LECTURE NOTES

ON

HIGHWAY ENGINEERING (TH. 4)

FOR

DIPLOMA IN CIVIL ENGINEERING

(4^{TH} SEMESTER STUDENTS)

AS PER SCTE&VT SYLLABUS

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HIGHWAY ENGINEERING

1.0 Introduction: The branch of Transportation Engineering which deals with the design, construction and maintenance of different types of road is called Road Engineering or Highway Engineering.

1.1 SCOPE OF HIGHWAY ENGG.

Apart from the design, construction and maintenance of different types of roads, Highway Engg. also includes the study of following topics

- → Development, planning, alignment
- → Highway geometric design & location
- → traffic operation and its control
- → Materials, pavement design, Economic consideration, finance &
- → Administration etc.
- → special aspects like problems of hill road construction, road-side development, landscaping and legal issues are also covered under highway engineering.

Technical Terms

Road :- A public thoroughfare ([illegible]) over which vehicles, cyclists, pedestrians, etc may lawfully move from one place to another is called a road or highway.
Usually the term highway is used for an important road of National or State importance in a country.

Traffic :- The vehicles, cycles, carts, pedestrians, etc travelling together on a road constitute the traffic.

Side walk :- The portion of roadway of an urban road reserved only for pedestrians is called foot path, side walk or foot way.
The minimum width of side walk should be 1.5m

Cycle track :- The portion of roadway of an urban road reserved only for pedal bicycles is called cycle track.
The min^m width of cycle track should be 2m.

Motor way :- The portion of roadway of an urban road reserved for use only by high speed and power driven vehicles is called motor way, express way or super highway.
The land width for an Express way is recommended as 50-60
The function of Express way is to cater for movement of heavy volumes of motor traffic at high speeds.

Importance of Highway Transportation :

Considering the utility of roads anywhere in the different parts of a country, they can be rightly compared to arteries in a human body.

Just as arteries ([illegible]) maintain man's health by providing circulation of blood; similarly roads promote ([illegible]) nation's wealth by keeping its people and goods moving.

Thus, we see that progress and well-being ([illegible]) of a nation depends much on roads. In fact, roads are the life lines of nations economy.

The importance or necessity of highway transportation can be easily judged from the following purposes or advantages of roads :-

1. They facilitate conveyance of people, goods, raw-materials, manufactured articles, etc. speedily and easily in the different parts of a country.
2. They act as the only source of communication in regions of high altitude i.e in mountainous regions.
3. They help in growth of trade and other economic activities in and outside the villages and towns by establishing contact between town & villages.
4. They help in providing efficient distribution of agricultural products and natural resources all over the country.
5. They help in price stabilization of commodities due to mobility of products all over the country.
6. They help in cultural & social advancement of people and making the villagers active and alert members of the community.
7. They help in promoting the cultural & social ties among people living in different part of a country and thus strengthen the national unity.
8. They help in providing improved medical facilities quickly to human beings, especially to those who live in rural areas.
9. They provide more employment opportunities.

10. They enhance land value and thus bring better revenue
11. They serve as feeders for Airways, waterways & Railways
12. They help in reducing distress ([illegible]) among the people, caused due to famine, by supplying them food & clothing quickly.
13. The help in maintaining better law & order in a country.
14. They play a very important role in the defence of a country during war days.

Lastly, it can be said that roads are the symbol of country's progress and thus development made by any country can be judged by the quality and network of its road system.

History of Highway Development in India

Indian civilization, being one of the oldest in the world (4000 to 3000 B.C), saw the development and growth of roads alongwith its own development. Thus, while tracing out the history of development of roads in India, one is to study it alongwith the development in political, economic and cultural life of this country.

Pre-historic Period

The history of roads is as old as the history of man on earth. The pre-historic man traced out a narrow way for going out for hunting the food. The narrow way was named as footpath or pathway. This pathway is considered as the first roadmark laid on the surface of earth. The utility & necessity of the pathway gradually developed with the introduction of wheeled carts. The pathway was widened into a roadway which was the beginning of road as a means of communication & transport.

Roads under early Indian Rulers

Ancient history of India reveals that long long ago, Indians were knowing the science of road construction. The excavations at Mohenjodaro and Harappa (Pakistan) have established that even 3500 years B.C, there was a well designed network of roads, and streets were paved at that time.

(a) Aryan Period

During the Aryan period, there are references in Rig veda (Part 1, para 5) about 'Mahapathas' as a means of communication. About 600 year B.C, a pucca road (6.1m to 7.3m wide) was built in Rajgir (ancient Rajagriha) of Patna District by king **Bimbisara**, This road was made of stones and is still in existence.

(b) Mauryan period

During this period, roads were developed on technical basis. Specifications were laid down for width of roads, road surfaces, types of roads for different purposes, etc. A camber was given to the surface of roads and the convexity of road surface was compared to the back of a tortoise. Artha Shasthra, the well known treatise on administration, gives a good deal of information regarding roads along with specifications adopted during Mauryan period. The book of Artha shasthra was written in about 300 years B.C by **Kautilya**, the first Prime Minister of Emperor Chandragupta Maurya.

Chandragupta Maurya (322-298 B.C) took keen interest in the maintenance & development of roads. He had a separate department of communications to look after the public roads. He got constructed the Grand Trunk road connecting North-west Frontier with capital patliputra, the modern patna. He has also fixed some sign post in the form of pillars and mile stones along the road side at regular intervals.

Emperor Ashoka took special interest in the improvement of roads & provided facilities to the travellers. Such facilities were in the form of plantation of trees, digging wells and constructing rest houses at about 4.8 to 6.4 km distance along the roads. The famous chinese traveller **Faheen** had spoken very highly of the roads of that time in the record of his travel.

Roads during the Mughal period

The roads were very greatly improved in India during the Mughal period. Chahar Gulshan, which was written in eighteenth century, gives an information regarding 24 important roads which formed the network of roads in India during the Mughal period.

The road system in those days was considered as one of the best road system in the world.

The road from Delhi to Daultabad was constructed by Mohammad Tughlag. Sher shah Suri got constructed the longest road i.e the road from Punjab to Bengal. The present Grand Trunk Road forms the greater part of the old shershahi road also called Badshahi Sarak. The road from Agra to Allahabad and that from Ujjain to Bijapur were also got constructed by Muslim Emperors. Many of the roads, constructed during mughal period, exist even today.

Roads during the British rule

The economic and political shifts caused much damages in the maintenance of road transportation. Thus, with the fall of Mughal Empire, the condition of roads became deteriorated.

At the beginning of the British period, a number of old Mughal roads, connecting important military & business centres, were metalled and some new roads were constructed by Military boards during the time of **Lord William Bentick**. But the administration of roads under Military Boards was not a satisfactory arrangement. It was only during the administration of **Lord Dalhausie** that the central public works Department was established to look after the construction & maintenance of roads. Later, such departments were created in other provinces also. **Lord Mayo** and **Lord Rippon** contributed a lot in the development of roads because the affairs of construction & maintenance of roads came directly under the control of Local Bodies.

With the development of Railways in India, the road development received a serious set back. The work of road construction & maintenance was given a secondary importance and thus the roads gradually lost the interest of the Government. Major roads, except those of military importance, were altogether neglected & attention was mainly concentrated on the feeder roads to Railways. Thus, the outlook on road development was completely changed and they were considered to be only of local importance. According to Government of India Act of 1919, the affairs of all the roads, except those of military importance & certain other roads of national importance, were transferred from the central Government to the Provincial Governments. The Provincial Governments in their turn, took over direct responsibility of construction and maintenance of roads of provincial importance & placed the greater part of road mileage in the charge of Local Bodies.

After World War-I, motor transport came to the ~~fore f~~ fore-front which created revolution in India's transportation system. Under the continued effect of high speed motor transport, the existing roads soon got deteriorated. The Local Bodies, with their limited financial & meagre technical resources, could not deal with the situation properly & with the increased motor traffic, the condition of roads went from bad to worse. Then the central Government took the following steps towards the development of roads:-

(a) Appointment of Jayakar Committee
(b) creation of central Road Fund
(c) Indian Roads Congress
(d) Nagpur plan

(a) Appointment of Jayakar Committee

In 1927, the central Government appointed the Jayakar committee under the chairmanship of Dr. M.R. Jayakar to report on the condition of existing roads and to suggest ways and means for their future development. In 1928, the Jayakar committee recommended that since the Provincial Governments and the Local Bodies were unable to look after all the roads and, therefore, the central Government should look after all the important roads of national importance.

(b) Creation of central Road Fund

On recommendation of the Jayakar committee, the central Road Fund was enforced on 1st March 1929. The petrol tax surcharge at the rate of 2 annas per gallon (2.64 paisa/Litre) of the petrol consumed by motor traffic was imposed to build the road development Fund. Out of annual revenue, thus collected, 20 percent was to be retained by central Government for meeting expenses on the administration purpose, research and the development of roads under its charge. The balance 80 percent of the Central Road Fund was to be distributed among the provinces according to their petrol consumption, for maintenance & construction of roads

(c) Indian Roads Congress

In December 1934, a semi-official technical body (semi-govt body) known as Indian Road Congress (I.R.C) was established by the central Govt. as per recommendation of the Jayakar committee. This body was formed of national importance for controlling standardisation, specification and recommendation regarding design & construction of roads & bridges. But the economic depression during that time delayed the road development programmes.

After World War-II, there was a revolution in respect of automobiles using the roads in our country. The road development at that time could not keep pace with the rapid increase in road vehicles & therefore, the existing road started deteriorating fast. This necessitated proper highway planning by the authorities.

(d) Nagpur plan

In 1943, a conference of the chief Engineers of central & state Governments was convened by the central Govt at Nagpur. It is a landmark in the history of road development in India since it was the first attempt to prepare road development programme in a planned manner. That conference finalised a Twenty year Road Development plan (1943-1963), popularly known as the Nagpur plan. According to that plan, all roads were classified into four broad categories namely National Highways, State Highways, District Roads and Village Roads. It was also recommended that the central Government should assume complete financial liability for construction and maintenance of roads classified as National Highways and the construction of roads of national importance was made the responsibility of the central Government.

Roads during the Post-independence period

After independence, the Govt. of India started taking much interest towards the development of roads in this country. The Nagpur plan targets were mostly achieved by 1960 through the first and second five year plans (1951-56 & 1956-1961)

The various steps taken by the Government of India towards the development of roads in the country after independence are

(a) Central Road Research Institute

(b) National Highway Act

(c) Road Development plan

(d) Highway Research Board

(a) Central Road Research Institute

In 1950, Central Road Research Institute (CRRI) was started at New Delhi. This Institute is considered as one of the National Laboratories of the Council of Scientific and Industrial Research in India. This institute is mainly engaged in applied research and offers technical advice to state Govt. on various problems concerning to roads.

(b) National Highway Act

In 1956, the National Highway Act was passed. According to this act, the responsibility of development and maintenance of National Highways was given provisionally to the central Govt.

(c) Road Development plan (1961-81)

In 1958, the next Twenty Years Road Development plan (1961-81) was finalised at the meeting of chief Engineers of the states. This is popularly known as the chief Engineer's plan. In this plan, due consideration was given to the future developments in various fields of our country.

According to this Road Development plan, the total length was almost double to that of Nagpur Plan target.

(d) Highway Research Board

On October, 1973, a Highway Research Board has been set up by the Govt. of India on the recommendations of the I.R.C council. This board is a separate organisation for roads just as the Railway Board in our country.

The Highway Research Board has been entrusted with functions to identify the nature, extent and priority for road research & to advice ~~the~~ and recommend to the Govt items of priority research. This Board is to spread the results of research at home and abroad and also to apply these results in the actual highway construction.

Let us hope that with increased allocation of funds, better organisational arrangements and through intensive future plannings, India will not make up the deficiency in roads but she will lead many other countries in this respect in near future.

Indian Roads Congress (I.R.C) (semi-Govt body)

The Indian Roads Congress (I.R.C) is a distinguished association of all the engineers who are in charge of roads from strategic importance to the rural ones. It constitutes the rank engineers from the central & state Govt, Military Engg services, Boarder Roads, Engg colleges and commercial fields. All these members of I.R.C have a common platform to pool in their ideas on road research, construction, maintenance and standardisation.

The I.R.C was established by the central Govt in 1934 as per recommendation of the Jayakar Committee. This technical body was having 73 members at that time, where as now there are ~~more~~ than about 13500 members of this association.

The affairs(मामले) of the Indian Roads congress are controlled by a Governing Body known as the council. It constitutes 55 members nominated by the Govt. of India, central P.W.D, E.I.C's branch, C.R.R.I, the state Govts and also elected from the ordinary & the Associate Members.

The Executive committee of I.R.C constitutes the following officials:

(a) President;
(b) vice-President (4);
(c) Honorary Treasurer;
(d) Honorary Secretary

The Director-General (Road development) and Additional Secretary to the Govt. of India, Ministry of Shipping and Transport (Road wing) is the permanent treasurer of the Executive committee of the I.R.C.

1.2

Functions of Indian Roads Congress

Before 1934, there were no generally accepted road standards or bridge specifications of any kind. The Indian Roads Congress was, therefore, formed to perform the following functions:-

(i) To provide forum for regular pooling up the information, knowledge and experience for all matters affecting the construction and maintenance of roads in India.

(ii) To recommend standard Specifications regarding design and construction of road bridges in India

(iii) To provide platform for the expression of professional opinion on matters relating to road engg.

Indian Roads congress holds its sessions at different places in the country, problems pertaining to various aspects of road & bridge construction are discussed and results are further disseminated (প্রচার করা) through paper readings. This programme of the association has helped in promoting research and publicising the economic techniques adaptable to road construction and development in India.

Thus, the activities of I.R.C have been ultimately linked with the Govts. economic development programme. In fact, this technical body is devoted to the cause of better roads in India.

Classification of Roads

Roads are classified into different categories as ...

① According to location
② According to importance
③ According to traffic
④ According to tonnage

① According to location

According to location and financial responsibility, non-urban roads in India are classified into following 5 categories

(a) N.H (b) S.H (c) M.D.Rs (d) O.D.Rs (e) V.R

This classification of roads was done as per recommendations made in the Nagpur plan finalised by the I.R.C in 1943.

This classification is, therefore popularly known as I.R.C classification of road

(a) <u>National Highways</u>

The main highways running through the length and breadth of the country connecting major ports, foreign highways and capitals of states, etc are known as National Highways.

These highways constitute the main arteries (प्रधान पथ का) of transport in the country and are also of military importance. National Highways should have carriageway of atleast two lane width. They should have modern type of surfacing. The responsibility of construction and maintenance of these roads lies with the central Govt.

(b) State Highways

The highways linking district headquaters and important cities within the state or connecting them with National Highways or with highways of the neighbouring states are known as State Highways (SH)

The highways are also called Provincial Highways. These highways serve as arterial (ধমনী সদৃশ) routes of traffic to and from District Roads within the state. State Highways should preferably be of two lane width. They should also have a modern type of surfacing. The responsibility of construction and maintenance of these roads lies with state Govts.
However, the central Govt. gives grant for the development of these roads.

(c) Major District Roads

The important roads within a district serving areas of production and markets and connecting these places with each other or with the main highways are known as Major District Roads (M.D.Rs)

M.D.Rs should have atleast metalled single lane carriage-way. The responsibility of construction & maintenance of these roads lies with the District Authorities. However the state Govt gives grant for development of these roads.

(d) Other District Roads

The roads serving rural areas of production & providing them with outlet to market centres, Tehsil headquarters, block development headquarters, railway stations, etc are known as the O.D.Rs.

(e) Village Roads

The roads connecting villages or group of villages with each other or with the nearest road of higher category are known as V.Rs.

The roads are very important from the rural area development point of view. They are generally unmetalled & should have single lane width of stabilized soil or gravel. The responsibility of construction and maintenance of these roads lies with the Local District Authorities.

② **According to importance**

According to importance of connecting holy places([illegible]), stations of strategic ([illegible]) importance, roads are classified into the following categories.

(a) class I Roads
(b) class II Roads
(c) class III Roads

③ **According to traffic**

According to intensity of traffic, roads are classified into following categories

(a) very heavy traffic roads: which carry above 600 vehicles per day.

(b) Heavy traffic roads: which carry 251 to 600 vehicles per day

(c) Medium traffic roads; which carry 70 to 250 vehicles per day

(d) Light traffic roads: which carry below 70 vehicles per day.

④ **According to tonnage**

According to total tonnage per day, roads are classified into the following categories -

(a) very heavy traffic roads: which carry over 1524 metric tonnes per day.

(b) Heavy traffic roads: which carry 1017 to 1524 metric tonnes per day.

(c) Medium traffic roads: which carry 508 to 1016 metric tonnes per day

(d) Light traffic roads: which carry below 508 metric tonnes per day

ORGANISATION OF THE STATE HIGHWAY DEPT.

There are different departments organised by the Govt. for its proper & smooth working. One such department in a state is the (P.W.D) public works Department.

The B&R or R&B branch, R.W (Rural works) is the concerned organised body of the state Highway Department. This branches of PWD looks after construction & maintenance of roads and government buildings in a state.

The minister is the over-all incharge of his Department. He is assisted by Principal secretary (Administration), Deputy Secretary & Under secretary (Administration), Joint secretary, Engineer-in-Chief, Special secretary, chief Engineers, Deputy secretary (Technical) in each branch/ department of the state Govt or in a state.

Chapter-2 **Road Geometrics**

Def^n :- The physical features of a road are known as road geometrics.

These physical features have direct connection with the highway users. Then are provided according to their geometrical design in order to facilitate safe and economical operation of vehicles.

With the development of fast moving traffic, the speed, safety and comfort have become the ~~more~~ main requirement of road users now-a-days. Every road users wants to reach his destination within the shortest possible to time & that too in a comfortable manner without meeting with an accident. In order to fulfil these requirements, physical features of a road such as pavement width, formation width, right of way, curves, etc. The success and failure of road construction depends much upon the design of the physical features of the road.

Road geometrics include the following elements of a highway -

1. cross-sectional elements such as right-of-way, road margins, formation width, carriageway width, shoulders, side slopes, kerbs formation level, camber, gradients etc.
2. speed of road vehicles i.e design speed, average running speed, etc.
3. Sight distances such as stopping or non-passing sight distance, passing or overtaking sight distance, intermediate sight-distance and lateral sight distance.
4. Curves such as horizontal and vertical curves
5. Superelevation, ...etc

Road geometrics are greatly influenced by the topography of the area, traffic characteristics and requirements of road users.

Geometrical Design of Highways

The phase of highway design which deals with the visible elements of different highways is called geometrical design of highways

A proper geometrical design of a highway is essential before its actual construction to provide speed, safety and comfort to the road users.

②

Ideals to be kept in view while doing the geometrical design of a highway :-

Following ideals should be kept in view while doing the geometrical design of a highway.

(i) There should be proper record of survey work done in the field.

(ii) There should be sufficient cross-sectional dimensions such as carriageway width, formation width, right of way, etc.

(iii) The road alignment should be economical

(iv) There should be easy gradient

(v) There should be adequate camber on straight portion of the road.

(vi) There should be proper super-elevation on curved portion of the road.

(vii) There should be efficient drainage system

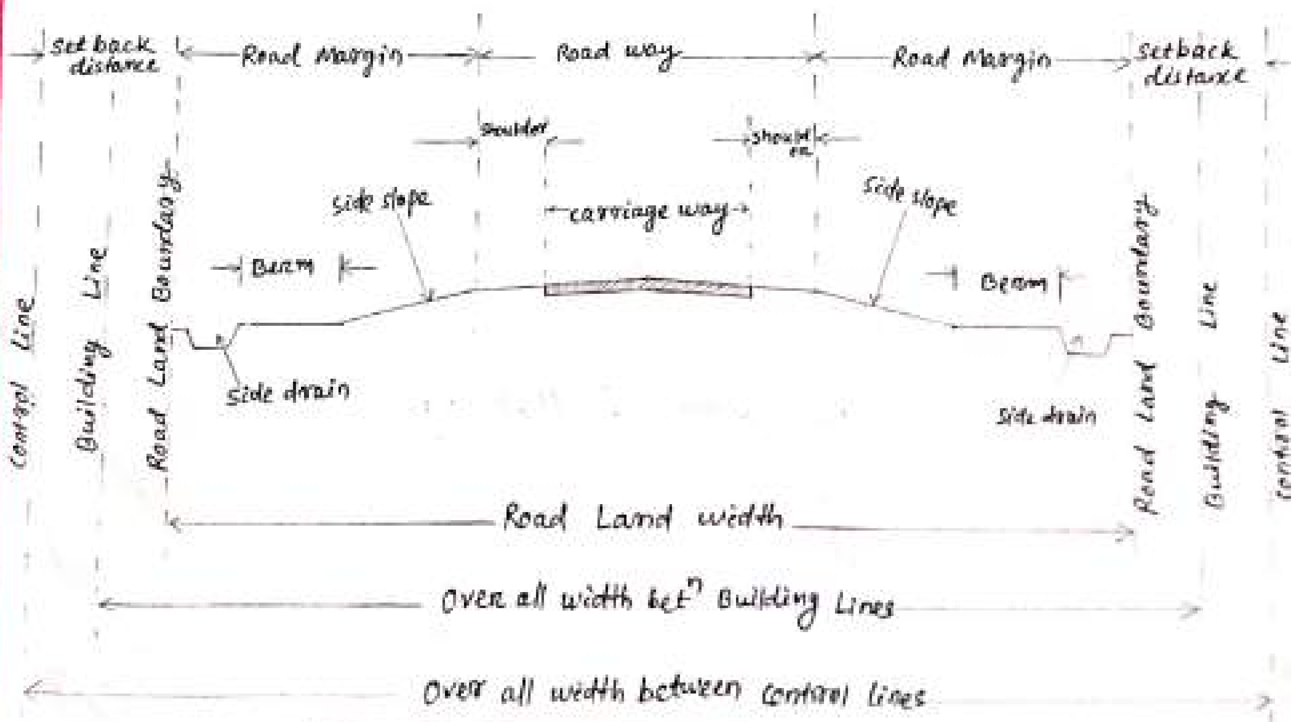
(viii) There should be provision of proper curves.

(ix) There should be provision of extra road width on curves.

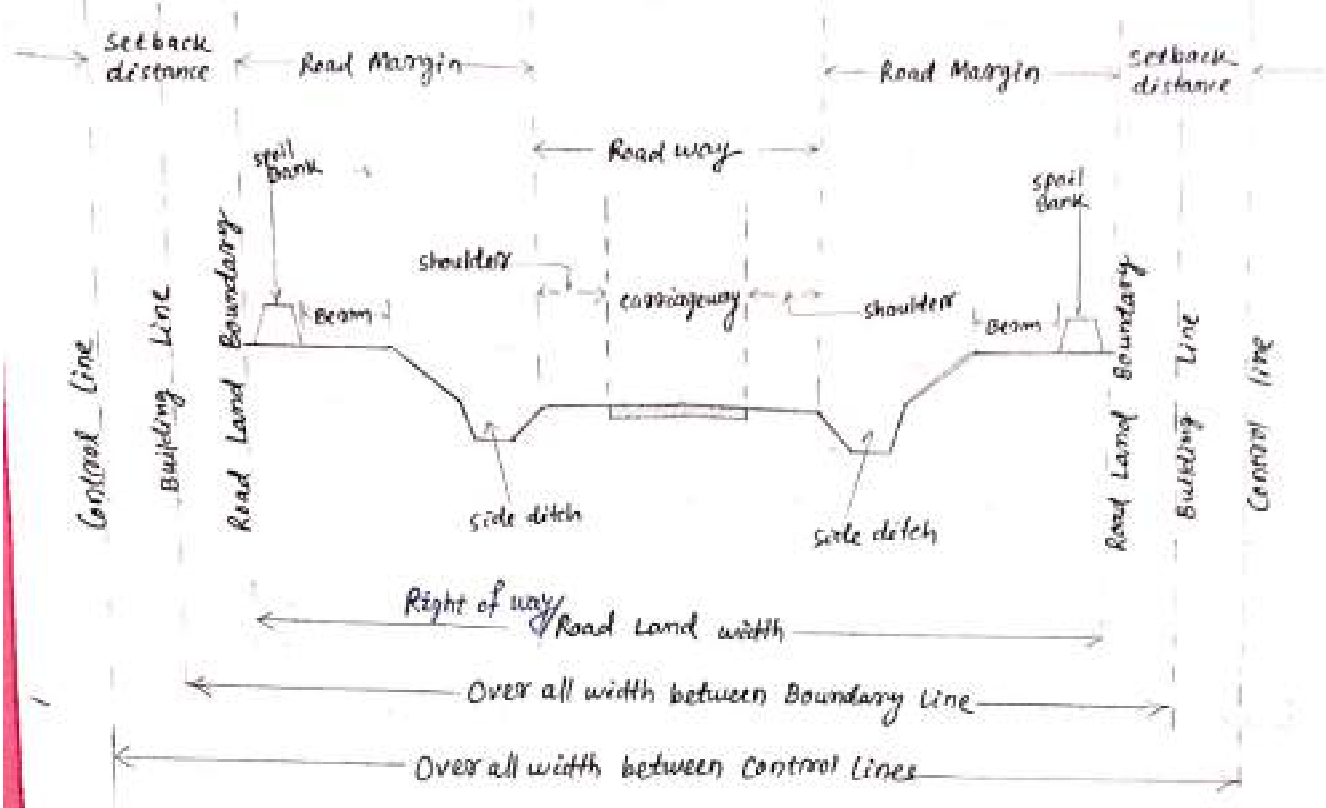
(x) There should be provision of sufficient sight distances available on curves.

(xi) There should be provision of road signals, particularly at road junctions.

(xii) Estimated cost of the project should also be kept in view.



A ROAD IN EMBANKMENT



A ROAD IN CUTTING

Right of way:

The area of land required and reserved for construction and development of a road along its alignment is called right of way/permanent land/.

→ The width of right-of-way is called permanent land width or road land width.

→ The width of right of way of a road depends upon the importance of the road and its possible future development. It is determined by the width of formation, slope of embankment or cutting, depth of embankment or cutting, possible future widening of the road and the min^m sight distance required.

→ At the time of acquiring land for the right-of-way for a new road, the traffic requirements, topographical features, design needs, future developments and ultimate economy should be considered.

→ It is always better to acquire more width near cities, towns and industrial areas because the cost of the adjoining land always increases due to the opening of the new communications route and also ribbon development starts taking place making it difficult, later on, to acquire more land.

Ribbon development : The constructional development, occuring on the side of a road in the form of shops, hotels or other buildings is known as ribbon development.

On curves, the building line on the inner side shall be at a greater distance from the centre line of road pavement in order to provide adequate sight distance.

Thus, right of way meets the present traffic requirements, design needs and also allows for future development of a road. If sufficient land width is acquired at the time of planning and constructing a new road, the same can be widened & other improvements can be made as & when desired in future.

Road Margin

The portion of land width on either side of the roadway of a road are known as road margins.

The various elements included in the road margins are parking lane, frontage road, driveway, cycle track, footpath, guard rail, slopes and side drains.

The road margins are secured and reserved to meet the present & future demands of development of the road.

Roadway width / Formation width

The top width of a highway embankment or bottom width of highway cutting excluding the side drains is called roadway width or formation width.

Roadway width comprises of the width of carriageway including traffic separator, if any, plus the shoulders on either side.

Roadway width is decided and constructed to meet the present traffic requirement, topographical features, design needs and ultimate economy of the road.

The roadway width for different categories of roads has finalised by I.R.C

Carriageway / Pavement / Crust

The portion of roadway constructed for movement of vehicular traffic is called carriageway / pavement / crust.

The width of carriageway or pavement depends on the width of traffic lane and number of lanes required.

→ According to I.R.C specifications, the carriageway width for single lane traffic is 3.75m.

The number of traffic lanes required for a highway depends on the following factors :-

(i) Type of existing traffic and expected in next 10 years
(ii) Intensity of traffic expected in next 10 years
(iii) Over all maximum expected width of a vehicle
(iv) Minimum side clearance required for safe driving.

Thus, carriageway width is a very important factor in the safe design of a highway. The position selected by a driver while meeting an incoming vehicle or passing a slow moving vehicle safely depends mostly upon the carriageway width.

Shoulders

The portion of the roadway between the outer edges of the pavement and edges of the top surface of embankment or inner edges of the side drains in cutting are known as shoulders.

The width of shoulders varies from 0.5m to 4.0m according to the nature of the area and type of road. They form an essential part of the roadway. They may be consisting of asphaltic, water bound macadam or simply earthen surface according to the type of pavement. They are always given an outward slope to drain off the rain water quickly towards the sides.

The outward slopes to be given to the surface of shoulders as recommended by the I.R.C are as follows

(a) Paved surfaces :- 1 in 24 to 48
(b) Earth surfaces :- 1 in 16 to 24

Objects of providing shoulders

(i) They act as components of the roadway
(ii) They provide lateral stability to the carriageway.

(iii) They serve as parking places for vehicles in case of emergency.

(iv) They provide space for erecting road signals.

(v) They provides pace for animal drawn vehicles, cyclist & pedestrains to retreat when a fast moving vehicles tends to cross or over-take them.

(vi) They provide space for accidental repairs to vehicles when they become unservicable on the road.

Side slopes

The slopes given to the sides of earthwork of a road in embankment or in cutting for its stability are called side slopes.

Side slopes should be so designed as to keep the earthwork stable in embankment or in cutting. Flatter side slopes would make the earthwork uneconomical whereas steeper side slopes would result into erosion & slips.

The main factors affecting the design of slopes are :-

(i) The nature of soil constituting the road embankment or cutting

(ii) climatic conditions

(iii) The method of drainage provided

(iv) The method of protecting the side slopes from erosion & slips.

Earth embankments of usual height can stand safely with side slope of 1 in 1.5. In cutting, a side slope of 1:1 can serve the purpose. In hard rock stretches, side slopes varying from 1 in $\frac{1}{2}$ (batter 1 in 2) to 1 in $\frac{1}{4}$ (batter 1 in 4) can be provided safely.

(*) But modern tendency is to provide flatter slopes as they result in safe movements of vehicles and low maintenance cost.

I.R.C has recommended the following side slopes for road embankments or cuttings.

In Felling :-

Generally 2:1 slopes of embankments when,

(i) the height of the embankment is over 0.6 m

(ii) the filling material / subsoil strata consists of heavy clay.

(iii) the height of the embankment is more than 3m & subject to weathering.

In cutting :-

(i) Ordinary soil = 1:1 to $\frac{1}{2}$:1

(ii) Disintegrated rock or conglomerate = $\frac{1}{2}$:1 to $\frac{1}{4}$:1

(iii) soft rock and shale = $\frac{1}{4}$:1 to $\frac{1}{8}$:1

(iv) medium rock = $\frac{1}{12}$:1 to $\frac{1}{16}$:1

(v) Hard rock = Nearly vertical

Berms :

The portions of land width left in between the toe of road embankment and the inner edges of borrow pits or the portions in between the top edge of road cutting and the nearest edge of spoil banks on either side are known as berms.

They prevent side slopes of the road embankment from damage by erosion or the cutting from damage by lateral thrust due to spoil bank.

Kerbs

The boundaries between the pavement and shoulders or footpaths are known as kerbs.

The kerbs may also be provided between the pavement & traffic separator or dividing ~~signal~~ island.

Kerbs are generally constructed of cut stone or cement concrete slabs which are usually chamferred or rounded off. The kerb & the road surface near the edge together form a side channel which carries away rain water that comes to it after falling on the surface of road.

The height of kerbs is about 10 to 20 cm above the surface of pavement edge where footpath is provided next to it.

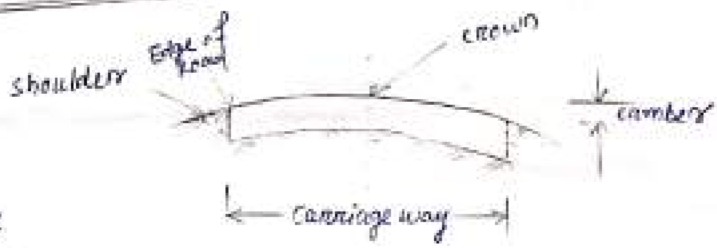
In urban roads, the function of kerbs is to prevent the traffic from getting off carriageway, whereas in rural roads, submerged kerbs, consisting of bricks on edge, are constructed between the pavement & its shoulders to provide lateral stability to the road pavement.

Formation level

The reduced level of the finished surface of earthwork for a road in embankment or in cutting is known as formation level.

Formation level of a highway should be decided such as to provide economical earthwork in the road project. when the road is to be constructed in embankment, the formation level should be kept above the highest flood level in the area. In case of road in cutting, the formation level should be sufficiently above the sub-soil water table.

CAMBER / CROSS FALL / transverse slope



The convexity provided to the surface of carriageway or the rise given to the centre of carriageway above its edges on straight portion of a road is called camber or cross fall.

→ camber is provided on the straight reaches of a road.

→ It is usually expressed as the **percentage of rise** given to the crown of the carriage way above its edges.

→ It is also expressed as slope of the line joining the crown with the edges of the carriageway.

Thus, a camber of 2.5 percent (1 in 40) means that for a 7m wide carriageway, its crown lies $\frac{2.5}{100} \times \frac{7}{2} \times 100 = 8.75 cm$

The amount of road camber depends on the intensity of rainfall in the locality & the permeability of the road surfacing material. Thus, a hard or less permeable smooth surface will require less camber than a soft or more permeable rough surface.

Objects of providing camber

(i) To drain off rain water from the surface of carriageway towards the sides of a road as quickly as possible

(ii) To regulate the vehicles to their proper lanes

(iii) To improve the architectural ~~appea~~ appearance of the roadway.

Types of Camber

Following types of camber are generally provided to the road surface.

(a) composite camber,
(b) sloped or straight camber
(c) Two straight line camber
(d) Barrel camber

(a) Composite camber

It consists of two straight slopes from the edges with a parabolic or circular crown at the centre of carriageway as shown....

→ This type of camber can be easily constructed & maintained.

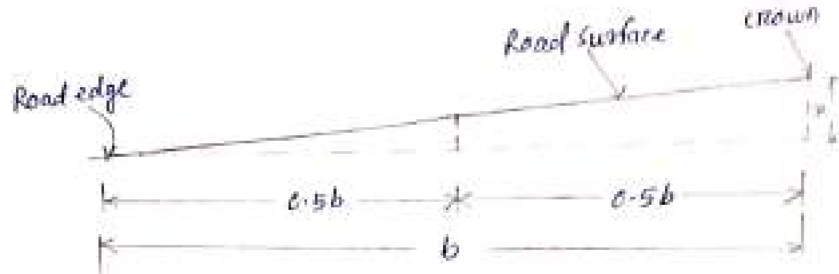
(b) Sloped or straight camber

It consist of two straight slopes from the edges joining at the centre of carriageway.

→ This type of camber is very simple and can be easily constructed & maintained.

→ This type of camber is provided when very flat cross slope is required as in the case of cement concrete pavement.

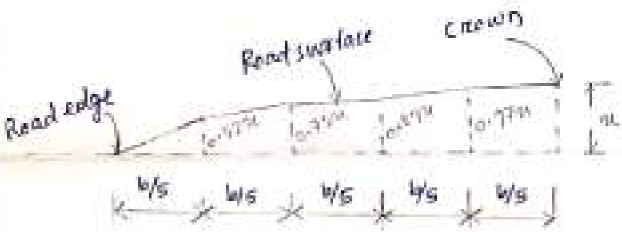
(c) Two straight line camber



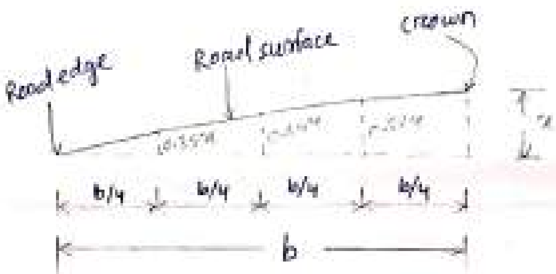
It consists of two straight lines steeper near the edges & flatter near the crown of carriageway.

* This type of camber is considered to be the best for Indian Roads because it provides more contact area of the tyres with the road surface than in other types of camber. Thus, it provides less damage to the road surface.

(d) Barrel camber



Parabolic Barrel Camber



Elliptical Barrel Camber

It consists of a continuous curve either elliptical or parabolic. It provides a flat road surface at the middle & 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 is suggested for Urban roads.

* This type of camber is difficult to construct & maintain. The barrel camber has more steeper edges which are inconvenient to use. Moreover, the steep edges are eroded quickly and hence additional Korbs are to be provided.

Advantages of excessive camber

(i) Excessive camber provides quick drainage of rain water to the sides and thus saves the foundation course of the road structure from weakening by percolation of rain water to it through the road surface.

(ii) This prevents rain water to accumulate in local sinkages or depressions and forming water pool on the road surface, which are disagreeable to public as well as to the road structure.

Dis-advantages of excessive camber

(i) The road surface with excessive camber wears out excessively and quickly at the central portion because the drivers have a tendency to run along the centre of the road to avoid camber pull & thus results in more maintenance cost.

(ii) This results in more number of accidents because the vehicles, moving at high speed, have a tendency to slip towards the edges.

(iii) This causes problems of toppling([illegible]) over of heavily ladden bullock carts.

(iv) Excessive camber results into formation of cross ruts([illegible]) and the shoulders may be washed away due to rapid flow of water

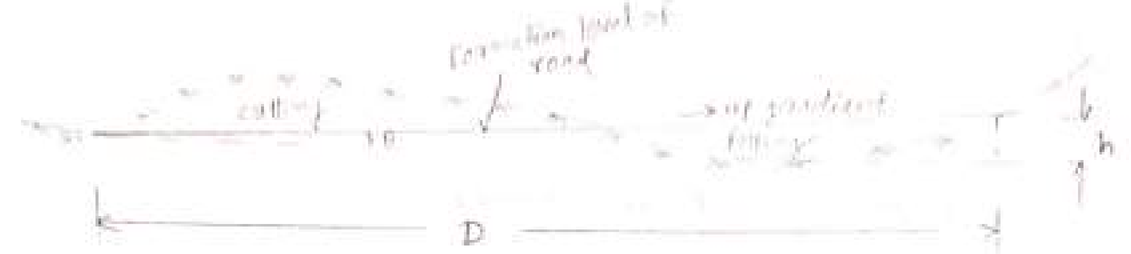
Methods of providing camber

The required camber is provided to the subgrade during consolidation. For providing the desired amount and shape of camber, templates or camber boards are prepared conforming to the specified camber. The material to be used in the subgrade is spread & hard packed to the shape of the desired camber. The rolling is then started from the edges and shifted towards the centre. Overlapping equal to half the width of the roller should be given while shifting the roller towards the centre of the road after rolling each strip. Then checking of the top surface of the subgrade should be done by means of camber boards and deficiency, if any, is rectified by spreading or removing the material as required.

GRADIENT / GRADE / LONGITUDINAL SLOPE

The ground is never dead flat, and hence the road to be provided will also have rise and falls along the length of the road.

The rate of rise or fall provided to the formation of a road along its alignment is called grade or gradient or longitudinal slope.



It is expressed as the ratio of rise or fall to the horizontal distance or as percentage rise or fall.

(*) In India (ratio of fall or rise to the horizontal distance) being mostly adopted.

Thus, if a road ascends or descends one metre for every 50m the gradient is said to be 1 in 50 or 2%.

(*) The gradient may also be expressed in degrees of elevation or depression above or below a horizontal plane.

(*) A gradient of 1° represents a rise or fall of 1m in a horizontal distance of 57.3 m (as π rad = 180°, 1 rad = $\frac{180}{\pi}$ = 57.2957..)

Gradient to a road is necessary to drain off surface water easily through the side drains. Even in plains, flat gradients of 1 in 300 to 500 are provided for satisfactory drainage and to keep the roads in good conditions with less maintenance cost.

Object of providing gradient

1. To connect the terminal stations situated at different levels.
2. To provide effective drainage of rain water falling over the road surface, particularly when the pavement is provided with kerbs.
3. To make the earth work of the road project economical since a perfectly level road involves more cutting & filling.
4. To construct side drains economically with convenient depths below ground level.

(5) To reduce the maintenance cost of road surface. It has been experienced that maintenance cost is reduced by 15% to 25% on a road with slight gradient than that with level surface.

Factors affecting gradient selection

Following are the various factors which govern the selection of gradient in the alignment of a road...

(i) Nature of ground
(ii) Nature of traffic
(iii) Drainage required
(iv) Type of road surface
(v) Total height to be covered
(vi) Road and railway intersections and bridge approaches
(vii) safety required.
(viii) Type & importance of highway

Types of gradient

The following are the different types of road gradient

(a) Ruling gradient/permissible gradient
(b) Limiting gradient/Maximum gradient/momentum grade.
(c) Exceptional gradient/[illegible]/
(d) Average gradient
(e) Floating gradient
(f) Minimum gradient

There are no such universal classification and limits for the various types of gradients. The different categories of the gradients depends on the type of terrain of the country such as flat or mountainous & the type of conveyance such as heavy transportation vehicles, goods transporters, passenger buses, jeeps, animal drawn carts, pedestrians, with this reservation, gradient may be classified as ......

(a) Ruling gradient

This is such a gradient that all vehicles, whether drawn by power or by animals can traverse long length of the road without undue consumption of fuel or much fatigue.

→ This gradient is generally adopted for designing vertical profile of a road

→ This gradient should never be exceeded in any part of a road in the normal course.

→ The gradient usually adopted while making the alignment of a road is called ruling gradient.

The choice of ruling gradient depends on the following factors:-

→ The nature of vehicles

→ The type of road surface

→ The local topographical conditions.

The ruling gradient is also defined as the permissible gradient on the alignment of the highway which the engineer must endeavour (urge) to design and stick to.

(b) Limiting / Maximum / Momentum Gradient

This gradient is slightly steeper than the ruling gradient. It is provided when the natural ground profile is slightly steeper than the ruling gradient. It is necessary to adopt such a steeper gradient, to keep the earth work operation minimum. This gradient is generally adopted to connect plain & rolling terrain or to reach hilly areas.

(c) Exceptional Gradient

The gradient steeper than the limiting which ~~may be used in~~ short lengths of the road, only in extraordinary situations, is called exceptional gradient.

This type of gradient is adopted only in very difficult situations & for short lengths not exceeding 100m at a stretch. In mountainous & steep terrain, successive stretches of exceptional gradients must be separated by a minimum length of 100m having gentlier gradient.

(d) Average Gradient

The total rise or fall between any two points along the alignment of a road divided by the horizontal distance between them is called average gradient.

(*) This gradient is determined to carry out the preliminary surveys i.e proper location, reconnaissance survey, etc

(e) Floating Gradient

The gradient on which a motor vehicle, moving with a constant speed, continues to descend with the same speed without any application of power or brakes is called floating gradient.

In case of floating gradient, the downward component of the weight of the moving vehicle remains equal to the frictional resistance of the road surface.

(f) Minimum Gradient

The minimum desirable slope essential for effective drainage of rain water from the road surface is called minimum gradient.

On unkerbed pavements in embankment, near-level grades are not objectionable when the pavement has sufficient camber to drain the rain water laterally. But, in cut sections or where the pavement is provided with kerbs, it becomes necessary that the road should have minimum gradient for efficient drainage. Desirable minimum gradient for this purpose is 0.5 percent if the side drains are lined and 1.0 percent if the drains are unlined.

Design Speed

The maximum safe speed of vehicles assumed for geometrical design of a highway is known as design speed.

This is the approximately uniform speed that can be maintained by majority of the drivers over the specified category of road. This speed is assumed for co-relation of geometrics (physical-features) of a road that influence the operation of vehicles. Since the overall geometrical design of any road depends on design speed, it is essential that the assumed design speed should be in conformity with the high standards of mobility, safety and efficiency desired on different categories of road.

The design speed depends upon the following factors

(a) Type and condition of the road surface

(b) Structure of the road

(c) Nature, type and intensity of traffic

(d) Type of curve along the road.

(e) sight distance required

(f) Nature of the country

Design speed on different categories of Roads as per Recommendation of I.R.C in km/h

	Plain Area		Rolling Area		Hilly Area		Steep Area	
	Ruling	Minm	Ruling	Minm	Ruling	Minm	Ruling	Minm
NH & SH	100	80	80	65	50	40	40	30
M.D.R	80	65	65	60	40	30	30	20
O.D.R	65	50	50	40	30	25	25	20
V.R	50	40	40	35	25	20	25	20

The Economic Commission for Asia and Far East (E.C.A.F.E) has recommended the following design speed for the low cost roads.

(i) plain or rolling area : 48 km/hr

(ii) Hilly area : 32 km/hr

These design speeds have been recommended on the possibility of further development of the low cost roads and future expansion of traffic.

Average Running Speed

The speed maintained by vehicles over the particular section of a road is called average running speed.

* It is less than the design speed

This is calculated by dividing the distance covered by a vehicle with the actual running time (excluding any stopping time).

It is varies from 70% to 90% of the design speed. If the design speed is 100 km/hr, then the average running speed is 75 km/h i.e 75 percent of the design speed.

$$\text{Average running speed} = \frac{\text{Distance covered by vehicle}}{\text{Actual running time}}$$

Approximate Relationship between Design Speed and Average Running speed of vehicles.

Design speed	Average Running Speed	
	Percent of design speed	km/h
50	90	45
65	85	55
80	80	64
100	75	75
110	70	77

Sight Distance

The distance along the centre line of a road at which a driver has visibility of an object, stationary or moving, at a specified height above the carriageway is known as sight distance.

or

sight distance is the length of road visible ahead to the driver at any instance.

or

The longest distance a driver can see in front of him, may be termed as sight distance.

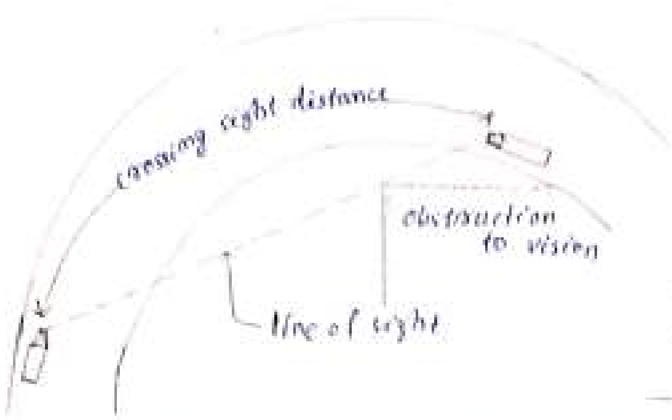
or

sight distance is the maximum distance visible to the driver along the centre line of a highway.

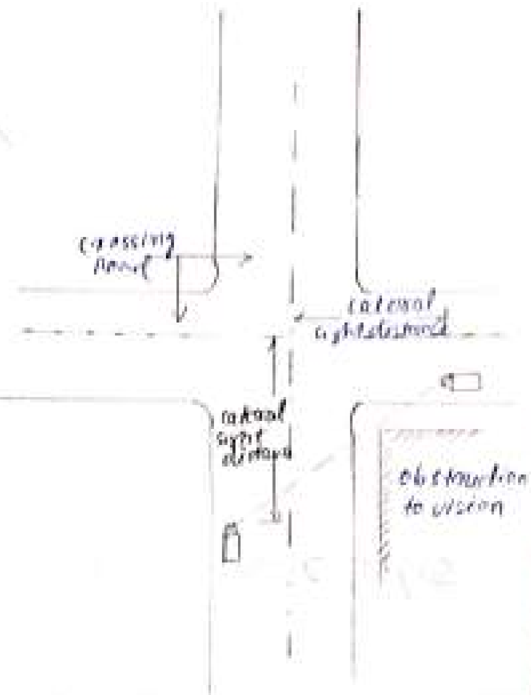
(*) When a fast moving vehicle negotiates a horizontal or vertical curve on approaches a road intersection, a certain distance of visibility through which the driver can see the opposite vehicle, a pedestrian or some fixed object on the road in the direction of travel is essential so that the driver may react and avoid any collision or accident. Therefore, provision of such a distance of visibility, known as the sight distance, becomes necessary to provide safe & efficient movement of vehicles on the road.

Moreover, the geometrical design of highways and traffic control both are affected much by the sight distance required by the drivers.

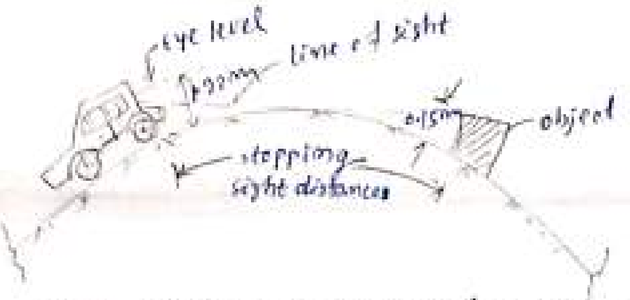
Restrictions to sight distance



Sight Distance at a Horizontal curve



Sight Distance at a Road intersection (Lateral sight Distance)



Sight Distance on a vertical summit curve (stopping sight Distance)

Restriction to sight distance may be caused at horizontal curves, by objects obstructing vision at the inner side of the road, on the **vertical summit curves** or at road intersection.
But the sight distance at such locations should be such that the drivers & pedestrians get sufficient time to react to an emergency to avoid not only accident but also to extend road courtesy(সৌজন্য) to each other.

The design standards for sight distance must satisfy the following 3 conditions

(i) The driver travelling at a design speed should have sufficient road length visible to enable him/her to stop his/her vehicle in case of obstruction on the road ahead, without causing collision or accident.

(ii) The driver travelling at a design speed should be able to overtake the slow moving vehicles at reasonable intervals during his journey without endangering the traffic from opposite direction.

(iii) The driver entering an uncontrolled road intersection should have sufficient visibility to enable him/her to control his vehicle & avoid collision with other vehicle approaching the intersection.

Factors affecting the sight Distance

The safe sight distance depends upon the following factors:-

(a) speed of the vehicle
(b) perception time and brake reaction time.
(c) Efficiency of brakes of the vehicle
(d) The frictional resistance of the road surface
(e) Height of the driver's eye.
(f) slope of the road surface.

In addition to these factors, the following factors also affect the sight distance of a road.

(i) Eye sight of the driver
(ii) Efficiency of the screen wipers during rain
(iii) Efficient lighting system during night hours.
(iv) weather conditions.

Types of Sight Distance

The various sight distances which are considered for geometrical design of a road can be splitted up into the following types

(a) safe stopping sight distance (SSD) or Absolute min^{m} sight distance or Non-passing sight distance

(b) Safe overtaking sight distance (OSD) or Passing sight distance

(c) Intermediate sight distance

(d) lateral sight distance.

(a) Safe-stopping / Non-passing / Absolute Min^{m} sight Distance

distance required for an emergency stop.

The clear distance ahead needed by a driver to bring his vehicle to a stop before meeting a stationary object on the road is called stopping or non-passing sight distance.

→ Min^{m} stopping sight distance is the distance travelled by the vehicle during perception and brake reaction time plus the braking distance.

In case of a summit curve, min^{m} stopping sight distance is the distance measured along the centre line of a road at which a driver whose eye sight is 1.22m above the road surface can see the top of an object 15cm high on the road as shown in fig:

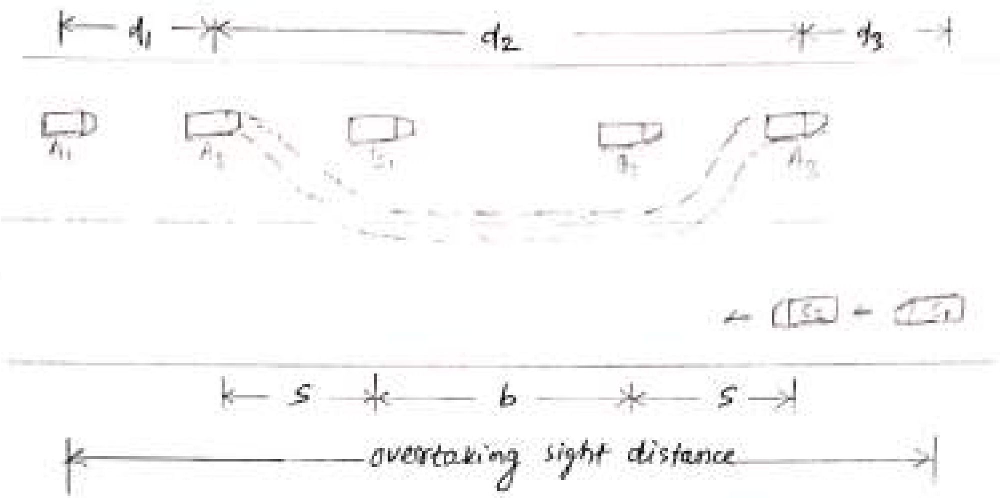
Vehicle speeds as recommended by I.R.C are given in following table

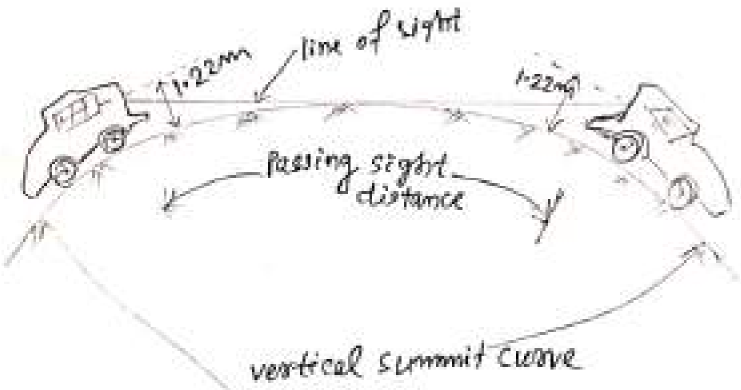
Speed	Perception & Brake Reation		Braking		Safe stopping sight Distance (m)	
V (km/h)	Time, t(sec)	Distance(m) $d_1 = 0.278\,Vt$	co-efficient of Longitudinal friction (f)	Distance (m) $d_2 = \frac{V^2}{254f}$	calculated values (d_1+d_2)	Design values (mts)
20	2.5	14 (13.9)	0.4	4.0 (3.937)	18 (17.837)	20
25	2.5	18 (17.375)	0.4	6.[illegible] (6.15)	24	25
30	2.5	21 (20.85)	0.4	9.0 (8.858)	30	30
40	2.5	28 (27.8)	0.38	17.0 (16.57)	45	45
50	2.5	35 (34.75)	0.37	27.0 (26.60)	62	60
60	2.5	42 (41.7)	0.36	39.0 (39.37)	81	80
65	2.5	45 (45.175)	0.36	46.0 (46.20)	91	90
80	2.5	56 (55.6)	0.35	72 (71.991)	128	130
100	2.5	70 (69.5)	0.35	112 (112.485)	182	180

All these value mentioned are based on perception and brake reaction time of 2.5 seconds & co-efficient of longitudinal friction varying from 0.40 at 20 $\frac{km}{h}$ to 0.35 at 100 $\frac{km}{h}$

(b) Safe Over-taking / Passing sight Distance / Non stopping sight Distance

distance required when vehicles can overtake & pass each other.





The minm sight distance needed by a driver on a two way road to enable him to overtake another vehicle ahead with safety against the traffic from opposite direction is called overtaking or passing sight distance.

The minm overtaking sight distance depends upon the following factors:

(i) speed of overtaking, overtaken and that of the vehicle coming from the opposite direction.

(ii) Rate of acceleration of the overtaking vehicle

(iii) spacing between vehicles

(iv) skill and reaction time of the driver.

In case the driver of vehicle A running at design speed tries to overtake a slow moving vehicle B on a two lane road while the third vehicle 'c' comes from the opposite direction, its overtaking manoeuvre (ఓవర్ టేకింగ్) ... is shown in fig ...

Then, the overtaking sight distance required for vehicle A

$= d_1 + d_2 + d_3$

where

d_1 = the distance travelled by the overtaking vehicle A during the reaction time A_1 to A_2

d_2 = the distance travelled by vehicle A from A_2 to A_3 during the actual overtaking operation.

d_3 = the distance travelled by vehicle C coming from the opposite direction i.e from C_1 to C_2 during the overtaking operation by vehicle A.

→ Design values for overtaking sight distance as per recommendations of I.R.C are given .. in table.

→ These values are based on time component of 9 to 14 seconds for the actual overtaking manoeuvre depending upon design speed, increased by about $\frac{2}{3}$rd to take into account the distance travelled by a vehicle from the opposite direction travelling at the same speed.

Safe overtaking Sight Distance for various Design speeds

speed in km/h	Time component in seconds			Safe overtaking Sight Distance (mtrs)
	For overtaking manoeuvre	for opposing vehicle	Total	
40	9	6	15	165
50	10	7	17	235
60	10.8	7.2	18	300
65	11.5	7.5	19	340
80	12.5	8.5	21	470
100	14	9	23	640

(c) Intermediate sight distance

The distance which affords reasonable opportunities to drivers to overtake the vehicle ahead with caution is known as intermediate sight distance.

At approaches of intersections between the main highway & intermediate or single or unimportant roads, intermediate sight distance is provided. Intermediate sight is also used when provision of OSD is not possible due to economic reasons or space limitation at site.

→ According to Indian practice, intermediate sight distance is taken as two times (twice) the value of safe stopping sight distance.

→ The place where the overtaking sight distance in as much length of the road as feasible is not available, intermediate sight distance should be adopted as the next best alternative.

→ Because of practical reasons, intermediate sight distances are not provided on summits & horizontal curves. If there is no space for SSD, restrictive pavement markings or 'no over-taking' sign boards should be installed at appropriate places along the road.

Design values of intermediate sight distance as recommended by I.R.C are given below

Intermediate Sight Distance for various Design Speeds.

Speed Km/h	Intermediate sight Distance (meters)	Speed km/h	Intermediate sight Distance (meters)
20	40	50	120
25	50	60	160
30	60	65	180
35	80	80	240
40	90	100	360

(d) Lateral sight distance

The sight distance needed by the driver of a vehicle who sees another vehicle approaching the intersection, reacts and applies brakes to bring his vehicle to dead stop at the intersection.

without any collision or accident is called safe sight distance for entering into an intersection or lateral sight distance.

The line of sight is usually obstructed by structures or other objects at the corners of road intersections. It is, therefore, important that on all approaches of road intersections, there should be a clear views across the corners from a sufficient distance so as to avoid collision of vehicles. This is more important in case of unchannelised road intersections. This sight distance should be equal to the stopping sight distance along each intersecting road.

The lateral sight distance should be sufficient to satisfy the following three(3) conditions: -

(i) To enable either one or both the approaching vehicles to change their speeds to avoid collision.

(ii) To bring either one or both the approaching vehicles to stop before reaching a point of collision.

(iii) To enable the stopped vehicles on minor road (controlled by a stop sign) to start, accelerate and cross the main road before the approaching vehicle, travelling at design speed on main road, reaches the intersection.

REACTION TIME - PIEV THEORY

The time required by the driver, say, to apply the brake on seeing a vehicle or obstruction, is not an instantaneous action, but is a "time consuming" phenomena based on the psychological ([illegible]) processes involved. These processes may be divided as those due to perception, intellection, emotion and volition.

According to PIEV theory, the driver perceives ([illegible]) a situation on the road, analyses it using his intelligence ([illegible]), emotionally ([illegible]) feels it and reacts with volition ([illegible])

Perception time :- The time required to perceive an object or situation

or

The time taken by the driver of a vehicle in motion to realise a danger before trying to take any preventive measure to avoid accident is known as perception time.

or

It is the time required for a driver, while driving the vehicle, to observe, notice, assess and mentally analyse a given situation - the driver will then decide whether to react, apply the brake or steer away. In other words, during driving, it is the minimum time required for a driver to react instantly and exercise control.

Intellection time :- The time required for comparing the different thoughts, regrouping and registering new sensations.

Emotion time :- The time elapsed during emotional sensation and disturbances.

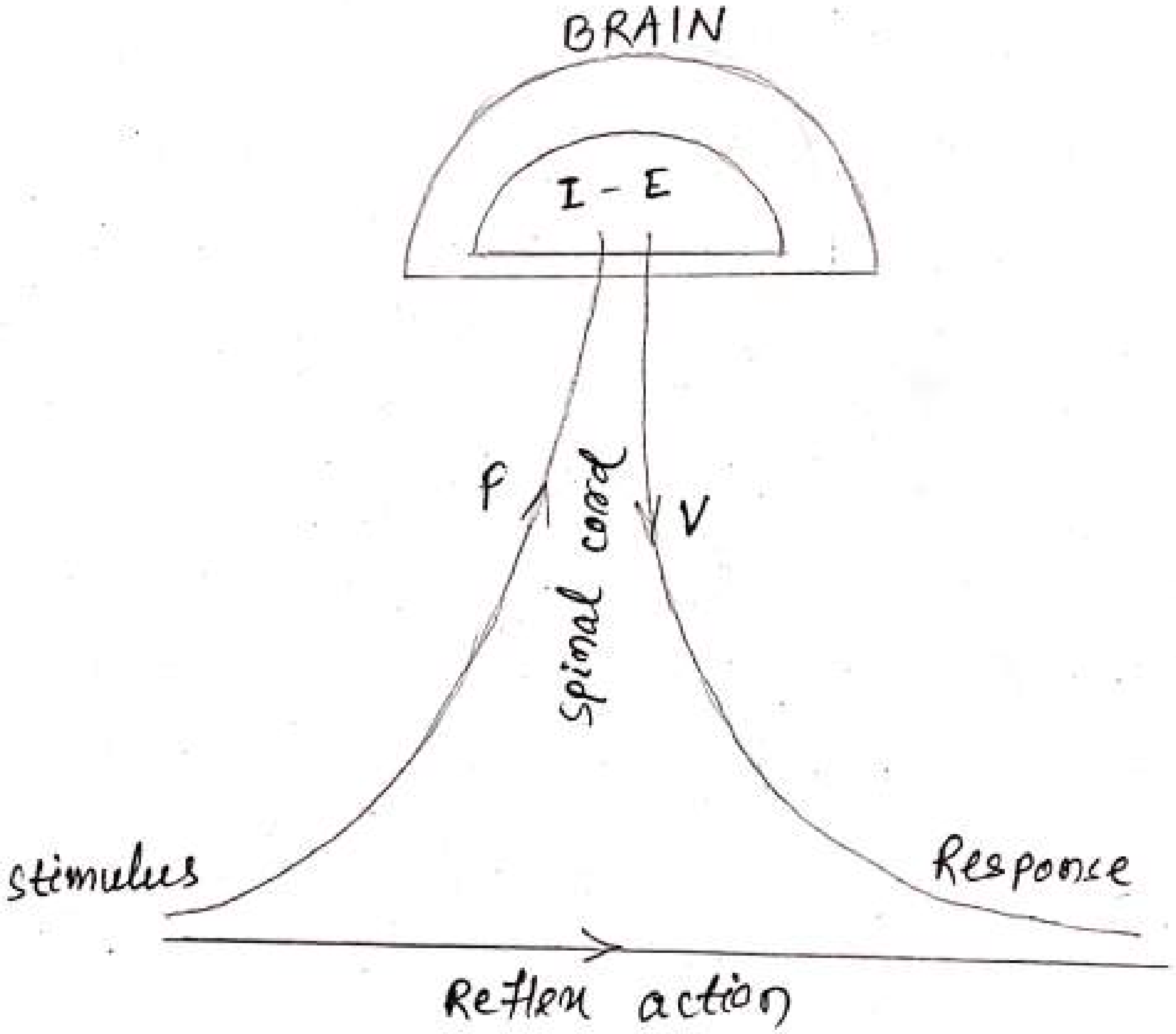
Volition time :- The time required for the final actions.

The PIEV time depends upon

(a) Physical fitness/characteristics of driver
(b) Psychological factors (intelligence, age ...)
(c) Environmental condition
(d) Purpose of trip
(e) Speed of vehicle

[The total reaction time of an average driver may be as low as 0.5 second for situations to as high as 3 to 4 seconds for complex problems.]

Diagramatic representation of PIEV Theory



P - perception
I - Intellection
E - Emotion
V - volition

According to I.R.C recommendations, total reaction time is considered as 2.5 seconds. (96)

or However for design purposes, the total time required from perception to reaction (say application of breaks) is taken to be 2.5 seconds.

(*) Brake reaction time :— The brief interval between the perception of danger and the effective application of brakes is called brake reaction time.

(*) Reaction time/Total reaction time :—

The sum of perception time and brake reaction time is called total reaction time or simply reaction time.

(*) Lag distance :— It is the distance travelled by a vehicle from perception of a situation to application of brakes by the driver. or The distance travelled by a vehicle from perception of a situation to application of brakes by the driver.

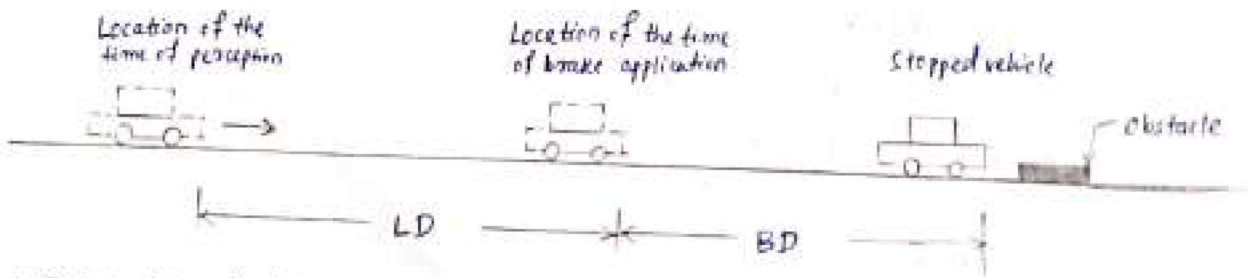
(*) Braking distance :—

It is the distance travelled by a vehicle just after application of brakes, either to bring the vehicle to a complete halt/stop or steer it away.

A vehicle moves further even after application of brakes since kinetic energy of the vehicle cannot be reduced to zero instantly.

Following are the factors affecting braking distance

- velocity of the travelling vehicle and its inertial force
- Brake efficiency of vehicle and type of braking system
- Surface friction or road surface characteristics
- Longitudinal slope or gradient of a road.



LD :→ Lag distance
BD → Braking distance

SSD = LD + B.D

Lag distance / Reaction distance

During the total reaction time, 't' seconds the vehicle may be assumed to move forward with a uniform speed at which the vehicle has been moving and this speed may be taken as the design speed.

If 'v' is the design speed in m/sec and 't' is the total reaction time of the driver in seconds, then

Lag distance = vt metre

If the design speed is V $\frac{km}{h}$, then Lag distance = $Vt \times \frac{1000}{60 \times 60}$

$= 0.278\,Vt$ metre

Braking distance

On level surface

Assuming a level road, the braking distance may be obtained by equating the work done by the frictional force (F) in stopping the vehicle & the kinetic energy of the vehicle moving at design speed.

The kinetic energy of the vehicle of mass 'm' in motion at a speed of 'v' m/s is $\frac{1}{2}mv^2$ or $\frac{Wv^2}{2g}$ [if weight of vehicle = W, W = mg]

$\frac{1}{2}mv^2 = f_s W l$

$= F \times l$ where F = Frictional force developed

force x distance = workdone

$= Wfl$ F = Wf where W = total weight in kg

$\Rightarrow \frac{1}{2}\frac{W}{g}v^2 = Wfl$

f = co-efficient of friction or skid resistance (0.35 to 0.4).

$\Rightarrow$ $$\boxed{l = \frac{v^2}{2gf}}$$

l = braking distance in m

v = speed of vehicle $\frac{m}{sec}$

g = acceleration due to gravity = 9.81 $\frac{m}{sec^2}$

When v in $\frac{km}{hr}$ = $0.278\,V$ $\frac{m}{sec}$

$\therefore l = \frac{(0.287V)^2}{2 \times 9.81 f} = \frac{0.077284\,V^2}{19.62 f}$ * Dividing 0.077284 in numerator & denominator

$$\frac{\frac{0.077284}{0.077284}}{\frac{19.62 f}{0.077284}} = \frac{V^2}{253.868 f} \approx \frac{V^2}{254 f}$$

$$\therefore l = \frac{V^2}{254 f}$$

Stopping distance on level surface/road / Plane road

SSD or SD (in m) = lag distance or Reaction distance + Braking distance

$$SD \text{ or } SSD \text{ (in m)} = LD + B.D$$

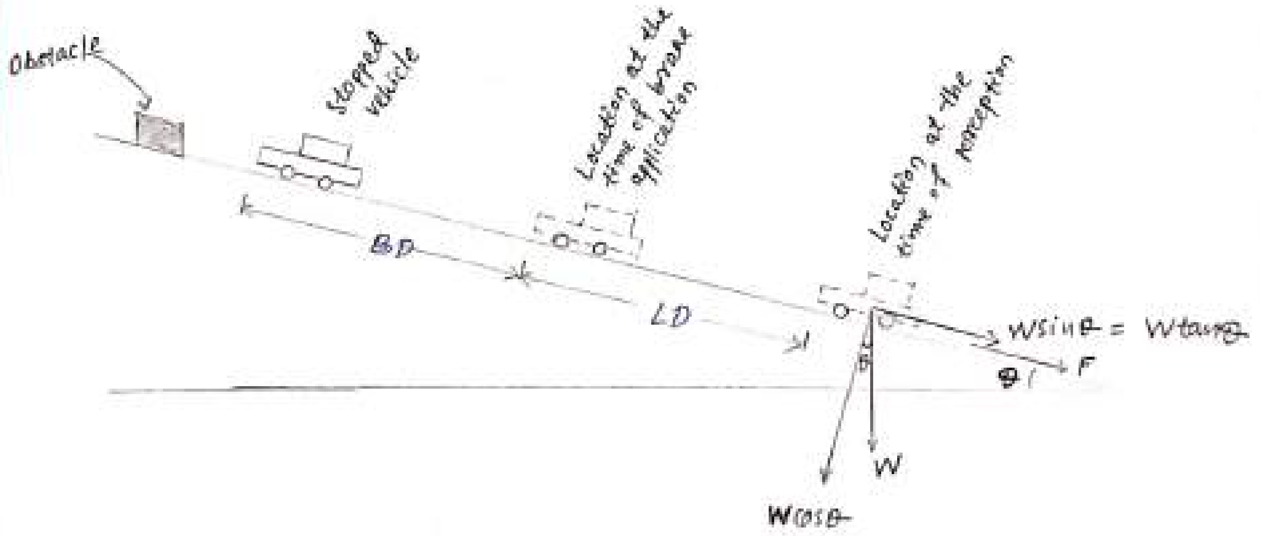
$$= 0.278 Vt + \frac{V^2}{254 f}$$

{ value of 'f' ranging from 0.35 to 0.4

'V' in km/h

't' in second

SSD on a sloped road



When there is an ascending gradient of say, +n% the component of gravity adds to the braking action and hence the braking distance is decreased.

The component of gravity acting parallel to the surface which adds to the braking force = $W\sin\theta = W\tan\theta = W\left(\frac{n}{100}\right)$

Equating the kinetic energy and work done

$$\frac{1}{2}mv^2 = f_s WL + WL\tan\theta \qquad (f_s = f)$$

$$\frac{W}{g}\frac{v^2}{2} = f_s WL + WL\tan\theta$$

$$\frac{v^2}{2g} = f_s L + L\tan\theta \quad \text{(canceling } W \text{ on both sides)}$$

$$\frac{v^2}{2g} = L(f + \tan\theta)$$

$$L = \frac{v^2}{2g(f+\tan\theta)}$$

$\tan\theta = \frac{n}{100}$
$= +0.01n$ or 1 in n

$$\boxed{L = \frac{v^2}{2g(f+0.01n)}} \quad \text{— (A)}$$

Similarly, in descending gradient of $-n\%$, the braking distance increases, as the component of gravity now opposes the braking force.

$$\boxed{\therefore L = \frac{v^2}{2g(f-0.01n)}} \quad \text{— (B)}$$

Hence the above eqn A & B, for SSD may now be written as

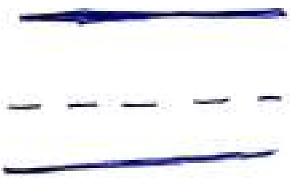
$$\boxed{SSD = vt + \frac{v^2}{2g(f\pm 0.01n)}} \quad \text{in 'm' if } v \text{ in m/s}$$

or

$$\boxed{SSD = 0.278\,Vt + \frac{V^2}{254(f\pm 0.01n)}} \quad \text{if } V \text{ is in km/hr}$$

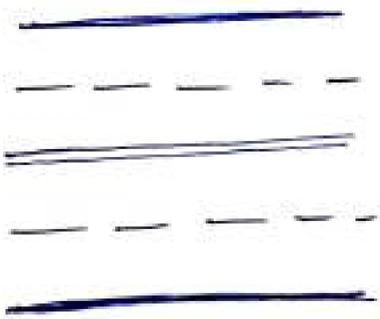
On any road stretch if the stopping sight distance for the design speed is not available, the speed should be restricted by installing suitable speed limit regulation sign alongwith warning signs.

However the option of speed restriction should be considered only as a temporary measure and wherever possible the stretch of the road should be re-aligned or the obstruction to visibility removed so as to provide at least safe stopping sight distance for the design speed.

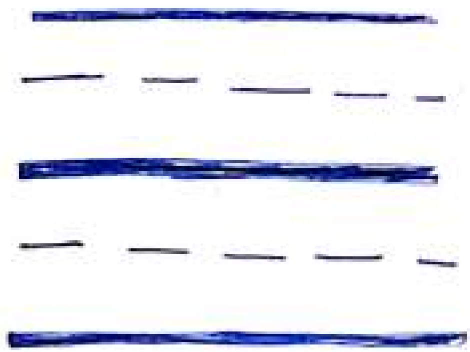


single carriageway with 2 lane

single carriageway with 3 lane



single carriageway with 4 lanes



Duel carriageway with 2 lanes in each direction

Pb Calculate the stopping sight distance for
(i) two lane highway having two way traffic.
(ii) single lane road having two way traffic.
Design speed = 40 km/hr, $f = 0.35$, $t = 3$ seconds

Soln: stopping distance

$= Vt + \frac{V^2}{2gf}$ $\left\{ 40 \frac{km}{hr} = 11.11 \frac{m}{s} \right.$

$= (11.11 \times 3) + \frac{(11.11)^2}{2 \times 9.81 \times 0.35}$

$= 51.30$ m

(i) when there are two lane two way traffic = 51.30 m

(ii) when single lane two way traffic = 2 × 51.30 = 102.6 m

when V in km/hr

SD/SSD

$= 0.278Vt + \frac{V^2}{254f}$

$= (0.278 \times 40 \times 3) + \frac{40^2}{254 \times 0.35}$

$= 51.35$ m

(i) 51.35 m

(ii) 2 × 51.35 = 102.7 m

(i) stopping sight distance in one-way traffic lane and also in two-way traffic lane, should be equal to the stopping distance

(ii) In single lane road, when two-way movement of traffic is permitted then stopping sight distance should be equal to twice the stopping distance.

Pb calculate the stopping sight distance for
(a) two lane road having two-way traffic
(b) single lane road having two-way traffic.
The design speed of road is 50 $\frac{km}{hr}$. The coefficient of friction between the road surface and the tyres may be taken as 0.4 and the reaction time of the driver may be assumed as 3 seconds. The roadway is level.

Soln: V in km/hr

SD = 66.30 m

(a) 66.30 m
(b) 2 × 66.30 = 132.6 m

Pb: Calculate the stopping sight distance for a road for which the design speed is 40 km/hr. The brake efficiency is 40% and the reaction time of the driver may be assumed as 3 s.

Soln: Reaction time = 3 seconds

co-efficient of friction = ? brake efficiency = 40%.

~~effective co-efficient of friction fs with 40% brake efficiency~~
~~during stopping = ...~~

$$SD = 0.278\,Vt + \frac{v^2}{254f}$$

$$= (0.278 \times 40 \times 3) + \frac{40^2}{254 \times 0.4} = 49.10\,m \simeq 50\,m$$

Pb: Calculate the minm sight distance required to avoid a head on collision of two cars approaching from the opposite directions at 90 and 60 kmph. Assume a reaction time of 2.5 seconds, co-efficient of friction of 0.7 & a brake-efficiency of 50 percent in both the cases.

Soln: Reaction time = 2.5 seconds

Effective co-efficient of friction f, with 50% brake efficiency during stopping $= 0.5 \times 0.7 = 0.35$ ✓

1st car speed 90 km/hr $V_1 = 90\ \frac{km}{hr}$

2nd " speed 60 km/hr $V_2 = 60\ \frac{km}{hr}$

SSD for 1st car $= 0.278\,Vt + \frac{v^2}{254f} = 153.66\,m$

SSD for 2nd car $= 0.278\,Vt + \frac{v^2}{254f} = 82.194\,m$

) Total sight distance required to avoid head on collision of the two approaching cars $= SSD_1 + SSD_2$

$= 153.66 + 82.194$

$= 235.86 \simeq 236\,m$

(4) Head-light sight distance :-

This is the distance visible to a driver during night driving under the illumination of the vehicle head light. The sight distance is critical at up-gradients and at the ascending stretch of the valley curves.

Pb (later) calculate the stopping sight distance on a highway at a descending gradient of 2%. for a design speed of 80 kmph. Assume other data as per IRC recommendations.

Soln gradient is 2%, reaction time = 2.5 second, design coefficient of friction $f = 0.35$

$V = 80$ kmph, $n = -2\% = -0.02$

$$SSD = 0.278Vt + \frac{V^2}{254(f \pm 0.02f)}$$

$$0.278Vt + \frac{V^2}{254(f \pm 0.01n)}$$

$$= (0.278 \times 80 \times 2.5) + \frac{80^2}{254(0.02 - 0.35)}$$

$$= (0.278 \times 80 \times 2.5) + \frac{80^2}{254(0.35 - 0.02)}$$

$$= 131.95\,m \simeq 132\,m$$

Pb The design speed of a road is 65 kmph, the friction coefficient is 0.36 and reaction time of driver is 2.5 sec. Calculate (i) Head light sight distance
(ii) intermediate sight distance required for the road.

Soln $V = 65$ kmph, $f = 0.36$, $t = 2.5$ second

$$SSD = 0.278Vt + \frac{V^2}{254f}$$

$$= (0.278 \times 65 \times 2.5) + \frac{65^2}{(254 \times 0.36)}$$

$$= 91.38 \simeq 91.4\,m$$

(i) SSD = 91.4m

(ii) 2SSD = 182.8 ≃ 183m

pb Calculate the min^m non-passing sight distance on a highway at a descending gradient of 6%. Given the following data (i) Design speed = 80 kmph

(ii) Reaction time of driver = 2.5 s

(iii) coefficient of friction betn tyre & road surface = 0.4

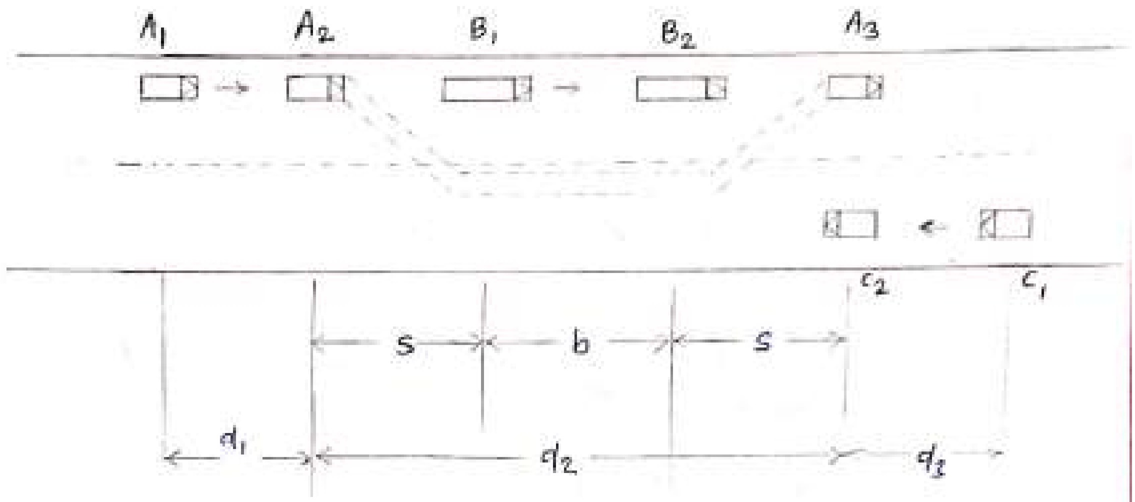
Soln

$$0.278Vt + \frac{V^2}{254(f - 0.01n)}$$

$$= (0.278 \times 80 \times 2.5) + \frac{80^2}{254(0.4 - 0.06)}$$

$$= 129.7 \simeq 130 \text{ m}$$

Over taking Sight Distance (OSD) / Passing sight Distance (PSD) / Non-stopping Sight Distance



Analysis of overtaking sight distance (OSD) on a two-way/two-directional road

Simple overtaking process on a two-lane highway with two-way traffic movement/

vehicle 'A' travelling at the design speed $V \frac{m}{sec}$ or V kmph desires to overtake another slower vehicle B moving at a speed of $V_b \frac{m}{sec}$ or V_b kmph. The vehicle 'A' has to accelerate, shift to the adjacent right side lane, complete the overtaking manoeuvre and return to the left lane, before the on-coming vehicle 'C' approaches the overtaking stretch as shown...

The overtaking manoeuvre may be split up into three operations thus dividing the overtaking sight distance, OSD into three(3) parts, d_1, d_2 and d_3

'd_1' is the distance (m) travelled by the overtaking vehicle A during the reaction time 't' (sec) of the driver from position A_1 to A_2 before starting to overtake the slow vehicle B.

'd_2' is the distance (m) travelled by the vehicle A during the actual overtaking operation during T (secs) from position A_2 to A_3

'd_3' is the distance (m) travelled by on-coming vehicle 'C' during the actual overtaking operation of A during T (secs) from position C_1 to C_2

(2 lane undivided straight road)

Thus on a 2-lane road with 2-way traffic the overtaking sight distance, $OSD = d_1 + d_2 + d_3$ (m)

Assumptions made in the analysis & determination

Assumptions made to calculate the values of d_1, d_2, d_3 in mtr as given below...

➡ the overtaking vehicle A is forced to reduce its speed from the design speed V (m/sec) to V_b (m/s) of the slow moving vehicle B and move behind it, allowing a space 'S' (m), till there is an opportunity for safe overtaking operation.

or

d_1 = distance travelled by the vehicle 'A' (from position A_1 to A_2) at speed V_b m/s during the time in which vehicle 'A' decides whether or not, he should take over the slow moving vehicle B i.e perception time 't' seconds

$$\boxed{d_1 = V_b t \text{ (m)}}$$

The IRC suggests that this reaction time 't' of the driver may be taken as 2.0 seconds as an average value, as the aim of the driver is only to find an opportunity to overtake.

$$\boxed{\therefore d_1 = 2V_b \text{ (m)}}$$

➡ From position A_2, the vehicle A starts accelerating, shifts to the adjoining lane, overtakes the vehicle B. and shifts back to it original lane ahead of B in position A_3 during the overtaking time, T (sec)

The straight distance between position A_2 and A_3 is taken as d_2 (m), which is further splited into three parts,

$$d_2 = (s + b + s)\ m$$

→ The min^m distance between position A_2 and B_1 may be taken as the min^m spacing s (m) between the two vehicles while moving with the speed V_b (m/sec).

The min^m spacing between vehicles depends on their speed and is given by formula $\boxed{s = (0.7 V_b + 6)\ m}$

→ The min^m distance between B_2 and A_3 may also be assumed equal to s(m).

If the overtaking time by vehicle A for the overtaking operation from position A_2 to A_3 is T (sec), the distance covered by the slow moving vehicle B travelling at a speed of V_b (m/s) $= b = V_b T$.

Thus the distance $= d_2 = (b + 2s)$

→ Now the time 'T' depends on speed of overtaken vehicle B and the average acceleration 'a' (m/sec²) for overtaking vehicle A

The overtaking time T (sec) may be calculated by equating the distance $d_2 = \left(V_b T + \frac{1}{2} a T^2\right)$ .... using the general formula for the distance travelled by an uniformly accelerating body with initial speed V_b m/sec and 'a' is the average acceleration during overtaking in m/sec²

$$d_2 = b + 2s$$

$$= (V_b T + 2s)$$

as $b = V_b T$, $2s = \frac{aT^2}{2}$, $T = \sqrt{\frac{4s}{a}}$ where $s = (0.7 V_b + 6)\ m$

$d_2 = (V_b T + 2s)$ m

➔ The distance travelled by vehicle 'C' moving at design speed V (m/s) during the overtaking operation of vehicle A i.e during time T (sec) is the distance d_3 (m) between positions C_1 to C_2

Hence $d_3 = VT$ (m)

$= VT$

Thus OSD/PSD $= d_1 + d_2 + d_3$

$$= \left[(V_b t + V_b T + 2s + VT)\ \text{m}\right]$$

In kmph the above values may be written

$$PSD/OSD = \left(0.28 V_b t + 0.28 V_b T + 2s + 0.28 VT\right)\ \frac{km}{hr}$$

Here

V_b = initial speed of overtaking vehicle in $\frac{km}{hr}$

t = reaction time of driver = 2 sec

V = speed of overtaking vehicle or design speed in $\frac{km}{hr}$

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

$s = (0.7 V_b + 6)$ m

$= (0.7 \times 0.28 V_b + 6)$

$= (0.196 V_b + 6)$

$= (\simeq 0.2 V_b + 6)$

$= (0.2 V_b + 6)$ m

(*) In case the speed of overtaken vehicle (V_b or V_b) is not given, the same may be assumed as 4.5 $\frac{m}{sec}$ or 16 $\frac{km}{hr}$, less than the design speed of the highway. Therefore $V_b = (V - 4.5)\frac{m}{sec}$ or $V_b = (V - 16)\frac{km}{hr}$ where V is the design speed in $\frac{m}{sec}$ * V is the design speed in kmph.

$T = \sqrt{\frac{4S}{a}}$ sec, if 'a' is in $\frac{km}{hr/sec}$ ($\frac{m}{sec^2}$) ← initial

$= \sqrt{\frac{4 \times S}{0.278\, A/sec}}$ $= \frac{1000}{3600}$ /sec

$= \sqrt{\frac{14.388\, S}{A}} \simeq$

$= \sqrt{\frac{14.4\, S}{A}}$ where A is average acceleration during overtaking, kmph/sec

(*) when, the road is unidirectional & there is no interference of the opposite traffic, then d_3 becomes zero, & $P.S.D = d_1 + d_2$

Criteria for overtaking Sight Distance Requirement on Highways

It is desirable that adequate sight is available on most of the road stretches such that the vehicles travelling at the design speed can overtake slow vehicles at the earliest opportunity.

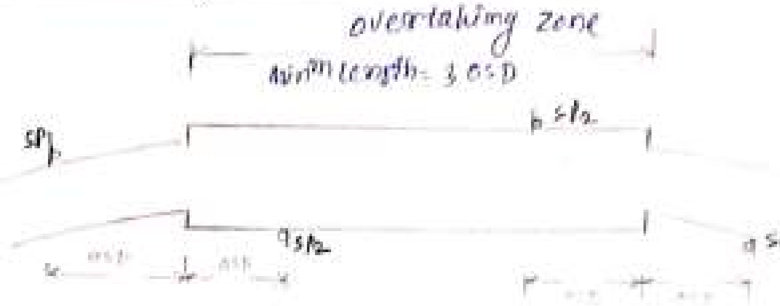
→ On road stretches with two way traffic movement, the min^m overtaking distance should be $(d_1 + d_2 + d_3)$ where overtaking is not prohibited.

→ on divided highway and on roads with one way traffic regulation, the overtaking distance need only be $(d_1 + d_2)$ as no vehicle is expected from the opposite direction.

→ On divided highways with four or more lanes, it is not essential to provide the usual OSD.

→ On horizontal curves the overtaking sight distance requirements cannot always be fulfilled especially on sharp curves, if the safe overtaking sight distance requirements are high. In such cases overtaking should be prohibited by regulatory signs.

Criteria for overtaking zones



$SP_1 \rightarrow$ sign post "overtaking zone ahead"

$SP_2 \rightarrow$ sign post "End of overtaking zone"

$OSD = 3(d_1 + d_2)$ for one way traffic

$OSD = 3(d_1 + d_2 + d_3)$ for two way traffic

It is desirable to construct highways in such a way that the length of road visible ahead at every point is sufficient for safe overtaking. This is seldom practicable and there may be stretches where the safe overtaking distance cannot be provided.

→ In such zones where overtaking or passing is not safe or is not possible, sign posts should be installed indicating "No passing" or "overtaking prohibited" before such restricted zones start.

However overtaking opportunity for vehicles moving at design speed should be given at as frequent intervals as possible. These zones which are meant for overtaking are called "overtaking zones".

→ Figure above shows an overtaking zone with specification ~~for~~ the positions of the sign posts. The width of carriageway and the length of overtaking zone should sufficient for safe overtaking. Sign posts should be installed at sufficient distance in advance to indicate the start of the overtaking zones. Similarly the end of the overtaking zones should also be indicated by appropriate sign posts installed ahead at similar distances specified above.

The minimum length of overtaking zone should be 3 times the safe overtaking sight distance i.e O.S.D.

Thus min^m length of overtaking zone should be $3(d_1+d_2+d_3)$ for two way roads and $3(d_1+d_2)$ for one way roads.

It is desirable that the length of overtaking zones is kept 5 times the overtaking sight distance i.e 5(O.S.D).

Pb The speed of overtaking & overtaken vehicles are 70 and 40 kmph, respectively - on a two way traffic road. The average acceleration during overtaking may be assumed as $0.99 \frac{m}{s^2}$.

(a) calculate safe overtaking sight distance
(b) what is the min^m length of overtaking zone?
(c) Draw a neat sketch of the overtaking zone & position of the sign posts.

Sol^n speed of overtaking vehicle, V = 70 kmph

$v = \frac{70}{3.6} = 19.44$ m/sec

or

$\frac{70000}{3600} = 19.44$ m/sec

Speed of overtaken vehicle $V_b = 40$ kmph, $V_b = \frac{40}{3.6} = 11.11 \frac{m}{sec}$

Average acceleration during overtaking $a = 0.99 \frac{m}{sec^2}$

(a) OSD for 2 way traffic

$= d_1+d_2+d_3$

$= (V_b t + V_b T + 2s + VT)$ m

$d_1 = V_b t = 11.11 \times 2 = 22.2\,m$

d_2 - $S = (0.7V_b + 6) = (0.7 \times 11.11 + 6)$

$= 13.77$

$T = \sqrt{\frac{4S}{a}} = \sqrt{\frac{4 \times 13.77}{0.99}} = \sqrt{55.63636363636}$

$= 7.46\ sec$

$d_2 = V_b T + 2S$

$= (11.11 \times 7.46) + 2(13.77)$

$= 82.89 + 27.54$

$= 110.43\,m$

$d_3 = VT = 19.44 \times 7.46$

$= 145.022\,m$

$OSD = d_1 + d_2 + d_3$

$=$ ~~13.77~~ 22.2 $+ 110.43 + 145.022$

$=$ ~~277.652~~ $\cong 278\,m$

(b) $Min^m = 3\,OSD$

$= 3 \times 278 = 834\,m$

Desirable $= 5\,OSD = 5 \times 278 = 1390\,m$

(c)

BEFORE GOING TO PROBLEM → should complete the Table work in Page 45, 46 ...

Pb// Calculate the safe overtaking sight distance for a design speed of 96 kmph. Assume all other data suitably.

Ans: V = speed of overtaking vehicle

∴ speed of overtaken vehicle = 96 - 16 = 80 kmph (assumed)

reaction time t = 2 sec

A = Average acceleration assumed = 2.56 kmph/sec

$= 0.72\ m/sec^2$

$$96 \frac{km}{hr} = \frac{96 \times 1000}{3600} = 26.67 \frac{m}{sec}$$

$$80 \frac{km}{hr} = \frac{80 \times 1000}{3600} = 22.23 \, m/sec$$

$$d_1 = V_b t = 22.23 \times 2 = 44.46 \, m$$

$$d_2 = b + 2s = V_b T + 43.122 \quad \left(\because b = V_b T, \; 2s = 2(0.7 V_b + 6) \right)$$

$$2s = 2(0.7 \times 22.23 + 6) = 43.122$$

$$T = \sqrt{\frac{4s}{a}} = \sqrt{\frac{4 \times 21.561}{0.72 \, (\text{from table})}} = 10.95 \, sec$$

$$d_2 = (22.23 \times 10.95) + 43.122 = 286.54 \, m$$

$$d_3 = VT = 26.67 \times 10.95 = 292.03 \, m$$

$$\therefore OSD = d_1 + d_2 + d_3 = 44.46 + 286.54 + 292.03 = 623.03 \, m$$

Max^m overtaking acceleration at different speeds

Speed		Max^m overtaking acceleration	
V, Kmph	V, m/sec	A, kmph/sec	a, m/sec^2
25	6.94	5.0	1.41
30	8.33	4.8	1.30
40	11.10	4.45	1.24
50	13.88	4.0	1.11
65	18.05	3.28	0.92
80	22.22	2.56	0.72
100	27.78	1.92	0.53

- About 9 to 14 seconds of time duration is taken for completion of an overtaking manoeuvre.
- The time taken for initial manoeuvre is about $\frac{1}{3}$ the total time required for overtaking. The remaining $\frac{2}{3}$ of the time is accounted for by the opposing vehicle that is travelling at design speed.
- OSD is the unobstructed distance between two points on the carriage way which are 1.22m above the road surface. One point represents the position of the drivers eye & the other point represents

the height of the object.

Safe overtaking sight Distance on 2 lane highway for various Design speed.

speed km/hr	Time component in seconds: For overtaking manoeuvre	For opposing vehicle	Total	Safe overtaking sight Distance (OSD) m
40	9	6	15	165
50	10	7	17	235
60	10.8	7.2	18	300
65	11.5	7.5	19	340
80	12.5	8.5	21	470
100	14	9	23	640

Curves

The geometrical arcs provided at the change in alignment or gradient of a road are known as curves.
curves play an important role in the geometrical design of a road. Therefore, they should be so designed as to provide safety and convenience to the traffic.

Necessity of providing curves

The necessity of providing curves at the change in alignment or gradient of a road arises due to the following reasons:-

(i) To lay the road according to topography of the country

(ii) To provide access to the particular place.

(iii) To avoid costly land

(iv) To avoid excessive cutting or filling

(v) To avoid certain religious, monumental or such other important structures

(vi) To make use of the existing bridge.

(vii) To keep the driver alert by making change in the direction of road.

(viii) To make use of existing right of way

(ix) To avoid mental strain caused by the monotony of continuous journey along a straight route.

(x) To check the tendency of the driver to increase the speed of his vehicle beyond the safe limits on straight routes.

Advantages of curves

(i) They provide gradual change in direction

(ii) They provide gradual change in gradient

(iii) They provide easy turning of vehicles.

(iv) They provide comfort to the passengers

(v) They increase the life of vehicles.

(vi) They help to keep the speed of vehicles within limits

(vii) The help to keep the drivers alert due to change in the direction of road.

(viii) They help to avoid mental strain caused by the monotony of continuous journey along straight routes.

(ix) They help in providing adequate visibility to the traffic.

(x) They help in providing safe & economical alignment of a road.

Factors affecting the design of curves

The following are the factors which play an important role in the design of a road curve:—

(a) The design speed for the road

(b) The safe allowable coefficient of friction in the lateral direction between the tyres & the road surface.

(c) Max^{m} allowable superelevation.

(d) permissible centrifugal ratio

(a) The Design speed for the road

The relation between superelevation, co-efficient of lateral friction, the design speed & radius of curvature of the road is given by the following equation :-

i.e $$e+f = \frac{v^2}{gR}$$

where

- e = The superelevation in mtr
- f = co-efficient of lateral friction between the tyres & the road surface.
- v = The design speed for the road in $\frac{m}{sec}$
- R = The radius of the curve in mtr.

The design speed for the road affects the curvature & hence the design of curves.

(b) Safe allowable co-efficient of friction in lateral direction

The safe allowable co-efficient of lateral friction between the tyres & the road surface generally depends upon the speed of the vehicle ; type & condition of tyres, condition of the road surface & the effect of the weather.

(*) For design of curve, the co-efficient of friction 0.2, with a factor of safety of 1.33 may be considered so that the working value of co-efficient of lateral friction be taken as 0.15 in above eqn to design the curve.

(c) Max^m allowable superelevation

The maximum rate of Superelevation on Indian highways as recommended by I.R.C is 7%.

This value is considered for finding the radius of curvature in the above eqn while designing the curve.

(d) Permissible centrifugal ratio

The ratio between centrifugal force & the weight of the vehicle is known as centrifugal ratio (C.R.)

The expression $\frac{v^2}{gR}$ in the above mentioned eq^n is known as centrifugal ratio

$C.R = \frac{f}{W} = \frac{Wv^2}{gRW} = \frac{v^2}{gR}$

Allowable value of C.R in road $= \frac{1}{4}$, railways $= \frac{1}{8}$

→ The max^m permissible value of centrifugal ratio for comfortable travel on rural highway is taken as $\frac{1}{4}$ or 0.25

(*) Thus, with the min^m allowable superelevation (7% / 0.07) and safe coefficient of lateral friction (0.15), the sum of 'e' and 'f' or the value of centrifugal ratio from the above mentioned eq^n works out 0.22 which is less than the prescribed value of 0.25.

Hence, the value of 'e' and 'f', assumed for the design, ensure adequate comfort to the passengers.

Now, from the relation $\frac{v^2}{gR} = 0.22$, the required radius of curvature (R) can be calculated after fixing the value of the design speed, which shall be used in the design of curve.

Types of curves

Curves on highways have been divided into the following two main classes.

1. Horizontal curves
2. vertical curves

1. Horizontal curves

The curves provided at the turning points in the alignment (in the horizontal plane) of a road are known as horizontal curves.

These roads are provided to achieve gradual change in the direction of alignment of a road in the horizontal plane.

The min^m radius of a horizontal curve depends on the permissible design speed for the road or in other words, on the category of the road in that area. The values of min^m radii for various categories of roads in different areas, as recommended by IRC are given in table ... (1)

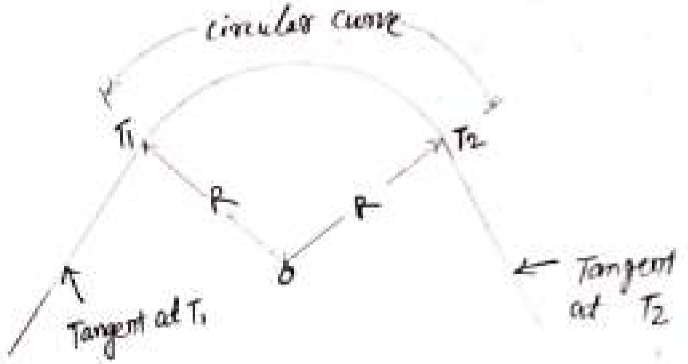
Horizontal curve used in the alignment of highways are further divided into following types:-

(a) Simple curve
(b) compound curves
(c) Reverse curves
(d) Transition curves
(e) Lemniscate curves

(a) Simple curve

A circular curve consisting of a single arc of uniform radius connecting two tangents is called simple curve.

This curve is expressed in terms of degree of the curve, which is the angle in degree subtended at the centre by a chord of 30m length.



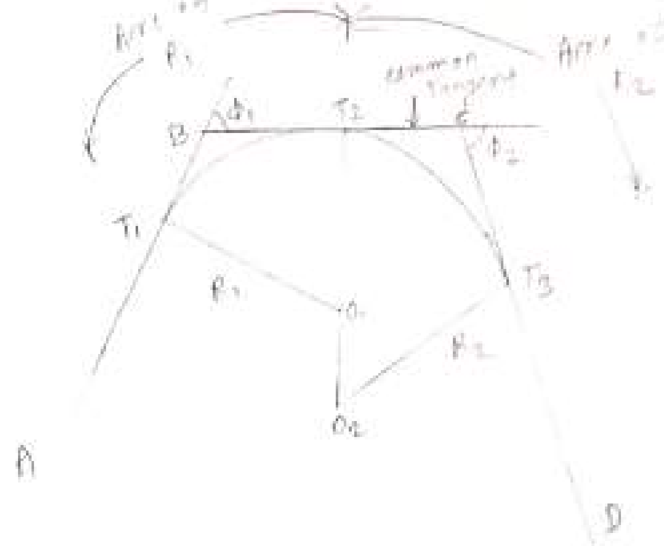
This type of curve is suitable for slow moving traffic & for radius. Such a curve may lie within two tangents lengths or two transition curves.

Table-1

Classification of Roads	plain terrain		Rolling terrain		Mountainous terrain				steep terrain			
					Area not affected by snow		Snow bound areas		Area not affected by snow		Snow bound areas	
	Ruling Minm	Abs Minm	Abs	Minm Ruling Minm	Ruling Minm	Abs Minm	Ruling Minm	Abs Minm	Ruling Minm	Abs Minm	Ruling Minm	Abs Minm
NH & SH	360	230	230	155	80	50	90	60	50	30	60	33
MDR	230	155	155	90	50	30	60	33	30	14	33	15
ODR	155	90	90	60	30	20	33	23	20	14	23	15
VR	90	60	60	45	20	14	23	15	20	14	23	15

(b) Compound curves

When a circular curve consisting of series of two or more simple curves of different radii, which turn in the same direction is called a compound curve.

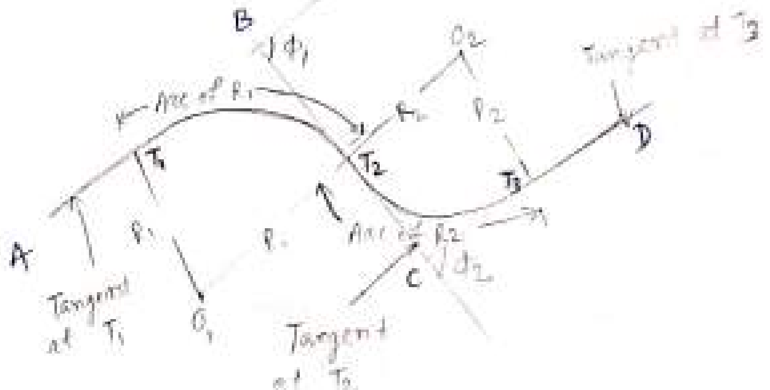


In this curve, the adjacent simple curve (T_1T_2 & T_2T_3) have a common tangent (BC at T_2) & they lie on the same side of the curve.

This type of curve is used when compelled by topography of the area in ordered to avoid cutting through hard rock, heavy cutting or filling etc.

(c) Reverse curve/serpentine curve

A circular curve consisting of two simple curves of same or different radii in the opposite direction is called a reverse or serpentine curve

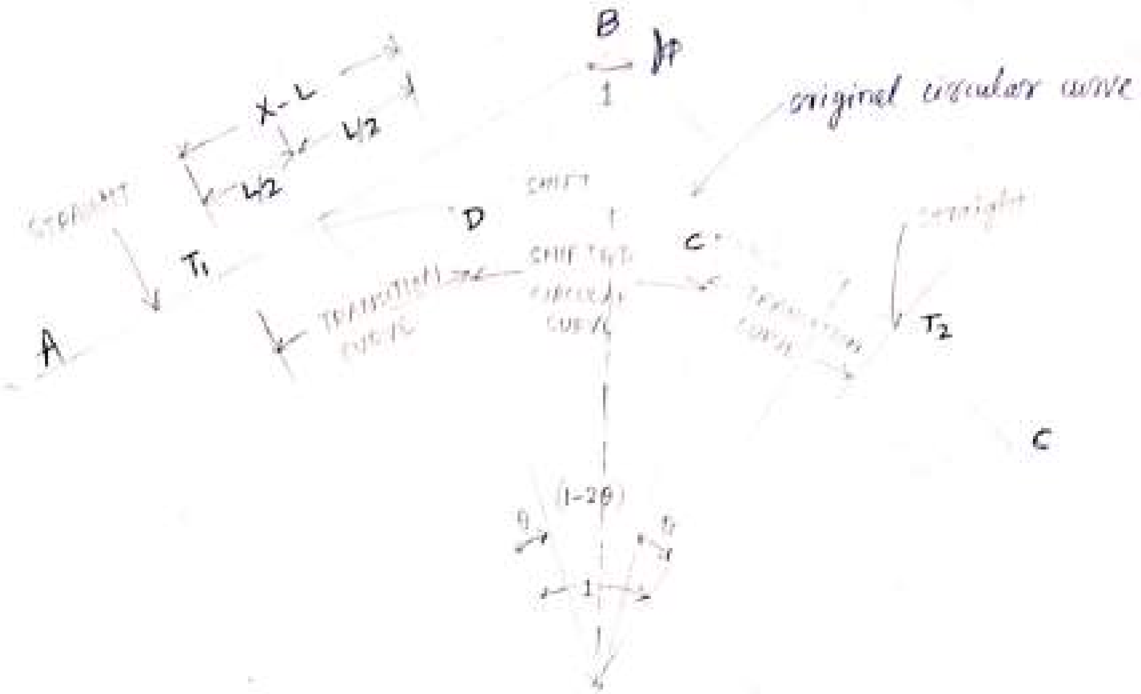


In this curve, the adjacent simple curves (T_1T_2 & T_2T_3) have a common tangent (BC at T_2) and their centres lie on opposite sides of the curve.

(*) This type of curve is oftenly used in the alignment of a hill road.

(d) Transition curve/spiral curve/easement curve

The curve having its radius varying gradually from an infinite to a finite value equal to that of the circular curve to be connected



or vice versa is known as transition, spiral or easement curve. This type of curve is commonly introduced on highways between a tangent and a circular curve or between the circular curve & a tangent to provide ease and gradual change in direction of a road alignment.

Objects

(i) To provide gradual change in the radius of curvature from infinite value at the tangent to the radius of circular curve to be introduced & vice-versa.

(ii) To provide smooth entry of vehicle from a straight portion to a curved portion of the road so as to avoid discomfort to the passengers which may otherwise cause due to sudden increase of curvature from a straight to a circular path.

(iii) To permit gradual application of the superelevation & thus reducing shocks on the vehicle.

(iv) To permit gradual application of extra widening of carriageway needed at the horizontal curves.

(v) To minimise wear on pavements.

(vi) To provide safety to the vehicular traffic.

Essential requirement of a transition curve

(i) Its radius of curvature should vary gradually from infinite value at the straight to a finite value at the circular curve.

(ii) It should meet the straight and the circular curve tangentially.

(iii) The length of transition curve should be such that the designed superelevation is attained at or before its junction with the circular curve.

(iv) The rate of increase of curvature and that of superelevation should be same.

(*) The IRC has recommended the use of spiral transition curve in the horizontal alignment of highways.

Length of transition curve

Min^m length of the transition curve should be determined from the following two considerations and the larger of the two values be adopted for design purposes:-

(i) The rate of change of centrifugal acceleration should not cause discomfort to drivers. From this consideration, the length of transition curve is given by the equation

$$L_s = \frac{0.0215\, V^3}{CR}$$

Where

L_s = Length of transition in metres

V = speed in km/h

R = Radius of circular curve in metre

$C = \frac{80}{75+V}$ (subject to a max^m of 0.8 and min^m of 0.5)

(ii) The rate of change of superelevation (i.e the longitudinal grade developed at the pavement edge compared to through grade along the centre line) should be such as not to cause discomfort to passengers or to make the road appear unsightly. Rate of change should not be steeper than 1 in 150 for roads in plain and rolling terrain, and 1 in 60 in mountainous and steep terrain. On this basis, min^m length of transition is foundout from the relations...

(a) For plain & Rolling Terrain

$$L_s = \frac{2.7V^2}{R}$$

(b) For mountainous and steep Terrain

$$L_s = \frac{1.0V^2}{R}$$

On the bases of above consideration, the min^m transition lengths for different speeds and curve radii as per reco-mmendation of IRC are given below in table ↓ xerox copy to be pasted.

Minimum Transition Lengths for different Speeds and Curve Radii

Plain and Rolling Terrain

Curve Radius (R) (metres)	Design Speed (km/h) 100	80	65	50	40	35
45					NA	70
60				NA	75	55
90				75	50	40
100			NA	70	45	35
150			80	45	30	25
170			70	40	25	25
200		NA	60	35	20	20
240		90	50	30	20	NR
300	NA	75	40	25	NR	
360	130	60	35	20		
400	115	55	30	20		
500	95	45	25	NR		
600	80	35	20			
700	70	35	20			
800	60	30	NR			
900	55	30				
1000	50	30				
1200	40	NR				
1500	35					
1800	30					
2000	NR					

Mountainous and Steep Terrain

Curve Radius (R) (metres)	Design Speed km/h 40	40	30	25	20
14				NA	30
20				35	20
25			NA	25	20
30			30	25	15
40		NA	25	20	15
50		40	20	15	15
55		40	20	15	15
70	NA	30	15	15	15
80	55	25	15	15	15
90	45	25	15	15	NR
100	45	20	15	15	
125	35	15	15	NR	
150	30	15	15		
170	25	15	NR		
200	20	15			
250	15	15			
300	15	NR			
400	15				
500	NR				

Note: In the table, NA stands for not applicable and NR for Transition not required.

Vertical curves

The curves provided at change of gradient (in vertical plane) of a road are called vertical curves.

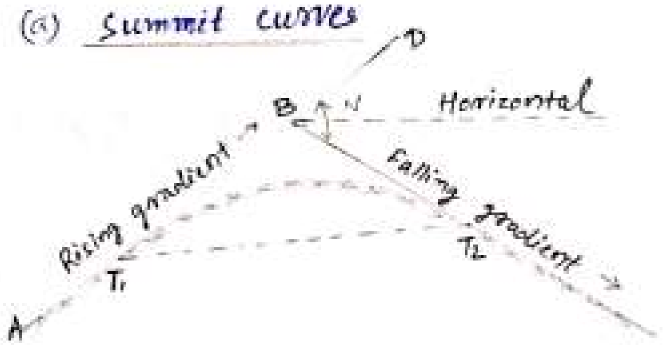
Vertical curves are provided to achieve the following objects:-

(i) To provide gradual change in grade
(ii) To provide Safety and adequate visibility to the traffic
(iii) To provide comfort to the passengers

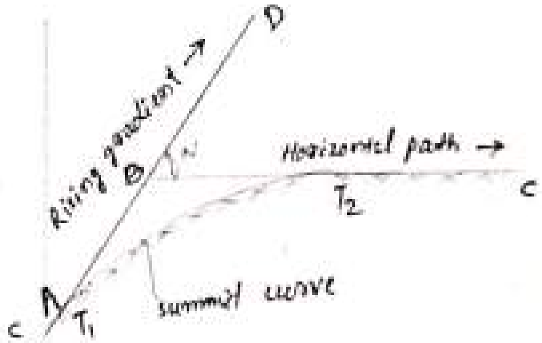
Vertical curves are further divided into following two types..

(a) Summit curves/ spur curves
(b) Valley curves

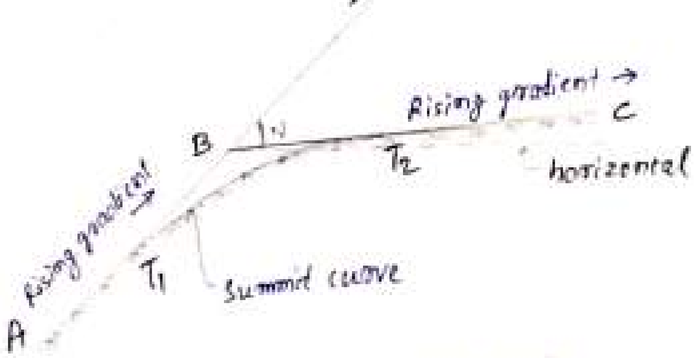
(a) Summit curves



A Rising gradient intersecting a Falling gradient



A rising gradient meeting a horizontal path



A rising gradient meeting another rising gradient

The vertical curves having their convexity upward are known as ~~summit~~ or spur curves

* This type of vertical curve is provided when a rising gradient intersects a falling gradient, a rising gradient meets another rising gradient or a rising gradient meets a horizontal path... as shown in alongside figures respectively.

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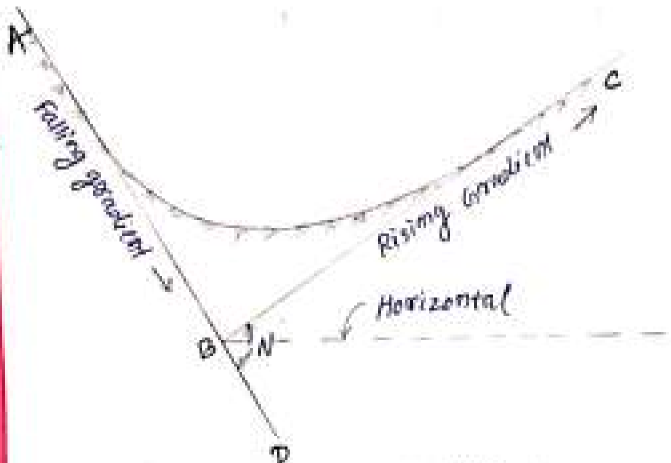
The length of summit curves is governed by the choice of sight distance whether stopping sight distance or the overtaking sight distance. On hill roads, application of the overtaking sight distance may not be practicable except at a very high cost. Hence, this criterion should not be enforced except in very easy terrain.

(b) valley curves/sag curves

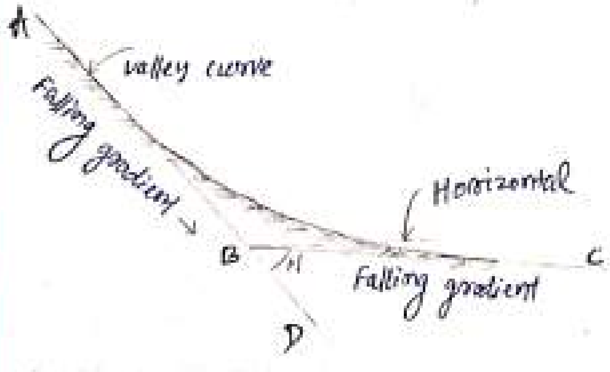
The vertical curves having their convexity downward are called valley/sag curves

These curves are provided when a falling gradient intersects a rising gradient, a falling gradient meets another falling gradient & a falling gradient meets a horizontal path as shown alongside.

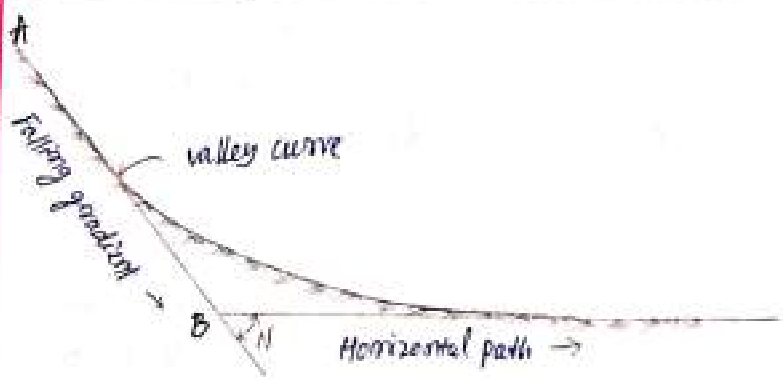
(*) Valley curves should be designed as square parabolas. Their length should be such that for night travel the head light beam distance is the same as the stopping sight distance.



A Falling Gradient intersecting a rising gradient



A falling Gradient meeting another falling Gradient.



A falling Gradient meeting a Horizontal path

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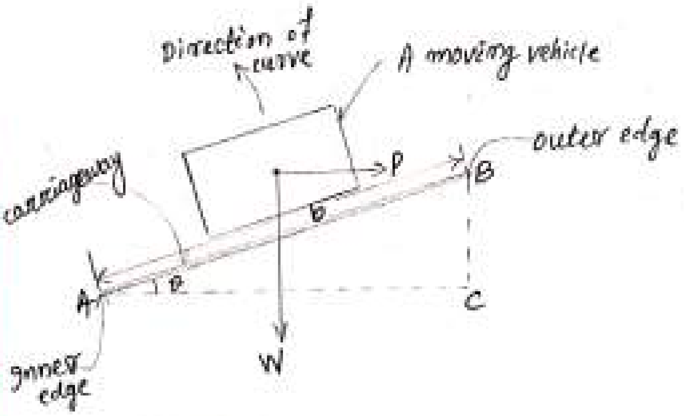
Super elevation

The inward transverse inclination provided to the cross-section of the carriageway at horizontal curved portion of a road is called **superelevation, cant or banking**.

It is expressed as the ratio of elevation of outer edge above the inner edge to the horizontal width of carriageway or as the tangent of the angle of slope of the road surface. It is generally denoted by 'e' or 'S.E'



Centrifugal Force

In physics, centrifugal force is the force that makes objects move outwards when they are spinning around something or travelling in a curve.

(*) centrifugal force is the out-ward pushing force felt by bodies moving in a circular motion.

superelevation, $e = \frac{BC}{AC} = \tan\theta$

In practice, the value of 'e' is very small. The max^m^ superelevation allowed is 1 in 15 $\theta = \tan^{-1}\left(\frac{1}{15}\right) = 3^\circ 48' 50.67'' \simeq 4^\circ$

Therefore, the value of $\tan\theta$ would be practically equal to $\sin\theta$.

Hence, $e = \tan\theta = \sin\theta = \frac{BC}{AB}$

The ratio of elevation of the outer edge above the inner edge to the width of carriageway.

(*) Thus superelevation of 1 in 20 means that the outer edge will be raised by $\frac{1}{20} \times 7 \times 100 = 35\,cm$ above the inner edge in 7m width of carriageway.

Objects of providing superelevation

(i) To counteract the effect of centrifugal force acting on the moving vehicle to pull the same outward on a horizontal curve.

(ii) To help a fast moving vehicle to negotiate a curved path without overturning and skidding.

(skidding :- The linear motion of vehicle with its wheel locked on a road surface is known as skidding.

→ In skidding, the distance travelled along the road is more than the movement of wheels' circumference. It is due to application of brakes & provision of improper superelevation.

Slipping :- The revolving of wheels without any linear motion along the road surface is called slipping.

→ In slipping, the movement of wheel's circumference is more than the distance travelled along the road as in case of a muddy road. It is due to lack of friction between wheels & the road surface.)

(iii) To ensure safety to the fast moving traffic

(iv) To prevent damaging effect on the road surface due to improper distribution of load.

Advantages of providing superelevation

(i) It permits running of vehicle at high speed on a curved path as on a straight path without any danger of overturning and thus results into increased volume of traffic.

(ii) It provides more or less even distribution of load on wheels & hence uniform stress is offered on the foundation which results into less wear on wheel tyres and springs as well as economy in maintenance cost of the road.

(iii) It also helps to keep the vehicles to their proper side on the pavement and thus prevents collision of vehicles moving in opposite directions on a curved portion of the road.

(iv) It provides drainage of the whole width of road towards the innerside. Thus, there is no necessity of providing side drain on the outerside of the road.

3.0 ROAD MATERIALS

3.1 Subgrade Soil:-

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

→ The supporting soil beneath pavement & its special under courses is called subgrade.

→ Compacted subgrade is the soil compacted by controlled movement of heavy compaction.

Aggregate :-

→ It is collective term for mineral materials such as sand, gravel & crushed stone that are used with a binding medium (such as water, portland cement etc) to form compound materials (such as bituminous concrete & portland cement concrete).

→ By volume, aggregate generally accounts for 92 to 96% of bituminous concrete & 70 to 80% of portland cement concrete.

Binder Materials

→ The bituminous binder used in pavement construction include both bitumen & tar.

→ Bitumen is a petroleum product obtained by the distillation of petroleum.

→ Tar is obtained by destructive distillation of coal or wood.

→ When bitumen contains some inert materials, it is known as asphalt.

3.2 Function of soil as highway Subgrade :-

→ Stability

→ Incompressibility

→ Permanency of strength

→ Good drainage

→ Ease of compaction

→ Minimum changes in volume & stability under adverse condition of weather & ground water

3.3 California Bearing Ratio :-

→ This method is developed as method of classifying & evaluating soil subgrade & base course material for flexible pavements.

→ It is an empirical test to determine the material properties for pavement design.

→ It is a penetration test wherein a standard piston, having area 19.62 cm^2 (or 50 mm dia.) is used to penetrate the soil at a standard rate of 1.25 mm/min.

→ The pressure upto a penetration of 12.5 mm & its ratio to the bearing value of a standard crushed rock is termed as CBR.

→ In most cases, CBR decreases as penetration increases.

→ The ratio at 2.5 mm penetration is used as CBR.

→ In some cases, 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 if confirmed by repeating the test.

→ CBR test is measure of resistance of a material to penetration of standard plunger under controlled density & moisture condition. It can be performed in re-moulded or undisturbed specimen in laboratory. It is extensively used for field correlation of flexible pavement thickness requirement.

Procedure :-

→ CBR apparatus consist of a mould 150mm dia with a base plate & collar, a loading frame & dial gauge for measuring the penetration value & expansion on soaking.

→ The specimen in the mould is soaked in water for 4 days & the swelling & water absorption values are noted.

→ Load is applied on the sample by standard plunger with dia. of 50mm at the rate of 1.25 mm/min. A load penetration curve is drawn.

→ The loads values on standard crushed stones are 1370 kg ($70\ kg/cm^2$) & 2055 kg ($105\ kg/cm^2$) at 2.5mm & 5mm penetration respectively.

→ CBR value is expressed as percentage of actual load causing the penetration of 2.5mm or 5mm to the standard loads mentioned above.

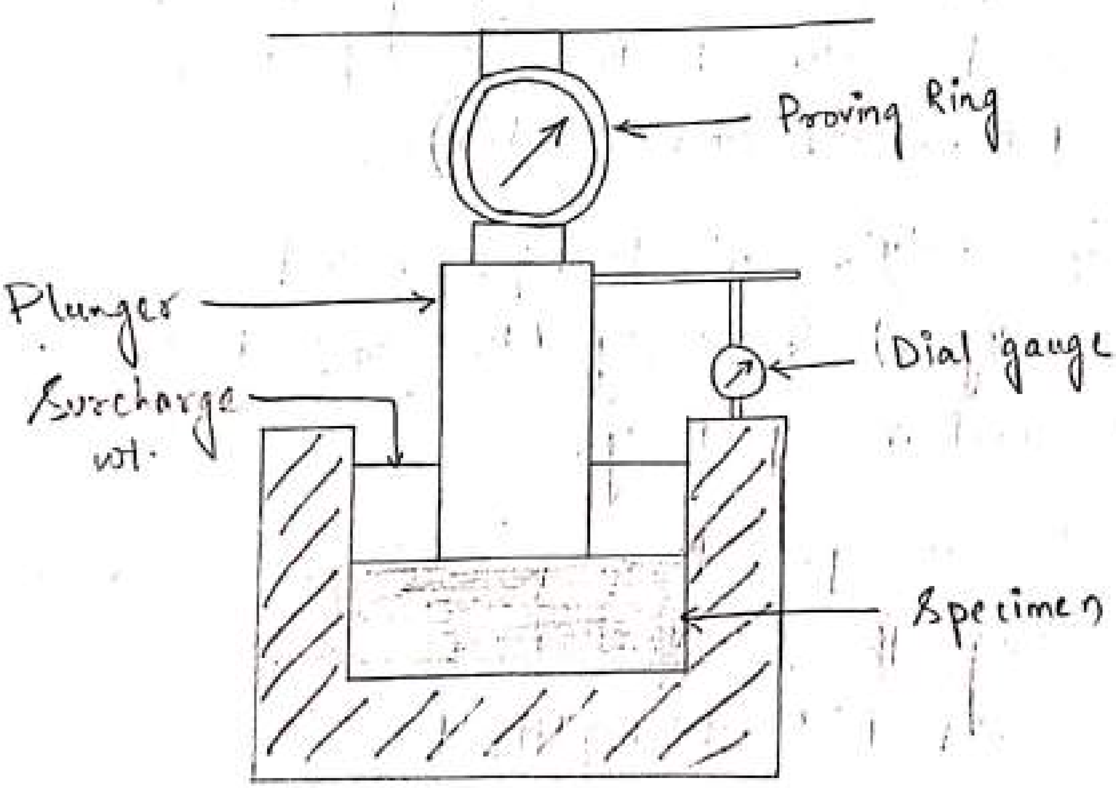
$$CBR = \frac{\text{load carried by specimen}}{\text{load carried by standard specimen}} \times 100$$

→ Two values of CBR will be obtained. If the value of 2.5mm is greater than that of 5mm penetration, the former is adopted.

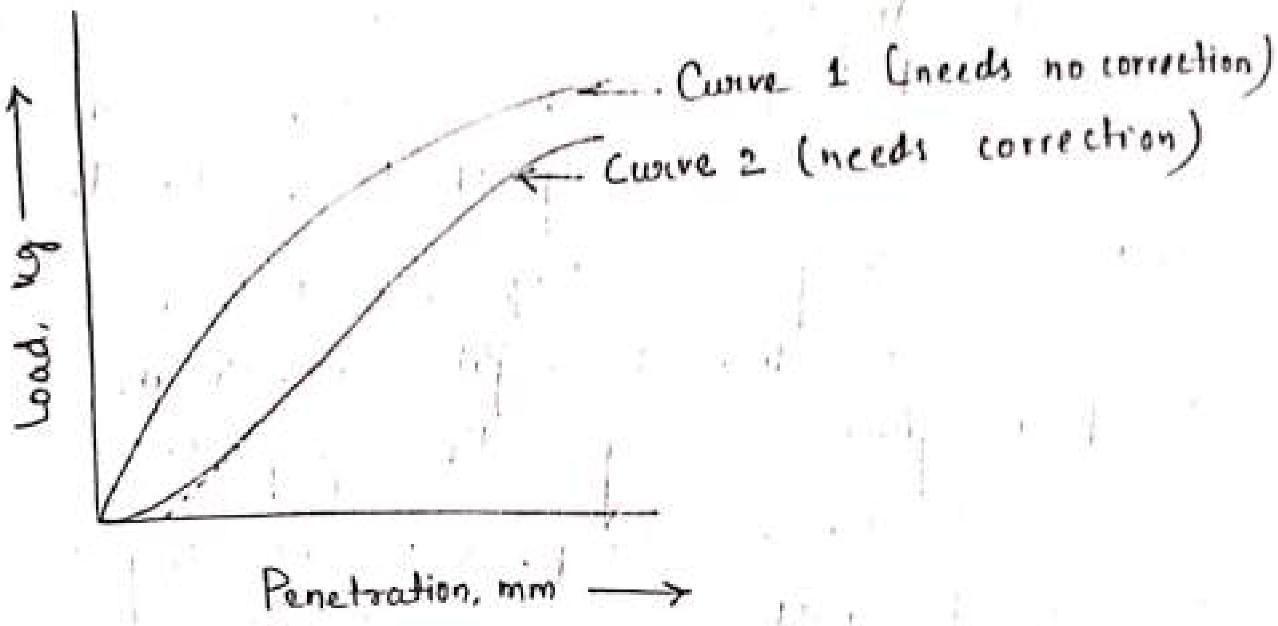
→ If the CBR value obtained from test at 5mm penetration is higher than that at 2.5mm, then the test is to be repeated for checking.

→ If the check test again gives similar results, then higher value obtained at 5mm penetration is reported as CBR value.

→ The avg. value of CBR of three test specimens is reported as CBR value of sample.



→ If the specimen has surface irregularities, the initial portion of curve may have concavity upwards. In that case, a tangent is drawn to the curve at the point of greatest slope. This tangent plus the convex portion of original curve is the corrected curve, with origin moved to the point where the tangent cuts the x-axis.



3.4 Testing Aggregates

1. Abrasion Test:

→ It is carried out to test the hardness property of aggregate & to decide whether they are suitable for different construction work.

This test are of following types:-

a) Los Angeles Abrasion test
b) Derel Abrasion test
c) Dorry Abrasion test

→ Los Angeles Abrasion test is preferred one for carrying out hardness property.

→ The principle of Los Angeles abrasion test is to find the percentage wear due to relative rubbing action between the aggregates & steel balls used as abrasive charges.

→ The Los Angeles machine consist of circular drum of internal dia. of 700mm & length 520mm mounted on a horizontal axis enabling it to be rotated.

→ An abrasive charge consisting of cast iron spherical balls of 48mm dia. & weight 340-445gm is placed in cylinder along with aggregates.

→ The no. of abrasive charges varies according to the grading of sample.

→ The quantity of agg. to be used depends upon the gradation & usually ranges from 5-10kg.

→ The cylinder is then locked & rotated at the speed of 30-33 rpm for a total of 500-1000 revolutions depending upon gradation of aggregates.

→ After specified revolutions, the material is sieved through 1.7mm sieve & passed fraction is expressed as percentage total wt. of sample.

$$\text{Abrasion Value} = \frac{\text{Wt. of aggregate re ined on 1.7mm Sieve}}{\text{Total wt. of agg taken}} \times 100$$

→ This value is called Los Angeles Abrasion Value. A max. value of 40% is allowed for WBM base course in Indian conditions.

→ For bituminous concrete, a maximum value of 35% is specified.

2. Impact Test

→ This test is carried out to evaluate the resistance to impact of aggregate or toughness of aggregate.

→ Aggregate passing 12.5mm IS sieve & retained on 10mm IS sieve is filled in a cylindrical steel cup of internal diameter 10.2 cm & depth 5cm which is attached to a metal base of impact testing machine.

→ The material is filled in 3 layers where each layer is tamped for 25 no. of blows.

→ Metal hammer of weight 13.5 to 14 kg is arranged to drop with a free fall of 38 cm by vertical guides & the test specimen is subjected to 15 no of blows.

→ The crushed aggregate is allowed to pass through 2.36mm IS sieve. The impact value is measured as percentage of aggregates passing sieve (W_2) to the total weight of sample (W_1).

$$\text{Aggregate impact Value} = \frac{W_2}{W_1} \times 100$$

→ Aggregates to be used for wearing course, the impact value should not exceed 30%. For bituminous macadam the maximum permissible value is 40%.

3. Soundness Test

→ This test is carried out to study the resistance of aggregates to weathering action, by conducting accelerated weathering test cycles.

→ The porous aggregates subjected to freezing & thawing are likely to disintegrate prematurely. To ascertain the durability of such aggregates, they are subjected to an accelerated soundness test.

→ Aggregates of specified size are subjected to cycles of alternate wetting in a saturated solution of either sodium sulphate or magnesium sulphate for 16-18 hours & then dried in oven at 105°c - 110°c to a constant weight.

→ After 5 cycles, the loss in wt. of aggregates is determined by sieving out all undersized particles & weighing. The loss in weight should not exceed 12% when tested with sodium sulphate & 18% with magnesium sulphate solution.

4. Crushing Strength Test

→ Aggregate crushing value provides a relative measure of resistance to crushing under gradually applied crushing load.

→ The test consist of subjecting the specimen of aggregate in standard mould to a compression test under standard load conditions.

→ Dry aggregates passing through 12.5mm sieve and retained on 10mm sieve are filled in a cylindrical measure of 11.5 cm dia. & 18cm ht. in three layers.

→ Each layer is tampered 25 times with standard tamping rod.

→ The test sample is weighed & placed in the test cylinder in three layers each layer being tampered again.

→ The specimen is subjected to a compressive load of 40 tonnes gradually applied at the rate of 4 tonnes per minute.

→ Crushed aggregates are then sieved through 2.36 mm sieve & wt. of passing material (W_2) is expressed as percentage of wt. of total sample (W_1) which is the aggregate crushing value.

$$\text{Aggregate Crushing Value} = \frac{W_2}{W_1} \times 100$$

→ A value less than 10 signifies an exceptionally strong aggregate ~~which~~ while above 35 would normally be regarded as weak aggregate.

5. Water Absorption :-

→ The difference between the apparent & bulk specific gravities is nothing but the water - permeable voids of the aggregates.

→ We can measure the volume of such voids by weighing the aggregates dry & in saturated surface dry condition with all permeable voids filled with water.

→ The difference of above two is Mw.

~~→ Mo = wt. of dry agg.~~

→ M_w = wt. of saturated surface dry aggregate − wt. of dry aggregate

$$\text{Water Absorption} = \frac{M_w}{M_D} \times 100.$$

Requirement of Road Aggregates :-

→ They shall be clean, hard, durable & cubical in shape.

→ They must be free from dust, organic matter & other deleterious matter.

→ They shall not be flaky or elongated.

→ They must not consist of injurious or harmful materials such that they reduce the strength of structure.

→ They should resist wear due to abrasive action of traffic on the surface course.

Bitumen :-

→ It is petroleum product obtained by the distillation of petroleum crude.

→ It is black to ~~dr~~ brown in colour.

→ It is soluble in carbon disulphide & carbon tetra chloride.

→ Molecular wt. range for road bitumen is 400 to 5000.

→ Bitumen show resistance to coating road aggregate & also does not retain in ~~prese~~ presence of water.

→ It shows resistance to weathering action.

→ less temperature susceptibility.

Tar :-

→ It is obtained by destructive distillation of coal or wood.

→ It is soluble in toluene.

→ Molecular wt. range for road tar is 150 to 3000.

→ Tar coats more easily & retain it better in presence of water.

→ It shows less resistance to weathering action.

→ More temperature susceptibility.

Cement :-

→ It is a binder, a substance used for construction that sets, harders & adheres to other materials to bind them together.

→ Cement is seldom used on its own, but rather to bind sand & gravel together.

→ Cement mixed with fine aggregate produces mortar and with sand & gravel produces concrete.

Properties of Cement :-

→ Provides strength to masonry.

→ Stiffens or hardens early.

→ Possesses good plasticity.

→ An excellent building material.

→ Easily workable.

→ Good moisture resistant.

Penetration Test :-

→ A method of measuring viscosity by penetration of standard needle under standard condition of load, time & temperature. The test measures the hardness or softness of bitumen in terms of penetration expressed in mm/10th of standard needle.

Temperature = 25°c.

Load on needle = 100 gm.

Time in which penetration is recorded = 5 sec

Penetration is measured by a graduated dial.

→ Bitumen softens to a poring consistency ~~to~~ a depth more than 15mm in the ~~diameter~~ container is poured. The expected penetration sample is cooled in 60 min. in air & 60 min in water before testing. The standard needle is positioned to get a penetration value for 5 sec & is noted.

The penetration value obtained is represented in 80-100 or 80/100 grade bitumen at standard consistence, & it range from 20-225 mm.

In cold region bitumen with high penetration value is used.

In warm region low penetration value is used i.e 30/40 grade.

The factor which affect the penetration test is test temperature, needle size & weight & period of cooling.

Viscosity Test :-

Viscosity is the property of a fluid that determines the resistance offered by the fluid to a shearing force under laminar flow condition. it is thus the opposite of fluidity.

The liquid under test is poured to a specified level into a container surround by water or oil bath providing temperature control at the base of container is a small orifice with a simple valve control on opening valve, the time in seconds is recorded for a stated quantity of liquid to discharge into a measuring liquid below.

The bitumen is placed into a standard tar viscometer & its temperature is raised to test temperature specified. When the temp. reaches respective test temperature orifice valve is open. Time elapse is noted to collect the bitumen of 50ml. The time required to collect a bottom container of 50ml is five indirectly the viscosity of bitumen.

Cutback Bitumen :-

The viscosity of bitumen is reduced by a volatile diluents. Cutback bitumens are available in three types:-

i) Rapid Curing (RC)
ii) Medium Curing (MC)
iii) Slow Curing (SC)

→ Cutbacks are designated by numerals representing progressively thicker or viscous cutback. For example RC-2 is more thick than RC-1 but RC-2, MC-2 & SC-2 have same viscosity.

→ RC-0 & SC-0 may have 45% solvent & 55% bitumen where as RC-5 & MC-5 may contain 15% solvent & 85% bitumen.

→ RC-Cutback : They have penetration value of 80 to 120 e.g. petroleum such as naptha or gasoline.

→ MC-Cutback: They have good wetting properties e.g. kerosene & light diesel oil.

→ SC-Cutback : These can be obtained by blending bitumen with high boiling point gas oil or by controlling the rate of flow & temperature of crude during the first cycle of refining.

ROAD PAVEMENTS

General

A natural earth track, under modern traffic load, can hardly be expected to perform functions of a road satisfactorily. It lacks two basic requirements of a good road, namely the strength and a good riding surface. Therefore, it becomes necessary to construct some structure in the form of pavement on the top of the natural earth track to enable it to support wheel load safely and to provide a good riding surface for a longer period.

ROAD PAVEMENTS

A layered structure supported by the subgrade soil to form the carriageway of a road is called a road pavement.

→ A pavement is essentially constructed in order to fulfill the two basic requirements of the road, namely the strength and a good riding surface. Thus, with the provision of pavement, the road can carry heavy wheel loads of vehicular traffic and provide a smooth riding surface.

→ The road pavement may be flexible or rigid according to their method of construction and their structural action.

Purposes of road pavements :-

(i) To carry heavy wheel loads of vehicular traffic and to distribute the same over a large area of the underlying subgrade soil.

(ii) To prevent the subgrade soil from the bad effects of weathering agencies

(iii) To provide a smooth riding surface.

Requirement of a good road pavement

(i) It should be cheap & easy in construction.

(ii) It should be strong & durable.

(iii) It should provide an impervious & sanitary surface.

(iv) It should be smooth enough to provide low tractive resistance but not so smooth which may become slippery.

(v) It should not develop corrugations

(vi) It should not cause glare in the sun

(vii) It should provide good visibility at night

(viii) It should be suitable for all types of traffic

(ix) It should provide a safe and comfortable riding surface under all weather conditions.

(x) It should have long life.

(xi) It should have low maintenance cost.

Component parts of a Road Pavement structure

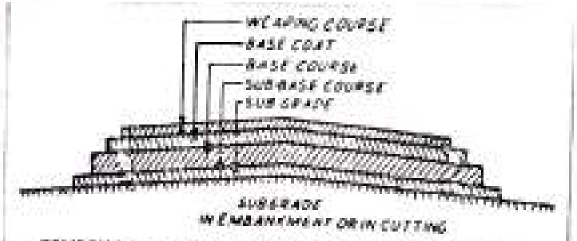
The following are the component parts of the pavement structure of a road starting from bottom :-

1. subgrade or formation ;
2. sub-base ;
3. Base course or foundation course ;
4. Base coat or intermediate course ;
5. wearing course

All these component parts may occur in a typical flexible pavements, whereas a rigid pavement usually consists of subgrade, sub-base and a concrete slab, plain or reinforced.

1. Subgrade :-

The finished and compacted surface of earthwork on which a road pavement rests is called subgrade or formation.



COMPONENT PARTS OF A ROAD PAVEMENT STRUCTURE

The subgrade of a road pavement may be provided on an embankment, in cutting or at existing ground level depending upon the topography & the finalised formation level. It consists of well compacted natural soil brought to the required camber and gradient. The thickness and type of pavement structure depends upon the supporting power of the subgrade because the entire load of the pavement, including the load of traffic transmitted through the pavement, is ultimately taken up by the subgrade.

Functions of sub-grade :-

(i) To bear ultimately the entire load of pavement including the load of traffic transmitted through the pavement.

(ii) To provide an adequate and uniform support to the road pavement.

2. Sub-base :-

A layer of granular material provided in between the sub-grade & the base course in a road pavement is called sub-base.

→ It is provided as an additional layer when subgrade is of poor quality. It consists of a layer of comparatively cheaper material like burnt clinker, natural gravel or slag.

Functions of sub-base :-

(i) To improve the bearing capacity of the subgrade

(ii) To improve drainage and to check capillary rise of sub-soil water

(iii) To eliminate frost heave in frost affected area

(iv) To prevent subgrade material from working up into the base course

3. Base course :-

A layer of boulders or bricks (in single or double layers) provided over the sub-base or immediately over the sub-grade in the absence of sub-base in a road pavement is called base course, soling or foundation course.

This course is considered as the most important and a major component of road pavement structure because this course is to bear the impact of traffic transferred through the wearing course.

→ It consists of a stable material like boulders, gravel, one or two layers of well burnt bricks, etc.

→ In case of a rocky subgrade, this layer is not provided.

Functions of base course :-

(i) To withstand high shearing stresses imposed upon it due to impact of traffic on the wearing course.

(ii) To act as foundation for the road pavement and to transfer the wheel loads coming over the pavement surface safely to the sub-base and subgrade lying underneath.

4. Base coat :-

The layer of hard stones provided in between the base course and the wearing course in a road pavement is called base coat/intermediate coat/ bearing course.

This course may be provided in flexible pavements. It is usually omitted in case of a rocky subgrade, rigid pavements or when the base course consists of hard stones.

Functions of base coat :-

(i) To transmit wheel loads coming on the pavement surface over large area of the base course.

(ii) To act as a layer of transmission material since, otherwise, there is great difference in sizes of aggregates used in wearing course & base course.

5. Wearing course :-

The topmost layer of the road pavement directly exposed to traffic is called wearing course / surfacing.

It may consist of one or more number of layers in case of flexible pavements. A good wearing course should be impervious & weather resisting.

It should be able to resist abrasive action of the traffic.

Functions of wearing course :-

(i) To distribute the traffic load safely to the base course.

(ii) To act as an impervious layer so that the surface water may find its access to the base course

(iii) To prevent dust nuisance

(iv) To withstand abrasion caused due to movement of traffic.

(v) To provide a smooth riding surface.

Quality of materials required in different courses of a road pavement :-

The top layer of a road pavement is directly exposed to traffic. It is obvious that this layer is subjected to max^m stresses developed by the traffic load. Therefore, this layer should be made of dense material of the best quality. The stresses go on reducing with increase of depth. By the time, stresses are transmitted to the subgrade, their intensity is considerably reduced. So, we can generalise that quality of materials in different layers of a road pavement goes on improving, starting from its bottom to the top layer.

Types of Road Pavements

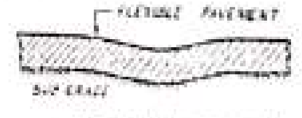
Road pavements are broadly classified into the following two basic types :-

1. Flexible pavements ;
2. Rigid pavements

1. Flexible pavements

The road pavements which can change their shape to some extent without rupture are known as flexible pavements.

→ Any change of shape occuring in the subgrade and subsequent layers provided on it, is reflected by the surface of these pavements as shown alongside.



A Flexible Pavement indicating depression due to settlement of Subgrade

→ The common examples of flexible pavements are :- All bituminous pavements gravel pavements, water bound macadam (WBM) pavements, etc.

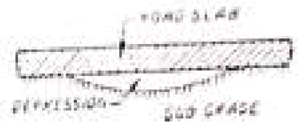
2. Rigid Pavements

The road pavements which cannot change their shape without rupture are known as rigid pavements.

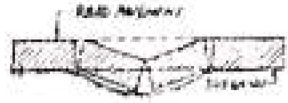
→ Any change occuring in the shape of subgrade is not reflected by the surface of these pavements

- The best example of rigid pavements is :- cement concrete pavement.

- In case of a depression in subgrade occuring due to settlement, a rigid pavement acts as a beam or cantilever. It remains in its position unless bending stresses induced in the pavement are so great as to cause failure of the road pavement as shown in fig: alongside.



A Rigid Pavement acting as a beam over a depression due to settlement of subgrade

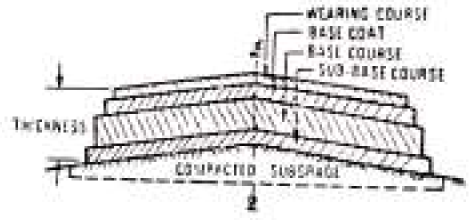


Failure of Rigid Pavement in case of depression due to settlement of Subgrade

Typical cross-sections of flexible and rigid pavements

Flexible and rigid pavements consists of different structural components as shown in fig alongside.....

- A typical flexible pavement usually consists of the following structural components, starting from the bottom:-
  - (i) subgrade;
  - (ii) sub-base;
  - (iii) Base course;
  - (iv) Base coat;
  - (v) wearing course.



(a) Structure of a Flexible Pavement

(b) Structure of a Rigid Pavement

TYPICAL CROSS-SECTIONS OF FLEXIBLE AND RIGID PAVEMENTS

- A typical rigid pavement usually consists of the following structural components, starting from the bottom :-
  - (i) sub-grade;
  - (ii) sub-base;
  - (iii) A concrete slab, P.C.C or R.C.C

→ In case of a rocky subgrade, sub-base is omitted.

(*) Under similar subgrade and traffic conditions, the thickness of pavement required in case of a flexible pavement is considerably more than that in case of a rigid pavement.

Selection of type of road Pavement

The factors which may affect the selection of flexible and rigid Road pavements are given below :-

(a) **Flexible Pavement** This type of road pavement is selected under the following circumstances:-

(i) when funds are not sufficiently available.

(ii) Large number of roads are to be constructed.
(iii) Good subgrade is available.
(iv) Local materials are to be advantageously used.
(v) Traffic load is not very heavy.
(vi) Pavement is to be constructed in stages.

(b) Rigid Pavement :-

This type of road pavement is selected under the following circumstances.

(i) When funds are sufficiently available.
(ii) Long life of the road pavement is desired.
(iii) Traffic load is very heavy.
(iv) Subgrade is poor or of varying nature.
(v) Route is very important and frequent interruptions in the movements of traffic for repair, etc. are not desirable.

Merits & demerits of flexible and rigid road pavements :-

The comparative study of merits and demerits of flexible and rigid road pavements are as per follows.

Sl.No	Points of comparison	Flexible pavements	Rigid pavements
01.	Initial cost	Their initial cost is low.	Their initial cost is high.
02.	Life span	Their life span is short.	Their life span is long.
03.	Thickness	Their thickness is more.	Their thickness is less.
04.	Joints	Joints are not required.	Joints are essentially required.
05.	Skill & supervision	Moderate skill and less supervision is required.	High degree of skill & more supervision is required.
06.	Repair work	Their repair work is easy.	Their repair work is difficult.
07.	Subgrade	A reasonably good subgrade is required.	A good subgrade is not necessary.
08.	Durability	They are less durable.	They are more durable.
09.	Maintenance cost	Their maintenance cost is high.	Their maintenance cost is low.
10.	Resiliency	They are more resilient to traffic load.	They are less resilient to traffic load.
11.	Corrugations	They develop corrugations.	They do not develop corrugations.
12.	Glaring effect	They do not usually cause glare due to reflected sun light.	They often cause glare due to reflected sun light.
13.	Traffic suitability	They are suitable for all types of traffic.	They become noisy under iron wheeled traffic.
14.	Tractive resistance	They offer more tractive resistance.	They offer less tractive resistance.

15.	Temperature effects	Stresses are not induced in these pavements due to temperature variations.	Heavy stresses are induced in these pavements due to temperature variations.
16.	Behaviour with subgrade settlement	They adjust according to any deformation of subgrade without rupture.	They donot adjust according to any deformation of subgrade without rupture.
17.	Feasibility of providing underground works	It is easy to lay, locate or repair underground pipes below these pavements.	It is very difficult to provide or repair underground pipes below these pavements.
18.	Opening to traffic after construction	They can be opened to traffic shortly after construction.	They require curing after construction and thus cause delay in opening to traffic.
19.	Night visibility	Black top pavements provide poor visibility at night.	They provide good visibility at night.
20.	Fesibility of stage development	Stage development is feasible in their case.	Stage development is not feasible in their case.
21.	Effect of loading	They adjust themselves to normal loading by undergoing elastic deformation.	They tend to act as a beam or cantilever and resist deformation.

Subgrade Preparation

The art of providing a finished and compacted surface of earthwork according to the desired gradient and camber along the alignment of a proposed road is known as preparation of subgrade.

- This is the first step in the construction of a proposed road after setting out its alignment on the ground.

The subgrade may be provided on an embankment, in cutting or at existing ground level depending on the topography and the finalised level as per longitudinal section of the proposed road.

The preparation of a road subgrade involves the following operations :-

1. Site clearance & grubbing;
2. Earthwork;
3. compaction & consolidation;
4. checking of subgrade.

1. Site clearance & grubbing

These operations are performed in advance of earthwork operations in accordance with the required specifications.

The site clearance operation includes removal and disposal of all materials such as trees, shrubs, stumps, rubbish, etc. which are unsuitable for use in the work, from within the right of way and such other areas as may be specified on the drawings or by the Engineer-in-charge.

→ The grubbing operation includes removal and disposal of the roots and stumps of trees. The grubbing should be done to a depth of atleast 0.5m below final subgrade level because the roots remaining within the ground are liable to decay in due course of time and may create hollow pockets. Such hollow pockets may cause settlement and result into road failure.

2. Earthwork

After site clearance and grubbing, earthwork is to be done for preparing the subgrade of the proposed road. Before handling earthwork, control pegs should be established for guidance. These control pegs include clearing stakes, batter pegs, reference pegs etc.

In almost all types of areas, road construction involves some amount of earthwork. In open country, a major portion of the road length is constructed in embankment due to drainage consideration.
In a rolling terrain (area with many ups & downs), the embankments and cutting are to be very frequently provided in a road length. Thus, the earthwork for constructing a road may be done in the following two forms:-

(a) Earthwork in embankment
(b) Earthwork in cutting

(a) Earthwork in embankment

The process of removing earth from borrow pits or cuttings, transporting and placing it as a fill in the form of an embankment is known as earthwork in embankment.

when the finalised formation level of a road is to be kept higher than the natural surface level, the road is to run in embankment. The side slopes of an embankment vary from $1\frac{1}{2}:1$ to $3:1$, depending upon the type of soil and drainage conditions.

The earthwork in an embankment is carried out in the following steps:-

(i) marking profiles of embankment
(ii) stripping and storing top soil
(iii) constructing embankments

(i) Marking profiles of embankment

Profiles of embankment are constructed with poles and strings as shown in fig-alongside. These are constructed at 30m intervals for guidance of labour.

PROFILE FOR AN EMBANKMENT

- For making profiles of an embankment, batter pegs are driven on both sides of the centre line to mark toes of the embankment. Bench marks consisting of masonry pillars are erected at about 100m interval to indicate edge of the embankment and formation level. For ordinary embankments, 10% allowance for settlement is kept while making profile as shown in figure.

Materials for embankments :-

The materials used in the construction of embankment is earth, moorum, gravel, a mixture of these or any other approved material obtained either from excavation for road construction borrow-pits and other sources. Such materials should be free of logs, stumps, roots, rubbish or any other material likely to affect the stability of the road embankment.

The size of the coarse material in the mixture of earth to be used in the construction of road embankment should not usually exceed 75mm. Ordinarily only the materials satisfying the density requirement, as per give table below should be used in embankment construction.

Density Requirements of Embankment Materials

Sl. No	Types of work	Max^m Laboratory Dry Density as per IS; 2720 (Part VII)
1.	Embankment upto 3m height	Not less than 1.44 gm/cc
2.	Embankment exceeding 3m height or embankments of any height subjected to constant weathering	Not less than 1.52 gm/cc
3.	Top 0.5m of the embankment below the subgrade level & earth shoulders	Not less than 1.65 gm/cc

Borrow pits :-

The pits dug along the alignment of a road for using their material in the construction of road embankment are known as borrow pits.

LOCATION OF BORROW PIT AND MUTAM

These pits are usually prismoidal or rectangular in shape and dug just outside the permant land width acquired for the proposed road.

Borrow pits should be dug at least 5m away from toe of embankment. These are dug to uniform depth which is limited to 1.5m. The longer sides of borrow pits are kept parallel to the centre line of the road. These pits should never be made continuous because in rainy season, they are likely to become a running stream and may endanger the embankment. Therefore, ridges of not less than 8m width should be left at intervals not exceeding 300m.

Mutams :-

The small portion of earth left undug in a borrow pit to measure the quantity of excavation work is known as mutam/deadman.

→ It should be located at such a position that gives the average depth of excavation for the area to which it belongs. Mutams are maintained till the measurement of earthwork is completed.

(ii) Stripping and storing top soil

After making profiles of embankment, the top soil existing over the embankment foundation is stripped to specified depth not exceeding 150mm & stored for covering embankment slopes, cut slopes and other disturbed areas where re-vegetation is desired.

(iii) Constructing embankments

After stripping and storing top soil, the original ground is consolidated by rolling with a max^m of six passes of 8-10 tonne roller. Then filling is started from edges and worked towards centre of the embankment in layers of thickness not more than 250mm in loose state. These layers are kept slightly concave in shape with convexity downward for proper compaction of the previous layer. The successive layers of earth should be placed only when the previous layer has been thoroughly compacted.

(b) Earthwork in cutting

The process of cutting or loosening and removing earth including rock, from its original position, transporting and damping the same as a fill or in the form of a spoil bank is known as earthwork in cutting or excavation.

When the finalised formation level of a road is to be kept lower than the natural surface level, the road is to run in cutting. The side slopes of a cutting vary from 3:1 to even vertical, depending upon the starta through which cutting is to be done.

The earthwork in cutting is carried out in the following steps:-

(i) Setting out
(ii) Stripping and storing top soil
(iii) Excavation

(i) Setting out

After clearing the site, the limits of excavation are set out true to lines, curves, slopes, grades and sections as shown on the drawings or as directed by the Engineer-in-charge.

(ii) Stripping and storing top soil

After setting out the limits the top soil existing over the sites of excavation is stripped to specified depths and stored at suitable locations for re-use in covering cut slopes, berms and other disturbed areas where re-vegetation is desired.

(iii) Excavation

The excavation is done in lifts. The initial lift for which the contractor is not made any additional payment varies from 0.5m to 1.5m, depending upon the soil condition. Paths & gangways, required for movement of labours, should be provided well within the cutting so that when these are removed the section in cutting becomes true to drawing.

3. Compaction & Consolidation

The earthwork in embankment is compacted to increase the density & stability of the subgrade soil. It reduces settlement and decreases the adverse effects of moisture. Hence, proper compaction of embankment is considered essential for highway construction.

For better results, each layer of the material should be thoroughly compacted to the densities as per following values mentioned in tabular form.

Specification requirements for minimum subgrade soil compaction as recommended by the IRC ... are given

Compaction Requirements for Embankments

S. No.	Type of Work/Material	Field Dry Density as percentage of Maximum Laboratory Dry Density as per IS1 : 2720 (Part VII)
1.	Top 0.5 m portion of embankment below subgrade level and shoulders.	Not less than 100
2.	Other portion of embankment.	Not less than 95
3.	Highly expansive clays.	85 to 90

The subsequent layers should be placed after the finished layer has been tested and accepted by the Engineer-in-charge. The moisture constant at the time of compaction should be optimum moisture content for obtaining maximum dry density of the soil.

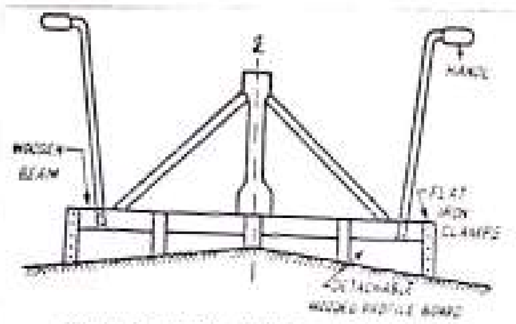
soil compaction is achieved in the field either by rolling, ramming vibration or by watering. Hence, the compacting equipment may be rollers, rammers or vibrators.

After completion of earthwork, a trench is usually dug for finishing the subgrade finally. The depth of this trench is kept equal to the designed thickness of the pavement. The bottom of the trench is provided with some cross-slope i.e camber prescribed for the proposed pavement.

4. Checking of Subgrade

After preparing subgrade, it is checked for its trueness. Surface levels to the subgrade along the road alignment can be checked by a levelling instrument. As per IRC specifications, actual levels should not differ from levels given on drawings by more than 25mm.

The transverse profile is checked by a template. The max^{m} variation permissible is 15mm



TEMPLATE WITH ADJUSTABLE PROFILE

Quality control in preparation of subgrade :-

For adequate quality control in preparation of subgrade, it is essential to have proper field control in compaction.

The following two field control tests are performed to have the required quality control :-

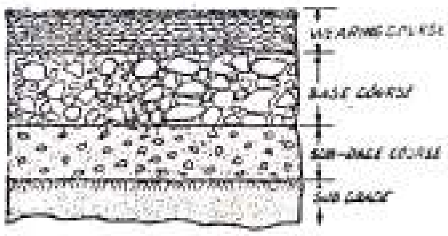
(i) Measurement of moisture content ;
(ii) Measurement of dry density

The moisture content of the soil is found before compaction by suitable method at the site. The soil should have optimum moisture content (OMC) at the time of compaction. After controlling the moisture at OMC, the next control of density is achieved. Dry density may be found by any suitable method, the sand replacement method is considered quite satisfactory.

⇒ The top 50cm layer of soil is compacted thoroughly by rolling at optimum moisture content. (OMC)

Sub-bases & Bases for Flexible Pavements :-

The comparison between sub-base and base course of a flexible pavement is given as below



TYPICAL SECTION THROUGH A FLEXIBLE PAVEMENT

Sl NO	Points of comparison	Sub-base	Base course
01.	Construction	It consist of one or two layers of granular materials.	It consists of more stable material than that of sub-base or subgrade.
02.	Thickness	It is of less thickness.	It is of more thickness.
03.	Design accuracy	It may or may not be accurately designed.	It should be accurately designed according to the wheel loads expected over the pavement.
04.	Location as a structural component	It is provided on the subgrade when the later is of poor quality.	It is provided after sub-base or on subgrade in the absence of sub base
05.	Materials to be used	The materials used in the construction of this layer are natural sand, gravel, laterite, kankar or other naturally occuring or artificial soft aggregate	The materials used in the construction of this layer are first class bricks, stone aggregate etc.
06.	Function	Its function is to improve the bearing power of the subgrade and to prevent capillary rise of subsoil water in the foundation course.	Its function is to act as foundation to the pavement & distribute uniformly the stresses developed due to wheel load over larger area of the subgrade.

TYPES OF BASE COURSES OF FLEXIBLE ROAD PAVEMENTS

The following are the various types of base courses or bases of flexible road pavements according to their method of construction :-

1. Stabilized soil base courses;
2. Brick or stone soling;
3. Macadam base courses.

1. Stabilized soil base courses

The base consisting of stabilized soil is known as stabilized soil base course.

* The process of improving the stability or bearing power of the ordinary soil by the use of controlled compaction, proportioning and adding of suitable stabilizers is known as soil stabilization.

→ Earth roads, constructed from ordinary soil available along their alignment, wear out very soon & become unserviceable within no time. Such roads require constant repair which is not practicable in villages. Hence, to keep these roads in serviceable condition for a longer period and to reduce their maintenance cost, soil stabilization techniques are being extensively utilized for their construction.

Thus, the principle of soil stabilized road construction is the effective utilization of local soil & other suitable stabilizing agents.

Objects of soil stabilization :-

(i) To increase the bearing power of the soil.
(ii) To increase shear strength i.e resistance to punching action of the soil.
(iii) To increase resistance to softening action (due to water) of the soil.
(iv) To increase flexibility in the soil to take the wheel load without deformation & cracking.
(v) To reduce the tendency of swelling or increase in volume of the soil due to wetting & shrinkage on account of withdrawl of moisture.
(vi) To increase the stability of earthwork in embankment as a whole.

Common soil stabilizers :-

Following stabilizers or admixtures are in common use for soil stabilization
(a) cement ; (b) Lime ; (c) Bitumen ; (d) organic compounds such as resinous materials.
(e) chemicals such as calcium chloride, sodium chloride, etc.

Stabilized soil has been satisfactorily used in base course construction in flexible pavements. Such bases are becoming very popular in India because of their low cost & good performance under moderate traffic.

Some important types of stabilized soil bases are

(a) Mechanically stabilized base courses
(b) Lime stabilized base course
(c) cement stabilized base course
(d) Fly-ash stabilized base course

(a) Mechanically stabilized base courses :-

The base consisting of soil stabilized simply by controlled compaction is called mechanically stabilized base course.

Mechanical stabilization is based on the principle that quantity of various size particles in a soil is so adjusted that the particles of one size are just sufficient to fill the voids existing in the particles of next higher size. Such a soil produces dense and stable material after compaction. It is called gradation concept of mechanical stabilization.

For constructing a mechanically stabilized base course, a suitable gradation is adopted. Locally available soil and other materials are blended, mixed & compacted at optimum moisture content and thus the base of desired thickness is prepared.

* Dr. Mehra has recommended the use of 7.5 cm thick mechanically stabilized soil base course for Indian conditions. According to him, the sand content in soil should be 50% and P.I between 5 to 7.

* Equipment used for blending and mixing includes disc harrow, spring tooth and cultivator's plough. Compaction is done by rollers.

(b) Lime stabilized base course :-

The base consisting of soil stabilization by mixing the required proportion of hydrated lime as a stabilizer is called lime stabilized base course.

Lime stabilization has gained popularity in improving subgrades and constructing base courses in areas rich in clayey soil. Black cotton soils responds very well to lime stabilization.

Lime reacts chemically with soil and affects it in the following ways :-

(i) It reduces plasticity and shrinkage of the soil.
(ii) It makes clayey soil easily workable.
(iii) It brings about flocculation of soil particles
(iv) It ~~blends~~ binds the soil particles together

For constructing a lime stabilized base course, the top of existing surface may be flattened or slightly trenched to receive the lime which may be mixed with the prepared material either in slurry form or dry state. The soil is excavated upto 15 cm depth, pulverised, sieved and mixed with 2 to 10% by weight of commercial dry lime slaked at site or pre-slaked lime delivered to the site in suitable packing. The lime used for this purpose should have purity not less than 70 percent when tested in accordance with IS : 1514. The mixing of lime and soil is done by rotary mixers, disc harrow or other suitable equipment. Immediately after spreading, grading & levelling of mixed material, compaction should be carried out with 8 to 10 tonne smooth wheel rollers. The soil is compacted by rolling at OMC and in this way the base course of desired thickness is prepared.

(C) cement stabilized base course :-

The base consisting of soil stabilized by mixing the required proportion of cement as a stabilizer is called cement stabilized base course. The cement stabilized base courses are also known as soil-cement bases.

Almost all types of soils can be stabilized by cement. However, the quantity of cement required, and difficulty in mixing it with the soil, prohibits the use of cement for stabilizing organic and clayey soils. Due to shortage of cement, this type of stabilization is rarely used in India

Construction of a cement stabilized base course involves rigid control on moisture content, mixing & compaction. Damp curing over a period of 10 days is required for cement stabilized bases.

The method of construction of a cement stabilized base is same as in case of the lime stabilized base. The quantity of cement required varies from 5% to 20%. The exact quantity of cement for a soil is found out experimently.

(d) Fly-ash stabilized base course :-

The base consisting of soil stabilized by mixing fly-ash (cinder) in suitable proportion is called fly-ash stabilized base course.

Fly-ash is a residual material left after burning of coal. Big utility plants, using coal, are producing large amount of fly-ash as a waste material. In the past, fly-ash posed a problem for disposal. But in the recent times, use of fly-ash has been made in soil stabilization.

The mix of fly-ash, lime and Jhama brick aggregates, in suitable proportions, has been found to produce a concrete like material. This mix can be advantageously used for base course construction of flexible pavements subjected to light traffic.

2. Brick or stone soling

A compacted layer of bricks or stones laid directly on subgrade of a road pavement is called soling.

In India, brick or stone solings are commonly used in important road pavement. These two types of soling are

(a) Brick soling

One or two layers of bricks laid directly on subgrade of a road pavement is called brick soling.

Bricks may be laid flat or on edge, in one layer or in two layers to get the desired thickness of soling. The thickness of soling depends upon traffic conditions. A row of bricks on end is provided on each side of subgrade trench to contain the running layers of pavement to be laid on the top of soling. Bricks are laid with their lengths at right angles to the centre line of road, breaking joints in adjacent rows.

After laying bricks, sandy soil is worked into joints by using broome and water. Then a layer of sand of about 2.5cm thickness is spread on bricks. The soil is sufficiently sprinkled over with water & rolled by light roller. Brick soling is allowed to dry before the next component layer is placed on it.

(b) Stone soling

A compacted layer of hammer dressed stones laid directly on subgrade of a road pavement is called stone soling.

Stones of proper size and shape, according to thickness of soling required, are selected and hand packed on the prepared subgrade. Stones are laid on their wider faces in such a way that their tops conform to the profile of pavement. Voids in stones are filled with smaller stones. Stone soling is laid to extend 15cm on either side beyond the proposed width of pavement. After laying stones, the profile is checked with a template & corrected wherever found defective. Stones are then consolidated by rolling with a heavy roller. Dry rolling is followed by spreading of sandy soil of 2.5cm thickness, watering & then rolling by a 6 to 8 tonne roller. Stone soling is then allowed to dry.

3. Macadam base courses

The bases consisting of broken stone aggregates bound together under controlled compaction with or without a binding material are known as macadam base courses.

The important types of macadam base courses are :-

(a) Water-bound macadam base course
(b) Built-up spray grout base course
(c) Bituminous macadam base course

(a) Water-bound macadam base course

The base consisting of clean, crushed aggregates, mechanically interlocked by rolling and bounded together with screening and water is called water-bound macadam base course.

Materials required :-

The materials required for a W.B.M. base course are coarse aggregates, screenings & filler materials.

The coarse aggregates used may be either crushed or broken stone, crushed slag or overburnt brick aggregate. The aggregate should conform to the physical requirement given in the following table -

From previous page

The coarse aggregate is of 90mm to 40mm size, 63mm to 40mm size or 50mm to 25mm size according to the type of aggregate available & the total consolidated thickness of base course required.

Physical requirements of Course Aggregates for Water Bound Macadam Base Course

S. No.	Test	Test Method	Requirements
1.	Los Angles Abrasion Value OR Aggregate Impact Value	IS : 2386 (Part IV) IS : 2386 (Part IV) OR IS : 5640	50 per cent max. 40 per cent max.
2.	Flakiness Index	IS : 2386 (Part I)	15 per cent max.

It should fulfil the specified gradation requirement as per following table →

The Grading Requirements of Course Aggregates for W.B.M. Base Course

Grading No.	Size Range	Sieve Size mm	Per cent by Weight passing the Sieve
1.	90 mm to 40 mm	100 80 63 40 20	100 65 to 85 25 to 60 0 to 15 0 to 5
2.	63 mm to 40 mm	80 63 50 40 20	100 90 to 100 35 to 70 0 to 10 0 to 5
3.	50 mm to 20 mm	63 50 40 20 10	100 95 to 100 35 to 70 0 to 15 0 to 5

The screenings to fill voids in the coarse aggregate should be of the same material as the coarse aggregate. However, where permitted, moorum or gravel (other than rounded river born material) may be used for this purpose provided liquid limit & plasticity index of such materials is below 20 & 6 respectively and fraction passing 75 micron sieve does not exceed 10 percent. The screening should conform to the grading given as per following table ...

The Gradation Requirements of Screenings for W.B.M. Base Course

Grading Classification	Size of Screenings	Sieve Size mm	Per cent by Weight Passing the Sieve	Grading No. of C.A.
A	12·5 mm	12·5 10·0 4·75 150 micron	100 90 to 100 10 to 30 0 to 8	1 and 2
B	10 mm	10·0 4·75 150 micron	100 85 to 100 10 to 30	2 and 3

The binding material used for WBM course may be comprising of a suitable material approved by the Engineer-in-charge, having plasticity index value less than 6. Its application may not be necessary when the screening used are of crushable type such as moorum or gravel.

Method of construction:-

The construction of a WBM base course is completed in the following steps:

(i) preparing the base

(ii) Spreading coarse aggregate

(iii) Rolling

(iv) Application of screening

(v) sprinkling and grouting

(vi) Application of binding material

(vii) setting & drying.

(i) Preparing the base

The subgrade or subbase to receive the WBM base course is prepared to the specified grade and camber. Any ruts or weak spots are corrected and rolled until firm. If the water bound macadam is to be laid directly over the subgrade, without any other intervening pavement course, a 25mm course of screening (Grading B) shall be spread on the prepared subgrade before spreading of coarse aggregate. This layer is known as inverted choke.

(ii) Spreading coarse aggregate

After preparing the base, the coarse aggregates are spread uniformly and evenly upon it in such quantities that the thickness of the compacted layer does not exceed 75mm in general and in no case, however, it should exceed 100mm. Thus, upto 100mm compacted thickness of the base course, its construction may be done in single layer and for greater thickness, its construction should be completed in two or more layers.

The stone aggregates should be laid carefully with the broad face downwards. The aggregates are then hand-packed to the desired camber of the top surface. After the hand packing has been completed, the irregularities in surface should be checked by template and carefully set right.

(iii) Rolling

Immediately after the spreading of coarse aggregate, rolling is started with three wheeled power roller of 6 to 10 tonne capacity or tandem or vibratory roller of approved type.

Except on superelevated portions of the road where the rolling should proceed from inner edge to the outer, rolling of the coarse aggregate should be started from the edges and gradually progressed towards the center. Rolling is stopped when the aggregates are partially compacted with sufficient void space in them to permit application of screenings. The rolled surface is then again checked transversely and longitudinally with templates and irregularities, if any are corrected and consolidated.

(iv) Application of screenings

After dry rolling, screenings are applied gradually over the surface. Dry rolling should be done while the screenings are being spread so that vibrations of the roller may cause them to settle into the voids of the coarse aggregate.

The screenings should be applied at a slow & uniform rate accompanied by dry rolling and brooming so as to ensure filling of all voids. This operation should be continued until no more screenings can be forced into the voids of the coarse aggregate.

(v) Sprinkling & grouting

After the screenings have been applied, the surface is sprinkled over with sufficient quantity of water, swept & rolled.

Hand brooms should be used for sweeping the screenings into voids & to distribute them evenly. The sprinkling, sweeping and rolling operations should be continued with additional screenings applied as necessary, until the coarse aggregate has been thoroughly keyed, well bonded and firmly set in its full depth.

(vi) Application of binding material

After sprinkling and grouting, the binding material consisting of sandy soil (containing about 75% sand & remaining clay or moorum) is applied successively in two or more thin layers. After each application, the surface is sprinkled over with sufficient quantity of water. The resulting slurry is swept in with hand brooms or mechanical brooms to fill the voids properly and then the surface is rolled. During rolling, the water is sprinkled over wheel of the roller to wash down the binding material sticking to them.

These operations should be continued until the resulting slurry after filling of voids, forms a wave ahead of the wheels of the moving roller.

(vii) Setting & drying

After the final compaction of the WBM base course, the surface is allowed to dry overnight. Next morning, the depressions, if any, are filled with screening of binding material, lightly sprinkled with water & rolled. The W.B.M base is then allowed to dry completely.

(b) Built-up spray grout base course

The base course consisting of two layers of crushed coarse aggregates with application of bituminous binder after each layer and key aggregate on the top of the second layer is known as built-up spray grout base course.

In this type of base course, the aggregate are laid in accordance with the desired specifications and, in conformity with the lines, grade and cross-sections shown on the drawings or as directed by the E.I.C. This type of base course is always constructed during dry weather and laid on a dry base when the atmospheric temperature in shade is above 16°C

Materials required :-

The materials required for the construction of a built-up spray grout base course are binder, coarse aggregate and key aggregates.

The binder should be straight-run bitumen of a suitable grade, as directed by the Engineer-in-charge complying with IS 73, or as approved cut-back

The aggregates should consist of crushed stone, crushed gravel (shingle) or other stones. They should be clean, strong, durable, cubical in shape & free from disintegrated pieces, organic and other harmful matter & adherent coatings.

(*) The aggregates to be used for built-up spray grout base course should fulfil the gradation and physical requirements as per IRC specifications given in following tables.

IRC Specifications for Coarse and Key Aggregates to be used in Built-up Spray Grout Base Course

(A) *Gradation Requirements*

Sieve Size mm	Per cent by Weight passing the Sieve	
	coarse aggregate	key aggregate
50	100	—
25	35—70	—
20	--	100
12·5	0—15	35-70
4·75	—	0-15
2·36	0—5	0-5

(B) *Physical Requirements*

Sl. No.	Test	Test Method	Requirement
1.	Los Angeles abrasion value*	IS : 2386 (Part IV)	50% Max
2.	Aggregate impact value*	—do—	40% Max
3.	Flakiness index	IS : 2386 (Part I)	25% Max
4.	Water absorption	IS: 2386 (Part III)	1% Max
5.	Stripping value	—	25% Max

Method of Construction :-

The construction of a built-up spray grout base course is completed in the following steps :-

(i) preparing the base
(ii) Applying prime coat
(iii) spreading the coarse aggregates
(iv) Rolling the first layer of coarse aggregates
(v) spraying the first layer of binder
(vi) Spreading the second layer of coarse aggregate
(vii) Rolling the second layer of coarse aggregate
(viii) spraying the second layer of binder
(ix) spreading the key aggregate
(x) Rolling the surface.

(i) Preparing the base

The subgrade or sub-base to receive the built-up spray grout base course is prepared, shaped and conditioned to the specified grade and camber. Any ruts or weak spots are corrected and rolled until firm.

(ii) Applying prime coat

After preparing the base, prime coat, consisting of a single coat of low viscosity liquid bituminous material, is applied to surface of prepared base.

(iii) Spreading the coarse aggregates

Immediately after the application of prime coat, the coarse aggregates in dry and clean form are spread uniformly and evenly at the rate of $0.5\ m^3$ per $10\ m^2$ area. After this, the surface of the aggregate layer is checked carefully with templates and the deficiency, if any should be rectified.

(iv) Rolling the 1st layer of coarse aggregates

Immediately after spreading of the coarse aggregates, the entire surface is rolled with 8-10 tonne smooth wheeled roller, taking all the precautions during rolling of the road surface.

After initial rolling, the entire surface is checked transversely and longitudinally with templates and corrected followed by re-rolling the surface. Rolling should be stopped before voids in the aggregate layer are closed to such as extent as to prevent free and non-uniform penetration of the cinder.

(v) Spraying the 1st layer of binder

The binder is heated to the temperature appropriate to the grade of bitumen and sprayed on the aggregate layer at the rate of $12.5\ kg/10\ m^2$ in a uniform manner with the help of a mechanical sprayer. Excessive deposits of binder, if any; should be promptly corrected.

(vi) Spreading the 2nd layer of coarse aggregate

Immediately after spraying the first layer of binder, the second layer of coarse aggregate is spread in a similar manner as done in case of 1st layer.

(vii) Rolling the 2nd layer of coarse aggregate

After spreading the second layer of coarse aggregate, the entire surface is again rolled in a similar manner as done in case of first layer.

(viii) Spraying the second layer of binder

After rolling the second layer of coarse aggregate, the binder is sprayed on the aggregate layer at the rate of $12.5\ kg/10\ m^2$ in a similar manner as done in case of first layer.

(ix) spreading the key aggregate

Immediately after spraying the second layer of binder, key aggregate in a clean and dry state is spread uniformly at the rate of 0.13 m³/10 m² so as to cover the entire surface. The surface is then broomed, if necessary to ensure uniform application of the key aggregate.

(X) Rolling the surface

After spreading the key aggregate uniformly, the entire surface is rolled with 8-10 tonne smooth wheeled roller. While rolling is in progress, additional key aggregate is spread, where required. Rolling should be continued until the entire base course is properly compacted & the aggregate is firmly in position.

(C) Bituminous macadam base course

The base course consisting of a single layer of crushed aggregates premixed with a bituminous binder is called bituminous macadam base course.

In this type of base course, the crushed aggregates premixed with a bituminous binder is laid, immediately after mixing, on a base prepared previously in accordance with the desired specifications, and in conformity with the lines, grade and cross sections shown on drawings or as directed by the Engineer-in-charge. This type of base course usually consists of 50mm / 75mm thick compacted layer of crushed aggregates premixed with a bituminous binder. It should not be laid during rainy weather or when the base is damp or wet.

Materials required :-

The materials required for the construction of a bituminous macadam base course are binder and aggregates which should fulfill the requirements mentioned in the case of built-up spray grout base course.

The binder content for premixing should be 3.5 and 4 percent by weight of the total mix for aggregate grading No. A and B respectively. The quantities of aggregates should be sufficient to provide the specified thickness of the bituminous macadam base course after compaction.

The aggregates for different compacted thickness of bituminous macadam base course should fulfil the gradation and physical requirements as per IRC Specifications given in following tables (A and B) respectively.

(B) Physical Requirements

S. No.	Test	Test Method	Requirements
1.	*Los Angeles Abrasion Value**	IS : 2386 (Part IV)	35% Max.
2.	*Aggregate Impact Value**	—do—	30% Max.
3.	Flakiness Index	IS : 2386 (Part I)	35% Max.
4.	Water Absorption	IS : 2386 (Part III)	2% Max.
5.	Stripping Value	—	25% Max.

Method of construction :-

The construction of a bituminous macadam base course is completed in the following steps :-

(i) Preparing the base
(ii) Applying the prime coat
(iii) preparing & transporting the mix
(iv) spreading the mix
(v) Rolling the surface

IRC Specifications for Aggregates to be used is different Thicknesses of Bituminous Macadam Base Binder Course

(A) *Gradation Requirements*

Sieve Size mm	Per cent by Weight passing the Sieve for different Compacted Thicknesses			
	75 mm compacted thickness		50 mm compacted thickness	
	Grading A	Grading B	Grading A	Grading B
63	100	—	—	—
50	90–100	—	100	—
40	35–65	100	90–100	—
25	20–40	70–100	30–50	100
20	—	50–80	—	70–100
12.5	5–20	—	10–30	—
10	—	—	—	35–60
4.75	—	10–30	—	15–35
2.36	—	5–20	—	5–20
75 micron	0–5	0–4	0–5	0–4

(i) Preparing the base

The subgrade or sub-base to receive the bituminous macadam base course is prepared, shaped and conditioned to the specified lines, grade & cross sections in accordance with the desired specifications or as directed by the Engineer-in-charge. The surface is then thoroughly swept and scraped clean so as to make it free from dust and foreign matter.

(ii) Applying the prime coat

After preparing the base, the prime coat of a suitable bituminous material is applied to the surface of prepared base except when the laying of bituminous macadam is being preceded by a bituminous levelling course.

(iii) preparing and transporting the mix

For preparing the mix, hot mix plant of adequate capacity should be used. The temperature of binders at the time of mixing should be in the range of 150° – 177°c and that of aggregates in the range 155° – 163°c. The difference in temperature between the aggregates and binder should not be allowed to exceed 14°c while preparing the mix.

The aggregate and binder both are mixed thoroughly in the hot mixing plant to ensure that a homogeneous mixture is obtained. The mix is then transported from the mixing plant to the point of use in suitable vehicles. Dump trucks are efficiently used for this purpose.

(iv) Spreading the mix

Immediately after mixing, the mix is transported and spread by means of a self propelled mechanical paver with suitable screeds capable of spreading, tamping and finishing the surface to the specified lines, grade and cross-sections. The spreading of the mix can also be done manually, especially in restricted locations and in narrow widths where the available plants cannot operate.

The temperature of the mix at the time of spreading should be in the range of 121° – 63°c

(v) Rolling the surface

Immediately after the spreading of mix, rolling is done by 8-10 tonne smooth wheeled power roller. After initial rolling, the entire surface is checked transversely and longitudinally with templates and corrected. The rolling is then continued until the entire surface is rolled to compaction, there is no crushing of aggregates and all roller marks are eliminated.

Comparative Merits/De-merits of Three Types of Base courses (W.B.M, Built-up spray grout and Bituminous Macadam)

Sl. NO	Points of comparison	W.B.M	Built-up spray-grout	Bituminous macadam
01.	Structural strength	low	medium	high
02.	Traffic intensity suitable for base course	low	medium	high
03.	Thickness of base course for same traffic intensity	Maximum (75mm)	medium (60mm)	Minimum (45mm)
04.	Durability	low	medium	high
05.	Susceptibility to manual construction	high	medium	low
06.	Initial cost of construction	lowest (100)	highest (200)	high (190)
07.	Superiority equivalency factor	1.00	1.25	1.75

-: PAVEMENT SURFACES :-

The topmost component of a road pavement structure directly exposed to traffic is called pavement surface or wearing surface of the road.

In a flexible pavement, the wearing surface is supported by a base course, whereas in a rigid pavement, the road slab serves the function of wearing surface as well as of base course.

Roads are usually named according to the type of their pavement surfaces. Various types of pavement surfaces are classified into the following groups:

1. Low cost surfaces
2. High cost surfaces

1. Low cost surfaces

The pavement surfaces which can be constructed as well as maintained at low cost are known as low cost surfaces, and the roads with such surfaces are known as low cost roads.

These roads are also known as fair weather roads since such roads remain in serviceable condition only during the period when the weather is fair. These roads become almost unserviceable or present great difficulty to the free movement of traffic during rainy season.

The various types of low cost surfaces/roads are given below :-

(a) Earth roads (ordinary or natural soil roads as well as stabilized soil roads)
(b) Kanker roads ;
(c) Gravel roads ;
(d) Traffic bound macadam roads ;
(e) water bound macadam (W.B.M) roads.

2. High cost Surfaces

The pavement surfaces constructed as well as maintained at high cost are known as high cost surfaces, and the roads with such surfaces are known as high cost roads.

These roads are also known as all weather roads since such roads remain in serviceable condition in all weathers throughout the year. These roads present no difficulty to the free movement of traffic even during rainy season.

The various types of high cost surfaces roads are given below :-

(a) Bituminous roads ;
(b) concrete roads.

Comparative Merits & De-merits of low cost and High cost Surfaces/Roads

Sl.No	points of comparison	Low cost surfaces/ Roads	High cost surfaces / Roads
01.	Initial cost	Their initial cost is less	Their initial cost is more
02.	construction & Repair	Their construction as well as repair is easy	Their construction as well as repair is difficult
03.	Labour & Supervision	These road surfaces require ordinary labour & supervision for their construction.	These road surfaces require skilled labour & supervision for their construction
04.	Riding surface	These road surfaces provide inferior riding surface	These road surfaces provide superior riding surface
05.	Imperviousness of surface	Their surface is pervious.	Their surface is impervious.
06.	Sanitary surface	Their road surfaces do not provide sanitary surface since they cannot be washed and cleaned easily	These road surfaces provide sanitary surface since they can be washed and cleaned easily.

07.	Dust nuisance	These road surfaces cause dust nuisance under pneumatic tyred traffic	These roads surfaces do not cause dust nuisance under pneumatic tyred traffic
08.	Suitability to weather	These road surfaces remain serviceable during the period when the weather is fair.	These road surfaces remain serviceable during all weathers even during monsoon.
09.	Traffic capacity	Their traffic capacity is less	Their traffic capacity is more.
10.	Life	Their life is less (1 to 4 years)	Their life is more (12 to 30 years)
11.	Maintenance cost	Their maintenance cost is low	Their maintenance cost is high

WATER BOUND MACADAM ROADS (W.B.M ROAD)

The road having its wearing surface consisting of clean, crushed aggregates, mechanically interlocked by rolling and bound together with filler material (screening) and water, laid on a prepared base course is called water bound macadam / W.B.M road

In W.B.M roads, the aggregate used for their construction is known as macadam. These are superior type of low cost roads. These roads are constructed in thickness ranging between 8 to 30 cm, depending upon design requirements. The thickness of each layer of W.B.M is kept 12 to 15 cm and thus thickness up to 30 cm is composed of two or three layers. A camber of 1 in 36 to 48 is recommended for these roads.

These roads get deteriorated rapidly under the mixed traffic conditions so therefore, W.B.M is frequently used as base course for important high cost roads such as bituminous macadam, premix carpet and asphalt concrete roads.

Thus, a W.B.M road is considered as mother road for all types of modern road construction.

Construction of W.B.M roads

Materials required

The materials required for construction of a W.B.M road are coarse aggregates, screenings and binding materials, where necessary.

The coarse aggregates should be either crushed or broken stone, crushed slag, overburnt brick aggregate or one of the naturally occuring aggregates such as kankar or laterite of suitable quality. It should conform to one of the gradings mentioned in page 17 (The grading Requirement of coarse Aggregate for W.B.M Base course)

The screenings, to be used for filling voids in the coarse aggregate should generally consist of same material as the coarse aggregate. However, where permitted, moorum or gravel (other than rounded river borne material) may be used for this purpose. The gradation requirements of screenings have already mention in page 17 (The gradation requirement of screening for W.B.M base course.

Screenings of type A or B should be used with coarse aggregate of grading 2 and type B screenings should only be used with coarse aggregate of grading 3.

Binding material, to be used for WBM construction, should comprise a suitable material approved by the Engineer-in-charge, having plasticity index value of less than 6. Its application may not be necessary when the screenings used are of crushable type such as moorum or gravel.

All these materials required in the construction of a W.B.M road are stacked on the road side.

It is recommended to provide 20% extra broken stones on volume basis. Thus, the quantity of aggregate required for constructing one kilometre length per metre width and one centimetre thickness of W.B.M road surface will be $= \frac{120}{100} \times 1000 \times 1 \times \frac{1}{100} = 12\ m^3$

The quantity of screenings required is about $30 m^3$ per $100 m^2$ surface area. The quantity of screenings for constructing 1 km length, of the road. Thus, the quantity of screenings for constructing 1 km length per metre width of W.B.M road surface will be $\frac{30}{100} \times 1000 \times 1 = 300\ m^3$

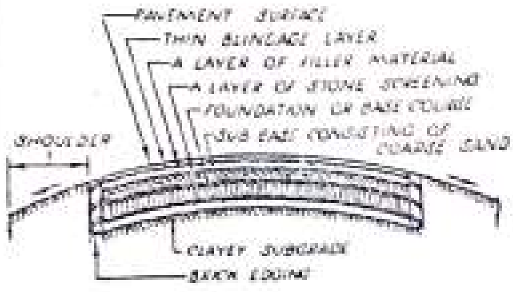
Method of construction

The construction of a W.B.M road is completed in the following stages :-

(i) preparation of sub-grade
(ii) preparation of the base course
(iii) preparation of intermediate and wearing course
(iv) preparation of shoulders
(v) opening to traffic

(i) preparation of subgrade

Unless otherwise specified, subgrade is in the form of a trench. The bottom level of the trench is fixed after deducting the pavement thickness from the finished formation level. Thus, for preparing the subgrade, a trench is dug in conformity with the lines, grade and cross-section after completion of earth work as shown on the drawings.



A WATER BOUND MACADAM ROAD

No trenching is necessary in rocky-cutting areas, where the rock excavation is done upto subgrade level and the haunch support to soling is provided by stone spall edging.

After making the trench, the subgrade is thoroughly compacted by rolling with a road roller of weight not less than 8 tonnes. Water is sprinkled uniformly on the subgrade on evening prior to rolling. Any low spot, that develop in the subgrade during rolling, is rectified and the surface is brought to grade as required.

On clayey subgrade, a layer of granular material such as natural sand, moorum, gravel, laterite or kankar is spread to a thickness varying from 100 mm to 150 mm.

(ii) Preparation of the base course

The base of foundation course consists of 12 to 18 cm size boulders or broken pieces of stones, long size kankar, overburnt bricks or brick soling. The width of this course should be 60 cm wider than the pavement width, projecting 30 cm on each side.

After preparing the subgrade or sub-base, the required type of base course is constructed with specified materials in conformity with lines, grade, thickness and cross-sections.

(iii) Preparation of intermediate & wearing course

It is laid in one or two layers, depending upon the total designed thickness. The thickness of loose metal in each layer should not exceed 10 cm.

Preparation of intermediate & wearing course of a W.B.M road is done in the following steps:-

(a) preparing the surface
(b) providing edging or earthen kerbs
(c) spreading of coarse aggregate
(d) Dry rolling
(e) spreading of screenings
(f) wet rolling
(g) Application of binding material, watering & rolling
(h) Finishing the surface
(i) setting & drying

(a) Preparing the surface

The surface of the newly laid base course i.e soling, on which some traffic has been allowed, is checked and the defective portions are rectified. In case of an existing metalled road, the surface is sacrified & brought to the required camber. The sacrifying may not be done in case when the thickness of renewal coat is 6.5 cm or above and stones of old course have not lost their angular faces or when the old surface consists of kankar.

(b) Providing edging or earthen kerbs

After preparing the surface brick on end edging is provided along the outer edges of the carriageway of the road. where the edging is not possible as in the case of stone or kankar soling or remetalling, earthen kerbs consisting of two parallel bunds of clay puddle 15 cm × 15 cm in section, are made. These earthen kerbs should be strong enough to prevent the new road metal from spreading as well as to retain the water used in consolidation of the wearing course.

(c) Spreading of coarse aggregate

The road metal is spread evenly over the prepared base to the specified thickness. After spreading the aggregate, it is hand packed with bigger pieces placed below and smaller pieces in the interstices and the surface is thus brought to the required camber.

(d) Dry rolling

After spreading the coarse aggregate, dry rolling is done by means of a suitable roller. This dry rolling provides interlocking of the aggregates. The rolling should be started from edges and gradually shifted towards the centre after properly rolling each strip.

The rolling should be continued until the aggregates are partially compacted with sufficient voids space in them to permit application of screenings.

(e) Spreading of screenings

After dry rolling, a bindage layer consisting of stone screenings (12 mm grits) is spread at a slow and uniform rate so as to ensure filling of all voids. This is accompanied by dry rolling and brooming. These operations should be continued until no more screenings can be forced into the voids of the coarse aggregates.

(f) Wet rolling

After spreading the screenings, the surface is sprinkled over with sufficient quantity of water, swept & rolled.

(g) Application of binding material, watering & rolling

After the application of screening and wet rolling, the binding material is applied successively in two or more thin layers at a slow and uniform rate. After each application, the surface is freely sprinkled with water. The resulting slurry is swept in with brooms to fill the voids properly and rolled with 6 to 10 tonne roller. water is poured on the wheels of the roller to wash down the clayey material sticking to them. This layer of binding material is also known as bindage layer. The surface is then sprinkled over with heavy dose of water (40 to 50 litres per m^2 of surface area). The slurry is allowed to fill the voids and the surface is rolled with 6 to 10 tonne roller.

The spreading of binder, sprinkling of water, sweeping with brooms & rolling should be continued until the slurry, that is formed after filling all voids, forms a wave before the wheels of the moving roller.

(h) Finishing the surface

After the final compaction, road surface is allowed to dry overnight. Next morning, a layer of sand or earth, about 6mm thick, is spread on the surface. The surface is then lightly sprinkled with water & rolled.

(i) Setting and drying

The surface is then allowed to cure for 7 to 9 days. In dry season, the surface should be lightly sprinkled with water during the curing period.

(*) The object of curing is to enable the road surface to become hard which remains otherwise soft due to heavy sprinkling of water.

(iv) Opening to traffic

After drying, the road is opend to traffic. The traffic should be well distributed over the full width of the road by placing obstacles longitudinally in the form of drum, branches of trees, etc. on the road surface. The process of placing such obstacles longitudinally on the newly prepared road surface for distribution of traffic is known as Lik-katai

(V) Preparation of shoulders

During curing, the shoulders are prepared by filling earth to the specified cross slope. These are then properly compacted by rolling or tamping.

Defects of water bound macadam roads

In W.B.M roads, the aggregates are keyed together and prevented from moving out simply by means of slurry of screenings, sand and clay, since no other binding material is used. Binding effect of this slurry mostly depends upon the presence of moisture. When a fast moving vehicle passes over a W.B.M road, the binding material, in the form of slurry, is easily sucked out by pneumatic wheel tyres of vehicle and thus the surface is disintegrated. Under the very high contact pressure of iron tyred bullock carts and due to attraction effects, the aggregates are crushed to powder. Thus, mixed traffic is likely to destroy the W.B.M road in a very short time. This can be improved by surface dressing or painting.

BITUMINOUS ROADS :-

· The roads having their surface consisting of bituminous materials are known as bituminous roads or black-top roads.

These roads are constructed of different thickness varying from a thin layer of bituminous surface dressing to about 22 cm thick layers of bituminous materials, according to importance of the road. The bituminous binders used in the construction of bituminous roads are either straight-run bitumen, road tar, cut-back or emulsion.

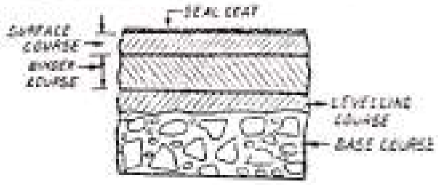
The choice of a particular binder depends upon the type of construction, availability of material, equipments, climatic conditions, etc.

Bitumen and tar require heating to bring them to proper viscosity before their use. The construction technique using these materials is known as hot mix technique - since the bituminous materials are applied cold.

(1) The bituminous roads are considered as high cost roads.
Since bituminous roads are economical in construction and can be immediately opened to traffic after their construction as compared to concrete road, these roads are in extensive use in developing nations like our country. These roads also facilitate stage development which help in improving their surface according to traffic demands in future.

Components of a bituminous surface and their functions :-

A bituminous surface rests on a base course. If the base course is wavy or it has developed excessive irregularities, a layer of aggregates of varying sizes may be provided which is known as levelling course.



SECTION SHOWING COMPONENTS OF A BITUMINOUS SURFACE

The various components of a typical bituminous surface road shown above and are described below :-

(a) Binder course (b) surface course (c) seal coat (d) prime coat (e) Tack coat

(a) Binder course

The layer of bituminous material, provided in between the base course & surface course of a bituminous surface, is called binder course.
It serves as a stress distribution medium and provides an adequate bed for surface course.

(b) Surface course

The layer of bituminous material provided on the top of binder course of a bituminous surface, is called surface course or wearing course.

This course is directly exposed to traffic. The thickness of this course is less than that of binder course but it is made of superior material.

* The function of this course is to provide a good riding surface and to bear safely the wheel pressure due to traffic safely.

(c) seal coat

A final coat of bituminous material provided on the top of surface course for sealing the voids against entry of moisture is known as seal coat.

The main functions of providing seal coat on a bituminous surface are given below:-

(i) To make the surface water-tight

(ii) To provide a more desirable surface texture.

(iii) To reduce slipperiness of the surface

(iv) To enliven an existing dry or weathered surface.

Seal coat may be either of the following two types :-

Type A

This type of seal coat is a liquid seal coat which consists of a layer of bituminous binder followed by a cover of stone chippings.

method of construction of Type A seal coat

For constructing Type A seal coat, the binder is heated in a boiler of suitable design and to the temperature appropriate to the grade of bitumen approved by the Engineer-in-charge. Then the seal coat is applied in accordance with the construction operations.

Type B

This type of seal coat is a premixed seal coat which consists of a thin application of fine aggregate premixed with bituminous binder.

method of construction of Type B seal coat

For constructing type B seal coat, the binder is heated in a boiler of suitable design and to the temperature appropriate to the grade of bitumen approved by the Engineer-in-charge. Then fine aggregates, in dry state, are also heated to specified temperature before the same are placed in a mixer. After this, mixing of binder with aggregates to the specified proportions is done in the mixer. Mixing should be continued till the aggregates are thoroughly coated with the binder. Then the mix is immediately transported from the mixing plant to the point of use and spread uniformly on the bituminous surface to be sealed. As soon as sufficient length of the bituminous surface has been covered with the premixed mix, the surface is rolled with 6-9 tonne smooth wheeled power roller. Rolling should be continued until the premixed material completely seals the voids existing in the bituminous course and a smooth uniform surface is obtained.

Opening to traffic

In case of Type A seal coat, traffic should not be permitted to run on any newly laid surface till the following day. In special circumstances, the Engineer-in-charge may open the road to traffic immediately after rolling, but in such cases, its speed should be limited to 16 km/hr till the following day.

Opening to traffic

In case of Type B seal coat, traffic may be allowed soon after final rolling when the premixed material has cooled down to the surrounding temperature.

→ In addition to the components of a bituminous surface described above, the following two coats are also recommended to achieve proper bond i.e adhesion of the bituminous surface with the existing base at the interface.

(d) Prime coat

A single coat of low viscosity bituminous binder applied to an existing un-treated base of pervious nature like W.B.M, in order to promote adhesion between the base and the bituminous surface is called prime coat.

The bituminous binder used for prime coat is the low viscosity cut-back.

The functions of providing prime coat to an existing untreated road surface preparatory to any bituminous construction are given below:-

(i) To promote adhesion or bond between the existing pervious base & the wearing surface.
(ii) To bind together any loose aggregate which may be present on the base.
(iii) To plug the capillary rise of moisture.
(iv) To provide a temporary seal against the infiltration of surface water.

(e) Tack coat

A single coat of low viscosity bituminous binder applied to an existing treated base of impervious nature like bituminous or cement concrete base in order to promote adhesion between the treated base and the bituminous surface is known as tack coat.

The bituminous binder used for tack coat is a bitumen of suitable grade as directed by the Engineer-in-charge and conforming to IS:73, 217 or 454, as applicable or any other approved cut-back.

The function of providing tack coat is to ensure adequate bond between the existing impervious base and the wearing surface.

For applying a prime or tack coat, the surface should be thoroughly swept and scraped clean of dust and any other objectionable material. The binder is then heated to the temperature appropriate to the grade of bitumen used, and the rate of spread in terms of straight run bitumen should be 5 kg per 10 m^2 area for an existing bitumen treated surface and 10 kg per 10 m^2 area for an untreated water bound macadam (W.B.M) surface. The binder should be applied uniformly with the aid of sprayers. This coat should be applied just before the next bituminous construction.

Types of Bituminous roads :-

The various bituminous roads are generally classified on the basis of their methods of construction. The following techniques are being used for constructing bituminous roads and they are named accordingly:

1. Inverted penetration type construction;
   Example: surface dressing

2. Penetration type construction;
   Example: penetration macadam

3. Premix type construction;
   Example: (i) premix macadam or bitumen bound macadam
   (ii) Premix carpet
   (iii) Asphaltic concrete
   (iv) sheet asphalt or rolled asphalt
   (v) Mastic asphalt

(1) Inverted penetration type construction :-

In this type of bituminous road construction, the binder is sprayed first which is followed by application of aggregates. Light rolling is then done which sets the aggregates into the binder due to upward penetration of the later into the former. This upward penetration of binder into the aggregates is considered as inverted penetration type construction technique.

The best method of constructing a bituminous road by this technique is surface dressing or surface painting which is described below:-

Surface dressing or surface painting :-

The method of applying one or two coats of bituminous material, each consisting of a layer of bituminous binder sprayed on the prepared base, followed by a cover of stone chipping properly rolled to form a wearing course is known as surface dressing or surface painting.

When one layer of bituminous material is applied, the process is called single-coat surface dressing, and when two layers are applied, it is known as two-coat surface dressing. The thickness of this type of surfacing varies from 20 to 30 mm. The bituminous roads having their surface course prepared by surface dressing or surface painting are known as

· Surface painted roads.

Surface dressing thus provides a thin, water proof and dustless wearing surface. Though the film does not reinforce the pavement structure, yet it provides a better surface than a W.B.M road. Surface painted roads can take light pneumatic traffic very well and can withstand only some portions of bullock cart traffic because too much of iron wheeled traffic will cause depressions and pot holes very soon and thus the road will become unserviceable and uncomfortable. Hence, such roads are recommended for light pneumatic traffic such as buses, trucks, cars, etc. mixed with some iron wheeled traffic.

Advantages :-

The following are the advantages of surface dressing or surface painting on water bound macadam and other low cost roads :-

(i) It prolongs the life of the road by providing a water-proof surface.
(ii) It eliminates the dust nuisance.
(iii) It provides a sanitary surface since the road can be easily cleaned and washed.
(iv) It yields a non-skid surface and thus provides comfort to the traffic.
(v) It provides a smooth surface & thus the wear & tear of vehicle tyres is reduced.
(vi) It provides less frictional resistance and thus the petrol consumption by vehicles is reduced.

Limitations / Disadvantages :-

The following are the limitations of surface dressing or surface painting :-

(i) It does not strengthen the pavement
(ii) It cannot rectify the irregularities in the existing base.
(iii) It is unsuitable under heavy traffic

(2) Penetration type construction :-

In this type of bituminous road construction, the aggregates are spread on the prepared base & compacted by a roller. Then the bituminous binder is sprayed on the surface which penetrates to full or part depth of the compacted aggregates & thus binds them together.

The best method of constructing a bituminous road by this techniques is grouted or penetration macadam as stated below/next page..

Grouted or penetration macadam :-

The method of bituminous road construction in which the aggregates are bound together by grouting bitumen into the voids to full or part depth of the compacted aggregate is called grouted or penetration macadam. It is also known as built-up spray grout macadam.

When the bitumen is allowed to penetrate to full depth of compacted aggregate, the process is known as full grout macadam, and when the penetration of bitumen is upto about half the depth of the compacted aggregate, the process is called semi-grout macadam.

This type of bituminous road construction is usually adopted for preparing base course of important bituminous surfaces subjected to heavy and mixed traffic. Full grout macadam construction is adopted in regions of heavy rainfall and the semi-grout in regions of average rainfall. The recommended thickness for full grout is 5 to 8 cm and that for semi-grout macadam construction, it is usually kept 5 cm.

(3) Premix type Construction :-

The bituminous road construction in which the aggregates and the binder are mixed together in a mixing plant prior to their placing & spreading is known as premix type construction.

Advantages :- The following are the advantages of premix type construction over grouted or penetration macadam construction.

(i) It facilitates to coat each and every individual aggregate with uniform thickness of binder film whereas it is not possible in grouted macadam construction.

(ii) It requires comparatively less quantity of bitumen to achieve the same strength.

(iii) It provides increased stability of the mix as compared to grouted macadam construction.

The various bituminous roads constructed according to premix type construction are
a. premix macadam
b. Premix carpet
c. Asphaltic concrete
d. Sheet asphalt
e. Mastic asphalt

a. Premix macadam

The premix type construction in which a mix of dense graded macadam and bitumen is used in hot state for constructing the base course or wearing course of a bituminous road is known as premix macadam or bitumen bound macadam construction.

Thus the bituminous roads having their wearing surface prepared by premix macadam are known as premix macadam bituminous roads or bitumen bound macadam roads. The finished thickness of premixed macadam varies from 5 to 7.5cm.

In this method, bitumen and dense graded macadam are heated separately to specified temperature and mixed in a bitumen mixer. The quantity of bitumen varies from 3.5 to 4 percent by weight of the total mix the aggregate of grading No A and B. This hot mixture is then laid on the prepared base in between the kerbs and adequately rolled.

It has been observed in advanced countries that bitumen bound macadam for base course construction results in stronger and economical pavement section than other conventional type of bituminous pavements. These days, the use of bitumen bound macadam is also recommended for constructing bases as they can last longer under adverse climatic and poor subgrade situations.

b. Premix Carpet

The premix type construction in which a single layer of mix, composed of stone chippings, sand and binder is laid in hot state for constructing the wearing course of a bituminous road is called premix carpet construction.

Thus, the bituminous roads having their wearing surface constructed of premix carpet are known as premix carpet roads.

The thickness of premix carpet varies between 20 to 25mm, General practice in our country is to provide 20mm thick carpet for surface course laid on a previously prepared bituminous or non-bituminous base course.

This type of bituminous road construction provides smooth surface and pleasant looking finish. It is quite suitable for light and moderate traffic. It is a very popular bituminous surface provided on roads.

c. Asphaltic concrete

The premix type construction in which a single layer of 25 to 50mm thick asphaltic concrete is laid in hot state for constructing the wearing course of a bituminous road is called asphaltic concrete construction, and the mix used is called asphaltic concrete.

Thus, the bituminous roads having their wearing surface constructed of asphaltic concrete are known as asphaltic concrete roads.

The term asphaltic concrete denotes the mix of high cost specifications. Such mixes should, therefore, be properly prepared to satisfy the design requirements of the stability and durability of road surface. Asphaltic concrete consists of a well proportioned mixture of coarse aggregates, fine aggregates, mineral filler and a bitumen binder. The mix is prepared in a hot mix plant. The asphaltic concrete, thus prepared is then laid & compacted to the desired thickness under rigidly controlled conditions. Asphaltic concrete used in the construction of superior type of bituminous surface is of hot-mix hot-laid type. The other varieties such as hot-mix and cold-mix cold-laid are used under exceptional circumstances and for repair work. Hot-mix hot-laid is the best type of asphaltic concrete, and the road surface, so prepared, can be opened to traffic as soon as it cools down to the surrounding temperature.

Asphaltic concrete road surfaces are provided on heavy duty highways. In India, 40mm thick surface courses of asphaltic concrete are generally provided. The outstanding merits of asphaltic concrete roads are their high stability and durability under heavy loads and adverse climatic conditions.

d. Sheet asphalt

The premix type construction in which a carpet of sand and bitumen mix is used for preparing the wearing course of a bituminous road is known as sheet asphalt or rolled asphalt construction, and the mix used is called sheet asphalt.

Thus, the bituminous roads having their wearing surface constructed of sheet asphalt or rolled asphalt are known as sheet asphalt roads or rolled asphalt roads.

sheet asphalt provides a better type of wearing surface. It consists of 60mm thick layer of asphaltic concrete over which 20 to 40 mm thick carpet of sand-bitumen mix is laid. This type of construction is generally used as wearing course on existing W.B.M or cement concrete slab base.

e. Mastic asphalt

The premix type construction in which a well proportioned mixture of bitumen, fine aggregate and filler is used for preparing the wearing course of a bituminous road is known as mastic asphalt construction, and the mix used is known as mastic asphalt.

Thus, the bituminous roads having its wearing course constructed of mastic asphalt are known as mastic asphalt roads.

Mastic asphalt provides a hard, stable and durable wearing course which is capable of withstanding heavy traffic. It can also withstand vibrations and has got property of self healing of cracks without bleeding. Thus, this type of surfacing is very suitable for road pavements over bridges

Construction procedure for surface dressing :-

The surface dressing is done either in a single coat or in two coats for providing a renewal or wearing course over an existing or new water bound macadam base course.

(a) **Materials required**

The materials required for surface dressing include bituminous binder and stone chippings.

The binder used for surface dressing should be straight-run bitumen of a suitable grade as directed by the Engineer-in-charge and conforming to IS : 73

The selection of binder is done keeping in view the climatic conditions, availability of materials, equipments etc. The grade of the bitumen is decided according to the climatic condition. However, 80/100, 180/200 penetration grade bitumen are commonly used. The quantity requirements of binder required for surface dressing, as per IRC specifications are given in table

IRC Specifications for Quantity Requirements of Binder Required for Surface Dressing

S. No	Type of Base Course	Recommended Quantity of Binder in kg per $10\ m^2$ of Road Surface					
		First or single coat			Second coat		
		Bitumen	Tar	Cut-back	Bitumen	Tar	Cut-back
1.	*Water bound macadam*	17 to 19.5	17 to 22	19 to 22	10 to 12	12 to 15	12 to 15
2.	*Renewal of black top surfacing*	10 to 12	12 to 17	10 to 12	10 to 12	12 to 15	12 to 15

Note :—The quantity of binder required for $10\ m^2$ of road surface dressing is it usually taken as 18 kg for single coat or first coat of two-coat surface dressing and 11 kg for second or renewal coat on all types of base courses.

The stone chippings, used for surface dressing, should consist of fairly cubical fragments of clean, hard, tough and durable rock of uniform quality throughout. These are obtained by crushing stone, river gravel or other approved materials.

The size and quantity of stone chippings should be in accordance with the IRC specification given as per following table. The stone chippings should satisfy the physical requirements already mentioned in page - 22 (B) physical requirement

IRC Specifications for Gradation and Quantity Requirements of Stone Chippings for Surface Dressing

S. No	Type of Construction	Normal size of Stone Chippings	Recommended Quantity for $10\ m^2$ of Road Surfaces	Specifications
1.	*Single coat surface dressing or the first coat of two coat surface dressing*	12 mm	$0.15\ m^3$	100 per cent passing through 20mm IS sieve and retained on 10 mm IS sieve.
2.	*Renewal coat or second coat of two coat surface dressing*	10 mm	$0.10\ m^3$	100 per cent passing through 12.5 mm IS sieve and retained on 6.3 mm IS sieve.

(b) Method of construction

Surface dressing is completed in the following steps :-

(i) preparing the base
(ii) Application of binder
(iii) Application of stone chippings
(iv) Rolling
(v) Application of second coat of surface dressing
(vi) Finishing the surface & opening to traffic

(i) Preparing the base :-

Usually surface dressing is done on an existing or new W.B.M road surface. In case of an existing W.B.M road, the base is prepared, shaped and conditioned to the specified lines, grade and cross-sections in accordance with the desired specifications, as directed by the Engineer-in-charge. In the case of a new W.B.M road, the bindage and blindage layers are not applied. In that case, the aggregates are properly rolled by sprinkling water & when road metal is sufficiently interlocked & the surface becomes dry, the coat of surface dressing is applied.

The surface is then thoroughly swept and scraped clean of dust and any other harmful matter before spraying the binder. As necessary, the cleaning of surface should be done first with hard brushes, then with soft brushes and finally by blowing with sacks or gunny bags.

(ii) Application of binder :-

The binder is heated to 160°- 177°c and then sprayed on the prepared base in a uniform manner preferably with the help of a mechanical sprayer. Excessive deposits of binder, if any, should be suitably corrected before the stone chippings are spread.

(iii) Application of stone chippings :-

Immediately after the application of binder, stone chippings in a dry & clean state are spread uniformly on the layer of binder. A twisting motion is given to baskets while throwing chippings to avoid segregation. The spreading of stone chippings is preferably by means of a mechanical gritter. If necessary, the surface may be broomed to ensure uniform spreading of stone chippings.

(iv) Rolling :-

Immediately after the application of stone chippings, rolling is done by 8 to 10 tonne smooth wheeled roller. Rolling is done longitudinally starting from edges and working gradually towards the centre except in superelevated portions where it should proceed from the inner edge to the outer. Each pass of the roller should uniformly overlap not less than one-third of the width rolled in the preceding pass.

while rolling is in progress, additional chippings in required quantity, may be spread by hand to make up irregularities. Rolling should be continued until all aggregate particles are firmly bedded in the binder and present a uniform closed surface.

This is the final rolling in case the surface dressing is to be done in single coat.

(V) Application of second coat of surface dressing :-

In the case of two-coat surface dressing, application of second coat is done in steps in a similar manner as described/written in the case of single coat surface dressing.

(Vi) Finishing the surface & opening to traffic :-

After final rolling, the surface is checked for its profile. A tolerance of 6mm unevenness for every 3m length is permissible. After finishing the surface, the road is opened to traffic after 24 hours. In special circumstances, however, the Engineer-in-charge may open the road to traffic immediately after rolling, but in such cases, its speed should be limited to 16km per hour till the following day.

(c) Quality control for surface dressing

control on the quality of materials and works can be exercised by taking the following precautions :-

1. materials should be checked for specification requirements. For this purpose, one check per 50 cum of aggregate has been recommended by the IRC.
2. Surface dressing should be permitted after the underlying course has been repaired to correct profile and grade.
3. Surface dressing should not be done under the following situations :-
   (i) when the temperature in the area is less than 16°C
   (ii) when aggregates are damp
   (iii) when weather is foggy, rainy or dusty
   (iv) when underlying surface is wet.
4. Temperature of binder should be checked regularly
5. Rate of application of materials should be checked once in every 500 sq-m of surfacing. Rate of spraying of binder should be within 2.5% of the specified rate.
6. Aggregates should be spread uniformly without causing segregation.
7. Excessive rolling should not be permitted.
8. second coat, if specified, should be applied immediately after applying the first coat.

9. Road should be kept closed to traffic for 24 hours after completion, in special circumstances, however, the Engineer-in-charge may open the road to traffic immediately after rolling, but in such cases, its speed should be limited to 16 km per hour till the following day.

Construction of premix carpet

The construction of a premix carpet road is carried out under the following stages:-

(a) materials required
(b) method of construction
(c) quality control for premix carpet

(a) materials required

The materials required for premix carpet construction include aggregate & the bituminous binder.

The aggregates should consist of angular fragments of clean, hard, tough & durable rock of uniform quality throughout. The gradation and quality requirements for 20mm thick premix carpet for surface course are given in following table

JRC Specifications for Gradation and Quantity Requirements of Aggregates for 20 mm Thick Premix Carpet

S. No.	Aggregate Size	Sieve Size, (mm)		Quantity in m^3 for 10 m^2 of Road Surface
		passing	retained	
1.	Stone chippings (12 mm)	20	10	0·18
2	Stone chippings (10 mm)	12·5	6·3	0·09

Note: Stone chippings of both the sizes are mixed in the ratio of 2 : 1.

The binder used for premix carpet should be of a suitable grade as directed by the Engineer-in-charge, and satisfying the requirements of IS: 73, 217, 454 or other approved cut-back. Bitumen of 80/100 grade or road tar of grade RT = 3 is used as binder for premix carpet construction.

The quantities in terms of straight-run bitumen for 20mm thick premix carpet construction are given in following table...

IRC Specifications for Quantity Requirements of Binder for 20 mm thick Premix Carpet Construction

S. No.	Detail of Constructing	Recommended Quantities of Binder (in terms of Straight run Bitumen)
1.	For 0·18 m^3 of 12 mm size stone chippings at 52 kg per m^3	9·5 kg
2.	For 0·09 m^3 of 10 mm size stone chippings at 56 kg per m^3	5·1 kg
	Total quantity of binder for 1 m^2 of road surface	14·6 kg

(b) Method of construction

The bituminous premix carpet construction for wearing course of the road is completed in the following steps:-

(i) preparing the base
(ii) Applying prime coat or tack coat
(iii) Preparation of mix
(iv) Transporting and spreading the mix
(v) Rolling
(vi) Applying seal coat
(vii) opening to traffic

(i) Preparing the base :-

The underlying base on which the premix carpet is to be laid is prepared, shaped and conditioned to the specified lines, grade and cross-sections.

(ii) Applying prime coat or tack coat :-

After preparing the underlying base, a prime coat is applied when there is untreated W.B.M surface. The tack coat is applied when there is an existing black top or cement concrete slab surface. This coat is applied by spraying bitumen at specified rate & temperature by means of a spraying device fitted to the tar-boiler. The tack coat is, however, not necessary when the laying of carpet follows soon after the provisions of a bituminous base / levelling course.

(iii) preparation of mix :-

The mix of aggregates and binder in specified ratio is prepared in a hot-mix plant or hot mix unit. Aggregates are heated to the specified temperature before these are placed in the mixer. After about 15 seconds of dry mixing, the binder is distributed over the aggregates at the specific rate. These are then thoroughly mixed to ensure uniform coating. Excessive mixing is avoided & the temperature during mixing is rigidly controlled.

(iv) Transporting & spreading the mix :-

The mix is immediately transported from the mixer to the site of use in dump trucks or wheel barrows. The mix is then spread on the prepared base with rakes to the required thickness and camber or distributed evenly with the help of a drag spreader or paver finisher immediately after applying the prime or tack coat. The profile and thickness is adjusted with the help of screeds.

(v) Rolling :-

As soon as sufficient length (about 15m) of premix materials has been laid rolling is started with 6-9 tonne smooth wheeled power roller. All the necessary precautions should be taken during rolling. Rolling is continued until the entire surface has been rolled to compaction & all the roller marks are eliminated. The roller wheels should be kept damp to prevent the mix from sticking to the wheels and being picked up.

(vi) Applying seal coat :-

After rolling, the seal coat is provided. The most popular seal coat is type B which consists of a layer of sand-bitumen mixture, laid hot on the carpet and rolled.

(vii) Opening to traffic :-

In case Type B seal coat, traffic may be allowed soon after final rolling when the premixed material has cooled down to the surrounding temperature. However, as regards Type A seal coat, the Engineer-in-charge may open the road to traffic immediately after rolling, but in such a case, its speed should be limited to 16 km per hour till the following day.

(C) Quality control for premix carpet

Control on the quality of materials and works can be exercised by taking the following precautions :-

1. Materials should be checked for specification requirements. For this purpose, one test per 50 cum of aggregates has been recommended by IRC
2. Base binder course should conform to the specified grade and camber before laying the premix.
3. Premix construction should not be permitted under the following situations :-
   (i) Temperature in the area is less than 16°C
   (ii) Underlying surface of materials are wet or damp
4. Binder content in the mix should be within 2.5% of specified rate. It should be checked twice in a day.
5. Mixing of material should be thoroughly done at specified temperature but excessive mixing should be avoided as it hardens the bitumen.
6. Spreading and rolling should be done at proper temperatures. Rate of spread of the mix should be controlled through checks.
7. Seal coat, if specified, should be provided evenly and the surface is then finally rolled.
8. The finished surface should be checked for profile and grade. Deviations beyond permissible tolerance should not be allowed.
9. Traffic should not be allowed until the surface cools down to the surrounding temperature when type B seal coat is provided, whereas in the case of Type A seal coat, the speed of traffic should be regulated to 16 km per hour for one day after opening the road to traffic

Construction of asphaltic concrete surfaces

The construction of an asphaltic concrete surface is carried out under the following stages:-

(a) Materials required
(b) Methods of construction
(c) Quality control for asphaltic concrete construction

(a) Materials required :-

The materials required for constructing an asphaltic concrete surface include coarse aggregate, fine aggregates, mineral filler and the bitumen binder.

The coarse aggregates to be used for asphaltic concrete construction are crushed stone, crushed gravel (shingle) or other suitable stones. These aggregates should be clean, strong, durable and of fairly cubical shape. They should satisfy the physical requirements already given in page-22 & table (3) physical requirements.

The fine aggregate to be used for asphaltic concrete construction is the fraction passing 2.36 mm IS sieve and retained on 75 micron IS sieve. These aggregates should be consisting of crusher run screenings, natural sand or mixture of both. They should be clean, hard, durable, uncoated & dry.

The filler to be used for asphaltic concrete construction is an inert material, the whole of which passes 600 micron IS sieve, atleast 90 percent passing 150 micron IS sieve and not less than 70 percent passing 75 micron IS sieve. The filler should be consisting of stone dust, cement, hydrated lime, fly ash or other non-plastic mineral matter approved by the Engineer-in-charge.

The aggregates including mineral filler to be used for asphaltic concrete construction should be so graded or combined as to conform to the requirement as per following table.

IRC Specifications for Gradation Requirements of Aggregates for Asphaltic Concrete Construction

Sieve Size	Percentage by Weight	
	Grading 1	Grading 2
20 mm	—	100
12.5 mm	100	80—100
10 mm	80—100	70—90
4.75 mm	55—75	50—70
2.36 mm	35—50	35—50
600 micron	18—29	18—29
300 micron	13—23	13—23
150 micron	8—16	8—16
75 micron	4—10	4—10

Note :—For compacted layer thickness of 25—40 mm of asphaltic concrete construction, any of the two gradings can be used but for layer thickness of 40—50 mm, only grading 2 should be used.

The binder to be used for asphaltic concrete construction is straight run bitumen of a suitable grade satisfying the requirements of IS : 73. However, bitumen of grades 30/40, 60/70 and 80/100 can be used for asphaltic concrete construction. The actual grade of the binder to be used is decided by the Engineer-in-charge, keeping in view the climatic conditions of the area.

The quantity of binder to be used for asphaltic concrete construction varies from 5 to 7.5 percent by weight of the total mix.

(b) Method of construction :-

Asphaltic concrete construction for wearing surface of a road is completed in the following steps :-

- (i) Preparing the base
- (ii) Applying tack coat
- (iii) Preparation of mix
- (iv) Transporting and spreading the mix
- (v) Rolling
- (vi) Opening to traffic

(i) Preparing the base :-

Asphaltic concrete surface is generally laid on a bituminous base. Permanent side supports such as kerbs of stone, precast cement concrete blocks or first class bricks are provided well in advance of laying asphaltic concrete surface course. For laying an asphaltic concrete wearing surface, the underlying base is prepared, shaped and conditioned to the specified levels, grade and camber. The base is then thoroughly swept and scraped clean to make the surface free of dust and other foreign matter.

(ii) Applying tack coat :-

After preparing the underlying base, the tack coat of suitable binder (at the rate of 5 to 10 kg per 10 sqm) is applied on the prepared surface.

Application of tack coat is, however, not necessary when the laying of asphaltic concrete follows soon after the provision of a bituminous base / levelling course.

(iii) Preparation of mix :-

Asphaltic concrete mix is made in a central hot mix plant under strictly controlled conditions. Aggregates conforming to specified grading are heated to 155° — 163°C and the bitumen is is heated to 150° - 177°C. Materials, in pre-determined proportions, are then thoroughly mixed to ensure that a homogeneous mixture is obtained in which all particles of the mineral aggregates are coated with the binder uniformly.

(iv) Transporting and spreading the mix :-

The prepared mix is then immediately transported from the mixing plant to the site of use in suitable vehicles such as dump trucks, wheel barrows, etc. After transporting the mix to the site of use, it is immediately spread by means of a self-propelled mechanical paver provided with suitable screeds capable of spreading tamping and finishing the mixture to the specified lines, grade and cross-sections. The temperature of the mix at the time of laying should be in the range of 121° - 163°C.

(v) Rolling :-

Immediately after spreading the mix, it is thoroughly compacted by a set of rollers, moving at a speed not exceeding 5 km per hour. The initial rolling is done with 8 - 12 tonne three wheeled roller and the surface is finished by final rolling with 8 - 10 tandem rollers. The wheels of the roller should be kept moist to prevent the mix from sticking to them. Usual precautions should be taken during rolling the surface. Rolling should be continued until the density achieved is at least 95% of that of the laboratory specimen and all roller marks are eliminated.

(vi) Opening to traffic :-

After final rolling, the traffic is permitted as soon as the surface cools down to the surrounding temperature.

(c) Quality control for asphaltic concrete construction

Asphaltic concrete is a very extensive mix. Therefore, a rigid control on quality is exercised on every stage of asphaltic concrete construction. A field laboratory is set up for this purpose. Quality control recommendations for asphaltic concrete construction as per IRC : 29 - 1968 are given below :

1. Periodic sieve analysis of each type of aggregate at the cold feeder end of the mixing plant should be done to see that the gradations of aggregates reasonably follow the original gradations as per design. The number of samples per day would depend upon the number of bulk supply of aggregates made in a day at the plant site.

2. Periodic checks on penetration and softening point of the binder should also be done in the manner specified by ISI.

3. Aggregates should not be wet. The temperature of aggregates in dryer should not exceed 163°C. A tolerance of 8°C on lower side is permitted.

4. The binder should be heated to a temperature between 150° to 177°C. Temperature of binder is checked regularly.

5. At no time, the difference between temperature of aggregates and that of binder should exceed 14°C

6. Gradation of aggregates should be checked periodically.

7. At least one sample for every 100 tonnes of asphaltic mix, discharged at the exit of pug-mill or minimum one sample per plant per day should be collected and tested for :-
   - (i) stability, flow, void ratio and density requirements.
   - (ii) Binder content
   - (iii) Gradation requirements.

8. Temperature of mix while laying should not exceed 163°C and it should not be less than 121°C.

9. Rolling should be done when the mix is neither too hot nor too cold so that the development of hair cracks can be eliminated.

10. Density of compacted surface in the field should be determined once for every 1000 sq.m of the road surface. It should not be less than 95% of the density obtained in the laboratory.

11. Finished surface is tested with a straight edge 4.5 m long and irregularities greater than 6mm should be corrected.

-: CEMENT CONCRETE ROADS :-

The roads having their wearing surface consisting of cement concrete slab (plain or reinforced) are called cement concrete roads or simply concrete roads.

These roads fall under the category of rigid pavements. These are high cost roads which remain in serviceable condition under all weather conditions. Thus, concrete roads are also considered as all weather roads. Due to their excellent riding surface, pleasing appearance and long life under most severe traffic conditions, the cement concrete roads are much preferred. But due to their high initial cost and inadaptability to stage construction, concrete roads are not popular in India.

These roads are very popular as high cost pavements in developed countries like America, Russia, Japan, etc. Considerable research has been done towards improvements in the design and construction of concrete road pavements.

(3) These roads are superior to most of other types of roads including bituminous roads.

Advantages and dis-advantages of cement concrete roads :-

Advantages :-

(i) concrete roads have got long life.
(ii) They are quite durable and are practically unaffected by weathering agencies.
(iii) They provide an excellent riding surface under all weather conditions.
(iv) They provide an impervious surface.
(v) They provide a dustless and sanitary surface.
(vi) They do not develop corrugations.
(vii) They can be laid on any subgrade.
(viii) They can be easily reinforced when they are to resist high stresses due to heavy wheel loads of the traffic.
(ix) They are practically non-slippery.
(x) They offer less tractive resistance.
(xi) They provide good visibility for traffic during night hours.
(xii) Their maintenance cost is very low.

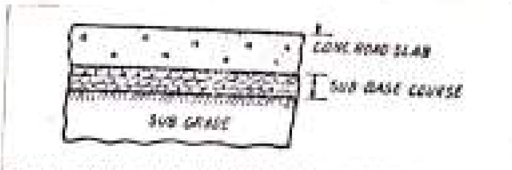
Disadvantages :-

(i) The initial cost of concrete roads is high.
(ii) They require skilled supervision and labour for their construction.
(iii) They are liable to crack and warp due to temperature variations.
(iv) They become noisy under iron-tyred traffic.
(v) They are less resilient than bituminous or W.B.M roads.
(vi) They may cause glare due to reflected sun-light.
(vii) They require long time (upto 28 days) for their curing and thus they cannot be opened to traffic earlier.
(viii) It is very difficult to locate & repair sewers and water mains lying under the pavement in their case.

Structural components of concrete pavements :-

The following are the structural components of concrete pavements, starting from the bottom :-

(a) Subgrade ;
(b) sub-base ;
(c) Concrete slab



STRUCTURAL COMPONENTS OF CONCRETE PAVEMENTS

The cement concrete road pavements may be constructed with or without sub-base, depending upon the type of subgrade. The various functions of the sub-base course beneath the concrete slab are :-

(i) to provide a strong supporting layer.
(ii) to provide a capillary cut-off, preventing damages due to mud pumping.
(iii) To reduce the thickness of concrete slab.

The concrete road slab performs the functions of base course as well as of wearing surface. The thickness of road slab varies from 15 to 20 cm, depending upon the traffic load. In case of heavy traffic and poor subgrade, reinforcement may be provided in the concrete road slab.

Materials required for concrete road slab & their requirements :-

The different materials required for constructing a road slab are given below:-

(a) cement
(b) coarse aggregate
(c) Fine aggregate
(d) water
(e) Reinforcement

(a) **cement** :- Ordinary portland cement is mostly used for concrete road slab construction. Rapid hardening cement may also be used in emergency when the construction is to be completed in short time.

The cement to be used in the construction of a road slab should fulfil all the requirements

(b) **coarse aggregate** :- Crushed stone, crushed gravel (shingle), other suitable stone is used as coarse aggregate for concrete road slab construction. It should be clean, strong, durable and free from dirt, dust etc.

The desirable values of important properties of coarse aggregates for cement concrete road construction are stated ...:

(i) Los Angeles abrasion value —— 16% max

(ii) Aggregate impact value —— 30% max

(iii) Aggregate crushing value —— 30% max

(iv) Soundness (average loss in weight after 10 cycles) —— (a) 12% max in sodium sulphate
(b) 18% max in magnesium sulphate.

(c) **Fine aggregate :-** Natural sand is commonly used as fine aggregate. When natural sand is not available, crushed stone sand may be used. It should be sharp and clean.

(d) **Water :-** Water is used for mixing and curing of concrete. It should be free from harmful substances. The water fit for drinking purposes is recommended for preparing the concrete mix to be used for constructing a road slab and also for its curing.

(e) **Reinforcement :-** It consists of mild steel bars or steel wire fabrics. It is to be provided when the subgrade is of poor strength and the road is subjected to heavy traffic. The usual practice of providing reinforcement in a concrete road slab is to place the steel at 3 to 7 cm depth below the surface of the slab.

The basic object of providing reinforcement is to prevent widening of cracks developed in the concrete road slab.

The following are the advantages and disadvantages of providing reinforcement in a concrete road slab :-

Advantages :-

(i) It prevents the cracks from widening and thus entry of dirt and water in the road structure is prevented.

(ii) It strengthens the structure of concrete pavement in case of weak subgrade and thus prevents the cracking of a road slab in its early age.

(iii) It facilitates provision of thinner sections of the road slab.

(iv) It controls warping, prevents cracking and increase the flexural strength of the road slab and thus ultimately prolongs the life of the concrete road.

Disadvantages :-

(i) It increases the cost of construction of the concrete road.

(ii) It interferes with the smooth progress of the construction work & thus delays the construction of the road pavement.

(iii) The construction of reinforced concrete road slab requires more skilled labour and supervision than that of a plain concrete slab.

Methods of laying cement concrete road slab :-

The cement concrete slabs are laid after taking the convenient length of the road at a time and then dividing it into bays or strips of suitable length. The length of these bays is kept 4 to 5 m and their width varies according to the width of pavement.

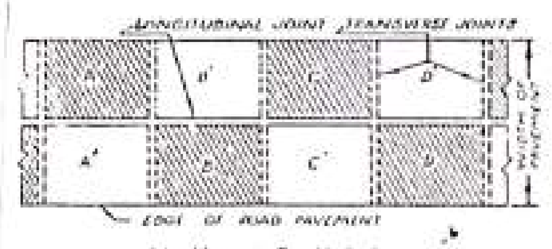
When the proposed width of pavement is less than 4.5m, the width of each bay is kept equal to the pavement width. In case, the pavement width is more than 4.5m, the width of each bay is kept 2.5m to 3.5m so as to divide the whole width into a number of strips. Thus, a 7m width pavement is divided into two strips with a central longitudinal joint. In this case, the width of each bay will be 3.5m and length varying from 4 to 5m.

There are the following two methods of laying cement concrete road slabs.

(a) Alternate bay method;

(b) continuous construction method.

(a) Alternate bay method :-



(a) Alternate Bay Method

In this method of construction, bays or slabs are constructed in alternate succession (ABCD), leaving the intermediate bays (A'B'C'D') as shown in figure alongside. These intermediate bays are constructed after a gap of atleast one week if ordinary Portland cement is used and two days in the case when rapid hardening cement is used.

The main object of this method is to allow the concrete placed in the previous bays to set and take up their initial contraction before the intermediate bays are constructed.

This method is practicable and found useful when the proposed width of pavement is more than 4.5 m. This method provides additional working convenience for laying of slabs. In this method, the construction of joints is also easier but this method has got ~~may~~ many drawbacks.

The main draw backs of alternate bay method are given below:-

(i) Large number of transverse joints are to be provided.

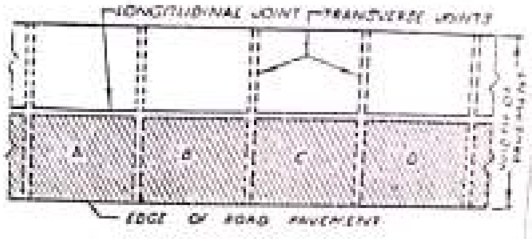
(ii) There is risk of sub-soil drying out when laying the intermediate bays.

(iii) During rains, the surface water collects on the subgrade and there is danger of uneven settlement of the subgrade.

(iv) The construction is spread over full width of the road pavement and the traffic will have to be completely diverted.

(b) Continuous construction method :-

In this method of construction, all the bays or slabs (ABCD) of a strip are constructed continuously without any break as shown in figure alongside. In this case construction joints are, however, provided when the day's work is not ended at the specified joint.



(b) Continuous Construction Method

In addition to these construction joints, dummy joints are also provided at 5m intervals in the transverse direction to check the planes of weakness so to control cracking. In this case, expansion joints are constructed at about 16 to 20m intervals i.e after every fourth slab.

This method is generally preferred as compared to alternate bay method because of its main advantage of construction of half the pavement width at a time. Thus, the essential traffic can be diverted on the other half of the road. This method is also very rapid. The only drawback of this method is that the construction of joints is difficult in its case.

Construction of cement concrete roads :-

The construction of cement concrete roads involves the following operations :-

(a) preparation of subgrade;
(b) provision of sub-base;
(c) placing of forms;
(d) Batching of materials and mixing;
(e) Transporting and placing of concrete;
(f) Compaction;
(g) Floating;
(h) Belting;
(i) Brooming;
(j) Edging;
(k) curing;
(l) Filling of joints and edging;
(m) opening to traffic.

(a) Preparation of subgrade

The subgrade to receive the road slab is prepared to the required grade and profile in the usual manner. The profile is checked by scratch templates. Unevenness greater than 12 mm in 3m, if any should be rectified. When concrete is to be directly placed on subgrade, the surface should be saturated with water 6 to 20 hours in advance of placing the concrete. This is done to ensure that the subgrade does not absorb water from the concrete. If water proof paper is to be laid between subgrade and concrete, moistening of subgrade may not be done.

(b) Provision of sub-base

When natural subgrade is not very firm, a sub-base over the subgrade is desirable. It may consist of any one of the following layers:-

(i) A layer of well graded soil-gravel mixture of maximum thickness 15cm.

(ii) Brick soling with one layer of W.B.M of maximum total thickness 15cm

(iii) Two layers of W.B.M of maximum total thickness 15cm.

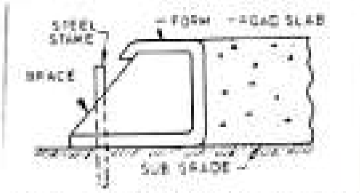
(iv) A layer of lean cement concrete of maximum thickness 10cm.

When the subgrade contains harmful salts, a capillary cut-off of any of the following materials may be provided below the sub-base:-

(i) 4 to 6 cm coarse sand
(ii) 30 to 45 cm fine sand
(iii) A suitable cut off of bituminous material

When subgrade soil is very poor, the sub-base should be placed over a blanket of some granular material or stabilized soil.

(c) placing of forms



SECTION OF A TYPICAL METAL FORM FOR ROAD SLAB CONSTRUCTION

concrete road slab is constructed between side forms. These forms are made of mild steel channel section in 3m length. The depth of form is equal to the thickness of concrete pavement. Forms are properly braced and fixed to the ground by means of stakes. Three stakes for every 3m length are provided. Forms lengths are connected to each other by suitable arrangement. A typical side form is shown alongside.

When the forms have been fixed, they are checked for their trueness. Maximum deviations permissible in the vertical plane is 3mm and in horizontal plane, it is 5mm in 3m length of the form. The forms are oiled before placing concrete in them.

(d) Batching of materials and mixing

After determining the proportions of ingredients for the concrete mix, the fine and the coarse aggregates are properly proportioned by weight in a weight-batching plant. They are then fed into the hopper alongwith necessary quantity of cement which is also measured by weight. Generally, quantities of various ingredients in a concrete batch are determined for one or more number of cement bags.

• Mixing of concrete mix is done in a batch mixer. Cement, sand and coarse aggregates of a batch are fed into the mixer simultaneously. Water is poured into the mixer within the first 16 seconds of mixing. Mixing of each batch is then done for one and a half minute after adding water.

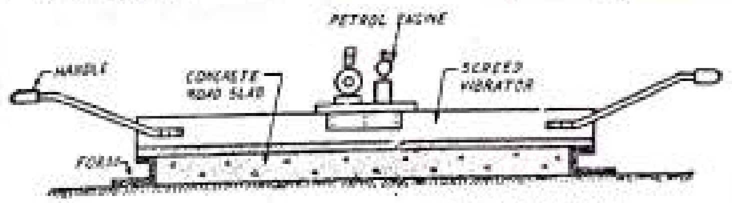
(e) Transporting & placing of concrete

After mixing, the concrete is transported to the site in wheel barrows or in pans which are carried manually. It is deposited on the subgrade or sub-base to the required depth and width of pavement section. While placing the concrete, it is roded with suitable tool to eliminate voids. Segregation of concrete is avoided during transportation and placing.

When reinforcement has been specified in road slab, concrete is placed in two stages. In the first stage, concrete is placed and compacted to the depth corresponding to the level of reinforcement shown on the drawings. Reinforcement is then placed on the top of compacted concrete and remaining thickness of slab is then completed in second stage.

(f) Compaction

After placing the concrete in position, compaction of road slab is achieved by means of a power driven finishing machine or by vibrating hand screed. Upto 12.5 cm thickness of slabs, screed vibrators alone can be used for compaction. For greater thickness, screed vibrator alongwith immersion vibrator is used. Edges and corners of concrete pavement are best compacted by immersion vibrators. Screed vibrators rest on the forms and vibrate the surface of road slab as shown in figure alongside.



COMPACTION OF ROAD SLAB BY A SCREED VIBRATOR

In case of hand consolidation, the tamper is placed on the side forms and is drawn ahead in combination with a series of lifts and drops to compact the road slab.

(g) Floating

After compaction, the entire slab surface is floated longitudinally with a wooden float board. The longitudinal float is held in position parallel to the centre line of the carriageway and is passed from one edge of the pavement to the other.

The purpose of floating is to provide an even surface free from corrugations. After floating, unevenness of the surface is checked with a wooden edge 3m long which should not be more than 3 mm.

(h) Belting

After floating, the surface is further finished by belting just before the concrete becomes hard. Belting consists in drawing 20cm wide belt of canvas across the pavement in short strokes.

The purpose of belting is to make the road surface non slipping and skid resistant. This operation is sometimes committed.

(i) Brooming

After belting, brooming is done by drawing brushes at right angles to the centre line of road from edge to edge. It is done with 45 cm wide steel or fibre brooms with long handles. Corrugations produced by brooming should be uniform and not greater than 1.5 mm deep. Brooming is done just before the concrete becomes non plastic. This operation is also sometimes omitted.

(J) Edging

After brooming, the edges of the slab are carefully finished with an edging tool before the concrete is finally set.

(K) Curing

Curing consists in checking the loss of water from the concrete slab and keeping the fresh concrete slab moist during hardening period.

It is started as soon as the concrete has been finished and it has become non plastic. Initial curing consists of spreading burlap or jute mats saturated with water on the surface of fresh concrete slab.

Spreading of mats is done from foot bridges. Initial curing is done for 24 hours. By this time, the concrete becomes hard enough to walk upon and then wet mats are removed and final curing is done for 2 to 3 weeks.

Final curing is done by any one of the following methods:-

(i) By ponding
(ii) By covering the slab with 4 to 8 cm thick layer of wet sand or earth.
(iii) By using a suitable chemical such as sodium or calcium chloride.
(iv) By using a water-proof paper.

(l) Filling of joints and edging

After curing, the surface is cleaned and washed. Then the joints are properly filled-in with a suitable sealing compound.

After this, the concrete road slab is protected by brick edging. Then the shoulders are prepared in level with the top of brick edging.

(m) Opening to traffic

After filling of joints and edging, the concrete road is opened to traffic when the concrete attains the required strength or after 28 days of curing.

-: JOINTS IN CONCRETE ROADS :-

Joints are essential in concrete roads to allow for expansion, contraction and warping of the road slab due to temperature variations. They are also sometimes required when there is abrupt break in the construction or the day's work is not ended at the specified joints in order to make proper bond between the old and new construction work of the road slab.

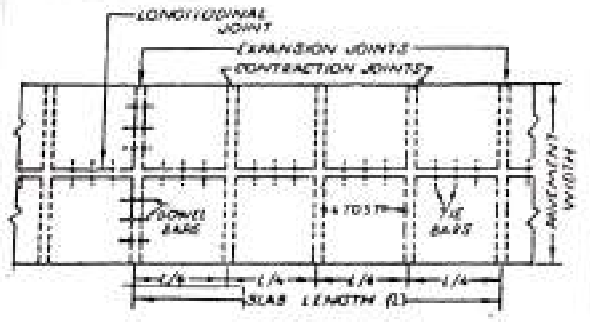
The various joints in concrete roads are classified into the following two categories :-

1. Longitudinal joints ;
2. Transverse joints.

1. Longitudinal joints

The joints provided in the longitudinal direction between two strips of the road slab when the pavement width exceeds 4.5m are known as longitudinal joints.

These construction joints are usually provided at the centre of road slab of two lane width (7m) and can be placed at 1/3 or 1/4 width if it is 9m or more. Such joints are also recommended at the extreme ends betn the kerbs and the road slab. The space between longitudinal joints should not exceed 4.5m.



JOINTS IN CONCRETE ROADS

Objects :-

The following are the objects of providing longitudinal joints in a road slab :-

(i) To control development of longitudinal cracks due to transverse contraction, warping and uneven settlement of subgrade.

(ii) To facilitate construction of road slab (more than 4.5m in width) in convenient widths with hand tampers.

(iii) To help to maintain the two slabs together at the same level.

The various types of longitudinal joints are described as below ...

(a) plain butt joint (b) Butt joint with tie bars (c) Tongue and groove warping joint.

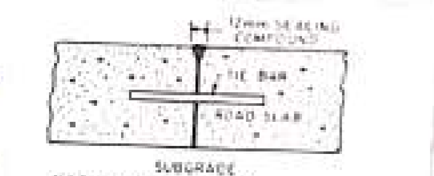
(a) plain butt joint :-

It is the simplest type of longitudinal joint. It is formed by simply painting the joints faces with a sealing compound as shown in figure alongside.

(a) Plain butt joint

(b) Butt joint with tie bars :-

In this type of longitudinal joint, tie bars of 12 to 15 mm diameter are provided as shown in figure alongside. These tie bars are about 1m in length and are placed at 600mm centre to centre distance. The top of the joint is then sealed with a sealing compound.



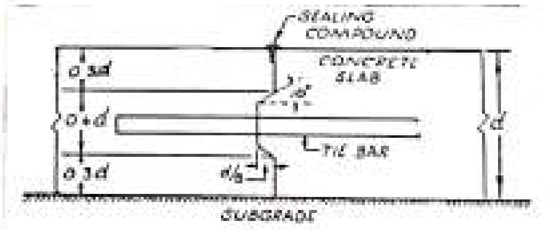
(b) Butt joint with tie bars

The function of providing tie bars is to hold the adjacent strips of the road slab together.

Butt joint with or without tie bars have been recommended by IRC for their use in concrete road slabs.

(c) Tongue & groove warping joint :-

In this type of longitudinal joint, a tie bar is inserted between the two strips with a key as shown in figure alongside. The top of the joint is then sealed with a sealing compound.



(c) Tongue and Groove Warping Joint

2. Transverse joints

The joints provided in the transverse direction of the road slab, max^m at 5m intervals are known as transverse joints.

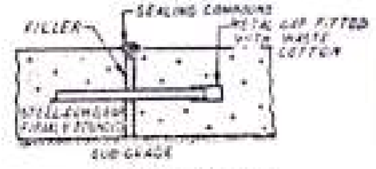
The function of transverse joints is to allow for expansion, contraction and warping of road slab and thus to prevent development of cracks in the transverse direction.

The various types of transverse joints are described below :-

(a) Expansion joints
(b) contraction joints
(c) warping joints
(d) construction joints

(a) Expansion joints :-

The transverse joints constructed to allow for expansion of the road slab due to increase in temperature are known as expansion joints.



(a) Expansion Joint

These transverse joints are provided at right angles to the centre line of the road at 18 to 20m intervals. These joints extend to the full width & thickness of the road slab.

In these transverse joints, dowel bars of 15 to 18 mm dia are provided to transfer the wheel load from one slab to the other. These bars are 300 mm to 600mm in length and are placed at 300 to 500mm centre to centre distance as shown in figure above.

One end of each dowel bar is fixed in the concrete slab on one side of the joint. The other end lying in the adjoining slab is placed in a 100mm long metal sleeve or this end is oiled. Thus, the end of the dowel bar which is placed in metal sleeve or oiled, remains free to move whenever there is increase in temperature.

(b) Contraction joints :-

The transverse joints constructed to allow for contraction (shrinkage) of the road slab due to decrease in temperature are known as contraction joints.

These transverse joints are provided at 4 to 5 metres intervals usually at right angles to the centre line of the road. These joints are either or plain butt type or dummy type joints.

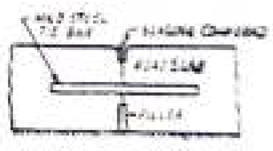
plain butt type contraction joints are vertical and extend to the full thickness of the road slab as already written in case of longitudinal joints (a & b)

→ Dummy type contraction joints are also vertical but extend to about $\frac{1}{3}$rd of thickness from top of the slab as shown in figure alongside. This type of joint is formed by cutting into the surface after finishing the slab by means of wedge shaped plate and then this cut is sealed by a suitable sealing compound.

(ii) Dummy Type Contraction Joint

(c) Warping joints :-

The transverse joints constructed to control the bending or warping of a road slab due to difference in moisture content or temperature at its top and bottom are known as warping joints.



(c) Warping Joint

These joints are in the form of butt joints with tie bars as shown in figure..

(d) construction joints :-

The transverse joint constructed when the construction work of the road slab is to be ended at a place other than a specified joint due the any reason is called a construction joint.

such transverse joints are to be constructed under the following circumstances :-

(i) when the day's work of constructing the road slab is not ended at a specified joint due to any mishappening.

(ii) when some mechanical defect occurs in the mixing plant & full length of the slab is not completed

(iii) when there is rain & the work is to be stopped without completing the full length of the slab.

In such circumstances, construction joints are provided by embeding tie bars of 10 mm to 12 mm dia, at a depth of 3 cm from the top of road slab. The tie bars, about 1m long, are provided at 600 mm centres to centre distance.

Introduction

In India, about 259000 sq km of area is covered with hills. In some parts like Himalayan region, vegetation and human habitation extends upto altitudes as high as 4900m above mean sea level.
In such an area, navigation and railway routes are not feasible. Even air traffic is difficult in hilly areas due to heavy cost of construction of air ports, control towers, etc. Thus, the only source of communication left in these areas is through roads which are known as **ghat road** or hill roads.

In consideration of strategic need of this country, roads have now been constructed even upto altitude of 5500m in order to provide communication facilities for the military. To accelerate the development of roads in hilly areas, the Border Roads Development Board was set up by the Govt. of India in March 1960.

* The present expenditure on hill roads construction is about 30 to 40 percent of the total central budget for roads.

Right upto 1949 hilly region of the country which occupies about 10% of total area of the country was neglected. The British developed a few hill stations as their summer resorts and connected them by rail and road. Stations joined by road were Mussorie (UK), Shimla (Himachal Pradesh), Darjelling (West Bengal), Ooty, Dalhousie (Himachal Pradesh), Lansdone (UK), Nainital (UK).

* Where possible some of the stations such as Darjelling, Ooty and Shimla were connected by Railways.

→ Almost all these stations were cantonments made to serve the regime of Britishers.

Chinese attack in 1962 drew the attention of the Govt. of India for development of the hills.

* The extension of the Rail from Pathankot to Jammu, though not necessarily a hilly region, however, lays the base for extension of the Railway line well inside J&K. The project of constructing railway line well inside the valley is in a very advanced stage and preliminary work has already been started. This project is the latest in the development of Railways in the Hills.

Hill Roads

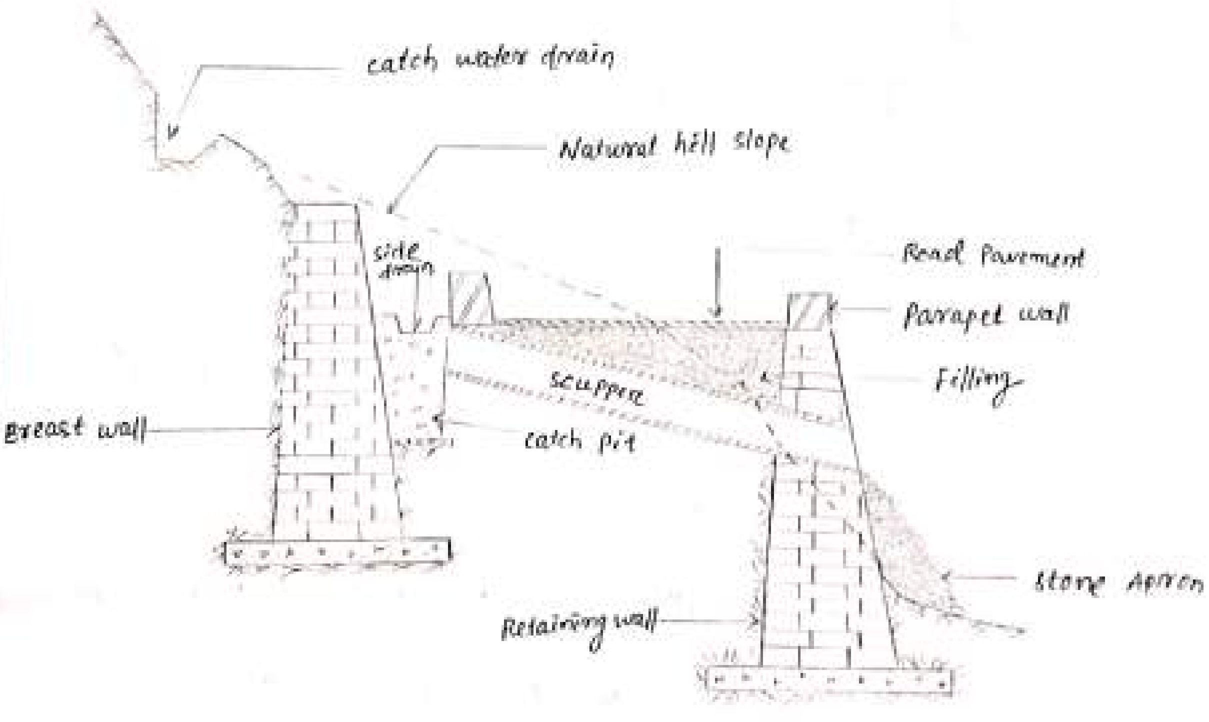
The road constructed in mountainous regions of a country are known as hill roads or ghat roads.

These roads present great difficulty in their alignment, design, construction and maintenance. Curves, sharp bends, steep gradient & limited width of roadway make hill roads more liable to accidents. Also the effects of heavy rainfall on the construction and maintenance of a hill road are serious.

→ At many locations on the hill roads, the landslides and slips may occur during heavy rainfall. Therefore, much care is needed during their layout and construction so as to provide a stable & safe road. Moreover, a large number of streams cross the road and hence a suitable facility for cross drainage is needed.

(4) The overall cost as well as cost per km length of a hill road is higher than that of a similar road in plains. The reason for this is that hill road construction involves difficult rock cutting, construction of more number of drainage crossings and costly protective works like retaining walls, breast walls, parapet walls, drains, etc. which are specially needed for hill roads.

Parts of a hill road & their functions



c/s of a Typical Hill Road showing its component parts

The following are the component parts of a typical hill road :-

(a) Road bed;
(b) side drains;
(c) Parapet walls;
(d) catch water drains;
(e) Breast walls;
(f) Retaining walls;
(g) cross drains

(a) **Road bed** The pavement portion of a hill road is known as road bed.

→ The function of a road bed is to resist safely the stresses caused due to the moving wheel loads of traffic

(b) **side drains**

The drain provided on the road side, usually at the foot of hill slope is known as side drain.

→ The function of side drains is to collect & drain off rain water, falling over the road surface as well as on hill slope, into any cross drainage works.

(c) **Parapet walls** The wall provided above the formation level of a hill road, usually towards the down slope side is known as parapet wall.

→ This type of wall is not constructed as continuous wall but with suitable gaps in between, for economy in its construction.

→ The function of such a wall is to provide protection to the traffic against falling down the hill slope.

(d) **catch water drains** The drains provided higher up on the hill slope side, parallel to the road are known as catch water drains.

→ These drains should not be provided less than 4.5m distance from the edge of the road.

→ The function of these drains is to intercept the run off from the hill slope, which would otherwise rush on to the road & wash it away, and then to divert the same into a nearby cross drainage work.

(e) **Breast wall** — The wall constructed towards upslope side of the road to prevent the hill side from sliding down is called breast wall

→ This type of wall is constructed when hill side is steep & there is tendency of its sliding down towards the road. Breast walls are constructed of stone masonry, brick masonry or cement concrete.

→ The top width of breast walls as well as of retaining walls should be 60 cm minimum. Their front face should have a batter of 1 in 4 to 1 in 3. The stones used in their construction should be of large size and roughly hammer dressed.

(f) **Retaining walls**

The wall constructed towards down slope side of the road to resist the pressure of earth filling & traffic load coming on the road is known as retaining wall.

→ This type of wall is commonly constructed in case of a hill road when the later is to be constructed partly in cutting & partly in embankment or wholly in embankment. Retaining wall can be constructed in stone masonry, brick masonry or cement concrete. Dry stone masonry retaining walls are the simplest and are, therefore, commonly constructed along a hill road.

→ The height of a dry stone masonry retaining wall is restricted to 6m.

→ when the height of the wall is more than 6m, three courses are provided in suitable mortar after every 3m height.

(g) **Cross drains**

The drain constructed to drain off the rain water across the road is known as cross drain.

→ The cross drains may be in the form of small under drains, scuppers, etc.

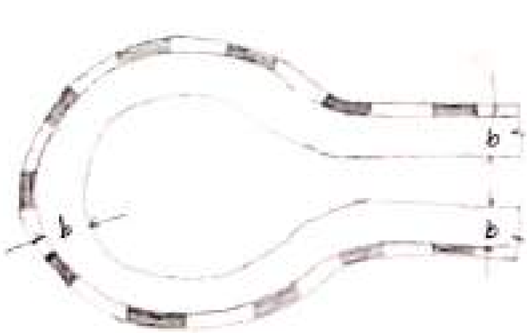
Types of curves on hill roads

The following are the important types of curves provided on hill roads:-

(a) Hair pin curves/bends
(b) salient curves
(c) Re-entrant curves

(a) Hair pin curves/bends

The curve in a hill road which changes its direction through an angle of 180° or so, down the hill on the same side is known as hair-pin curve/bend.



This curve is so called because of conforms to the shape of a hair-pi[n]
The bend so formed at the hair-pin curve in a hill road is known as

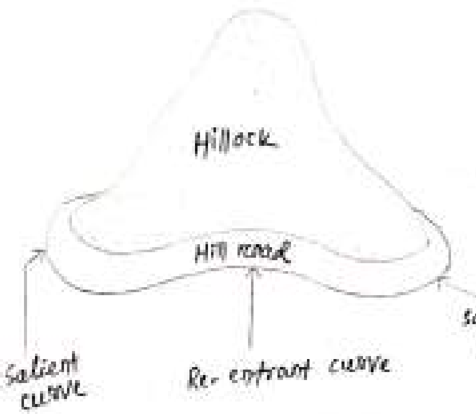
hair-pin bend.

This type of curve should be located on a hill side having the min^m slope and max^m stability. It must also be safe from view point of land slides and ground water.

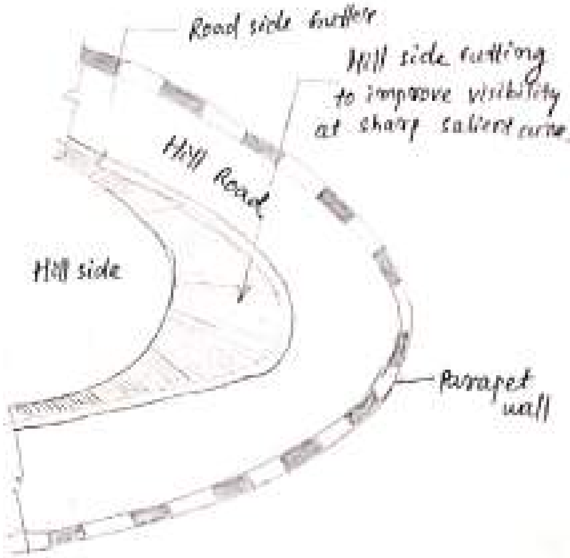
→ Hair pin bends with long arms and farther spacing are always preferred. They reduce construction problems and expensive protective works.

→ Hair pin curves or bends of serpentine nature are difficult to negotiate and should, therefore be avoided as far as possible.

(b) **Salient curves**



A hill road showing salient & Re-entrant curves



A corner bend at the salient curve

The curves having their convexity on the outer edges of a hill road are called salient curves.

→ The centre of curvature of a salient curve lies towards the hill side. This type of curve occurs in the road length constructed on the ridge of a hill. The bend so formed at the salient curve in a hill road is known as corner bend.

→ salient curves are very dangerous for fast moving traffic. At such a curve or at corner bend, the portion of projecting hill side is usually cut down to improve the visibility.

→ The outer edge of the road at such a curve is essentially provided with a parapet wall for protection of the vehicles from falling down the hill slope.

(c) **Re-entrant curves**

The curves having their convexity on the inner edge of a hill road are called re-entrant curves.

→ The centre of curvature of a re-entrant curve lies away from the hill side. This type of curve occurs in the road length constructed in the valley of a hill.

→ These curves are less dangereous as they provide adequate visibility to the fast moving traffic. At such curves, the parapet wall is provided only for safety of fast moving traffic.

Alignment of a Hill Road

The success & utility of a hill road depends much upon its proper alignment. In the alignment of a hill road, a number of sharp curves such as hair-pin bends, corner bends, etc are to be provided. The minm radius of such sharp curves should be 30m but not less than 14m in any case. The minm radii of curves recommended for different roads in hilly area are given below

Minimum Radii of curves in Hill Roads

Sl.No	Category of Road	Minm Radii, (mtr)			
		Mountaneous Terrain		Steep Terrain	
		not snow bound	snow bound	not snow bound	snow bound
1.	NH & SH	50	60	30	33
2.	MDRs	30	33	14	15
3.	ODRs	20	23	14	15
4.	VRs	14	15	14	15

During the alignment of a hill road, much care should be taken to see that the road should be as short as possible so as to achieve economy in the cost of construction, transportation and maintenance. It should have easy gradients so that all types of vehicles can traverse long distance without any difficulty.

The alignment of a hill road should be fixed in the following three stages

1. Reconnaissance
2. Trace cut
3. Detailed survey

Trace Cut: This operation consists in constructing 1 to 1.2m wide track along the selected alignment to facilitate access to the area for inspection & detailed surveys.

→ During reconnaissance, a general route for the alignment is selected. A trace is cut thereafter to translate this route on the ground, So as to provide an access for the subsequent detailed surveys.

→ The final alignment according to desired geometrics is fixed by detailed survey in the last phase.

Classification of Hill Roads

Normally hill roads are also classified, as in the case of plain roads into the following five categories.

1. NHs
2. SHs
3. MDRs
4. ODRs
5. VRs

Hill roads may also be classified into the following three categories :-

1. Motor Roads
2. Bridle paths
3. Village paths or tracks

1. Motor Roads

The hill roads meant for motors, trucks and other such traffic are known as motor roads.

→ These roads form main communication system in hilly areas. They may have one or more lanes width. The ruling gradient recommended for such roads is 1 in 20 & the limiting gradient is 1 in 15. The exceptional gradient recommended is 1 in 12 but it should only be provided in 75m per km length of the road. These roads are constructed with any suitable pavement according to their importance.

2. Bridle Paths
(लगाम)

The hill roads meant for pedestrians and other pack transport such as laden ponies, mules(खच्चर), camels, etc are known as bridle paths.
(भार लदा)

These paths serve as feeder roads to motor roads, thus connecting interior places with the main communication system. They are generally 2 to 2.5m in width but may be kept 2.45 to 3.65m wide when they are to be used as jeepable roads. The ruling grabient recommended for such paths is 1 in 10 and the limiting gradient is 1 in 7.5. The surface of these paths is generally paved with stone blocks.

3. Village paths or tracks

The hill roads meant for pedestrians, cattle, etc are called village paths or tracks.

These tracks connect small villages and other working places with bridle paths or motor roads. They are generally 0.9 to 1.2m in width. The ruling gradient recommended for such paths is 1 in 7.5 and the limiting gradient is 1 in 5. The surface of these paths generally consists of natural rock, dressed to the required gradient & camber.

The Board of Road organisation has classified hill roads as given below:-

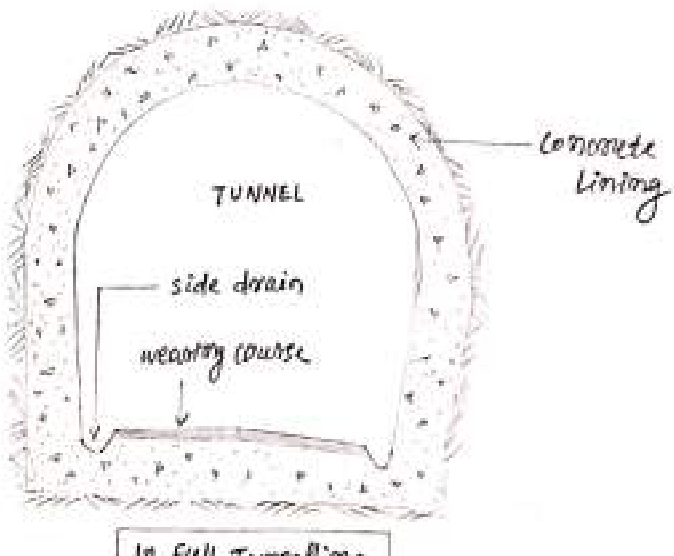
1. National Highways;
2. class 9 (6m wide for 3 tonnes vehicles);
3. class 5 (4.9m wide for 1 tonne vehicles);
4. class 3 (2.45 to 3.65m wide for jeeps);

Formation of Hill Roads :-

The formation of a hill road may be done in any one of the following three situations:-

1. wholly in cutting
2. wholly in embankment/Filling
3. partly in cutting and partly in embankment

1. Road wholly in cutting

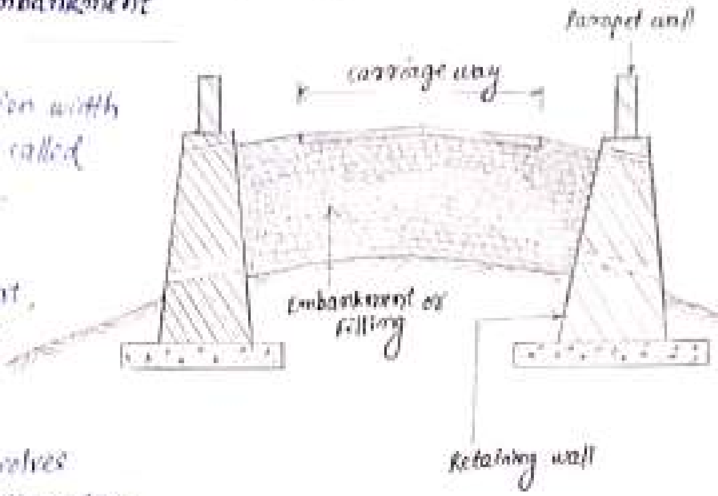


In Full Tunnelling

The hill road having its formation width constructed fully in cutting is called the road wholly in cutting.

A hill road, wholly in cutting, is constructed when the side slope of the hill is very steep. The road in cutting may be either in half tunnelling or in full tunnelling. The road in half tunnelling is provided when the rock strata dips away from the road side and when the rock is quite hard and stable. The road in full tunnelling is only provided when there is no other alternative, for the economy of the road project.

2. Road wholly in embankment

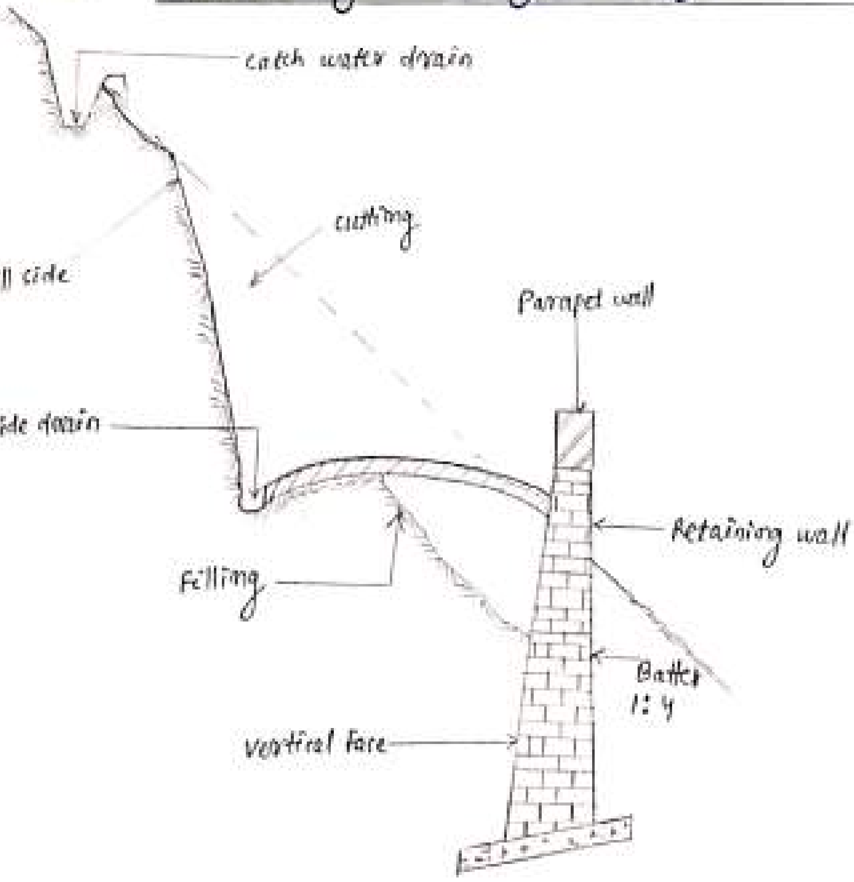


The hill road having its formation width constructed fully in filling is called the road wholly in embankment.

A hill road wholly in embankment, is constructed when a depression comes in the alignment of the road.

* This type of construction involves heavy earthwork and should, therefore, be avoided as far as possible.

3. Road partly in cutting & partly in embankment



The hill road having its formation width constructed partly in cutting and partly in filling is called the road partly in cutting & partly in embankment/filling.

→ Hill roads are generally constructed partly in cutting and partly in embankment. Usually the road section $\frac{2}{3}$ in cutting & $\frac{1}{3}$ in filling is preferred for more stability of the road.

→ This type of road construction is done when the side slope of the hill is not very steep & cost of cutting through rocks is too much

-: LAND SLIDES :-

The downward and outward movement of slope-forming materials such as natural rocks, soils, artificial fills, etc is known as land slide or land slip.

Land slide or land slip is the most important problem in the maintenance of hill roads. In rainy season, land slides or slips are frequent and the road often get blocked. Thus, land slides interfere with the free movement of traffic on hill roads.

Hence, it becomes essential to adopt suitable measures to prevent land slides so as to provide free movement of traffic on the hill roads throughout the year.

Types of land slides

Land slides occur along surface of separation by falling, sliding, flowing or by their combined effect. Thus, land slides may occur in any one of the following forms :-

(a) Fall;
(b) slide;
(c) flow;
(d) complex slide.

(a) Fall

It includes free fall and rolling of rocks and debris (accumulation of loose rocks) down the hill slope.

(b) Slide

It is the movement of slope forming materials along one or several surfaces down the hill slope. It is caused due to finite shear failure of rocks.

(c) Flow

It is the movement of the slope forming materials within the displaced mass. The form taken by the moving materials resembles (have a similarity to) to that of viscous fluid. In its case, the slip surface cannot be located.

(d) Complex land slide

It includes movement due to combined effect of two or more types of land slides.

Causes of land slides

The following are the causes of land slides....

(i) Increase in water content during rainy season.
(ii) Due to failure of a retaining wall or breast wall
(iii) Due to seepage pressure of percolating ground water
(iv) Undermining caused by erosion.
(v) Shocks and vibrations caused by earthquakes and nearby blasting of rocks.

(vi) increase of load due to traffic or accumulation of snow on the road surface.

(vii) Formation of faults in bedding planes of the strata due to vibration.
The fracture along which the movement of one block with respect to the other takes place is known as faults.

(viii) Removal of part of the mass by excavation and increase in slope angle.

(ix) Hair-cracking due to alternate swelling & shrinkage of the soil mass.

(x) Fissuring of pre-consolidated mass due to release of lateral pressure while doing cutting of rocks.

Prevention & control of land slides

Study of causes of land slides gives the clues to preventive measures against these slides. Though we are helpless to prevent land slides caused due to earthquakes, yet we can surely prevent and control land slides due to other causes by taking the following measures.

(a) By efficient surface and cross drainage

(b) By providing sub-surface drains at foot of the hill slope to control seepage flow.

(c) By benching of soil slope.
The art of cutting hill sides in steps is called benching.

(d) By reducing the angle of slope or providing breast walls and retaining walls

(e) By constructing buttresses at toe of hill slopes.

(f) By slope treatment to minimise the erosion and to improve the stability of hill sides. This is done by turfing, stone pitching, cement grouting, etc.

Drainage structures for Preventing land slides

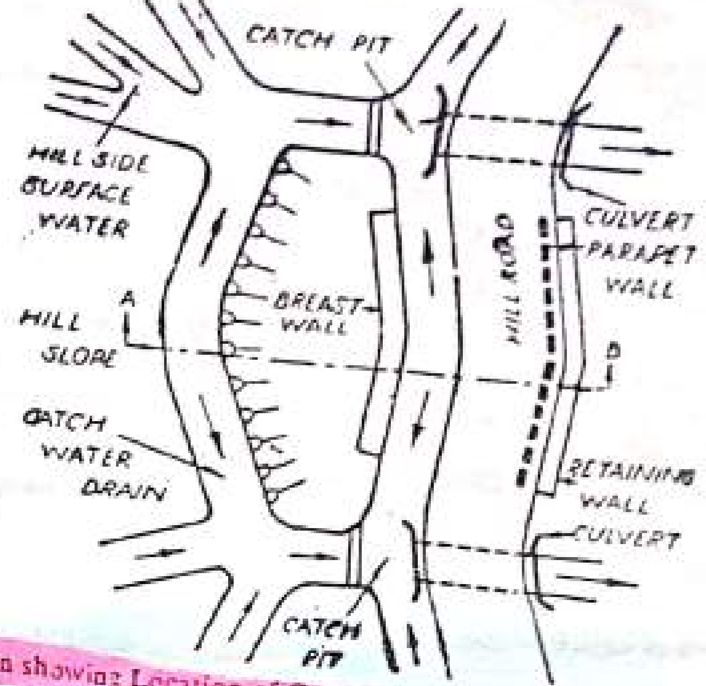
The various drainage structures for preventing land slides are given below.

(a) catch water drains

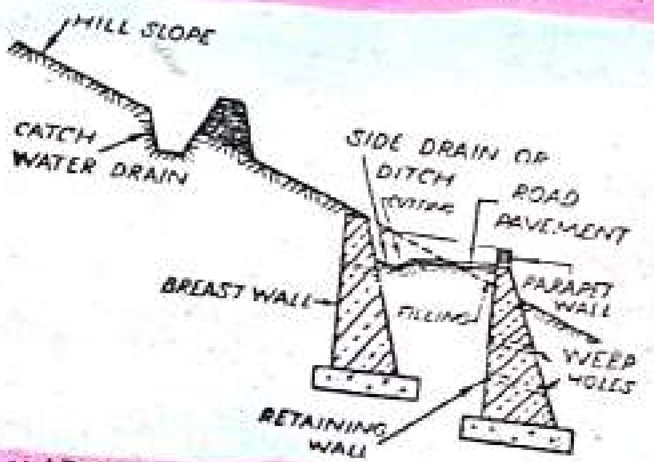
(b) side drains

(c) Sub-surface drains

(d) cross drainage structures in the form of under drains, scuppers, causeways, culverts, minor or minor bridges, etc.



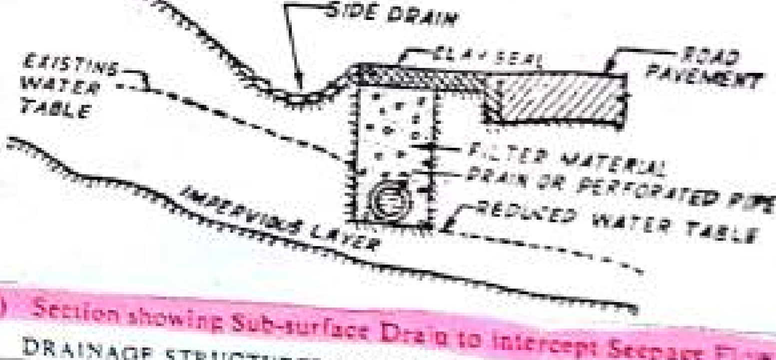
(a) Plan showing Location of Catch Water Drain and Side Drain



(b) Section at AB showing Location of Catch Water Drain and Side Drain

Fig. 7-8

(Contd.)



(c) Section showing Sub-surface Drain to intercept Seepage Flow

DRAINAGE STRUCTURES FOR PREVENTING LAND SLIDES

Road Drainage

Introduction :

The stability of road pavements can only be maintained if their surface and foundation bed remain in dry condition. The entrance of water in the subgrade or any other layer of the road pavement, even for short intervals is undesirable and dangerous because it is considered as one of the major causes of the road pavement failure. Thus, efficient collection, removal and disposal of surface and sub-surface water known as road drainage, is very essential for proper design & adequate maintenance of roads.

Road Drainage

The process of removing & controlling the access of surface & sub-surface water within the right-of-way of a road is called road drainage.

It also includes interception (collection) & diversion of water from the road surface and the subgrade.

(*) The process of interception and diversion of surface water through suitable side drains is called surface drainage, and the process of interception and removal of sub-soil water through suitable sub-surface drains is called sub-surface drainage.

(*) The main object of road drainage is to keep the road surface and its foundation as dry as possible so as to maintain its stability.

Thus, a good drainage system is essential for efficient highway transportation with minimum maintenance cost.

~~Method~~ Modes of water penetration into road structure

The following are the different modes of water penetration into the road structure

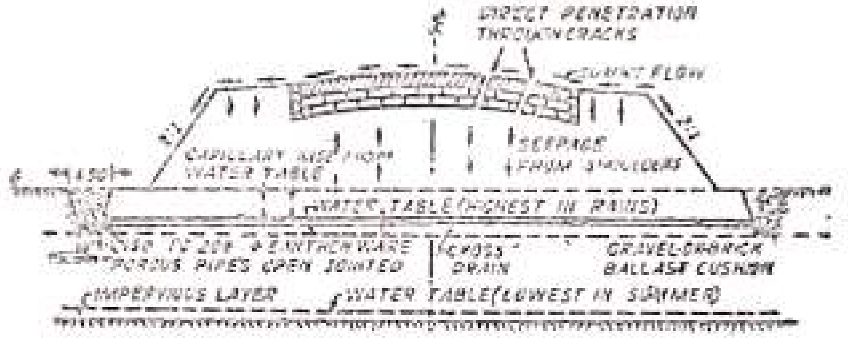
(i) surface water from the top of pavement by percolation through cracks and poor pavement surface.

(ii) surface water from sides of the pavement

(iii) sub-soil water from underside of the pavement by capillary rise.

(iv) sub-soil water from sides of the pavement

(v) Intercepted water due to overflooding of cross drainage works.



MODES OF WATER PENETRATION INTO ROAD STRUCTURE

Ill effects of water entering the pavement structure on sub-grade materials

The following are the ill effects of water entering the pavement structure on sub-grade materials:-

(i) The water entering the road pavement causes softening & reduction in bearing strength of sub-grade materials.

(ii) It causes mud pumping in rigid pavements

(iii) It causes the clayey masses of the road bed to expand.

(iv) It causes the black cotton soil forming the sub grade material to swell

(v) It causes the sand loam to retain moisture by capillary action.

(vi) It causes the peat loam to loose its cohesion which finally disintegrates with increase of moisture.

Necessity of Road drainage

The surface water may enter the pavement structure from top, bottom or sides due to percolation. The subsoil water may find its access to the pavement subgrade from bottom due to capillary rise.

The water entering the pavement structure causes the clayey mass of the road bed to expand. Expansion in the soil mass of the bed may also take place due to freezing or salt action. It also causes softening of the subgrade soil and decrease in its bearing capacity. All these ill effects of water entering the pavement result into consequent breaking up & shattering of the road pavement. Water also causes erosion of bank slopes whether in embankment or in cutting and may also result into land slides.

The following are the factors which necessiate the provision of road drainage :-

(i) The entrance of the water in the soil subgrade of the pavement causes considerable decrease in its bearing strength and thus the pavement is likely to fail due to poor strength of the subgrade.

(ii) Excess of moisture content causes reduction in bearing strength of base course bed materials like stabilized soil, water bound macadam etc.

(iii) The increase in moisture content causes the clayey masses of the road bed to expand considerably which may sometimes result in pavement failure.

(iv) Due to poor drainage, waves and corrugations are formed in flexible pavements. This also causes mud-pumping in rigid pavements. All these defects lead to pavement failure.

(v) The increase in moisture contents causes increase in weight & simultaneously reduction in strength of the soil mass of side slopes. This is considered as the main reason of failure of side slopes.

(vi) At places where temperature often reaches to freezing point, the frost action of water entering the pavement structure may cause damage to the road pavement.

(vii) Poor drainage of road also causes washing out unprotected of top surface of roads, erosion of bank slopes, land slides etc.

Considering all these factors, the provision of an adequate & efficient road drainage for quick removal of surface and sub-soil water has become very essential in the design and proper maintenance of roads. With an adequate & efficient drainage system, the efficiency and life of a road can be considerably increased.

Requirement of a good road drainage system

The following are the requirement of a good road drainage system :—

(i) In a good drainage system, the road pavement should have an impervious top surface provided with sufficient camber so as to drain off the surface water without allowing it to percolate into the road pavement

(ii) The shoulders of road pavements should also have an impervious top with proper cross slopes so as to drain off the surface water effectively towards the road sides.

(iii) The side slopes of road embankment or cutting should be sufficiently flat and well compacted so as to allow the surface water to flow sideways without causing cross ruts or erosion.

(iv) The side drains should have sufficient capacity & longitudinal slope to carry away the collected water without overflowing.

(v) Where the topography of the area is such that the water flows towards the roadways, intercepting drains of adequate capacity should be constructed parallel to the road but outside the road limit to intercept water of the outer area.

(vi) There should be adequate arrangement for sub-surface drainage so that the height level of ground water table should remain preferably 1.2m below the level of subgrade.

(vii) Seepage & other sources of underground water, if any should be tapped and the water should be drained off by sub-surface drains.

(viii) In water logged areas, special measures should be taken especially, if salts are present or if flooding of water is likely to occur.

(ix) All drainage structures should be of adequate design to drain off water immediately without overflooding.

Road drainage systems

Road drainage systems, adopted for removing & controlling the surface and sub-soil water, entering the pavement structure, are grouped into the following heads:-

1. Surface drainage
2. Sub-surface drainage
3. Cross drainage

1. Surface drainage

The system of collection & disposal of surface water within right-of-way of a road is called surface drainage.

This system consists in allowing the surface water to flow from the pavement surface without percolation into the shoulders & then down the embankment slope when the road is in embankment or in side drains when the road is in cutting or when it is on ground line.

The surface water is first collected in longitudinal suitable side drains which is then disposed off in the nearest stream, valley, etc.

Method of providing surface drainage

The following steps are taken to provide effective surface drainage on roads:-

(i) Providing an impervious type of road surfacing.

(ii) providing sufficient camber or superelevation as desired & adequate gradient to the road surface.

(iii) Making shoulders of rural highways impervious and providing them proper side slope towards side drains.

(iv) Protecting side slopes from erosion by properly rounding off edges and also by turfing.

(v) Keeping height of the road embankment atleast 1.2m above the highest flood level of the area.

(vi) Providing side drains on one or both the sides according to the alignment of the road.

(viii) Providing intercepting drains when the slope of the surrounding area is towards the road. Such drains should be constructed parallel to the road but outside the right-of-way

2. Sub-surface drainage

The system of collection & removal of sub-soil water from underside of a road pavement is called sub-surface drainage or sub-soil drainage.

(*) The function of sub-surface drainage is to control the moisture content of the road subgrade.

This system consists in first controlling the **free water**.

The water which originates under the pavement due to spring action or has penetrated the pavement structure due to perviousness of road surface is called free water or gravity water.

This can be done by intercepting surface water before it enters the road subgrade. The second step is to reduce the **capillary moisture**.

The particles of water drawn due to capillary action of soil particles from free water or saturated strata, lying below the road subgrade is known as capillary moisture.

This is achieved by providing sub-surface drains to lower the ground water table or by providing a granular subgrade.

Sub-surface drainage system is recommended under the following conditions:

(i) when the road is through a flat country and the ground water table is considerably high (less than 1.2m below the road subgrade).

(ii) when there is danger of rise of moisture to the pavement structure due to capillary rise even if the underground water table is sufficiently low.

(iii) when the road is in cutting & there is considerable seepage through the side slopes.

(iv) When the pavement structure is subjected to the action of spring.

(v) When the road is at the foot of a hill and the water there from may seep into the road subgrade.

Methods of providing sub-surface drainage

The following the methods of sub-surface drainage adopted under different situations :-

(a) lowering the water table;

(b) control of seepage flow;

(c) control of capillary rise.

(a) Lowering the water table

The height level of ground water table should be atleast 1.2m below the level of road subgrade so that the subgrade & pavement layers are not subjected to excessive moisture. In plains, where the sub-soil water table is high, the best remedy is to provide the road formation in embankment of height not less than 1.2m. When the road formation is to be provided at ground level or in cutting, then it becomes essential to lower the sub-soil water table.

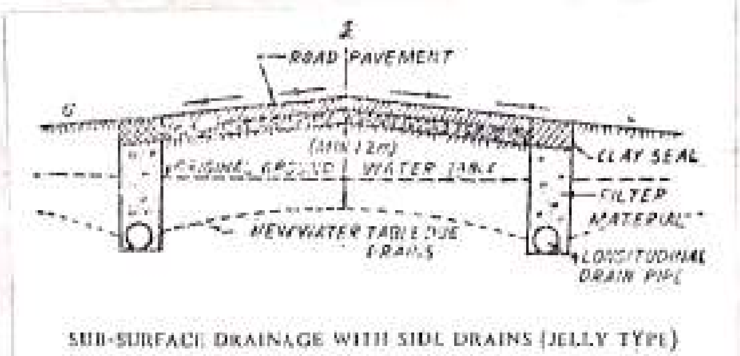
The sub soil water table can be lowered by any one of the following three methods.

(i) By merely constructing longitudinal side drains (Jelly type) with drain pipe & filter bed

(ii) By providing transverse drains in addition to longitudinal drainage trenches

(iii) By providing perforated pipes or open-jointed drains along side slopes of cutting in addition to longitudinal side drains

(i) By merely constructing Longitudinal side drains (Jelly type) with drain pipe and filter bed :-



SUB-SURFACE DRAINAGE WITH SIDE DRAINS (JELLY TYPE) WITH DRAIN PIPE AND FILTER BED

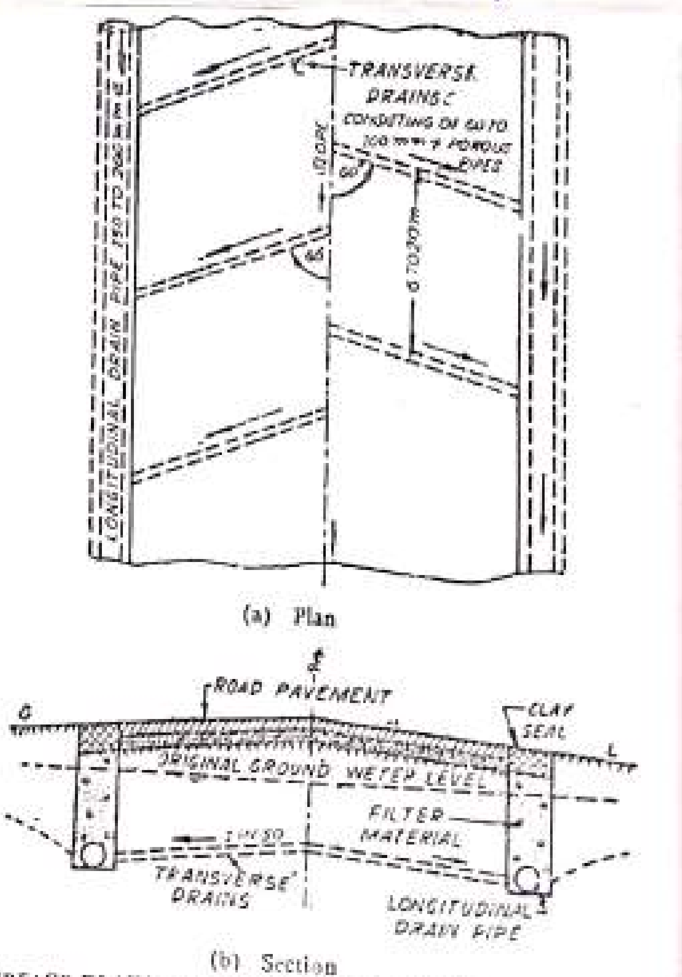
In this method, Jelly type side drains are constructed. These drains are provided with drain pipe and filter bed as shown in fig. The depth of drainage trenches depends on the required lowering of the sub-soil water table.

Suitability :- This method is only suitable when the soil is more permeable.

(ii) By Providing transverse drains in addition to longitudinal drainage trenches

In this method, longitudinal drain pipe are provided in trenches below the pavement structure at the specified depth.

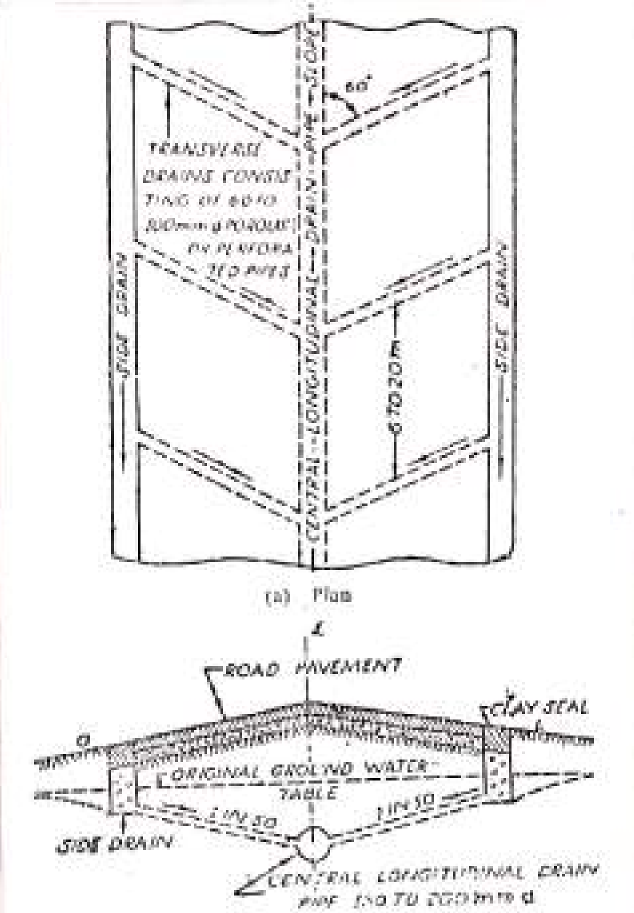
The pipes are usually made of vitrified clay and are placed with open joints butting against each other. They are laid on a bed of sand, crushed stone or clay bed 150mm thick. The longitudinal drain pipes are 150 mm to 200mm in diameter. Cross or transverse drains, known as 'Mitre drains' or 'French drains' are 60 mm to 100mm in diameter & are laid



(a) Plan

(b) Section

SUB-SURFACE DRAINAGE WITH TRANSVERSE DRAINS ALONGWITH LONGITUDINAL SIDE DRAINS



(b) Section

SUB-SURFACE DRAINAGE WITH TRANSVERSE DRAINS AND A LONGITUDINAL CENTRAL DRAIN

cross wise from the centre of the road, sloping 1 in 50 diagonally towards the flow. The distance between adjacent cross drains is kept 6m 20m depending upon the nature of the subgrade soil.

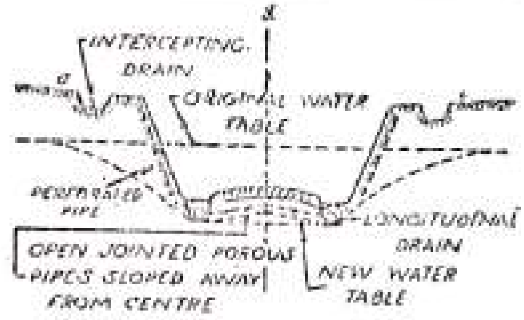
The main longitudinal drain pipes (150 to 200 mm dia) may be provided on both sides or at centre of the road. When the main longitudinal drain pipes are provided on both the sides of a road, the slope of transverse or ~~of~~ cross drains is kept 1 in 50 from centre towards sides as shown in fig along side. This method of sub-surface drainage is comparatively costly but can be easily constructed and maintained.

When the main longitudinal drain pipe is provided at the centre, sufficiently below the road pavement, the side drains may be open or jelly type without perforated pipes. In this case, the slope of the transverse or cross drains is 1 in 50 from side drains towards the main longitudinal drain pipe provided at the centre as shown above in fig. This method of sub-surface drainage is comparatively economical but cannot be easily constructed and maintained.

The cross pipes thus collect, remove and dispose off sub surface water into the central longitudinal drain pipe. The longitudinal drain pipe in turn disposes of the sub soil water, received from cross drains or pipes, to a suitable cross drainage structure.

Suitability The above two methods of lowering the water table are adopted when the soil is relatively less permeable and where the road runs in a flat country with low embankment or in cutting where maximum sub-soil water table lies just below the road subgrade.

(iii) By Providing perforated pipes or open jointed drains along side slopes of cutting in addition to longitudinal side drains



DRAINAGE OF SIDE SLOPES IN CUTTING BY PROVIDING PERFORATED PIPES ALONG SIDE SLOPES OF THE CUTTING IN ADDITION TO LONGITUDINAL SIDE DRAINS

In this method, perforated pipes or open-jointed drains are provided along the side slopes of cutting to prevent water seeping through the sides of slopes and thus the erosion of side slopes is prevented. The detail of construction of perforated pipes or open jointed drains are drawn alongside's figure.

Suitability This method is suitable when the road is in cutting and where the sub-soil water table is higher than the top surface of the pavement.

(b) **Control of the seepage flow**

seepage flow is likely to exist when the ground as well as the impervious starta, lying below, are sloping. This system of sub-surface drainage is required particularly in case of hill roads.

(c) **control of capillary rise**

When there is danger of rise of moisture to the road subgrade due to capillary rise, the same may be checked by any one of the following two methods.

(i) By providing a capillary cut-off, consisting of a thick layer of coarse material like gravel between the sub-soil water table and the road subgrade.

(ii) By providing an impermeable membrane between the sub-soil water table and the road subgrade.

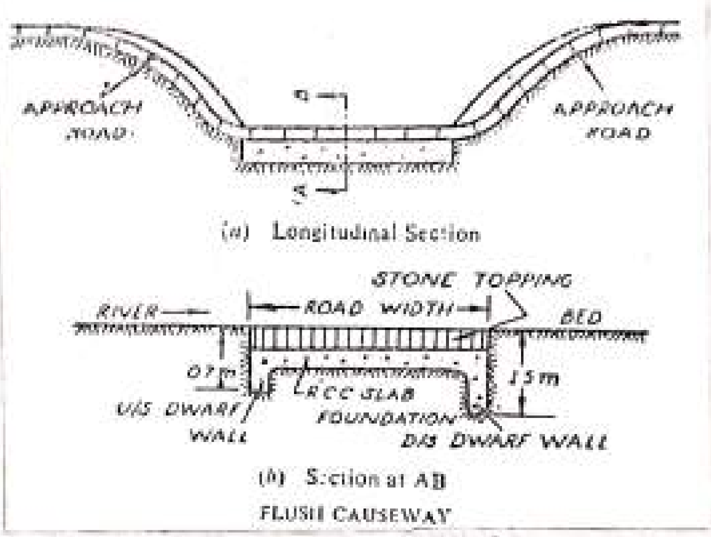
Cross drainage

: The system of disposing the water collected in side drains or that of the natural streams across a road is known as cross drainage.

The system consists in providing a suitable cross drainage structure in the form of causeways, scuppers, culverts, minor bridges, major bridges etc.
Where streams have to cross the road or when the water from side drains is to be taken across the road in order to divert the same away from the road to a water course or valley.

(i) Causeways :-

These are submersible bridges which are generally constructed with their floor either flush or little above the bed of the stream. In these case, the high flood discharge always passes over the surface of road pavement. They are provided on roads of less importance for passing a large quantity of water across the road for short intervals in a year.



(b) Section at AB
FLUSH CAUSEWAY

A causeway may consist of a concrete slab with its top level flush with the bed of stream without any opening underneath or in combination with under drains or scuppers. If no opening is provided, it is termed as flush causeway or metal dip and if there is any opening provided below the road slab, it is known as low level causeway or Irish bridge.
To guard against scour and to protect the flooring, dwarf curtain walls are constructed, both on upstream sides and downstream sides as shown in fig above

(2) When a small stream crosses a road with linear waterway (Horizontal width) less than 6m, the cross drainage structure provided is known as culvert.
→ The common types of culverts in use are:- slab culvert, arch culvert, pipe culvert & box culvert.

Side Drains

The drains provided parallel to the road for collecting & disposing the surface water are known as side drains.

They are usually trapezoidal in section, cut into ordinary soil at a suitable distance parallel to the road. When the road is in embankment, the distance of side drains should not be less than 1.85m from the toe of embankment.

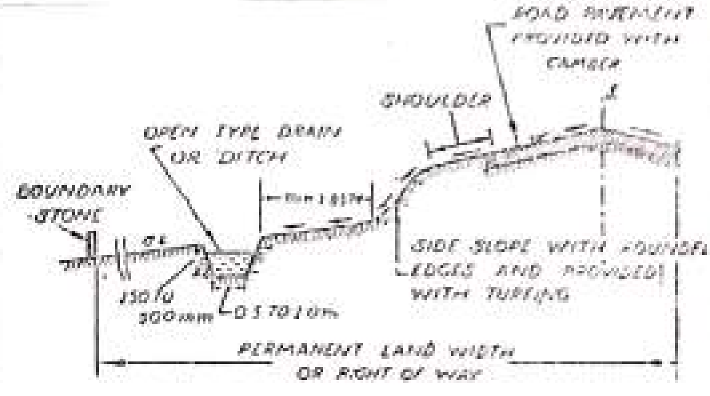
⇒ In case of cutting, these drains are provided just after the edges of shoulders

The various side drains, usually provided for surface drainage of roads, are mainly classified into following two groups...

1. Open drains ;
2. closed drains

1. Open drains

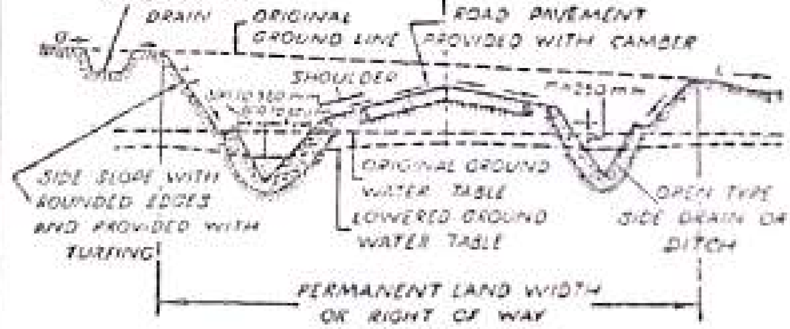
The side drains constructed without any filter material & remain open to view are known as open drains.



(a) A Road Section in Embankment showing an Open Type Side Drain (Trapezoidal in Section)

These drains are usually provided parallel to roads in rural areas when the designed depth of side drains is less & the road is subjected to light traffic.

(*) The function of open side drains is to collect the surface water. The open drains in plain areas are generally trapezoidal or triangular in section as shown in fig alongside.



(b) A Road Section in Cutting showing an Open Type Side Drain (Triangular in Section)

OPEN TYPE SIDE DRAINS

They are having sufficient depth, so that the sub-soil water, if any, from the road bed can be drained into them. The bed width of such a drain varies from 0.5 to 1m and depth 150mm to 500mm, depending upon topography of the area. These drains should be so designed that the max^m water level in them remains atleast 250mm below the road bed in cutting.

* These drains can be cheaply and easily constructed & maintained. But these drains provide an ugly look & prove very dangerous because of having deep excavations. Open drains are, therefore, undesirable where the traffic is heavy.

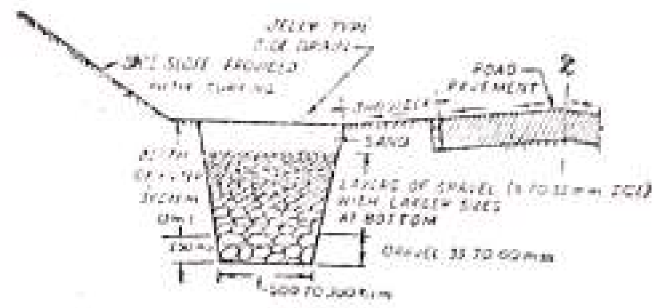
2. Closed drains

The side drains covered at their top are known as closed drains.

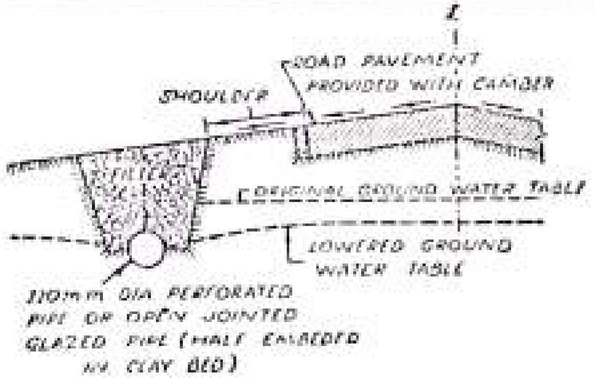
→ These drains are provided parallel to the road subjected to heavy traffic in rural area as well as in urban area.

→ These drains are costly & difficult to construct and maintain. But these are neither dangerous nor provide an ugly look.

→ closed drains are further divided into the following two types:-
  (a) Jelly drains;
  (b) Drain provided with C.I gratings



(a) Road Section showing a Jelly Drain without perforated Pipe

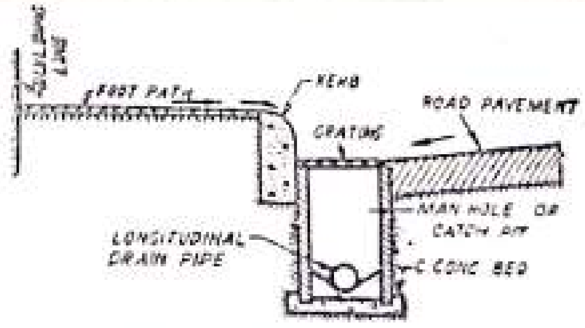


(b) Road Section showing a Jelly Drain with Perforated Pipe
JELLY TYPE SIDE DRAINS

(a) Jelly drains

The closed drains filled with filter material are known as jelly drains.

These drains are usually provided along a road in rural area when the depth of drains required is more and the road is subjected to heavy traffic.



DRAIN PROVIDED WITH GRATING

Jelly drains are usually trapezoidal in section & may be deeper than open type side drains. The filter material is filled in these drains in such a manner that the particle size increases towards the bottom of the drain. These drains may be having 150mm thick layer of gravel (35 mm to 60 mm size) at the base or provided with a 110mm perforated or open jointed glazed pipe at the bottom. The pipe is generally half embeded in the clay bed of the drain.

Suitability: These drains are usually preferred when more depth of side drains is required in order to lower down the sub-soil water level in rural areas.

(b) **Drains provided with Gratings**

These are under ground longitudinal drains which are usually constructed along a road in urban areas. These drains collect the surface water & then convey the same to an underground sewer.

Water, drained from the pavement surface, is carried forward in longitudinal direction between the kerb and the road pavement for short distances. The water then flows down into catch pits through gratings provided over them. The water thus collected in catch pits is lead through an under-ground longitudinal drain pipe into a storm sewer.

Drainage of Hill Roads

An adequate and effective drainage is very essential for better service & less maintenance cost of hill roads. The drainage of hill roads consists of the following systems :-

1. surface drainage;
2. Controlling seepage flow;
3. Cross drainage

1. Surface drainage

In the case of hill roads, surface water causes erosion to the road surface & hill sides and may result in land slides or slips. A proper arrangement for drainage of surface water is, therefore, of utmost importance to prevent erosion & land slides. An efficient network of surface drainage system of a hill road consists of the following works,

(i) providing side drains
(ii) providing catch water drains or intercepting drains
(iii) stabilizing the hill slopes by any suitable method such as

providing adequate side slope, benching, gravel pitching, cement grouting or by constructing breast walls.

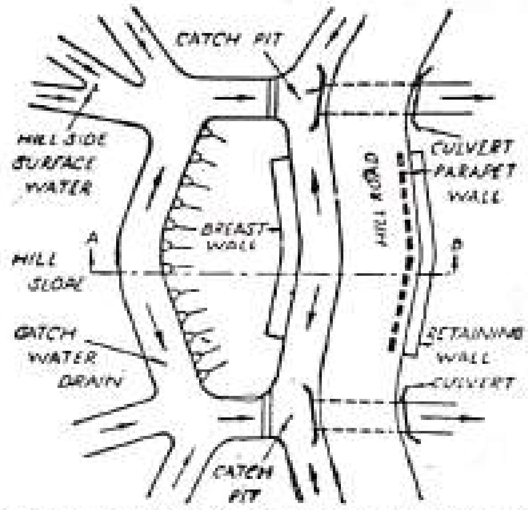
The following drainage structures are required for surface drainage of hill roads:-

(a) Side drains;
(b) catch water drains or intercepting drains.

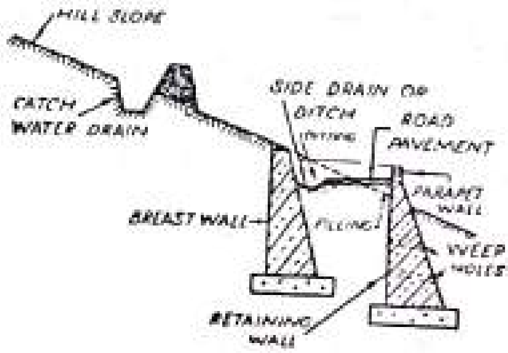
(a) Side drains ;-

These drains are provided to carry rain water from the surface of road and also from sloping side of the hill. These drains may be provided on both sides of the roadway only where the road runs in through cutting. In case of side cutting such drains are recommended only on one side, usually on the hill side of the road.

The side drains, provided in case of hill roads, should be of such a form that even if wheels of a moving vehicle get into any drain in emergency, the same should be able to come out of that drain easily.



(a) Plan showing Location of Catch Water Drain and Side Drain



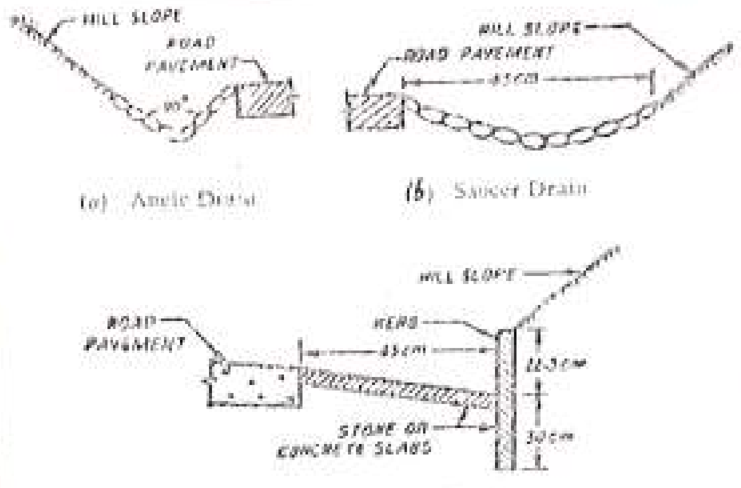
(b) Section at AB showing Location of Catch Water Drain and Side Drain

The various forms of side drains being used in case of hill roads are given below

(i) Angle drains
(ii) saucer drains
(iii) Kerb and channel drains

The min^{m} depth of these drains should be 30cm. where there is soft formation, the side drains should be suitably lined or provided

with stone pitching.
The water from these side drains is collected in catch pits and diverted across the road through suitable cross drainage works, provided at convenient intervals.



(a) Angle Drain (b) Saucer Drain

(c) Kerb and Channel Drain
TYPES OF SIDE DRAINS ALONG HILL ROADS

(b) Catch water drains :-

These drains are also known as intercepting drains. One or more catch water drains are provided higher up the hill side, parallel to the road — as shown in Fig (Page-16)

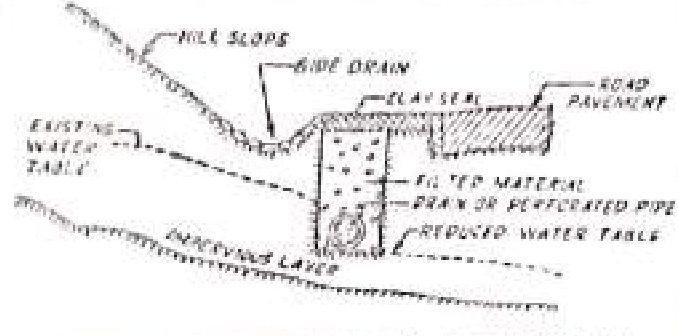
The function of providing catch water drains is to intercept the large quantity of surface water which is likely to come on to the road from the hill side. These drains thus prevent heavy rush of water on to the road which may otherwise cause land slides or slips. They also help in reducing the size of side drains.

These drains are generally 0.9m × 0.9m in section and should not be located closer than 4.5m from the road edge.
The flow in catch water drains is very rapid and hence outlets must be provided at suitable intervals. The slope of these drains should be kept min^m to control high velocity with which water usually flows through them.

2. Controlling seepage flow

When the general ground as well as the impervious strata lying underneath are sloping, the seepage flow is likely to exist. If the seepage zone is at a depth less than 0.6m to 0.9m from the surface of pavement, it is desirable to intercept the seepage flow. For controlling seepage flow, sub-surface drains are provided at foot of the hill slope as ~~shown~~ per fig shown alongside.

When retaining walls or breast walls are to be constructed along a hill road, weep holes should also be provided in these walls to allow drainage of seepage flow.



CONTROL OF SEEPAGE FLOW BY A SUB-SOIL DRAIN

3. Cross drainage

An efficient cross drainage system is essential for disposing off the surface water collected by catch water drains & side drains across the hill road. It consists in providing cross drainage structures at frequent intervals. An effective cross drainage system prevents side drains from overflowing and flooding the road surface. The provision of cross drainage structures at frequent intervals also helps in reducing the size of side drains as well as of catch water drains.

Cross drainage is provided by constructing the following structures, according to their suitability :-

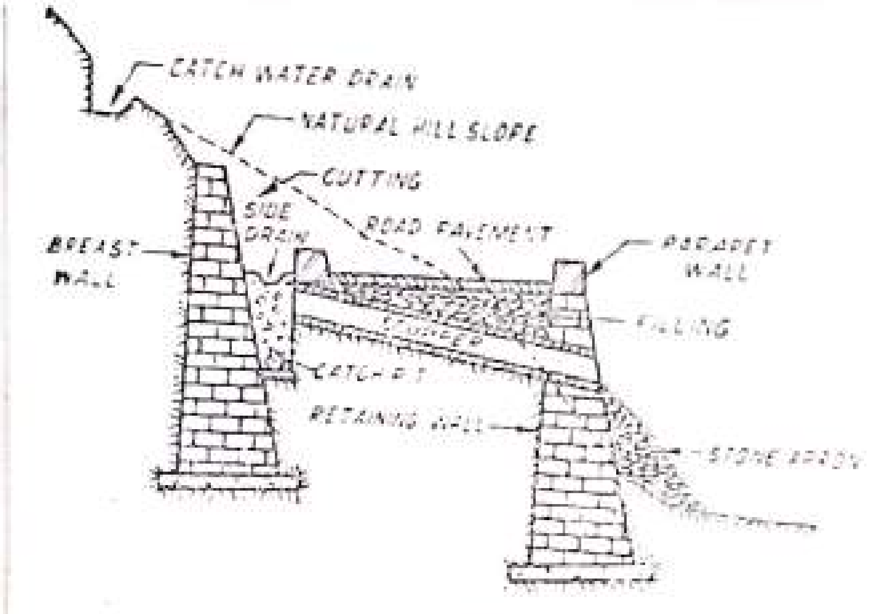
(a) small under drains ;
(b) scuppers ;
(c) causeways ;
(d) culverts ;
(e) Minor or Major bridges

(a) Small under drains

These drains are in the form of small openings of 0.3m to 0.5m span, provided across hill roads below their bed level. These drains are usually built of random rubble masonry or in the form of small pipes drains. A minimum cross slope of 1 in 6 is provided to the bed of these drains for proper drainage.

(b) Scuppers

These are small culverts which are usually constructed of random rubble masonry. These are of 0.6m to 0.9m span and minm cross slope of 1 in 6 is provided to the bed of this type of cross drainage structure.



A SCUPPER

A catch pit of 0.3m square in plan with its floor 0.3m below the bed of the under drain or scupper is provided.

⊗ The function of a catch pit is to hold boulders, sand particles, etc. and thus to prevent choking of under drains or scuppers as shown above in fig. :-

weep hole :- The holes provided in a retaining structure (retaining wall, breast wall, abutment, etc) to drain off the seepage flow are known as weep holes.
These holes are 8 cm to 12 cm in diameter or square in section and are provided at 1.2m centres in a staggered fashion.

CH-7 # Road Maintenance

Defn:- The art of preserving and upkeeping the road pavements, shoulders, sides and other facilities provided on roads in the best possible condition to enable the traffic to move smoothly and safely is known as road maintenance or maintenance of roads.

Object :- The object of road maintenance is to provide safe and convenient movements of passengers and goods at all the times.

General

After any road is constructed and opened to traffic, its pavement, shoulders, sides, etc are subjected to wear and tear. Unless constant and proper upkeep of these road elements is not made, they get deteriorated and may lead to unsafe, uneconomical and inconvenient movement of traffic. Hence, maintenance i.e upkeeping of road elements & other facilities provided on roads in their best condn is essential to provide safe & smooth movements of traffic.

The possible defects and cause of failures should be considered before hand for properly designing and constructing the road pavements, poorly designed and ill-constructed roads pose constant maintenance problems. Even, if the roads are well designed and constructed, periodic repairs are essential to keep them in best serviceable condition. However, the extent of maintenance depends upon the type of road pavement.

Need for Highway Maintenance

Highway maintenance is needed firstly to ensure smooth functioning of the highway so that the flow of traffic is not obstructed and secondly to maintain the various components of the highway so that they remain in satisfactory working conditions. Maintenance is an important activity which helps in providing better service facilities, longer life and better appearance. Highway location, design and construction have a bearing on the maintenance cost. Highway maintenance is the function of preserving, repairing and restoring a roadway and keeping it in condition for safe, convenient and economical use. Maintenance includes both physical maintenance activities such as patching, filling joints etc. and traffic service, activities including painting pavement marking. Maintenance works are planned to offset the effect of weather, organic growth, deterioration due to the effects of aging material failures design & construction faults. The failures may be due to any one or a combination of several causes.

General causes of pavement Failures

Following are the general causes of the failure of road surfaces

(a) Poor quality of material used either in surfacing or base course

(b) Construction defects and lack of quality control

(c) Inadequate surface or sub-surface drainage in the vicinity may result stagnation of water in the subgrade or in any of the pavement layers

(d) Increase in the wheel load beyond the designed capacity.

(e) settlement of base, sub-grade or embankment

(f) Natural calamities such as heavy snow fall, frost, heavy rains and floods, earthquake etc.

Road maintenance Jobs

The following are the road maintenance jobs:-

(a) Maintenance of road pavement

(b) maintenance of shoulders

(c) maintenance of road sides

(d) maintenance of roadway drainage

(e) maintenance of bridges & other structures

(f) maintenance of traffic control devices such as road signs, traffic marking, traffic signals, traffic islands etc.

(g) maintenance of miscellaneous items such as railway crossings, boundary stones, kilometre stones, etc.

Pavement Failures

The development of pot holes, ruts, waves & corrugations resulting excessive unevenness in flexible pavements or structural cracks resulting in progressive settlement of some portions of rigid pavements is known as pavement failure.

The possible failure and their causes should be considered before hand for properly designing & constructing the road pavements.

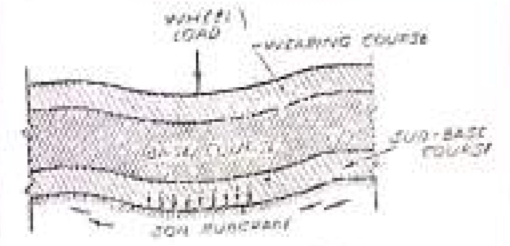
Types of failures in Flexible Pavements :-

The following are the different types of failures in flexible pavements :-

(a) subgrade Failure

(b) Base course failure or Base failure

(c) wearing course failure or surface failure



(a) Subgrade Failure

(a) Subgrade failure :- Excessive deformation in subgrade soil of a flexible pavement is known as subgrade failure.

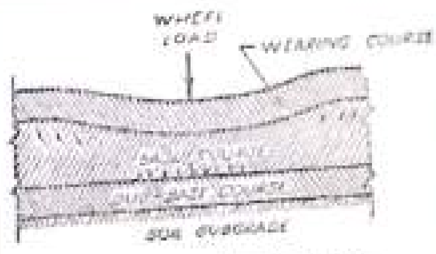
This is considered as one of the main causes of failure of flexible pavements. This type of failure causes excessive undulations (ups & downs) and corrugations in the pavement surface.

The following are the basic causes of subgrade failure

→ Inadequate stability

→ Inadequate road drainage

→ Excessive stress application



(b) Base Course Failure

(b) Base Course Failure :-

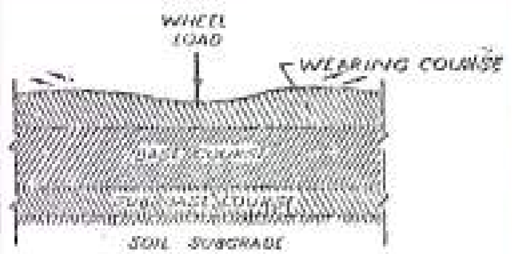
Excessive deformation in the base or foundation course of a flexible pavement is known as base course failure or base failure.

This type of failure causes pot holes, waves and corrugations in the pavement surface.

The following are various causes of base course failure:-

(i) Insufficient strength
(ii) Loss of binding action
(iii) Crushing of base course material
(iv) Lack of lateral confinement of the granular base course.
(v) Insufficient wearing course
(vi) Inadequate quality control
(vii) Inadequate road drainage

(c) wearing course failure



(c) Wearing Course Failure
FLEXIBLE PAVEMENT FAILURES

Excessive deformation or dis-integration of the wearing course of a flexible pavement is known as wearing course failure or surface failure.

This type of failure causes ruts, pot holes, cracks, etc. in the pavement

The following are the causes of wearing course failure:-

(i) Lack of proper mix design
(ii) use of inferior type of binder
(iii) Inadequate quality control
(iv) Volatization and oxidation of binder

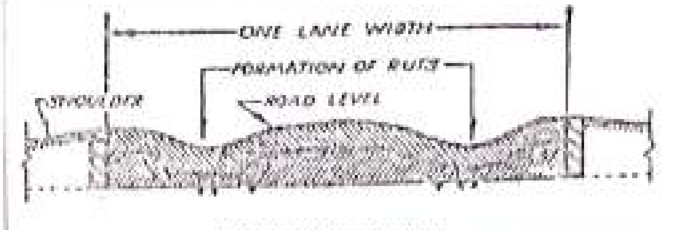
Important Flexible pavement Failures

Some of the important flexible pavement failures are

(a) Ruts
(b) pot holes
(c) Frost heaving
(d) shear failure cracking
(e) Longitudinal cracking
(f) Map cracking

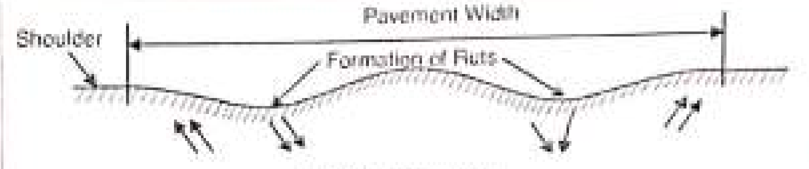
(a) Formation of Ruts

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



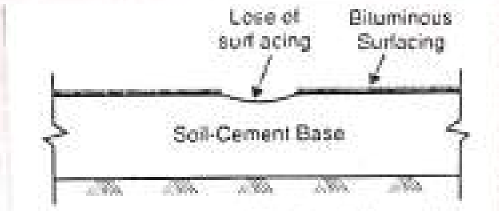
FORMATION OF RUTS

→ These are usually formed in earth or W.B.M road pavements of one lane width due to repeated application of traffic wheel loads on the same location, particularly under iron wheeled traffic.

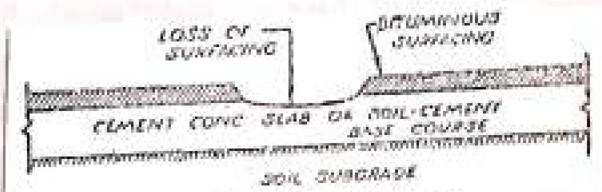


(b) Ruts Formation

(b) Formation of pot holes



Failure due to lack of Binding with lower layer



FORMATION OF POT HOLES

The isolated depressions, more or less circular in plan, formed in flexible road pavement are called pot holes or patches. These are usually formed in all types of flexible pavements either due to disintegration of road metal or due to lack of binding of surface course with the underlying base.

(c) Frost heaving

A localized heaving-up of pavement portion is called frost heaving.

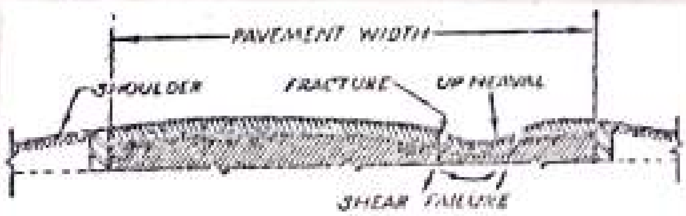
FROST HEAVING

The water which may find access to pavement structure, freezes in cold climates. The expansion accompanying this frost action causes upheaval which in turn may crack the pavement surface.

(a) Frost Heaving

(d) Shear Failure Cracking

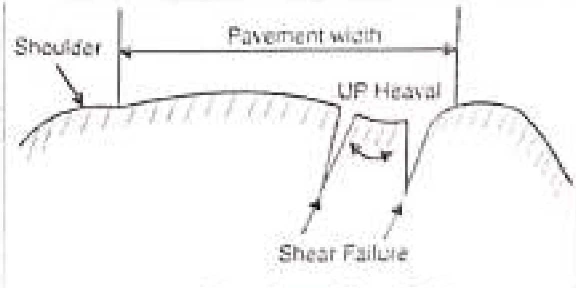
The formation of a fracture or cracking due to upheaval of pavement portion followed with



SHEAR FAILURE CRACKING

a depression called shear failure cracking.

* This type of failure occurs due to localized weakness in the pavement.



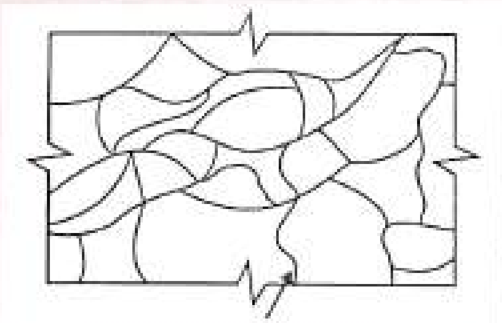
Failure Due to Shear Cracks

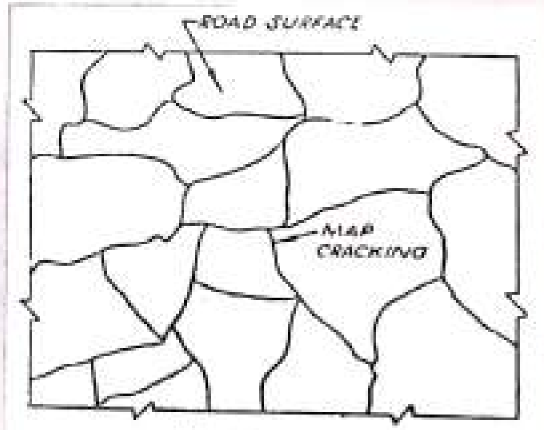
(e) Longitudinal cracking

The formation of cracks in the longitudinal direction of a road pavement is called longitudinal cracking.

* This type of road failure is caused due to frost action, different volume changes in subgrade, settlement of filling material or due to sliding of side slopes

(f) Map cracking


Map Cracking



MAP CRACKING

The development of irregular cracks, usually formed on bituminous surfacing is called map cracking.

* This type of flexible road failure is due to excessive wear of the road surface or due to localized weakness in the underlying base course.

Types of failures in rigid pavements (cement concrete pavement)

Failures in cement concrete pavements are mainly in the form of development of structural cracks. However, the different failures in cement concrete pavements are divided into the following two types: -

(a) Subgrade failure
(b) slab failure

(a) Subgrade failure :-

The development of excessive deformations in the subgrade of a rigid pavement either in the form of general or differential settlement is known as subgrade failure.

The following are the causes of sub grade failure:

(i) Insufficient thickness of the road slab

(ii) Non-uniform compaction

(iii) Inadequate compaction

(iv) Inadequate road drainage

(v) Poor soil forming the subgrade

(b) Slab failure :-

The development of structural cracks which may further result in progressive subsidence of some portion of the road slab is known as slab failure.

The following are the basic causes of pavement slab failure:

(i) Faulty design

(ii) Inferior material and bad workmanship

(iii) Due to weather and abnormal traffic

Various Causes of Failures and their Effects in Concrete Pavements

S. No.	Category of Cause	Causes	Common Failure
1.	Faulty Design	(a) Inadequate foundations.	(i) General settlement of the slab. (ii) Differential settlement of slab (iii) Cracking of slab corners and edges. (iv) Widening of longitudinal joints.
		(b) Unsuitable foundations with poorly sealed joints.	(i) *Mud pumping at joints. (ii) Cracking of road slab.
		(c) Incorrect slab thickness.	General cracking and disintegration.
		(d) Incorrect spacing of joints.	(i) Transverse and longitudinal cracking. (ii) Compression failures (blow-ups).
2.	Faulty Material and Workmanship	(a) Soft aggregate.	Disintegration of slab.
		(b) Inferior quality of concrete mix.	Servere map cracking of slab.
		(c) Inadequate compaction.	Honey-combing of concrete.
		(d) Poor workmanship in joint construction.	(i) Poor riding surface by coming out filling material and bad joints finishing. (ii) Cracking due to incorrect placing of *tie* or *dowel bars* in joints. (iii) Spalling due to incorrect positioning of filling and [illegible]
		(e) Poor surface finish.	(i) Slippery surface caused by smooth finishing. (ii) Poor riding surface caused by surface irregularity.
		(f) Inadequate curing.	Shrinkage cracks.
		(g) Poor maintenance of joints.	Entrance of water causing softening of subgrade, mud pumping and cracking.
3.	Weather and abnormal Traffic	(a) Frost action on weak subgrade.	Heaving up of slab.
		(b) Frost action on weak concrete.	(i) Scaling of slab surface. (ii) Disintegration of kerbs.
		(c) Wet weather during construction of slab.	Cracking and settlement of slab.
		(d) Tracked vehicles	Excessive wear and abrasion of surface.

Important Failures in rigid pavements

There are various types of failures in rigid pavements. Some of the important failures are
(a) scaling of concrete slab
(b) Shrinkage cracks
(c) Warping cracks
(d) Mud pumping

(a) scaling of concrete slab

The defect showing overall deterioration of the concrete slab is known as scaling of concrete slab.

→ This defect is due to deficiency in the concrete mix, presence of some chemical impurities or due to excessive vibrations given to the mix during compaction of the road slab.

This makes the slab surface rough & shabby in appearance.

(b) shrinkage cracks

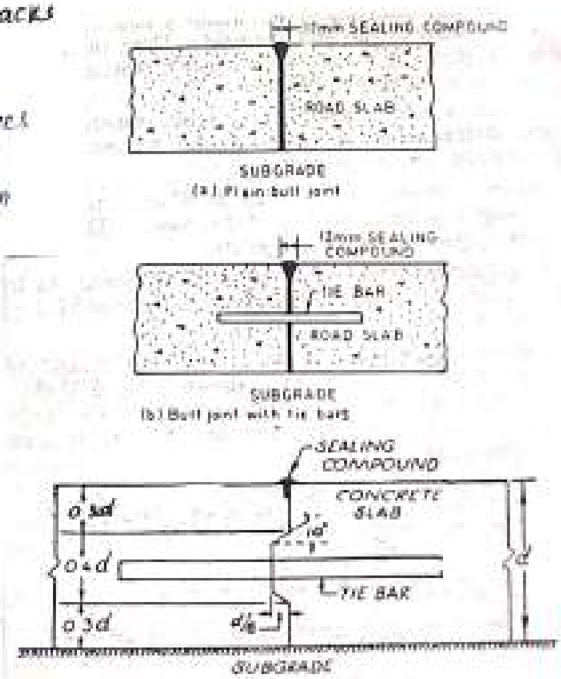
The cracks developed due to inadequate curing after construction of road slab are known as shrinkage cracks.

→ These cracks develop in longitudinal as well as in transverse directions.

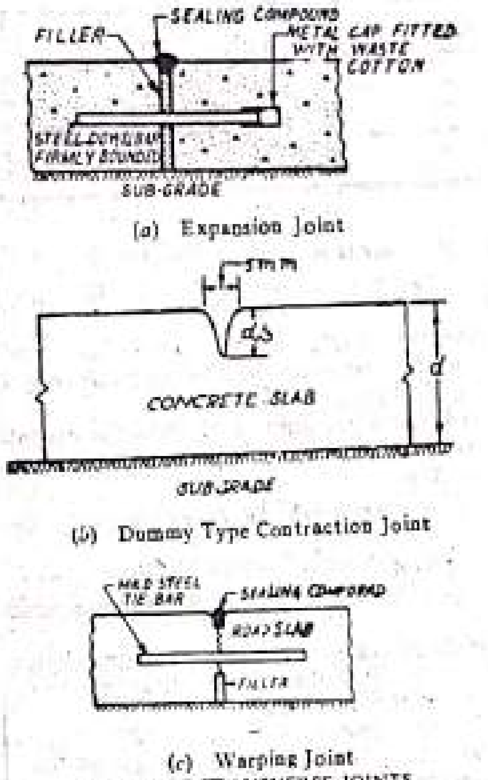
(c) Warping cracks

The cracks developed at the edges of road slab due to excessive warping stresses are known as warping cracks.

→ These cracks do not cause any structural defect if proper reinforcement in the form of tie bars and dowel bars is provided at the longitudinal & transverse joints.



(c) Tongue and Groove Warping Joint
TYPES OF LONGITUDINAL JOINTS



(a) Expansion Joint

(b) Dummy Type Contraction Joint

(c) Warping Joint

TYPES OF TRANSVERSE JOINTS

(d) mud pumping

The ejecting out of the soil slurry through the joints and cracks of road slab when depressed due to traffic wheel loads is known as mud pumping.

The following are the factors which result in mud pumping in cement concrete pavements :-

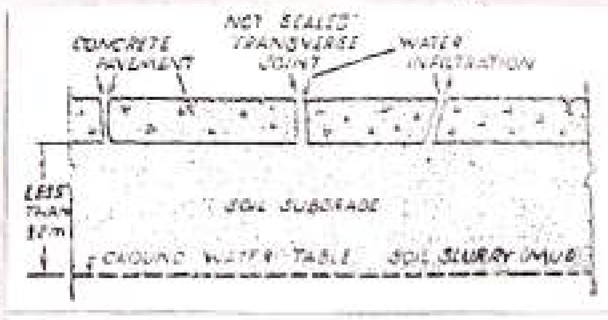
(i) when the subgrade is consisting of cohesive soil like silt or clay.

(ii) when the joints are defective and there is development of structural cracks in the road slab.

(iii) when there is access of water to the soil subgrade of road slab either from top (through not sealed or defective joints and structural cracks) or from bottom due to capillary rise.

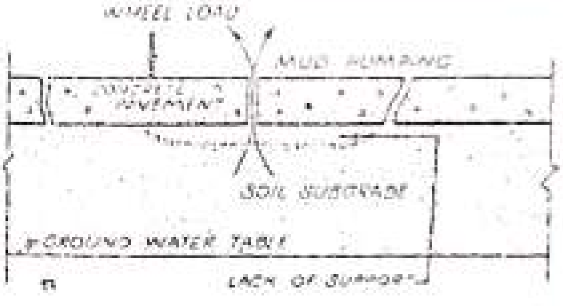
In case, the water find its access to the soil sub-grade of road slab, it forms soil slurry or mud and thus weakens the subgrade.

Due to application of repeated wheel loads, the soil under the joints gets consolidated & thus a



(a) Entry of Water through Joints and Cracks water pocket is formed under the joint.

⇒ When the wheel load comes on one side of the joint, the road slab deflects, ejecting the water out of the joint. Since this water also carries with it small particles of soil, it is called soil slurry or mud, and this ejecting out of the soil slurry or mud is known as mud pumping.

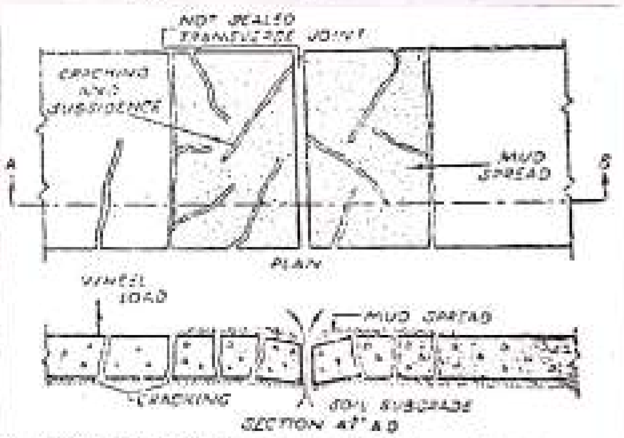


(b) Formation of Water Pocket causing Mud Pumping

In due course of time, more & more subgrade soil in the form of mud is ejected out, which goes on depositing over the road surface. In this way, size of the cavity increases resulting considerable loss of subgrade support at such locations.

With continued traffic movements, there is progressive increase in the wheel load stresses in the road slab & thus cracks are developed which ultimately results in failure of the road slab.

In order to prevent failure of road slab due to mud pumping, the subgrade should be consisting of good quality material and all the joints should be properly located and sealed.



(c) Cracking and Failure of Road Slab due to Mud Pumping

MUD PUMPING AND ITS EFFECTS

CLASSIFICATION OF ROAD MAINTENANCE JOBS

The various road maintenance jobs are classified into the following 3 groups :-

1. Routine or periodic repairs;
2. Special repairs;
3. Re-surfacing.

1. Routine or periodic repairs

The day to day or through repairs done to road pavements are known as routine or periodic repairs.

periodic repairs are usually carried out for low cost roads. The day to day routine or periodic repairs are generally carried out by the departmental labour, whereas through repairs are generally carried out at certain intervals by contract system.

2. Special repairs

The repairs carried out to overcome special problems which may otherwise lead to the pavement failure are known as special repairs.

Special repairs are usually carried out for high class road. These repairs are very difficult & require special attention for their carrying out.

3. Resurfacing

The process of renewal or surface dressing of the pavement which is sevely damaged (or after its useful service life) is known as re-surfacing.

(*) This is usually done in case of bituminous roads.

MAINTENANCE OF ROAD PAVEMENTS

The art of upkeeping the road surfaces in the best possible condition for their excellent traffic functioning is known as maintenance of road pavements.

The maintenance techniques of various types of road pavements are stated below :-

1. Maintenance of earth roads.
2. Maintenance of gravel roads
3. Maintenance of water bound macadam roads
4. Maintenance of bituminous roads
5. Maintenance of cement concrete roads

4. Maintenance of bituminous roads

Maintenance jobs of bituminous roads can be divided into the following 3 categories

(a) Day to day repair; (c) Re-surfacing

(b) Through maintenance;

(a) Day to day repairs

Day to day repairs of bituminous roads include the following operations :-

→ patching pot holes
→ patching ruts
→ patching corrugations

→ **Patching pot holes :-**

For patching pot holes (over 35mm) depth, these should be cut out square or rectangular in shape upto the affected depth. The holes are then cleaned of all loose aggregate, dust, foreign matter etc. The internal portion of the holes is then painted with tar or bitumen. After this, usually premixed patching mix is placed in the holes and the surface is rammed or rolled according to the size of the patch. when the pot hole is more than 75mm deep, the patch should be made in two or three layers and each layer is rammed before placing the next layer. The finished level of the patches is kept slightly above the original level to allow for further compaction under traffic.

when the pot holes are only 12 to 25mm deep, their patching is done simply by cleaning, painting and gritting with dry chipping of 3 to 6mm size. Their surfacing is then finished according to the adjacent road surface.

→ **Patching ruts :-**

For patching ruts or ravelled areas, continuous trenches are excavated to enclose the ruts or ravelled areas to establish a solid foundation for the patch. These ruts are then patched as per patching pot holes.

→ **Patching corrugations :-**

For patching corrugations, the high ridges, existing in the road surface, are cut off and the depressions are cleaned, painted and filled up with premix material. This is done to remove inequalities and waviness of the bituminous surface.

(b) Through maintenance

Through maintenance of a bituminous road is done annually to prevent formation of pot holes, ruts, etc. This includes the following operations :-

(i) Base repairs
(ii) Surface treatment

→ **Base repairs :-**

Before any repair is carried out to the base of a bituminous road; its cause of failure should be determined & the necessary correction should be decided. When it is established that the failure is due to inadequate thickness of the base course, the same may be corrected by providing additional surface thickness. Thus, base repairs usually consist of increasing thickness of the base as decided by the Engineer-in-charge.

For base repairs, old surface of the base is loosened by scarifying into the full depth. The sub-grade may also be removed to the depth necessary to provide the decided additional thickness of the new base.

The old road metal is screened and may be utilized in the bottom of the base. The new base is then prepared in layers, not more than 75 mm in thickness. The base, thus prepared, should be covered with a suitable surface finish.

→ **Surface treatment :-**

Surface treatment of a bituminous road consist of correcting bleeding and applying a renewal coat or seal coat.

Bleeding of bituminous surface is corrected as soon as it occurs. For correcting bleeding, a layer of blotting material such as aggregate chipping (max^m size 15 mm) or coarse sand is applied and the rolling is done if necessary.

A renewal coat or seal coat is applied when structural cracks are developed in the road surface.

(C) Re-surfacing

Resurfacing of a bituminous road consists in applying a new layer of bituminous material over the existing wearing surface. This is done when the existing wearing course is totally worn out & provides a poor riding surface.

For re-surfacing, the existing surface is repaired by suitable patching. Then a light tack coat is applied over the surface.

5. Maintenance of cement concrete roads

Maintenance work of cement concrete roads includes the following operations :-

(a) Repair of joints;
(b) Repair of cracks;
(c) patch repair;
(d) Repair of blow-ups;
(e) Repair of settlement due to mud pumping or sub-grade failure;
(f) Repair of scaling & other such surface defects

(a) Repair of joints

Repair of joints in cement concrete roads consists of refilling or resealing the squeezed out joints periodically. This is done to prevent entry of surface water through joints into the road subgrade and to maintain a good riding surface.

For repair of joints, it is necessary to do routine inspection of all the joints atleast twice a year & to refill or reseal the joints if the sealing compound has lost its adhesion or it has become too soft in any joint for re-filling or resealing the joint, the old sealing compound is removed by means of a sharp pointed tool & the joint is properly cleaned by a stiff wire brush and then by a camel brush. The joint is then resealed with a suitable sealing compound. The joint should be dry at the time of resealing. After resealing, the top surface of the joint should be dusted with lime dust filler or sand to prevent the sealing compound sticking to the wheels of moving vehicles.

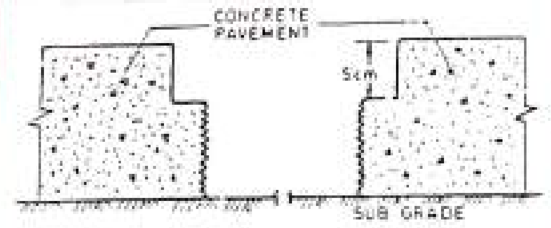
(b) Repair of cracks

Repair work of cracks in a cement concrete road consists of treating the cracks which are wide enough to admit water and grits into the road subgrade. Such cracks should be treated as soon as they occur. Fine cracks, usually known as hair cracks or shrinkage cracks, do not require any repair as they do not admit surface water to penetrate into the subgrade.

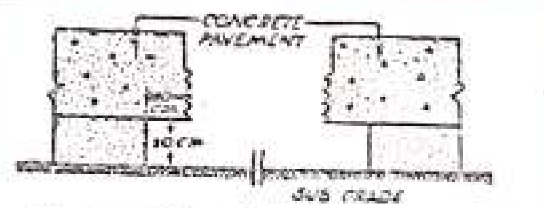
For repairing any cracks, the same is throughly cleaned by means of suitable sharp pointed tool and then dirt is blown off by a blower. The surface of the crack is then coated with kerosene oil to facilitate the adhesion of the sealing material with the old concrete. The crack is then filled with a molten sealing compound. The repair work of cracks should be done during summer season before monsoon.

(c) Patch repair

Patch work of cement concrete roads consists of patching any hole, depression or sharp break as soon as it occurs in the slab. Such irregularities or local failures, when less in number, can be successfully & economically patched with bituminous materials. However, when such irregularities have extended to full depth of road slabs over considerable area, concrete patching is done, since bituminous patching is considered inadequate under such circumstances.

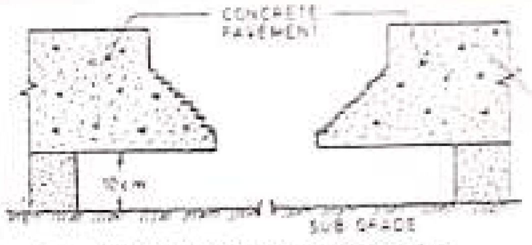


(a) Patch Hole with Vertical Sides when Subgrade is not to be repaired



(b) Patch Hole with vertical Sides when Subgrade is to be repaired

For concrete patching, the patch hole should be cut out square or rectangular in shape and to full depth of the slab with edges parallel or normal to the centre line of the road.

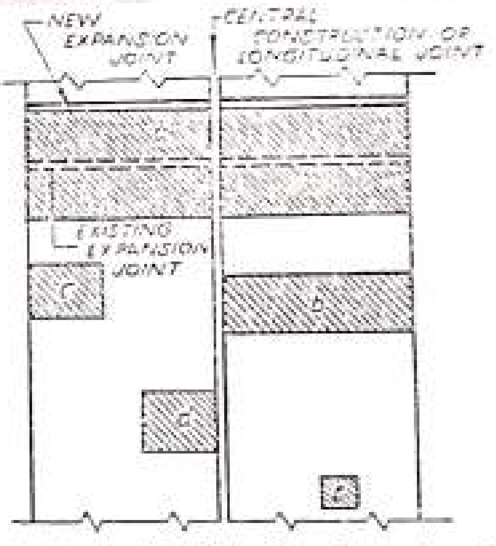


(c) Patch Hole with Sloped Sides when Subgrade is to be repaired

METHODS OF CUTTING PATCH HOLES FOE CONCRETE SLAB PATCHING

The different methods of forming holes for patch repair are shown in fig alongside (previous page & in this page). The subgrade should be carefully examined for its stability. If the subgrade also requires improvements, the same should be excavated atleast upto 10 cm depth & equally more in dimensions than the size of the patch hole.

After patch holes have been cut, their edges are thoroughly cleaned and welled with water. A thick coat of cement grout is then applied on the sides of each patch holes. After this, the cement concrete is placed into the patch hole & compacted.



(a) Full Width Patch on Both Sides of the Existing Expansion Joint
(b) Half Width Patch (c) Exterior Edge Patch
(d) Interior Edge Patch (e) Plug Patch

LOCATIONS AND TYPES OF CONCRETE SLAB PATCHES

The ~~post~~ proportions of the concrete mix should be same as in the original slab except that quick setting cement may be used in the concrete mix prepared for concrete patching. The surface of patches is then allowed to cure. During concrete patching continuity of joints should be maintained.

(d) Repair of blow ups

Repair work of blow ups in concrete roads consists of breaking the blow ups and correcting the surface of road slab. The blow ups should be corrected immediately after their occurance to provide smooth riding surface.

For repairing blow ups, 15 cm depth of pavement is removed & replaced with a patch of concrete or biterminous material.

Sometimes, repair of blow-ups is done temporarily with road side soil to allow the pavement to settle down to its original position under traffic & then permanent patch work is done.

(e) Repair to settlement due to mud pumping or sub.grade failure :-

This type of repair work of a concrete road consists of mudjacking or bituminous underscaling the depressions caused due to mud-pumping or sub-grade failure and raising the road slab to the desired elevation.

Mudjacking consists of pumping slurry, prepared by mixing soil, cement and water, through drilled holes in the pavement with a mudjacking machine. The slurry should have consistency of thick cream so as to fill majority of the voids under the pavement.

Bituminous undersealing consists of pumping highly viscous asphalt, heated to a temperature of about 200°c, through a drilled hole in the concrete pavement. This will also control mud-pumping in future. It is a good technique to underseal the road slab with asphalt during earlier stages of mud-pumping and thus preventing damage due to this cause to a large extent.

(f) Repair of other defects

Apart from repair work of defects mentioned above, the other defects in concrete roads needing repair are "scaling spalling at joints, disintegration & wear of pavement."

Repair work of scaling consists of cleaning the scaled area by means of wire brushes. The cleaned surface is then given one or more applications of bituminous material. The surface is then immediately covered with coarse sand, grit or any other suitable material. In case of excessive scaling (more than 2.5 cm), it is repaired by providing a layer of premixed asphalt concrete on the primed surface of the scaled area. This type of repair produces bad appearance & hence not commonly recommended.

. Repair work of spalling of joints consists of cutting the defective edge to a depth not less than 50mm & to a width 80mm to 150mm normal to joint. The surface of cutting is then cleaned with wire brushes and wetted with water. Then a thick coat (3 to 6 mm) of neat cement grout is applied over the surface and a rich mix of concrete (1:1.5:3) with low water cement ratio (16 to 18 litres per bag of cement) is laid & compacted.

Repair work of disintegration of concrete slab consists of cleaning the affected area of all dust and foreign matter. The surface is then sealed with one or more application of surface treatment.

Repair work of wear consists of treating the isolated spots such as steep areas or sharp curves which are subjected to excessive wear. This is done by bituminous surface treatment.

Maintenance of Shoulders

The art of upkeeping the shoulders of road pavements in their best serviceable condition is known as maintenance of shoulders.

The importance of maintenance of shoulders lies in the fact that they act as a part of the roadway & provide lateral strength to the road pavement. The necessity of maintenance of shoulders can be well realised by considering their various functions. shoulders are properly maintained to keep them stable, smooth, with proper cross slope and in level with the edges of road pavement.

Shoulders are mostly constructed of earth in our country. Such shoulders present great difficulty in their maintenance since they become dusty during dry weather, slippery during wet weather and are subjected to erosion during heavy rains.

The following are the common defects in shoulders

→ Depression along the edges of pavement;

→ Deep ruts;

→ Abrupt holes or pot holes, etc

Maintenance jobs of shoulders

Maintenance jobs of shoulders can be divided into the following two categories :-

(a) Daily maintenance;

(b) periodic maintenance

→ **Daily maintenance :-**

The daily maintenance of shoulders is done to remove the common defects as soon as they are noticed. It includes the following operations..

(i) Repair of depressions along the edge of pavement

(ii) Repair of ruts and pot holes

(iii) Repair of cross slope

→ **periodic maintenance ;-**

The periodic maintenance of shoulders is done before the start of the monsoon and after the periodic maintenance of pavements because the shoulders are used as traffic lanes during such times and get badly damaged.

periodic maintenance of shoulders includes the following operations ;-

(i) Levelling the shoulders

(ii) Providing the required cross slope

(iii) Covering the pavement edges

(iv) Treating the shoulders, i.e turfing, stabilizing, etc according to availability of funds.

The periodic repairs of shoulders should be done in August and September so that the new earth is not washed away by rains.

Maintenance of Traffic control Devices

Traffic control devices are signs, signals and marking provided for direction, warning and regulation of traffic stream for the safety of traffic. Therefore, such devices must be maintained. The maintenance work includes installation, repair, painting, or signs and care of markings. The marking should be renewed every year and for this purpose mechanised marking equipments are available in the market. Thermoplastic compounds are also used for markings. Traffic signal should be periodically checked and if found defective, then, they should be repaired & readjusted to the traffic condn. warning signs should also be given due attention. These should be checked and if found defective, then these should be required on a high priority basis.

Blow ups :- The raised portions of the road slab at transverse joints of cracks, developed due to longitudinal expansions of the slab are known as blow ups.

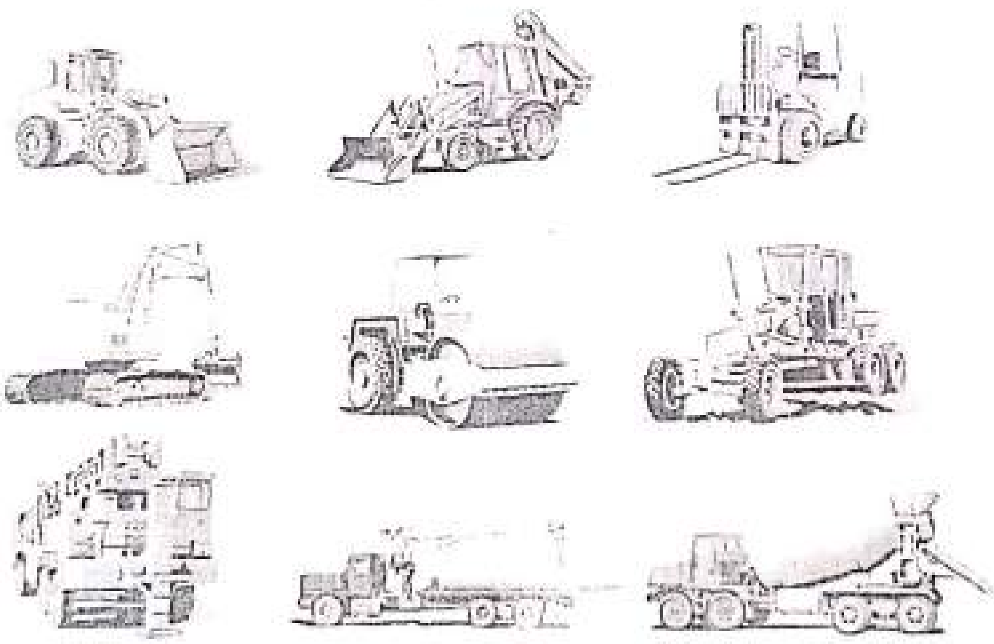
Scaling :- The chipping of thin pieces from the surface of pavement due to excessive application of salt during curing & ice removal etc is called scaling.

Spalling :- The chipping of pavement at joints or cracks due to entry of grits or defective construction is known as spalling.

Disintegration of Pavement :- The breaking up of concrete pavement into small pieces due to unsound aggregate, freezing etc is called disintegration of concrete pavements.

CHAPTER-8

ROAD CONSTRUCTION EQUIPMENTS



INTRODUCTION

- Modern age is the age of science and technology . All the crude and slow methods of construction of roads have been replaced by refined & quick methods by the use of modern plants and machinery. How ever in India, modern machinery is so far used for big road projects because the financial condition of this country do not permit the use of such a machinery for ordinary road projects. But highway engineer must be familiar with the use of modern road construction equipment such as plant and machinery.
- Here we will discuss the output and use of common types of plants and machinery so as to have basic knowledge about the use of all construction equipments used in road construction.

TRACTOR

- Tractor is a self propelled machine which work with diesel engine having HP varying from 20-200
- Tractors are generally provided with various attachment such as dozer,scraper,..etc

Types of Tractors

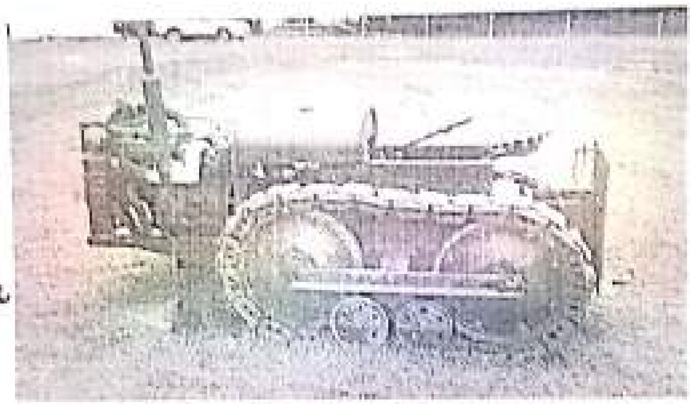
(i) Crawler Tractor

(ii) Wheel Tractor

(a)Two wheel

(b)Four wheel

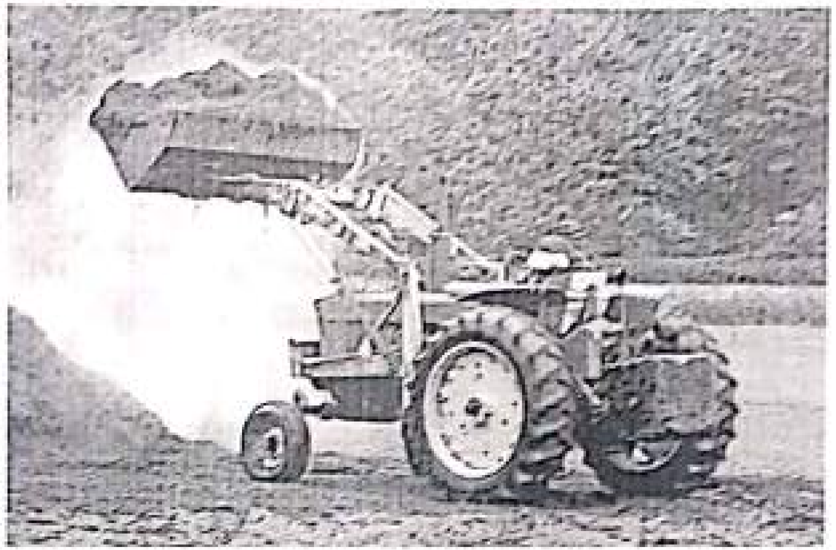
CRAWLER TRACTORS



These tractors move on an endless chain of plates. A crawler tractor is consider as the most basic and versatile machine among the road construction equipment.

USE

Crawler tractor are used when the area is uneven and rough.

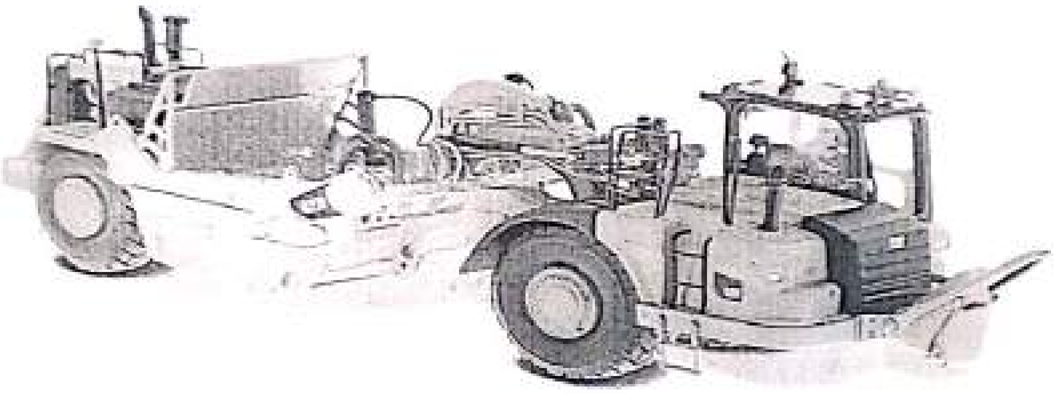


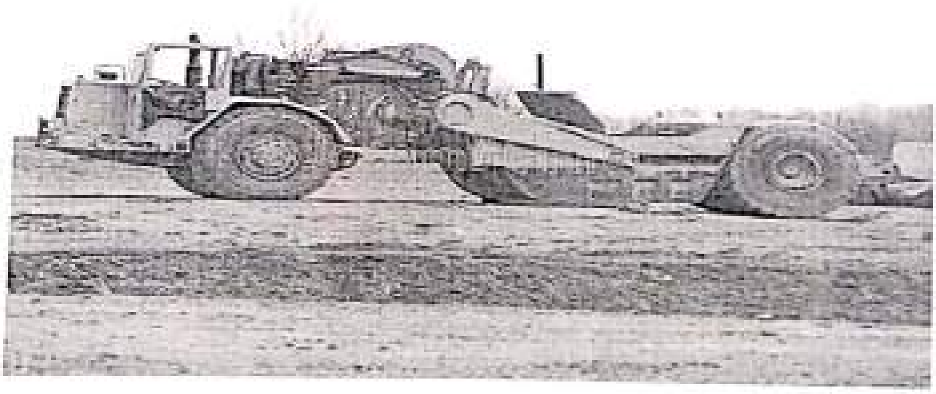
These tractor move on pneumatic tyres . A wheel tractor moves faster than crawler tractor. Some these tractors have maximum speed more than 50 kmph.

USE

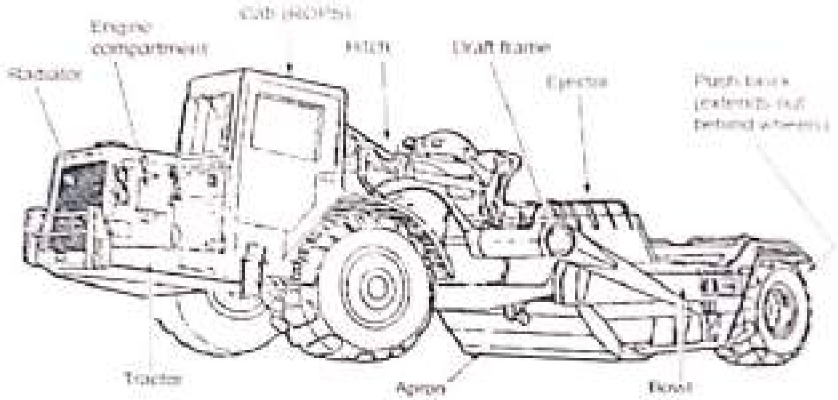
Wheel tractors are used when the area is even and smooth.

SCRAPER





SCRAPER



A Scraper is a combination of the best loading and best hauling machines. It essentially consist of a large scoop provided with a cutting edge. The scoop is in the form of a bucket or a shallow container which is known as bowl or body. The scoop can excavate , transport and dump the material where required.

It is mounted on a four or two pneumatic wheel and is pulled by a tractor . Thus a scraper is consider as a sufficient machine, as it can do all the operation necessary for light soil ,viz it can excavate ,load, transport and dump the soil at the required site.

USE

(i)To excavate soft soils

(ii) To load the excavate soils

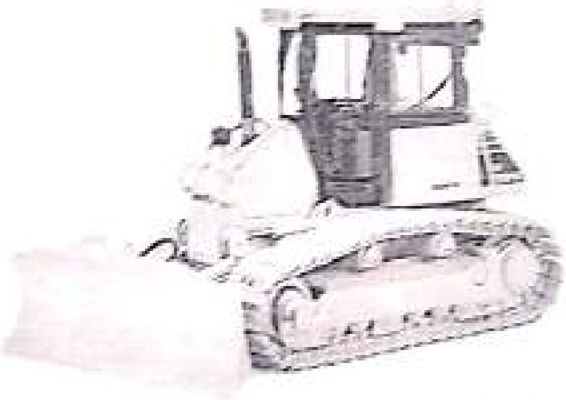
(iii) To Transport the excavate soils

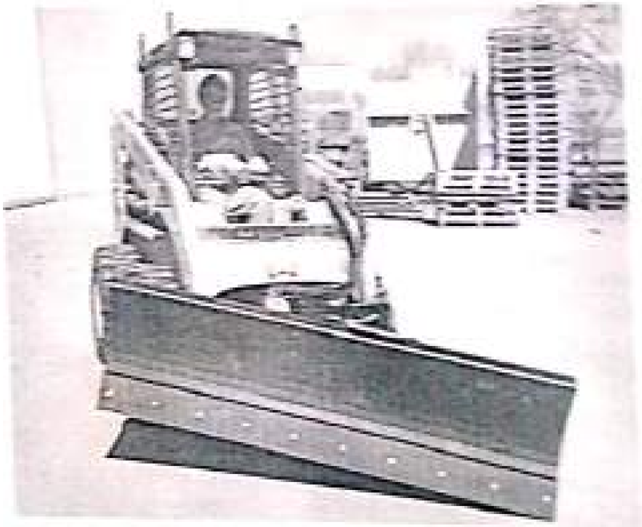
(iv) To dump the excavate soil at required site

DOZERS

These are attachment of tractor which are used for various works. Dozers are very versatile machines for various operation in road construction viz to clear the site ,moving earth ,levelling earth fills and to clear the floor of borrow pits, ets

TYPE OF DOZER





1. Bull Dozer;
2. Angle Dozer;
3. Tree Doze

BULL DOZER

This type of dozer consist of straight and wide blade of steel attached to the front side of a tractor, which is kept at right angle to the direction of movement of the machines.

The blade can be raised or lowered as desired.

USE

(i)Bull Dozer is commonly used for excavating the material and pushing the same in the forward direction.

(ii)It is mainly used for pushing and leveling a heap of exacted material.

ANGLE DOZER

This type of dozer consist of suitable blade attachment to the front side of a tractor, which can be set obliquely to the direction of movement of the machine. The maximum possible angle of the blade to the front face of the tractor is 30°.

USE

Angle dozer is mainly used for pushing the material side ways , to the right or to the left .

TREE DOZER

This is also sometimes called a *stumper* .This type of dozer consists of a slightly curved blade attached to a tractor with its concavity in the forward direction of motion of the machine. The blade is specially design for felling tree and for uprooting the stump.

USE

Tree dozer is mainly used for feeling trees and for uprooting stumps ,shrubs ,etc.

DUMPERS

A dump truck is also called a dumper. It is a self propelled machine which works with a diesel engine. It consists of a trolley or container fitted on a truck, which can be quickly tilted in one or the other direction.

In dump truck one or two hydraulic operated pistons are provided to raise or lower the container carrying the material.

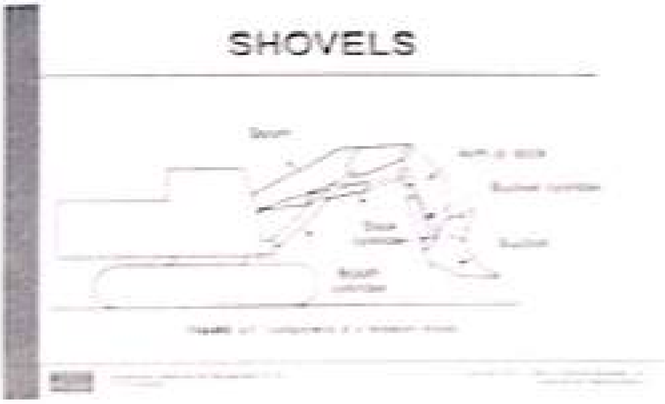
USE

Dump truck are used for loading, conveying and dumping the material at the required site quickly and conveniently. These truck may also be used for transporting bituminous concrete and air-entrained cement concrete to the construction site.

DIAGRAMS OF POWER SHOVEL(2D & 3D)

Shovel

- Shovel is the most powerful and usual excavation machinery includes power shovels. It is one of the most versatile equipment used in the construction of highways especially for earth work.



Working

Power Shovel

POWER SHOVELS

A power shovel essentially consist of mounting,cabin,boom,dipper stick,dipper or lid and hoist or cable line . The dipper or lid,also known as digging bucket,of a power shovel is capable of being forced upwards through the earth and away from the machine.

- Power shovels are available in different sizes ranging from0.375 cum to 5 cum. They can be mounted on crawler tractor or on wheel tractors as required.

USES

1. To excavate soils of all types except solid soils.
2. To collect and dump the material at required place within the reach of dipper stick.
3. To load the excavated soil into dump truck, conveyor belt or other hauling equipment.

GRADER/MOTOR GRADER

A grader is an earth-moving machine which is either self propelled or towed to a tractor. It mainly consist of an angled blade 3 to 4 metres long supported on a frame work which is mounted on wheels. In case of a motor grader which is self propelled, the blade is supported.

USES

1. To give the proper shape to the road subgrade.
2. To construct earth roads quickly.
3. To spread the loose material evenly.
4. This is also useful for general maintenance of roads during land slides and snow clearance.

ROLLER

SMOOTH WHEEL ROLLER

PNEUMATIC TYRED ROLLER

SHEEP FOOT ROLLER

ROLLERS

A roller is considered as an essential road making machinery. It usually consist of a number of wheels or rolls for rolling and compacting the road construction material. It generally self propelled but some of the rollers are towed to tractors also.

TYPES OF ROLLERS

1. Smooth wheeled roller
2. Pneumatic tyred roller
3. Sheep foot roller

Smooth Wheeled Roller

These rollers consist of one to three smooth wheels and may be hand or animal driven or power driven. A hand or animal driven smootl wheeled roller usually consist of one roll of stone or iron,about 0.9 m dia and 1.2m to 1.5m long and of two tonnes weight. Th consolidation with such a roller is not good and moreover, it takes more time than a power driven roller to complete the compaction of road construction material.

The weight of tandem(two wheeled) roller is 6 to 8 tonnes and that of three wheeled types 8 to 10 tonnes.

SUITABILITY

These rollers are preferred when the soil is granular and are useful in compacting soils and other materials where crushing action is advantageous.

PNEUMATIC TYRED ROLLER

These roller consist of a number of pneumatic wheels mounted on two or more axles under a loading platform. This type of roller is pulled by a tractors.

SUITABILITY

These roller are considered to be most suitable for compacting non-plastic silts and fine sands

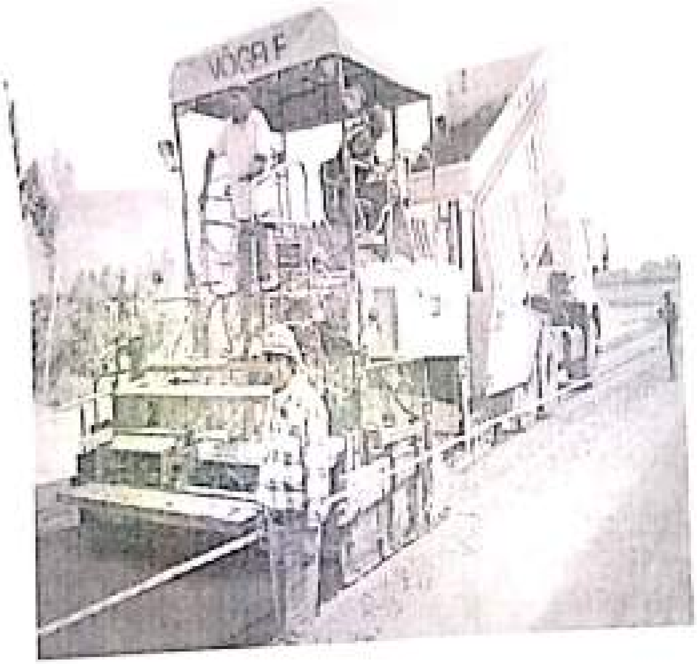
SHEEP FOOT ROLLER

- This type of roller consist of a hollow steel cylinder with raised projections each resembling sheep's foot. Its weight can be increased by filling the drum with wet soils. This type of roller is pulled by tractor.
- Since, these rollers do not provide a proper finish to the surface, their use is recommended to compact the lower layers except the top layer of earthwork for which smooth wheeled roller is used.

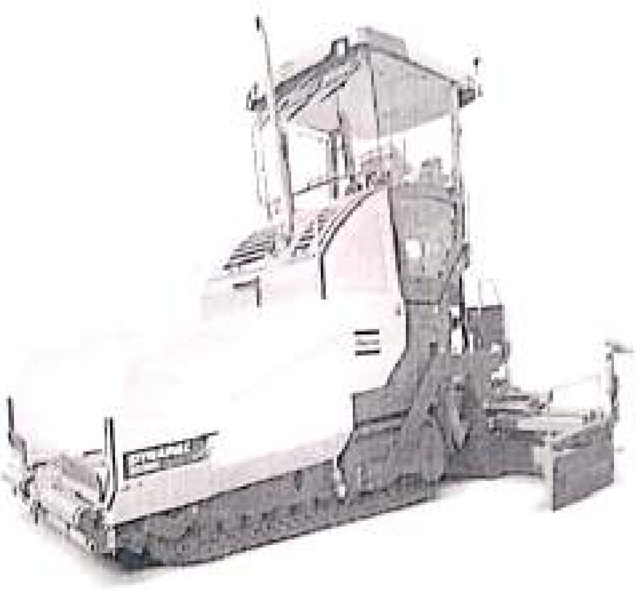
SUITABILITY

Sheep foot roller is considered to be most suitable for compacting clayey soils. The thickness of each compacting layer is kept 5 cm more than the legth of projections on the roller.

ROAD PAVERS



ROAD PAVERS



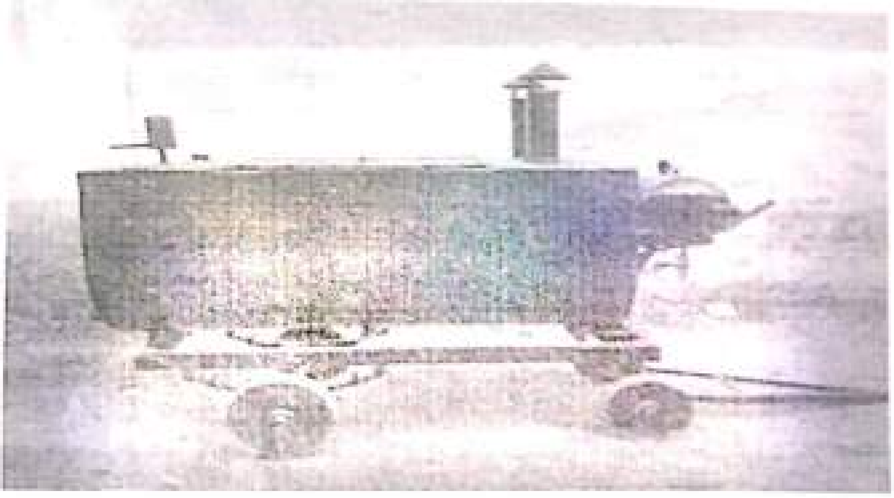
ROAD PAVER/PAVER FINISHER

- A machine which can lay the bituminous mix to a compact and uniform layer of desired thickness and profile is known as paver finisher/road paver.
- A paver finisher can lay bituminous mix in a layer of 1.25 cm to 15 cm thickness upto 4.25m width at a time.

TAR BOILERS

- The tank mounted on wheels in which bitumen is heated by burning coal underneath and the same is sprayed by means of spraying device is called tar boiler with spraying device.

The spraying device is worked by a hand pump. Tar boiler of 300 litre capacity are commonly used.



DRAGLINE