
# GOVT.POLYTECHNIC, KANDHAMAL, PHULABANI

**(State Council for Technical Education & Vocational Training, Odisha)**

## Th-4 Highway Engineering

**4th semester, Diploma Engineering.**

**Lecture Notes**

**Prepared by**

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**Sr. Lect. in Civil Engineering**

**Department Of Civil Engineering**

# Th4. HIGHWAY ENGINEERING

# 1. Introduction

## CENTRAL ROAD RESEARCH INSTITUTE (CRRI)

CSIR-Central Road Research Institute (CRRI), a premier national laboratory established in 1952, a constituent of Council of Scientific and Industrial Research (CSIR) is engaged in carrying out research and development projects on design, construction and maintenance of roads and runways, traffic and transportation planning of mega and medium cities, management of roads in different terrains, improvement of marginal materials, utilization of industrial waste in road construction, landslide control, ground improvements environmental pollution, road traffic safety and analysis & design, wind, fatigue, corrosion studies, performance monitoring/evaluation, service life assessment and rehabilitation of highway & railway bridges. The institute provides technical and consultancy services to various user organizations in India and abroad. For capacity building of human resources in the area of highway Engineering to undertake and execute roads and runway projects, Institute has the competence to organize National & International Training Programmes continuing education courses since 1962 to disseminate the R&D finding to the masses.

WEBSITE URL:

https://crridom.gov.in/

## Importance of Highway transportation

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 altitudes i.e. in mountainous regions.
3. They help in growth of trade and other economical activities in and outside the villagers and towns by establishing contact between towns and 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 and social advancement of people and making the villagers active and alert members of the community.
7. They help in promoting the cultural and social ties among people living in different part of a country and thus strengthen the rational 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 airway, waterways and railways.
12. They help in reducing distress among the people, caused due to famine, by suppling them food and clothing quickly.
13. They help in maintaining better law and order in a country.
14. They play a very important role in the defense of a country during war days.

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

## Indian Roads Congress (IRC)

The Indian Roads Congress (IRC) is the Apex Body of Highway Engineers in the country. The IRC was set up in December, 1934 on the recommendations of the Indian Road Development Committee best known as Jayakar Committee set up by the Govt. of India with the objective of Road Development in India.

WEBSITE URL: http://www.irc.nic.in/

## Ministry of Surface Transport

An apex organization under the Central Government is entrusted with the task of formulating and administering, in consultation with other Central Ministries/Departments, State Governments/UT Administrations, organizations and individuals, policies for Road Transport, National Highways and Transport Research with a view to increasing the mobility and efficiency of the road transport system in the country. The Ministry has two wings: Roads wing and Transport wing.

### Road Wing

Deals with development and maintenance of National Highway in the country

### Main Responsibilities:

- Planning, development and maintenance of National Highways in the country.
- Extends technical and financial support to State Governments for the development of state roads and the roads of inter-state connectivity and economic importance
- Evolves standard specifications for roads and bridges in the country.
- Serves as a repository of technical knowledge on roads and bridges.

### Transport Wing

Deals with matter relating to Road Transport

### Main Responsibilities:

- Motor Vehicle legislation.
- Administration of the Motor Vehicles Act, 1988.
- Taxation of motor vehicles.
- Compulsory insurance of motor vehicles.
- Administration of the Road Transport Corporations Act, 1950.
- And promotion of Transport co-operatives in the field of motor transport.
- Evolves road safety standards in the form of a National Policy on Road Safety and by preparing and implementing the Annual Road Safety Plan.
- Collects, compiles and analyses road accident statistics and takes steps for developing a Road Safety Culture in the country by involving the members of public and organizing various awareness campaigns.
- Provides grants-in-aid to Non-Governmental Organizations in accordance with the laid down guidelines.

## Functions of Central Road Research Institute (CRRI)

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

It offers the following services.

1. Carries basic and applied research for the design, construction and maintenance of the highways.
2. Carries research on traffic safety and transport economics.
3. Carries research on economical utilization of locally available materials for construction and maintenance of roads.
4. Research for the development of the new machinery, tools equipment and instruments for highway engineering.
5. To provide technical advice and consultancy services to various organizations.
6. To provide library and documentation services.

## Functions of Indian Roads Congress (IRC)

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

1. It provides a forum for the expression of the collective opinion of its members for all matters affecting the construction and maintenance of roads in India.
2. It promotes the use of standard specifications and practices.
3. It provided with the suggestions for the better methods of planning, designing, construction, administration and maintenance of roads.
4. It conducts periodical meetings to discuss technical problems regarding roads.
5. It makes the laws for the development, improvement and protection of the roads.
6. It furnishes and maintains libraries and museums for encouraging the science of road-making.

## 10 Types of Classification of Roads

Indian roads are classified as a rural (non-urban) and urban roads, they are further classified as a national highway, state highway, expressway, village roads, etc.

following 10 types of roads are described below:

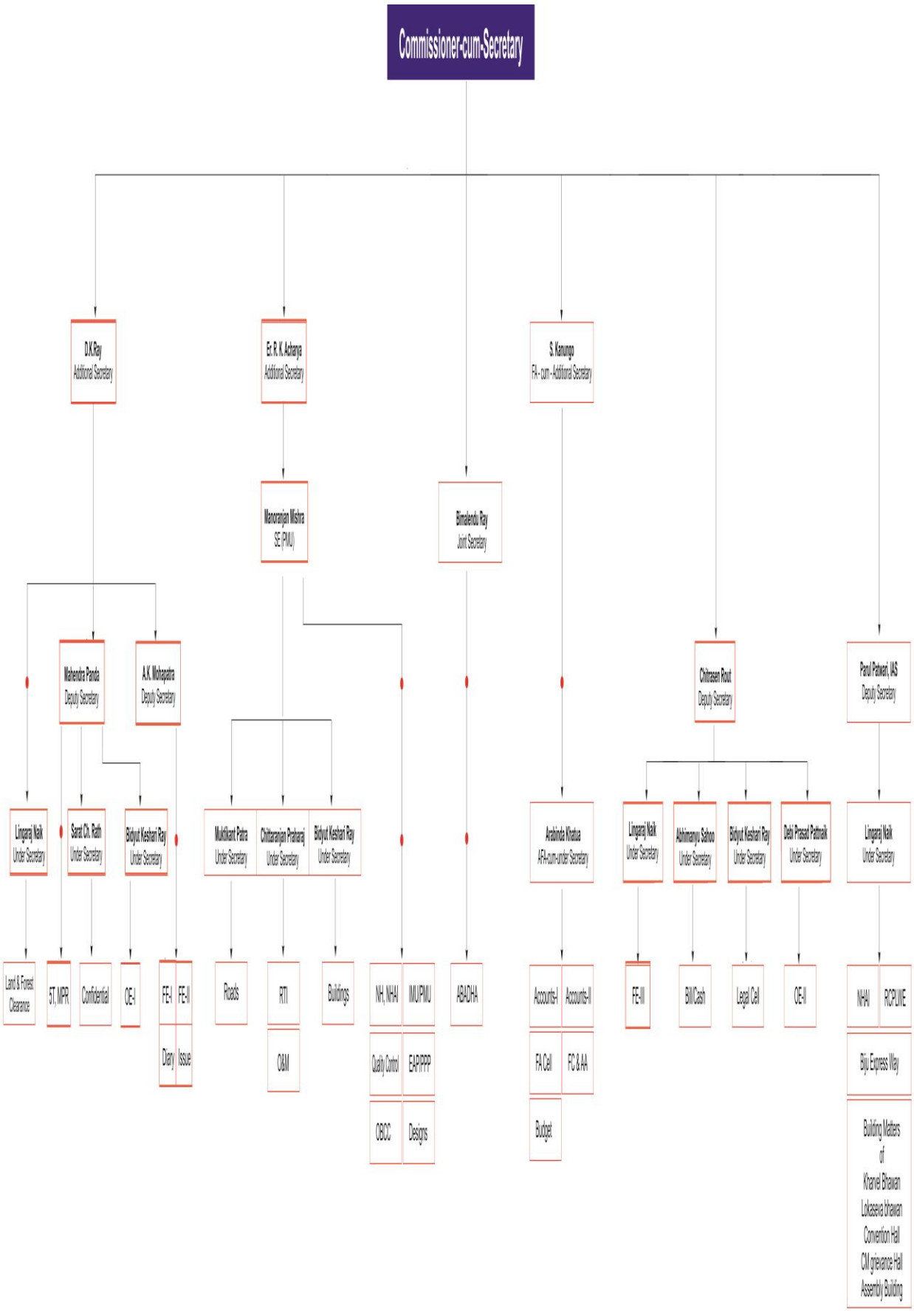
## 10 types of Roads Classification in India (Urban and Non-Urban Road)

Classification of Rural (Non-Urban) Roads

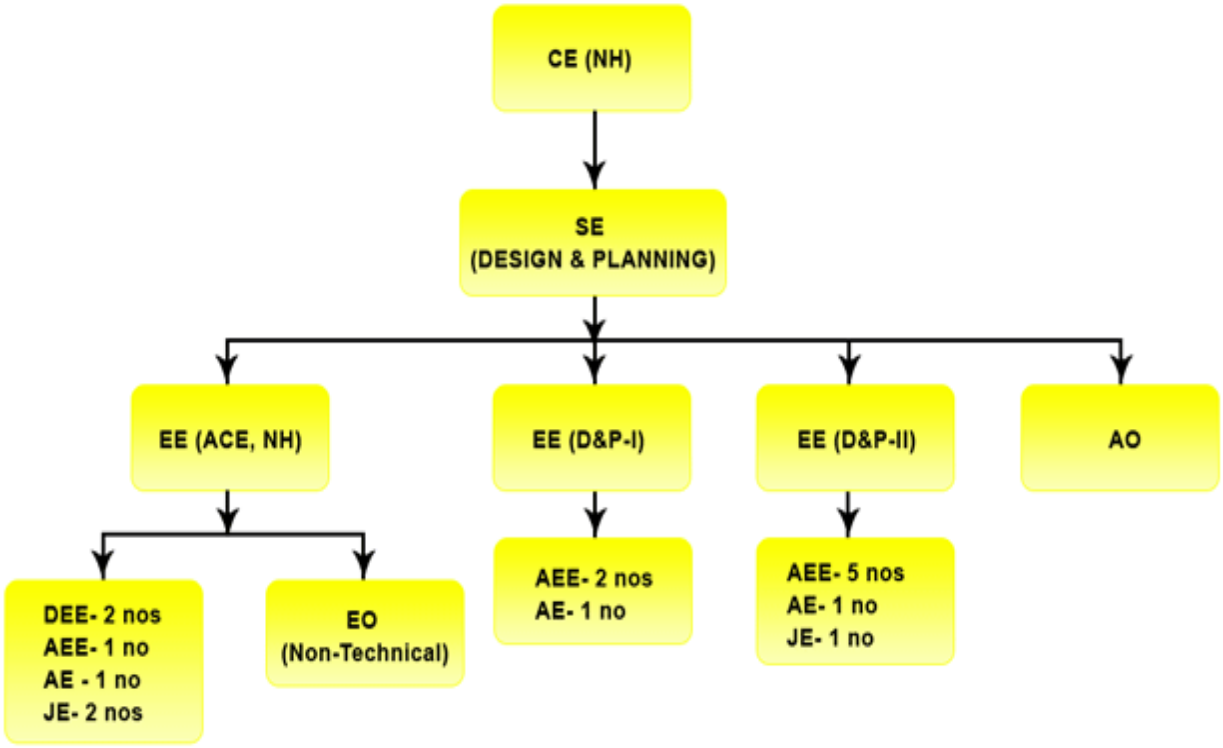
The road which is located in the non-urban areas connects cities & towns across the country are called rural roads or non-urban roads. This classification also known as IRC classification of roads. In India, Non-urban roads are classified into five categories as follows.

1) National Highway (N.H)

The national highway is the main roads running through the length and breadth of the country. They connect capitals of states, ports, large towns, industrial centre's, and foreign highways.


Commissioner-cum-Secretary
D.K.Ray
Additional Secretary
Er. R. K. Acharya
Additional Secretary
S. Karuppp
FA - cum - Additional Secretary
Manoranjan Mishra
SE (PMU)
Bimalendu Ray
Joint Secretary
Chitresen Rout
Deputy Secretary
Parul Patwari, IAS
Deputy Secretary
Mahendra Panda
Deputy Secretary
A.K. Mohapatra
Deputy Secretary
Lingaraj Naik
Under Secretary
Sarat Ch. Rath
Under Secretary
Bidyut Keshari Ray
Under Secretary
Mukthant Patra
Under Secretary
Chitaranjan Pradhan
Under Secretary
Bidyut Keshari Ray
Under Secretary
Arabinda Nhatua
AFA-cum-under Secretary
Lingaraj Naik
Under Secretary
Abhimanyu Sahoo
Under Secretary
Bidyut Keshari Ray
Under Secretary
Debi Prasad Pattnaik
Under Secretary
Lingaraj Naik
Under Secretary
Land & Forest Clearance
ST, MPR
Confidential
OE-I
FE-I
FE-II
Diary
Issue
Roads
RTI
O&M
Buildings
NH, NHAI
IMU/PMU
Quality Control
EAP/PPP
OBCC
Designs
ABADHA
Accounts-I
Accounts-II
FA Cell
FC & AA
Budget
FE-III
Bill/Cash
Legal Cell
OE-II
NHAI
RCPLWE
Biju Express Way
Building Matters of
Khanel Bhawan
Lokaseva bhawan
Convention Hall
CM grievance Hall
Assembly Building

**NH in Odisha**




| Sl. No. | New NH | Name of N.H. | Starting & Terminating Place. | Starting & Terminating chainage in Orissa | Total Length of N.H.in Odisha . | NH UNDER STATE P.W.D. IN KM |
|---|---|---|---|---|---|---|
| 1 | | 2 | 3 | 4 | 5 | 6 |
| 1 | 16 | 60,5 | Laxman Nath- Balasore - Bhadrk-Bhubaneswar-Cuttack-Berhampur | 0.0 to 443.81 | 443.810 | 443.810 |
| 2 | 316 | 203 | Bhubaneswar-Puri | 0.0 to 59.0 | 59.000 | 59.000 |
| | | 203E | Puri-Konark | 59.0 to 96.521 | 37.521 | 0.000 |
| | | 203A | Puri-Satapada | 0.0 to 48.0 | 48.000 | 0.000 |
| 3 | 516 | 217 | Berhampur-Goplapur | 0.0 to 5.92 | 5.920 | 0.000 |
| 4 | 18 | 5 | Jharpokharia-Baripada-Balasore | 0.0 to 80.06 | 80.060 | 0.000 |
| 5 | 20 | 75E, 215 | Champua-Parsora-Panikoili- | 0.0 to 174.57 | 174.570 | 160.570 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 6 | 520 | 215 | Parsora-Rajamunda | 0.0 to 108.43 | 108.430 | 108.430 |
| 7 | 26 | 201,43 | Baragarh-Bolangir-Bhawanipatna-Nabarangpur-Borigumma-Jeypore-Koraput-Sunki | 0.0 to 435.567 | 434.767 | 0.000 |
| 8 | 49 | 200,6 | Kanaktora-Deogarh-Pallhara-Keonjhar-Jamsola | 197.3 to 626.577 | 429.277 | 0.000 |
| 9 | 149 | 23 | Pallhara-Pitri-Banarpal | 0.0 to 83/798 | 84.000 | 6.950 |
| 10 | 53 | 6,200,5A | Luhurachati-Sambalpur-Deogarh-Talcher-Chandikhol-Paradeep | 0 to 524.538 | 524.538 | 524.538 |
| 11 | 353 | 217 | Nuapada to Khariar | 65.416 to 145 | 80.214 | 0.000 |
| 12 | 55 | 42 | Cuttack-Angul-Sambalpur | 0.0 to 266.23 | 266.230 | 266.230 |
| 13 | 57 | 224 | Bolangir-Khurdha | 0.0 to 299.9 | 299.900 | 0.000 |
| 14 | 59 | 217 | Khariar-Daringibadi-Berhampur | 0.0 to 351.1 | 351.100 | 0.000 |
| 15 | 63 | 43 | Kotpad to Borigumma | 316.75 to 357.8 | 41.055 | 0.000 |
| 16 | 143 | 23 | Biramitrapur-Rajamunda-Barkote | 211.5 to 337.3 | 125.800 | 125.800 |
| 17 | 220 | | Tiringi-Rairangpur-Jashipur-Dhenkikote | 0/0 to 125.41 | 125.410 | 0.000 |
| 18 | 153B | | Sarpal-Naktideul-Rairakhol-Boudh | 0/0 to118/41 | 118.410 | 0.000 |
| 19 | 157 | | Purunakatak-Phulbani-Kalinga-Bhanjanagar-Asika | 0/0 to 159/0 | 159.000 | 0.000 |
| 20 | 326 | | Asika-Rayagada-Koraput-Jeypore-Malkanagir-Motu | 0/0 to 513/7 | 513.700 | 0.000 |
| 21 | 130C | | CG Border to Baldhiamal (22.75) | 0/0 to 102.9 | | 0.000 |
| 22 | 326A | | Mohana to Paralakhemundi (102.90) | 0/0 to 20/0 | | 0.000 |
| | | | | **GRAND TOTAL** | **4510.712** | **1695.328** |

**National Highways Wing**

Responsibility for new construction and maintenance works on the National Highways is under the control of the Chief Engineer National Highways (CE (NH)). The CE (NH) reports to MOST for works carried out on the National Highway network.

This wing has been set up in keeping with the requirements of MOST to:

- reduce the line of communication between the GOI and State Authorities
- achieve efficiencies in implementation by avoiding the cumbersome and outdated delegations for administrative and technical sanction which limit the ability of

the Odisha Works Department to respond quickly

- achieve uniform maintenance and construction standards on NHs.

At present, 16 Nos. of National Highways measuring 3592.932 km in length traversed through the state of Odisha. Out of 3592.932 km of total length of National Highways in Odisha, 3071.722 km is under the control of NH wing of State PWD, and remaining 521.210 km have been transferred to National Highways Authority of India for improvement under NHDP and Port connectivity.

# 1. Road Geometrics

## 2.1

## What is side slope?

**Side slopes** means the **slope** of the **sides** of a channel, dam, or embankment. It is customary to name the horizontal distance first, as 3 to 1, or frequently, 3:1, meaning a horizontal distance (H) of 3 feet to 1 foot vertical (V).

### 5. Side slope:-

- The slope of earthwork in filling or in cutting is called **Side slope**. It imparts stability to the earthwork.

- **For Filling:**

Normally, 1:2

- **For cutting:**

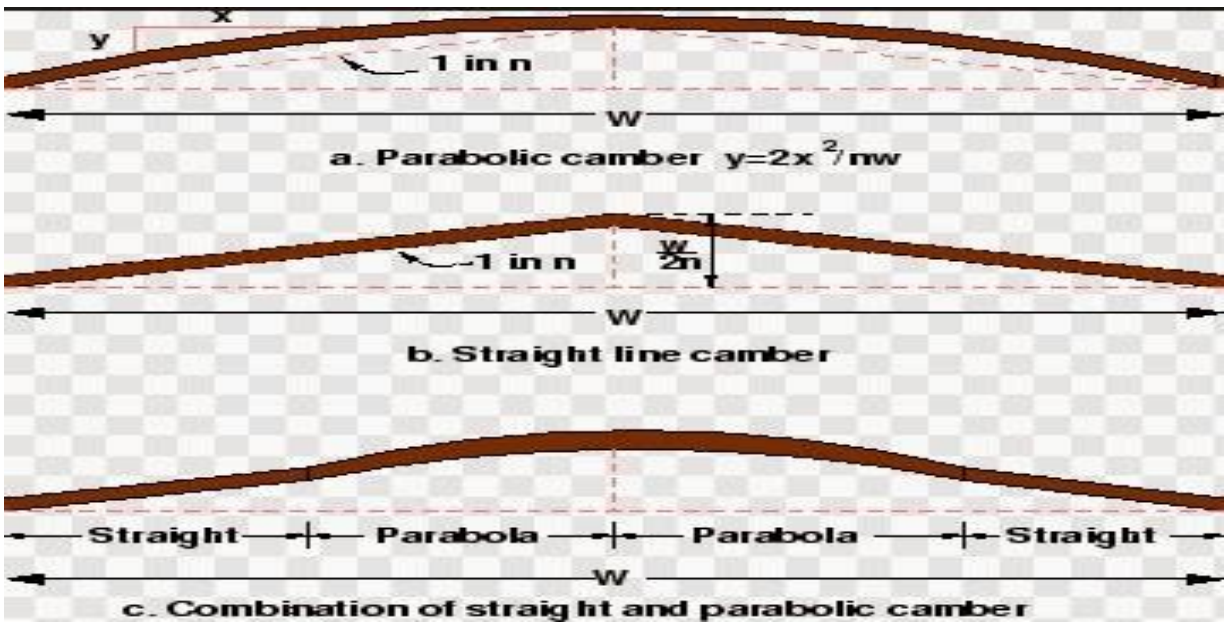
| Type of soil | Slope |
|---|---|
| Ordinary soil | 1:1 to 1:1/2 |
| Broken Rock | 1:1/2 to 1:1/4 |
| Soft Rock | 1:1/4 to 1:1/8 |
| Hard Rock | Approx. Perpendicular |

## Camber

***Camber is the transverse slope provided to the road surface for the drainage of the rainwater for the better performance of the road. Camber can be written as 1 in n or x%.*** **Drainage of the rainwater is necessary:**

(1) To maintain the safe value of the friction between the road surface and the tyres
(2) To maintain the strength and durability of the surface concrete
(3) To maintain the durability and strength of the sub-grade soil this can be harmed if the infiltration of the water takes place to it.

There are generally *three types of camber:*
(a) Straight Camber (b) Parabolic Camber (c) Mixed Camber.




Types of Camber

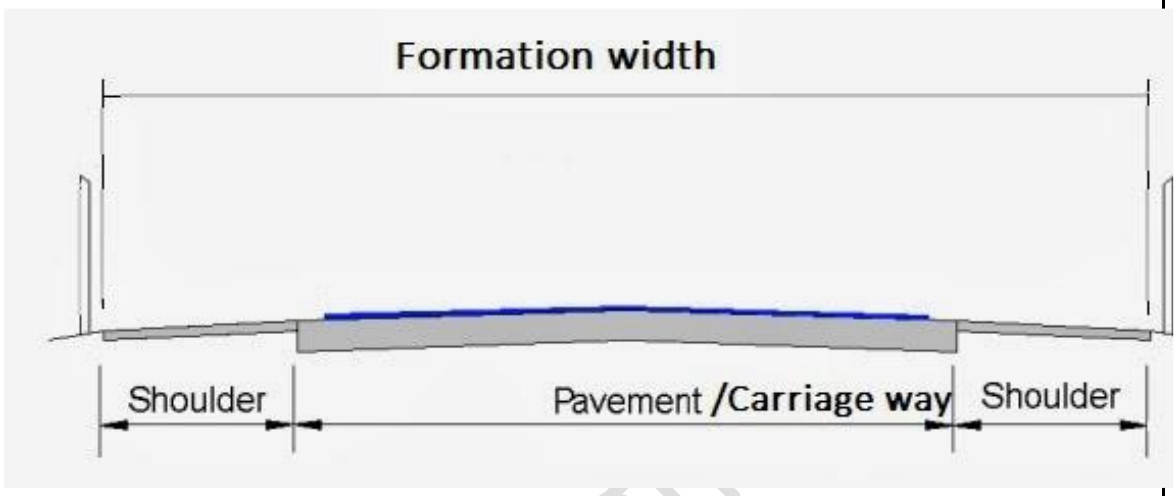
**(a) Straight Camber**
This type of camber is provided by meeting two straight surfaces at the crown. Crown is the central and topmost point on the surface of the road. The edge shape produces inconvenience to the traffic so it is not used in general.

**(b) Parabolic Camber**
Parabolic camber is provided by providing a parabolic shape to the surface of the road. It is also not used in general because it has steep slopes towards the edges, which can create the outward thrust to the vehicles.

What does carriageway mean?

A **carriageway** (British English) or roadway (North American English) consists of a width of road on which a vehicle is not restricted by any physical barriers or separation to move laterally.

- ## Carriage Way:



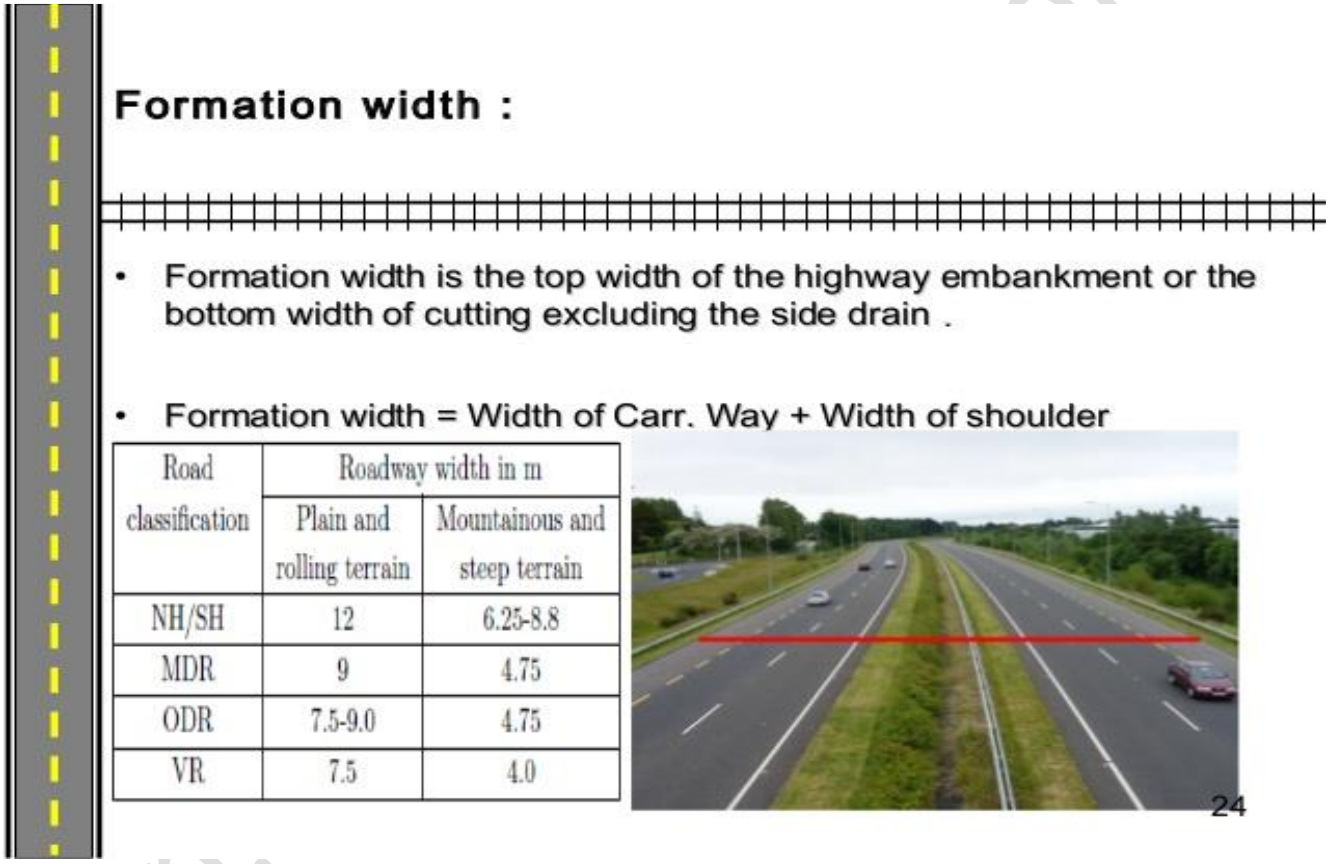

**Carriageway and formation width**

It is the width of the road which is used by the traffic for moving on it. It is generally central portion of the total land width and is paved and surfaced with the bituminous concrete for service to the road users. Width of the carriageway depends on the number of the lanes in the road which again depends on the class of the highway. If it is a higher level road like NH then it will need more numbers of lanes and therefore the carriageway width will be more.

## What does formation level mean?

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

The Formation Level is the level at which excavation ceases and construction commences. It is the lowest point of the path structure. It is the prepared ground on which the sub base layer is laid.




**2.2**

# 1 Overview

The safe and efficient operation of vehicles on the road depends very much on the visibility of the road ahead of the driver. Thus the geometric design of the road should be done such that any obstruction on the road length could be visible to the driver from some distance ahead . This distance is said to be the sight distance.

# 2 Types of sight distance

Sight distance available from a point is the actual distance along the road surface, over which a driver from a specified height above the carriage way has visibility of stationary or moving objects. Three sight distance situations are considered for design:

1. Stopping sight distance (SSD) or the absolute minimum sight distance
2. Intermediate sight distance (ISD) is defined as twice SSD
3. Overtaking sight distance (OSD) for safe overtaking operation
4. Head light sight distance is the distance visible to a driver during night driving under the illumination of head lights
5. Safe sight distance to enter into an intersection.

The most important consideration in all these is that at all times the driver traveling at the design speed of the highway must have sufficient carriageway distance within his line of vision to allow him to stop his vehicle before colliding with a slowly moving or stationary object appearing suddenly in his own traffic lane.

The computation of sight distance depends on:

1. Reaction time of the driver

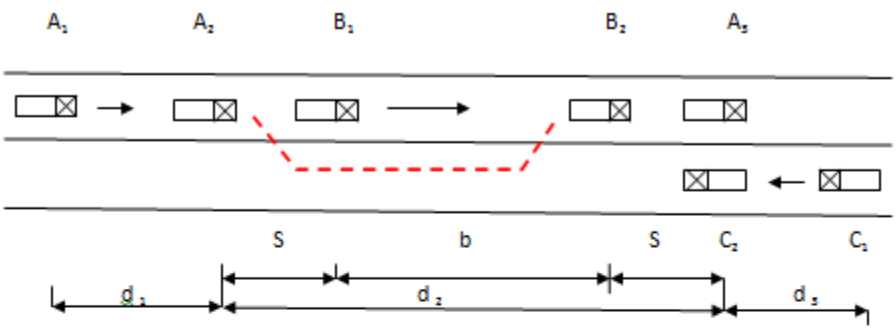
   Reaction time of a driver is the time taken from the instant the object is visible to the driver to the instant when the brakes are applied. The total reaction time may be split up into four components based on PIEV theory. In practice, all these times are usually combined into a total perception-reaction time suitable for design purposes as well as for easy measurement. Many of the studies shows that drivers require about 1.5 to 2 secs under normal conditions. However, taking into consideration the variability of driver characteristics, a higher value is normally used in design. For example, IRC suggests a reaction time of 2.5 secs.

2. Speed of the vehicle

   The speed of the vehicle very much affects the sight distance. Higher the speed, more time will be required to stop the vehicle. Hence it is evident that, as the speed increases, sight distance also increases.

3. Efficiency of brakes

   The efficiency of the brakes depends upon the age of the vehicle, vehicle characteristics etc. If the brake efficiency is 100%, the vehicle will stop the moment the brakes are applied. But practically, it is not possible to achieve 100% brake efficiency. Therefore the sight distance required will be more when the efficiency of brakes are less. Also for safe geometric design, we assume that the vehicles have only 50% brake efficiency.




$OSD = d_1 + d_2 + d_3$

$= Vb.t + Vb + 1/2.a.\sqrt{(\frac{4S}{a})} + vT$

$= (Vb + VbT + 2S + vT)$

Where, S = (0.69 Vb + 6.1) is spacing between vehicles.

Here, T is overtaking time from $A_2$ to $A_3$.

Where, 'a' is the acceleration of overtaking vehicle.

## Overtaking sight distance

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

The factors that affect the OSD are:

1. Velocities of the overtaking vehicle, overtaken vehicle and of the vehicle coming in the opposite direction.

2. Spacing between vehicles, which in-turn depends on the speed

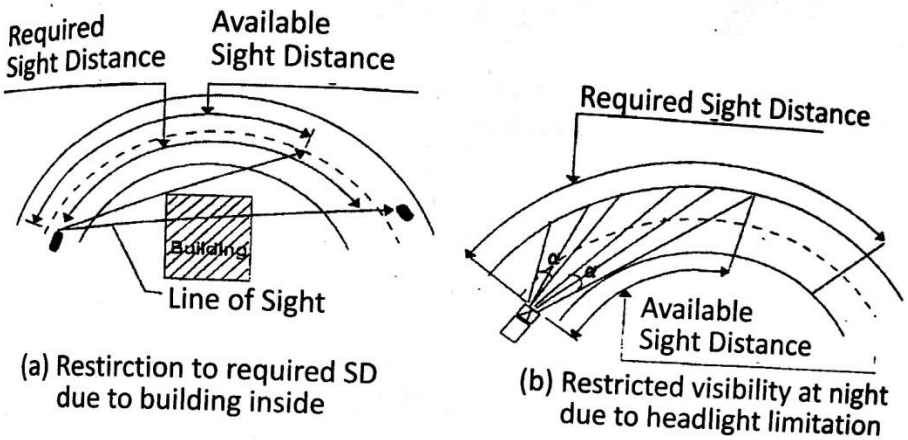
3. Skill and reaction time of the driver.
4. Rate of acceleration of overtaking vehicle.
5. Gradient of the road.

The dynamics of the overtaking operation is given in the figure which is a time-space diagram. The x-axis denotes the time and y-axis shows the distance traveled by the vehicles. The trajectory of the slow moving vehicle (B) is shown as a straight line which indicates that it is traveling at a constant speed. A fast moving vehicle (A) is traveling behind the vehicle B. The trajectory of the vehicle is shown initially with a

SIGHT DISTANCE

**3.4.3 Sight distance: Stopping sight distance, overtaking sight distance, set – back from obstructions**

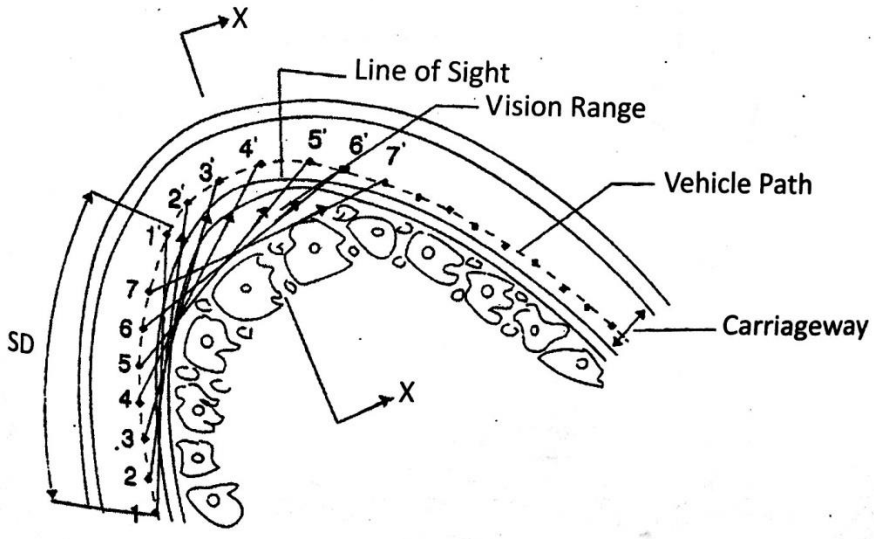
The ability of the driver to see ahead a long section of road is very important for safe and efficient operation in highway traffic. Thus obstacles should be clearly visible to the driver some distance ahead. So sight distance is defined as the distance within which the operator of a vehicle from a specified height above the carriageway moving at design speed has a clear, unobstructed view of surface pavement ahead or of an object of a specified height standing on it. Experiments showed that the possibilities of accidents were reduced when the visibility was increased.




(a) Restirction to required SD due to building inside

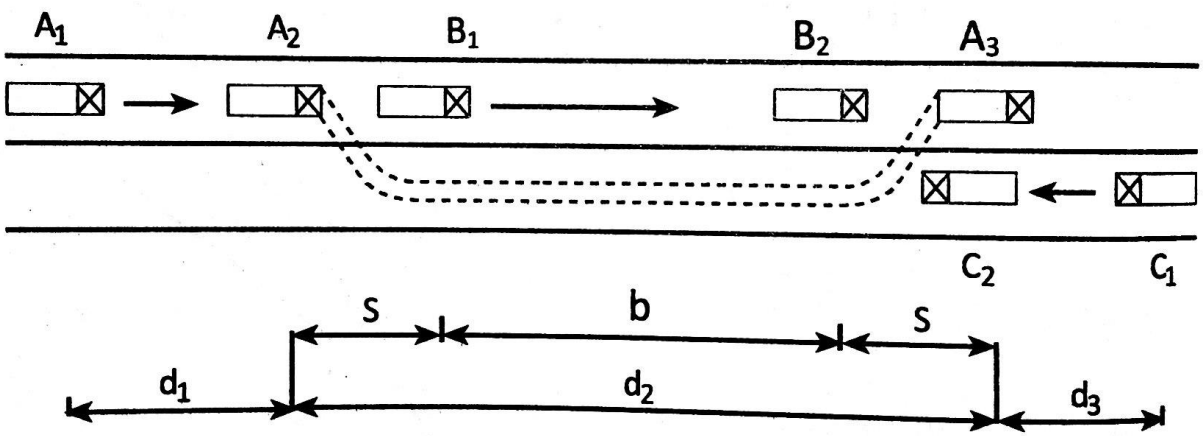
(b) Restricted visibility at night due to headlight limitation

**Road Situations with Sight Distance Restrictions at Horizontal Curves**




(c) Restriction Visibility due to Trees/Shrubs

**Road Situations with Sight Distance Restrictions at Horizontal Curves**

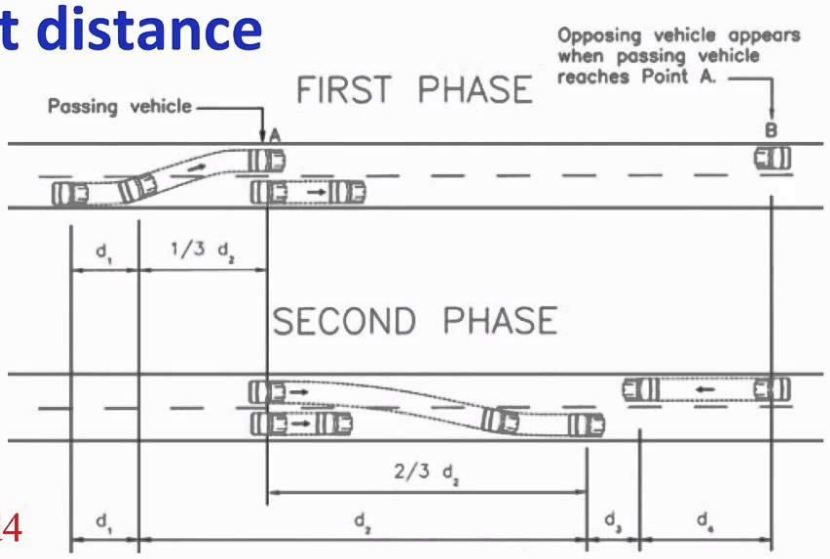







Source: "The Green Book"

# Passing Sight distance




IMPORTANT

PSD = d1+d2+d3+d4

# Design Speed

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

The design speed also depends on the type of terrain. A plain terrain can afford to have any geometry, but for the same standard in a hilly terrain requires substantial cutting and filling implying exorbitant costs as well as safety concern due to unstable slopes. Therefore, the design speed is normally reduced for terrains with steep slopes.

For instance, Indian Road Congress (IRC) has classified the terrains into four categories, namely plain, rolling, mountainous, and steep based on the cross slope as given in table. Based on the type of road and type of terrain the design speed varies. The IRC has suggested desirable or ruling speed as well as minimum suggested design speed and is tabulated in table.

**Table:** Terrain classification

**Table :** Terrain classification

| Terrain classification | Cross slope (%) |
|---|---|
| Plain | 0-10 |
| Rolling | 10-25 |
| Mountainous | 25-60 |
| Steep | 60 |

The recommended design speed is given in Table .

**Table :** Design speed in as per IRC (ruling and minimum)

| Type | Plain | Rolling | Hilly | Steep |
|---|---|---|---|---|
| NS&SH | 100-80 | 80-65 | 50-40 | 40-30 |
| MDR | 80-65 | 65-50 | 40-30 | 30-20 |
| ODR | 65-50 | 50-40 | 30-25 | 25-20 |
| VR | 50-40 | 40-35 | 25-20 | 25-20 |

## Highways Design: Factors affecting Sight distance

The most important consideration in all these is that at all times the driver traveling at the design speed of the highway must have sufficient carriageway distance within his line of vision to allow him to stop his vehicle before colliding with a slowly moving or stationary object appearing suddenly in his own traffic lane.

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The computation of sight distance depends on:

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**2.3**

## Highways Design: Analysis and Design of Super elevation

Super-elevation or cant or banking is the transverse slope provided at horizontal curve to counteract the centrifugal force, by raising the outer edge of the pavement with respect to the inner edge, throughout the length of the horizontal curve.

## Analysis of Super-elevation

Super-elevation or cant or banking is the transverse slope provided at horizontal curve to counteract the centrifugal force, by raising the outer edge of the pavement with respect to the inner edge, throughout the length of the horizontal curve. When the outer edge is raised, a component of the curve weight will be complimented in counteracting the effect of centrifugal force. In order to find out how much this raising should be, the following analysis may be done. The forces acting on a vehicle while taking a horizontal curve with superelevation is shown in figure

Forces acting on a vehicle on horizontal curve of radius R m at a speed of v m=sec$^2$ are:

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

P cos = W sin? + FA+ FB

= W sin? + f (RA+ RB)

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

where W is the weight of the vehicle, P is the centrifugal force, f is the coefficient of friction, is the transverse slope due to super elevation. Dividing by W cos?, we get:

By substituting the value of P/W this in equation

# Design of super-elevation

While designing the various elements of the road like superelevation, we design it for a particular vehicle called design vehicle which has some standard weight and dimensions. But in the actual case, the road has to cater for mixed traffic. Different vehicles with different dimensions and varying speeds ply on the

## Highways Design: Horizontal curve

The presence of horizontal curve imparts centrifugal force which is reactive force acting outward on a vehicle negotiating it.

## Horizontal curve

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

They are the centrifugal force (P) acting outward, weight of the vehicle (W) acting downward, and the reaction of the ground on the wheels (RA and RB ). The centrifugal force and the weight is assumed to be from the centre of gravity which is at h units above the ground. Let the wheel base be
assumed as b units. The centrifugal force P in kg=$m^2$ is given by

$$\frac{1}{2}mv^2 = \frac{1}{2}\frac{Wv^2}{g}$$
$$fWl = \frac{Wv^2}{2g}$$

where W is the weight of the vehicle in kg, v is the speed of the vehicle in m=sec, g is the acceleration due to gravity in m=$sec^2$ and R is the radius of the curve in m.

The centrifugal force has two effects: A tendency to overturn the vehicle about the outer wheels and a tendency for transverse skidding. Taking moments of the forces with respect to the outer wheel

when the vehicle is just

The second tendency of the vehicle is for transverse skidding. i.e. When the centrifugal force P is greater than the maximum possible transverse skid resistance due to friction between the pavement surface and tyre. The transverse skid resistance (F) is given by:

$$F = F_A + F_B$$
$$= f(R_A + R_B)$$
$$= fW$$

where FA and FB is the fractional force at tyre A and B, RA and RB is the reaction at tyre A and B, f is the lateral coefficient of friction and W is the weight of the vehicle. This is counteracted by the centrifugal force (P), and equating:

## Highways Design: Length of transition curve and Vertical alignment

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

# Length of transition curve

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

Rate of change of centrifugal acceleration

At the tangent point, radius is infinity and hence centrifugal acceleration is zero. At the end of the transition, the radius R has minimum value R. The rate of change of centrifugal acceleration should be adopted such that the design should not cause discomfort to the drivers. If c is the rate of change of centrifugal acceleration, it is given by an empirical formula suggested by by IRC

# Vertical alignment

The vertical alignment of a road consists of gradients(straight lines in a vertical plane) and vertical curves. The vertical alignment is usually drawn as a pro le, which is a graph with elevation as vertical axis and the horizontal distance along the centre line of the road as the the horizontal axis. Just as a circular curve is used to connect horizontal straight stretches of road, vertical curves connect two gradients. When these two curves meet, they form either convex or concave. The former is called a summit curve, while the latter is called a valley curve.



# 3. Road Materials

## 3.1

# 3.2

The importance of soil as a highway subgrade lines in the fact that it act as an integral part of road pavement. the soil as a highway subgrade serves the following functions :-

1. To provide an adequate support to the road pavement.
2. To provide stability to the road pavement.
3. To provide good drainage of rain water percolating through the road pavement.
4.

**Soil** is used for the construction of the bottom most layer of the pavement, i.e. **sub-grade**. Here is a short details of the sub-grade and its function.:


Soil as sub-grade material

- sub-grade is the layer of the pavement whose main function is to support the upper layers of the pavement and to provide the good drainage facility to the infiltrating rain water. It has to act as a single structure along with other layers of the pavement.
- Soil is compacted to its maximum dry density which can be achieved by using the optimum moisture content and the methods of compaction control. Strength has to be ensured which is required for the given design thickness of the pavement.
- Strength analysis and the thickness of pavement are inter linked because more thickness of the pavement is needed if the soil is weak but if the soil possess a good strength then less thickness is needed.

# 3.3

# CALIFORNIA BEARING RATIO TEST

## 1. Objective

CBR is the ratio expressed in percentage of force per unit area required to penetrate a soil mass with a standard circular plunger of 50 mm diameter at the rate of 1.25 mm/min to that required for corresponding penetration in a standard material. The ratio is usually determined for penetration of 2.5 and 5 mm . When the ratio at 5 mm is consistently higher than that at 2.5 mm, the ratio at 5 mm is used.

The following table gives the standard loads adopted for different penetrations for the standard material with a C.B.R. value of 100%.

| Penetration of Plunger (mm) | Standard Load (kg) |
|---|---|
| 2.5 | 1370 |
| 5.0 | 2055 |

**Table 1 : Standard Load Values at Penetration**

For Railway Formation purpose, the test is performed on remoulded specimens which are compacted dynamically. The methodology covers the laboratory method for the determination of C.B.R. of remoulded /compacted soil specimens in soaked state.

## 2. Apparatus Required

**Fig. 1: CBR Test Apparatus**

Consisting of Loading machine with capacity of atleast 5000 kg and equipped with a movable head or base which enables Plunger of 50 mm dia. to penetrate into the specimen at a rate of 1.25 mm/ minute.

**California bearing ratio test (CBR) – Procedure, formula, and Significance**

|

**Definition**

California bearing ratio test (CBR) is defined as the ratio force per unit area which is required to penetrate a mass of soil with the standard circular piston at a rate of 1.25 millimeters per minute to that required for corresponding penetration of standard material.

$$\text{CBR} = \frac{Total\ load}{Standard\ load} \times 100$$

The table given below the standard loads adopted for a standard material with 100% CBR value for various penetrations.

| Percentage of plunger (mm) | Standard load (Kg) |
|---|---|
| 2.5 | 1370 |
| 5.0 | 2055 |
| 7.5 | 2630 |
| 10.0 | 3180 |
| 12.5 | 3600 |

This test is performed on remoulded specimens & undisturbed specimens which may be compacted either dynamically or statically.

**Objective**

It is conducted for evaluating the stability of soil sub grade and other flexible pavement materials for the design of pavement thickness.

**California bearing ratio test apparatus**

- The laboratory CBR apparatus having of mould 150 millimeters internal diameter with base plate and a collar
- A loading frame with a cylindrical plunger of 50 millimeters diameter.

**California bearing ratio test procedure – CBR**

Briefly, the penetration test consists of causing a cylindrical plunger of 50 millimeters diameter to penetrate a pavement component material at 1.25 mm per minute.

# CALIFORNIA BEARING RATIO TEST

## OBJECTIVE

To determine the California bearing ratio by conducting a load penetration test in the laboratory.

## NEED AND SCOPE

The california bearing ratio test is penetration test meant for the evaluation of subgrade strength of roads and pavements. The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavement.

This instruction sheet covers the laboratory method for the determination of C.B.R. of undisturbed and remoulded /compacted soil specimens, both in soaked as well as unsoaked state.

## PLANNING AND ORGANIZATION

Equipments and tool required.

1. Cylindrical mould with inside dia 150 mm and height 175 mm, provided with a detachable extension collar 50 mm height and a detachable perforated base plate 10 mm thick.

2. Spacer disc 148 mm in dia and 47.7 mm in height along with handle.

**3. Metal rammers.** Weight 2.6 kg with a drop of 310 mm (or) weight 4.89 kg a drop 450 mm.

**4. Weights.** One annular metal weight and several slotted weights weighing 2.5 kg each, 147 mm in dia, with a central hole 53 mm in diameter.

**5. Loading machine.** With a capacity of atleast 5000 kg and equipped with a movable head or base that travels at an uniform rate of 1.25 mm/min. Complete with load indicating device.

6. Metal penetration piston 50 mm dia and minimum of 100 mm in length.

7. Two dial gauges reading to 0.01 mm.

**8. Sieves.** 4.75 mm and 20 mm I.S. Sieves.

9. Miscellaneous apparatus, such as a mixing bowl, straight edge, scales soaking tank or pan, drying oven, filter paper and containers.

### DEFINITION OF C.B.R.

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

C.B.R. = Test load/Standard load ⨽ 100

**California Bearing Ratio Test Contents:**



**1. Definition of CBR:**

It is the **ratio of force per unit area** required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. to that required for the **corresponding penetration** of a standard material. The California Bearing Ratio Test (CBR Test) is a penetration test developed by ***California State Highway Department (U.S.A.)*** for evaluating the bearing capacity of subgrade soil for design of flexible pavement.

Tests are carried out on natural or compacted soils in water soaked or un-soaked conditions and the results so obtained are compared with the curves of standard test to have an idea of the soil strength of the subgrade soil.

**2. Apparatus:**

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


- CBR Graphs
- Significance of CBR Concrete tests
- Bitumen tests
- Civil Lab Tests
- Transportation Engineering
- Road Structure Cross Section Raised Pavement Markers
- Highway Maintenance
- Bearing Capacity

# 3.4

# Water Absorption of Aggregates

## WATER ABSORPTION

This test helps to determine the water absorption of coarse aggregates as per IS: 2386 (Part III) – 1963. For this test a sample not less than 2000g should be used. The apparatus used for this test are :- Wire basket – perforated, electroplated or plastic coated with wire hangers for suspending it from the balance, Water-tight container for suspending the basket, Dry soft absorbent cloth – 75cm x 45cm (2 nos.), Shallow tray of minimum 650 sq.cm area, Air-tight container of a capacity similar to the basket and Oven.

***Procedure to determine water absorption of Aggregates.***

i) The sample should be thoroughly washed to remove finer particles and dust, drained and then placed in the wire basket and immersed in distilled water at a temperature between 22 and 32°C.

ii) After immersion, the entrapped air should be removed by lifting the basket and allowing it to drop 25 times in 25 seconds. The basket and sample should remain immersed for a period of 24 + ½ hrs afterwards.

iii) The basket and aggregates should then be removed from the water, allowed to drain for a few minutes, after which the aggregates should be gently emptied from the basket on to one of the dry clothes and gently surface-dried with the cloth, transferring it to a second dry cloth when the first would remove no further moisture. The aggregates should be spread on the second cloth and exposed to the atmosphere away from direct sunlight till it appears to be completely surface-dry. The aggregates should be weighed (Weight 'A').

iv) The aggregates should then be placed in an oven at a temperature of 100 to 110°C for 24hrs. It should then be removed from the oven, cooled and weighed (Weight 'B').

**Formula used is Water absorption = [(A – B)/B] x 100%.**

Two such tests should be done and the individual and mean results should be reported. A sample proforma for the record of the test is

WATER ABSORPTION OF COARSE AGGREGATES

| S.No. | Determination No. | I | II | III |
|---|---|---|---|---|
| 1 | Weight of saturated surface-dried sample in g (A) | 2409 | 2380 | 2491 |
| 2 | Weight of oven-dried sample in g (B) | 2404 | 2375 | 2486 |
| 3 | Water absorption $= \frac{A - B}{B} \times 100\%$ | $\frac{5}{2404} \times 100 = 0.208\%$ | $\frac{5}{2375} \times 100 = 0.210\%$ | $\frac{5}{2486} \times 100 = 0.201\%$ |
| | Average value | 0.206% | | |

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***Note:*** *The figures given in the above table are for illustration purpose only.*

# AGGREGATE ABRASION VALUE (IS:2386-PART 4-1963)

## OBJECTIVE

For determination of the aggregate abrasion value of coarse aggregate.

## REFERENCE STANDARDS

IS: 2386 (Part IV)-1963 Methods of test for aggregate for concrete Part IV Mechanical Properties.

## EQUIPMENT & APPARATUS

- Los Angeles machines
- Sieves (1.70mm)
- Cylindrical metal measure
- Tamping Rod
- Balance (0-10kg)
- Oven (300°c)

## PREPARATION SAMPLE

Test sample is dried in oven for a period of four hours at a temperature of 100 to 110C.

## PROCEDURE

1. The required weight of test sample(A) is selected conforming to one of the grading mentioned in Table II of IS : 2386 (Part IV) – 1963.
2. The test sample and the abrasive charge is to be placed in the machine and rotated at a speed of 20 to 33 rev/min.
3. For grading A, B, C & D [as per Table II of IS : 2386 (Part IV)- 1963] the machine is to be rotated for 1000 revolutions.
4. At the completion of the test, the material is discharged from the machine and separation of the sample is made on 1.70 mm. IS sieve.
5. The material coarser than 1.70 mm. IS sieve is washed, dried accurately weighed to the nearest gram (B).

## CALCULATION

The difference between the original weight and the final weight of the test sample is expressed as a percentage of the original weight of the test sample.

$$Agg\,Abrasion Value = \frac{A-B}{A} \times 100$$

## REPORT

The mean of the two results is reported to the nearest whole number as the aggregate abrasion value of the tested material.

## SAFETY & PRECAUTIONS

- Use hand gloves while removing containers from oven after switching off the oven.
- Use safety shoes, mask & aprons at the time of test.
- Before testing, machine should be checked.
- After test electric supply should be off.
- Thoroughly clean & dry the container before testing.
- The drum & the cover of the opening should be cleaned thoroughly before & after every test.

## Los Angeles abrasion test on aggregates

Los Angeles abrasion test on aggregates is the measure of aggregate toughness and abrasion resistance such as crushing, degradation and disintegration. This test is carried out by AASHTO T 96 or ASTM C 131: Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.

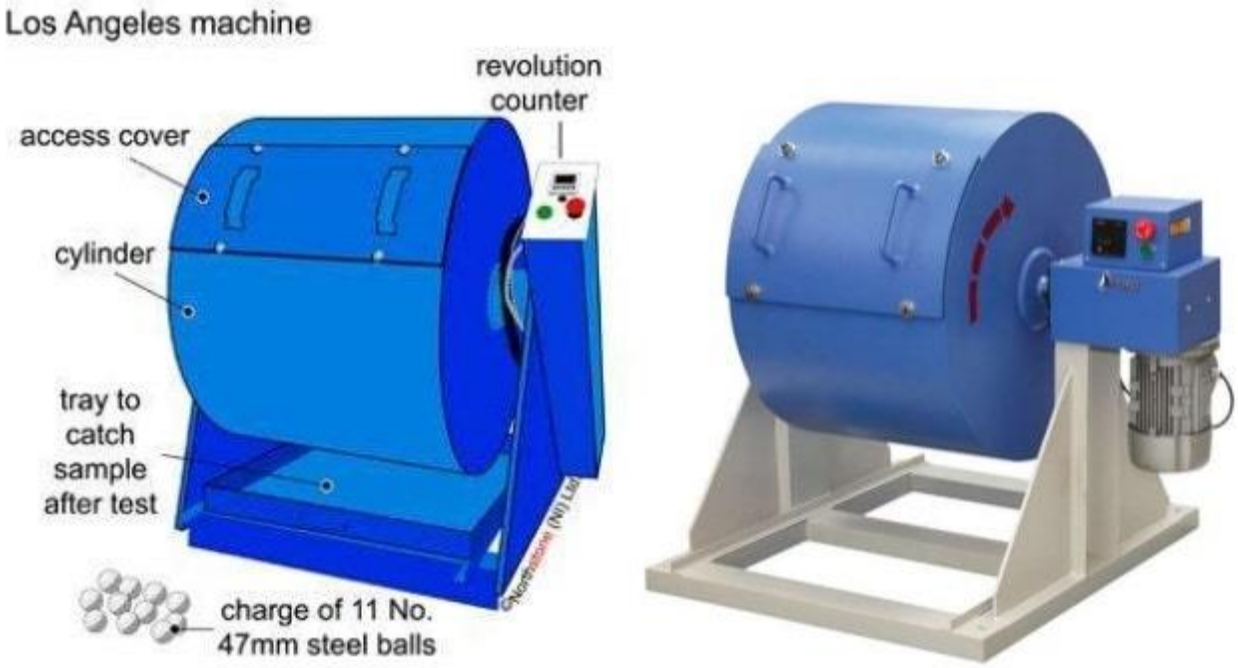
The aggregate used in surface course of the highway pavements are subjected to wearing due to movement of traffic.

When vehicles move on the road, the soil particles present between the pneumatic tyres and road surface cause abrasion of road aggregates. The steel rimmed wheels of animal driven vehicles also cause considerable abrasion of the road surface.

Therefore, the road aggregates should be hard enough to resist abrasion. Resistance to abrasion of aggregate is determined in laboratory by Los Angeles test machine.

The principle of Los Angeles abrasion test is to produce abrasive action by use of standard steel balls which when mixed with aggregates and rotated in a drum for specific number of revolutions also causes impact on aggregates.

The percentage wear of the aggregates due to rubbing with steel balls is determined and is known as Los Angeles Abrasion Value.




Los Angeles abrasion test setup

### Determination of Los Angeles Abrasion Value

The Los Angeles abrasion tests on aggregates are done for following purposes:

1. To determine the Los Angeles abrasion value.
2. To find the suitability of aggregates for use in road construction.

### Apparatus for Los Angeles Test

The apparatus as per **IS: 2386 (Part IV) – 1963** consists of:

Aggregate crushing value test on coarse aggregates gives a relative measure of the resistance of an aggregate crushing under gradually applied compressive load.

Coarse aggregate crushing value is the percentage by weight of the crushed material obtained when test aggregates are subjected to a specified load under standardized conditions.

Aggregate crushing value is a numerical index of the strength of the aggregate and it is used in construction of roads and pavements.

Crushing value of aggregates indicates its strength. Lower crushing value is recommended for roads and pavements as it indicates a lower crushed fraction under load and would give a longer service life and a more economical performance.

The aggregates used in roads and pavement construction must be strong enough to withstand crushing under roller and traffic. If the aggregate crushing value is 30 or higher' the result may be anomalous and in such cases the ten percent fines value should be determined instead.

**Aggregate Crushing Value Test**

The objective of this test is to:

1. Determine the aggregate crushing value of coarse aggregate
2. Assess suitability of coarse aggregates for use in different types of road

**Apparatus**

1. A steel cylinder 15 cm diameter with plunger and base plate.
2. A straight metal tamping rod 16mm diameter and 45 to 60cm long rounded at one end.
3. A balance of capacity 3 kg readable and accurate to one gram.
4. IS sieves of sizes 12.5mm, 10mm and 2.36mm
5. A compression testing machine.
6. Cylindrical metal measure of sufficient rigidity to retain its from under rough usage and of 11.5cm diameter and 18cm height.
7. Dial gauge

# Aggregate Crushing Value

**AGGREGATE CRUSHING VALUE**

This test helps to determine the aggregate crushing value of coarse aggregates as per IS: 2386 (Part IV) – 1963. The apparatus used is cylindrical measure and plunger, Compression testing machine, IS Sieves of sizes – 12.5mm, 10mm and 2.36mm

## *Procedure to determine Aggregate Crushing Value*

i) The aggregates passing through 12.5mm and retained on 10mm IS Sieve are oven-dried at a temperature of 100 to 110°C for 3 to 4hrs.

ii) The cylinder of the apparatus is filled in 3 layers, each layer tamped with 25 strokes of a tamping rod.

iii) The weight of aggregates is measured (Weight 'A').

iv) The surface of the aggregates is then leveled and the plunger inserted. The apparatus is then placed in the compression testing machine and loaded at a uniform rate so as to achieve 40t load in 10 minutes. After this, the load is released.

v) The sample is then sieved through a 2.36mm IS Sieve and the fraction passing through the sieve is weighed (Weight 'B').

vi) Two tests should be conducted.

**Aggregate crushing value = (B/A) x 100%.**

### Aggregate Crushing Values for Roads and Pavement Construction

The table below shows limits of aggregate crushing value for different types of road construction:

| Types of Roads / Pavements | Aggregate Crushing Value Limit |
|---|---|
| **Flexible Pavements** | |

Determination of Aggregate Impact Value – Impact Test on Aggregates is done to carry out to:

- Determine the impact value of the road aggregates,
- Assess their suitability in road construction on the basis of impact value.

**Aggregate Impact Value on Coarse Aggregates**

**Apparatus for Aggregate Impact Test**

The apparatus as per IS: 2386 (Part IV) – 1963 consists of:

(i) A testing machine weighing 45 to 60 kg and having a metal base with a painted lower surface of not less than 30 cm in diameter. It is supported on level and plane concrete floor of minimum 45 cm thickness. The machine should also have provisions for fixing its base.

(ii) A cylindrical steel cup of internal diameter 102 mm, depth 50 mm and minimum thickness 6.3 mm.

(iii) A metal hammer or tup weighing 13.5 to 14.0 kg the lower end being cylindrical in shape, 50 mm long, 100.0 mm in diameter, with a 2 mm chamfer at the lower edge and case hardened. The hammer should slide freely between vertical guides and be concentric with the cup. Free fall of hammer should be within 380±5 mm.

(iv)A cylindrical metal measure having internal diameter 75 mm and depth 50 mm for measuring aggregates.

(v) Tamping rod 10 mm in diameter and 230 mm long, rounded at one end.

(vi)A balance of capacity not less than 500g, readable and accurate up to 0.1 g.

**Theory of Aggregate Impact Test**

The property of a material to resist impact is known as toughness. Due to movement of vehicles on the road the aggregates are subjected to impact resulting in their breaking down into smaller pieces.

The aggregates should therefore have sufficient toughness to resist their disintegration due to impact. This characteristic is measured by impact value test.

The aggregate impact value is a measure of resistance to sudden impact or shock, which may differ from its resistance to gradually applied compressive load.

**Procedure of Aggregate Impact Test**

The test sample consists of aggregates sized 10.0 mm 12.5 mm. Aggregates may be dried by heating at 100-110° C for a period of 4 hours and cooled.

(i) Sieve the material through 12.5 mm and 10.0mm IS sieves. The aggregates passing through 12.5mm sieve and retained on 10.0mm sieve comprises the test material.

(ii) Pour the aggregates to fill about just 1/3 rd depth of measuring cylinder.

(iii) Compact the material by giving 25 gentle blows with the rounded end of the tamping rod.

(iv) Add two more layers in similar manner, so that cylinder is full.

(v) Strike off the surplus aggregates.

(vi) Determine the net weight of the aggregates to the nearest gram(W).

(vii) Bring the impact machine to rest without wedging or packing up on the level plate, block or floor, so that it is rigid and the hammer guide columns are vertical.

# AGGREGATE IMPACT VALUE TEST-10+ IMPORTANT NOTES TO REMEMBER

1. Aggregate impact value test gives an indication of aggregate's toughness property (i.e. property of a material to resist impact)
2. Aggregate impact values are used to classify the stone aggregates with respect to toughness property as given below.

| Aggregate impact value (%) | Toughness Properties |
|---|---|
| <10 | Exceptionally tough / Strong |
| 10 – 20 | Very tough / Strong |
| 20 – 30 | Good for pavement surface course |
| >35 | Weal for pavement surface course |

Aggregate Impact Value Testing machine

3. The test equipment and the test procedure are quite simple and it determines the resistance to impact of stone aggregates simulating field condition.
4. This test can be performed even at construction site or at stone quary, as the apparatus is simple and portable.

# Aggregate Impact Value

AGGREGATE IMPACT VALUE

this test is done to determine the aggregate impact value of coarse aggregates as per IS: 2386 (Part IV) – 1963. The apparatus used for determining aggregate impact value of coarse aggregates is

Impact testing machine conforming to IS: 2386 (Part IV)- 1963,IS Sieves of sizes – 12.5mm, 10mm and 2.36mm, A cylindrical metal measure of 75mm dia. and 50mm depth, A tamping rod of 10mm circular cross section and 230mm length, rounded at one end and Oven.

## Preparation of Sample

i) The test sample should conform to the following grading:

– Passing through 12.5mm IS Sieve – 100%

– Retention on 10mm IS Sieve – 100%

ii) The sample should be oven-dried for 4hrs. at a temperature of 100 to 110$^{o}$C and cooled.

iii) The measure should be about one-third full with the prepared aggregates and tamped with 25 strokes of the tamping rod.

A further similar quantity of aggregates should be added and a further tamping of 25 strokes given. The measure should finally be filled to overflow, tamped 25 times and the surplus aggregates struck off, using a tamping rod as a straight edge. The net weight of the aggregates in the measure should be determined to the nearest gram (Weight ‘A’).

## *Procedure to determine Aggregate Impact Value*

i)The cup of the impact testing machine should be fixed firmly in position on the base of the machine and the whole of the test sample placed in it and compacted by 25 strokes of the tamping rod.

ii) The hammer should be raised to 380mm above the upper surface of the aggregates in the cup and allowed to fall freely onto the aggregates. The test sample should be subjected to a total of 15 such blows, each being delivered at an interval of not less than one second.

## SOUNDNESS TEST OF AGGREGATES (IS-2386-PART-5)

### OBJECTIVE

This test is intended to study the resistance of coarse and fine aggregates to weathering action and to judge the durability of the coarse aggregate.

### APPARATUS

| Name | Capacity | Least count |
|---|---|---|
| Balance | 500 g | 0.1 g |
| Balance | 5000 g | 1 g |
| Oven | 105 to $110^0$C | |
| Sieves | 80 mm, 63 mm, 40 mm, 31.5 mm, 25 mm, 20 mm, 16 mm, 12.5 mm, 10 mm, 8.0 mm, 4.75 mm, 4.0 mm, 2.36 mm, 1.18 mm, 600 micron, 300 micron, 150 micron | |
| Wire mesh basket | | |
| container | | |


Chemicals and wire mesh basket

### CHEMICAL SOLUTION

- Sodium Sulphate Solution
- Magnesium Sulphate Solution

# 4.Road Pavements

# 4.1

## Composition and Structure of Rigid Pavement

Rigid pavements support loads through rigidity and high modulus of elasticity of concrete slab. The loads will distribute to natural soil layer through different layers of rigid pavement. The composition and structure of rigid pavement tells us about the function of each layer of rigid pavement as explained below.

## Composition of Rigid Pavement

In general, Portland cement concrete is used as primary structural element for rigid pavement. The reinforcement is provided in the slab depending upon the soil strength and loading conditions. Pre-stressed concrete slabs can also be used as surface course. The concrete slab usually lies on a compacted granular or treated sub base, which is supported, in turn, by a compacted sub grade. Better results of pavement are obtained when the support layers under the pavement are uniform. The strength of rigid pavement is Rigid pavement is mostly depends upon the concrete slab so, it should be laid strongly while the bottom layers are constructed using low cost materials to make it economical.

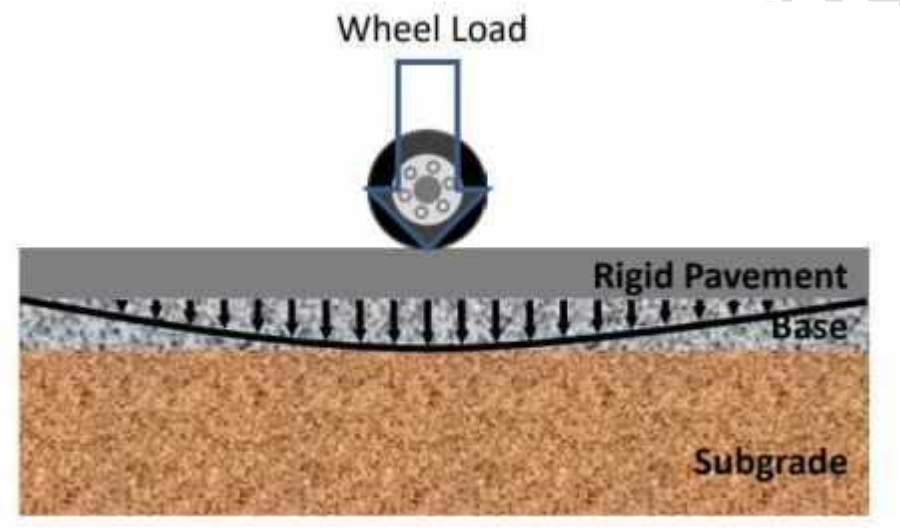



Fig 1: Transfer of Wheel Load to Sub grade in Rigid Pavement

**Structure of Rigid Pavement**

The structure of a rigid pavement consists following layers.

- Concrete slab or surface course
- Granular base or stabilized base course
- Granular sub base or stabilized sub base course
- Frost protection layer
- Sub grade soil

# 4.2

## Method of Camber Construction

After the suitable design value of camber has been computed, it is duly provided on the highway pavement.

First of all, templates or the camber boards are prepared with the required camber.

Then, the material to be used for the subgrade is duly spread and paced until the desired shape of the camber is achieved.

The rolling of the spread material is carried out. It must be ensured that the rolling is done from the edge towards the centre.

After rolling is completed, the top surface is checked by means of the templates and camber boards.

Finally, the excess of the material is removed in case of excess and additional material is spread in case of deficiency of material.

## IRC Recommended Values for Camber

As per IRC, the recommended values of camber for different types of highway pavements can be listed as follows:

a. For bituminous surface pavements or concrete surface pavements, the recommended camber value is 1 in 5 ( heavy) and 1 in 60 (light).

b. For thin bituminous surface pavements, the recommended camber value is 1 in 40 ( heavy) and 1 in 50 (light

c. For water-bound macadam and gravel surface pavements, the recommended camber value is 1 in 33 ( heav and 1 in 40 (light).

d. For earthen surface roads, the recommended camber value is 1 in 25 (heavy) and 1in 33 (light).

## Steps for Preparation of Sub grade:

The road subgrade shall be prepared as per the MORTH specifications if it is not mentioned in contract technical specifications.

The limits of filling shall be marked by fixing batter pegs at regular intervals on both sides of the layer and working line with a white the help of lime powder.

The layer shall be built 300mm wider than the designed and drawing dimensions so that after proper compaction is achieved up to the toe, the surplus materials shall be trimmed to get the properly compacted slopes of the subgrade. Where the fill is to be deposited against an existing subgrade, continuous horizontal benches of 300 mm wide shall be cut into the old slope.

In the cutting section, where cutting is to be done up to subgrade top its top layer, shall be loosened and re-compacted as per technical specification.

The topsoil in the borrow area shall be removed by grubbing or stripping, so that earth without vegetation is excavated and loaded.

Soil from approved borrow areas shall be excavated with Excavators and loaded onto tippers or dumpers for transportation to the stretch ready to receive fill Material.

The material shall be dumped between the limiting lines marked with lime powder.

The material shall be spread in layers of a uniform thickness not exceeding 250mm of compacted thickness. Grader or a combination of dozer and grader can be used for this activity.

Crawler Dozers for Road subgrade construction

The grader will initially spread the heap of earth dumped over a stretch maintaining an approximate line and level.

At this stage, the material should have an Optimum Moisture Content (OMC), ranging from +1% to –2%. The following mixing or drying process should be adopted if it is not found within the permissible limit.

- **The material at the site is too Dry:** Additional water shall be added to increase the moisture content up to the permitted limit. After sprinkling water with the browser, the material shall be thoroughly mixed with the help of grader to obtain a homogenous mix. After that, the grader shall carry out the final precise grading.
- **The material at the site is too Wet:** If the material at the site is too wet, it shall be dried by aeration and exposure to the sun until the moisture content is acceptable.

When a combination of grader and dozer is used, the dozer shall carry out the initial spreading of borrowed material to the approximate line and level. After that, the grader shall carry out the final precise grading.

The in-situ moisture content shall be checked with the help of rapid moisture meter.

## Scope of the Methodology:

Excavation is necessary for the construction of the roadway complete as per Technical Specifications.
Loosening and compaction of the original ground/subgrade up to the required depths as directed by the Engineer.
Construction of subgrade layer with the help of approved borrow area material, including all leads and lifts, completed.
Construction of road subgrade with suitable approved material available from the roadway excavation or any other excavation, completed.
Construction of subgrade with approved material satisfying soaked CBR equal to or greater than 8% and complete as per MORTH.

## 2.1 Highway Alignment:
### 2.1.1 INTRODUCTION:

The position of the center line on the highway in the ground is called highway alignment. Highway alignment includes horizontal alignment and vertical alignment. The projection of highway alignment in the horizontal plane is termed as the horizontal alignment and the projection of highway alignment in the vertical plane is called vertical alignment. Alignment must be selected in such a way that the overall cost during construction, operation and maintenance is minimum. Road design outputs are in the form of following drawings:

**Plan:** Includes centre line, structures, Right of Way (ROW), carriage way, shoulders, side drain.
**Longitudinal Profile:** Soil Type, Depth of cut, Height of Fill, Side drain (Information on from which chainage to which chainage), Direction of flow in the drain.
**Cross section:** Ground Level, Formation Level, Superelevation, Area of Cutting and Area of Filling thus computation of the volume and then cost estimation can be done.

### 2.1.2 REQUIREMENTS OF HIGHWAY ALIGNMENT:

The ideal alignment must have the following requirements:

- Safe (S)
- Easy (E)
- Short (S)
- Economical (E)
- Comfort (C)

The requirements can be memorized as **SESEC.**
**Safe:** The alignment need to be safe during construction, operation and maintenance especially at slopes, embankments and cutting.
**Easy:** The construction materials if present at the place of construction makes the construction easier. Similarly, it should be easy during the operation of vehicles with easy gradients and curves.
**Short:** The distance between the initial and final point need to be short so as to reduce the construction cost.
**Economical:** The alignment should be economical during construction, operation, and maintenance. However, if the construction turned out to be economical, the gradient may not be easy which in turns increases the cost of operation and maintenance. Similarly, if the vehicle operation is taken under consideration and is made economical, the construction cost becomes higher as the gradient and curves need to be easy.
**Comfort:** The alignment should be fixed such that it provides comfort to the drivers and the passengers.

### 2.1.3 FACTORS CONTROLLING HIGHWAY ALIGNMENT:

- **Government Alignment:**

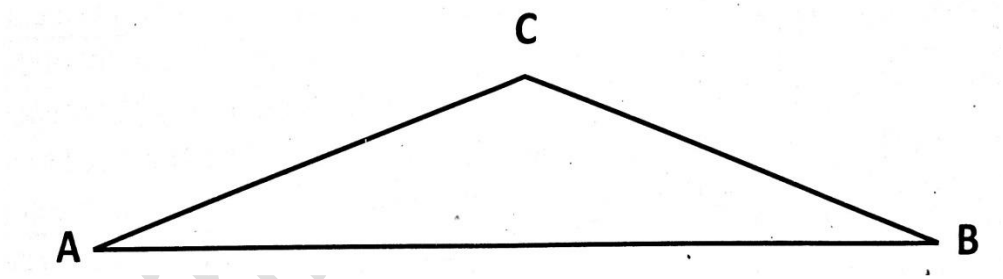
As the road project needs a large investment, the government should be clear about the requirement of the road (when, what, how and why to construct).

- **Obligatory Points:**

Obligatory points determine the highway alignment. They are further divided into positive obligatory points and negative obligatory points.

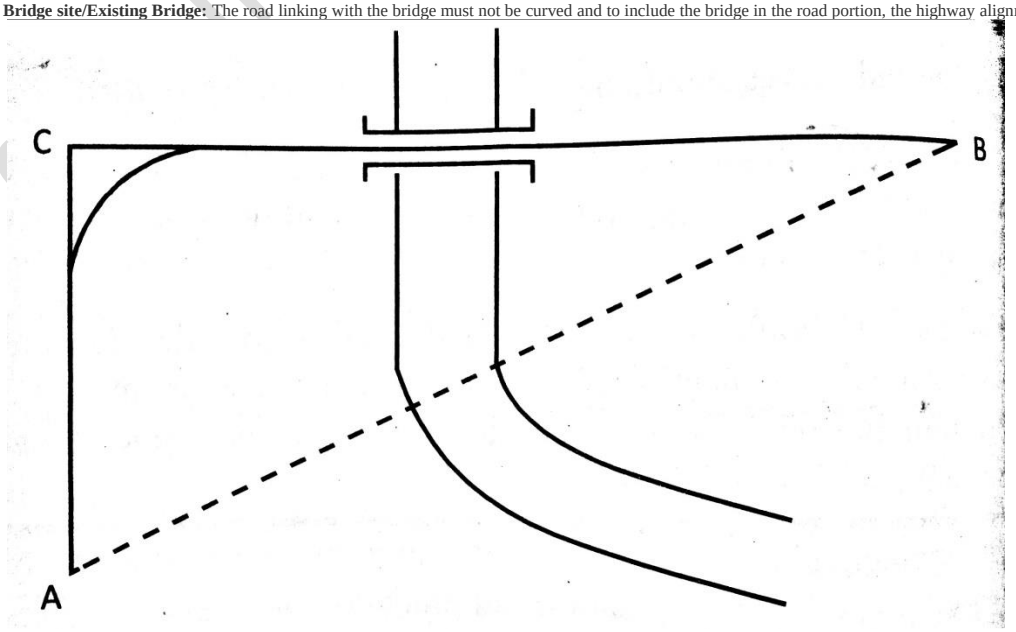
**Positive Obligatory Points:** These are those points through which the alignment should pass.

- **Existing Road:** The alignment should be fixed such that the newly constructed road should link to the existing road. It reduces the cost of construction.
- **Intermediate Town:** If there is the possibility of a straight road between point A and B and there lies the intermediate town at C as shown, then the road need to link the intermediate town reducing the change in highway alignment.




Intermediate Town

- **Bridge site/Existing Bridge:** The road linking with the bridge must not be curved and to include the bridge in the road portion, the highway alignment may be changed.



# SETTING OUT

## A. Methodology

1. Establish working bench marks at 250 m intervals and also at or near all drainage structures and bridges on the road. All the bench marks should be tied with the Reference Bench Mark in the area.

2. In hilly areas, reference pillars handed over by the Engineer to the Contractor shall work as bench marks.

3. Establish centre line of the carriageway and have it referenced by marker pegs and chainage boards set near the road land boundary at 50 m intervals for roads in plain and rolling terrains. For roads in hilly areas and on curves in plains, the interval of reference pegs should be 20 m. For sharp curves, the interval should be 10 m and for hair pin bends the interval should be 5 m.

4. For hill roads, the valley side top edge of reference pillar shall be at ground level. The top levels of reference pillars should be tied with the level of Bench Mark adopted in the DPR.

5. For hill roads, back cutting line shall be demarcated on the hill face by digging, taking into account the designed slope of hill cutting. Back pillars showing the requisite information should be located at about 1.5 m away (towards hill side) from the back cutting line. Alternatively, back pillars can also be fixed on any permanent existing structures in difficult terrain. Check distance of back cutting line from reference pegs.

6. Prepare a schedule of reference dimensions and maintain the markers/ reference pillars until the works reach finished formation level and are accepted by the Engineer.

7. Verify the dimensions and levels, shown on the drawings or mentioned in contract documents, on the site and inform the Engineer of any apparent errors or discrepancies.

8. The lines and levels of formation, side slopes, drainage works, carriageway and shoulders should be carefully set out and frequently checked, care being taken to ensure that correct gradients and cross-sections are obtained everywhere.

9. The plan dimensions of the foundations for culverts shall be set out at the bottom of foundation trench and checked with reference to original line of reference and axis.

## B Quality Control Requirements

### 1. Horizontal Alignment

Horizontal alignment shall be reckoned with respect to the centre line of the carriageway as shown on the drawings.

2. The permitted tolerances are given in Table

| Alignment | Plain and Rolling Terrain | Hilly Terrain |
|---|---|---|
| Edges of carriageway | ± 20 mm | ± 30 mm |
| Edges of roadway and / lower layers of pavement | ± 30 mm | ± 50 mm |

## C Do's

1. Check whether Reference benchmark is indicated on the drawings.
2. Regularly check the working bench marks as work proceeds.
3. Arrange safety of survey bench marks, monuments, beacons etc. and reference pillars in hilly areas
4. Check layout of Curves.

## Setting Out

1) All construction should be with reference to the final centre line of the main location survey.

2) The centre line should be accurately referenced every 50 m interval in plain and rolling terrains, 20 m intervals in hilly terrains and at all curve points, by marker pegs and chainage boards set in or near the fence line. The schedule of reference dimensions should be prepared and marker pegs shall be maintained till the end of the work.

3) Working bench marks tied with the reference bench mark should be established at the rate of four numbers per km and also at or near all drainage structures, other bridge and underpasses. An up to-date record of all bench marks should be maintained and the working bench marks should be checked frequently.

4) On construction reaching the formation level stage, the centre line should again be set out and accurately referenced by marker pegs at the outer limits of the formation posts of timber or steel should be kept one meter from the formation edges showing the finished formation/finished base course/finished road levels. It should be possible to stretch a thread across to verify the finished levels of various courses.

5) All survey monuments, bench marks, beacons, etc. should be maintained accurately during the construction process. A survey file containing the setting out data for traverse points and levels shall be prepared and maintained during the construction process.

6) Precision automatic levels, having a standard deviation or + 2 mm per km and fitted with micrometer attachment shall be used for all double run levelling work. Setting out of the road alignment and measurement of angles shall be done by using theodolite with traversing target, having a accuracy of one second. Measurement of distances shall be done preferably using precision instruments, like, distomat.



## What is Road Subgrade?

The foundation of the pavement structure is known as subgrade. Preparation of subgrade consists of all operations before the pavement structure could be placed over it and compacted. The subgrade may be situated on an embankment or excavation or at the existing ground surface. In all the above cases, **Site Clearance -Clearing Grubbing Operation** should be done before starting the pavement structure construction. After that, the grading operation is started as per the design and drawing of the highway plan and profile.

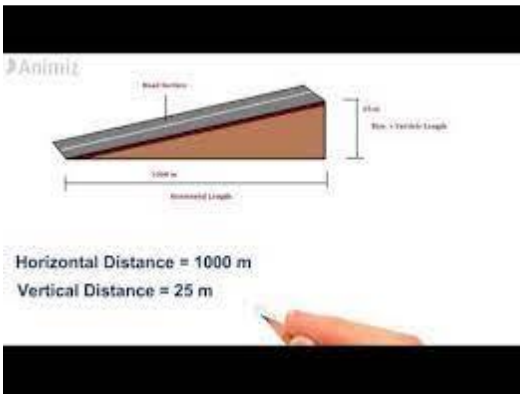
**Subgrade Construction Equipment:**

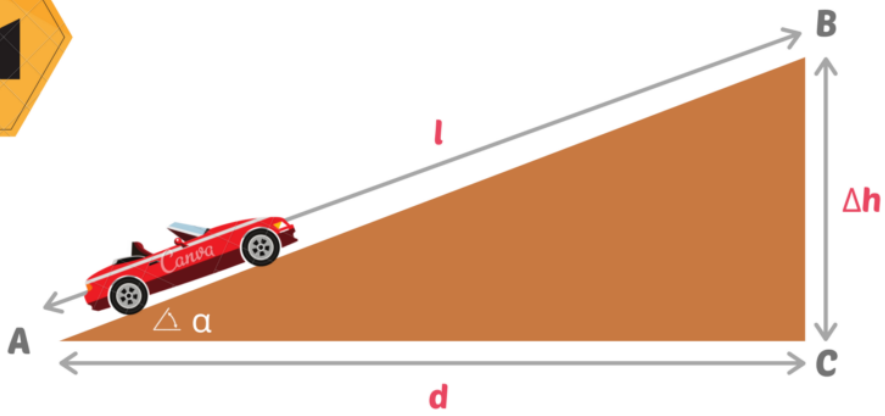
The following sets of equipment are necessary for the planned progress of road subgrade construction work.

Excavator
Air Compressor & Pavement Breaker /Jack Hammer
Tippers /Dumpers
Motor Graders
Vibratory Compactor
Tractors Dozer with Disc Harrows/Spreading Blade/Ploughs
Water Bowser with Sprinklers etc.
Crawler Dozers


Excavator

## GRADIENT OF ROAD AS PER IRC

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# Gradient of Road

**4.3**

# Types of stabilization

### 1. Mechanical Soil Stabilization Method

The mechanical Soil Stabilization Method is the method of improving soil properties by changing its gradation. This method of soil stabilization methods includes compaction and densification of soil matter by application of mechanical energy using various sorts of rollers, rammers, vibration techniques, and sometimes blasting. The stability of the soil generally depends on the inherent properties of the soil material.

In this method, two or more natural soils are mixed together which is superior to any of its components. Mechanical stabilization of soils is done by mixing or blending soils of two or more gradations to obtain a material meeting the required specification.

## 2. Lime Soil Stabilization Method

Lime stabilization is one of the cheapest **soil stabilization methods.**

The soil stabilization method in which lime is added to the soil to improve its properties is known as lime stabilization. There are different types of lime used like hydrated high calcium lime, monohydrated dolomite lime, calcite quick lime, dolomite lime. The amount of lime generally added in most soil stabilizers is in the range of 5% to 10%.


**Lime Soil Stabilization Method**

Lime Soil stabilization method improvement properties show by increase in strength brought by cation exchange capacity rather than the cementing effect brought by the pozzolanic reaction.

## Necessity of sub base

Impart strength and support to overlying pavement
Help workers to stay out of mud
Improved drainage and frost protection
Can be reused
Provide a workable surface
Reduce the construction cost

- Provide strength and support to the overlying pavement
- Provide drainage and frost protection
- Prevent settlements to pavement and slab on grade
- Be reusable if you decide to change your pavement surface
- Keep workers out the mud
- Create a workable surface prior to the placing of the finished pavement
- Reduce construction costs

## What is the purpose of stabilization?

Stabilization is accomplished by increasing the shear strength and the overall bearing capacity of a soil. Once stabilized, a solid monolith is formed that decreases the permeability, which in turn reduces the shrink/swell potential and harmful effects of freeze/thaw cycles.

Soil stabilization is defined as chemical or physical treatments which increase or maintain the stability of a soil or improve its engineering properties.

## What is stabilized sub base?

Stabilized base or sub base materials are **either mixed in place at the job site, or are mechanically combined in a mixing plant and transported to the site**. These materials are spread evenly in loose layers on a prepared sub grade or sub base using either a blade-grader bulldozer, spreader box, or paving machine.

# Wet Mix Macadam Construction and Quality Control

Wet Mix Macadam(WMM) work includes laying and compacting clean, crushed, graded aggregate and granular material, premixed with water, to a dense mass on a prepared GSB layer or existing pavement as per the requirement of the project. WMM can be laid in one or more layers, but the thickness of the single compacted layer not less than 75mm, and the maximum of 200mm when vibrating or other approved types of compacting equipment are used.

**1.0**

## Plants, Equipment and Machinery for Wet Mix Macadam:

The following sets of plant and equipment are necessary for Wet Mix Macadam works.

- WMM plant – 01 No
- Loader – 1 No
- WMM Paver (Sensor) – 01 No.
- Motor Grader – 01 No
- Vibratory Rollers, capacity 80-100KN static wt – 2 Nos.
- Tipper/Dumpers, Cap – 10T/20T (As per site requirement)
- Plate compactor (as per site requirement)


Note: The above equipment deployment list is for single WMM setup, whereas the number of sets shall be mobilized as per the requirement of the program.

**2.0**

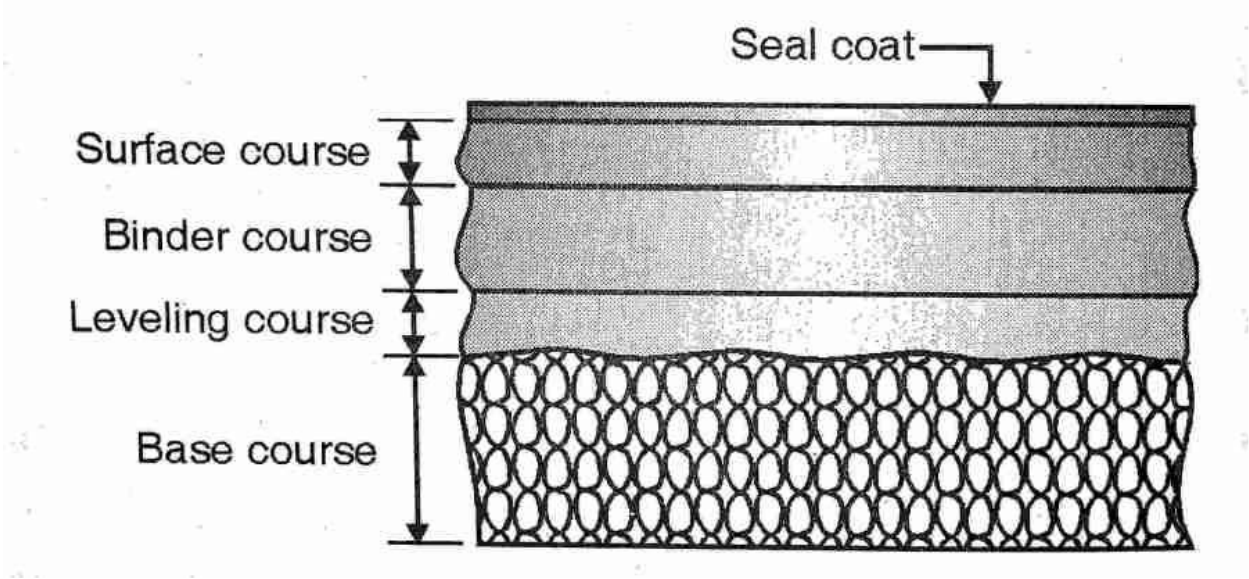
## Material for Wet Mix Macadam:

**Coarse aggregate** The coarse aggregate shall be crushed stone of identified Quarry having the following physical characteristics. The material should conform to the physical requirement & strength contained at sub-clause 406.2.1.1of Technical Specification Contract. The aggregate for Wet Mix Macadam shall conform to requirements specified in the Table 400-10 of MORTH & Technical Specifications.

| Sl. no | Test | Test method to be followed as per | Requirement |
|---|---|---|---|
| 1. | Los Angeles Abrasion Value or,<br>Aggregate Impact Value | IS 2386 (Part -4)<br>IS 2386 (Part -4) or IS :5640 | 40 % (Max.)<br>30% (Max |

# Bituminous Road: Types & Construction Procedure

## What is Bituminous Road




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

## Different Types of Bituminous Surfaces.

### 1. Prime Coat:

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

**Functions:**

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

### 2. Tack Coat:

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

**Function:**

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

### 3. Seal Coat:

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

**Function:**

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

### 4. Surface Dressing:

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

**Function:**

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

## METHODOLOGY FOR WET MIX MACADAM

**Wet Mix Macadam consist of laying spreading and compacting of clean, crushed, well-graded granular materials on a prepared and approved Granular sub-Base. The material is well mixed with water and rolled to a dense mass. It shall be laid on one or more layers as per line and level, grade and cross section shown in the drawing or as directed by the Engineer. The thickness of single compacted Wet Mixed Macadam (WMM) Base shall not be less than 75 mm. Maximum thickness of single compacted layer base can be up to 250 mm upon approval of Engineer.**

**1. Reference**

**2. Setting Out.**

**3. Selection of Material.**

**4. Equipments.**

**5. Methods of Operation.**

**6. Quality Control.**

**7. Work Safety.**

**8. Environmental Safety.**

**1.0 Reference**

**Reference Documents:-**
**I) Ministry of Road Transport& Highways Specifications**
**II) Technical Specifications**
**III) Relevant Drawings.**
**IV) IS 2720 Codes.**

**2.0 Setting Out**

**After the layer of GSB Sub-Base has been approved, then line and level are carried out to fix the Wet Mix Macadam base layer (herein after called WMM Base). Pegs are fixed at regular intervals on the safe side of the road edge where blade of grader should not disturb the peg while blending of the Base materials. On each peg's top level of Base layer is marked. The chainage boards and working bench mark shall be set out side the limits of construction areas.**

**3.0 Selection of Material**

**3.1 Aggregate**

**Coarse aggregate shall be crushed stone or crusher run as per IRC 109 or clause 406.2.1 of MORT&H specification.**

**3.2 Physical requirement**

**Pavement materials: Bitumen**

**Lecture notes in Transportation Systems Engineering**

**3 August 2009**

**Overview**

Bituminous materials or asphalts are extensively used for roadway construction, primarily because of their excellent binding characteristics and water proofing properties and relatively low cost. Bituminous materials consists of bitumen which is a black or dark coloured solid or viscous cementitious substances consists chiefly high molecular weight hydrocarbons derived from distillation of petroleum or natural asphalt, has adhesive properties, and is soluble in carbon disulphide. Tars are residues from the destructive distillation of organic substances such as coal, wood, or petroleum and are temperature sensitive than bitumen. Bitumen will be dissolved in petroleum oils where unlike tar.

**Production of Bitumen**

bitumen is the residue or by-product when the crude petrolium is refined. A wide variety of refinery processes, such as the straight distillation process, solvent extraction process etc. may be used to produce bitumen of different consistency and other desirable properties. Depending on the sources and characteristics of the crude oils and on the properties of bitumen required, more than one processing method may be employed.

**Vacuum steam distillation of petroleum oils**

In the vacuum-steam distillation process the crude oil is heated and is introduced into a large cylindrical still. Steam is introduced into the still to aid in the vapourisation of the more volatile constituents of the petroleum and to minimise decomposition of the distillates and residues. The volatile constituents are collected, condensed, and the various fractions stored for further refining, if needed. The residues from this distillation are then fed into a vacuum distillation unit, where residue pressure and steam will further separate out heavier gas oils. The bottom fraction from this unit is the vacuum-steam-refined asphalt cement. The consistency of asphalt cement from this process can be controlled by the amount of heavy gas oil removed. Normally, asphalt produced by this process is softer. As the asphalt cools down to room temperature, it becomes a semi solid viscous material.

**Different forms of bitumen**

**Cutback bitumen**

Normal practice is to heat bitumen to reduce its viscosity. In some situations preference is given to use liquid binders such as cutback bitumen. In cutback bitumen suitable solvent is used to lower the viscosity of the bitumen. From the environmental point of view also cutback bitumen is preferred. The solvent from the bituminous material will evaporate and the bitumen will bind the aggregate. Cutback bitumen is used for cold weather bituminous road construction and maintenance. The distillates used for preparation of cutback bitumen are naphtha, kerosene, diesel oil, and furnace oil. There are different types of cutback bitumen like rapid curing (RC), medium curing (MC), and slow curing (SC). RC is recommended for surface dressing and patchwork. MC is recommended for premix with less quantity of fine aggregates. SC is used for premix with appreciable quantity of fine aggregates.

**Bitumen Emulsion**

Bitumen emulsion is a liquid product in which bitumen is suspended in a finely divided condition in an aqueous medium and stabilised by suitable material. Normally cationic type emulsions are used in India. The bitumen content in the emulsion is around 60% and the remaining is water. When the emulsion is applied on the road it breaks down resulting in release of water and the mix starts to set. The time of setting depends upon the grade of bitumen. The viscosity of bituminous emulsions can be measured as per IS: 8887-1995. Three types of bituminous emulsions are available, which are Rapid setting (RS), Medium setting (MS), and Slow setting (SC). Bitumen emulsions are ideal binders for hill road construction. Where heating of bitumen or aggregates are difficult. Rapid setting emulsions are used for surface dressing work. Medium setting emulsions are preferred for premix jobs and patch repairs work. Slow setting emulsions are preferred in rainy season.

1. What is bitumen?

2. Types bitumen

3. Requirements of bitumen

4. Tests of bitumen

5. Factors affecting of bitumen

6. Uses of bitumen

7. Functions of bitumen

Vision-what to be achieve- future

Mission-how to achieve-present

Goal-what achieved-past

Your journey-all correlated to each other

# Preparation of base course

**paration of Base Course**

After preparing of layer of sub base course we provide base material which is 43mm down aggregate. Process are same as sub base course but material and time of rolling should change i.e 0.033 hr/cum, to make Water Bond Macadam WBM road. The irregularities are filled in with premix chippings at least a week before laying surface course. If the existing pavement is extremely way, a bituminous leveling course of adequate thickness is provided to lay a bituminous concrete surface course on a binder course instead of directly laying it on a WBM.

Base Course

# WBM Road: Construction Procedure, Advantages and Disadvantages

## WBM Road (Water Bound Macadam Road).

WBM road means water bound macadam road. The wearing surface of WBM road consists of clean and crushed aggregates which are mechanically interlocked by rolling operation. The material is bound with filler material (which are also called as screenings) and water, laid on prepared base course.

## Materials Required For WBM Road Construction.

There are mainly 3 types of materials which are used in the construction of WBM road.

- Course Aggregate
- Screenings (filler material)
- Binding Material

a) Course Aggregate:

Unlike other course aggregates it consists of mixture of hard and durable crushed aggregates and broken stones. The aggregates used for each layer of the WBM road construction should be properly graded. Below table shows the standard gradation of the aggregates that can be adopted.

4.5

## What is surface dressing?

Surface dressing involves spraying bitumen binder (a sticky tar-like substance) on a clean, dry road surface, over which stone chippings are spread (small, consistently-sized aggregate). The surface is rolled to embed the stones into the bitumen although some loose stones will remain on the road surface for about a week. The weight of vehicles passing over these loose stones will force them in to the bitumen to finish the new road surface. To be successful, surface dressing relies upon warm dry weather, and for this reason work is usually carried out between May and August.

# 4 Steps in Bituminous Road Construction

For **bituminous road construction**, various steps and techniques are used **such as** interface treatment (tack coat, prime coat), surface dressing and seal coat etc.

**Contents** [show]

## Steps in Bituminous Road Construction

The following **4 major steps** and techniques are used for bituminous road pavement construction:

### 1. Interface Treatment

Before the construction of any types of bituminous layer over and existing pavement, the existing surface is cleaned and **a thin bituminous layer is spread over the existing surface of the road**.

This treatment with bituminous material is known as interface treatment. The interface treatment may either be a **prime coat** or a **tack coat**.

# Bitumen Road Construction.

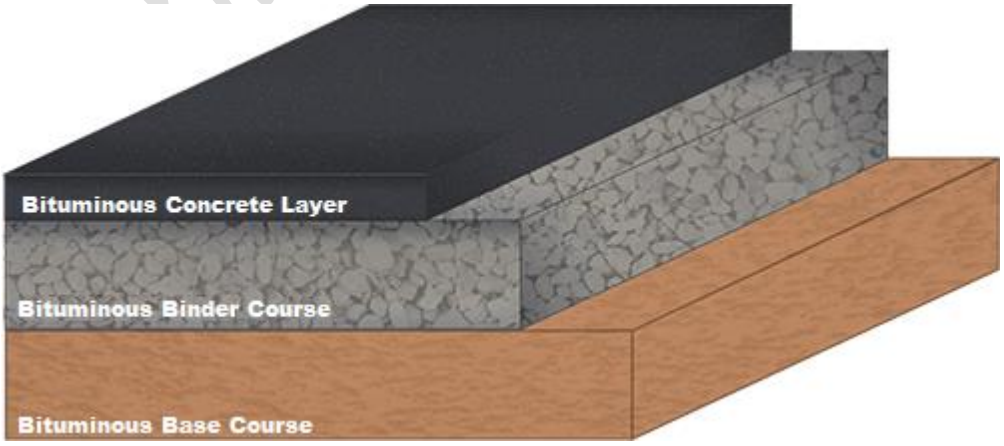
Bitumen road construction consists of different phases that are addressed, such as base course planning, bituminous coat application, bituminous mix placement, rolling and quality control, etc.

In various layers, such as the base course, binder course, and surface course, bituminous pavements are constructed.

These layers are constructed of various materials and the bituminous pavements have different functions.

**Also, Read: What Is Softening Point | Ring-Ball Test for Softening Point of Bitumen | List of Proposed to Determine the Softening Point**

# Layers in a Bituminous Pavement.




Bituminous road has three layers. Which is as follows.

## Bituminous Concrete Mixes (BC)

The bituminous concrete mix is used in two forms: Grade-1 and Grade-2. Grade-1 with NMAS of 19mm. The Grade-2 of 13mm as the NMAS. From the above description about dense bitumen mixes, it was clear that dense bitumen mix grade-2 have larger use as the base course due to its fewer disadvantages compared to dense bitumen mix Grade-1. This hence was necessary to determine a grade for the binder and the surface course. The bituminous concrete grading-1 with nominal maximum aggregate size 19mm as the binder course binds the base course (dense bitumen mix Grade-1) as well as the wearing course bituminous concrete grade-2 of nominal maximum aggregate size 13mm, with NMAS 19 mm employed as a transition. The bituminous concrete grading-2 is good to be used as a wearing course. To facilitate medium and low traffic, a bituminous concrete grade of nominal maximum aggregate size 9.5 mm was necessary to considered for the construction of smooth and impermeable pavement in urban areas. To facilitate thin asphalt lifts, bituminous concrete grading-3 is more suitable than grade-2. The bituminous concrete grade-2 of NMAS 9.5mm has been efficiently used in the highway construction for the US. For higher traffic BC grade-2 are recommended.

**Table-1: Recommended Bitumen Concrete(BC) Gradations**

| *Specification* | *BC grading number** | | |
|---|---|---|---|
| Grading | 1 | 2 | 3 |
| Nominal maximum aggregate size | 19 mm | 13.2 mm | 9.5 mm |
| Layer thickness | 50–75 mm | 35–50 mm | 25–40 mm |
| IS sieve size (mm) | Percent passing by weight | | |
| 26.5 | 100 | | |
| 19 | 90–100 | 100 | |
| 13.2 | 59–79 | 90–100 | 100 |
| 9.5 | 52–72 | 70–88 | 90–100 |
| 4.75 | 35–55 | 53–71 | 55–75 |
| 2.36 | 28–44 | 42–58 | 40–55 |
| 1.18 | 20–34 | 34–48 | 29–44 |
| 0.6 | 15–27 | 26–38 | 21–33 |
| 0.3 | 10–20 | 18–28 | 14–25 |
| 0.15 | 5–13 | 12–20 | 7–15 |
| 0.075 | 2–8 | 4–10 | 4–7 |
| Bitumen content (minimum) | 5.2% | 5.4% | 5.7% |

*BC grading 1 should be used as binder course; BC gradings 2 and 3 should be used for wearing courses. Proposed BC grading 3 should be preferred over BC grading 2 for thin asphalt lifts and city streets.

# Cement Grouted Bituminous Mix for Flexible Pavements

**Manoj Kumar Shukla**, Principal Scientist, Central Road Research Institute, New Delhi

**Cement Grouted Bituminous Mix (CGBM)**

India has the second largest road network with heterogeneous traffic conditions. Although the road construction in India has improved a lot in the last two decades, at times, it is observed that the pavements, especially in urban areas, are unable to last for the desired life and are subjected to premature distresses. One of the major forms of such distresses is moisture induced damages, which occur due to poor drainage conditions in the city roads and sensitivity of bituminous pavements to the water. Keeping this in mind, CSIR-Central Road Research Institute (CRRI) has developed and demonstrated a composite surfacing wearing course for pavements called Cement Grouted Bituminous Mix (CGBM). It is a different type of composite surface course that consists of an open graded high voids bituminous mix as core structure, grouted with a proper cementitious material. Technically, it is a designed amalgamation of concrete pavement and bituminous pavement, thus, consequently and desirably having the nature of both rigidity and flexibility. Need of such new kind of pavement material was being felt for a long time to overcome the deficiencies of the conventional surfacing layer (Bituminous Concrete) while retaining its advantages and benefits. The rutting in bituminous pavements and 'provision of joints' in concrete pavements giving poor riding quality are likely to be completely eliminated in future by this new 'Cement Grouted Bituminous Mix', which has several important and unique properties; a few of them are listed below:

- More durable than the commonly used flexible pavements
- A prime solution to overcome fuel spillage related problems at bus stops, parking areas and fuel stations
- Low temperature susceptibility
- Joint-free and impermeable

# HOT BITUMEN GROUTING

**Hot Bitumen Grouting** is a special type of grouting where melted bitumen is used as grouting material. Hot-Bitumen grouting is often used to cut off high magnitude, subterranean water inflows.

The major feature of hot bitumen grout is its temperature dependent viscosity. The bitumen is first preheated up to approximately 200° Celsius. At this temperature, the grout has a dynamic viscosity in the range of 15 to 100 cp, which is only slightly greater than water at room temperature. Unlike the least viscous chemical resin grouts or the stiffest cement-based mortar grouts, which each have curing processes that are time-dependent, hot bitumen's curing is thermally driven. When hot bitumen is injected into medium saturated with water, it cools quickly at the interface, and turns from its fluid state to a highly viscous, tenaciously sticky, elasto-plastic state. Eventually, after enough hot bitumen is injected, the aperture through which the inflow passes becomes plugged.

Hot bitumen grout is often used in conjunction with cement based suspension grout, in order to reduce grout spread, to make bitumen less creep susceptible, and to increase the mechanical strength of the end product.

There are many types of bitumen with wide range of characteristics, but the desirable type for use in grouting, is a "hard" oxidized environmentally friendly type of bitumen with a high solidification point.

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

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

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

# Semi-Dense Bitumen Mixes

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

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

## Semi-Dense Bituminous Concrete (SDBC)

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

**Fig.4: Semi-Dense Bituminous Concrete Highways with Shallow Potholes**

## Mixed Seal Surfacing (MSS)

The Mixed Seal Surfacing design mix is based on the IRC: SP:78-2008. This is an alternative used for the premix carpet (PMC). Both the PMC and the MSS are employed in 20mm thickness. **There are two gradations that are specified for the mixed seal surfacing mix. They are**

- Type A - Closed Gradation with an NMAS value of 9.5mm
- Type B- Open Gradation with an NMAS value of 9.5mm or 12mm

The aggregate grading for the MSS mix is mentioned in table-2.

**Table-2: Aggregate Grading for Mixed Seal Surfacing Mix**

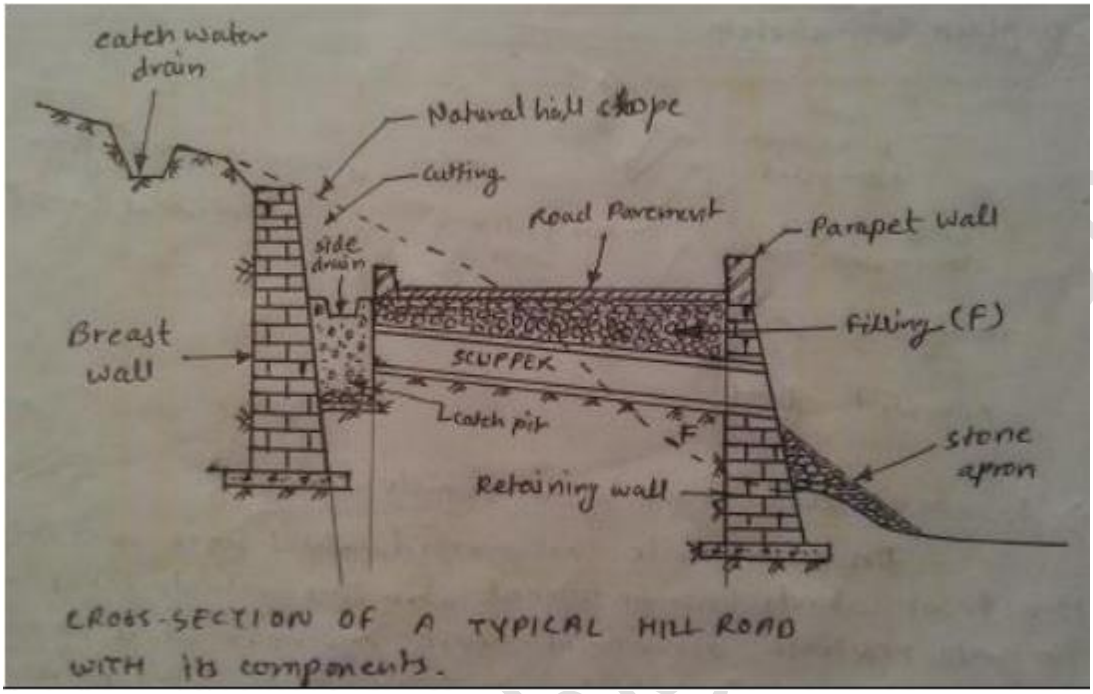
| *IS sieve size, mm* | *Type A* | *Type B* |
|---|---|---|
| | Percent passing by weight | Percent passing by weight |
| 13.2 | — | 100 |
| 11.2 | 100 | 88–100 |
| 5.6 | 52–88 | 31–52 |
| 2.8 | 14–38 | 5–25 |
| 0.090 | 0–5 | 0–5 |

**4.6**

# 5. Hill Roads

## 5.1

**Typical cross-sections showing all details of a typical hill road**




**Typical cross-sections showing all details of a typical hill road partly in cutting and partly in filling**

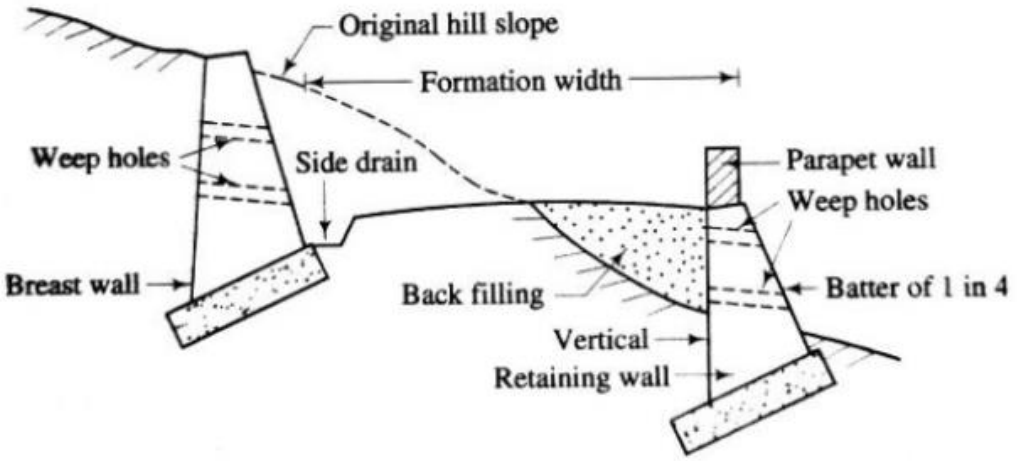



*Fig.5. Retaining wall and breast wall for protective works for hill road*

## 5.2

# Retaining walls:

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

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

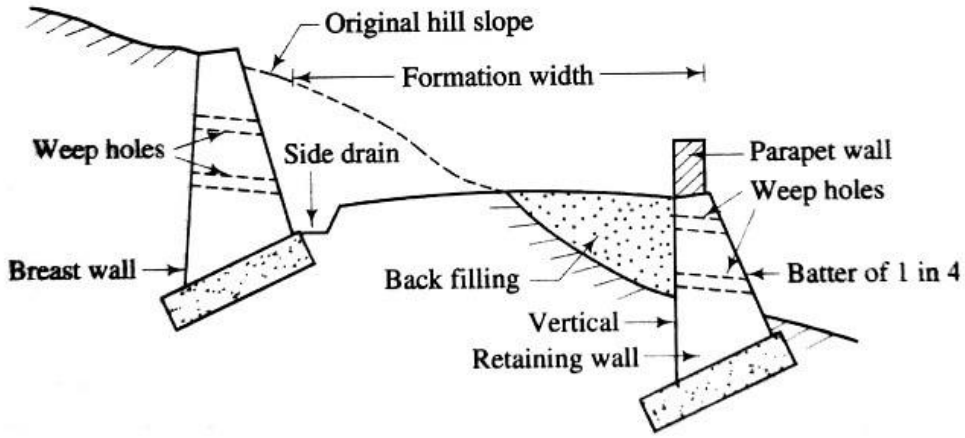



***Fig.5. Retaining wall and breast wall for protective works for hill road***

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

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

# Breast walls:

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

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

# Types of curves in Hill Roads

- Bridle Paths
- Salient Curve
- Re-entrance curve
- Village path or tracks
- Hairpin bend
- Corner bents

## Bridle paths –

These are the paths used by pedestrian and mule traffic. Mule traffic is a very predominant mode of transport in the hilly region.

The width of the bridle path is 2 m to 3 m. The slope may be as high as 1 in 8 to 10.

## Salient curve –

A hill road going around a spur will have convexity outward. This curve is known as the salient curve.

The cross-section of the carriageway at the salient curve shows a straight cross fall of the road surface from its outer edge towards the inner edges.

## Re-entrant curve –

at the hill slope valley, the road has a curve having concavity outwards and is known as a re-entrant curve.

The cross-section of the carriageway at the re-entrant curve is will have its cross fall towards the outer edge of the road.

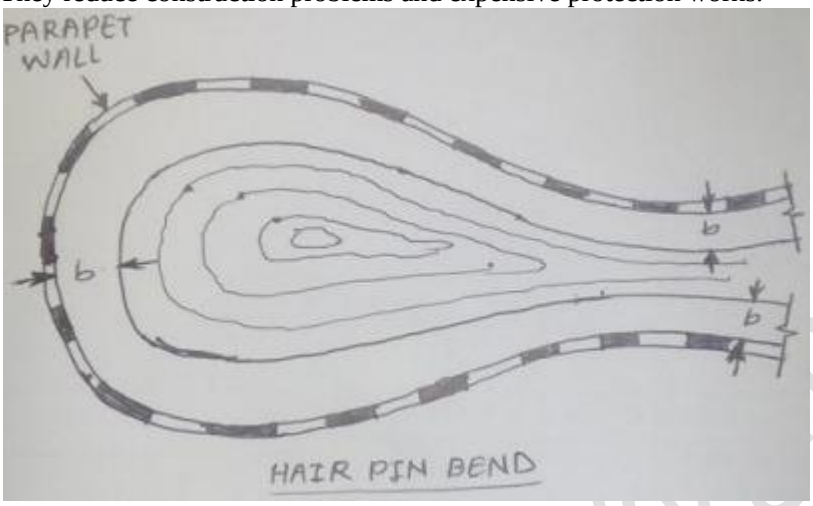
## Village path or tracks

In hilly areas, communication between villages and other working areas is mostly established through village tracks. They are 1 to 1.2m wide and may have a slope of more than 45 degrees.

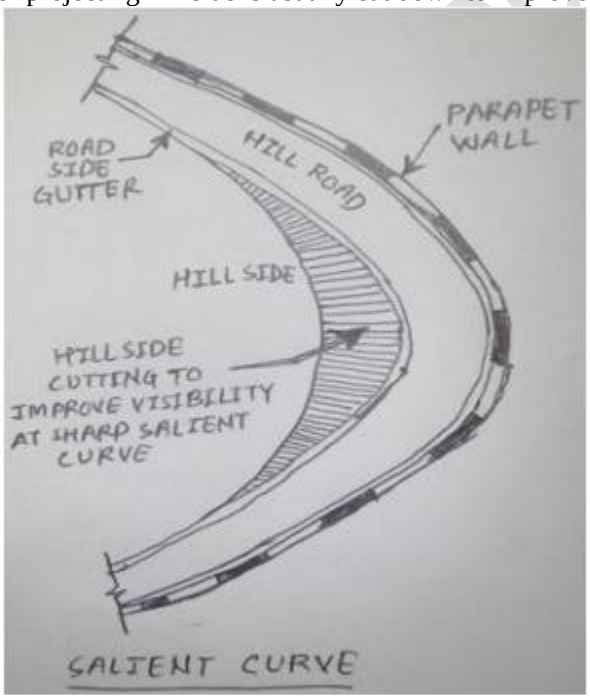
## Explain the types of hill road curve with neat sketch.

Types of curves provided on hill road are as follow:

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




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




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