stiffness/strength characterizations are commonly used:

- California Bearing Ratio (CBR),
- Resistance Value (R-value) and
- Elastic (resilient) modulus

Although there are other factors involved when evaluating subgrade materials (such as swell in the case of certain clays), stiffness is the most common characterization.

Construction Works

Surface Preparing for Construction

Before a pavement is actually placed at the construction site, the surface to be paved must be prepared. Adequate surface preparation is essential to long-term pavement performance. Pavements constructed without adequate surface preparation may not meet smoothness specifications, hence it would not bond to the existing pavement (in the case of overlays) or may fail because of inadequate subgrade support.

Surface preparation generally takes one of two forms:

- *Preparing the subgrade and granular base course for new pavement.*

This can involve such activities as subgrade stabilization (e.g., with lime, cement or emulsified asphalt), over-excavation of poor subgrade, applying a prime coat or compacting the subgrade.

- *Preparing an existing pavement surface for overlay*

This can involve such activities as removing a top layer through milling, applying a leveling course, applying a tack coat, rubblizing or cracking and seating an underlying rigid pavement, and replacing localized areas of extreme damage.

Specific actions for each method depend upon the pavement type and purpose, environmental conditions, subgrade conditions, local experience and specifications.

Subgrade Preparation for New Pavement

The overall strength and performance of a pavement is dependent not only upon its design (including both mix design and structural design) but also on the load-bearing capacity of the subgrade soil. Thus, anything that can be done to increase the load-bearing capacity (or structural support) of the subgrade soil will most likely improve the pavement load-bearing capacity and thus, pavement strength and performance. Additionally, greater subgrade structural capacity can result in thinner (but not excessively thin) and more economical pavement structures. Finally, the finished subgrade should meet elevations, grades and slopes specified in the contract plans.

Subgrade Compaction

In order to provide maximum structural support (as measured by MR, CBR or R-value), a subgrade soil must be compacted to an adequate density. If it is not, the subgrade will continue to compress, deform or erode after construction, causing pavement cracks and deformation. Generally, adequate density is specified as a relative density for the top 150 mm (6 inches) of subgrade of not less than 95 percent of maximum density determined in the laboratory. In fill areas, subgrade below the top 150 mm (6 inches) is often considered adequate if it is compacted to 90 percent relative density. In order to achieve these densities the subgrade must be at or near its optimum moisture content (the moisture content at which maximum density can be achieved). Usually compaction of in situ or fill subgrade will result in adequate structural support. MRCBRR-value

Increasing Subgrade Support

Alternative Means

If the structural support offered by the in situ compacted subgrade is or is estimated to be inadequate, there are three options (any one or combination of the three can be used):

Stabilization

The binding characteristics of these materials generally increase subgrade load-bearing capacity. Typically, lime is used with highly plastic soils (plasticity index greater than 10), cement is used with less plastic soils (plasticity index less than 10) and emulsified asphalt can be used with sandy soils. For flexible pavements, a prime-coat is not effective on silty-clay or clay soils because the material cannot be absorbed into such a fine soil (TRB, 2000).

Over-excavation

The general principle is to replace poor load-bearing in situ subgrade with better load-bearing fill. Typically, 0.3 - 0.6 m (1 - 2 ft.) of poor soil may be excavated and replaced with better load-bearing fill such as gravel borrow.

Add a base course and perhaps a sub-base course over the subgrade

A base course offers additional load-bearing capacity. New pavement structural designs often use some sort of granular base course unless subgrade structural support is extremely good and expected loads are extremely low. Base courses are subjected to the same compaction and elevation requirements as subgrade soils.

Subgrade Elevation

Alignment of Road

he position occupied by the center line of a road in plan is called alignment of road. A new road should be aligned very carefully as the cost of construction, maintenance, safety and ease in travel etc. depends much upon the alignment of road.

Once the construction of the road is completed, the alignment of the road cannot be changed. It is difficult to change the alignment after the completion of road construction.

Due to increase in cost of land and construction of costly roadside structures, it difficult to change the road alignment post the construction. Hence road alignment should therefore, be carefully selected and located.

Also Read : Cement Concrete Road Construction Procedure

Also Read : Maintenance of Roads & Its Classification

Requirements of an Ideal Alignment of Road :

The following are the basic requirements of an ideal road alignment.

- Easy
- Short
- Economical
- Safe
- Utility
- Natural aspects

Easy :

The alignment must be easy in construction, maintenance and traffic operations. The alignment should be easy for the operation of vehicles with easy gradients and curves to meet this requirements.

Short :

In between two terminal station the alignment should be as short as possible. Short alignment provide economy in the cost of construction, maintenance and transportation.

The alignment should be as straight as possible to meet this requirement.

Economical :

The alignment should be economical in its cost of construction, maintenance and traffic operations.

Safe :

The alignment should be safe for traffic operation. To fulfill this requirement, the alignment should be safe enough for construction and maintenance from the view point of stability of natural hill slopes, embankment and cut slopes and foundation of embankments.

Utility :

The alignment should offer maximum utility by serving maximum population by connecting intermediate important towns and group of villages.

Natural Aspects :

The alignment should pass through regions of natural beauty and scenery to have good natural aspects.

Factors Affecting Alignment of Road :

Various factors affecting the alignment of the road are as follows :

- Need of traffic
- Purpose and class of road
- Obligatory points
- Curve
- Gradient
- Sight distance
- Number of drainage crossing
- Railway and river crossing
- Obstruction
- Formation bed
- Earthwork
- Availability of labour and material
- Existing right of way
- Lengthy straight route
- Aesthetical aspect.

Need of Traffic :

Alignment should suit need of traffic. For fast moving traffic, it must be as straight as possible. For slow moving traffic, like bullock cart and other it may have sharp bend.

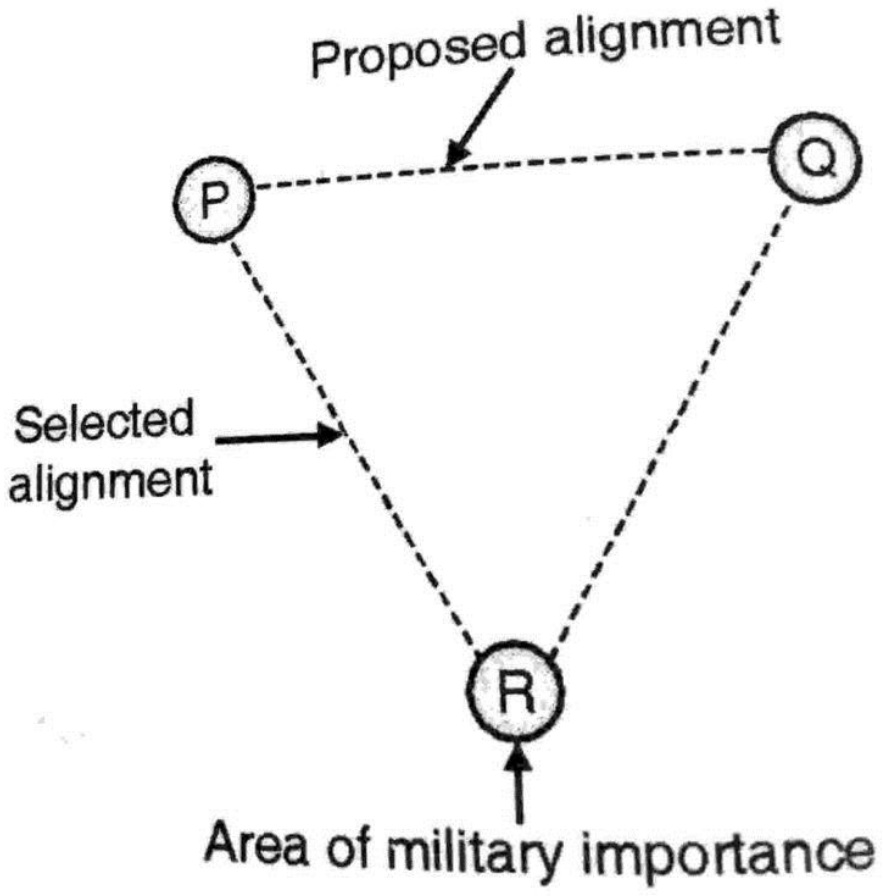
Purpose and Class of Road :

The alignment should be selected according to the purpose and class of road. The national highway connecting two important towns should be kept perfectly straight as far as possible.

On the other hand alignment of other category of road can be deviated when straight alignment is not feasible.

Obligatory Points

The alignment should pass through obligatory points such as intermediate important towns, group of villages and area of commercial, political, military and social importance.



Hence to connect obligatory points alignment may be changed.

Curve :

Curves must be as flat as possible. It may be necessary to make adjustment in the horizontal alignment of roads keeping in view the minimum radius of curve and the transition curves.

Gradient :

While aligning a new road, the gradient should be flat and less than the ruling or design gradient. Thus in order to avoid excessive fall or rise the alignment is to be changed.

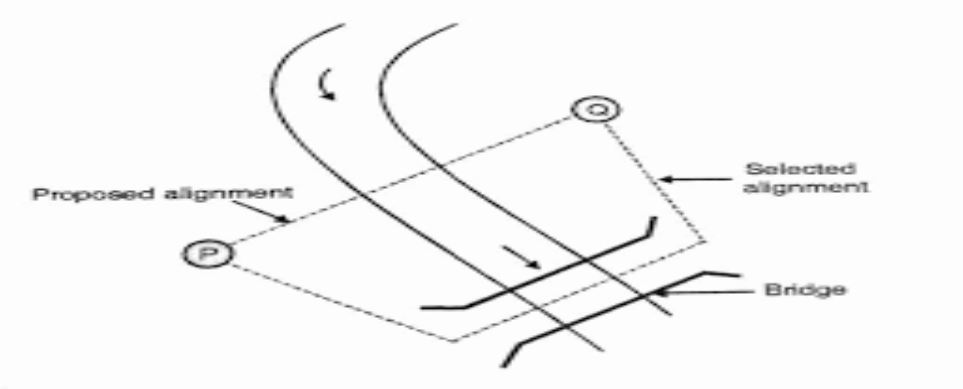
Sight Distance :

The minimum sight distance, which should be available in every section of the road, is the safe stopping distance for the fast moving vehicles.

Also there should be enough distance visible ahead for safe overtaking operations of vehicles moving at design speed on the road. Hence the alignment should be finalized in such a way that it should provide good sight distance.

Number of Drainage Crossing :

The alignment should have minimum number of drainage crossing. To have maximum number of drainage crossing alignment must be changed.



Railway and River Crossing :

The alignment should cross river or the railway line at right angles. In case of river crossing point, it should fulfill the essential requirements of a good bridge site.

Obstruction :

Alignment should be free from obstruction. Hence alignment can be changed to avoid well, lake, pond, historical and religious, buildings etc.

FOrmation Bed :

Alignment should run on good soil as far as possible. Hence to fulfill this requirement alignment can be changed.

Earthwork :
The alignment should have less earthwork. Hence to avoid excessive cutting or filling, the alignment must be changed.

Availability of Labour :
The alignment should provide proximity to labour and material required for the construction of road. Hence to make construction and maintenance of the road economical, alignment of road is changed.

Existing Right of Way :
The alignment should make use existing right-of way. Hence to satisfy the requirement, alignment is changed in order to curtail the cost of land acquisition.

Lengthy Straight Route :
The alignment should not be monotony caused due to lengthy straight routes. Hence alignment must be have slight bend to break the monotony and to keep the driver alert.

Aesthetical Aspect :
The alignment can be changed in order to pass the road through regions of natural beauty and scenery.

Establishing a **benchmark** is the first step towards a **topographical survey being carried out. This is the point where** all data will be compared to the topographical survey performed and a drawing made, which will be the foundation for it. A benchmark is a reference point that helps one to calculate something.

Embankment Meaning:
The earthen material, which is laid and compacted to raise the grade line of a proposed highway or railway above the Existing Ground Level(EGL) of the original ground, is called an road embankment. The grade line of the road may be raised due to some reasons, which are as follows:

- keeping subgrade above Ground Water Table(GWT)
- preventing damage to the pavement from the surface and capillary water.
- To maintain the designed vertical alignment of the road.

Embankment design considerations include filling height, the material used, settlement consideration and stability analysis. In the case of grater fill height and weak foundation soil, ground improvement is

necessary to control the settlement of the foundation soil. After construction, due to consolidation or fill height settlement or both, the embankment may settle.

Borrow pits provide the source material for the construction of road embankments, which, depending on the local area, can consist of gravel or aggregates, silica sands, laterite sands, and calcite.

What is the purpose of borrow pit?

In fact, it's not a finance term at all, it's a construction term: A borrow pit is a hole, pit or excavation that has been dug for the purposes of **removing gravel, clay, soil or sand to be used in a construction project**. It's sometimes called a sandbox.
explained that barrow meant the mound of earth formed when the pit was dug. A few informants connect barrow with the wheelbarrow probably used to carry away the dirt. Informants who use borrow pit explain that **the dirt is borrowed from one place to be used in another**.

Borrow pits **provide the source material for the construction of road embankments**, which depending on the local area are: gravel/aggregates, silica sands, laterite sands and calcite.

What should be the minimum distance of borrow pits?

Borrowpits on the river side: All earth for the embank- ment should be borrowed, as far as possible, from the river side. The inner edge of any borrowpit should not be less than **15 metres** from the toe of the bank, the distance depending upon the magni- tude and the duration of the flood to be withstood.

Compaction is the process used to reduce the volume of a mass of material. The goal of compacting a hot mix asphalt (HMA) pavement is to achieve the optimum air void content in-place and to provide a smooth, uniform surface.

Soil stabilization is the process of improving the shear strength parameters of soil and thus increasing its bearing capacity in road construction. It is required when the soil available for construction is not suitable to carry structural load
Method Of Providing Camber
The rate of camber or cross slope is usually designed by 1 in 'n' which means the transverse slope is in ratio 1 vertical to "n" horizontal. Camber is also expressed in percentage. If the camber is x %, the cross slope is x in 100.

What Is Camber?

Camber is the slope provided to the road surface in the transverse direction to drain off the rainwater from the road surface. It is also known as the cross slope of the road. In this article, we will briefly discuss types of camber used in road.

Why Are Camber Provided In Road?

1. To protect the road by preventing the entry of surface water into the subgrade soil through the pavement.

2. To prevent the entry of water into the bituminous pavement layers.

3. To remove the rainwater from the pavement surface as quickly as possible and to allow the pavement to get dry soon after the rain.

Types Of Camber In Road

1. Sloped Or Straight Camber

It consists of two straight slopes from the edges joining at the center of the carriageway. This type of camber is very simple and can be easily constructed and maintained.

2. Parabolic Or Barrel Camber

It consists of a continuous curve either elliptical or parabolic. It provides a flat road surface at the middle and steeper towards the edges. On account of steeper edges, this type of camber provides better drainage property. This camber is therefore preferred by fast-moving vehicles and suggested for urban roads.

3. Composite Camber

It consists of two straight slopes from the edges with a parabolic or circular crown in the center of the camber. This type of camber can be easily constructed and maintained.

Advantages Of Camber

1. Camber provides quick drainage of rainwater and thus saves the foundation course of the road structure from weakening by the percolation of rainwater to it through the road surface.

2. This prevents rainwater to accumulate in local shrinkages or depressions and forming water pools on the road surface, which are disagreeable to the public as well as to the road structure.

Method Of Providing Camber

Usually, camber is provided on the straight roads by raising the center of the carriageway with respect to the edges, forming a crown or highest point on the centerline.

At horizontal curves with superelevation, the surface drainage is affected by raising the outer edge of the pavement with respect to the inner edge while providing the desired superelevation.

The rate of camber or cross slope is usually designed by 1 in 'n' which means the transverse slope is in ratio 1 vertical to "n" horizontal. Camber is also expressed in percentage. If the camber is x %, the cross slope is x in 100.

Bitumen soil stabilization: can occur in different forms either as bitumen, cutback bitumen or bitumen emulsions. Selection of type and grade of bitumen is soil type, construction method and weathering conditions dependent. The most important parameters affecting bitumen stabilization include moisture content, bitumen viscosity, bitumen content, uniformity in mixing, aeration, compaction, and curing. The mechanism of action in bitumen stabilization involves binding that it imparts to the soil particles making it more weather resistant. Consequentially, the lack of water ingress leads to a significant improvement in soil strength as well as weather resistance capacity. Presence of organic matter, dissolved salts and high pH values of soils negatively affects bitumen stabilization. The quantity of bitumen required varies from 4% to 7% with higher than optimum values filling voids between soil or aggregate particles which results in poor compaction, decreased strength and compromised deformation behavior of the stabilized soil.

Fly ash soil stabilization: is another popular chemical stabilizer. It is a by-product of coal fired electric power generation facilities. The mechanism of soil stabilization using fly ash is the pozzolanic reaction and the filing of the voids in the mix. It is among types of soil stabilization suitable for coarse grained particles with little or no fines. Soil to be stabilized should have low moisture content. After proper amount of fly ash added, an activator is usually used to intensify pozzolanic reaction in the mixture because fly ash produced from the combustion of harder, older bituminous, anthracite coal is pozzolanic but not self-cementing. The activator is lime or Portland cement in rate 20 to 30 % of fly ash. Fly ash contains heavy metals and other harmful compounds which leach easily into soil and water bodies.

Cement soil stabilization: is the oldest and still very common soil binder. Cement can be used for the stabilization of a wide range of soil types – and is very effective in pavement stabilisation. However,

cement application has many limitations as the organic content in soil should be generally limited to 2% in additional to non-compatibility with soils with high amount of clay. The soil should also be free from deleterious salts such as sulphate which affect the setting time of the cement and result in subsequent disruption of the soil-cement structure. It is not compatible with soils with high amount of clay. On the other side certain concentration of clay is necessary for the method to be successful. Any presence of organic material is not allowed. Application process is quite complicated. High control of water content has to be performed, as well as demanding procedure for determination of right time for compaction. If viewed from economic and environmental aspect, cement production is extremely energy demanding.

What are the benefits of soil stabilization?

1. Enhances the physical and/or mechanical properties of a soil for a specific application.
2. Improves durability and strength, where the locally available soil is poor
3. Increased resistance of soil to loading.
4. Enables use of environmentally friendly products which feeds into the Earth Stewardship approach to material use.
5. Dust suppression is achieved through soil stabilization which improves workplace health and safety
6. Erosion and sediment control is prioritized through soil stabilization hence offering protection to topsoil and its nutritional value.

Base Course. The layer immediately beneath the surface course. It provides additional load distribution and contributes to drainage. Base courses are usually constructed out of crushed aggregate or HMA.

Water Bound Macadam Road

Water bound macadam road is a road wherein the wearing course comprises of clean squashed aggregates which are precisely interlocked by rolling. These aggregates are bound along with filler material and water laid on an all-around compacted base course. WBM road is the most regularly utilized road development strategy for over 200 years and in the principal stage in the vast majority of the road ventures, water–bound macadam road is built, and the surfacing is finished with the premix cover bituminous macadam or concrete cement.

n this type of road, coarse aggregates are mechanically interlocked together by rolling, screening, etc. Binding materials are used to fill the gap between the coarse aggregate.

Material Required For Water Bound Macadam Road

1. Coarse Aggregate

2. Screenings (Filler Material)
3. Binding Material

Advantages

- very low construction cost.
- There is no need for skilled workers.
- Material is easily available.
- It provides very good quality.

Disadvantages

- The maintenance cost is very high.
- Not much durable.
- It is permeable to water.

Difference Between WMM and WBM Road

Here are the differences between WMM (Wet Mix Macadam) and WBM (Water Bound Macadam) roads.

WMM Road	WBM Road
WMM roads are more durable.	WBM roads are less durable.
WMM roads get dry very fast	WBM roads take time to get dry.
It can be constructed at a faster pace.	It took more time to construct.
It consumes less water.	It consumes more water.
In WMM roads stone aggregates and binders are used.	In WBM roads stone aggregates, screenings, and binder material (Stone dust with water) is used.

Three types of bituminous emulsions are available, which are Rapid setting (RS), Medium setting (MS), and Slow setting (SC). Bitumen emulsions are ideal binders for hill road construction.

What is Bituminous Road. Bituminous road **consist of their surface with bituminous materials which is also called as Asphalt**. It is sticky dark viscous liquid obtained from natural deposits like crude petroleum.

Bituminous road consist of their surface with bituminous materials which is also called as Asphalt. It is sticky dark viscous liquid obtained from natural deposits like crude petroleum.

Different Types of Bituminous Surfaces.

1. Prime Coat :

This is a single coat of low viscosity bituminous binder. This coat is applied to existing untreated pervious layer like WBM. The main purpose is to improve the adhesion between base and bituminous surface.

Functions :

- The most important function is to imporve the adhesion between existing pervious base and wearing surface.
- To bind the dust and loose particles together to form hard and tough surface.
- It provides temporary seal to prevent the surface water from penetrating through the surface.

2. Tack Coat :

This is single coat of low viscosity bituminous binder applied to the existing treated impervious layer such as bitumen or cement-concrete base. This boat is applied between treated base and bituminous surface.

Function :

- It is provided to improve the adequate bond between existing impervious base and wearing surface.

3. Seal Coat :

Seal coat is the final coat of bituminous material that is applied on the top of surface to prevent the entry of moisture through the voids.

Function :

- To provide water tight surface.
- It improves the visibility at night and develops skid resistant texture.
- To improve the wearing resistance of an existing road surface.

4. Surface Dressing :

It is the process in which two or more coats of bituminous materials are applied to prepared base. This coat consist of bituminous binders sprayed on which chipped aggregates are properly rolled.

Function :

- It prevents the removal of binding material and prevents the damage of road due to waterproofing effects.
- Roads can be easily cleaned and washed as it reduces dust nuisance.
- Smooth surface of the road reduces the wear and tear of tyres.

Bituminous Road Construction Steps and Procedure :

1. Bituminous Penetration Macadam Road :

In this type of bituminous road the aggregates are bound together by grouting bitumen into the voids of the compacted aggregates. This type of bituminous road is generally adopted for the thickness of 50 and 75 mm.

Materials Required :

- The grade of bitumen to be used for this type of road suggested by IRC ranges from 80/ 100, 60/ 70 & 30/ 40. Any one of the above grade can be adopted.
- Road tars of grades such as RT-4 & RT-5 can also be used.
- Physical properties of the aggregates must fulfill the following standard test values given below :

Equipments and Plants Required :

- Bitumen heating device.
- Bitumen distributor.
- Roller for compacting operation.
- Aggregate spreader.

Construction Procedure of Bituminous Penetration Macadam Road :

• Preparation of Existing Surface :

First of all the surface on which bitumen macadam is to be applied is cleaned from dust and other debries. The gradient and the camber of the road is properly checked.

Priming coat can be also applied if necessary for porous surfaces.

• **Spreading of Course Aggregates :**

Spreading of aggregates can be done manually or by machine. To achieve the desired profile in cross-section, template cat or camber profile may be used.

• **Rolling Operation :**

After speeding of aggregates they are dry rolled with a minimum of 10 tonnes roller. It is assured that the aggregates are properly compacted and interlocked.

• **Bitumen Application :**

The uniform layer of bitumen binder is applied on the dry rolled compacted aggregates with the help of pressure distributor or mechanical hand sprayer.

• **Spreading of Key Aggregates :**

Once the bitumen is properly applied key aggregated are properly laid and rolling operation again continued for proper compaction. Cross Profile is also checked at the same time.

• **Seal Coat Application :**

If the road is going to be made open for the traffic and another surface course is not required then the seal coat is applied. It consist of sand bitumen or it may be of surface dressing type.

• **Finishing :**

Cross profile of the road should be checked with template and the longitudinal profile by straight edge of the road. The permissible undulation on 3 m road is 12 mm.

• **Open to Traffic :**

The road is made open to traffic after minimum of 24 hours after its construction.

2. Bitumen Carpet Road.

In the construction of bitumen carpet road the recommended bitumen binder is 80/ 100 grade and the tar required should be of grade RT-3. The stone chippings required for 2 cm carpet thickness should be 12 mm and 10 mm. Below table should the requirement that should be satisfied by the aggregates to be used.

Construction Procedure of Bitumen Carpet Road :

• **Preparation of the Existing Surface :**

For the existing layer if potholes or depressions are found then they are required to be filled with percolated chippings before the layer of carpet is applied. After the preparation of the surface the tack

coat is applied to WBM surface or old bitumen surface. If there is presence of softer aggregates such as laterite, kankar or murum, then prime coat application is necessary to be applied first.

• Application of Tack Coat :

The bitumen binder is heated up to required temperature and a tack coat is applied to the surface.

• Preparation and Placing of Premix :

Preparation of premix is carried out in mechanical rotary mixer or hand drum mixer. For this mix, aggregates and bitumen are separately heated for specified temperature. Mixing is done to obtain through and homogeneous mix. These mix is then carried out to site and it is ready to be placed on the surface. Cross profile is effectively checked after its application.

• Rolling and Finishing :

Rolling operation for compaction is carried out once the premix application is finished. It is carried out for completion of every 15 m surface of road. The rollers which are generally used are tandem type or pneumatic type rollers having capacity of 6-10 tonnes. The wheels of the rollers are kept damp to prevent the adhesion of mix to the wheels of roller.

Note : for heavy rainfall areas liquid seal is sprayed on the carpet at 9-10 kg per 10m2 area. It is then covered with layer of tone chippings and properly compacted.

• Surface Finish :

The surface is properly checked for undulations. For 3 m straight edge the undulation should not exceed 10mm. Cross profile should not have undulations exceeding 6mm

• Open to Traffic :

Road is opened for the traffic after 24 hours of application of seal coat or surface dressing.

Advantages of Bituminous Road :

- Generally Bituminous road do not develop cracks on the surface for long period.
- Maintenance cost of this road is also very less.
- Bituminous road are waterproof, non-slippery, smooth, durable and it provides comfortable road surface for the traffic.
- It can withstand the adverse natural effects caused by heavy rain, excess heat and change in temperature.

Disadvantages of Bituminous Road :

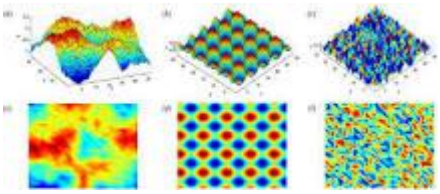
- The viscosity of the bitumen and aggregate mix plays important role in defining the performance of bituminous road.

- If the bituminous material is used in excess than the value for given mix, it effects the performance of the bituminous road.

Surface Dressing is a mixture of polymer modified bitumen emulsion and a layer of chippings. It will seal the surface, improve surface texture and prolong the life of the road by many years

What are types of surface dressing?

- Tarmac Driveways.
- Concrete Driveways.
- Concrete Repairs.
- Resin Bound Driveways. Resin Bound Driveway Colour Guide.
- Groundworks Services.
- Gravel Driveways.

- What is surface dressing in road maintenance?
- Surface dressing work consists of the application of a suitable grade of bitumen or emulsion by spraying over a prepared base course or existing pavement surface followed by spreading a specified size of hard aggregates at the recommended rate and rolling.
- What is surface dressing using bituminous?
- A bituminous surface treatment (BST), also known as a seal coat or chip seal, is **a thin protective wearing surface that is applied to a pavement or base course**. BSTs can provide all of the following: A waterproof layer to protect the underlying pavement. Increased skid resistance
- What are the 3 types of surfaces?
- 
- Three different types of surfaces–**(a) rough, (b) sinusoidal, (c) random**, and their 2D images (d)–(f) Metal-based powder-bed-fusion additive manufacturing (PBF-AM) is gaining increasing attention in modern industries, and is a promising direct manufacturing technology.
- What is compaction of surface dressing?
- Compaction of such surface dressing layers is **carried out exclusively by tyre compactors**, which ensure the placement of the chippings and their entrenchment in the binder film, finally completed by actual traffic once the treated road is put back into service.

Semi-Dense Bitumen Mixes

The two types of semi-bituminous mixes used in the pavement construction in India are;

- Semi-Dense Bituminous Concrete (SDBC)
- Mixed Sealed Surfacing (MSS)

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.

pen Graded Bitumen Surface Mixes

Three open graded mix types are employed as the surface mixes. They are:

- Open graded Friction course (OGFC)
- Premix Carpet (PMC)
- Surface Dressing

Open Graded Friction Course (OGFC) The OGFC system consists of interconnected voids that help to improve the surface drainage property. Here the rainwater will drain through the OGFC and reach the bituminous concrete grade 2 (BC), that will later flow laterally within the OGFC. Which is later ended at the shoulder. The last OGFC layer will have a thickness of 20mm. This system will have no trace of water on the surface. The OGFC system was developed in 2002, by the US nationals. The safety and the environmental features of OGFC are mentioned below:

- Improvement of frictional resistance of wet pavement
- Hydroplaning: Hydroplaning is the effect of skidding on ice and the loss of control problems of the vehicles. This is due to the presence of water during and after rain. The OGFC lets removal of water from the surface, letting no water trace on the pavement.
- The splash and the spray are reduced: The high-speed movement of vehicles will cause splashing and spraying of water to the nearby vehicles, which will cause problems to the visibility. The OGFC results in no water flooding in the road hence no splashing or spraying.
- Glare: The OGFC results in the reduction of glare from the headlights in the wet conditions. This will help in better visibility and have reduced driver fatigue.

- Noise Reduction

Premix Carpet (PC) Here the PC is laid as a wearing course with a thickness of 20mm. The mix will compose two single size aggregates. One is the aggregate that is passing through 22.5mm and that will retain in 11.2mm. The second aggregate type will pass through 13.2mm and retain on 5.6mm sieve. Here with respect to the climate and the traffic intensities, the viscosity grade bitumen are employed. It can be either VG-10 or VG-30. Based on the aggregate and aggregate application rates that are specified in IRC: 14-2004, in "Recommended Practice for Open Graded Premix Carpet", the bitumen content by weight of mix is 3.3%. **Surface Dressing** As per IRC:110 -2005, " Specification and Code of Practice for Design AND Construction of Surface Dressing", the surface dressing has the following significances and objectives:

- The surface dressing will provide a dust free wearing course over a granular base course that act similar to a water bound macadam (WBM) or a wet mixed Macadam (WMM).
- The surface Dressing will help in providing impermeability for water percolation for the road surface
- Surface Dressing provide high friction for the riding surface
- This will provide a renewal coat for periodic maintenance of bituminous wearing surfaces.
- The surface dressing work involves the process of spraying of proper grade paving bitumen mainly VG-10 or the rapid setting cationic emulsion. This is applied over an aggregate layer of appropriate size and gradation.

Surface dressing does not increase the structural strength and the riding quality of the pavement constructed.

Gap Graded Bitumen Mixes

The Stone Matrix Asphalt (SMA) is the most commonly used gap graded bituminous mixes. With the increasing traffic and the high pressure of tires of the vehicles will give large stresses to the road pavement. The roads are subjected to overloading conditions in certain cases. The stone matrix asphalt mix is tough, highly stable in structure and rut resistant asphalt mix. These systems rely on the stone to stone contact that will facilitate in strength. The rich mortar used in the system will provide better durability.

The advantages of stone matrix asphalt mix are:

- Surface Frictional Resistance are improved
- The noise is reduced

- Compared to the conventional dense graded asphalt mix, the night visibility is reduced.

The following steps are involved in the stone matrix asphalt mix design:

1. The selection of the materials i.e. aggregates, binder and the cellulose fiber.
2. Three trial gradations are involved to ensure stone to stone contact.
3. Optimum binder content is used for the all the gradation chosen
4. The binder drains down as well as the moisture susceptibility is evaluated.

The performance of the stone matrix asphalt mix pavement as studied by the US, based on the rutting effect seen in the road pavement. The figure-5 below shows the rut depth caused for different ranges of the project conducted.

Rigid Pavements: Concept of concrete roads as per IRC specifications

he pavement having high flexural strength and constructed utilizing RCC or PCC is called rigid pavement.

It is simply a concrete road (either RCC or PCC).

Rigid Pavement is divided into different slabs during construction, and a small gap is provided between the slabs so that concrete doesn't crack during expansion on summer days.

This pavement transfers the wheel load to subgrade by slab action.

Some examples of this pavement are PCC pavement, RCC pavement, and Prestressed concrete pavement.

1. Features of Rigid Pavement

Some features of rigid pavement are:

a. It transfers the wheel load to subgrade by slab action.

b. It requires joints.

c. Its initial construction cost is high.

d. Its durability is high.

e. It distributes wheel load uniformly.

f. It requires curing.

g. It doesn't require rolling (Compacting) of the surface.

h. It has high flexural strength.

2. How Rigid Pavement is Different From Flexible Pavement

S.N.	Flexible Pavement	Rigid Pavement
1.	It transfers the wheel load to subgrade by grain to grain mechanism.	It transfers the wheel load to subgrade by slab action.
2.	The initial construction cost is low.	The initial construction cost is high.
3.	It doesn't require joints.	It requires joints.
4.	Durability is low.	Durability is high.

5.	It doesn't distribute load uniformly. So, a good subgrade is required.	It distributes wheel load uniformly. So, there is no requirement for a good subgrade.
6.	There is no effect of temperature variation on stress variation.	Temperature variation affects the stress variation.
7.	The lifespan of flexible pavement is approximately 10 to 15 years.	The maximum lifespan of rigid pavement is approximately 20 to 30 years.
8.	Repair work is simple.	Repair work is complex.
9.	The maintenance cost is high.	The maintenance cost is low.
10.	It doesn't require curing.	It requires curing.
11.	Poor night visibility due to the use of asphalt.	Good night visibility due to the use of concrete.
12.	No glare due to sunlight. (Glare: shine with a strong or dazzling light.)	High glare due to sunlight.

13.	Easy to locate and perform underground works like repairing or finding pipes.	Hard to perform underground works.
14.	Its thickness is more.	Its thickness is less.
15.	The bearing capacity of the subgrade influences design.	The bearing capacity of the subgrade doesn't influence its design.
16.	Aggregate and bitumen are used as the key materials.	Concrete and steel are used as key materials.
17.	Stability depends upon the interlocking of aggregates, particle friction, and cohesion.	Stability depends upon joints between the slabs of concrete.
18.	It is capable of resisting settlements to some extent.	The settlement is permanent. It is not capable of resisting settlement.
19.	It is susceptible to heat, oils, greases, and chemicals.	It is highly resistive to heat, oil, greases, and chemicals
20.	Rolling (Compacting) of the surface is needed.	Rolling (Compacting) of the surface is not needed.
21.	It has a low flexural strength.	It has high flexural strength.

22.	The force of friction is less.	The force of friction is high.
23.	It is more comfortable for travel.	It is less comfortable for travel.

3. Types of Rigid Pavement

There are two types of rigid pavement. They are:

1. Un-Reinforced Concrete Pavement (URCP)

The rigid pavement in which reinforcement is not provided is called unreinforced concrete pavement.

Simply, it is a Plain Concrete Pavement.

There are two types of URCP pavement. They are:

a.Jointed Dowelled Concrete Pavements(JDCP):

They are also called jointed plain concrete pavement(JPCP).

In this type of pavement, the load transfer mechanism is implemented using aggregate interlocks or dowel bars provided in transverse joints.

They have a joint spacing of 5 m -10 m.

b.Jointed Un-Dowelled Concrete Pavements(JUDCP):

This type of pavement is constructed when the traffic is very low. Dowel bars are not provided in JUDCP.

2. Reinforced Concrete Pavement(RCP)

The rigid pavement in which reinforcements are provided is called reinforced concrete pavement.

They are used when traffic is high.

There are two types of RCP. They are:

a.Jointed Reinforced Concrete Pavements(JRCP):

JRCP steel mesh or mat is provided at the centre of the slab.

The primary use of reinforcement is to control cracking rather than a structural purpose.

It can be used for low or medium-traffic roads.

b.Continuous Reinforced Concrete Pavements(CRCP):

Continuous reinforcements are provided on this pavement.

They are mainly used for constructing high-traffic roads

The gap between the slab is also eliminated. They are mainly used where the strength of sub-grade soil is very less.

This pavement can resist different types of load and adverse weathering effects easily.

4. Requirements of Good Rigid Pavement

~ It should have a long-life design with low maintenance cost.

~ It should be waterproof enough to protect sub-grade soil.

~ It should have a high coefficient of friction to resist skidding.

~ It should be smooth enough to provide comfort to the users.

~ It should be structurally strong to withstand all types of loads.

5. Construction Steps of Rigid Pavement

a. Preparation of subgrade

~ The first step of rigid pavement construction is the preparation of subgrade.

~ In this step, cutting and filling work is done according to the requirement, and compaction work is carried out. The slight application of water should be made during the compaction work, i.e. compaction should be done at optimum moisture content.

b. Provision of sub-base course

~ Sub-base course is provided when the subgrade is weak. In the case of a strong sub-grade, there is no need to give a sub-base course.

~ Sub-base course is a mixture of soil & small stone pieces. After the provision of the sub-base, it should be compacted.

c. Preparation of Base Course

~ After sub-base course; built non-erosive base coarse with boulders and stones maintaining slopes for water disposal.

~ Voids and gaps between the boulders or big stones are filled with small stones.

Strong stones with irregular shapes are generally preferred for the base.

~ Thickness of base course should be a minimum of 6 inches.

d. Surface Course Preparation

~ Construct the concrete slab above the base course (either with RCC or PCC).

~ Their thickness should not be less than 12 inches for high-traffic roads.

~ For low-traffic roads, their thickness should not be less than 6 inches.

6. Facts of Rigid Pavement

1. They are also called single-layer pavement.

2. They may last up to 40 years if timely maintained and cared for.

3. They may require asphalt for toping to reduce the noise during vehicle operation.

4. The vehicle operation cost of rigid pavement is low.

5. They are cheaper while considering the life-cycling cost.

6. Maintenance cost is very low.

7. Advantages of Rigid Pavement

~ Low maintenance and operation cost.

~ Higher life span.

~ It has high flexural strength.

~ It has good resistance to petroleum products, oils, and chemicals.

~ More environment-friendly than flexible pavement.

CHAPTER -5

Hill Roads

Hill roads

The term hill road can be explained with reference to the cross slope, i.e., the slope approximately perpendicular to the centerline of the ***highway alignment***. Thus a road is termed as a hill road if it passes through a terrain with a ***cross slope of 25% or more*** and it is characterized by widely differing elevations, deep gorges, a number of watercourses, and steep slopes. The hill roads are also sometimes referred to as ***ghat roads***.

IMPORTANCE OF HILL ROADS

There are possibly two modes of transport for mountainous or hilly areas, namely, roads and railways. The choice between the two should be based on the relative economics and the following factors are certainly in favour of hilly roads:

(1) Development in stages: A road of small width involving less expenditure can open out the area of immediate economic development and the improvements in the roadway system can be carried out as and when the traffic develops.

(2) Initial cost: There is no doubt that the initial cost of construction of railways is much more than that of roads in hilly areas.

(3) Length: The roads can be constructed with comparatively steeper grades which will result in the reduction of the length of road as compared to the length of the railway track required with milder slopes for rail traction for the same height.

The importance of hill roads can be imagined by understanding the following purposes which they serve:

(i) Economic development: The hilly areas are backward as far as modern civilization, culture and education are concerned and hence, they require tremendous economic development. The main activity of the people in these areas is agriculture. The lands in hills are ideally suited for a variety of crops like the apples, apricots, cherry, etc. among fruits and potatoes, ginger, etc. among the vegetables. If these paying crops are grown in place of maize and other local food-grains and economically transported outside, the economic life of the population can be considerably improved.

(ii) Forest wealth: The hilly areas contain huge forest wealth

in the form of structural and other timbers, minerals, stones, etc. and all these items form the basic valuables for developing the country as a whole and the hilly areas in particular, provided there is an efficient transportation system for carrying these valuables to the plains from where they can be processed and sent to the consumers.

(iii) Industrial development: There are certain areas of hills which are ideally suited for growing tea and jute and for bringing up silk-worms. The presence of roads can help in setting up of the industries of these products in the hilly areas.

(iv) Strategic considerations: In case of an emergency such as war, a well layout system of roads in hilly areas helps considerably for moving the army from one place to the other.

(v) Tourism: Some of the hilly areas present immense natural scenic beauty which attracts thousands of local and foreign tourists. The construction of hill roads is probably the main contributing factor for the development of tourism all along the Himalayas from Gulmarg to Darjeeling and other important hill stations of our country.

BASIC PRINCIPLES OF PLANNING OF HILL ROADS

In a broad sense, the main aim of planning a hill road is to establish the shortest, most economical and safe route between the obligatory points, and to achieve this purpose successfully, the following basic principles are to be observed in the planning of hill roads:

(1) Construction work

(2) Existing routes

(3) Intensity of traffic

(4) Master plan

(5) Natural climatic conditions

(6) Use of contours.

(1) Construction work: The construction of hill roads requires considerable period and greater funds as compared to the roads in plains because it involves items such as parapets to demarcate

the roadway boundary, rock cuttings in difficult regions, provision of erosion control measures, greater number of drainage crossings, etc. It is therefore advisable to plan the construction work in stages over

a number of years in such a way that each stage of construction improves upon the previous construction stage so as to bring it upto the requirements of the developing traffic.

(2) Existing routes: The existing pedestrian and mule tracks or good animal beaten tracks present the most convenient routes for further improvements and extension and hence, it is one of the essential principles in hill road planning that maximum use should be made of such existing routes. They may however be suitably modified as the traffic requirements increase.

(3) Intensity of traffic: For the purpose of planning, the hill roads may be categorized as jeepable roads and motorable roads from the view point of intensity of traffic. These roads may then be converted into National Highways, State Highways, etc. depending upon the relative importance in the whole set up of planning. The jeepable roads are narrow in width, have comparatively sharper bends and steeper grades and they can be traversed by jeep cars only. The motorable roads can be used by the commercial vehicles in the hilly area. It may be a good policy to aim at jeepable roads first and to provide motorable roads at a later stage after studying the possibility of providing necessary standards of geometric design and construction.

(4) Master plan: It is advisable to draw a master plan for the development of the whole hilly area and work out the priorities instead of starting the work haphazardly. It may avoid the tremendous economic loss in the form of more construction and operation costs due to greater lengths covered by the haphazard planning.

(5) Natural climatic conditions: It is necessary to explore the natural climatic conditions of the hilly area before the planning of road alignment. It is observed that the sunny side of the hills above a height of about 4500 m and the shady side of the hills above a height of about 3600 m are covered with snow. Now the snow melts quickly on the sunny sides as compared to the shady sides of the hills. It is therefore advisable, as far as possible, to align the road on the sunny side of the hills. In a similar way, the convenient slopes are available along the river valleys and it is therefore economical to carry the alignment along the river valleys, as far as possible. The hilly areas subjected to heavy winds having velocity exceeding 100 km p.h. should also be located and avoided, as far as possible.

(6) Use of contours: When a virgin hilly area is to be explored, the use of contour maps should also be made. It should always be kept in mind that whatever height has been gained should never be lost. For instances, let us say that a ridge has to be crossed to go to a valley beyond it. It is then essential to touch the most convenient lowest points on the ridge to have the minimum length of road.

Method of surveying For Hill Road

The conventional surveying methods of reconnaissance survey, preliminary survey and final location survey may also be adopted for hilly areas. But they prove to be time consuming, depending on the type

of country and the nature of project. Some other drawbacks of these methods of surveying are as follows:

(1) Delay in work. The surveying work may have to be withheld during rainy or unfavourable climatic conditions.

(2) Details of area. The details to be collected relates to a number of aspects and it is generally found that there is always a possibility of a few details being missed.

(3) Information. The information from maps may only relate to the time or period when the maps were prepared and it is quite likely that considerable changes might have taken place between the time the maps were prepared and the time of carrying out the project. The information as such may not also be comprehensive and lack of comprehensive information may involve a few difficulties at a later stage.

(4) Man-power. These surveys require lot of man-power to work in the field and co-ordination of work in the difficult sections of the whole project is difficult to achieve.

(5) Remote areas. For areas which are inaccessible and remote from habitations, it becomes necessary to establish special camps with facilities of tents, rations for party, guards to protect against wild animals, medical kit, transport arrangements, etc. The quick and most modern method of surveying for hilly areas is the use of aerial photographs. These photographs are obtained by special automatic cameras fitted in the aeroplanes flying at a constant height and they represent the exact images of the objects on the ground.

In fact, there is no chance of any detail being missed when stereo-pairs are viewed through a stereoscope and a model of the ground to the scale of the photographs is prepared for scrutiny. Thus, for reconnaissance survey, the models for possible routes are prepared and they are scrutinized in the office only instead of going to the field. The possible route or routes are decided and for preliminary survey, the best route is decided by low altitude photography with large-scale photographs.

For final location survey, the details may be collected from the field and necessary longitudinal sections and cross-sections may be prepared accordingly. The bench marks are fixed and the centre line is marked by stakes and reference pillars. Necessary hydrological and soil investigations are carried out for the final route before the construction work is commenced.

ALIGNMENT OF HILL ROADS

The success and utility of a **hill or ghat road** depend on its proper alignment. It is, therefore, necessary to exercise great care in fixing the alignment of hill roads. ***A good alignment has the following features:***

(i) It achieves the minimum costs of construction and maintenance.

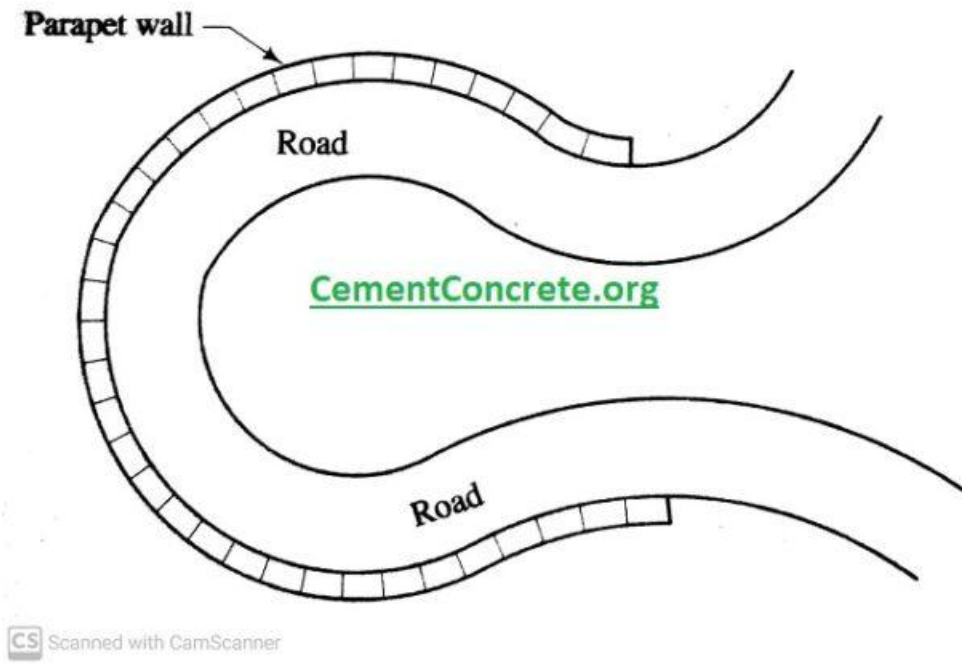
(ii) It allows comfortable travel and the expenditures on motive power, as well as wear and tear of vehicles, are also greatly reduced.

(iii) It contains sharp curves having small radius.

(iv) It gives a stable and safe road.

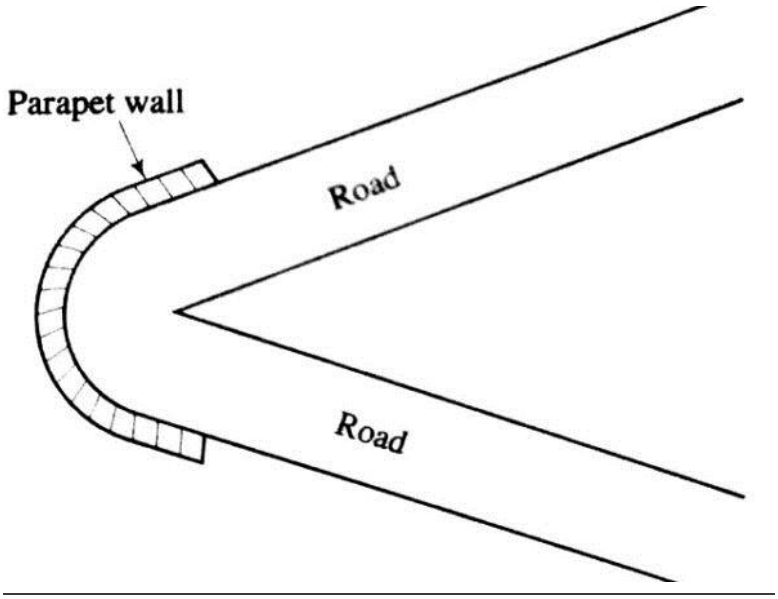
(v) It grants the easiest, shortest, and most economical line of communication between the obligatory points or important centers to be connected by the hill road.

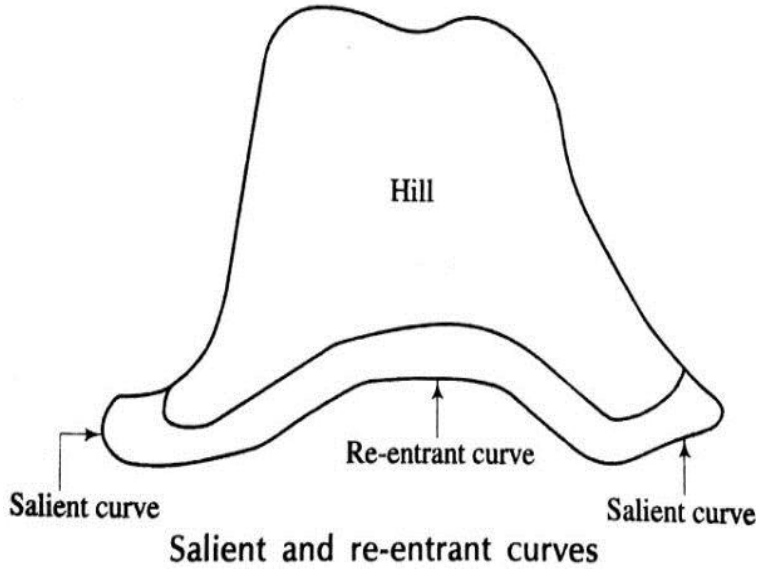
(vi) It has the gradient as easy as possible.



Scanned with CamScanner

In general, it can be stated that the best and most convenient alignment will be the one having the minimum of cutting and filling; and a minimum of walling and bridging. In many cases, the alignment of the hill road contains two types of sharp curves known as hairpin bends and corner bends. Fig. 1 shows the hairpin bend and fig. 2 shows the corner bend.





Salient and re-entrant curves

If the side of hill contains ridges and valleys, it will have to be provided with salient and re-entrant curves. A salient curve is a convex curve with its convexity on the outer edge of the road at the ridge of hillside. A re-entrant curve is a concave curve at the valley of the hillside. Fig. 3 shows the salient and

re-entrant curves. Due to these ridges and valleys, the visibility on a hill road is less and the traffic has to be very careful while negotiating the salient and re-entrant curves in succession. Otherwise, there are chances of fatal accidents to occur at these points. To improve the visibility at a salient curve, some portions of the hill may even be cut down.

GEOMETRIC STANDARDS OF HILL ROADS

The roads in the hilly areas require special attention in fixing up the standards for geometric design because of various factors, such as types of vehicles using the road, total daily tonnage, difficulty in construction, type of surface to be provided, topography of the area, etc.

If the desired geometric standards of a hill road are not permissible due to finance or any other reason, the economy can be achieved in aspects like the width of surfacing which can be improved at a later stage. But it is necessary to comply strictly with the aspects like gradients, curvature, sight distances, etc. which are prohibitive in cost for improvement subsequently.

It is also recommended that at places on a hill road where minimum geometric standards are not provided, proper signs at prominent points should be exhibited to inform the road users well in advance of the reduction in design speed.

The **geometric standards of hill roads** are to be considered with respect to the following aspects:

(1) Widths of carriageway, shoulder, roadway and land

(2) Camber

(3) Stopping sight distance

(4) Overtaking sight distance

(5) Gradients

(6) Super-elevation

(7) Radius of horizontal curve

(8) Widening at curves

(9) Transition curves

(10) Hairpin bends

(11) Cut slopes

12) Setback distance

(13) Passing places

(14) Vertical clearance

(15) Lateral clearance.

(1) Widths of carriageway, shoulder, roadway and land for hill road:

Table 1 shows the widths of the carriageway, shoulder, roadway, and land for different categories of highways. The following points should be noted:

(i) The roadway widths are exclusive of side drains and parapets. These should be considered separately, when necessary.

(ii) In hard rocky stretches, the shoulders may be reduced by 400 mm on either side on two-lane roads and by 200 mm in other cases.

(iii) The minimum setback for building line beyond the right of way should be 5 m in normal cases and 3 m in exceptional circumstances.

(iv) For roads subjected to heavy snowfall, the roadway width may be increased by 1.5 m

Highway Classification	*Carriage width in m*	*Shoulder Width in m*	*Roadway w*
NH and SH or DR			
Single lane	3.75	2 x 1.25	6.25
Double Lane	7.00	2X 0.90	8.80

(2) Camber:

The steeper camber or cross-slope is adopted for hill roads and table 10-2 shows its recommended values. However, if the road has a longitudinal gradient greater than 1 in 20, a flatter camber may be provided.

TABLE 2. CAMBER FOR HILL ROADS

No.	*Type of surface*	*Camber, per*
1	Subgrades, earth roads and shoulders	3.0 to 4.0
2	Gravel and W.B.M. surface	2.5 to 3.0
3	Thin bituminous surfaces	2.5
4	High type bituminous surface and cement concrete surface	2.0

(3) Stopping sight distance for hill roads:

The stopping sight distance (SSD) is calculated from the following expression:

Length of SSD = v2(254 f) + 0.278 Vt

Where,

V = Design speed in km p.h.

t = Total reaction time to be taken as 3 seconds,

f = Coefficient of friction to be assumed as 0.4.

Table 3. shows the values of SSD for various design speeds on hill roads as recommended by the I.R.C.

TABLE 3. VALUES OF SSD FOR HILL ROADS

No.	*SSD in m*	*Design speed in km p.h.*
1	20	20

2	30	25
3	35	30
4	50	40
5	70	50

(4) Overtaking sight distance for Hill roads:

The overtaking sight distance (OSD) is calculated from the following expression:

Length of OSD = $[d_1 + d_2 + d3]$

Where,

= [0.278 V_2t+ (0.278 V2 to + 2 s) + 0.278 Vto]

V = Speed of overtaking vehicle in km p.h.

V2 = (V – 16)

= Speed of overtaken vehicle in km p.h.

t = Reaction time of driver = 2 seconds

s = (0.2 V_2 + 6) Spacing of vehicles

to = (14.4 s/ A)^0.5 = Overtaking time in seconds

A = Acceleration in km p.h./sec. to be taken as 4.72, 4.45 and 4.0 for speeds of 30 km p.h.. 40 km p.h. and 50 km p.h. respectively.

(5) Gradients for Hill roads:

Depending upon the type of terrain and height above mean sea level, suitable values of ruling gradient, limiting gradient and exceptional gradient are to be adopted and grade compensation may be provided on chapter of horizontal curves.

(6) Super-elevation for Hill road:

The super-elevation on hill roads is to be provided by adopting the following formula:

e = V2 /225 R

Where,

e= Rate of super-elevation

V= Design speed in km p.h.

R = Radius of curve in m.

It is recommended that the super-elevation should not exceed 7 per cent in sections of hill roads which get snow bound and 10 per cent in other places.

(7) Radius of horizontal curve for hill road:

The minimum radius of horizontal curve is calculated from the following equation:

$R = 0.008 V^2 / (e + f)$

R = Minimum radius of horizontal curve in m,

V = Design speed in km p.h.

e = Roadway super-elevation to be taken as zero for snow bound area and 0.10 for snow free area

f = Lateral friction to be assumed as 0.15.

(8) Widening at curves in hill road:

The extra width of carriageway required at the curve is calculated from the following expression:

We = (18n / R) + (0.1 V / ÖR)

Where,

We = Extra width in m,

n = Number of lanes,

V = Design speed in km p.h.

R = Radius of curve in m.

(9) Transition curves for hill roads:

The length of transition curve is calculated from the following expression:

Lt = (0.0215 V3) / CR

Where,

Lt = Length of transition curve in m

V = Design speed in km p.h.

R = Radius of circular curve in m

C= 80 /(V + 75) subject to a maximum of 0.76 for speeds less than 30 km p.h. and 0.46 for speeds above 100 km p.h.

(10) Hairpin bends:

A hairpin bend is a sharp curve and it is located on a hill side having the minimum slope and maximum stability. It must also be safe from the viewpoint of landslides and groundwater. For reducing the construction problems and expensive protection works, the hairpin bends should be provided with long arms and farther spacing. A hairpin model is shown in fig1.

A hairpin bend is designed as a circular curve with transition curves at each end. Following are the design standards of a hairpin bend:

1. Minimum design speed 20 km p.h.
2. Minimum radius of the inner curve 14 m.
3. Minimum length of transition curve 15 m.
4. Minimum gradient = 1 in 200.
5. Maximum gradient 1 in 40.
6. Super-elevation in circular portion of the curve = 1 in 10.
7. Minimum width of carriageway at apex of the curve = 11.5 m for NH and SH having two lanes of traffic

= 9 m for NH and SH having one lane of traffic

= 7.5 m for MDR and ODR = 6.5 m for VR.

- Minimum straight length between two successive hairpin bends 60 m.
- The approach gradient should not be steeper than 5 per cent for 40 m.

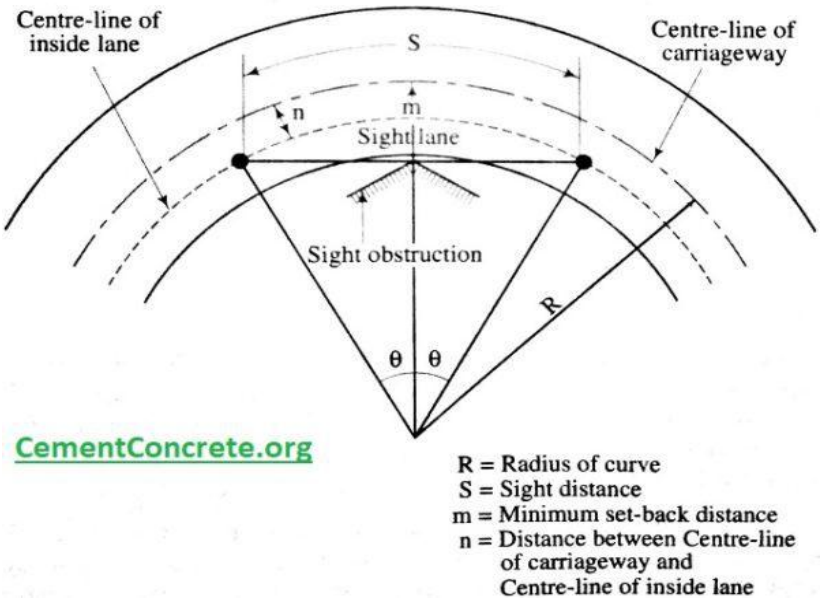
- The island portion of the hairpin bend should be cleared of trees, etc. for good visibility.

(11) Cut slopes:

The detailed investigations are necessary in deep cut and at places where the problem of instability is likely to occur. For hard rock, the side slope is provided nearly vertical or half-tunnelling, if the height of cut exceeds 7.5 m.

(12) Setback distance for hill road:

It is not practicable to provide clear visibility corresponding to overtaking sight distance all along the hill road. Hence the alignment is made in such a way that at least the safe stopping distance is provided. For this purpose, the setback is given and the LRC has specified the minimum setback distances from center-line of the inner side of horizontal curves for various speeds and radii of curves corresponding to the stopping sight distance.



The back distance is calculated from the following equation:

$m = R - (R-n)\cos\theta$ (Ref. fig. 4)

where,

$\theta = S / (2 (R-n))$ radians

m = the minimum set-back distance from the centre-line of the road to sight obstruction in metres at the middle of the curve.

R= radius of centre-line of the road in metres

n = distance between the centre-line of the road and the inside lane in metres

S = sight distance in metres.

For applying the above relationship, sight distance is measured along the middle of inner lane. However on single-lane roads, sight distance is measured along centre-line of the carriageway and 'n" is taken as zero.

R = Radius of curve

S= sight distance

m = minimum set back distance.

n = distance between centre-line of carriageway and centre-line of inside lane.

(13) Passing places.

In order to pass a vehicle against a convoy and to toe aside the disabled vehicle, the passing places are to be provided on the hill roads. There should be two passing places in every kilometer length of road and the dimensions of the passing place should be as follows:

Length on the inside edge … 30 m

Length on the outside edge … 15 m

Width …….. 3.75 m

(14) Vertical clearance.

The minimum vertical clearance of 5 m should be ensured for overhanging cliff or any structure coming above the road. The vertical clearance should be measured from the highest point of the carriageway, i.e., the crown of the super elevated edge of the carriageway or as the case may be.

(15) Lateral clearance:

The full roadway width at the approaches should be carried through the underpass. It means that the minimum lateral clearance (ie., the distance between the extreme edge of the carriageway and the face of nearest support whether a solid abutment, pier or column) should be equal to the normal shoulder width. In low category hill roads having narrow shoulders, it is desirable to increase the roadway width at the underpasses.

PROTECTIVE WORKS FOR HILL ROADS

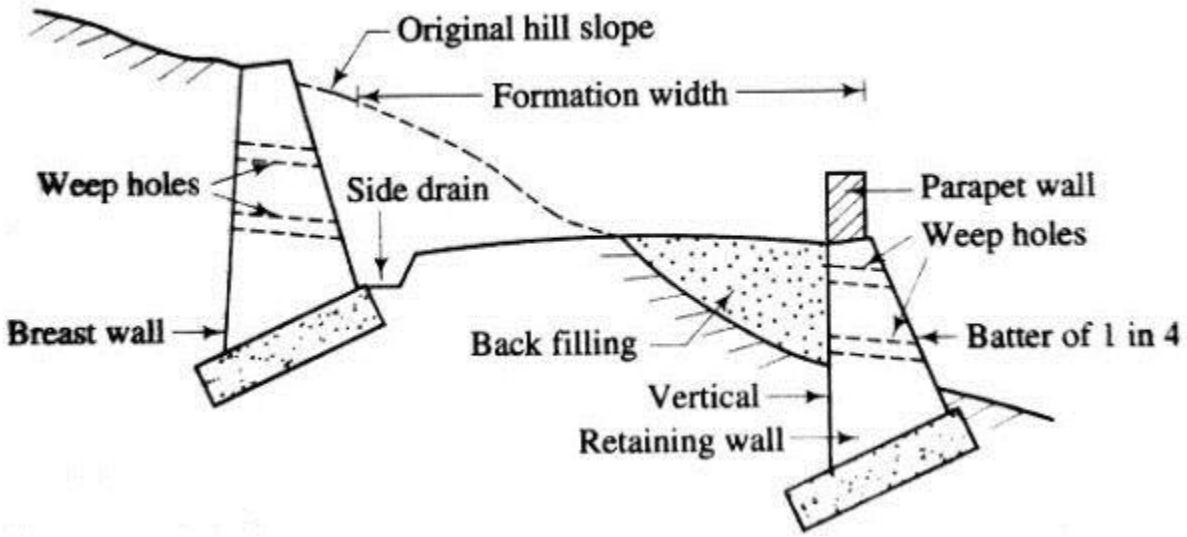
In order to give stability and a sense of safety to the hill roads, the following three types of protective works are provided:

(1) Retaining walls

(2) Breast walls

(3) Parapet walls.

- *Retaining walls:*



The formation of a hill road is generally prepared by the excavation of the hill and the material which is excavated is dumped or stacked along the cut portion. The retaining wall is constructed on the valley side of the roadway to prevent the sliding of backfilling as shown in fig.5. Thus the main function of a retaining wall for hill roads is to retain the back filling and it is provided at the following places:

- at all re-entrant curves;
- at places where the hill section is partly in cutting and partly in embankment; and
- at places where the road crosses drainage.

Where stones are economically and easily available, it is customary to construct the retaining walls in dry stone masonry as it permits easy drainage of seeping water. The design of retaining walls is based on rules-of-thumb and the performances of similar existing retaining walls. The minimum width of 600 mm is kept at the top. The rear side is kept vertical. The front side is provided with a batter of 1 in 4. If the height of the retaining wall exceeds 6 m or so, the bands of coursed *rubble masonry* in cement mortar at vertical and horizontal intervals of about 3 m are constructed to grant additional stability to the wall.

To facilitate the drainage of the water behind the retaining wall, suitable weep holes at vertical height of 1 m and horizontal spacing of 1.2 m are provided with slope outwards.

- ***Breast walls:***

The cut portion of hill is to be prevented from sliding and the wall which is constructed for this purpose is known as breast wall. See fig. 5. The breast walls are provided with a front batter of 1 in 2 and a back batter of 1 in 3. The back batter may be provided either in one straight batter or in the form of projections. If the height of the wall is less than 2 m, the entire section is made in random rubble stone masonry. If the height of wall exceeds 2 m, the top portion of 2 m height alone is made in random rubble masonry and the remaining portion is constructed in cement mortar of proportion (1:6).

The weep holes, as in case of retaining walls, are provided with slope outwards and sometimes, the vertical gutters connecting the weep holes to the side drain are provided.

- ***Parapet walls:***

The parapet walls are usually provided all along the valley side of the road except where the hill slope is very gentle. They are constructed immediately above the retaining wall, as shown in fig.5 and they prevent the wheels of the vehicles from coming on the retaining wall. It is to be noted that the construction of a parapet wall merely gives a sense of security to the driver and the passengers and it is very rare unless constructed in stone masonry with cement mortar that they act as protecting structures in the event of an accident.

The parapet walls are usually of wall type with uniform thickness of 600 mm and height of 600 mm above the berm level. They can also be constructed of R.C.C. posts of 150 mm x 150 mm section with 1 m height above ground level and 450 mm below ground level and spaced at 1 m centre to centre. In case of hard rocky stratum, the parapet walls may be replaced by the railing of cast-iron.

DRAINAGE IN HILL ROADS

The rain falls very heavily on the hills and as the slopes of hills are quite steep, the water reaches the roadside very quickly and creates drainage problems. The water thus collected should be disposed-off in a proper way through the well-planned and designed drainage system.

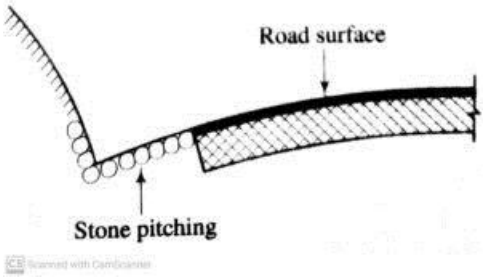
Related Article: Subsurface drainage system for Road (Highway): methods, diagram, filter design & control

(1) Sub-surface drainage:

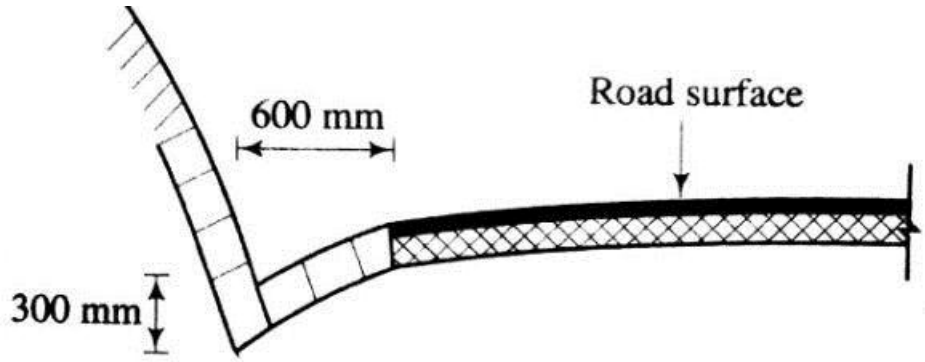
The seepage flow of water on hills creates problems during and after monsoons. The level of seepage water may be at, above, or below the road level depending upon several factors such as depth of hard stratum and its inclination, the quantity of underground flow of water, etc. The seepage flow also causes the weakening of the roadbed and the pavement and it also causes problems of slope stability. It is, therefore, necessary to control the seepage flow by adopting the suitable method of the sub-surface drainage system.

(2) Surface drainage:

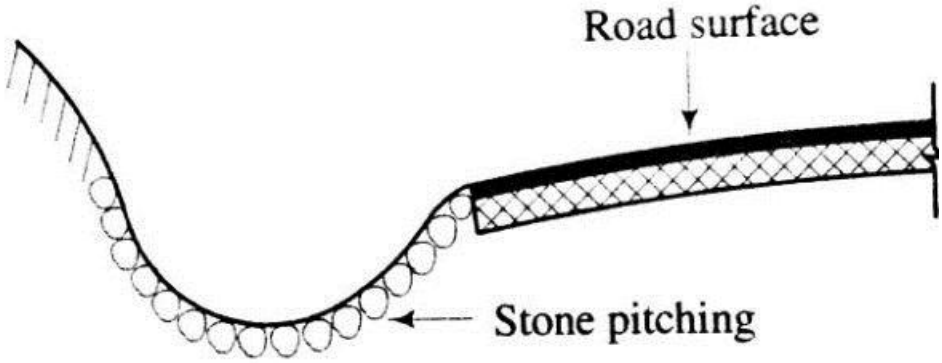
For carrying the surface water, the side drains are provided only on the hill side of the road, as shown in fig. 5. There is limitation in the formation width of road and hence, these drains are constructed of such a shape that the vehicles could utilize the space of side drains in case of an emergency for crossing or parking. The side drains are usually of the following three types:



Scanned with CamScanner



Scanned with CamScanner



In order to prevent the side drains from overloading and thereby causing the road surface flooding, the following two measures are taken:

- provision of catch water drain or intercepting ditch above the side drain; and
- suitable cross-drainage work to divert the water through the road on downside of the hill.

MAINTENANCE OF HILL ROADS

The hill roads because of their peculiar location require careful attention in their maintenance. For the purpose of convenience, the maintenance problems of the hill roads can be grouped into the following four categories:

(1) Control of avalanches

(2) Drainage structures

(3) Prevention of land slides

(4) Snow clearance.

Each of the above category will now be briefly described.

- **Control of avalanches:**

An avalanche indicates a large mass of loosened snow, earth, rocks, etc. which suddenly and swiftly slides down a hill. Where there are chances for an avalanche to occur, suitable remedial measures may be adopted so that minimum damage occurs to the road structures. One of such preventive measure which is commonly adopted is the construction of galleries above the road which permit the avalanche to slide over the gallery roof without inducing impact loads.

- ***Drainage structures:***

The drainage structures such as catch water drains, catch pits, side drains and culverts are to be periodically inspected and cleaned off all the debris and blockages which prevent the smooth flowing of water in such structures during rains.

As a precautionary measure, the upper slopes are planted with trees to reduce considerably scouring action of unstable ground due to rains.

- *Prevention of land slides:*

The term land slide is used to indicate the downward and outward movement of slope-forming materials composed of natural rock soils, artificial fills or combinations thereof. The landslides move along the surface of separation by falling, sliding and flowing.

When the shear stresses exceed the shear strength of the soil, the movement in the form of land slide occurs. Hence, anything which contributes towards a decrease in shear strength of the soll or an increase in the shear stress can cause a land slide.

The decrease in shear strength of the soil takes place mainly due to the following causes:

- decrease in inter-granular pressure;
- formation of faults in bedding planes of strata:
- hair-cracking due to alternate swelling and shrinkage of the soil structure;
- increase in water content and consequent swelling and increase in pore water pressure;
- seepage pressure of percolating ground water; etc.

The increase in the shear stress takes place mainly due to the following causes:

(i) external loads due to traffic:

(ii) increase in water or moisture content;

(iii increase in weight due to accumulation of snow:

(iv) removal of part of mass of excavation or removal of retaining wall or increase in slope angle: (v) shocks and vibrations due to earthquakes or blasting;

(v) undermining due to excavation or erosion; etc.

For prevention and correction of land slides, the commonly adopted techniques are as follows:

- construction of buttress at toe and providing suitable retaining structures;
- effective drainage measures to intercept and divert water:
- (iii) relocation or changing the position of the highway:
- (iv) slope treatment to minimise the erosion and to improve the stability conditions; etc.

Road Drainage

Necessity of road drainage work,

1. Variation of the moisture content in the soil causes variation in the volume of sub-grade and leads to the failure of the road pavement.

2. Excess moisture content in soil sub-grade causes a substantial reduction in its stability.

3. If the stability of the soil sub-grade fails due to poor drainage, the pavement structure is likely to fail due to sub-grade failure.

4. The entrance of water causes a reduction in the bearing capacity of soil sub-grades like WBM and stabilized soil.

5. The stagnation of water on the surface of the pavement reduces the strength of the pavement.

6. Due to poor drainage, waves and corrugations are formed in the flexible pavement which causes failure of the pavement.

7. Due to poor drainage of the road, water remains in contact with the bituminous material for a longer time causing the stripping of bitumen from aggregates and the formation of potholes.

8. In rigid pavements failure occurs by mud pumping due to the presence of water in fine sub-grade soil.

9. Poor and improper surface drainage work causes erosion of soil from the top of the un-surfaced road, slopes, hill side, etc.

cross drainage works

Cross drainage works is a structure constructed when there is a crossing of canal and natural drain, to prevent the drain water from mixing into canal water. This type of structure is costlier one and needs to be avoided as much as possible. Cross drainage works can be avoided in two ways:

- By changing the alignment of canal water way
- By mixing two or three streams into one and only one cross drainage work to be constructed, making the structure economical.

Types of Cross Drainage works:

There are three types of cross drainage works structures:

Type – 1: Cross drainage work carrying canal over the drain

The structures falling under this type are

- Aqueduct
- Syphon Aqueduct

Type – 2: Cross Drainage work carrying Drainage over the canal

The structures falling under this type are

- Super passage
- Canal Syphon

Type –3: Cross drainage works admitting canal water into the canal

The structures falling under this type are

- Level Crossing
- Canal inlets

Type – 1: Canal over drainage [HFL < FSL]

Aqueduct:

In an aqueduct, the canal bed level is above the drainage bed level so canal is to be constructed above drainage. A canal trough is to be constructed in which canal water flows from upstream to downstream. This canal trough is to be rested on number of piers. The drained water flows through these piers upstream to downstream. The canal water level is referred as full supply level (FSL) and drainage water level is referred as high flood level (HFL). The HFL is below the canal bed level. Aqueduct is similar to a bridge, instead of roadway or railway, canal water are carried in the trough and below that the drainage water flows under gravity and possessing atmospheric pressure.

Syphon Aqueduct:

In a syphon aqueduct, canal water is carrier above the drainage but the high flood level (HFL) of drainage is above the canal trough. The drainage water flows under syphonic action and there is no presence of atmospheric pressure in the natural drain. The construction of the syphon aqueduct structure is such that, the flooring of drain is depressed downwards by constructing a vertical drop weir

to discharge high flow drain water through the depressed concrete floor. Syphonic aqueducts are more often constructed and better preferred than simple Aqueduct, though costlier.

The road drainage system is used for the removal and disposal of water from the surface as well as subsurface water. It maintains the stability and durability of the road, by keeping it dry as possible. The longer water sits on a surface, the more susceptible it is to contamination. The installation of suitable surface and sub-surface drainage systems is an essential part of highway design and construction.

Sources of water ingress on roads;

- Capillary action of water
- Rainwater falling on the road surface
- Water accumulated from the surrounding area
- Sub-soil water collection

Why do we need road drainage?

Road drainage systems are installed to capture surface water run-off to alleviate flooding and protect the surface and sub-surface of the road. It is required for the following reasons:

- Prevent flooding, ponding and seepage
- Keep the carriageway, cycleway and footway free of water
- Keep the underlying road structure as dry as possible.
- Prevent damage caused by hazardous surface water
- Stopping surface water flooding adjacent properties

Defects caused due to improper road drainage

The improper highway drainage leads to the deterioration of the road in the form of the following defects:

- The formation of erosion, causing disembarkment along the roadsides
- Dislocation of pavement edge due to the presence of excess water.
- Stripping of bitumen from aggregates like loosening or detachment of some of the bituminous pavement layers

- Formation of potholes
- Failure of soil slopes because excess moisture causes an increase in weight and
- Formation of waves and corrugations in flexible pavements.
- Softening of subgrade soil bearing capacity
- Reduction in soil mass
- Shoulders are pavement edge distress

Requirements of Road Drainage System

Following are the essential requirements of a good highway drainage system:

1. The surface water from the carriageway and shoulder should effectively be drained off
2. The surface water from the adjoining land should be prevented from entering the roadway.
3. The side drain should have sufficient capacity and longitudinal slope to carry away all the surface water collected from the roadway.
4. The flow of surface water across the road and shoulders and along slopes should not cause erosion or form cross ruts
5. Seepage and other sources of underground water should be effectively intercepted and drained off
6. In water-logged areas, special precautions should be taken
7. The road surface should be provided with suitable camber to drain off quickly

Types of Road Drainage System;

There are many different types of drainage systems with different design features and attributes that can be used to manage flows and treat water quality. Each of them is discussed below;

1. Surface drainage system

Surface drainage system refers to the drainage wherein surface water is collected and disposed of. It is useful to carry rainwater away from the carriageway. It is applicable in heavy rainfall areas. The water in this drainage system is removed by providing a camber and cross slope to the pavement. The camber and slope depend upon the type of pavement and the intensity of rainfall. This type of drainage system prevents the infiltration of rainwater. includes interception and diversion of water from the road surface. Different types of drainage used for surface drainage systems are;

1- Closed drains

They vary in size and length and can be categorised as:

- Drains provided with gratings
- Jelly drains

2- Ditches or open drains

They vary in size and length and can be categorised as:

- Shallow surface drains
- Medium-sized drains

3- Side drains

4- Catch basins

5- Inlets

2. Subsurface drainage system

Subsurface drainage is used to remove water that has infiltrated into the soil in excess of the amount. It is useful to carry ground water away from the subsoil. It is feasible in water-logging areas. This type of drainage system helps to keep the pavement layers in dry conditions by avoiding a rise in the groundwater table. Different types of drainage used for surface drainage systems are;

- Subgrade Drain
- Longitudinal Drain Trenches
- Subsurface pipes
- Interceptor drains

3. Cross drainage system

Cross drainage is provided whenever streams have to cross the roadway facility. The water from the side drains is also often taken across these structures to divert the water away from the road to a water

course or a valley. 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:

- Box Culverts
- Aqueduct
- Syphon Aqueduct
- Super passage
- Canal Syphon
- Level Crossing
- Canal Inlets and Outlets
- Minor and major bridges
- Causeways

Typical details of side drains

These are **typically constructed along the side of contour paths in upland areas, or along sunken paths where water cannot easily be drained away from the path**. They intercept surface and sub-surface flow

function of side drain

The side drain should have sufficient capacity and longitudinal slope to **carry away all the surface water collected from the roadway**. The flow of surface water across the road and shoulders and along slopes should not cause erosion or form cross ruts .

, side ditches for surface drainage,

Surface drainage works are used to collect and direct surface runoff in a controlled manner, to minimize the quantity of surface water flowing into actually or potentially unstable slopes.

Surface drainage works are especially important at the head of the slope to intercept the run-off and reduce the surface water flowing downstream across the face of the slope. This may be achieved by open ditches at the head of the slope.

Ditches on the main landslide body are used to dispose of local surface runoff and any water arising from deep drainage works.

Different types of ditches are used to drain surface runoff. The cross-section of ditches is usually trapezoidal, although small ones may be V or U-shaped or semicircular; their dimensions vary according to the expected runoff, the need for open water storage, the risk of bank erosion, the need to accommodate the transit of construction or maintenance equipment and the available means for maintenance

Ditch gradient should be at least 2% to ensure rapid flow away from the potentially unstable areas and to promote self cleaning from any windblown or other debris that would tend to accumulate, causing local blockage and spillage.

Ditches should be lined to minimize erosion and uncontrolled infiltration. The lining may consist of cast-in-place or prefabricated concrete, pitched stone (Figure 3), rip rap, gabion mattresses or baskets, speciality geotextiles or geocomposites, zinc coated steel or PVC half-pipes. Flexible, self-healing lining or pipes should be used in areas susceptible to cracking and movements.

Where permeable linings are used, this should be in association with an impermeable geomembrane to minimize infiltration. Geomembranes may also be used by themselves for temporary or emergency applications, but they are easily damaged by wind and direct sunlight and should not normally be used by themselves for permnnent applications.

Techniques must be adapted to ground conditions and local technology; an example is provided by Anderson and Holcombe (2004; 2008) who describe the development and application at community level of good drainage practices with locally available, affordable technologies in St Lucia, West Indies, consisting of ditches lined with a specialised plastic, held in place by a wire mesh

Design methods

Ditches must have enough capacity to transport the drainage water in wet period; however they are sometimes made wider than needed in order to create more storage in the open water system. Such temporary storage is a good way of diminishing the peak outflow from the area, as occurs after heavy rains. Thus it reduces the required capacity of downstream constructions, such as the larger watercourses, culverts and pumpung stations.

Ditches are often relatively unaccessible and may receive less maintenance than would be appropriate. Accordingly, it is advisable to design them with a generous freebord to minimize the risk of blockage and spilling.

Steps or other energy dissipation systems should be used on and at the toe of steep sections, to prevent excessive flow speeds and the resulting erosion.

Intercepting drains

An interceptor drain, also known as a curtain drain, is a drainage system that is installed to collect, channel and remove surface and subsurface water within permeable soil as it flows across an impermeable soil layer.

A drain interceptor is **a tank installed within pipework to collect and hold contaminants, allowing the remaining wastewater to be discharged safely into the main sewerage system**. Drainage interceptors are referred to by other names, including interceptor traps, interceptor tanks, and filter tanks.

There are two types of subsurface drains: relief drains and interceptor drains. Relief drains are used to de-water an area where the water table is high. They are placed in a gridiron, herringbone, or random pattern. Interceptor drains are used to remove water where soils are excessively wet or subject to slippage .

, pipe drains in hill roads,

Longitudinal Drains (L-Drains) and Cross Drains :

In addition to longitudinal drains, Cross drains (C-drains) or transverse drains consisting porous pipes or perforated pipes are laid cross from the center of the road and opened to the L-drains with slope of 1 in 50. The diameter of C-drains varies from 60 to 100 mm.

The cross-drainage works are in the form of **culverts, scuppers or causeways**. They are constructed under the road and usually at right angle to it. For collecting the stones and debris and for preventing scour, the catch pits may be provided at the head of small cross drains.

CHAPTER–7

Road Maintenance

Highway (road) maintenance is defined as preserving and keeping the serviceable conditions highway as normal as possible and practicable. The main objectives of road maintenance men are the allocation of available maintenance resources according to actual needs and priorities. If the maintenance works are not done at all or done faulty or the pavement structure inadequate for present-day and loading.

Types of Failures in Flexible Pavements and their Repair Techniques

In general, the flexible pavement consists of the following component layers:

- Sub-grade
- Sub-base course
- Base Course
- Surface Course

Instability in any of the layers will result in the complete failure of the pavement system. This makes it necessary to construct each layer with utmost care and precision. There are different types of failures in flexible pavements. Determination of this failure and its reasons is necessary to facilitate correction in mix design and construction for the future projects.

Types of Failures in Flexible Pavements due to Exposure

The exposure that affects the flexible pavements adversely are:

Weather conditions

Change in weathers imposes distress in flexible pavements.

Use of chemical and salts in colder climates

The frost heave and the stripping of asphalt due to snow and ice will result in potholes and other distress.

Ultraviolet rays

The ultraviolet rays make the pavement to undergo oxidation and bring it to a brittle state. On a hot sunny day, the pavement temperature can be up to 140 degree Celsius. This is the softening point of liquid asphalt. This will make the pavement to expand and move. The reduction of temperature will make the pavement to contract. This expansion and contraction are the main reason for initial cracking.

Water (natural rain and irrigation)

Through the cracks, water can enter to the base and the subgrade, which will result in the structural damage

Vehicle loads and petroleum

The fuel spillage coming from the vehicles deteriorates the integrity of the pavement. This increase the softening point of the binder. A parked vehicle has chances to leak gasoline or brake fluid that make the asphalt to liquefy. This makes the binder to separate from the rock that may create softer areas. Hence sudden treatment of oil spots on parking area should not be ignored.

Aging of Flexible Pavements

Aging is a life cycle deterioration of the pavement. This results in highly accelerated oxidation and cracks formation. Small deterioration determined at the initial stages will help in reducing the intensity of the aging effect. As the exposure to temperature and ultraviolet increases the rate of deterioration.

Types of Failures in Flexible Pavements due to Distress

The distress faced by the pavement can be of two types:

- Environmental distress, and
- Structural distress

Environmental Distress in Flexible Pavements

The outside influence that affects the pavement performance are categorized under environmental factors. These include snow, the chemicals, water and problems with aging. These types of distress are observed from the top down. The remedy for such problems is a surface application. These include crack sealing, seal coating, chip seals, skin-parching. In certain situations, a hot mixed overlay is added to the surface as part of treatment.

Structural Distress in Flexible Pavements

The structural are categorized as the physical failures that are found on the pavement and the sub-base. These structural failures are occurred due to overloading, wet subgrade, frosting effect or lower standards of design. This kind of distress is found from bottom up. The only remedy for these

is removal and their replacement, mentioned as (R & R) of the area that is affected. Or repaving that includes total removal, milling, pulverizing the area and then paving back.

Types of Failures in Flexible Pavements due to Structural Distresses

Some of the structural distresses which can cause failures in flexible pavements are:

1. Alligator Cracking of Flexible Pavements

Alligator cracks are also called as map cracking. This is a fatigue failure caused in the asphalt concrete. A series of interconnected cracks are observed due to such distress. The tensile stress is maximum at the asphalt surface (base). This is the position where the cracks are formed, i.e. the area with maximum tensile stress. A parallel of longitudinal cracks will propagate with time and reaches the surface. Repeated loading and stress concentration will help the individual cracks to get connected. These will resemble as a chicken wire or similar to the alligator skin. This is termed as the alligator cracking. It is also known as the crocodile cracking. These cracking is observed only in areas that have repeated traffic loading. Alligator cracking is one of the major structural distress. This distress is later accompanied by rutting. The figure-1 below shows alligator cracks formed in the pavement.

2. Depressions in Flexible Pavements

There are certain areas in the pavement that are localized and have a lower elevation compared to the surrounding pavement level. These lowering are depressions found on the pavement. They are mainly noticed only when they are filled with water (After rain). Depressions in flexible pavements are a very common distress found in parking lot construction as well as in overlays. These depressions can be caused either by the foundation soil settlement due to continuous loading or it can be formed during the construction. There are different severity levels that are considered for the depression in the flexible pavement that is constructed for airfield purposes.

3. Corrugations in Flexible Pavements

The corrugations are distress seen in the pavement at regular intervals in the form of ridges and valleys. These are usually less than 5 feet, along with the direction of the pavement. The ridges form of corrugations will be perpendicular to the traffic direction. Unstable pavement plus traffic will create such distress. Where the traffic starts and stops, this distress are observed.

4. Shoving

A form of plastic movement that is seen in the form of the wave is called as shoving distress. These are also observed perpendicular to the direction of the traffic.

5. Potholes

In road surfaces where a portion of the same has broken away, cause a disruption by forming a pothole. These are also called as a kettle. In the Western United States, these are known as chuckhole. The pavement fatigue is the main reason behind the formation of potholes. The occurrence of fatigue cracking will interlock to form alligator cracking. These chunks between the cracks formed in the pavement will become loose and will be picked out under continuous loading and stresses. This will leave a pothole on the pavement. 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. Once the pothole is formed, the distress grows resulting in the continuous removal of pavement chunks. Water entrapped will increase this rate of expansion of distress. The pothole can expand to several feet in width. They don't develop too much in depth. The vehicle tires are damaged due to large potholes.

6. Rutting of Flexible Pavements

The depression formed in the surface is called the rutting. This is formed in the wheel path surface. This depression will make the other sides of the wheel to undergo uplift as shown in the figure-6. This pavement uplift is also called as shearing. These ruts like depressions are evident after rain. Where these depressions would be filled with water. There are two types of rutting that can occur;

- Pavement Rutting
- Subgrade Rutting

7. Swelling of Flexible Pavements

These are distress that long and gradual wave. These can be ten feet long. The swelling distress is characterized by the upward bulge in the pavement surface. Surface cracking is the next series of distress that is seen after swelling. The main reason behind swelling in flexible pavement is the frost action in the subgrade. Where frosting results in the swelling of the soil.

Environmental Distresses

1. Bleeding in Flexible Pavements

The phenomenon of formation of a film of asphalt binder over the surface of the pavement surface is called as bleeding. The occurrence of bleeding will give a shiny glass like reflecting surface. The layer will have bubbles which are seen as blisters. The asphalt binder formed will be sticky in nature. The filling of asphalt binder into the aggregate voids during hot weather conditions and their expansion in later situations will result in bleeding. As the process of bleeding cannot be reverted in cold temperatures, they remain on the top of the pavement as such. The bleeding can be caused due to the following factors:

- Excessive asphalt binder in the mix

- Excessive application of the binder during surface treatment
- Lower air void content - no adequate voids for the bitumen to penetrate

2. Block Cracking in Flexible Pavements

This is also called as thermal cracking. The cracking is happening in the form of blocks. These cracks are interconnected making the pavement to divide into rectangular pieces (almost rectangular). The size of each rectangle may vary from one foot by one foot to ten foot by ten foot. This is spread over a wide pavement area. But these are observed in areas of no traffic. This is an after effect of environmental exposure, hence it is called thermal cracking. The temperature effects and aging are the possible reasons.

3. Bumps and Sags

Pavement surface that is localized, small in area that has undergone an upward displacement will be named as bumps. These are caused due to the instability factor of pavement. Several factors contribute to bumping formation. They can be caused even due to buckling or the bulging of the concrete slabs. Areas, where an asphalt pavement is laid over a concrete pavement, observes such failures. Another contribution to bumps are the frost heaves that creates bumps due to expansion. Oxidation will result in the spelling of the crack edges. Any plant roots growing under the pavement too can cause bumps in the pavement. The sags are mainly caused due to the settlement or the displacement of the pavement surface. Sags are small, abrupt and localized. Large or long dips in the pavement can be created by the sags.

4. Edge Cracking in Flexible Pavements

In unconfined asphalt pavements, edge cracking is found to occur. During the compaction process of the pavement, the edges will start to yield, especially when there is no sort of confinement like curbs or edge barriers. The edges will yield with age, undergo oxidation and becomes brittle. The edge cracking is observed in the shape of 'C' formed along the edges of the street, parking lot or the roads.

5. Joint Reflection Cracking

These are cracks that are observed in the flexible overlay over a rigid pavement. The rigid pavement joints that are an underlying experience these cracks.

6. Raveling

The dislodgement of aggregate particles will result in the disintegration of the hot mixed asphalt progressively from the surface to downward direction. This failure is called as raveling. This dislodgement is the loss of bonding between the aggregate particles and the asphalt binder. The aggregates are sometimes coated with dust particles that result in lack of bonding. This will make the aggregate to bind with the dust rather than the binder.

7. Cold Joints in Flexible Pavements

These are longitudinal joints which are formed in the asphalt pavement. This failure occurs when a hot mix asphalt is poured adjacent to an existing pavement. This kind of failure is mainly common in

parking lots, inverted crowns and areas with lower traffic. The difference in temperature and the plasticity variation will bring a different between the two layers. This will cause a longitudinal joint to occur between the asphalt mats that are laid. The longitudinal joint possesses a lesser density compared to other pavements. These longitudinal joints called the cold joint, with time will let intrusion of water. It increases the roughness and hence limits the life of the pavement.

Longitudinal and Transverse Cracking Distress

This distress can be considered as either a structural or an environmental distress. The longitudinal cracks are formed parallel to the pavement alignment or the center line of the pavement.

Maintenance of bituminous road such as patch work and resurfacing

Edges of patch holes are thoroughly cleaned after cutting. Then cement grouting is done on the sides of each patch holes. Then the cement concrete is placed and compacted into the patch hole. After this the surface of patches are kept under water for better curing.

lassification of the Road Maintenance Operation :

Maintenance operation of highways are generally classified into 3 parts :

- Periodic and Routine Repairs
- Special Repairs
- Resurfacing

1. Periodic / Routine Repairs :

Through repairs or day-to-day repairs which are done properly to the road pavements are known as periodic or routine repairs. These are generally carried out to low cost roads.

Routine repairs are generally done by the departmental labours, whereas the periodic repairs are carried out by contractors which are invited at specific intervals.

2. Special Repairs :

Special problems need special solutions. Hence special repairs are carried out to overcome some serious special problems, so that the road may not get worsen in future.

These repairs are generally carried out for high class roads. These kind of repairs are difficult to carry out hence skilled labours are required.

3. Resurfacing :

When the surface dressing of the pavement is renewed which was severely damaged it is called as resurfacing. It is usually done for bituminous roads.

Maintenance of W.B.M Roads

WBM means water bound macadam roads. WBM roads are rapidly damaged because of heavy traffic and variation in climatic conditions. Hence the maintenance of such roads is much essential so as to keep the roads in serviceable conditions for longer time.
The maintenance operation of wbm roads is generally divided into 2 parts

- Day-to-Day Maintenance
- Periodic Maintenance

1. Day to Day Maintenance :

Due to heavy mixed traffic and change in climatic condition, pot holes appears on the road surface and it becomes much essential to do the patch work to the pot poles. In short, day to day maintenance involves the patch work to the pot holes.

2. Through Maintenance :

A. Rut filling

When deep and clear ruts are formed the these ruts are filled by the greater size of patch work with respect to the pavement which is in good condition.

In rut filling process, continuous trenches with vertical sides are excavated then road metal is filled in trenches and compacted and these surface is then finished to the pavement which is in good condition.

B.Treatment to the corrugations :

If the corrugations are formed on the surface of W.B.M road, then excess binding material is removed.

C. Re-surfacing :

When the surfacing becomes rough and weaved out then re-surfacing is preferably done to the pavement of W.B.M. In the process of re-surfacing, the surface is picked upto the affected depth with the help of pick-axes.

The road metal retained on 20 mm sieve is then spread, hand packed and rolled and surface is finished.

3. Renewal :

When the surface is worn out to the greater extent and road cannot be maintained by patch work, then renewal of WBM roads is essential. At the time of renewal of WBM road, the whole surface should be scarified ,upto the total depth by means of pick-axes.

The scarified surface of WBM should be well rolled. A mixture of fresh and screened metal is then applied on the rolled surface.

At the time at renewal of WBM road, the traffic can be continued and undisturbed by using temporarily shoulders as a diversion road.

Maintenance of Bituminous Road

Bituminous roads are most commonly adopted roads. It consist of flexible type of pavement. Following maintenance is commonly requires for bituminous roads.

1. Patching Pot Holes :

It comes under the part of day to day repairs. Due to heavy traffic, variation in climatic condition, variety of traffic and improper quality, the pot holes are developed on the surface of the road and has to be treated.

In case process of patching the pot holes , the pot jokes are first cut square or rectangular in shape upto the required depth. The holes are cleaned and broomed properly and a suitable tack coat or bitumen coat is applied.

Then usually a premixed patching mix is placed in the holes with the help of crow bars and the surface is rammed and rolled. The finished surface or the pot holes is kept slightly above the normal surface for compaction under traffic. In cold weather, cut back or emulsions are used as a refilling materials to repair the pot holes.

2. Patching Ruts :

The longitudinal depression or cuts formed in flexible pavement are known as ruts.

In the process of patching ruts, a continuous trenches are dug so as to enclose the ruts which becomes a solid foundation for the patch. Then patch work is further carried out as it is done in pot holes.

3.Patching Corrugations :

The corrugations are set up in case of bituminous roads due to bleeding which is normally happened in the summer. This can be repaired by cutting the crests or high ridges of corrugations.
Upto the small depth of depressions which are further cleaned, painted and filled up with the premix material.

4 . Base Repairs :

This repairs comes under the part of through maintenance in which cause of defect is first rectified and then necessary treatment is decided. If it is found that the particular defect is due to insufficient thickness of the base course, then it is repaired or corrected by providing the additional surface thickness.

In case of base repairs, the old surface of the base is first loosened by scarifying it to the full depth The old metal is screened and can be used in the bottom of base.

Then new base is prepared in layers not more than 75 mm in thickness and further covered with the surface finish

5. Surface Treatment :

Bleeding of bituminous surface is treated as soon as it appears bleeding treated by providing the layer of blotting material. Such as aggregate chippings or coarse sand and rolling is done if necessary.

A renewal coat or seal coat is applied when the cracks are set up on the road surface.

6. Re-surfacing :

The process of renewal or surface dressing of the pavement which is severely damaged or after it useful life is known as resurfacing.

If the existing wearing course a bituminous road is near about or completely worn out, then it becomes unfit for traffic and then it becomes essential to resurface the road entirely.

In the process of re-surfacing, the existing surface is repaired by suitable patching. A light tack coat is then applied over the surface and surface dressing is done.

Chapter-8

Construction equipments

Hot mixing plant-

Hot mix plants are used mostly for road construction. The cold aggregate mixer is used to spread and create the base and minimum level of a road; meanwhile, the hot aggregate is used to create the final layer of the road. Construction equipment manufacturers create two types of mobile asphalt hot mix plants.

Everything You Need to Know About Hot Mix Plants

- Asphalt Mixing Plant (1)
- Batching Plants (2)
- Concrete Plant (3)
- Road Construction (6)
- Wet Mix Macadam (3)

Tipper-

Tippers are used for the transport of all these materials in road construction (road-site to dump and burrow or plant to road-site). In dams, hydropower projects and canal work, nature of work involved is essentially removal and relocation of earth on the sites to obtain the desired profile.

A tipper truck, also commonly known as a dump truck, is a heavy goods vehicle with a tipper body on the rear. Their ability to carry heavy loads makes them widely used on construction sites to quickly, efficiently and safely transport various materials.

tractors (wheel and crawler)

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.

, **bulldozer-**

Bulldozers are used for shallow digging and ditching; short-range transportation of material; spreading soil dumped from trucks; rough grading; removing trees, stumps, and boulders; and cleaning and leveling around loading equipment.

Dozers are used in construction projects, mines, agriculture and forestry. Its tracks and low center of gravity **provides traction and stability on slopes and unstable surfaces**. This also increases the transfer of power to the ground.

Bulldozer types: **wheel dozer, crawler bulldozer and mini bulldozer**. There are three main types of bulldozers, which are classed based on their size and whether they have tracks or wheels.

Dumper-

A dumper truck is primarily used to transport materials to and from a construction site. It is the safest way to quickly transport loose materials from a site, and is especially important in the early phases of a project where the ground is being prepared for work to commence.

A dumper is a type of motor vehicle designed to **transport material**. It is for this reason that it is most commonly used in the construction industry: rubble, waste, soil, rubble and any loose material can be transported quickly and easily.

Shovels–Shovel is a tool used to dig as well as to move loose, granular materials (like dirt, gravel, grain, or snow) from one spot to another. Spade is a tool used for digging straight-edged holes or trenches, slicing and lifting sod, and edging flower beds or lawns.

A Shovel is **used to manually shift large quantities of cement and aggregates**. To use a shovel, clasp the D-shaped handle with one hand and hold the shaft closer to check with the other hand. Thrust the tip of the blade into the material, and scoop up a load that you are comfortable with carrying.

Types of Shovel

- Edging Shovel. This shovel is specifically designed to create neat edges around lawns or borders, creating a clean definitive edge. ...
- Trench Shovel. ...
- Flat Shovel. ...
- Tree-Planting Shovel. ...
- Power Shovel. ...
- Post Hole Shovel. ...
- Handheld Shovel. ...
- Root Shovel.

Graders–

Graders are commonly used in the construction and maintenance of dirt and gravel roads. In constructing paved roads, they prepare a wide flat base course for the final road surface. Graders are

also used to set native soil or gravel foundation pads to finish grade prior to the construction of large buildings.

There are two types of categories graders can fall under: **Rigid frame motor grader and Articulated frame motor grader**.

roller –

A roller is a piece of heavy equipment specifically designed for soil compaction applications. Several types of rollers are available, and each compacts the soil in different ways.

How do muscle rollers work? Muscle rollers work **by applying pressure, which helps the muscle unwind adhesions in and around the muscle fibers and recruit blood to the area.**

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.

Asphalt mixe-

Asphalt mixers are necessary to produce large and homogeneous batches of asphalt mix, ready to be compacted with an asphalt compactor and tested with a range of mechanical asphalt testers. All asphalt mixers include a heating system allowing the binder to reach optimal viscosity during the mixing process.

The asphalt plants or asphalt mixing plant is one plant that is used for **mixing the dry warm aggregate, padding and asphalt for homogeneous mixture at the required temperature**. And it is widely used to the construction of highway, city road and parking lot.

tar boilers-

Heavy gauge steel boiler for the rapid heating of bitumen for use in roofing, roadworks and general building work.

Tar is often used in asphalt layers **to embed them with higher resistance, imperviousness to water and to prolong their lifetime**

Coal tar is used primarily for the production of refined chemicals and coal-tar products, such as creosote and coal-tar pitch. Certain preparations of coal tar have long been used to treat various skin conditions, such as eczema, psoriasis, and dandruff.

Road pavers-

A paver (road paver finisher, asphalt finisher, road paving machine) is a piece of construction equipment used to lay asphalt concrete or Portland cement concrete on roads, bridges, parking lots and other such places. It lays the material flat and provides minor compaction.

Modern construction equipments for roads.

INTRODUCTION

Construction equipment have evolved as per changing requirements in the industry. Earlier for one job many equipment were required but now one equipment can do multiple jobs.
Appropriate use of equipment contributes to completion of project on time, work speed, quality, and most importantly economy.
It is not always possible for the contractor undergoing construction works to own each and every type of construction equipment required for the project due to complexity of project, shortage of skilled or efficient manpower, project involving handling of large quantity of earth materials, coping up with the time schedules, etc.
However, one can purchase or hire the equipment as per suitability.
If the equipment has to be used frequently and for a long duration of time then it proves to be economical to purchase the equipment. On the contrary, if the equipment has to be used occasionally and for a short duration of time, it proves to be economical to get it hired.

CLASSIFICATION OF EQUIPMENTS

Various equipment involved in construction works are-

1. Excavating Equipment

i) Power Shovel

ii) Hoe

iii) Dragline

2. Hauling Equipment
3. Earth-moving Equipment
4. Hoisting Equipment

a) Mobile Cranes

b) Tower Cranes

c) Crawler Mounted Cranes

d) Passenger Hoist

e) Builders Hoist

2. Dredging Equipment
3. Conveying Equipment
4. Compacting Equipment
5. Pumping Equipment
6. Pile Driving Equipment
7. Material Testing Equipment

8. Drilling Equipment
9. Aggregate, concrete and HMA (Hot Mix Asphalt) production Equipment.

Excavating Equipment-These equipment are commonly used for digging, excavating and placing earth materials to a distant place, to remove snow, lifting pipes, grading the ground, etc. It consists of a long bucket arm attached to a cabin where the operator operates and can rotate by 360^0 This is a large piece of equipment which is used for big jobs and it runs on tracks. It can also be used with different attachments, such as a clamshell attachment to pick up dirt and debris.
Power Shovel– It is a bucket-equipped machine, usually electrically powered, used for digging, loading fragmented rock or earth and for extract ion of minerals. Main parts includes the track system, cables, rack, stick, boom foot-pin, saddle block, boom, boom point sheaves, bucket and cabin.

Hoe– It is also known as back shovel or pull shovel. It is used to excavate beneath the natural surface on which it rests. It is used for works like excavating trenches, digging pitsforbasements, and it is also used forgradingworkswhich needs precision in case of controlofdepths. Here the basic parts include boom, jackboom, boomfootdrum, boomsheave, sticksheave, bucket, bucketsheave and stick.

Dragline– It is so named as its prominent operation involves dragging the bucket against the material to be dug. It consists of long light crane boom where the bucket is loosely attached to the boom through cables. They are useful for digging below its track level and effective while handling softer materials. Here the basic parts include boom, hoist cable, drag cable, hoist chain, bucket and drag chain. It has long reaches and also used for excavating canals and then depositing on embankments without use of hauling units.

Hauling Equipment– The equipment used for transporting material are known as hauling equipment or haulers. They may be operated on railways or roadways which involve operations like carriage and disposal of earth materials, haulage of big construction equipment and transportation of building materials. It is also classified as dump trucks and dumpers.
Earth Moving Equipment-These equipment include excavators, loaders, motor graders, trenchers, backhoes and bulldozers. They are used to shift large amounts of dig foundations,landscape areas and dirt.

Hoisting Equipment– Hoisting refers to the lifting of a weight from one location to another location at a reasonabledistance. These include jacks, winches, cranes and chain hoists.Crane is the only single piece machine capable of providing three-dimensional movement of a weight.

Mobile Cranes– Such type of cranes is mounted on mobile units which is either of wheel type or crawler type. Truck cranes are such having high mobility whereas the crawler mounted cranes move quite slowly. Crawler mounted cranes can move on rough terrain.
Tower Cranes– These cranes are derrick crane mounted on a steel tower. They are used for industrial and high-rise residential buildings especially for assembly of industrial plants consisting of steel structures. Such cranes resemble truss structures which are made by welding of steel bars and channel sections. Basic parts include carriage, slewing platform, jibs and tower with operator's cabin.

Crawler Mounted Cranes– These are the cranes which are placed on a set of rugged tracks that provides movement and stability for carrying heavy crane equipment. These crawler cranes are suitable for the rough surface area.Even though these cranes have no outriggers, they can operate lifts with minimal setup.Also, in addition to that they can move around easily. Crawler cranes can move around even with a heavy load.

Passenger Hoist– It is a lifting system very often used at construction sites to lift materials to upper levels of unfinished buildings. Basic part consists of a cage in which people stand during transport, and there is a track that is mounted to the building. The cage travels along this track by means of a pinion drive system and rack, and the car can be stopped at many locations along the track. This allows to load or unload at any floor along the length of the track.

Builders Hoist– These are available in various different configurations, sizes and budgets to suit different applications starting from small domestic gin wheel or wire rope hoists and professional scaffold hoists to gantry hoists as well as rack and pinion hoists for material transportation up the side of a high-rise building.

Dredging Equipment– The choice of the dredging equipment for executing a dredging operation depends on conditions such as the weather, accessibility to the site and wave conditions, anchoring conditions, required accuracy and many more. They can dig hydraulically or mechanically. Hydraulic digging involves using of working of a water flow which is erosive in nature. It is mostly done in cohesionless soils such as silt, sand and gravel. Whereas mechanical digging by teeth or cutting edges of dredging equipment or knives is applicable to cohesive soils.

Conveying Equipment– Such equipment carry material in continuous stream with its distinct feature such as endless belt or chain. They are used for transporting material from one place to another over a structure which is stationary. They can proceed work horizontally, vertically or in inclined position. They are used in mining and construction industries.

Compacting Equipment– They can be of type such as smooth-wheel rollers, sheep-foot rollers and pneumatic type rollers. Such equipmentare used to expel air from a soil mass so as to achieve a high density. Smooth-wheel rollers are suitable for gravels and sand. Pneumatic-tired rollers are suitable for clays with reasonably high moisture content.And sheepsfoot rollers are the suitable for clays with low moisture content.

Pumping Equipment– Pumping equipment are used to remove water from a volume of liquid, solid material or soil. Pumps remove liquid from a volume of liquid. They can be used for keeping water out of foundations, pits, tunnels, and other excavations and many more.

Pile Driving Equipment– Such equipment units involve lifting the piles from ground while taking in position to a specified depth. Here driving is accomplished by hammer on pile top. Equipment are so designed so as to remain economic while driving. Major pile driving equipment includes pile driving rigs and pile driving hammers.

Material Testing Equipment– It is frequently used in the quality control processes which are related with the analysis of soil, concrete, asphalt, bitumen, cement, mortar, steel, aggregates, and other materials used in construction. The mechanism in which the equipment performs analysis varies according to the material to be analysed.These testing instruments are capable of analysing the hardness, moisture content, permeability and other mechanical properties.

HMA Production Equipment– HMA is produced in a plant that takes into account the proportions, blends, heats aggregate and asphalt to produce an HMA. These are of two basic types.i.e. the batch plant, and the drum plant. Batch plants leads to production of HMA in individual batches while drum plants leads to production of HMA in a continuous operation.

OMPANIES IN PRODUCTION

Top companies that produce such construction industry-based equipment are-

- Caterpillar (USA)
- Podemcrane
- Optimas GmbH
- Komatsu (Japan)
- Volvo Construction Equipment (Sweden)
- Hitachi Construction Equipment (Japan)
- Fiori Group (Italy)
- Liebherr (Germany)
- Sany (China)
- Zoomlion (China)

- Terex (USA)
- Doosan Infracore (South Korea)
- John Deere (USA)
- Çeksan
- BOMAG

CONCLUSION

Apart from these there are several other types in construction industry which are directly or indirectly involved in such construction works. Hence with the development of construction industry, equipment are getting new makeovers in the process. More competitions are going on in the market for best supplier which in turn are generating more sophisticated equipment for better selection process. Ultimately it is up to the owner for selecting the suitable equipment to carry out the necessary work.

Questions

1.what is construction equipments ?

2.what is bulldozer?

3.what is dumper ?

4.what is greader ?

5.what is tractor ?define its types?

6.what is tipper ?

7.what is powershovel ?

Long questions

1.Explainn about Modern construction equipments for roads.

2.what is bulldozer ?&explain its types in details .

3.what is tractor ?& explain its types in details.

4.Explain about Asphalt mixer and tar boilers.