5^{TH} SEM

E- CONTENT

HIGHWAY ENGINEERING

SUBJECT CODE – 220752

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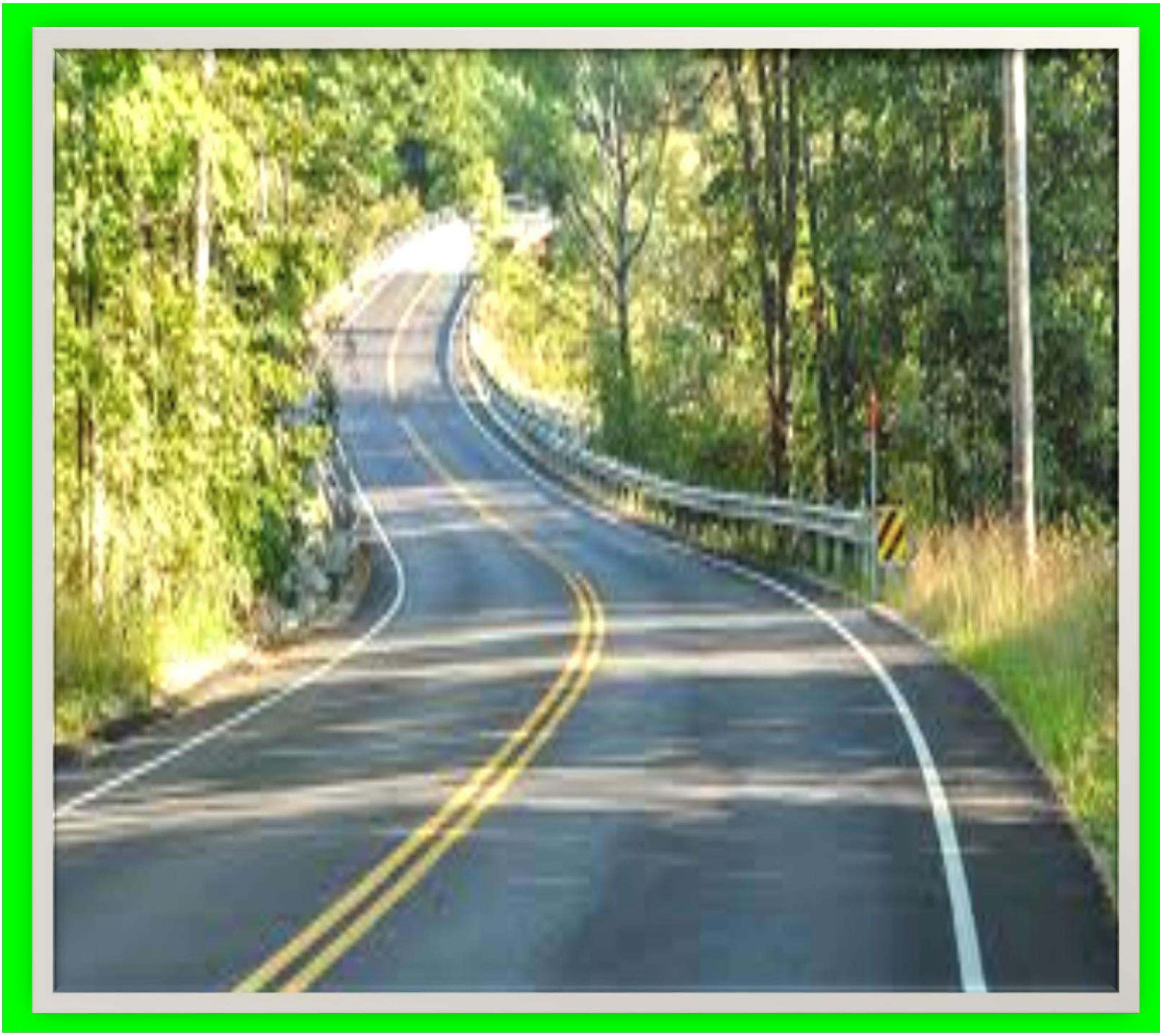
HIGHWAY ENGINEERING



BY: - CIVIL ENGINEERING DEPARTMENT

B.K.N. GOVT. POLYTECHNIC NARNAUL

CONTENT COVERED

1. INTRODUCTION

HIGHWAY ENGINEERING: The branch of transportation engineering with deals with the design, construction and maintenance of different types of road is called highway engineering.

Different Modes of Transportation:-

1. Land (Roadways and Railways)

2. Water (Waterways)

3. Air (Airways)

Importance of highway transportation:

Highway transportation is the means of detail distribution between homes, shops, factories etc. It is only the roads which can carry goods from and to aero drams, harbors and railway stations.

Considering the utility of roads anywhere in the different parts of a country; they can be rightly compared to arterials in a human body. Just as arteries maintain man's health by providing circulation of blood; similarly Roads promote nation's wealth by keeping it's people and goods moving. Thus, we see that progress and well-being of a nation depends much on roads. In fact, roads are the life lines of nation's economy.

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

1. They facilitate, conveyance of people, goods, raw-materials, manufactured articles etc. speedily and easily in the different parts of a country.

2. They act as the only source of communication in regions of high 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 supplying 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 ROAD CONGRESS (I.R.C)

The Indian Road Congress (I.R.C) was established by the central government in 1934 as per recommendations of the jayakar committee. The I.R.C was constituted to provide a forum for regular pooling of experience and ideas on all matter affecting the construction and maintenance of road in India.

Functions of Indian Roads Congress (IRC)

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

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

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

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

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

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

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

Functions of Central Road Research Institute (CRRI):

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

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

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

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

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

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

(6) To provide library and documentation services.

Ministry Of Roads Transportation & Highways (MORT & H):

The Ministry Of Roads Transportation & Highways (MORT & H) handles the matters related to road in India :

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

(b) To control the central road fund.

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

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

(e) To administer matters regarding road research.

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

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

NATIONAL HIGHWAY AUTHORITY OF INDIA (NHAI)

NHAI is an autonomous statutory organization which was established through National Highway Authority of Indian Act, 1988. It is responsible for development, maintenance and management of national highways in India.

FUNCTIONS OF N.H.A.I :-

To develop, maintain and manage National Highways vested in it by the Government.

- To collect fees on National Highways, regulate and control the plying of vehicles on National Highways for its proper management.
- To develop and provide consultancy and construction services in India and abroad and carry on research activities in relation to the development, maintenance and management of highways or any other facilities there at.
- To advise the Central Government on matters relating to highways.

- To assist on such terms and conditions as may be mutually agreed upon, any State Government in the formulation and implementation of schemes for highway development.
- Construct offices or workshops and establish and maintain hotels, motels, restaurants and rest-rooms at or near the highways
- Construct residential buildings and townships for its Employees
- Regulate and control the plying of vehicles on the highways
- Provide facilities and amenities for the users of the highways necessary for the smooth flow of traffic on such highways

IRC (Indian Roads Congress) has classified the roads in the India in the following five categories:

(a) National Highways

(b) State Highways

(c) Major District Roads

(d) Other District Roads

(e) Village Roads

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

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

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

State Highways (SH): State highways are the roads which connect the state capital to other states and to the district headquarters in the state. They have design specifications similar to those of the National Highways because they carry enough traffic.

Major District Roads (MDR): These roads connect the district headquarters to the main town centers in the district and to the headquarters of the other districts also. They also connect these major town centers to the other state highways of importance. They have lower design specifications as compared to the NH and SH.

Other district roads (ODR): These roads connect the rural areas town centers to the major district roads of higher importance. They provide the facilities for the transportation of the raw materials or the goods mainly of agricultural products from the rural towns to the higher markets and vice-versa.

Village Roads (VR): These roads connect the rural villages with one another and to the nearest higher level road or to the nearest town center. They have lower design specifications .

PMGSY AND MGNREGA ROAD

Pradhan Mantri Gram Sadak Yojana (PMGSY) :-

Rural Road Connectivity is a key component of Rural Development by promoting access to economical and social services and thereby generating increased agricultural income and productive employment opportunities in india.

Government has launched the Pradhan Mantri Gram Sadak Yojana on 25th December,2000 to provide all weather access to unconnected habitation. The Pradhan Mantri Gram Sadak Yojana (PMGSY) is a 100 % centrally sponsored scheme.

Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) :-

The National Rural Employment Guarantee Act 2005 (NREGA) renamed as the " Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) is an Indian Labour Law and social security measure that aims to guarantee the 'right to work '.Its aim to ensure livelihood security in rural area by providing at least 100 days of wage employment in a financial year to every household whose adult member volunteer to do unskilled manual work.

Employment is to be provided within 5 km of an applicant's residence and minimum wages are to be paid. If work is not provided within 15 days of applying, then applicant are entitled to an unemployment allowance.

2. ROAD GEOMETRICS

Road Geometrics: - Road geometrics means fixing the dimensions and layout of visible features of highway so that road users can utilize it with maximum efficiency, safety and comfort.

Road geometrics include the following elements of a highway:

a) Cross-section elements: Right of way, formation width. Road margin, road shoulder, carriageway, side slopes, kerbs, formation levels, camber and gradient.

b) Speed of vehicles: Design speed, average running speed.

c) Sight distance: Stopping sight distance, overtaking sight distance.

d) Horizontal and vertical alignments: Horizontal and vertical curve, transition curves, super elevation.

FACTORS AFFECTING THE DESIGN OF ROAD GEOMETRICS

Road geometrics are greatly influenced by the topography or terrain through which the highway is being aligned, locality, traffic characteristics and requirements of design speed. Design speed is the main factor which is important in governing most of the geometric design elements of roads.

Design speed:- Design speed is the single most important factor that affects the geometric design. It directly affects the sight distance, horizontal curve, and the length of vertical curves. Since the speed of vehicles vary with driver, terrain etc, a design speed is adopted for all the geometric design. Design speed is defined as the highest continuous speed at which individual vehicles can travel with safety on the highway when weather conditions are conducive. Design speed is different from the legal speed limit which is the speed limit imposed to curb a common tendency of drivers to travel beyond an accepted safe speed. Design speed is also different from the desired speed which is the maximum speed at which a driver would travel when unconstrained by either traffic or local geometry. Since there are wide variations in the speed adopted by different drivers, and by different types of vehicles, design speed should be selected such that it satisfy nearly all drivers. At the same time, a higher design speed has cascading effect in other geometric designs and thereby cost escalation. Therefore, an 85th percentile design speed is normally adopted. This speed is defined as that speed which is greater than the speed of 85% of drivers. In some countries this is as high as 95 to 98 percentile speed.

Topography: The next important factor that affects the geometric design is the topography. It is easier to construct roads with required standards for a plain terrain. However, for a given design speed, the construction cost increases multiform with the gradient and the terrain. Therefore, geometric design standards are different for different terrain to keep the cost of construction and time of construction under control. This is characterized by sharper curves and steeper gradients.

Other factors :-

In addition to design speed and topography, there are various other factors that affect the geometric design and they are briefly discussed below:

• **Vehicle**: :The dimensions, weight of the axle and operating characteristics of a vehicle influence the design aspects such as width of the pavement, radii of the curve, clearances, parking geometrics etc. A design vehicle which has standard weight, dimensions and operating characteristics are used to establish highway design controls to accommodate vehicles of a designated type.

• **Human**: The important human factors that influence geometric design are the physical, mental and psychological characteristics of the driver and pedestrians like the reaction time.

• **Traffic**: It will be uneconomical to design the road for peak traffic flow. Therefore a reasonable value of traffic volume is selected as the design hourly volume which is determined from the various traffic data collected. The geometric design is thus based on this design volume, capacity etc.

• Environmental: Factors like air pollution, noise pollution etc. should be given due consideration in the geometric design of roads. • Economy: The design adopted should be economical as far as possible. It should match with the funds allotted for capital cost and maintenance cost.

• Others: Geometric design should be such that the aesthetics of the region is not affected.

Various elements of road geometrics are:

1. Right of way

2. Formation width

3. Road Margin

4. Road shoulder

5. Carriage way

6. Side slopes

7. kerbs

8. Formation level

9. Camber

10. Gradient

11. Design and average running speed

12. Stopping and overtaking sight distance

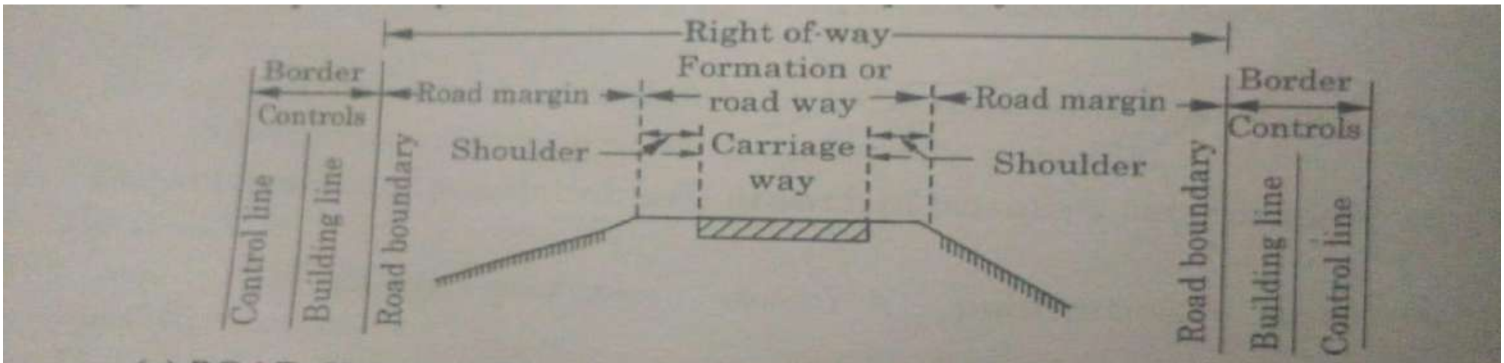
13. Horizontal, vertical and transition curves

14. Super elevation

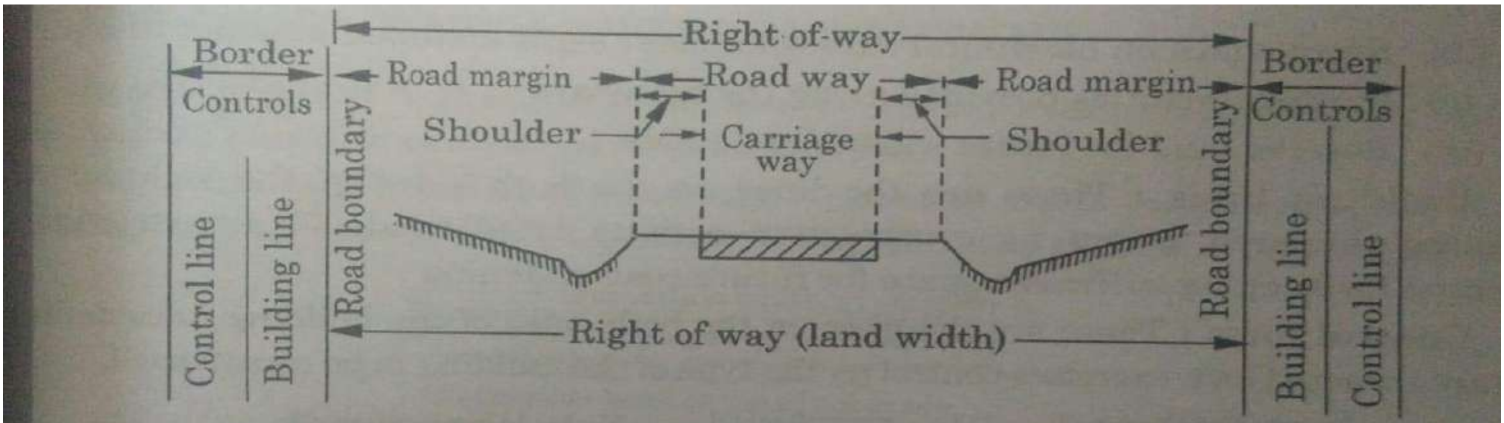
RIGHT OF WAY

It is the area of road acquired for road construction and for its future development along its alignment.

Right of way is also known as permanent land and land width.



(a) ROAD CROSS-SECTION IN EMBANKMENT SHOWING RIGHT-OF-WAY



(b) ROAD CROSS-SECTION IN CUTTING SHOWING RIGHT OF WAY

TABLE 2.1 : RECOMMENDED LAND WIDTH FOR RURAL ROADS

Sr. No.	Type of Road	Plain & Rolling Terrain				Steep & mountainous Terrain			
		Open area		Built-up area		Open area		Built-up area	
		Normal	Range	Normal	Range	Normal	Range	Normal	Range
1.	National & State Highways	45	30–60	30	30–60	24	No range specified	20	No range specified
2.	Major District Roads	25	25–30	20	15–25	18		15	
3.	Other District Roads	15	15–25	15	15–20	15		12	
4.	Village Roads	12	12–18	10	10–15	9		9	

The right of way width is governed by:

• **Width of formation**: It depends on the category of the highway and width of roadway and road margins.

• **Height of embankment or depth of cutting**: It is governed by the topography and the vertical alignment.

• **Side slopes of embankment or cutting**: It depends on the height of the slope, soil type etc.

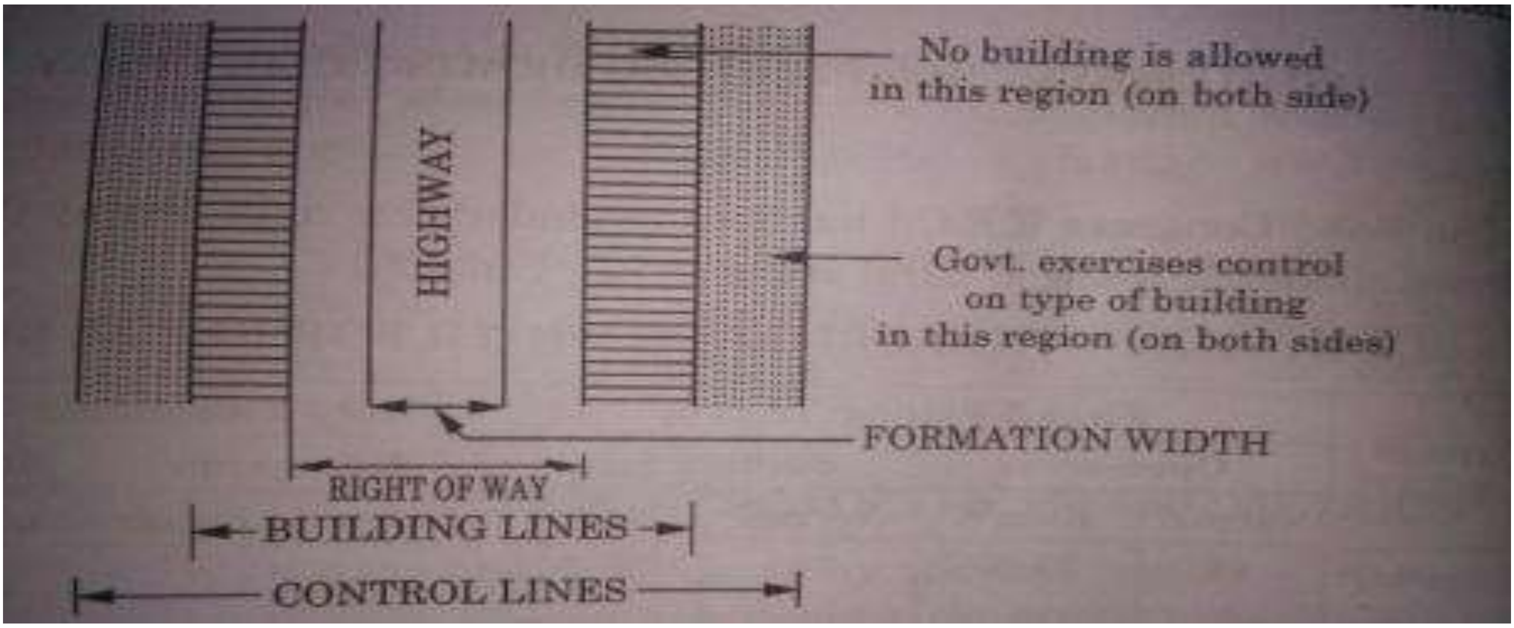
• Drainage system and their size which depends on rainfall, topography etc.

• **Sight distance considerations**: On curves etc. there is restriction to the visibility on the inner side of the curve due to the presence of some obstructions like building structures etc.

• **Reserve land for future widening**: Some land has to be acquired in advance anticipating future developments like widening of the road.

Building lines: These are the line on the both side of the right of way defining the area where no construction activity is allowed.

Control lines: These are the line on the both sides of the building lines defining the area where govt. exercises control on the type of the building to be constructed.



Width of formation: Width of formation or roadway width is the sum of the widths of pavements or carriage way including separators and shoulders. This does not include the extra land in formation/cutting .

Width of formation for various classed of roads

Road classification	Roadway width in m	
	Plain and rolling terrain	Mountainous and steep terrain
NH/SH	12	6.25-8.8
MDR	9	4.75
ODR	7.5-9.0	4.75
VR	7.5	4.0

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

Shoulders: Shoulders are provided along the road edge and are intended for accommodation of stopped vehicles, serve as an emergency lane for vehicles and provide lateral support for base and surface courses. The shoulder should be strong enough to bear the weight of a fully loaded truck even in wet conditions. The shoulder width should be adequate for giving working space around a stopped vehicle. It is desirable to have a width of 4.6 m for the shoulders. A minimum width of 2.5 m is recommended for 2-lane rural highways in India.

Parking lanes: Parking lanes are provided in urban lanes for side parking. Parallel parking is preferred because it is safe for the vehicles moving on the road. The parking lane should have a minimum of 3.0 m width in the case of parallel parking.

Bus-bays: Bus bays are provided by recessing the kerbs for bus stops. They are provided so that they do not obstruct the movement of vehicles in the carriage way. They should be at least 75 meters away from the intersection so that the traffic near the intersections is not affected by the bus-bay.

Service roads: Service roads or frontage roads give access to access controlled highways like freeways and expressways. They run parallel to the highway and will be usually isolated by a separator and access to the highway will be provided only at selected points. These roads are provided to avoid congestion in the expressways and also the speed of the traffic in those lanes is not reduced.

Cycle track: Cycle tracks are provided in urban areas when the volume of cycle traffic is high Minimum width of 2 meter is required, which may be increased by 1 meter for every additional track**.**

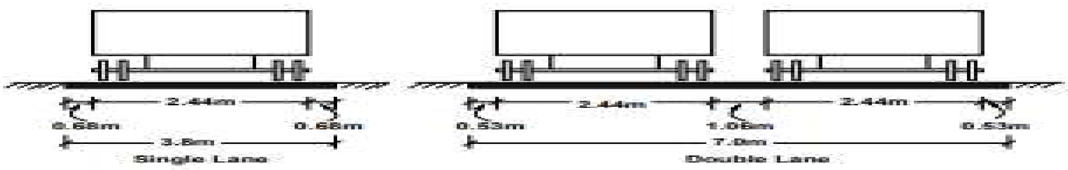
Footpath: Footpaths are exclusive right of way to pedestrians, especially in urban areas. They are provided for the safety of the pedestrians when both the pedestrian traffic and vehicular traffic is high. Minimum width is 1.5 meter and may be increased based on the traffic. The footpath should be either as smooth as the pavement or smoother than that to induce the pedestrian to use the footpath**.**

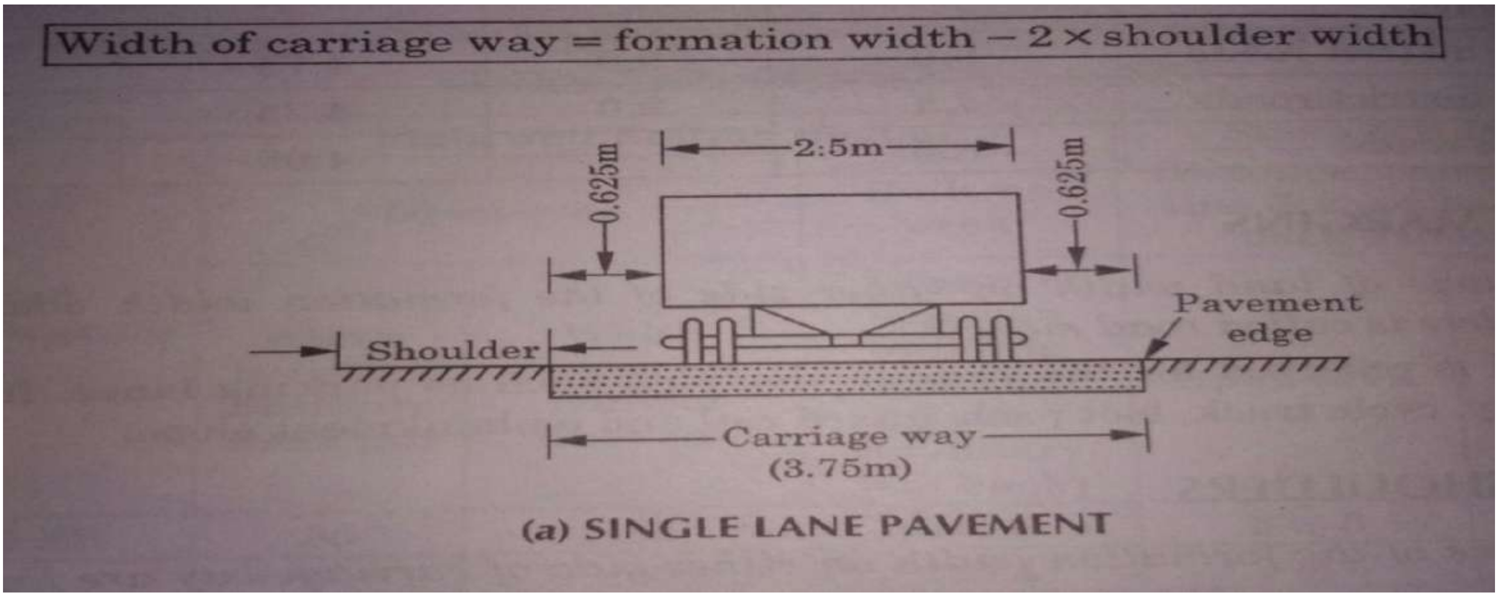
Guard rails: They are provided at the edge of the shoulder usually when the road is on an embankment. They serve to prevent the vehicles from running off the embankment, especially when the height of the fill exceeds 3 m. various designs of guard rails are there. Guard stones painted in alternate black and white are usually used. They also give better visibility of curves at night under headlights of vehicles.

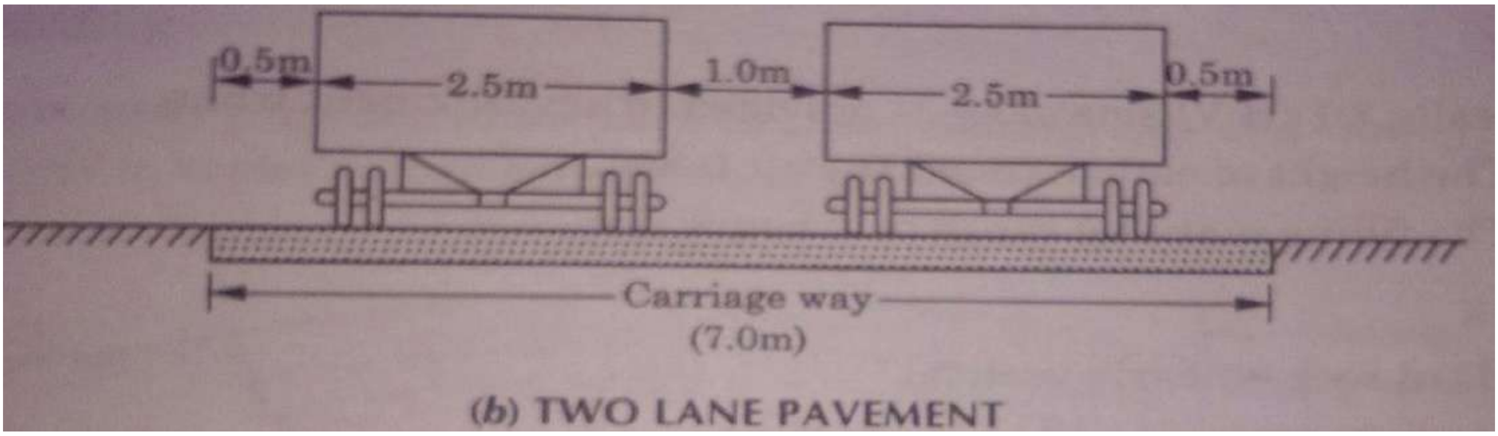
CARRIAGEWAY (WIDTH OF PAVEMENT):

This is the portion of roadway which is used for movement of vehicular traffic. This is also known as width of pavement.

Single lane	3.75
Two lane, no kerbs	7.0
Two lane, raised kerbs	7.5
Intermediate carriage	5.5
Multi-lane	3.5







SIDE SLOPES:-

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

Following factors affect the design of slopes:

1. The nature of soil in earthwork

2. Climatic conditions

3. The method of drainage provided.

In filling: - Generally 2:1(H: V) side slope

In cutting: - If ordinary soil -1:1 to 1:2

Disintegrated rock -1:2 to 1:4

Soft rock - 1:4 to 1:8

KERBS:-

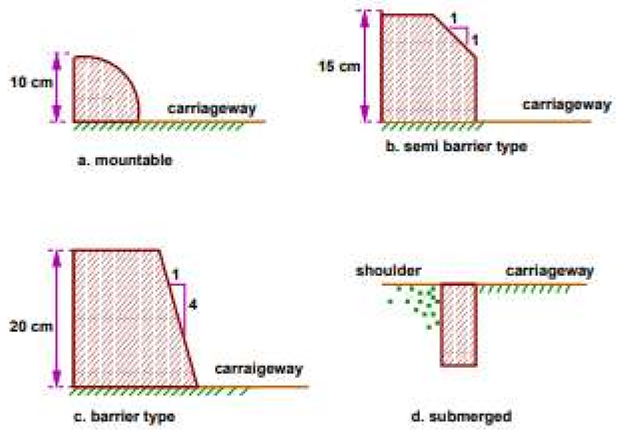
Kerbs indicate the boundary between the carriage way and the shoulder or islands or footpaths. Different types of kerbs are:

• Low or mountable kerbs : This type of kerbs are provided such that they encourage the traffic to remain in the through traffic lanes and also allow the driver to enter the shoulder area with little difficulty. The height of this kerb is about 10 cm above the pavement edge with a slope which allows the vehicle to climb easily. This is usually provided at medians and channelization schemes and also helps in longitudinal drainage.

• Semi-barrier type kerbs : When the pedestrian traffic is high, these kerbs are provided. Their height is 15 cm above the pavement edge. This type of kerb prevents encroachment of parking vehicles, but at acute emergency it is possible to drive over this kerb with some difficulty.

• Barrier type kerbs : They are designed to discourage vehicles from leaving the pavement. They are provided when there is considerable amount of pedestrian traffic. They are placed at a height of 20 cm above the pavement edge with a steep batter.

• Submerged kerbs : They are used in rural roads. The kerbs are provided at pavement edges between the pavement edge and shoulders. They provide lateral confinement and stability to the pavement.



FORMATION LEVEL:

Formation level is the reduced level of the finished surface of earthwork for a road in cutting or in embankment.

When road is constructed in embankment formation level kept above high flood level in the area.
When road is constructed in cutting formation level kept above sub –soil water table.

CAMBER:

Camber or cant is the cross slope provided to raise middle of the road surface in the transverse direction to drain off rain water from road surface. The objectives of providing camber are:

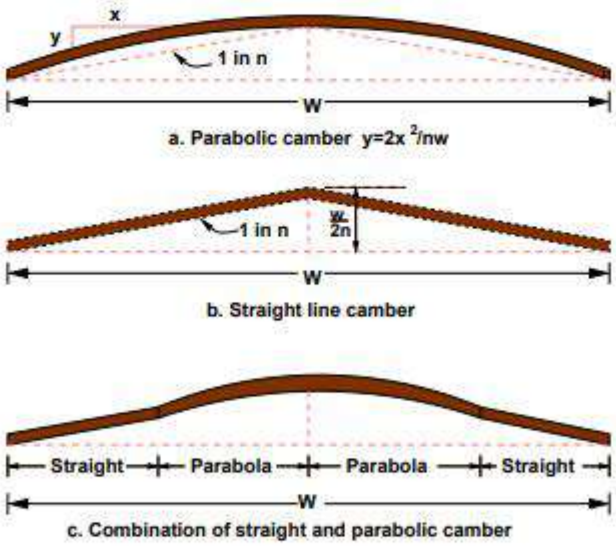
• Surface protection especially for gravel and bituminous roads

• Sub-grade protection by proper drainage

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

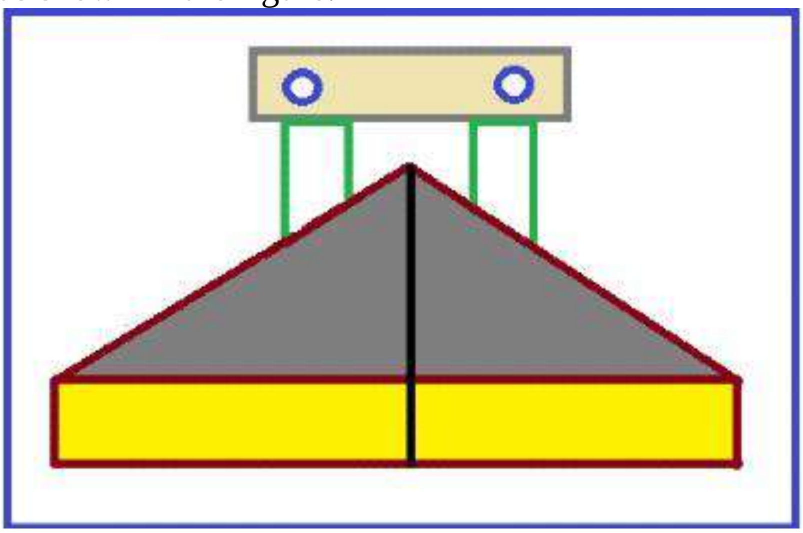
Surface type	Heavy rain	Light rain
Concrete/Bituminous	2 %	1.7 %
Gravel/WBM	3 %	2.5 %
Earthen	4 %	3.0 %

The common types of camber are parabolic, straight, or combination of them.



So the appropriate value of camber is desired but heavy camber has got the following disadvantages.

1) To counteract or neutralize the effect of heavy camber driver wants to use the central track as shown in the figure.



Due to this:-

- The possibility of an accident is high
- The central portion of the road surface on one and the same wheel track gets excessively worn.
- Due to the rigidity of wheelbase, wear and tear of tires are also high.

2) The transverse tilt of vehicles causes uncomfortable side thrust and drag on the steering of the vehicle.

3) In double roads presence of crown due to the provision of camber makes the overtaking operation more dangerous due to the "air born" effect, possibly especially at high speed.
4) low-cost surface and shoulder will be excessively eroded due to the increased velocity of surface water. This leads to the formation of cross ruts.
5) In steep camber, there is the possibility of the overturning of the vehicle

GRADIENT:

It is the rate of rise or fall of road level along its length. It is expressed either as the rate of rise or fall to the horizontal distance or as percentage rise or fall.

In India usually, former practice is used. The gradient of pavement is governed by the following factors :

1. Characteristics of traffic.
2. Physical factors of the site such as drainage, safety, appearance, access to adjacent property.
3. Bridge, approach road and railway, line-intersection etc.

Type of Gradient

1. Maximum Gradient
2. Ruling Gradient
3. Minimum Gradient
4. Exceptional Gradient

Maximum Gradient

It is the maximum or steepest gradient which is allowed to be provided in a road which must never exceed in any part of the road as steeper gradients are very inconvenient to the traffic, more especially for the slow-moving traffic..

The maximum gradient is allowed to be provided when compelled by the topography of the area to affect a large reduction in the cost of earthwork. Long stretches of such gradient should be separated comparatively flatter gradient or a level section. Thus it is also called a limiting gradient. IRC has recommended the following values of the maximum gradient:

In Flat or Rolling Terrain – 1 in 20

Hilly Terrain – 1 in 15

Ruling Gradient

This is the desirable upper limit or permissible limit of the gradient in the alignment of the road. This is governed by the mode of transport in the locality. Thus a design engineer must aim to provide a gradient within the ruling gradient limits keeping in view the mode of traffic and topography.

This gradient should be such that animal-driven vehicles can overcome long stretches without much fatigue of animals and power-driven vehicles without uneconomical fuel consumption. Indian Road Congress has suggested the value of ruling gradients as below.

In Flat or Rolling Terrain – 1 in 30

Hilly Terrain – 1 in 20

Minimum Gradient

The gradient provided on flat or level road to drain off the rainwater is called minimum gradient. It should be sufficient to drain off the rainwater from the pavement surface. Its value depends upon the topography, type of soil, run-off and other sites conditions.

In general 1 in 200 gradients is sufficient but for cement concrete surface a grade of 1 in 500 is quite sufficient. The 0.5% value may be reduced to 0.30 % for a good quality surface supported on a firm and accurately crowned sub grade.

Exceptional gradient : During the alignment of the road, there may be situations where grades may have to be provided with either lesser than the minimum or greater than the maximum.Thus exceptional gradients are provided in exceptional situations such as in approaches to causeways or near hairpin bends etc. this gradient should be provided only for very short stretches not exceeding 60 to 100 meters in one-kilometer length and should be separated by a minimum length of 100 m .

Disadvantages of Exceptional Gradients

1. More Fuel consumption
2. More friction losses
3. The efficiency of the engine reduces
4. Early fatigue to animals
5. More wear and tear to the pavement surface and vehicle too.

The maximum, ruling and exceptional gradients as recommended by Indian Road Congress

S.No.	Type of Terrain	Gradient		
		Ruling	Limiting or Max	Exceptional
1.	Plain or Rolling	1 in 30 (3.3%)	1 in 20 (5%)	1 in 15 (6.7%)
2.	Mountainous and steep Terrain with	1 in 20 (5%)	1 in 16.7 (6%)	1 in 14.3 (7%)
3.	Elevation more than 3000 m. Steep terrain up to 3000 m height	1 in 16.7 (6%)	1 in 14.3 (7%)	1 in 12.7 (8%)

OBJECTIVE OF PROVIDING GRADIENT:

1. To connect the terminal station situated at different vertical levels.

2. To reduce the maintenance cost of road surface.

3. To provide effective drainage of rainwater falling over the road surface.

DESIGN SPEED:

The design speed may be defined as the maximum continuous speed at which most of the vehicle will move with safety.

Design speed is the most important factor on which various road geometric elements depend.

The design speed depends upon the following factors:

1) Type and physical condition of the road surface.

2) Nature, type and intensity of traffic.

3) Type of curve along the road.

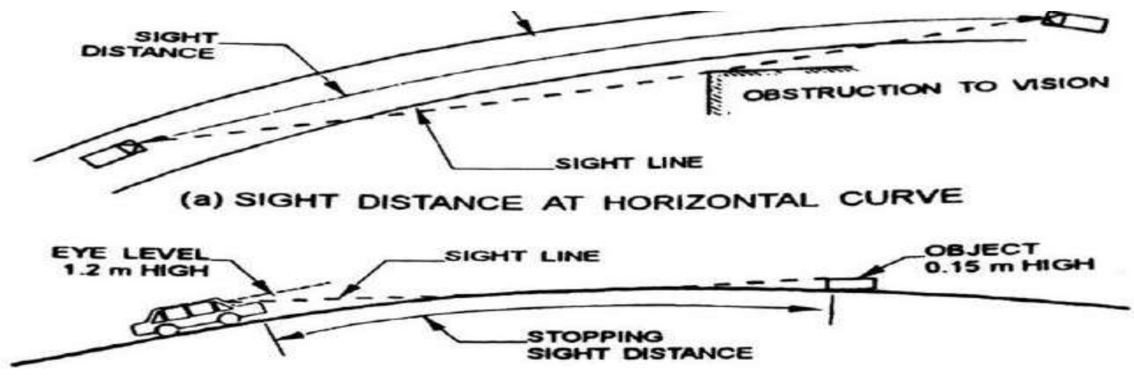
AVERAGE RUNNING SPEED:

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

Average running speed (km/hr) = Distance travelled/Actual time taken.

SIGHT DISTANCE:

Sight distance is the actual distance along the center line of a road at which a driver has visibility of an object, stationary or moving, at a specified height above the carriageway.



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.

4. **Frictional resistance between the tyre and the road**

The frictional resistance between the tyre and road plays an important role to bring the vehicle to stop. When the frictional resistance is more, the vehicles stop immediately. Thus sight required will be less. No separate provision for brake efficiency is provided while computing the sight distance. This is taken into account along with the factor of longitudinal friction. IRC has specified the value of longitudinal friction in between 0.35 to 0.4.

5. **Gradient of the road.**

Gradient of the road also affects the sight distance. While climbing up a gradient, the vehicle can stop immediately. Therefore sight distance required is less. While descending a gradient, gravity also comes into action and more time will be required to stop the vehicle. Sight distance required will be more in this case.

Stopping sight distance

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

There is a term called *safe stopping distance* and is one of the important measures in traffic engineering. It is the distance a vehicle travels from the point at which a situation is first perceived to the time the deceleration is complete. Drivers must have adequate time if they are to suddenly respond to a situation. Thus in highway design, sight distance at least equal to the safe stopping distance should be provided. The stopping sight distance is the sum of lag distance and the braking distance. Lag distance is the distance the vehicle traveled during the reaction time t and is given by vt, where v is the velocity in m/sec^2. Braking distance is the distance traveled by the vehicle during braking operation. For a level road this is obtained by equating the work done in stopping the vehicle and the kinetic energy of the vehicle. If F is the maximum frictional force developed and the braking distance is l, then work done against friction in stopping the vehicle is $Fl = fWl$ where W is the total weight of the vehicle. The kinetic energy at the design speed is

$$\begin{aligned} \frac{1}{2}mv^2 &= \frac{1}{2}\frac{Wv^2}{g} \\ fWl &= \frac{Wv^2}{2g} \\ l &= \frac{v^2}{2gf} \end{aligned}$$

Therefore, the SSD = lag distance + braking distance and given by:

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

Where v is the design speed in m/sec^2, t is the reaction time in *sec*, g is the acceleration due to gravity and f is the coefficient of friction. The coefficient of friction f is given below for various design speed.

Coefficient of longitudinal friction

Speed, kmph	<30	40	50	60	>80
f	0.40	0.38	0.37	0.36	0.35

Stopping sight distance at slopes

When there is an ascending gradient of say $+n\%$, the component of gravity adds to braking action and hence braking distance is decreased. The component of gravity acting parallel to the surface which adds to the the braking force is equal to $W \sin \alpha \approx W \tan \alpha = Wn/100$. Equating kinetic energy and work done:

$$\left(fW + \frac{Wn}{100}\right) l = \frac{Wv^2}{2g}$$

$$l = \frac{v^2}{2g\left(f + \frac{n}{100}\right)}$$

Similarly the braking distance can be derived for a descending gradient. Therefore the general equation is given by Equation

$$SSD = vt + \frac{v^2}{2g(f \pm 0.01n)}$$

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 steeper slope. The dotted line indicates the path of the vehicle A if B was absent. The vehicle A slows down to follow the vehicle B as shown in the figure with same slope from t_0 to t_1. Then it overtakes the vehicle B and occupies the left lane at timet_3. The time duration $T = t_3 - t_1$ is the actual duration of the overtaking operation. The snapshots of the road at time t_0,t_1, and t_3 are shown on the left side of the figure. From the Figure 1, the overtaking sight distance consists of three parts.

1. d_1 the distance traveled by overtaking vehicle A during the reaction time $t = t_1 - t_0$
2. d_2 the distance traveled by the vehicle during the actual overtaking operation $T = t3 - t1$
3. d_3 is the distance traveled by on-coming vehicle C during the overtaking operation (T).

Therefore:

$$OSD = d_1 + d_2 + d_3$$

CURVES:

A curve is nothing but an arc which connects two straight lines which are separated by some angle called deflection angle. Or the geometrical arcs provided at the change in alignment (horizontal plane) or gradient (in vertical plane) of a road are knows as curves.This situation occurs where the alignment of a road way or rail way changes its direction because of unavoidable objects or conditions. The object may be a hill or a lake or a temple etc. so, for the ease of movement of vehicle at this points a curve is provided.

Types of Curves in Alignment of Highways

In general, there are two types of curves and they are

- Horizontal curves
- Vertical curves

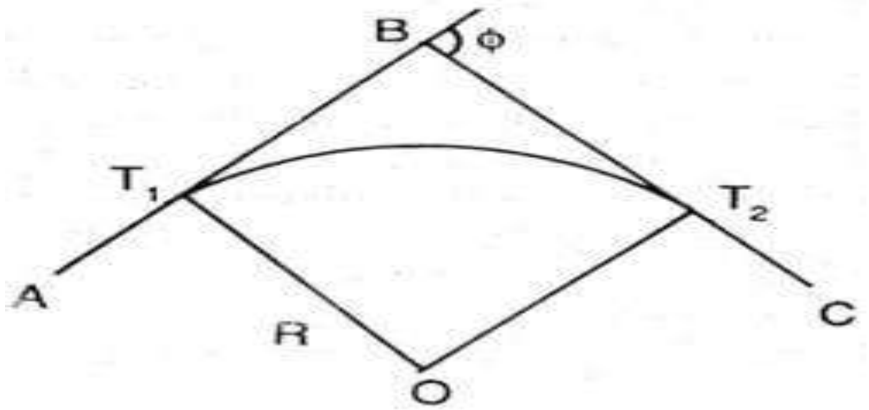
Horizontal Curves

The curve provided in the horizontal plane of earth is called as horizontal curve. In connects two straight lines which are in same level but having different directions. Horizontal curves are of different types as follows

- Simple circular curve
- Compound curve
- Reverse curve
- Transition curve
- Spiral
- Lemniscate

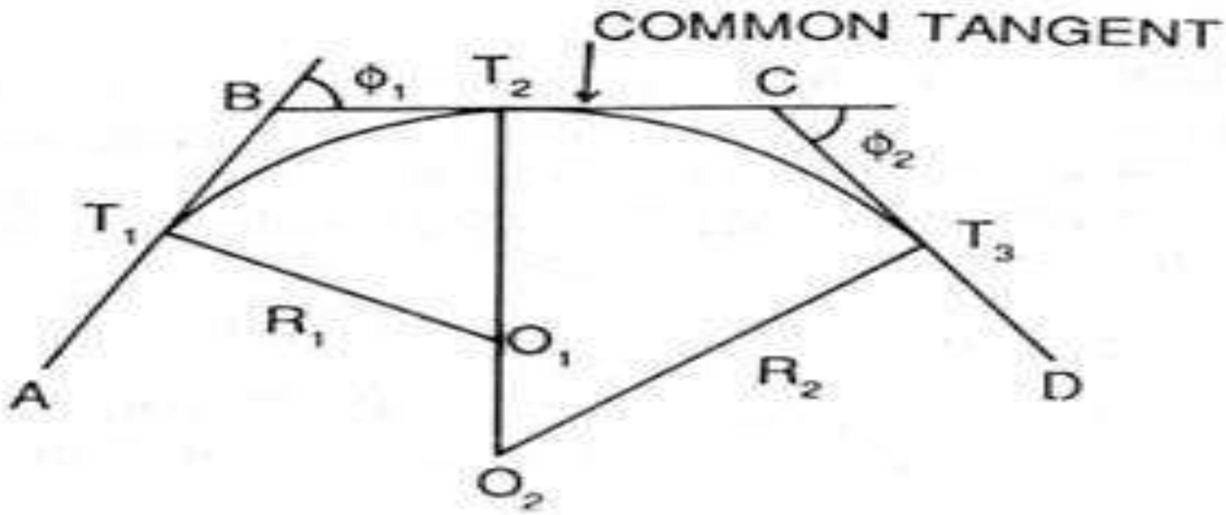
Simple Circular Curve

Simple circular curve is normal horizontal curve which connect two straight lines with constant radius.



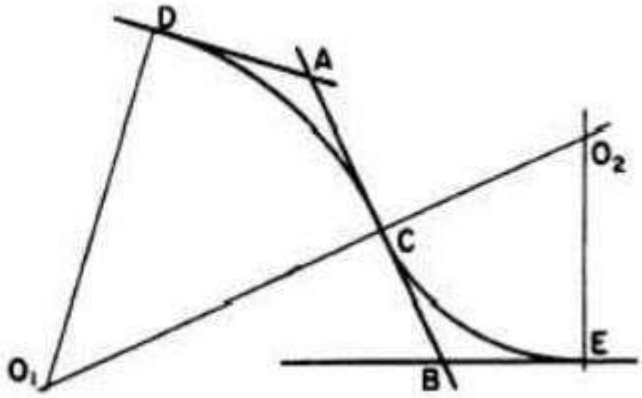
Compound Curve

Compound curve is a combination of two or more simple circular curves with different radii. In this case both or all the curves lie on the same side of the common tangent.



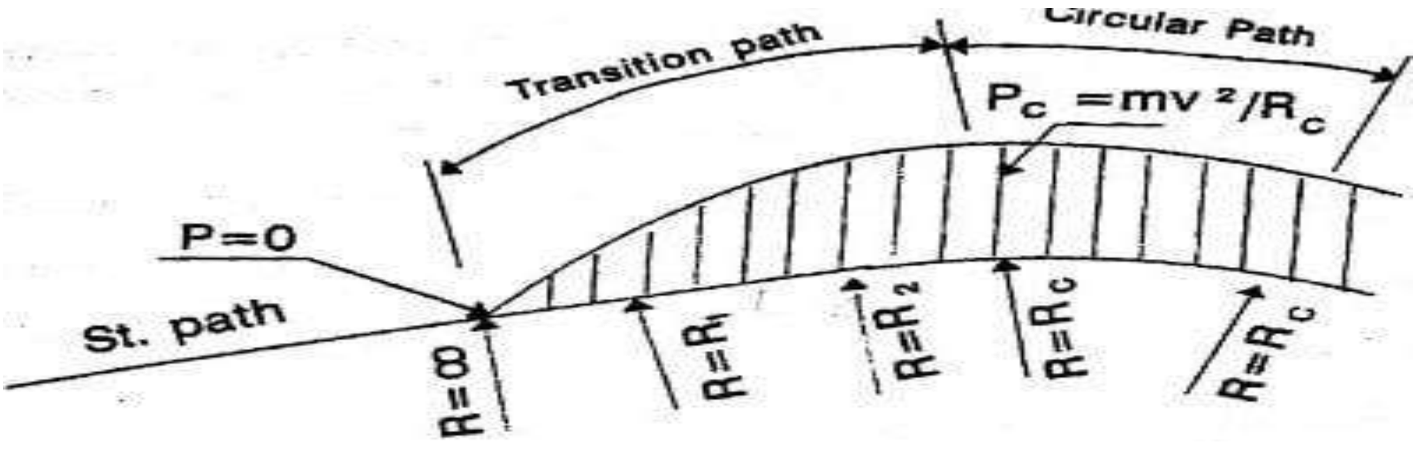
Reverse Curve

Reverse curve is formed when two simple circular curves bending in opposite directions are meet at a point. This point is called as point of reverse curvature. The center of both the curves lies on the opposite sides of the common tangent. The radii of both the curves may be same or different.



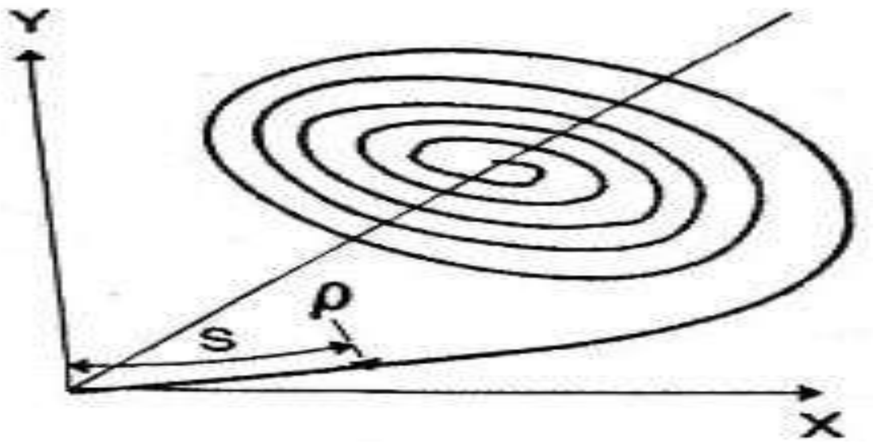
Transition Curve

A curve of variable radius is termed as transition curve. It is generally provided on the sides of circular curve or between the tangent and circular curve and between two curves of compound curve or reverse curve etc. Its radius varies from infinity to the radius of provided for the circular curve.Transition curve helps gradual introduction of centrifugal force by gradual super elevation which provides comfort for the passengers in the vehicle without sudden jerking.



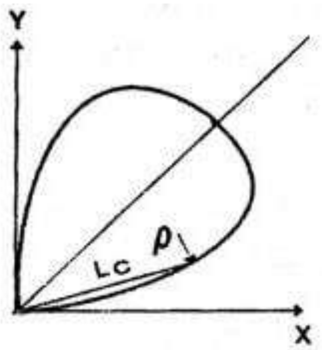
Spiral Curve

Spiral is a type of transition curve which is recommended by IRC as ideal transition curve because of its smooth introduction of centrifugal acceleration. It is also known as clothoid.



Lemniscate

Lemniscate is a type of transition curve which is used when the deflection angle is very large. In lemniscate the radius of curve is more if the length of chord is less.



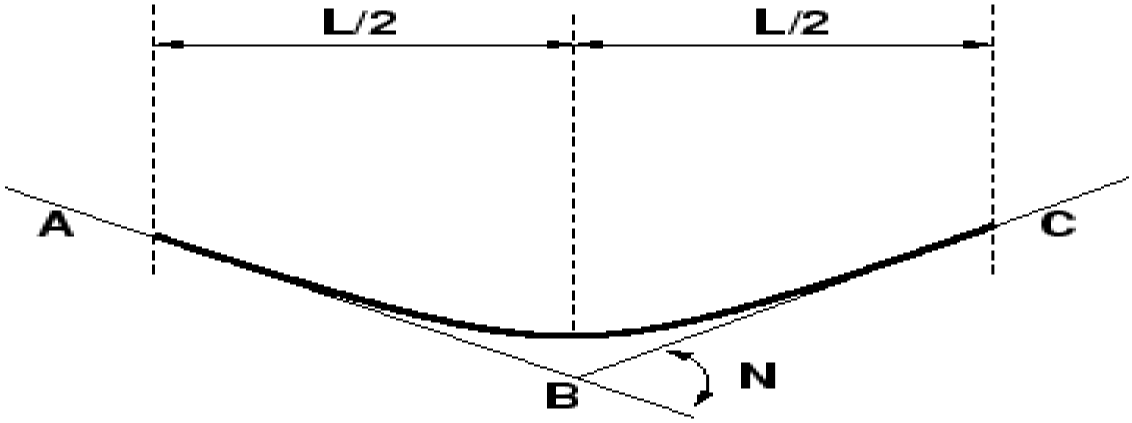
Vertical Curves

The curves provided in vertical plane of earth are called as vertical curve. This type of curves is provided when the ground is non-uniform or contains different levels at different points. In general parabolic curve is preferred as vertical curve in the vertical alignment of roadway for the ease of movement of vehicles. But based on the convexity of curve vertical curves are divided into two types

- Valley curve
- Summit curve

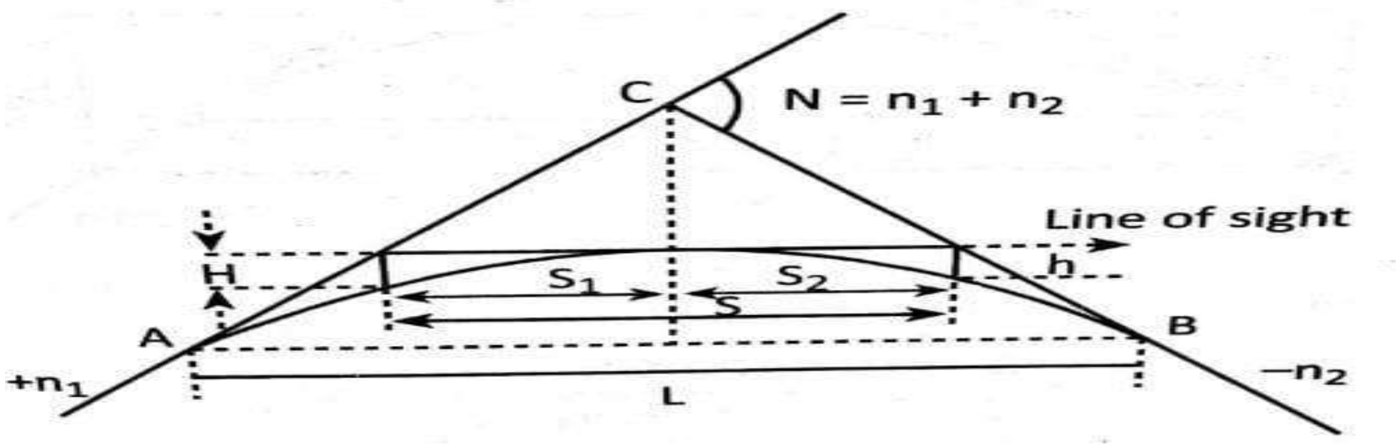
Valley Curve

Valley curve connects falling gradient with rising gradient so, in this case convexity of curve is generally downwards. It is also called as sag curve.



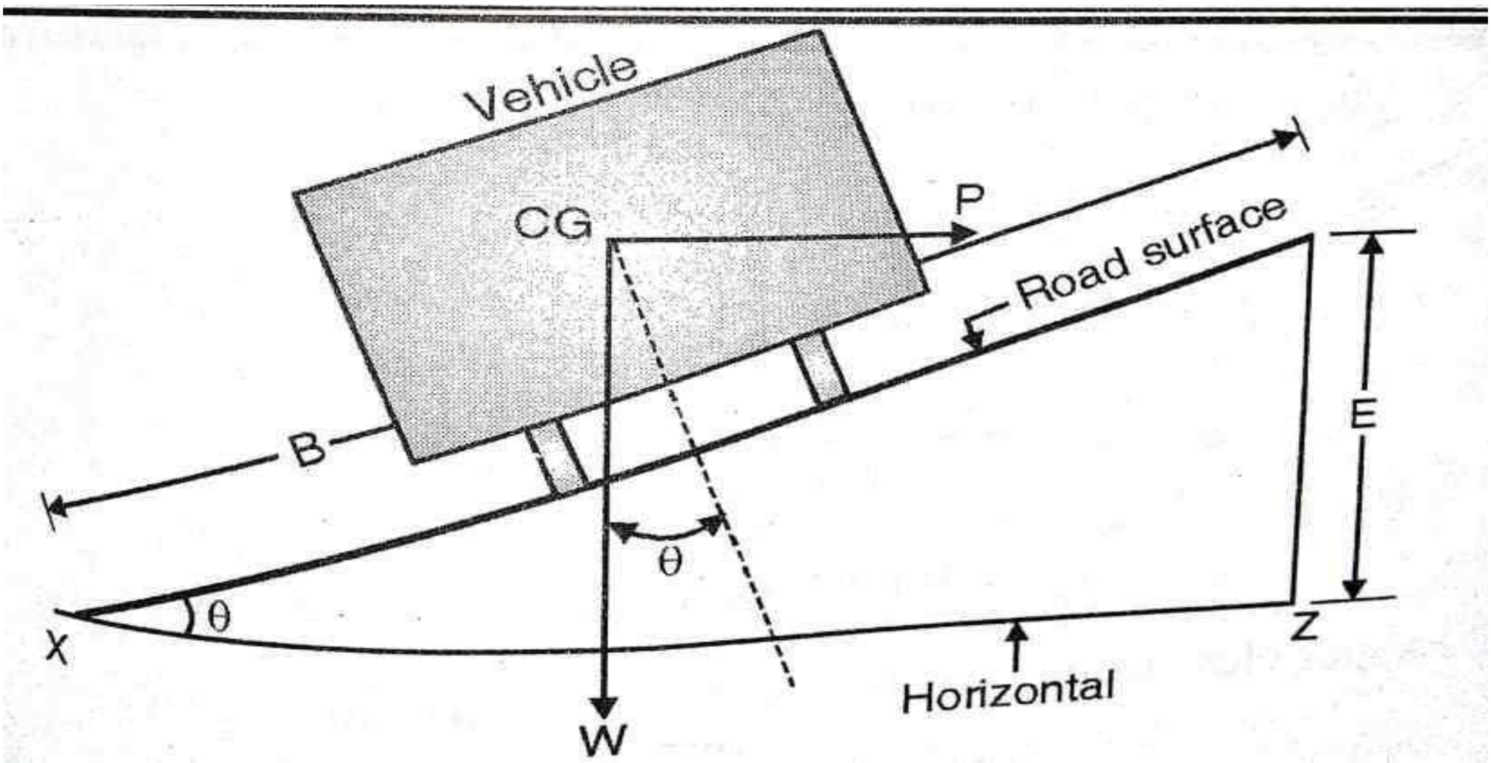
Summit Curve

Summit curve connects rising gradient with falling gradient hence, the curve has its convexity upwards. It is also called as crest curve.



Super Elevation:

The inward transverse inclination provided to cross section of carriage way at horizontal curved portion of the road is called as Super Elevation. It is also referred as to Cant or Banking



Objectives :

- To counteract the effect of centrifugal force acting on moving vehicle.
- To help a fast moving vehicles to negotiate a curved path Without overturning and skidding.
- To ensure smooth and safe movements of passengers and goods on the road.
- To prevent damaging effect on the road surface due to improper distribution of load.
- The maintenance cost of road on curve is reduced.

How to Calculate Super Elevation ?
For Example : Calculate the super elevation required for road of 7 m wide on a curve of 250 m radius for permissible speed of 80 kmph. Let the coefficient of friction be 0.15.

The formula for calculating is given below :

$$e + f = \frac{V^2}{g.R} = \frac{V^2}{127.R}$$

Where,

e=Superelevation.

f=coefficientfriction.

v=speed(kmph).

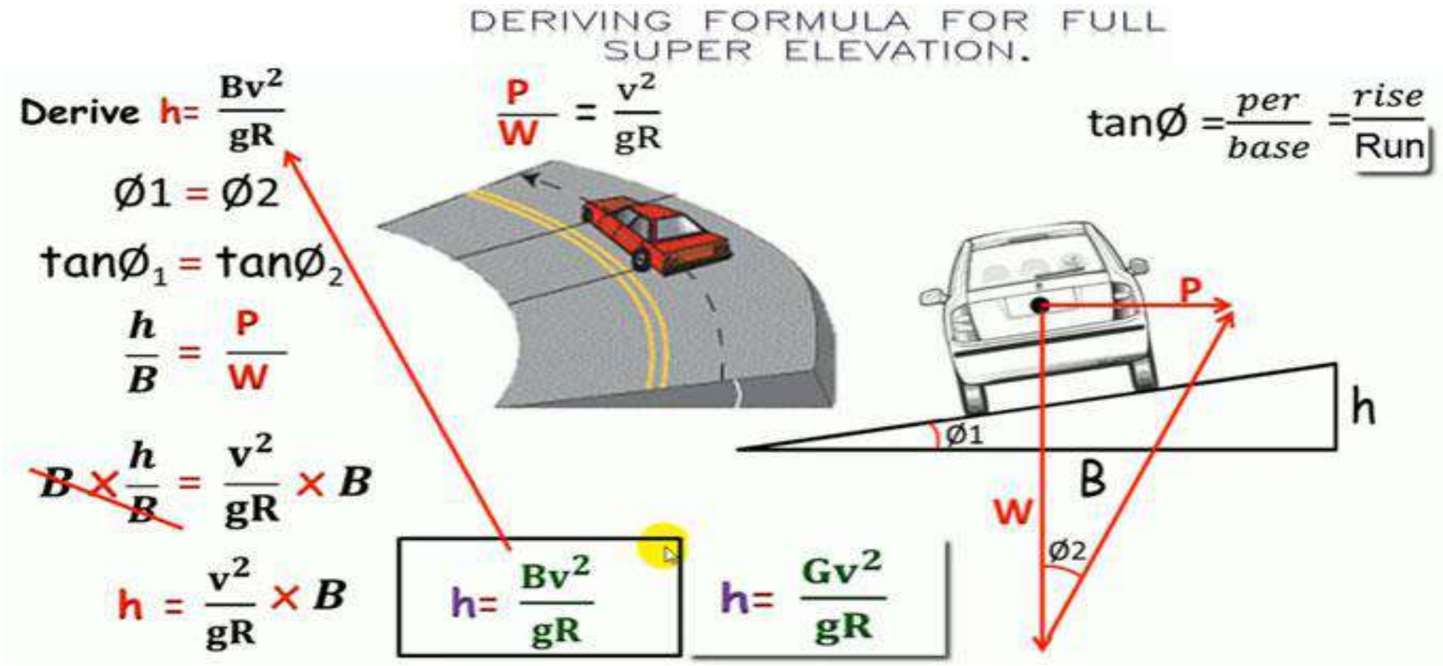
R = Radius of the curve in metre.

Putting all the values in the formula we get,

$$e + 0.15 = \frac{80^2}{127 * 250} = 0.201$$

∴ e = 0.201 – 0.15 = 0.051 per meter of carriage way.

∴ Super elevation = 0.051 * 7 = 0.357 m or 35.7 cm above the inner edge of the road.



Minimum and Maximum Super Elevation.

- If the elevation is less than the value of camber of a road, it should be kept equal to the camber of the road for drainage purpose.
- In case of flat curves with large radius, the super elevation will be negligible, as the centrifugal force which will be developed will be very small. Under such condition, the normal camber may be retained also on the curve.
- But, such a practice will result into negative elevation on the outer half of the road.
- The centrifugal force combined with negative elevation will be less than allowable friction coefficient.
- Below shows the recommended radius of horizontal curves beyond which normal cambered section may be maintained without the provision of super-elevation.
- Max value of super elevation does not exceed this values.

In plain and rolling terrain -7 %

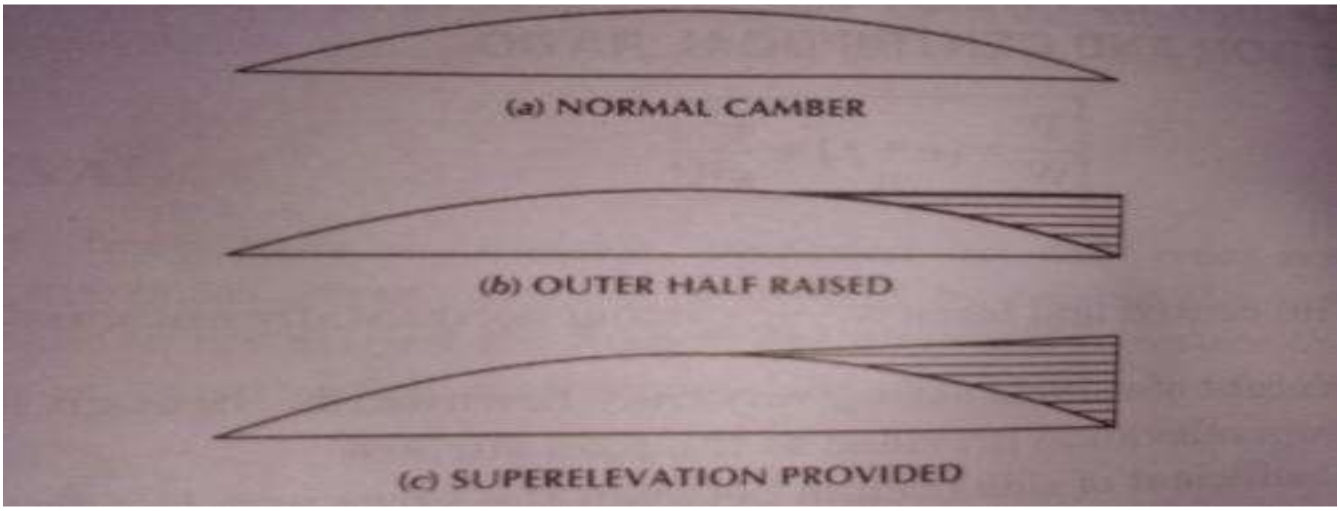
In hilly roads not bound by snow -10 %

Methods of introducing super elevation

- Elimination of the crown of the cambered section.
- Rotation of the pavement cross-section to attain full super elevation

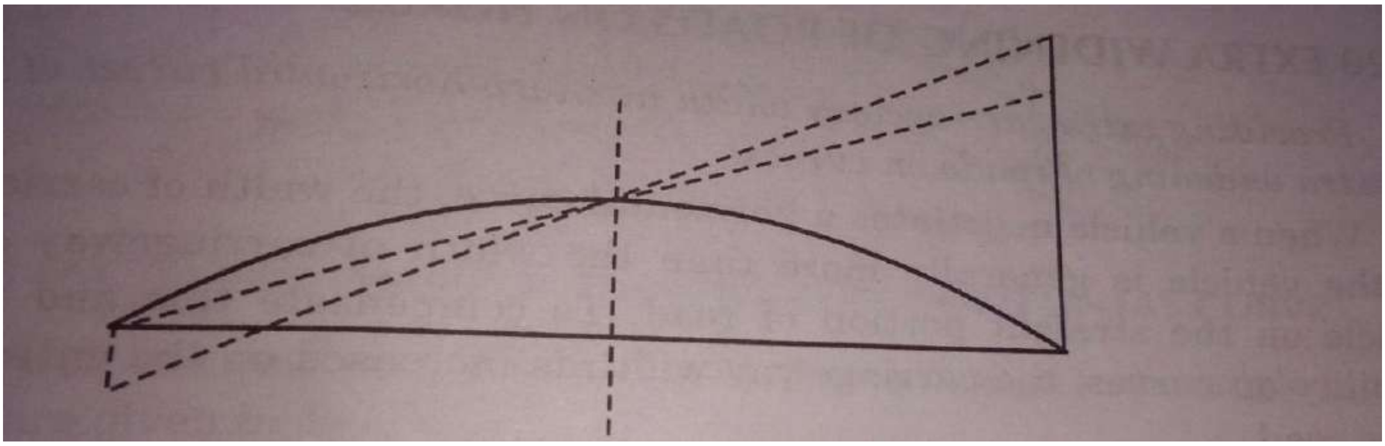
Elimination of the crown of the cambered section.

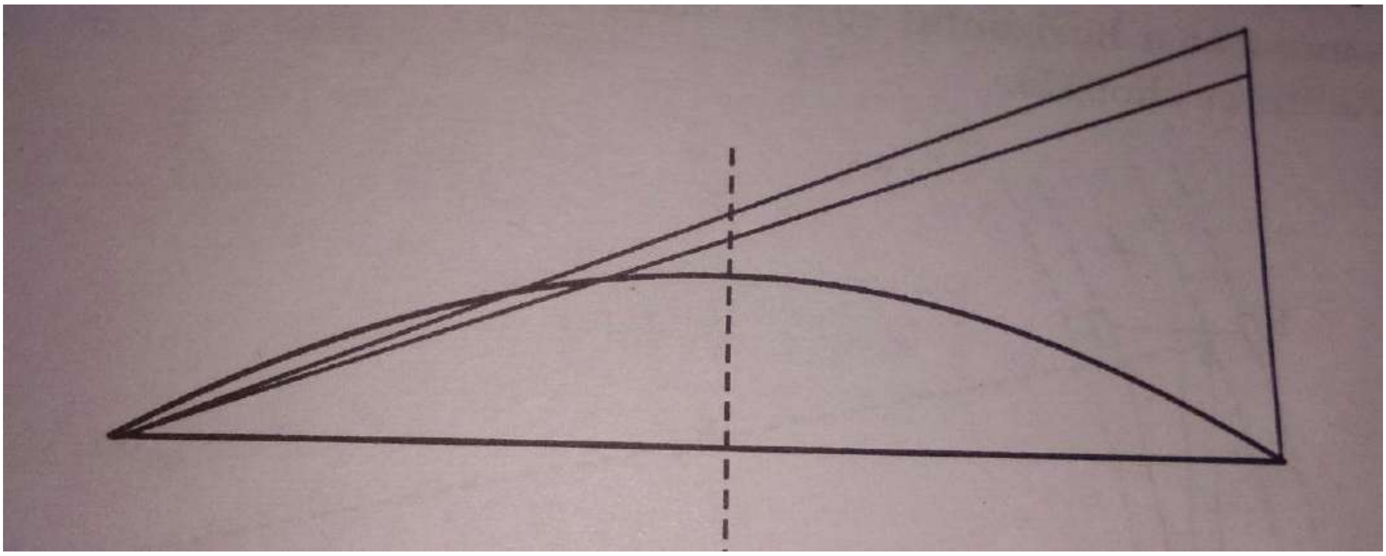
1. The outer edge half of the cross slope rotated the crown at the desire rate such that its surface falls on the same plane as the inner half.
2. The position of the crown is progressively shifted outwards which increases the width of the inner half of the cross-section progressively. It is also called a diagonal crown method.

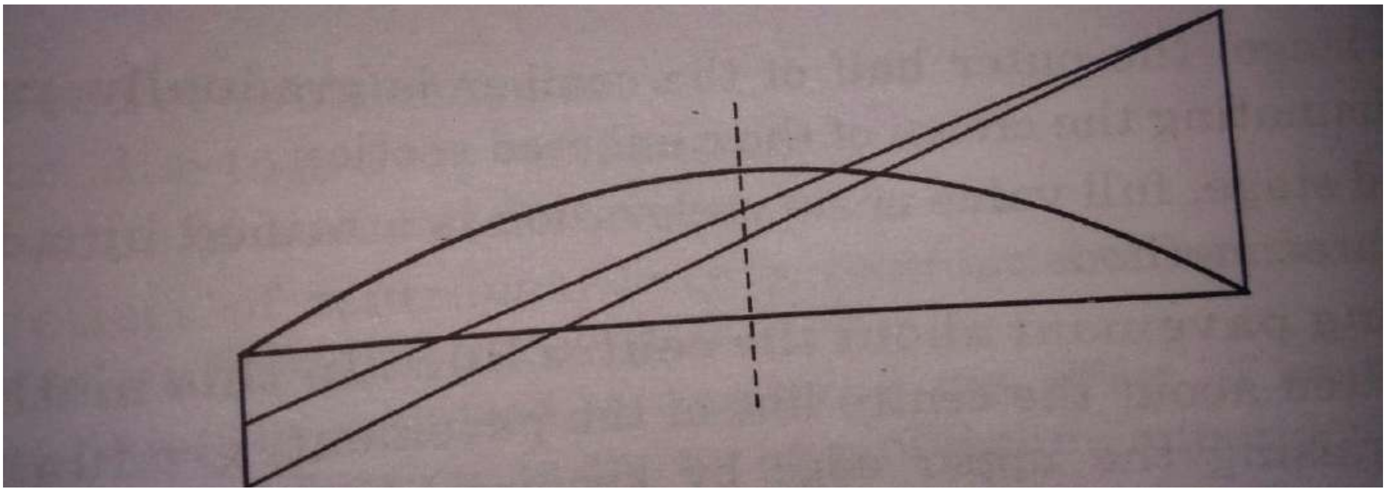


Rotation of the pavement cross-section to attain full superelevation.

1. **Rotation about the centre line** – this method involves progressively revolving the straight road surface about the centre line depressing the inner edge and rising the outer edge simultaneously an amount of half the total amount of super elevation. Thus the earthworks are balanced. This disadvantage of the method are drainage.
2. **Rotation about the inner edge**. This method involves progressively revolving the straight road surface about the inner edge thereby raising the centre line and outer edge proportionality to desire slope. The outer edge raised by a full super elevation. This method is preferred in very flat terrain in high rainfall areas in order to avoid drainage problem.
3. **Rotation about the outer edge**. This method involves progressively revolving the straight road surface about the outer edge thereby depressing the centre line and the outer edge proportionality to the desired slope. Here the inner edge is depressed by the full amount of super elevation with respect to the outer edge.







Advantages of providing superelevation

1. It permits high speed to be maintained on a curve as on a straight, without any danger and thus results in an increased volume of traffic.
2. The vehicle keeps to the correct side.
3. Super elevation less the danger skidding.
4. Super elevation of the pressure on the wheels is equally distributed load on the road.

Extra Widening Of Pavement On Curve Road

When a vehicle takes a turn to negotiate a horizontal curve, the rear wheels do not follow the same path as that of the front wheels. Normally the rear wheels follow the inner path on the curve as compared with front wheels.

The vehicle has occupies more width that it occupies on straight portion of the road. To compensate this, the carriageway width increased on the entire curved portion of the road, which is called **extra widening of pavement on curve.**

Types of extra widening of roads

1. Extra widening due to psychological reasons. (Wep)

While negotiating a horizontal curve, the driver has a tendency to follow the inner of the pavement. This reduces the effective width of the pavement at curves. In order to have a smooth operation at curves, you need to provide an extra widening at the curve of the road.

The IRC recommended a value of extra widening formula for psychological reasons

Wep = V / 9.5 √r

2. Mechanical Widening (Wem)

While negotiating a curve, rear wheels have a tendency to follow the inner track. To accommodate this, there will be a widening is provided called mechanical widening have to be provided. This is due to the offtracking of the vehicle.

The off-tracking in a highway is one the main criteria during curve widening design.

The IRC value for the mechanical widening is given by

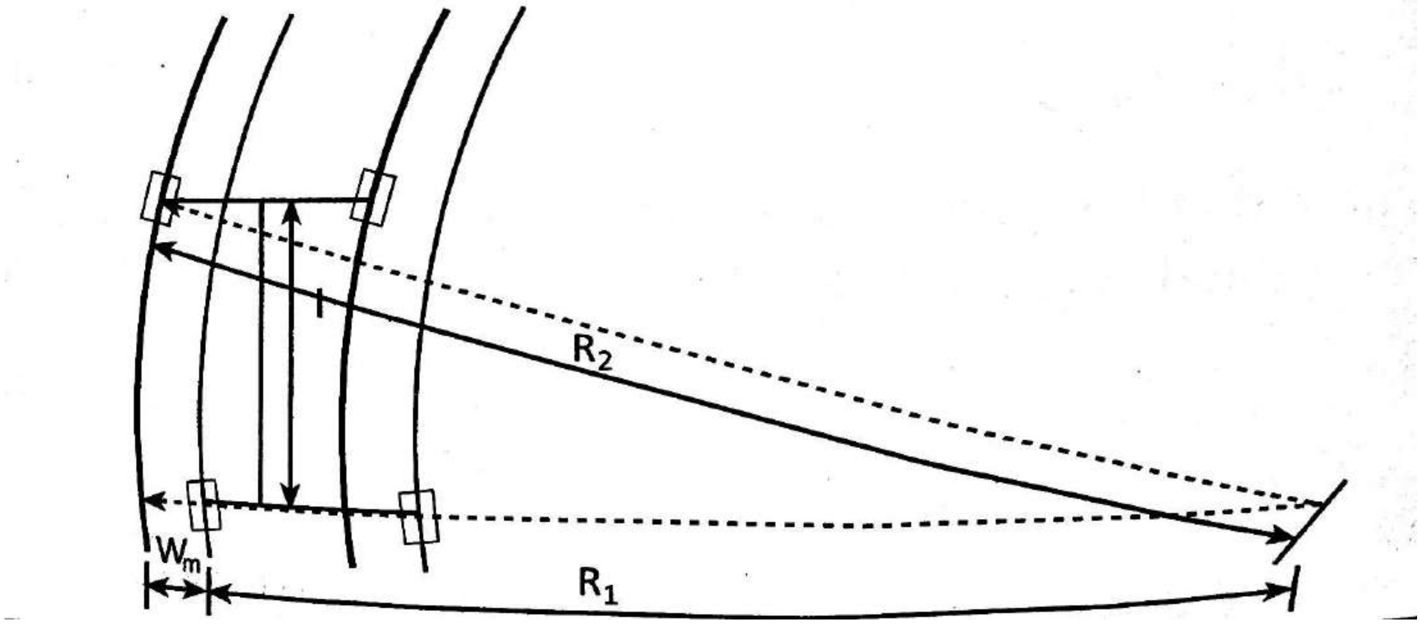
Wem = $nl^2 / 2R$

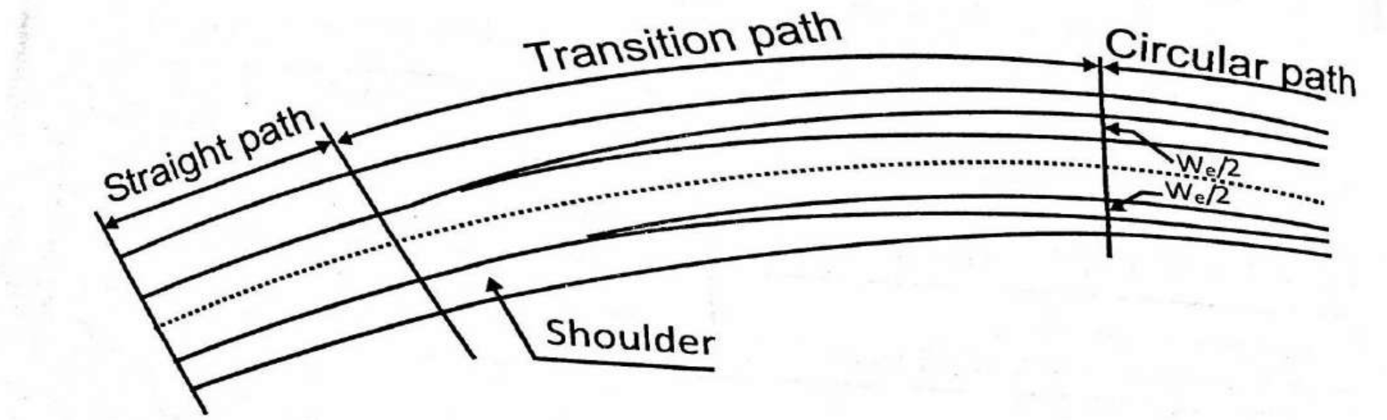
- n=Number of lanes
- l=Length of the curve
- R=Radius of curve or curvature

Therefore

Total extra widening formula is= Wep +Wem

$$= V / 9.5 \sqrt{r} + nl^2 / 2R$$





Necessity of Providing Extra Widening of Pavement on Curve

On curves, the following difficulties are observed, that why extra widening of pavement on a curve are provided:

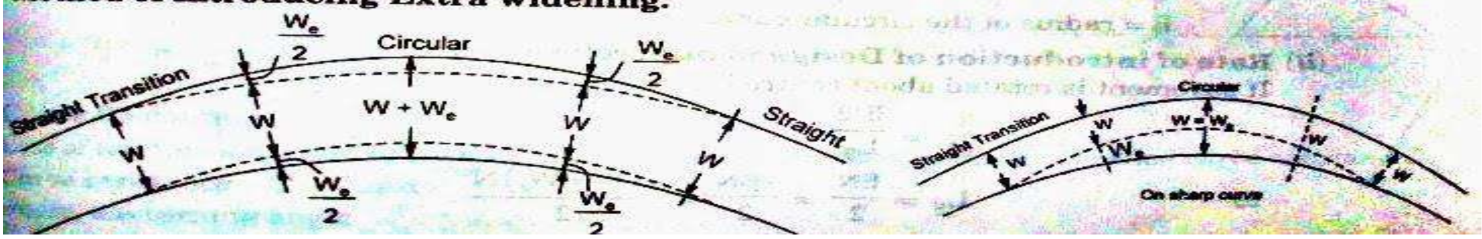
1. On curves, the vehicles occupy a greater width because the rear wheels follow the inner path as compared to the front wheel.

2. On curves, drivers have difficulty in steering their vehicle to keep to the center line of the road.

3. Drivers have psychological fear to drive close to the edge of the pavements on curves.

Radius of Curve (m)	*Upto 20 m*	*20-40 m*	*41-60 m*	*61-100 m*	*101-300 m*	*Above 300 m*
Extra width (m)						
Two-lane	1.5	1.5	1.2	0.9	0.6	Nil
Single-lane	0.9	0.6	0.6	Nil	Nil	Nil

Method of Introducing Extra widening.



3. HIGHWAY SURVEYS AND PLAN

HIGHWAY SURVEYS: Highway surveys or road surveys are the various stages of examination of an area for the finalization of a new road in an economical manner.

Highway surveys are conducted in the following four stages:

1) Map study

2) Reconnaissance survey

3) Preliminary survey

4) Location survey

TOPOGRAPHIC MAP : This is a map of an area in which general detail of that area such as building, hospitals ,school, roads, railway line, source of water , drainage system etc.

MAP STUDY: The process of marking several possible alternative of a road on the topographic map of an area is known as map study.

ROAD ALIGNMENT: The route along which the centre line of a road is located in the plan or on the ground is termed as road alignment.

REQUIREMENT OF AN IDEAL ROAD ALIGNMENT

The following are the basic requirement of an ideal road alignment between two terminal stations:

1) Short 4) Economical

2) Easy 5) Utility

3) Safe

(1) Short: The alignment must be the shortest of the various alternatives available. Of course the shortest path between any two points is a straight line but the topography of the area or other factors may necessitate it do divert and take some other route, but as far as possible it should be kept minimum.

(2) Easy: Alignment should be such that the road must be easy to construct and easy to maintain or repair. If curves are of large radius and the gradient is gentle it would be easy to construct the road.

(3) Safety: Safety is again the basic requirement of the highway alignment and special care must be taken to align the road in such a way that it must have the safe or minimum Sight distances and Radius of the curves, means the geometrical design features like Sight Distance.

(4) Economical: Road alignment must be designed to have the initial cost of construction, maintenance cost and the vehicle operation cost to a minimum. Also the locally available materials should be checked before and it may decrease the overall cost. There must be a balance in the cutting and filling on the alignment of the road.

Hill roads have some other basic requirements also which govern the alignment of the hill roads:

(1) Drainage: Drainage of the road must be kept in mind and it must be insured that enough drainage structures can be built on the route. As far as possible alignment must avoid the drainage works means it must have the minimum numbers of the drainage works.

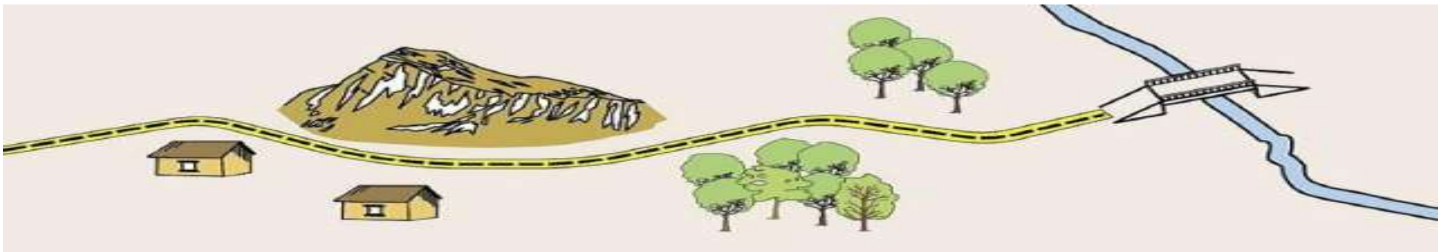
(2) Economy: Economy is governed by the numbers of the drainage works, cutting filling and the gradient.

(3) Safety: Safety is governed by the sight distance, super elevation and the design radius of the curves. It must be kept in mind that gradient must be kept below the ruling gradient. In hill roads special attention must be given to the side slopes, and thorough geological surveys must be carried out to ensure the safety while construction as well as while traffic movement.

(4) Minimum resisting length: The unnecessary rise and fall of the gradient must be minimized to reduce the cost and length of road.

FACTORS CONTROLLING ALIGNMENT OF A ROAD IN PLAIN AREA

There are a number of factors which are to be considered while selecting the alignment of roads. These factors also vary according to the type of roads and the areas through which these roads pass.



Factors controlling selection of road alignment

The factors which control alignment of roads in plain areas as under:

1. CLASS & PURPOSE

The alignment of the road may be decided keeping in mind the class and purpose of the road. National and state highways between two stations should be aligned as straight as possible whereas in the case of other types of roads, deviation may be permitted where found necessary.

2. OBLIGATORY POINTS

The roads are basically constructed for the development of the areas. Their alignments should necessarily pass through important towns, group of villages and places of religious, social, political and commercial importance.

Obligatory Points:

The control points governing highway alignment are called obligatory points. These points decide where the alignment should pass and where the alignment should not pass.

Alignment Should pass:

Roads are constructed for the development of the areas. A small deviation in alignment can be acceptable if highway passes through the towns, villages, cities etc.
If the alignment passes through the mountain, it is recommended to relook the best alternatives, either to construct the tunnel or go round the hills. The selection of the choice depends on factors like topography, site conditions and construction and operation cost

Alignment should not pass:

It is always recommended to avoid the alignment on small lakes and ponds and deviate the alignment upto some extent where required, construction of bridges on these lakes and ponds requires more funds.

The alignment should not pass through the places which are developed or having expensive buildings or high rise buildings acquisition of land at these places incurs huge initial cost and demolishing these structures takes more time. So the slight deviation in alignment is acceptable if above these points are in alignment.
The alignment should not pass through the dense forests and agricultural lands.

3. TYPE OF VEHICULAR TRAFFIC

The alignment should be provided according to the type of vehicular traffic. In case of fast moving traffic, the road alignment should be as straight as possible whereas in case of bullock carts, tongas, etc, the alignment may even have sharp bends.

4. GRADIENT

The alignment of roads should be selected so that longitudinal slopes are not steeper than ruling gradient. To achieve this, the alignment might need a deviation from straight line.

5. HORIZONTAL CURVES

The alignment of roads should be provided with flat curves wherever found necessary. In case of national and state highways, the radius of horizontal curve should not be less than 230 m. in order to have minimum radius the alignment must be changed.

6. SIGHT DISTANCE

The alignment of roads should be decided such that minimum sight distance is available for drivers of the vehicles.

7. OBSTRUCTIONS

The alignment of roads is decided keeping in mind the obstruction. For example, the alignment should be changed to avoid marshy land, ponds, wells, graveyards, historical monumental and religious sites etc.

8. CROSS DRAINAGE WORKS

The alignment should be adjusted so that minimum numbers of cross drainage work are required. To achieve this, the alignment should be chosen along the water shed line if possible.

9. BRIDGES

While crossing river, the sites should provide all the requirements needed for a good bridge construction. The alignment of the road should cross the river at 90^0 to avoid construction of skew bridge.

10. RAILWAY CROSSING

A road alignment should cross a railway preferably at 90^0.

11. FORMATION BED

The selected alignment should be through such areas which provide good formation bed.

12. EARTH WORK

To avoid excessive cutting and filling, the alignment should be changed where found necessary.

13. AGRICULTURAL LAND AND DENSE FORESTS

The alignment of roads should be decided so that costly agricultural land and dense forests are avoided for the acquisition of the land.

14. EXISTING RIGHT OF WAY (ROW)

In case upgrading a road, its existing right of way should be utilized for curtailing the cost of land acquisition.

15. PUBLIC DEMAND: The selected alignment of the road should meet the public demand of the area.

FACTORS CONTROLLING ALIGNMENT OF A ROAD IN HILLY AREA

The main factors to be considered while deciding the alignment of hill roads, are given below.

1. LENGTH

The cost of construction of a hill road per kilometer length is comparatively very high. It should therefore be ensured that length of the road connecting two stations should be minimum possible, adopting ruling gradient along its most of the length.

2. DRAINAGE:

The alignment should be parallel to the drainage line in order to provide minimum cross drainage structures.

3. SADDLES OR PASSES

While locating contour gradient of the proposed alignment of a hill road on a contour map, it should cross the ranges through saddles. Though length of the road is increased, the heavy cost of cutting through rocks is avoided. Due to increased length, ruling gradients can be suitably adjusted.

4. STABILITY OF HILL SLOPE

While deciding the alignment of hill roads, it should be ensured that the slopes are stable and not very steep. The area is not prone to landslides and settlements. This factor is of special importance in hills having sedimentary rocks.

5. GEOLOGICAL STRUCTURE

Cutting through solid hard rocks is very expensive. The alignment of roads may be suitably deviated to avoid such areas.

6. TUNNELS

Drilling of tunnels is very expensive. The long tunnels needed ventilation as well as lighting arrangement. As far as possible, tunnels should be avoided and resorted to only if other suitable alternative is not feasible.

7. VALLEYS

While deciding the alignment for crossing a river valley, due consideration should be given to avoid construction of a number of bridges on its attributes.

8. GEOMETRIC STANDARDS

The alignment of the hill roads should be selected on the hill slope which easily provides recommended geometric standards i.e. gradients, curves, sight distance etc. Hairpin bends on roads should be avoided and if found necessary, these should be on gentle and stable slopes. To have proper geometric standards, it might be necessary to change the alignment at number of places.

HIGHWAY LOCATION

The process of marking the centre line of a road finally on the ground is called highway location.

For locating a highway following field survey are undertaken:

1) Reconnaissance survey

2) Preliminary survey

3) Location survey

- After map study, engineering or field survey are carried out to finalize the highway alignment.
- The object of these surveys is to locate the alignment of a road which provides maximum transportation facilities with the minimum cost of construction and maintenance.
- For locating a highway the following engineering or field survey are undertaken.

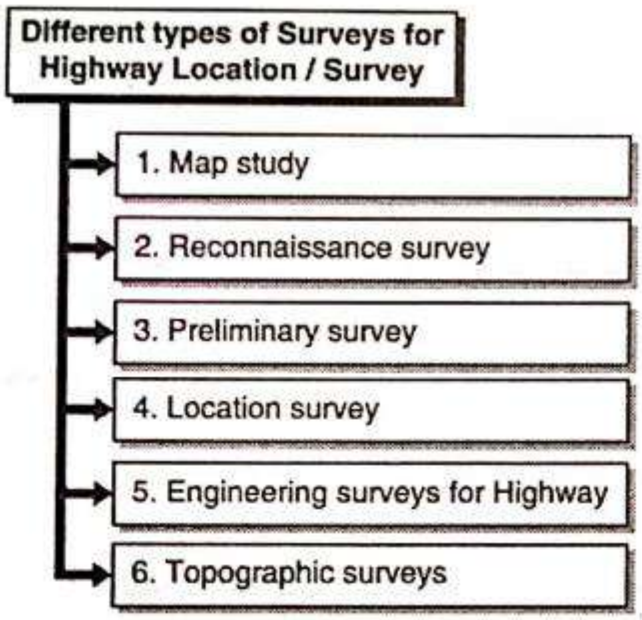


Fig. C1.12 : Different types of surveys for Highway Location / Survey

→→ **1. Map study**

- In the beginning, various data in the forms of maps, aerial photographs, charts or graphs, etc. are collected. Topographical maps are done by the survey of India are available with 15 m to 30 m contour interval.
- Maps show the various topographical features like river, hills, and valleys.
- With the proper map study at the office, it is possible to obtain the basic details to fix the alignment of roads.
- Possible alignment can be fixed based on the following details available on the map :

i) Alignment passing through valleys, lakes, and ponds.

ii) Location of bridges for crossing rivers.

iii) Availability of a mountain passing a mountain range.

iv) Joining of two stations at different elevation by taking a suitable ruling gradient.

v) Determination of length of the roadway using contour interval and ruling gradient.

→→ **2. Reconnaissance survey**

Definition

A field survey party examines the general character of a fairly broad stretch of land between the terminal stations in the field, along the proposed alternative alignments marked on the map is known as **reconnaissance survey.**

- In this survey, simple survey instruments like a prismatic compass, Abney level, tangent clinometer, barometer, etc. may be used to collect additional details rapidly.

OBJECTS

- To collect the details of obstruction along the route which are not available in the map. For example, Valleys, ponds, lakes, marshy land, ridge, hills, permanent structure, etc.
- To collect geological features of the field. For example, Soil type along the route from the field identification tests and the observation required for foundation work of bridges and construction of road pavements.
- To collect information regarding the availability of local construction material, water, and labor.
- To determine the approximate values of a gradient, length of gradients and radius of curves of alternate alignments.
- To locate the obligatory points along the alternative routes.
- To determine an approximate estimate of the total cost of construction of the road along each route.
- To determine two or three best possible routes.

→→ 3. preliminary survey

Definition: The art of finding the details of alternative alignments found suitable during the reconnaissance survey is known as **preliminary survey.**

- In a preliminary survey, the survey instruments to be used are chain type, prismatic compass, leveling instrument, plane table theodolite.

OBJECTS

1] To survey along the various alignments found after the reconnaissance and to collect all necessary physical information and details of topography, drainage, and soil.

2] To compare the different proposals in view of the requirements of good road alignment.

3] To estimate the cost of constructing the road including bridges and other construction aspects along each alternative alignment of the road.

4] To finalize the best alignment from construction, maintenance, and traffic operation point of view.

→→ 4. Location Survey

Definition

The detailed examination of the field along the alignment finally recommended during the preliminary survey is called **Location survey**.

- In this survey instruments used are theodolite, level, plane table, tape, etc.

OBJECTS

(i) The alignment finalized at the design office after the preliminary survey is to be first located on the field by establishing the centerline.

(ii) The detailed survey should be carried out for collecting the information necessary for the preparation of plans and construction details for the highway project.

(iii) To determine the cost of the total road project.

→→ 5. Engineering Surveys for Highway

Engineering Surveys

When the selection of final alignment or final centerline is done with the help of a planning survey, the next part is to perform an engineering survey.

Engineering surveys consists of three surveys to be carried out as follows.

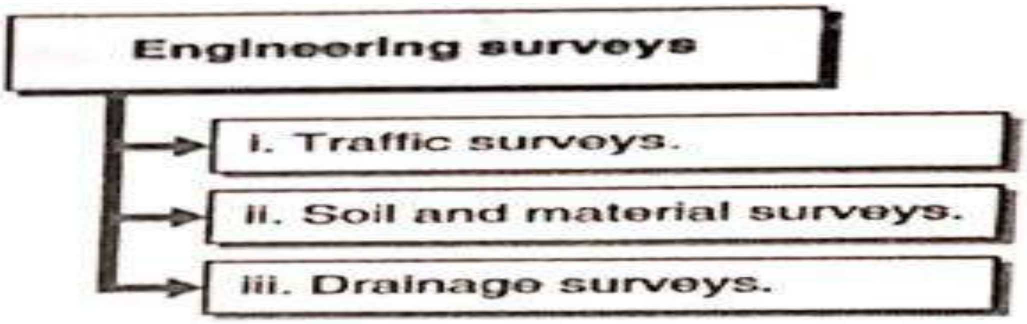


Fig. C1.13 : Engineering surveys

→→ (i) Traffic surveys

- In the case of a highway project, the detail information of traffic is much necessary so as to design the road pavement, fixing the number of traffic lanes, geometric design of roads and other economical aspects.
- Traffic surveys are started from simple traffic counts to detail of traffic nature and transportation studies. Various studies like speed studies, traffic volume studies, delays, journey time are more essential to carry out for the purpose of road design and also improvement of existing road network.

→→ (ii) Soil and material surveys

- Soil and material surveys are many important surveys since the earth work related with respect to the major portion of the road cost.
- Detailed information on various classifications of soils is collected and various field tests and laboratory test are being carried out for the purpose of their suitability for embankments.
- Hence soil investigation is more important in case of soil survey.

Materials such as road aggregates, bitumen, tar cement concrete, and any other required for the construction of the road. Hence material survey is also carried out in which its suitability, durability, availability has prime importance and varies laboratory test on-road materials are also being carried out.

→→ (iii) Drainage surveys

- Drainage surveys are required mainly for the purpose of design of cross drainage structure and survey on drainage is quite useful in fixing the gradient or grade lien of the road.

- Information about high flood level (HFL), depth of water table, rainfall intensity, etc is being collected.
- Proper drainage surveys are helpful in the good design of the surface drainage system.

→→ **6. Topographic surveys**

- Topographic surveys consist of determining the horizontal and vertical locations of objects on the surface of the earth.
- Topographic surveys show the nature of the ground or profile of ground which is the most essential part for proper road alignment.

4. ROAD MATERIALS

ROAD MATERIALS:

The different type of material used for the construction of road pavement known as road material.

The material used for highway construction can be broadly classified into the following categories :

1. Soil

2. Aggregates

3. Binder (cement , bitumen and tar)

SOIL

The top layer of ground consisting of a mixture of earthy materials with particles varying in size, shape, structure ,and chemical composition is known as soil.

TYPE OF SOILS

The common soil used in road construction are following:

1. clay

2. silt

3. sand

4. loam (mixture of sand and clay)

5. marle(mixture of minerals like quartz , calcite)

6. shale (compressed and laminated clay)

SUBGRADE SOIL

The well compacted soil which acts as a finished surface of earthwork in embankment or in cutting on which the road pavement rests is called subgrade soil.

CHARACTERISTICS OF A SUBGRADE SOIL

1. Stability

2. Durability

3. Incompressibility

4. Ease of compaction

5. Drain ability

Stability: The sub grade soil shoulder have adequate resistance to deformation under loads.

Durability: It should provide sufficient resistance to the effect of weathering agencies.

Incompressibility: The sub grade soil should have minimum variation of volume under load.

Ease of compaction: It should be easily compacted.

Drain ability: It should provide good drainage to rain water

Function of Soil as a Road Material

The soil as Roads subgrade has the following function:

1. Soil is an essential component in the road construction which is used as subgrade material.

2. It acts as an integral part of the road pavement.

3. It ensures the stability and durability of the road under adverse conditions.

4. It facilitates proper drainage for rainwater percolating through the road pavement.

5. It helps to overcome some critical defects on roads like waves, corrugation, rutting in blacktop pavement and cracking of cement concrete pavement by providing proper subgrade stability and durability.

Properties of Soil as a Road Material

The properties of soil as a road material are as follows:

1. The soil subgrade should remain stable in adverse condition.

2. It should have permanent strength.

3. It should be incompressible.

4. It should have proper drainage properties to evade excessive retention of moisture.

5. It should be easily compatible which ensures higher dry density(dry density of soil) and strength under particular type and amount of compaction.

6. It should have minimum variation in volume under adverse conditions of weather and groundwater. The minimum change in volume will ensure minimum variation in differential strength and differential expansion.

ROAD AGGREGATES

The innert mineral fragments and particles used for the construction of road pavement above the prepared subgrade are termed as road aggregrates.

Aggregates form the major portion of the pavement structure. Bear stresses occurring on the roads and have to resist wear due to abrasive action of traffic. Aggregates are also used in flexible as well as in rigid pavements. Therefore, the properties of aggregates are of considerable importance to highway.

Desirable Properties of Road Aggregates

1. Strength
2. Hardness
3. Toughness
4. Durability
5. Shape of aggregates
6. Adhesion with bitumen

1. Strength

The aggregates to be used in road construction, particularly the aggregates used in the wearing course of the pavement should be sufficiently strong/ resistant to crushing to withstand the high stresses induced due to heavy traffic wheel loads.

2. Hardness

The aggregates used in the surface course are subjected to constant rubbing or abrasion due to moving traffic. Abrasive action may be increased due to the presence of abrasing material like sand between the tyres of vehicle and the aggregates exposed to the top surface. Thus, they should be hard enough to resist the wear due to abrasive action of traffic.

3. Toughness

Aggregates in the pavement are also subjected to impact due to moving wheel loads. The magnitude of impact increase with roughness of road and speed of vehicle. Severe impact is common when heavily loaded steel tyred vehicles move on WBM. The resistance to impact or toughness is thus another desirable property of aggregates.

4. Durability

The aggregates used in roads are subjected to physical and chemical actions of rains and ground water, the impurities in them and that of atmosphere. Thus it is desirable that the road stones used in the construction should be sound enough to withstand the weathering action. The property of aggregates to withstand the adverse actions of weather may be called soundness.

5. Shape of Aggregate

Road aggregates may be rounded, angular, flaky or elongated. Flaky and elongated particles have less strength than rounded and cubical particles. Thus, too flaky and too much elongated particles should be avoided.

6. Adhesion with bitumen

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

Types of Aggregates-

1. Natural Aggregates

2. Artificial Aggregates

Natural Aggregates

Natural aggregates are found in our environment in different forms. They have different size and shape. They can resist the high compressive load. The different types of natural aggregates used in building purpose are mentioned below.

The main types of natural aggregates are sand, gravel, crushed rock such as granite, basalt etc..

You know that main origin of natural aggregates in from bedrocks. There are three classifications of bedrocks igneous rocks, sedimentary rocks and metamorphic rocks.

1. Sand

Sand is one of the main classifications of natural aggregate. You already know that sand is a finely divided granular material.

The sand is coarser than silt and finer than gravels. The major compound that consist is sand is silica. The silica is occupying in the sand in the form of quartz.

The diameter of the sand particles ranges from 0.075mm to 4,75mm. The sand is used as the fine aggregates for the purpose of concrete making.

2. Gravel

The gravel is another type of aggregates and is mainly used for as coarse aggregates in concrete. crushed stone are the examples of gravel. The size of gravel ranges from 4mm to 64 mm.

3. Crushed rock aggregates:

This type of road aggregate is obtained by crushing of natural rocks or stones to the required size.

Types of Artificial Aggregates

1.Broken bricks

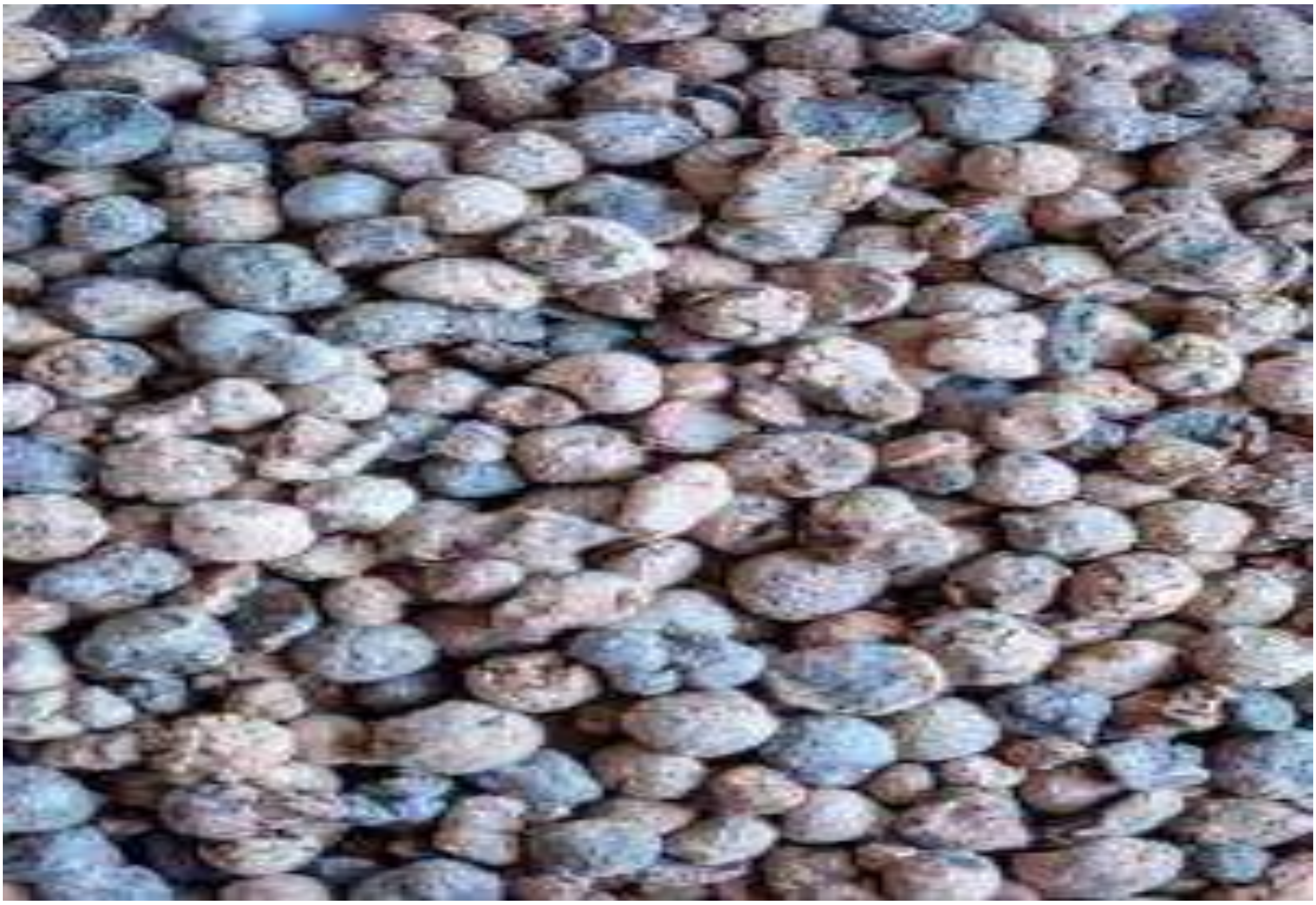
We mainly get artificial aggregates from the destruction of old buildings. Broken bricks come under in that classification.

Broken bricks are mainly used for the construction of temporary buildings.

2.Air-cooled slag

Air-cooled slag is lump ore getting from blast furnace on cooling**.**

3.Sintered Fly ash



You know that fly ash is one the main mineral admixtures used in concrete. Sintered fly ash is a lightweight material which can be used as an equivalent of stone aggregates in concrete. They can widely reduce the self-weight of the structure.

The sintered fly ash is used for bulk fill, land drainage, filter media, refractory material etc..They can locally available from thermal power plants. Sintered fly ash is cheaper than natural stones or crushed rocks.

BINDERS

The materials used in road construction for binding together the road aggregates in order to provide a smooth impermeable road surface for movement of vehicular traffic are called binder

FUNCTION OF BINDERS

1. They act as binding agent i.e they bind the surface particle together. This prevents the jumping of aggregate under the action of moving loads.

2. They make the road pavement durable i.e they resist the weathering agency

3. They act as cushion for the road surface and absorbs the kneading and abrasive action of wheel loads

4. They make the road surface impermeable i.e they seal the road surface against penetration of water**.**

Bitumen

Bitumen is defined as “A viscous liquid, or a solid, consisting essentially of hydrocarbons and their derivatives, which is soluble in trichloro-ethyelene and is substantially nonvolatile and softens gradually when heated”. It is black or brown in colour & possesses waterproofing and adhesive properties. It is obtained by refinery processes from petroleum.

Bitumen has the following five characteristic properties.

1. Bitumen Adheres
2. Bitumen is Elastic
3. Bitumen is Plastic
4. Bitumen is Viscoelastic
5. Bitumen Ages
6. Bitumen Hardens

1. BITUMEN ADHERES

Bitumen has excellent adhesive qualities provided the conditions are favorable. However in presence of water the adhesion does create some problems. Most of the aggregates used in road construction possess a weak negative charge on the surface. The bitumen aggregate bond is because of a weak dispersion force. Water is highly polar and hence it gets strongly attached to the aggregate displacing the bituminous coating.

2. BITUMEN IS ELASTIC

When one takes a thread of bitumen from a sample and stretches or elongates it, it has the ability to return to a length close to its original length eventually. For some bitumens this process may take longer than others. This property is referred to as the elastic character of bitumen.

3. BITUMEN IS PLASTIC

When temperatures are raised, as well as when a load is applied to bitumen, the bitumen will flow, but will not return to its original position when load is removed. This condition is referred to as plastic behavior. Applying a load means that you put a weight on the bitumen in order to subject it to stress. This could be in a lab or in the bitumens final position in the road and it is done to assess the bitumens reaction to the load.

4. BITUMEN IS VISCOELASTIC

Bitumen has a Visco-elastic character. Its behavior may be either viscous or elastic depending on the temperature or the load it is carrying. At higher temperatures there is more flow or plastic behavior, while at lower temperatures and short duration loading, the bitumen tends to be stiff and elastic. At intermediate temperatures it tends to be a combination of the two.

5. BITUMEN AGES

Aging refers to changes in the properties of bitumen over time, which is caused by external condition. These changes are visible as cracks or crumbling areas. When bitumen is exposed to atmospheric conditions, the bitumen molecules react with oxygen, which results in a change of the structure and composition of the bitumen. This process of combining with oxygen, called **oxidation**, causes the bitumen to become brittle and hard and to change colour from dark brown or black to grey. This change is usually referred to as **oxidative hardening** or **age hardening**. This form of ageing occurs more frequently in warmer climatic or during warm seasons, causing older pavements to crack more easily. The condition can also occur where the surface films of bitumen are thin, or if there has been inadequate compaction during construction.

6. BITUMEN HARDENS

Exposure to ultraviolet (UV) rays and the evaporation of volatile compounds can cause bitumen to harden. A volatile material is a material that can change in to a gas very quickly. There are two kinds of hardening:

- **Physical hardening**
- **Exudative hardening**

Physical hardening occurs when waxy crystals form in the bitumen structures, or when asphaltenes agglomerates clump together. This condition can be reversed if the temperature is raised.

Exudative hardening is caused by the absorption of oily components in the bitumen.

Bituminous Materials

The different types of Bituminous Materials are:

1. Asphalt
2. Tar
3. Emulsions

1. Asphalt : A bitumen containing some inert material or mineral substances is referred to as asphalt.

The term asphalt means a concrete substance cemented together by bitumen. Asphalt may be found as a natural deposite which is known as natural asphalt or prepared by distillation of crude petroleum which is known as petroleum asphalt

2. Tar:

The residual product obtained by destructive distillation of organic matter such as waterproofing material

Based on the natural organic matter from which tar is obtained as a byproduct it is referred to as coal tar or wood tar.

Coal tar is more popular and widely used for making roads and is referred as ‘road tar’. The road tar contain 72-95% of bituminous.

List Of Uses Of Different Grade Road Tar.

- RT 1 :- for surface painting under exceptionally cold weather conditions and on hill roads.
- RT 2 :- standard surface painting under normal Indian climatic condition.
- RT 3 :- surface paintings, renewal coats, premixing chips for top course.
- RT 4 :- premixing tar macadam in base course.
- RT 5 :- for grouting.

Difference between Bitumen and Tar

Sl. No.	Bitumen	Tar
1	Bitumen is found in black to brown in colour	Tar is usually found in brown colour
2	Bitumen is obtained from fractional distillation of crude oil	Tar is obtained by destructive distillation of coal or wood
3	Bitumen is soluble in carbon disulphide and carbon tetra chloride	Tar is soluble in toluene
4	Molecular weight range for road bitumen is 400 to 5000	Molecular weight range for road tar is 150 to 3000
5	Bitumen consists of large amount of aromatic hydrocarbon	Tar consist of large amount of oily matter with lower molecular weight
6	Bitumen show resistance to coating road aggregate and also does not retain in presence of water	Tar coats more easily and retain it better in presence of water
7	Free carbon content is less	Free carbon content is more
8	It shows more resistance to weathering action	It shows less resistance to weathering action
9	Less temperature susceptibility	More temperature susceptibility

EMULSION

- bitumen or refined tar broken up into fine globules and kept suspended in water, a small proportion of an emulsifier is used to facilitate the formation of dispersion,and to keep the globules in suspension.
- emulsifier usually adopted are:-
- soaps,surface active agents,and colloidal powders

USE:

1. They are used for maintenance and patch work of bituminous road .

2. They can also be use for stabilization of soils.

EMULSION

- bitumen or refined tar broken up into fine globules and kept suspended in water, a small proportion of an emulsifier is used to facilitate the formation of dispersion,and to keep the globules in suspension.
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- soaps,surface active agents,and colloidal powders

Modified Bitumen Certain additives or blend of additives called as bitumen modifiers can improve properties of Bitumen and bituminous mixes. Bitumen treated with these modifiers is known as modified bitumen.

Polymer modified bitumen(PMB)/crumb rubber modified Bitumen (CRMB) should be used only in wearing course depending upon the requirements of extreme climatic variations. The detailed specifications for modified bitumen have been issued by IRC: SP: 53-1999. It must be noted that the performance of PMB and CRMB is dependent on strict Control on Temperature during construction.

The advantages of using modified bitumen are as follows:

1. Lower susceptibility to daily and seasonal temperature variations

2. Higher resistance to deformation at high pavement temperature

3. Better age resistance properties

4. Higher fatigue life for mixes

5. Better adhesion between aggregates and binder

6. Prevention of cracking and reflective cracking.

TESTING OF ROAD MATERIALS

CALIFORNIA BEARING RATIO TEST (SOIL SUBGRADE)

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.

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 at least 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. Load values are measured by proving ring attached to the machine.

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.

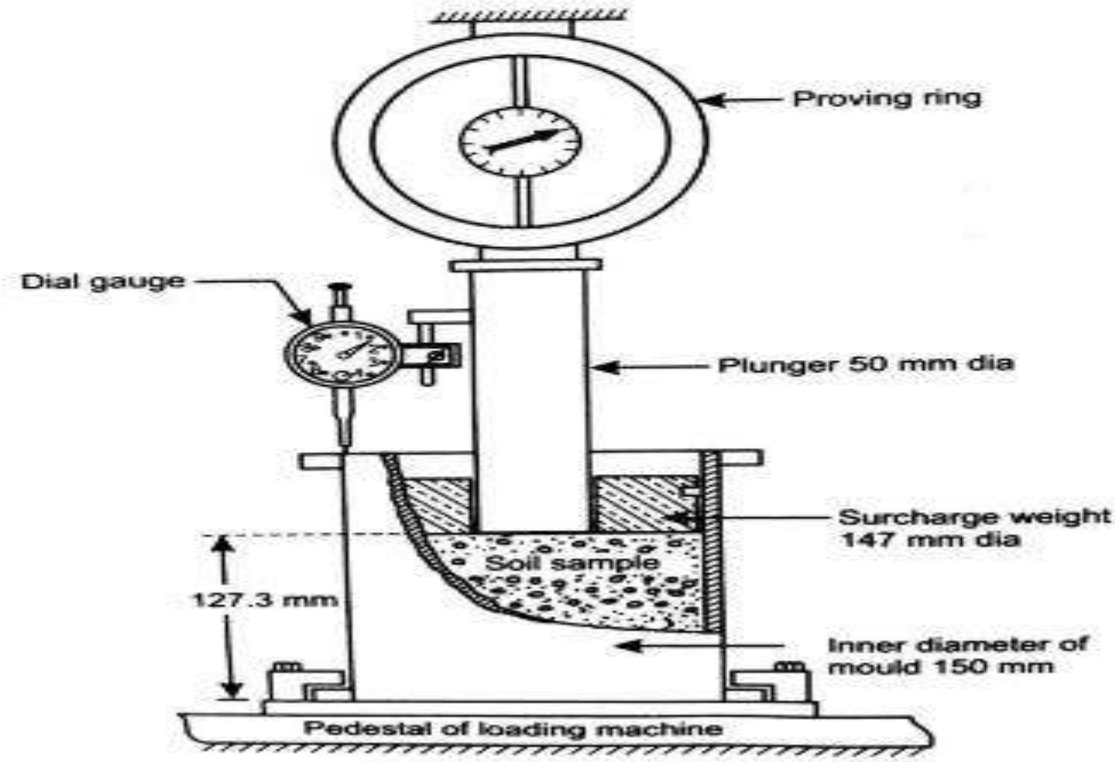


Fig.1. A set up for CBR test of soil

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 X 100

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
7.5	2630
10.0	3180
12.5	3600

Procedure of CBT test

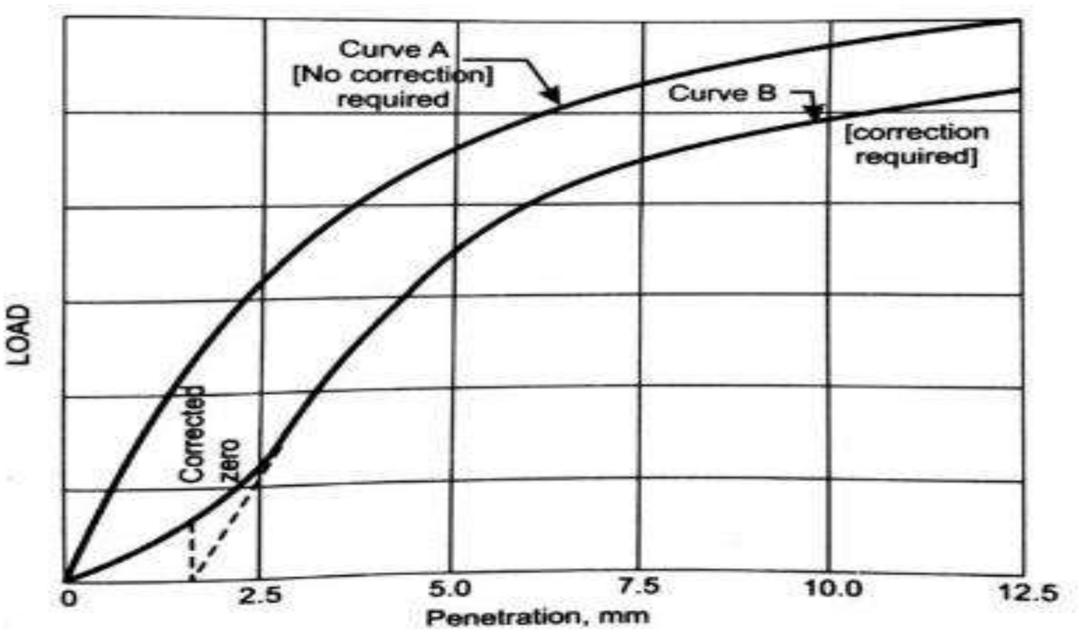
The specimen is placed in mould in four layers. After soaking and swelling for four days water absorption values are noted as per which a surcharge load is placed at the top of the specimen.

The setup is as per the above fig. and load is applied at the rate of 1.25mm/min. The loads are recorded as per the penetration values of 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 7.5 12.0 mm.

During this operation, a 5 cm diameter plunger is penetrated into the pavement component material at the rate of 1.25 mm/min The load for 2.5 mm or 5 mm penetration is recorded.

To obtain the C.B.R. value, this load is expressed in the percentage of a standard load value at a respective deformation level. The standard load values are obtained from the average of a number of tests on different crushed stones as given in the above table.

From the observations, the load penetration graph is drawn as penetration in X-axis and load in Y-axis. If correction on the curve is required then correction is done on the load penetration curve . Then the load corresponding to 2.5 mm and 5 mm penetration is calculated.



Plot- A load penetration curve of CBR test result

The C.B.R. value usually is selected at 2.5 mm penetration. If the C.B.R. at 5 mm is greater than at 2.5 mm, the test should be repeated. If the check test results are similar, then value for 5 mm penetration is used as.

Generally, CBR test is conducted for three test specimen and the average value is taken of the three.

The C.B.R. value is calculated using the relation :

$$\text{CBR, \%} = \frac{\left[\begin{array}{l}\text{Load (or pressure) sustained by the}\\ \text{specimen at 2.5 or 5.0 mm penetration}\end{array}\right]}{\left[\begin{array}{l}\text{Load (or pressure) sustained by standard aggregates}\\ \text{at the corresponding penetration level}\end{array}\right]} \times 100$$

SIGNIFICANCE OF CBR TEST:

1. It is used to evaluate the strength of soil sub grade for road pavement.

2. It is used to designing the thickness of flexible pavement.

3. It is also used for designing base course for airfield pavement.

Aggregate tests

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

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

Crushing test

One of the model in which pavement material can fail is by crushing under compressive stress. A test is standardized by IS:2386 part-IV and used to determine the crushing strength of aggregates. The aggregate crushing value provides a relative measure of resistance to crushing under gradually applied crushing load. The test consists of subjecting the specimen of aggregate in standard mould to a compression test under standard load conditions (Figure). Dry aggregates passing through 12.5 mm sieves and retained 10 mm sieves are filled in a cylindrical measure of 11.5 mm diameter and 18 cm height in three layers. Each layer is tampered 25 times with at standard tamping rod. The test sample is weighed and placed in the test cylinder in three layers each layer being tampered again. The specimen is subjected to a compressive load of 40 tonnes gradually applied at the rate of 4tonnes per minute. Then crushed aggregates are then sieved through 2.36 mm sieve and weight of passing material (W_1) is expressed as percentage of the weight of the total sample (W_2) which is the aggregate crushing value.

$$\text{Aggregate crushing value} = \frac{W_1}{W_2} \times 100$$

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

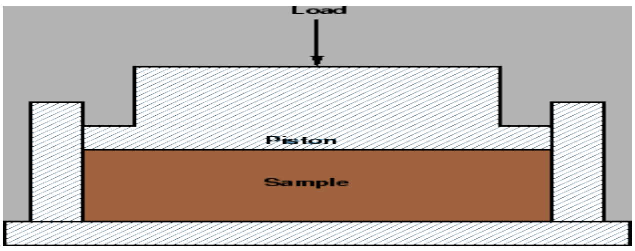


Figure 1: Crushing test setup

Abrasion test

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

Los Angeles machine consists of circular drum of internal diameter 700 mm and length 520 mm mounted on horizontal axis enabling it to be rotated (see Figure 2). An abrasive charge consisting of cast iron spherical balls of 48 mm diameters and weight 340-445 g is placed in the cylinder along with the aggregates. The number of the abrasive spheres varies according to the grading of the sample. The quantity of aggregates to be used depends upon the gradation and usually ranges from 5-10 kg. The cylinder is then locked and rotated at the speed of 30-33 rpm for a total of 500 -1000 revolutions depending upon the gradation of aggregates. After specified revolutions, the material is sieved through 1.7 mm sieve and passed fraction is expressed as percentage total weight of the sample. This value is called Los Angeles abrasion value. A maximum value of 40 percent is allowed for WBM base course in Indian conditions. For bituminous concrete, a maximum value of 35 is specified.

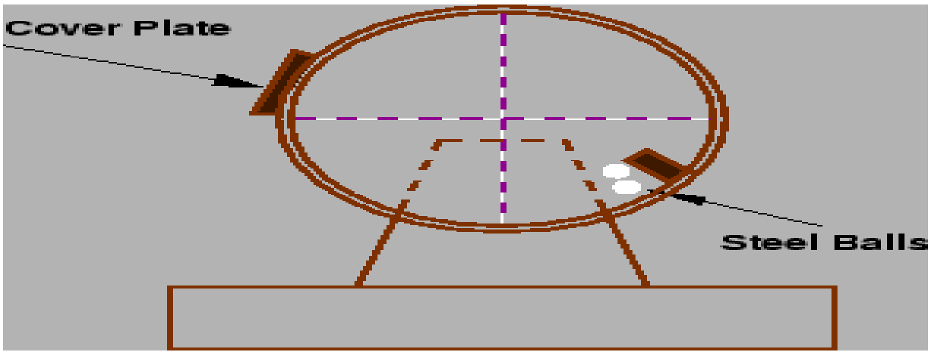


Figure 2: Los Angeles abrasion test setup

Impact test

The aggregate impact test is carried out to evaluate the resistance to impact of aggregates. Aggregates passing 12.5 mm sieve and retained on 10 mm sieve is filled in a cylindrical steel cup of internal dia 10.2 mm and depth 5 cm which is attached to a metal base of impact testing machine. The material is filled in 3 layers where each layer is tamped for 25 number of blows. Metal hammer of weight 13.5 to 14 Kg is arranged to drop with a free fall of 38.0 cm by vertical guides and the test specimen is subjected to 15 number of blows. The crushed aggregate is allowed to pass through 2.36 mm IS sieve. And the impact value is measured as percentage of aggregates passing sieve (W_1) to the total weight of the sample (W_2).

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

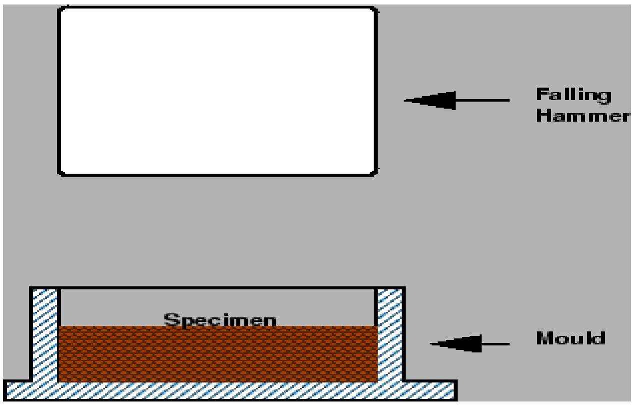


Figure 3: Impact test setup

Aggregates to be used for wearing course, the impact value shouldn't exceed 30 percent. For bituminous macadam the maximum permissible value is 35 percent. For Water bound macadam base courses the maximum permissible value defined by IRC is 40 percent

Soundness test

Soundness test is intended to study the resistance of aggregates to weathering action, by conducting accelerated weathering test cycles. The Porous aggregates subjected to freezing and thawing are likely to disintegrate prematurely. To ascertain the durability of such aggregates, they are subjected to an accelerated soundness test as specified in IS:2386 part-V. Aggregates of specified size are subjected to cycles of alternate wetting in a saturated solution of either sodium sulphate or magnesium sulphate for 16 - 18 hours and then dried in oven at 105-110 C^0 to a constant weight. After five cycles, the loss in weight of aggregates is determined by sieving out all undersized particles and weighing. And the loss in weight should not exceed 12 percent when tested with sodium sulphate and 18 percent with magnesium sulphate solution.

Shape tests

The particle shape of the aggregate mass is determined by the percentage of flaky and elongated particles in it. Aggregates which are flaky or elongated are detrimental to higher workability and stability of mixes.

The flakiness index is defined as the percentage by weight of aggregate particles whose least dimension is less than 0.6 times their mean size. Test procedure had been standardized in India (IS:2386 part-I)

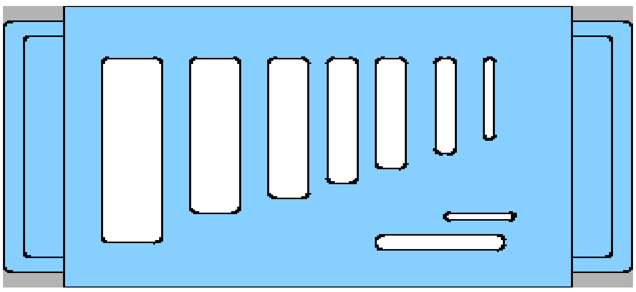


Figure 4: Flakiness gauge

The elongation index of an aggregate is defined as the percentage by weight of particles whose greatest dimension (length) is 1.8 times their mean dimension. This test is applicable to aggregates larger than 6.3 mm. This test is also specified in (IS:2386 Part-I). However there are no recognized limits for the elongation index.

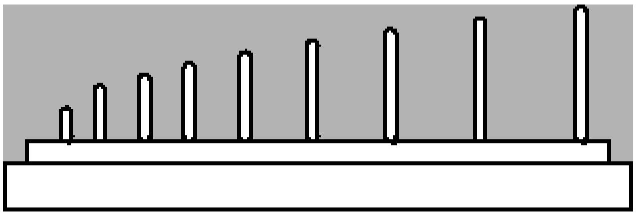


Figure 5: Elongation gauge

Specific Gravity and water absorption

The specific gravity and water absorption of aggregates are important properties that are required for the design of concrete and bituminous mixes. The specific gravity of a solid is the ratio of its mass to that of an equal volume of distilled water at a specified temperature. Because the aggregates may contain water-permeable voids, so two measures of specific gravity of aggregates are used: *apparent* specific gravity and *bulk* specific gravity.

Apparent Specific Gravity, G_{app}, is computed on the basis of the net volume of aggregates i.e the volume excluding water-permeable voids. Thus

$$G_{app} = \frac{M_D/V_N}{W}$$

where, M_D is the dry mass of the aggregate, V_N is the net volume of the aggregates excluding the volume of the absorbed matter, W is the density of water.

Bulk Specific Gravity, G_{bulk} , is computed on the basis of the total volume of aggregates including water permeable voids. Thus

$$G_{bulk} = \frac{M_D/V_B}{W}$$

where, V_B is the total volume of the aggregates including the volume of absorbed water.

Water absorption, The difference between the apparent and bulk specific gravities is nothing but the water-permeable voids of the aggregates. We can measure the volume of such voids by weighing the aggregates dry and in a saturated, surface dry condition, with all permeable voids filled with water. The difference of the above two is M_w. M_w is the weight of dry aggregates minus weight of aggregates saturated surface dry condition. Thus

$$\text{water absorption} = \frac{M_W}{M_D} \times 100$$

The specific gravity of aggregates normally used in road construction ranges from about 2.5 to 2.9. Water absorption values ranges from 0.1 to about 2.0 percent for aggregates normally used in road surfacing.

TESTS ON BITUMEN

There are a number of tests to assess the properties of bituminous materials. The following tests are usually conducted to evaluate different properties of bituminous materials.

1. Penetration test

2. Softening point test

3. Ductility test

4. Viscosity test

1. Penetration test:

An indirect method of measuring viscosity is the measure of penetration of a standard needle under standard conditions of load, time & temperature. The test measures the hardness or softness of bitumen in terms of penetration expressed in mm/10th of std needle. Temperature= 250C [test to be performed after sample is kept for 1hr in water bath at this temperature]

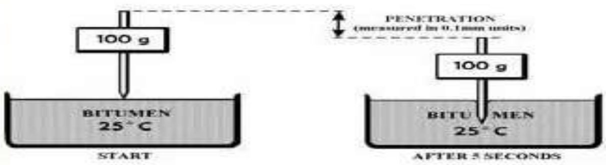
Load on needle = 100 g

Time in which penetration is recorded = 5 s

The penetration is measured by a graduated dial. Bitumen is softens to a poring consistency a depth more than 15mm in the container is poured.

The expected penetration sample is cooled in 60 min in air and 60 min in water before testing.

The standard needle is positioned to get a penetration value for 5sec and is noted. The penetration value obtained is represented in 80-100 or 80/100 grade bitumen at standard consistence and it range from 20-225mm. In cold region bitumen with High penetration value is used. In warm region low penetration value is used ex. 30/40 grade. The factors which affect the Penetration test is test temperature, needle size and weight and period of cooling



2. Softening point:

The softening point is the temperature at which the substance attains a particular degree of softening under specified condition of test. A viscosity material like bitumen or tar doesn't have a well defined softening point. However a std test determines the temperature at which a std ball will pass through a disc of bitumen contained in ring. The test is known as ring & ball test.

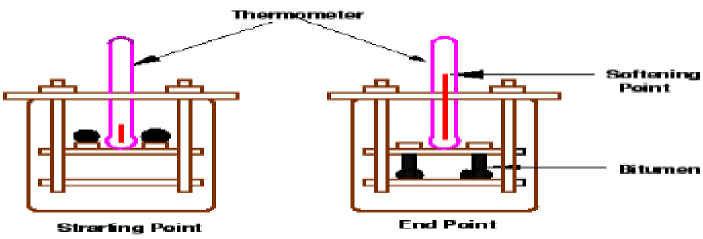
A brass ring of internal dia 17.5 mm at top and 15.9 mm at bottom and of depth 6.4mm. The steel ball of 9.5mm dia and 2.5g. Support distance is 25mm between the bottom of the ring and top surface of the bottom plate of support is provided. Glass container of 85mm dia and 120 mm depth is used. The bitumen is heated to poring consistency and poured into ring and cooled for half an hour before testing.

A brass ring containing the bitumen sample is suspended in water or glycerin at given temperature a steel ball is placed on the disc of bitumen. The liquid medium is then heated at a rate of 5 C^0 increase per minute. Metal plate placed at a specified bituminous material touches the bottom at the softening point.

With increase in temperature bitumen melts and come down with the weight of ball at particular temperature it touches the bottom plate that point temperature is noted. The softening point is range between 35 to 75 C^0. The liquid water is used for bitumen having softening point less than 80 C^0 and Glycerin is for softening point more than 80 C^0.

Higher softening point indicates lower temp. susceptibility and in warm climate.

The factors which affect the softening points are quality and type of liquid used, weight of ball, distance between bottom of the ring and bottom base plate and rate of temperature.



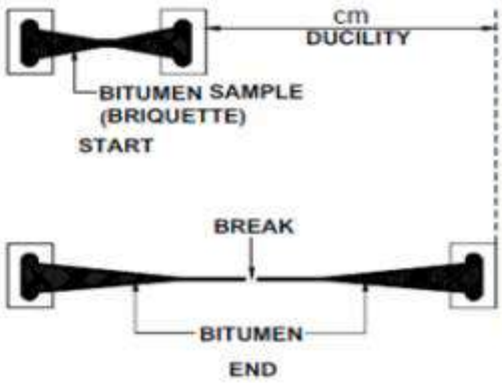
3. Ductility test:

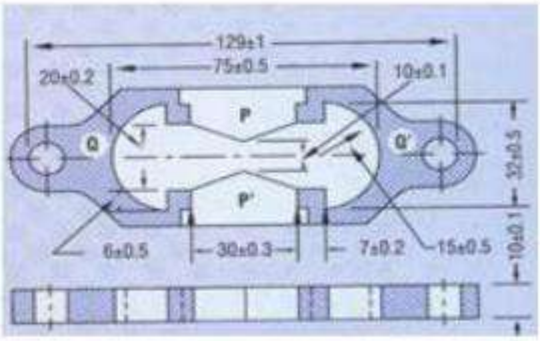
In flexible pavement construction it is important that the binders form ductile thin film around the aggregate. This serves as a satisfactory binder in improving the physical interlocking of the aggregate bitumen mixes. Under traffic loads the bitumen layer is subjected to repeated deformation and recoveries.

The binder material which does not possess sufficient ductility would crack and thus provide pervious pavement surface. The test is believed to measure the adhesive property of bitumen and its ability to stretch. The ductility of a binder is an indication of its elasticity & ability to deform under load & return to original condition upon removal of the load.

A material which doesn't possess adequate ductility would crack under a load. This is unsatisfactory since water can penetrate into the surfacing through there cracks.

The property is determined by measuring the distance that a std briquette of bitumen, necked to a cross section of 1 sq-cm will stretch without breaking when elongated at a rate of 5 cm/min at 270C. The ductility values should be a minimum of 50 as per IS. The briquette mould is filled with bitumen and cool for 30 min in air and 30 min in water before testing. Then it is fixed to expanding machine assembly which stretches the bitumen at a rate of 5cm/min and expands till to break and the point is noted by scale. The factors which affect the ductility is pouring and test temperature, dimension of briquette mould, rate of pulling and period of cooling.





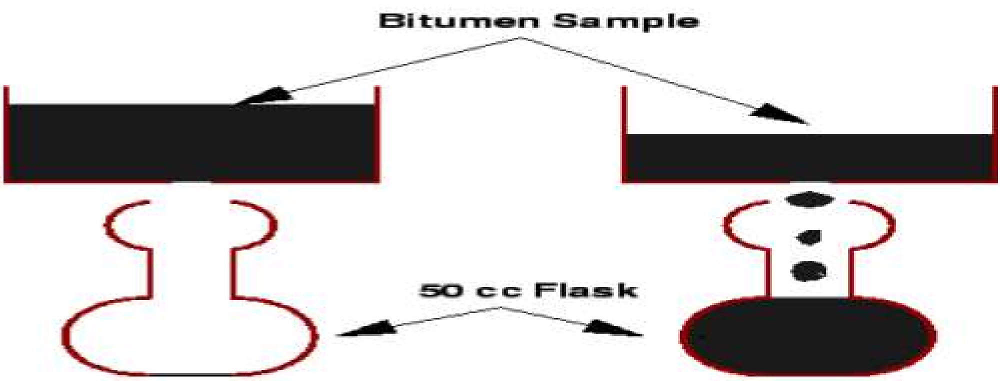
4. Viscosity Test:

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

The determination of viscosity is generally done by efflux viscometers. They work on common principles, though they differ in detail. The liquid under test is poured to a specified level into a container surround by water or oil bath providing temperature control at the base of the container is a small orifice with a simple valve control on opening valve, the time in seconds is recorded for a stated quantity of liquid to discharge into a measuring liquid below. The different type of viscosity testing operator is there they are Efflux viscometer, Standard tar viscometer (10mm dia orifice and 50ml fluid to discharge), Saybolt furol viscometer (3mm dia orifice and 60ml fluid to discharge).

The bitumen is placed in to a standard tar viscometer or efflux viscometer and its temperature is raised to test temperature specified (35, 40, 45, 55& 60^0 C). When the temperature reaches respective test temperature orifice valve is open time elapse is noted to collect the bitumen of 50ml. The time required to collect a bottom container of 50ml is five indirectly the viscosity of bitumen.

Then is specified in VG 10, VG20, VG 30 and VG 40.



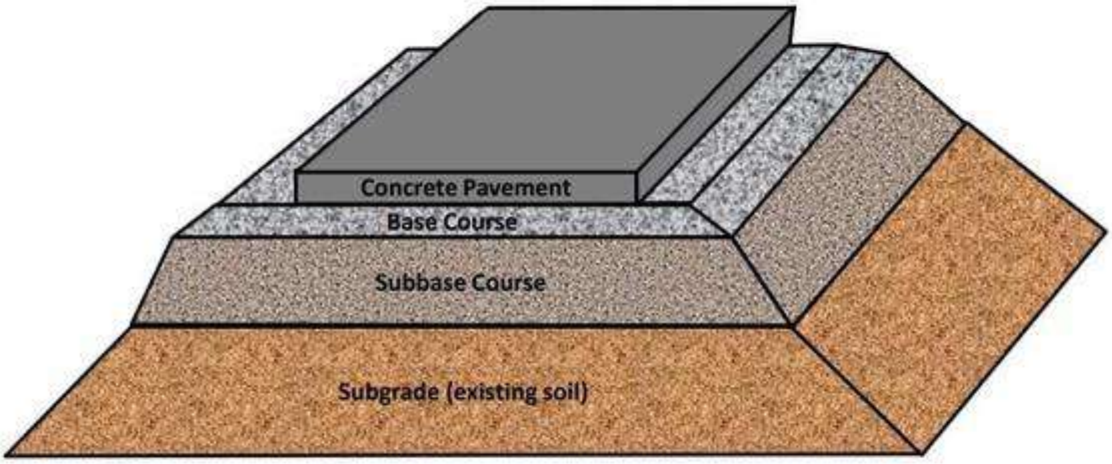
SIGNIFICANCE :

Viscosity measurement are essential as a means of selecting proper bitumen for specific uses .If the bitumen used for road surface is of low viscosity,the result may be loss of chippings under traffic and if the viscosity is too high bleeding may occur. The low viscosity bitumen are easy in handling,mixing and spraying.

5. ROAD PAVEMENTS

ROAD PAVEMENT :

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



The basic function of a road pavement is to distribute the wheel load acting on the road surface through a wider area below the soil subgrade in order to reduce the intensity of wheel load stresses.

PURPOSE OF A ROAD PAVEMENT

The following are the basic purposes of a road pavement :

1. To carry heavy wheel loads of vehicular traffic and to distribute the same over a large area below the subgrade soil.

2. To prevent the subgrade soil from the adverse effect of weathering agencies.

3. To provide a smooth riding surface .

Requirements of a pavement

An ideal pavement should meet the following requirements:

- Sufficient thickness to distribute the wheel load stresses to a safe value on the sub-grade soil,
- Structurally strong to withstand all types of stresses imposed upon it,
- Adequate coefficient of friction to prevent skidding of vehicles,
- Smooth surface to provide comfort to road users even at high speed,
- Produce least noise from moving vehicles,
- Dust proof surface so that traffic safety is not impaired by reducing visibility,
- Impervious surface, so that sub-grade soil is well protected, and
- Long design life with low maintenance cost.

Types of Pavements

Following are the two main types of pavements:

1. Flexible pavement
2. Rigid pavement

Flexible Pavements:

A typical flexible pavement consists of a bituminous surface course over base course and sub-base course. The surface course may consist of one or more bituminous or Hot Mix Asphalt (HMA) layers. These pavements have negligible flexure strength and hence undergo deformation under the action of loads. The structural capacity of flexible pavements is attained by the combined action of the different layers of the pavement. The load from trucks is directly applied on the wearing course, and it gets dispersed (in the form of a truncated cone) with depth in the base, sub base, and subgrade courses, and then ultimately to the ground. Since the stress induced by traffic loading is highest at the top, the surface layer has maximum stiffness (measured by resilient modulus) and contributes the most to pavement strength. The layers below have lesser stiffness but are equally important in the pavement composition. The subgrade layer is responsible for transferring the load from the above layers to the ground. Flexible pavements are designed in such a way that the load that reaches the subgrade does not exceed the bearing capacity of the subgrade soil. Consequently, the thicknesses of the layers above the subgrade vary depending upon strength of soil affecting the cost of a pavement to be constructed.

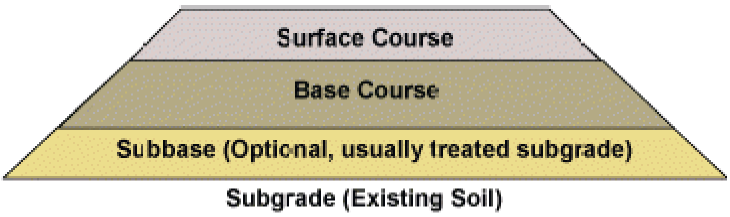
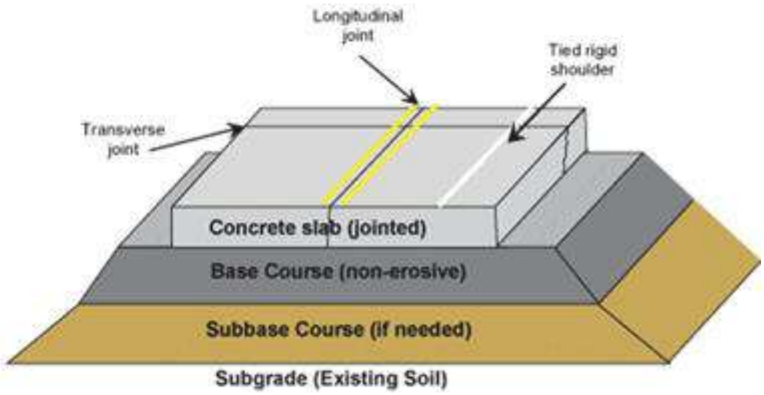


Fig: Flexible Pavement Cross-section

RIGID-PAVEMENT

Rigid pavements are named so because of the high flexural rigidity of the concrete slab and hence the pavement structure deflects very little under loading due to the high modulus of elasticity of their surface course. The concrete slab is capable of distributing the traffic load into a large area with small depth which minimizes the need for a number of layers to help reduce the stress. The most common type of rigid pavement consists of dowel bars and tie bars. Dowel bars are short steel bars that provide a mechanical connection between slabs without restricting horizontal joint movement. Tie bars on the other hand, are either deformed steel bars or connectors used to hold the faces of abutting slabs in contact. Although they may provide some minimal amount of load transfer, they are not designed to act as load transfer devices and are simply used to 'tie' the two concrete slabs together.



Rigid pavement Cross-Section

Difference between Flexible Pavements and Rigid Pavements:

	Flexible Pavement	Rigid Pavement
1.	It consists of a series of layers with the highest quality materials at or near the surface of pavement.	It consists of one layer Portland cement concrete slab or relatively high flexural strength.
2.	It reflects the deformations of subgrade and subsequent layers on the surface.	It is able to bridge over localized failures and area of inadequate support.
3.	Its stability depends upon the aggregate interlock, particle friction and cohesion.	Its structural strength is provided by the pavement slab itself by its beam action.
4.	Pavement design is greatly influenced by the subgrade strength.	Flexural strength of concrete is a major factor for design.
5.	It functions by a way of load distribution through the component layers	It distributes load over a wide area of subgrade because of its rigidity and high modulus of elasticity.
6.	Temperature variations due to change in atmospheric conditions do not produce stresses in flexible pavements.	Temperature changes induce heavy stresses in rigid pavements.
7.	Flexible pavements have self healing properties due to heavier wheel loads are recoverable due to some extent.	Any excessive deformations occurring due to heavier wheel loads are not recoverable, i.e. settlements are permanent

Difference between Flexible Pavements and Rigid Pavements

What are the advantages and disadvantages of Pavements ?

(i) Rigid pavements:

» Low maintenance costs

» Long life with extreme durability

» High value as a base for future resurfacing with asphalt

» Load distribution over a wide area, decreasing base and sub grade requirements

» Ability to be placed directly on poor soils

» No damage from oils and greases.

» Strong edges

The disadvantages of rigid pavements include –

» High initial costs

» Joints required for contraction and expansion

» Generally rough riding quality

» High repair costs

(ii) Flexible pavements:

The advantages of flexible pavements include –

» Adaptability to stage construction

» Availability of low-cost types that can be easily built

» Ability to be easily opened and patched

» Easy to repair frost heave and settlement

» Resistance to the formation of ice glaze

The disadvantages include –

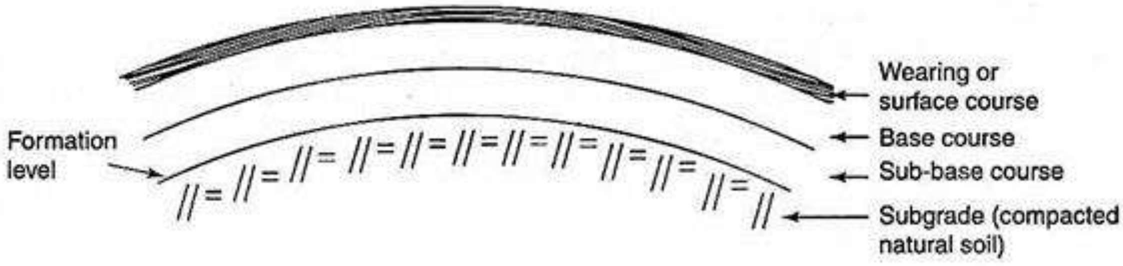
» Higher maintenance costs

» Shorter life span under heavy use

» Damage by oils and certain chemicals

» Weak edges that may require curbs or edge devices

PAVEMENT COURSE AND THEIR FUNCTION



i. Surface (or wearing) course

ii. Base course

iii. Sub-base course

iv. Subgrade soil.

The functions of each of these layers are given below:

i. Surface (or Wearing) Course:

This is the topmost layer; its function is to provide a smooth, strong, abrasion-resistant and reasonably impervious course. Since it is directly in contact with the vehicle tyres, it has to resist the imposed wheel loads and transmit them safely to the layer below. The material may be granular, bituminous or cement concrete depending upon the nature of the construction.

ii. Base Course:

This is immediately below the surface course and its function is to distribute the stresses transmitted through the surface course evenly onto the layers below. Invariably, it consists of granular or bituminous material, and acts as a structural part of the pavement.

iii. Sub-Base Course:

This comes just below the base course and provides additional help to the courses above it in distributing the loads. It also helps in preventing soil grains of the subgrade from intruding into the base course above, and counteracts frost action, if any. It may consist of stabilised soil or soil aggregate mixes, which facilitate drainage of free water from the pavement.

iv. Subgrade:

It is the compacted natural soil immediately below the pavement layers; this act as a foundation for the highway. The top surface of the subgrade is called the formation level.

Depending upon the alignment and the nature of the terrain, a roadway may be constructed over an embankment or a cutting, or at or nearly at the natural ground level. The formation of level, therefore, has to be properly decided to suit these conditions.

SUBGRADE PREPARATION:

The preparation of a road subgrade involve the following opertations:

1. Site clearance and grubbing

2. Setting out alignment of the road and locating bench mark control pegs

3. Earthwork

4. Compaction

5. Checking of sub grade

1. Site clearance and grubbing:

A good construction practice to follow cutting, removing and disposing of all unsuitable materials such as trees, bushes shrubs, stump, roots, grass, weeds, top organic soils up to a minimum depth of 150 mm from the road construction area known as site clearance-clearing and grubbing(C&G).

2. Setting out alignment of the road and locating bench mark control pegs :

1. On cleared site, centre pegs are fixed at 50 m interval on straight road. A v-shaped cut is marked between these centre peg with the help of a spade or other instrument.

2. Control pegs which include clearing stakes ,batter peg,reference peg are established for guidance. The batter pegs mark the limit of embankment slope.

3. Temporary bench mark are established at about 30 m interval and at 40 m distance from the center line of road by fly leveling from the nearest bench mark to work out the longitudinal profile and cross-section of the proposed road.

Making profile of an embankment

Profile of embankment is made by bamboo and string method as describe:

1. Two vertical bamboo pole are fixed vertical at the two ends of marked formation width.

2. A string is tied to the batter peg and the adjoining bamboo pole to form the side slope of one of the bank.

3. The string is taken horizontally from this bamboo pole to another bamboo pole. It is then tied to the batter peg fixed on the other side of road to present the side slope of the other bank. Thus the complete string and pole arrangement represent the trapezoidal cross section of the road embankment.

4. The horizontal joining the two vertical poles represents the top of embankment. This is kept at a slightly higher level than the required formation level to provide allowance of soil settlement.

5. These bamboo string profile are constructed at 30 m interval along the road alignment to guide the labour for earth filling

Earthwork

1. In embankment: After fixing the bamboo string profile, the earth is taken from borrow pits and filled between them .granular soil is generally preferred as highway embankment material . Fine soil like silt and clay are less desirable as embankment material as these take more time to settle.

2. In excavation : Excavation is the process of cutting or loosening and removing earth including rock from its original position, transporting and dumping it as fill or spoil bank. The excavation is needed when the finalized formation level of a road is to kept lower than natural ground level.

4. COMPACTION:

Subgrade compaction is the act of grading, shaping, and compacting the natural subgrade materials prior to placing an aggregate base or pavement. It mechanically increases the unit volume (density) of the soil or base. Different soil types have different optimum moisture contents and densities. Sandy soils require lower moisture contents and can typically achieve higher densities than silts or clays do. Also silts and high-fine clays are more prone to moisture retention and frost heave making them generally less optimal for performing well as a pavement subgrade.

Compaction achieves the following:

- increases load bearing capacity
- helps reduce future rutting/settling
- reduces voids which increase susceptibility to moisture changes/freeze thaw
- help ensure that freeze/thaw movement is uniform.

Subgrade compaction is an act that is sometimes overlooked in private, non-inspected, construction projects but (depending on the soil type and condition) can be critical in future performance of pavements.

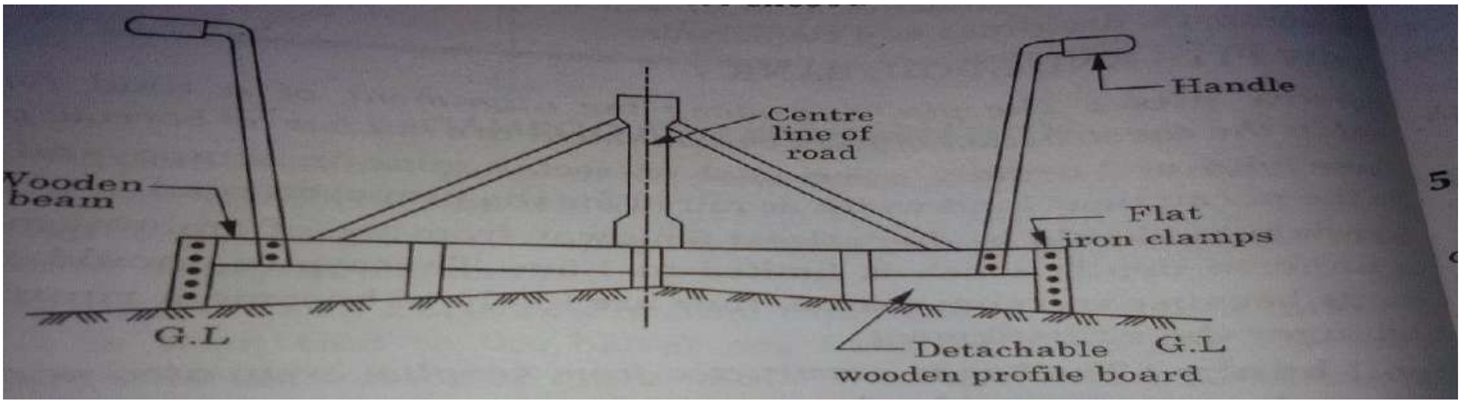
It's important to note that for subgrade areas that are found to be man made fill, overly moist, or otherwise questionable, subgrade compaction may actually make the situation worse by disturbing, consolidating, or working moisture up to the surface. Soils with higher than normal moisture content will 'pump' underneath tires and tracks of grading equipment, compaction equipment, trucks, and paving equipment. In these cases staying off of the subgrade and leaving it virgin may be the better option (if undercutting and replacement with premium material is not in the budget).

5. CHECKING OF SUBGRADE:

After the preparation of subgrade , it is essential to check the subgrade for its correctness:

It includes verification of longitudinal and cross profile of the road to ensure that desired camber and gradient has been achieved.The longitudinal gradient of the subgrade can be checked by a leveling instrument like dumpy level. As per IRC specification,actual level should not differ from levels given on drawings by more than 25mm

The camber provided to the subgrade is checked by a template . The maximum variation should not exceed 15 mm.



SOIL STABILISATION:-

Soil stabilization a general term for any physical, chemical, mechanical, biological or combined method of changing a natural soil to meet an engineering purpose. Improvements include increasing the weight bearing capabilities, tensile strength, and overall performance of in-situ subsoils, sands, and waste materials in order to strengthen road pavements.

Objectives of Soil Stabilization

1. To strengthen a weak soil and restrict the volume change potential of a highly plastic or compressible soil.
2. To reduce moisture susceptibility of fine grain soils.

Soil Stabilization Methods

a. Mechanical Stabilization

b. Stabilization by using different types admixers

(1) Lime Stabilization

(2) Cement Stabilization

(3) Fly ash Stabilization

a. Mechanical Stabilization

Mechanical Stabilization is the process of improving the properties of the soil by changing its gradation. This process includes soil compaction and densification by application of mechanical energy using various sorts of rollers, rammers, vibration techniques and sometime blasting. The stability of the soil in this method relies on the inherent properties of the soil material. Two or more types of natural soils are mixed to obtain a composite material which is superior to any of its components. Mechanical stabilization is accomplished by mixing or blending soils of two or more gradations to obtain a material meeting the required specification.

b. Stabilization by using different types admixers

(1) Lime Stabilization :

Lime provides an economical way of soil stabilization. The method of soil improvement in which lime is added to the soil to improve its properties is known as lime stabilization. The types of lime used to the soil are hydrated high calcium lime, monohydrated dolomite lime, calcite quick lime, dolomite lime. The quantity of lime is used in most soil stabilizer is in the range of 5% to 10%. Lime modification describes an increase in strength brought by cation exchange capacity rather than cementing effect brought by pozzolanic reaction . In soil modification, as clay particles flocculates, transforms natural plate like clays particles into needle like interlocking metalline structures. Clay soils turn drier and less susceptible to water content changes . Lime stabilization may refer to pozzolanic reaction in which pozzolana materials reacts with lime in presence of water to produce cementitious compounds . The effect can be brought by either quicklime, CaO or hydrated lime, $Ca(OH)_2$. Slurry lime also can be used in dry soils conditions where water may be required to achieve effective compaction.

(2) Cement Stabilization

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

Cement stabilized soils have the following improved properties:

(a) decreased cohesiveness (Plasticity)

(b) decreased volume expansion or compressibility

(c) Increased strength

3. Fly ash Stabilization

Fly ash stabilization is gaining more importance recent times since it has wide spread availability. This method is inexpensive and takes less time than any other methods. It has a long history of use as an engineering material and has been successfully employed in geotechnical applications. Fly ash is a byproduct of coal fired electric power generation facilities; it has little cementations properties compared to lime and cement. Most of the fly ashes belong to secondary binders; these binders cannot produce the desired effect on their own. However, in the presence of a small amount of activator, it can react chemically to form cementations compound that contributes to improved strength of soft soil. However, soil fly ash stabilization has the following limitations :

(a) Soil to be stabilized shall have less moisture content; therefore, dewatering may be required.

(b) Soil-fly ash mixture cured below zero and then soaked in water are highly susceptible to slaking and strength loss

(c) Sulfur contents can form expansive minerals in soil-fly ash mixture, which reduces the long term strength and durability.

TYPE OF BASE COURSES OF FLEXIBLE ROAD PAVEMENT

According to method of construction following are the various type of base course of flexible pavements:

1. Stabilised soil base courses

2. Brick soling or stone soling base courses

3. Macadam base courses

1. Stabilised soil base courses :

The base consisting of stabilized soil is known as stabilised soil base course. Stabilised soil is being satisfactorily used in base course construction in flexible pavement. Such base are very popular in india because of their low cost and good performance under moderate traffic conditions.

The following type of stabilized soil bases have already been discussed.i.e Mechanically stabilized base courses , Lime stabilized ,cement stabilized base courses.

2. Brick soling or stone soling base courses:

A compacted layer of brick and stone laid directly over soil subgarde of a road pavement is known as soiling.

a. Brick soiling : Brick soiling consist of one or two layers of brick either laid flat or on edges to the required thickness of pavement. The bricks are generally laid longer dimension at right angle to the central line of road , breaking the joint in consecutive rows. After bricks laid the granular soil like sandy or silty soil is spread over the top, the joint are filled with soil screenings using wire brooms. The water is sprinkled in sufficient quantity and the brick layers are compacted using a light roller Brick soiling is allowed to dry before the surface course is laid over it.

b. Stone soling : A compacted layer of well dressed stones of proper size and shape laid directly over soil subgrade is termed as stone soling.

Stone of proper size and shape are selected or hammer dressed properly according to the required thickness of soling. These stone are spread uniformly over the prepared surface. The void are filled with smaller size stone Stone are then consolidated by rolling heavy roller. Dry rolling is followed by spreading of sandy soil of 2.5 cm thickness, watering and then rolling by a 6 to 8 tonne roller . Stone soling is then allowed to dry.

3. MACADAM BASE COURSES:

Macadam construction means the base courses consisting of crushed or broken stone aggregates bound together with or without binding materials.

The term macadam refers to road metal used for construction of roads.

Various type of macadam road:-

a) Water bound macadam (W.B.M)

b) Wet mix macadam (W.M.M) base course

c) Bituminous macadam base course

a) Water bound macadam (W.B.M):

Water bound macadam road is a road in which the wearing course consists of clean crushed aggregates which are mechanically interlocked by rolling. These aggregates bound together with filler material and water laid on a well-compacted base course.

Water bound macadam road is the most commonly used road construction procedure for over more than 190 years and in the first phase in most of the road projects, water-bound macadam road is constructed, and the surfacing is done with the premix carpet bituminous macadam or cement concrete.

MATERIALS FOR WATER BOUND MACADAM ROAD:

In the construction of Water Bound Macadam (WBM) road, there are mainly 3 types of materials which are used such as;

1. Coarse Aggregate
2. Screenings (Filler Material)
3. Binding Material

COARSE AGGREGATE:

Coarse aggregates consist of a mixture of hard and durable crushed aggregates and broken stones, and aggregate should be properly graded for each layer of the WBM road construction.

In the construction of water bound macadam road, the coarse aggregates should hold the following properties such as;

1. It should be durable and hard.
2. The coarse aggregate should be free from elongated particles and flaky particles.
3. The coarse aggregate should be in acceptable size and shape.

Physical requirements of course aggregates required for construction of water bound macadam road is given in the fig below;

Sr. no.	Property	Requirements for pavement layer (maximum percent)		
		Sub-base	Base course	Surfalling course
1.	Los Angeles abrasion value	60	50	40
2.	Aggregate impact value	50	40	30
3.	Flakiness index	–	15	15

SCREENINGS: (FILLER MATERIAL)

Screenings are the material that is used up to fill up the excess voids present in the compacted layer of course aggregate and these materials are the aggregates of a smaller size than the coarse aggregates.



BINDING MATERIAL:

Binding material should be properly approved by engineer and it should have a plasticity index value less than 6 for the construction of water bound macadam road.

CONSTRUCTION PROCEDURE OF WATER BOUND MACADAM ROAD:

There are the following steps in the construction procedure of WBM road as given below;

PREPARATION OF FOUNDATION FOR WBM ROAD:

For the required grade and camber of WBM road, the subgrade or base course is properly prepared and the potholes and the depressions on the surface of the road is properly filled up & compacted.

PROVISION FOR LATERAL CONFINEMENT:

The shoulders having a thickness as that of compacted WBM layer should be constructed before laying of aggregates and with the proper quality of earth, they should be constructed.

The purpose of constructing shoulders is that the road surface to be constructed retains in between them and for the further laying of course aggregates, it becomes easy.

SPREADING OF COARSE AGGREGATES:

After the construction of the shoulders, the coarse aggregates are uniformly spread on the prepared base and the total number of layers and thickness of water bound macadam road depends upon the details of pavement design.

Single-layer of compacted thickness 75 mm may be sufficient for ordinary roads and 2 layers of 150 mm each compacted thickness may be provided for special roads.

ROLLING OPERATION:

For compacting the coarse aggregates, the rolling operation is carried out and it is done with the help of vibratory rollers or with the help of 3-wheeled power rollers weighing 6 to 10 tonnes.

For driving the rollers, skilled operators should be used because the fault rolling operations cause the formation of corrugations, the unequal finish of road surface, etc.

APPLICATION OF SCREENINGS:

The screenings are applied to properly fill the voids remained after the rolling operation is properly finished and in 3 or more layers as per the site conditions screening may be applied.

For each layer of screenings, compaction is carried out with the help of dry rollers, and to remove the uncompacted screening material, brooming of each layer should be properly done after compaction.

THE SPRINKLING OF WATER AND GROUTING:

The road surface is properly sprinkled with plenty of water after the application of screening and brooming is done to sweep the wet screening properly into the voids after the water is sprinkled.

APPLICATION OF BINDING MATERIAL:

As screenings, the same procedure is used in this step and rolling operation is carried out after each layer of water is sprinkled.

To washout, the binding material that gets stuck to the wheels of the rollers, the wheels of the roller should be constantly watered at the time of rolling operation.

SETTING AND DRYING OF SURFACE:

The road is allowed to cure or set over-night after the final rolling operation and the next day again sufficient amount of screenings or binding materials can be used and compaction is done if the depressions or voids are visible.

PREPARATION OF SHOULDERS:

The shoulders are constructed alongside by filling earth to specified cross slope at the time of the curing of the road and compacted properly.

OPEN FOR TRAFFIC:

The road is then made open for traffic after proper drying and without any depressions. By placing obstacles longitudinally in the form of drums, barricades, etc the traffic should be well distributed over the full width of the road.

MAINTENANCE OF WBM ROAD:

1. By the period of time when the potholes and ruts occur on the road, they should be filled with adequate materials and properly compacted.
2. By means of dragging, the corrugations that occurred on the roads should be removed and by fresh materials, broken materials of the roads should be properly restored.
3. In 2-5 years or based according to the traffic volume, the surface of the road should be renewed.

4. The loose aggregates start coming on the top of the surface of the road so they should be removed and leveled surface should be added by fresh binding material.

ADVANTAGES OF WATER BOUND MACADAM ROAD:

There are the following advantages of water bound macadam road such as;

1. The construction cost is comparatively low in WBM road.
2. No skilled laborers are required in the construction of WBM road.
3. From locally available materials they are constructed.
4. It can resist a load of traffic of about 900 tonnes per lane per day if these roads are maintained properly and from time to time.

DISADVANTAGES OF WATER BOUND MACADAM ROAD:

There are also some disadvantages of water bound macadam road such as;

1. There is a high cost for maintenance on this road.
2. There is a very less overall life span of these roads.
3. The WBM roads can cause inconvenience and danger to traffic if they are not properly maintained.
4. It leads to softening and yielding of subsoil because WBM roads are permeable to rainwater.

b) Wet mix macadam (W.M.M) base course :

Aggregates used are of the smaller sizes, varies between the 4.75 mm to 20 mm sizes and the binders(stone dust or quarry dust having PI(Plasticity Index) not less than 6%) are premixed in a batching plant or in a mixing machine. Then they are brought to the site for overlaying and compaction.The PI(plasticity Index) of the binding material is kept low because it should be a sound and non plastic material. If the plasticity index is more then there are the chances of the swelling and more water retention properties. So this value should be kept in mind.

- Comparison of the WBM and WMM road construction:

Although the cost of construction of the WMM is said to be more than that of the WBM sub-base and bases but the advantages given below will compensate for that.

Here are the points of difference:

1. The WMM roads are said to be more durable.

2. The WMM roads gets dry sooner and can be opened for traffic withing less time as compare to the WBM roads which take about one month for getting dry.

3.WMM roads are soon ready to be black topped with the Bituminous layers.

4. WMM roads are constructed at the faster rate.

5. The consumption of the water is less in case of the WMM roads.

6. Stone aggregates used in WBM is larger in size which varies from 90 mm to 20 mm depending upon the grade but in case of the WMM size varies from 4.75 mm to 20 mm.

7. In case of WBM, stone aggregates, screenings and binders are laid one after another in layers while in WMM, aggregates and binders are premixed in the batching plants and then brought to the site for overlaying and compacting.

8. Materials used in the WBM are the stone aggregates, screenings and binder material(Stone dust with water) while in WMM material used are only stone aggregates and binders.

9. Quantity of the WBM is generally measured in cubic meters while that of the WMM in square meters.

Construction steps:-

1. The selected W.M.M mix with water equal to optimum moisture content is prepared in a suitable mixing plant.

2. The W.M.M mix is transported to the site and is spread using a self propelled type paver – finisher machine to the required thickness, grade and cross slope.

3.The W.M.M layer is compacted using a vibratory roller of minimum weight of 10 tonnes . Rolling is done starting from the lower edge and proceeded towards the center of the undivided carriageway or towards the upper edge of the divided carriageway with a minium one third overlap between each roller

4. The W.M.M surface is checked for defected if any and allowed to dry.

5.After the W.M.M layer is dried for at least 24 hr in dry weather the preparation for the laying a bituminous pavement layer is started by applying the prime coat.

c) Bituminous macadam base course:

The base course consisting of a single layer of crushed aggregate premixed with a bituminous binder is called bituminous macadam base course. In this type of base course the crushed aggregate premixed with a bituminous binder is laid, immediately after mixing and then compacted. This type of course consist of 50/75 mm thick compacted layer of crushed aggregates premixed with a bituminous binder.It should not laid during rainy season.

Construction steps:-

1. Prepration of subgrade : The subgrade to receive the bituminous macadam base course is prepared to a specified grade and profile.The surface is then thoroughly swept and scraped clean so as to make it free from dust and foreign matter.

2. Application of prime or tack coat: After the preparation of base ,a prime or tack coat of thin layer of bituminous material is suitable applied by using sprayer or a pouring can.

3. Preparation and transportation of premix: The bitumen binder and stone aggregate as per specified grading are heated separately to a specified temperature and then placed in the mechanical mixer for

preparing the premix. The mixing is homogenous and uniform mixture is obtained. The mixing is transported from the mixing plant to the point of use in suitable vehicles.

4. Spreading the mix : Immediately after mixing ,mix is transported and spread by means of a self propelled mechanical paver. The spreading of the mix can done manually in restricted locations.

5. Rolling and finishing:

Immediately after the spreading of mix rolling is done by 8-10 tonnes smooth wheeled power roller.

PAVEMENT SURFACES (SURFACING)

The topmost component of a road pavement structure directly expose to traffic is called pavement surface.

In flexible pavement the wearing surface is supported by a base course.

Whereas in a rigid pavement, the road slab serves the function of wearing surface as well as of base course.

FUNCTION OF SURFACING

1. To bear the abrasive action of traffic.

2. To provide a water tight seal

3. To control or prevent dust nuisance

4. To provide a smooth riding surface for vehicular traffic.

TYPE OF SURFACING

1. Prime coat and tack coat

2. Surfacing dressing

3. Open graded premix carpet

4. Bituminous concrete

5. Mixed seal surfacing

6. Mastic asphalt

1. **Prime coat and tack coat**:

A prime coat is an initial application of a low viscosity liquid bituminous material to an existing base of previous texture like W.B.M.

The function of a prime coat are:

1) To seal the pores by penetrating into it.

2) To waterproof the underlaying layer.

3) To provide adhesion between the base and superimposed layer

Method of application of prime coat

1. The existing pavement surface is properly leveled and compacted to remove bumps and waves etc .This surface is properly clean before application of prime coat.

2. On the prepared surface the bituminous primer is sprayed uniformly with mechanical sprayer.

3. After 24 hr if primer is not completely absorbed ,sand layer is applied on the surface to blot up the excess primer.

TACK COAT:

A tack coat is an application of a bituminous binder to an existing surface to ensure a bond between the new construction and old surface.

Tack coat serves the following purpose:

1) It acts as an adhesive bond between the existing pavement and bituminous surface.

2) It binds together any loose material present on the existing pavement due to traffic blow and consolidates the surface.

METHOD OF APPLICATION TACK COAT

1) The old surface is properly repaired. Any loose material appearing on the surface is removed.

2) The tack coat is applied by spraying a bituminous material of higher viscosity at a uniform specified rate with the help of pressure distributor

3) The treated surface is allowed to completely dry.

SURFACE DRESSING

Surface Dressing is a mixture of polymer modified bitumen emulsion and a layer of chippings. It will seal the surface, improve surface texture and prolong the life of the road by many years. It is a speedy, efficient and economic method of preventative maintenance and carrying out minor re-profiling of carriageway surfaces.

The Surface Dressing Process :

1. The surface dressing process is very weather dependent and cannot be applied to wet or cold roads or during high air humidity levels or very high road temperatures.

2. The road is swept and cleared of any built up detritus and all ironwork masked over.

3. The Sprayer machine is driven slowly along the road spreading the bitumen evenly across the width of the box.

4. This is followed closely by the chipping spreader and lorries. There is an excess of chips spread on the road to prevent traffic or pedestrians from picking up wet tar.

5. Depending on the type of surface dressing there may be two coats of tar and chippings applied or two layers of chippings.

6. The material is given an initial embedment with a pneumatic tyred roller. The action of further trafficking helps the material to embed and achieve its optimum strength.

7. Following completion of the work there will be a degree of stone loss. This will be removed by a suction sweeper in stages. Traffic signs will be left in place advising of the risk of loose chippings and showing an advisory speed limit.

8. The first sweep will normally take place 24 to 48 hours after the initial process. Sweeping earlier than this may damage the surface in its early life.

9. The masking is then removed from the ironwork in the road.

10. Trafficking will continue to help with the embedment of chippings. However this must be at low speeds.

OPEN GRADED PREMIX CARPET:

A single layer of stone chipping premixed with a suitable binder and compacted to desired thickness to serve as the wearing course of road pavement is termed as premix carpet. It is also called as open graded premix carpet.

Method of construction:

1. Preparation of base:

The existing surface is prepared to the proper profile. The surface free from dust or loosen material.

2. Application of tack coat or prime coat:

After preparation of base a prime coat is usually applied when there is untreated porous surface like W.B.M road. Tack coat is generally applied when the existing surface is non absorbent black top pavement or cement concrete road.

3. Application of pre-mix :

The premix is prepared in a hot mix plant. The aggregates and the bitumen are preheated before mixing upto the specified temperature. The mix is then evenly spread on the surface with the help of suitable rakes to the required thickness. The cross profile of the laid material is checked with templates.

4. Rolling:

After spreading the mix rolling of premix layer is done with 6-10 tonne capacity smooth roller. The wheels of roller are kept wet to prevent sticking of premix material to the wheel.

5. Application of seal coat:

Seal coat of premixed sand bitumen layer is applied over the roller carpet layer as a protective covering. This layer rolled by lighter roller to provide smooth finished surface.

6. Seal coat:

A very thin surface treatment applied over pervious bituminous pavement like premix carpet or existing worn out black top pavement is known as seal coat.

Purpose of providing seal coat:

1. To provide a water tight surface against infiltration of surface water.

2. To provide a non – skidding road pavement

3. To protect the premix material from the abrasive effect of traffic wheels.

BITUMINOUS CONCRETE

Bituminous concrete is a superior type of surfacing used for heavy traffic.

Bituminous concrete is a dense graded premix material consisting of well proportioned fine and course aggregates mixed together with tar or bitumen .IRC recommended 40mm thick bituminous concrete surface course for highway.

Method of construction:

1. Preparation of base:

The base is prepared by filing all the depressions and pot hole and leveling the surface to remove all irregularities.

2. Application of tack coat:

A tack coat is applied to the prepared base before the application of bituminous concrete mix.

3. Placing of premix:

The bituminous binder and aggregate are heated to a pre determined temperature and mixed uniformly to obtain a homogenous mixture.The hot premix is spread evenly on the prepared base by mechanical sprayer.

4. Rolling:

After spreading the bituminous concrete mix rolling is started immediately with 8 to 12 tonnes capacity flat wheeled roller.

5. Application of seal coat :

After rolling operation, premixed seal coat is also sometime applied in that case suface is again rolled. The pavement is opened to traffic as soon as possible as it dries out.

MIXED SEAL SURFACING

Mixed seal surfacing (M.S.S) is thin bituminous surfacing. It is also called close graded premix surfacing.

M.S.S consists of aggregates of specific gradation premixed with suitable grade of paving grade bitumen binder in a hot mix plant, spread with a mechanical paver and compacted to a thickness of 20mm to form a thin bituminous surface. This forms a non porous surface course and there is no need to apply seal coat.

Material required:

1. Bitumen binder of appropriate type and grade

2. Coarse and fine aggregates fulfilling the specified properties and gradation.

CONSTRUCTION STEPS:

1. The receiving surface on which the mixed seal surfacing is to be laid is prepared by patching the pot hole and filling up the depressions.

2. The receiving surface is cleaned with a mechanical broom to remove loose material and dust.

3. If the receiving surface is granular base course,prime coat is applied as specified and allowed to cure fully.

4. The premix is prepared in a hot mix plant using the selected grade of bitumen binder and the aggregates. The premix is spread using mechanical paver at specific temperature.

5. Rolling is carried out by roller of 10 tonne.

6. The finished surface is checked using 3m straight edge,the undulation shall not exceed 6mm.

7. The pavement should be opened for traffic preferably after 24 hr of laying.

MASTIC ASPHALT

Mastic asphalt is also known as bitumen mastic .It consist of n intimate mixture of hard grade bitumen ,well graded coarse and fine aggregate and mineral filler.

Mastic asphalt can withstand very heavy wheel load and vibration

MATERIAL REQUIRED

1. Bitumen binder of specified consistency

2. Coarse aggregate

3. Fine aggregate

4. Filler

Construction steps

1. The base on which the bitumen mastic is to be laid is prepared to proper grade and camber and a tack coat of 80/100 bitumen binder is a sprayed

2 The mastic asphalt is prepared in the mechanically agitated mastic cooler in different stages by first heating the binder and then mixing with filler then fine aggregate and finally the coarse aggregate for specified periods and temperature ranging between 170 to 200 C, minimum total time required for cooking is three hours.

3. The hot bitumen mastic is transported to the site and deposited on the prepared base. It is then spread either by manual method or with a special mechanical paver.

4.Pre-coated aggregate of size 9.5 to 13.2 mm are spread at a rate of 0.05 m^3 per $10m^2$ area when the temperature of bitumen mastic is 80-100 ^{0}c

These are pressed into the surface using wooden flats such that the aggregates protrude about 3-4 above the mastic surface.

CAUSE OF FAILURE OF BITUMINOUS ROADS

1. Due to use of improper quantity of bituminous binder or improper proportion of aggregate.

2. Due to overheating of bitumen in mixing stage.This reduce strength and cohesive properties of bitumen

3. Due to excessive use of binder, binder material comes out at the top level.

4. Due to use of too hard grade bitumen.

5. Due to lack of adhesion because of moisture.

6. Due to delay of spraying of the binding material.

RIGID PAVEMENTS (CEMENT CONCRETE ROADS)

The road pavements which cannot change their shape without rupture are known as rigid pavements. The best example of rigid pavements is cement concrete road.

Advantages Of Cement Concrete Road

1. Concrete roads have a long life.

2. They are quite durable and practically unaffected by weathering agencies.

3. They provide an excellent riding surface under all weather condition.

4. They provide an impervious, dustless and sanitary surface.

5. No corrugations are developed in cement concrete roads.

6. They can be laid on any sub-grade.

7. They provide good visibility for traffic during night hours.

8. They are practically non-slippery and offer less tractive resistance.

9. Their load carrying capacity is more.

10. Their maintenance cost is very low.

Disadvantages of Cement Concrete Road

1. The initial cost of construction is very high.

2. They require skilled supervision and labour for their construction.

3. They are liable to crack and warp due to temperature variations.

4. They become noisy under iron-tyred traffic.

5. They are less resilient than bituminous or WBM roads.

6. They may cause glare due to reflected sunlight.

7. They can not be opened to traffic shortly after construction.

8. It is very difficult to provide or repair underground pipes below cement concrete.

Concrete pavements can be constructed using two different methods:

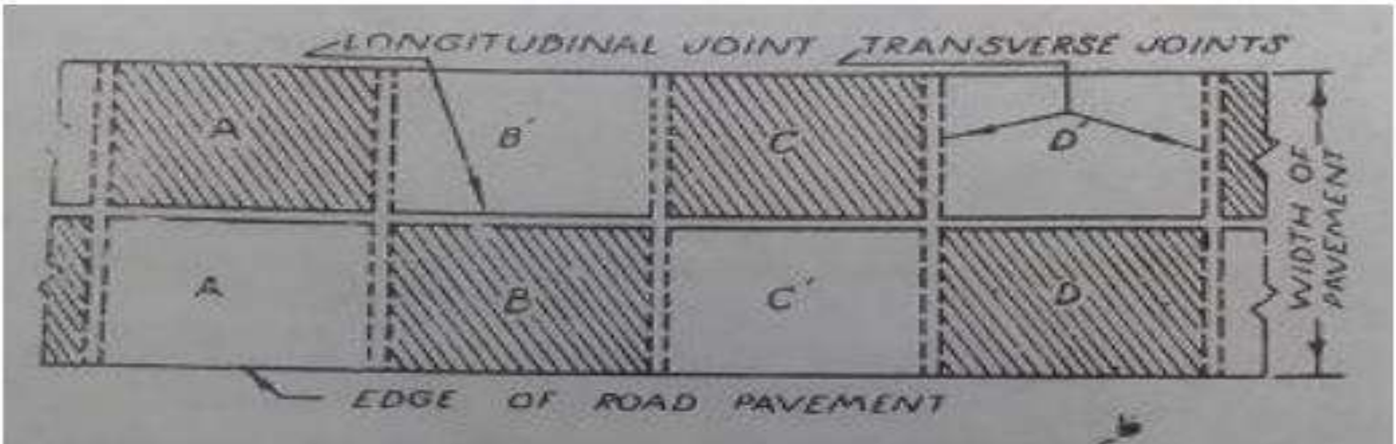
1. Alternate Bay method

2 .Continuous bay method

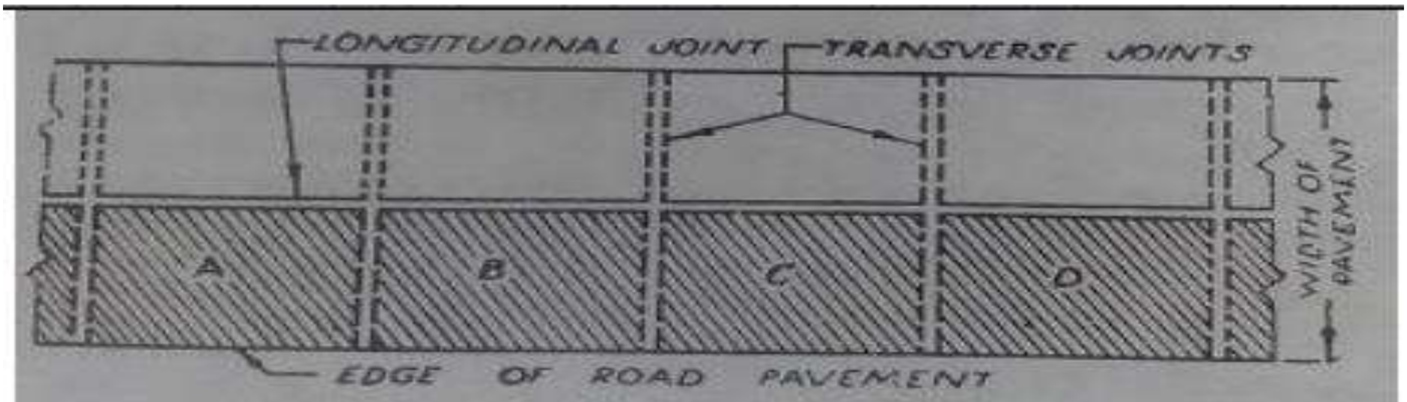
In alternate bay method, concrete pavement slab are laid on whole width of pavement in alternate bays.

In continuous bay method, concrete pavement slabs are laid continuously only on one bay and another bay is open for the traffic.

Generally the second method of continuous bay, is preferred over alternate bay method because, traffic movement is allowed while it is restricted in the first. Also, the alternate empty spaces invite the rainwater collection and create inconvenience to the construction work.



(a) Alternate Bay Method



(b) Continuous Construction Method

Alternate bay method is said to have the following advantages:

(i) Availability of more working space for laying a bay of the slab.

(ii) Joint-provision is considered to be easy.

(iii) The bay laid earlier can stand the adjacent bay laid later.

However, the method also has the following disadvantages:

(i) More number of transverse joints.

(ii) Rain water pooling in rainy season in the bays left to be laid in the second stage.

(iii) Since no single lane is ready for traffic, the diversion of traffic during construction is a disincentive.

(iv) Equipment has to be moved back and forth.

Material required for cement concrete road slab:-

1. Cement : ordinary Portland cement is most commonly used for concrete road slab.

2. Coarse aggregate : crushed stone, gravel- hard and durable

3. Fine aggregate : sand is commonly used as fine aggregate

4. Water : free from harmful substances

5. Reinforcement : Its consist of mild steel bars or steel wires.

Various steps for the construction of concrete pavements:

1. Preparation of subgrade :

The subgrade to receive the road slab is prepared to the required grade and profile in the usual manner. The cross and longitudinal profile should be checked by suitable templates.

When the water concrete is to be laid directly over the subgrade,the surface should be saturated with water 6-20 hr in advance of placing the concrete.This is done to ensure that the subgrade does not absorbed water from the concrete.

2. Provision of sub base or base course:

When the natural subgrade is not very firm, base course or sub base course is sometime provided. The base or sub base layer not only provides a smooth leveled surface and a layer, but it also reduces the thickness of concrete slab .

The base course for a concrete slab may be W.B.M surface,compacted granular material or stabilized soil base.

3. Placing of formwork: After preparing the base ,formwork for concrete slab pavement is laid the forms can be of steel and timber.

The final level and evenness of concrete pavement depend upon the forms .therefore, the forms should be properly and securely fixed to maintain their position, levels and shape at the time of laying and compaction of concrete. Formwork should be properly oil from inside.

4. Mixing and laying of concrete:

After laying formwork the surface of base or subgrade must be wetted with water before placing of concrete mix . the main function of watering is to saturated the surface completely so that it should not absorb any water from the concrete mix. After batching the required proportion of the material ,the material are mixed in a concrete mixer of adequate capacity. The properly mixed concrete is then transported in wheel barrows to the place of laying. The concrete is then spread uniformly. During placing concrete should not be dropped from a height greater than 900mm and should be spread within 20 minutes of discharge from the mixer.

When reinforcement has been specified in road slab,concrete placed in two stages. In the first stage, concrete is placed and compacted to the depth corresponding the level of reinforcement shown in drawings.Reinforcement is then placed on the top of compacted concrete and remaining thickness of slab is then compacted in second stage.

5. Compaction and finishing:

After placing the concrete in position compaction of road slab is done by means of a power driven finishing machine or by vibrating hand screed upto 12.5cm thickness slabs screed vibrators alone can be used for compaction. For greater thickness, screed ,vibrator along with immersion vibrator is used. Edges and corners of concrete pavement are best compacted by immersion vibrator.

The finishing work of concrete slab consists of number of operation such as floating belting brooming and edging etc.

6. Curing:

Curing consist in checking the loss of water from the concrete slab and keeping the fresh concrete slab most during hardening period it is started as soon as the concrete has been finished.

Initial curing consists of spreading jute mates saturated with water on the surface of fresh concrete slab. Initial curing is done for 24 hr . Final curing is done for 2-3 weeks. Final curing is done by ponding the surface by preparing small earth banks along the edges of the slab.

7. Opening to traffic:

Concrete pavement is opened to traffic after 28 days of curing. During this period brick edging is done to protect the slab.

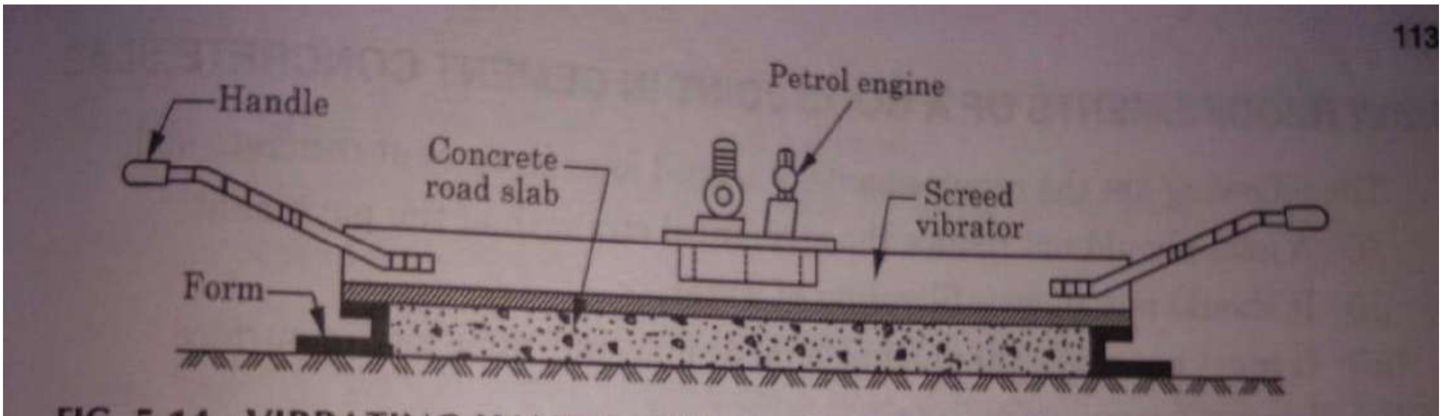


FIG. 5.14 : VIBRATING HAND SCREEN FOR COMPACTION OF CONCRETE MIX

JOINT IN CEMENT CONCRETE ROADS

Joint refer to the joining together of adjoining slab cast at different time in transverse or longitudinal direction so that it behave as a single joint.

JOINT IN CONCRETE PAVEMENT ARE PROVIDED DUE TO FOLLOWING REASONS

1. To allow expansion and contraction of concrete under the action of temperature an d moisture content.

2. To allow for break in construction at the end of days work,

3. To relieve for warping stress due to temperature difference between top and bottom of pavement slab.

4. To prevent irregular longitudinal cracks developed due to heavy wheel loads a continuous slab.

REQUIREMENTS OF GOOD JOINT IN CEMENT CONCRETE SLAB

1. A joint should not reduce the structural strength of the pavement

2. It should not allow infiltration of water

3. It must not make the road pavement uncomfortable riding surface

4. It must be easy to maintain.

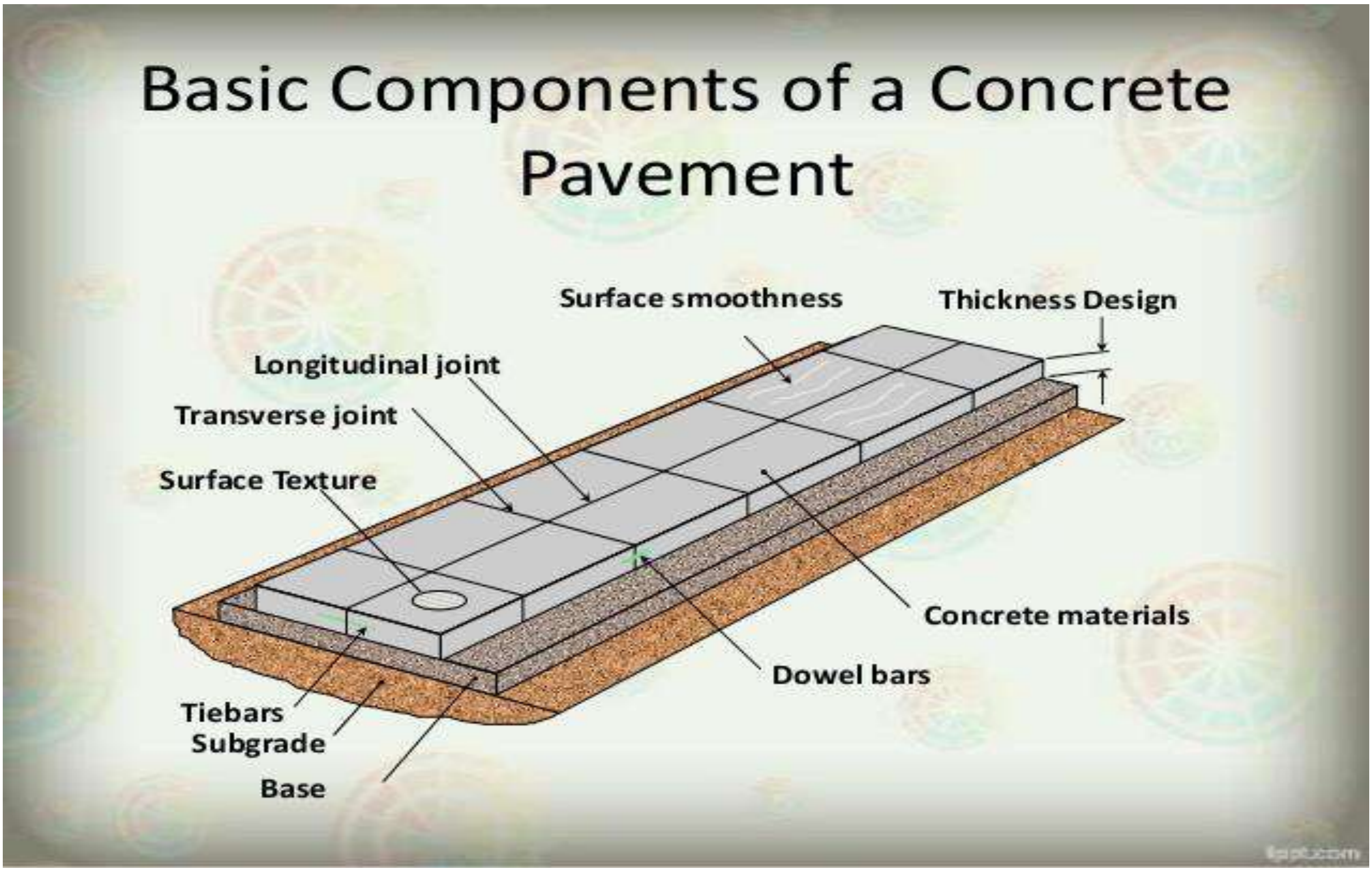
5.it must not come out of the general level of road surface.

TYPES OF CONCRETE JOINTS

The various joints in concrete roads are classified as:

1. Longitudinal joints

2. Transverse joints



1. Longitudinal joints :

The joints provided in the longitudinal direction between two strips of the road slab when the pavement width exceeds 4.5m are known as longitudinal joints.

OBJECTS OF PROVIDING LONGITUDINAL JOINTS

1.To facilitate construction of road slab (more than 4.5 m in width) in convenient width with hand tampers.

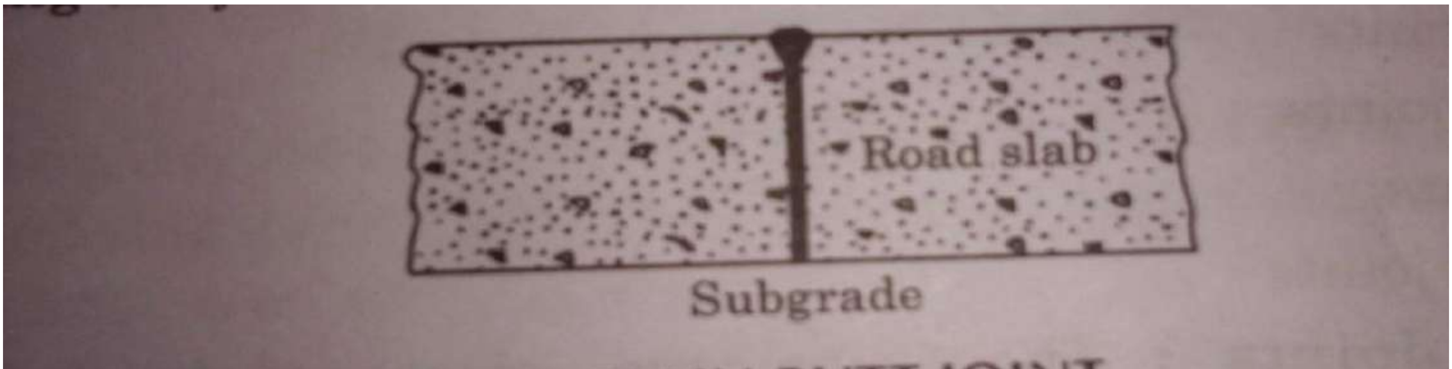
2. To control development of longitudinal cracks due to transverse contraction warping and uneven settlement of subgrade.

3.To help to maintain the two slabs together at the same level.

Types of longitudinal joints:

1. Plain butt joint:

It is the simplest types of longitudinal joints .It is formed by simply painting the joint faces with a sealing compound.

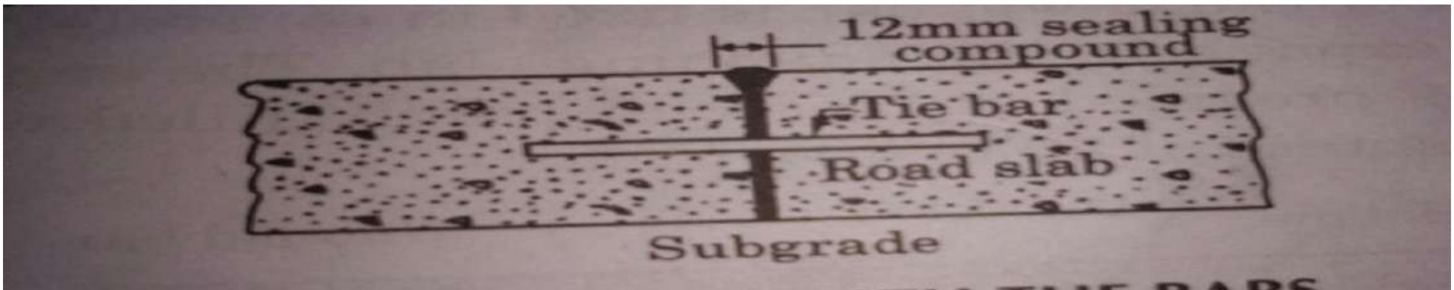


(a) PLAIN BUTT JOINT

2. Butt joint with tie bars:

In this type of joint, tie bars of 12-15 mm dia are provided. These tie bars are about 1m in length and are placed at 600 mm c/c . The top of the joint is then sealed with a sealing compound

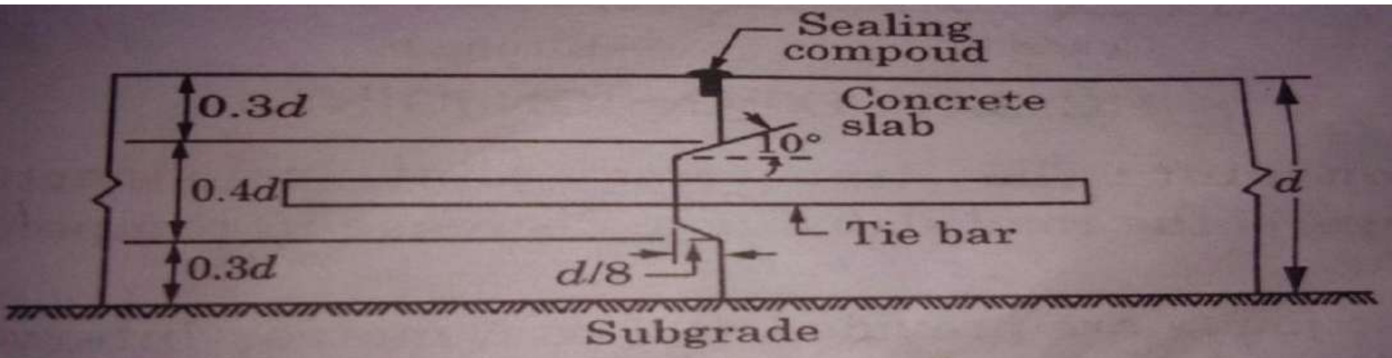
Tie bars are provided to hold the two slabs together .This joint acts as a hinge and help to maintain the two slabs at the same level.



(b) BUTT JOINT WITH THE BARS

3. Tongue and groove warping joint:

In this type of joint a tie bar is inserted between the two strips with a key. The top of the joint is sealed with a sealing compound.



(c) TONGUE AND GROOVE WARPING JOINT

TRANSVERSE JOINTS

The joints provided in the transverse direction of the road slab are known as transverse joints.

The following are the various types of transverse joints.

1. Expansion joints

2. Contraction joints

3. Warping joints

4. Construction joints

1. Expansion Joint

The purpose of the expansion joint is to allow expansion of concrete during rising in temperature with respect to construction temperature. They are provided along with longitudinal directions. These joints are extended to the full width and thickness of the road slab.

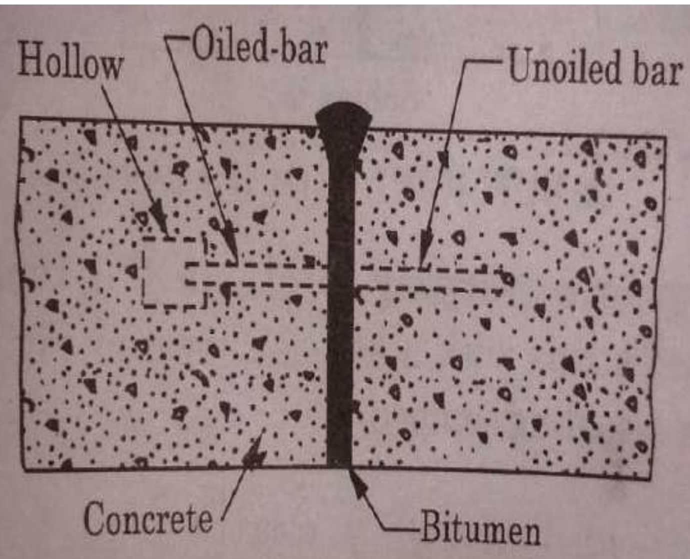
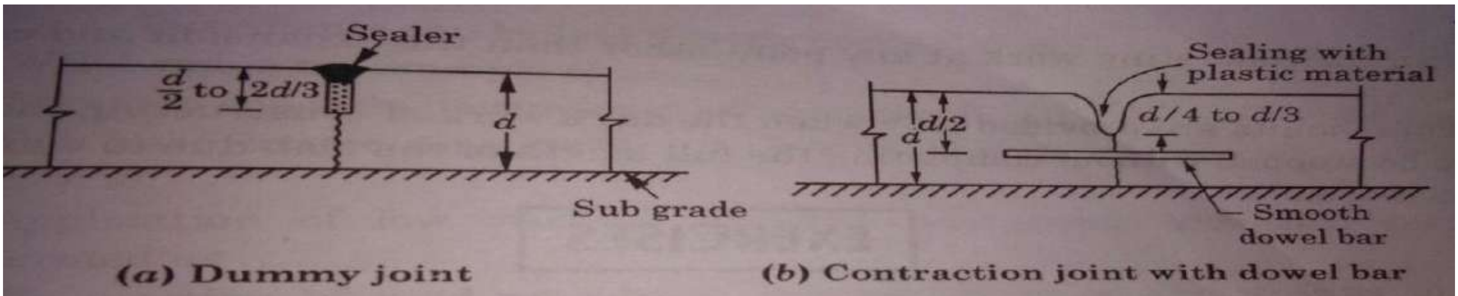


FIG. 5.17 : EXPANSION JOINT

2. Contraction Joints:

The purpose of contraction joints is to allow the contraction of the slab due to the fall in slab temperature below the construction temperature. These transverse joint are provided at 4 to 5 meter interval usually at right angles to the center line of the road.



(a) Dummy joint (b) Contraction joint with dowel bar

FIG. 5.18 : CONTRACTION JOINTS

3.Warping joints:

The transverse joint provided to control the bending or warping of a road slab due to different in moisture content or temperature at its top and bottom are known as warping joints. These joints are simply breaks in continuity of concrete which allow a small amount of angular movement to occur between adjacent slabs.

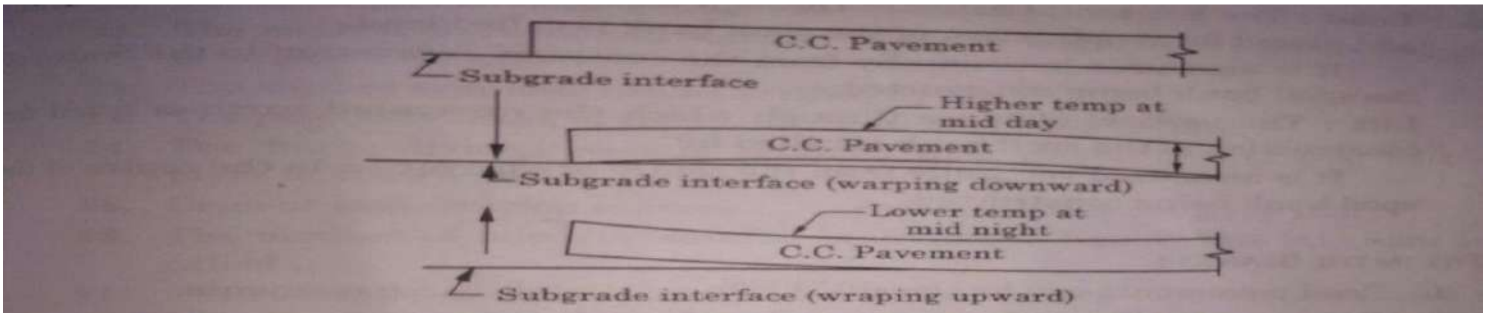


FIG. 5.19 : WARPING OF SLAB DUE TO VARIATION OF TEMPERATURE

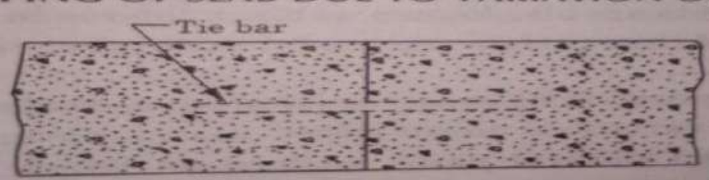


FIG. 5.20 : PLAIN WARPING POINT

4.Construction joints:

These joints are provided to facilitate the ease of construction. They are only constructed when it is essential to provide a compulsory break in concrete work at any point other than the expansion and contraction joint.

These joints are provided only when the days work of constructing the road slab has to be stopped without completing the full length of the slab due to whatever may be reason.

6. HILL ROADS

HILL ROADS :

The terrain having cross-slope of more than 25% is known as hilly terrain. The roads constructed in the area having cross-slope of 25% or more are called hill roads or ghat roads.

These roads present great difficulty in their alignment, design, construction and maintenance. Sharp curves, steep gradients and limited width of roadway make hill roads more liable to accidents. There are more chances of landslides in hilly terrain. Therefore, much care is needed during the layout and construction of hill roads.

CLASSIFICATION OF HILL ROADS

Hill roads may be classified into the following three categories :

1. Motor roads
2. Bridle paths
3. Village paths or tracks

1. Motor roads : The hill roads meant for motor, trucks and other such traffic are known as motor roads.Motor roads form main communication system in hilly region. All sorts of traffic can use these roads. These roads can have one or more than one lane width. These roads are constructed according to the design standards. The ruling gradient recommended for such roads is 1 in 20 and the limiting gradient is 1 in 15.

2. Bridle paths : The hill roads meant for pedestrians, laden ponies, mules,camels etc. are known as bridle paths. Bridle paths serve as feeder roads to motor roads. These are generally 2 m to 3m in width and 1 in 8 to 1 in 10 in slope. The surface of these paths is generally paved with stone blocks.

3.Village paths or tracks : The hilly roads establishing communication between villages and other working areas in hilly regions are known as village paths or tracks.These are, generally 1 m to 1.2 m wide and may have a slope of more than 45°. The surface of these paths generally consists of natural rock, dressed to the required gradient and camber

6.3 COMPONENTS OF A HILL ROAD

Following are the components of a hill road :

1.Road bed

2.Retaining wall

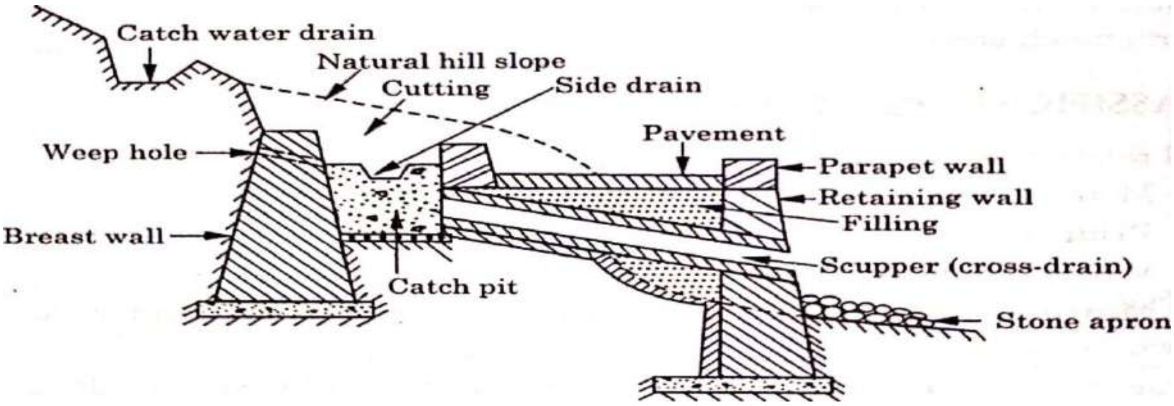
3.Breast wall

4.Parapet wall

5. Side drain

6. Cross-drain

7. Catch water drain



TYPICAL HILL ROAD SECTION PARTLY IN CUTTING SHOWING ITS COMPONENTS

(a) Road bed : The pavement portion of a hill road is known as road bed.

(b) Retaining wall : The wall constructed towards down slope side of the road to resist the pressure of earth filling and traffic load coming on the road is known as retaining wall.

This type of wall is constructed in case the cross-section of the road is partly cutting and partly in tilling. In order to permit easy drainage the retaining wall should be built in dry stone masonry.

The height of dry stone masonry retaining wall is restricted to 6m. When the height of the wall is more than 6 m, three coarses of rubble masonry in cement mortar are provided after every 3 m height.

(c) Breast wall : The wall constructed on the uphill side of roadway in or order to retain earth from slippage is called breast wall.

This type of wall is constructed when hill side is steep and there is tendency of its sliding down towards the road. Breast walls are constructed of stone masonary, brick masonary or cement concrete. The top width of breast wall is kept. as 600 mm thick and it should have number of weep holes to relieve the water pressure at the back of wall.

(d) Parapet wall : The wall constructed above the formation level of a hill road usually towards the downhill side is known as parapet wall. Parapet walls are provided to give protection, physical and psychological, to the motorists while travelling on roads with steep valley slopes. This type of wall should not be made continuous but suitable gap is provided in between.

(e) Side drain: The drain provided on the road side, usually at the foot of hill slope is known as side drain. The function of side drains is to collect and drain off rainwater, falling over the road surface as well as on hill slope, into any cross drainage work.

(f) Cross-drain: The drain constructed to drain off the rain water across the road is known as cross drain. The cross drains may be in the form of small under drains, scuppers etc.

(g) Catch water drain: The drain provided high up on the hill slope side in order to intercept and divert the water from the hill slope is called catch water drain.

Catch water drain is provided at suitable intervals parallel to the roadway. This drain is given a slope of about 1 in 33 to 1 in 50. This type of drain should not be provided less than 4.5 m distance from the edge of the road.

The function of these drains is to intercept the runoff from the hill slope, which would otherwise rush on to the road and wash it away, and then divert the same into a nearby cross drainage work.

TYPES OF CURVES ON HILL ROADS

The curves which are commonly used in hill roads are as follows:

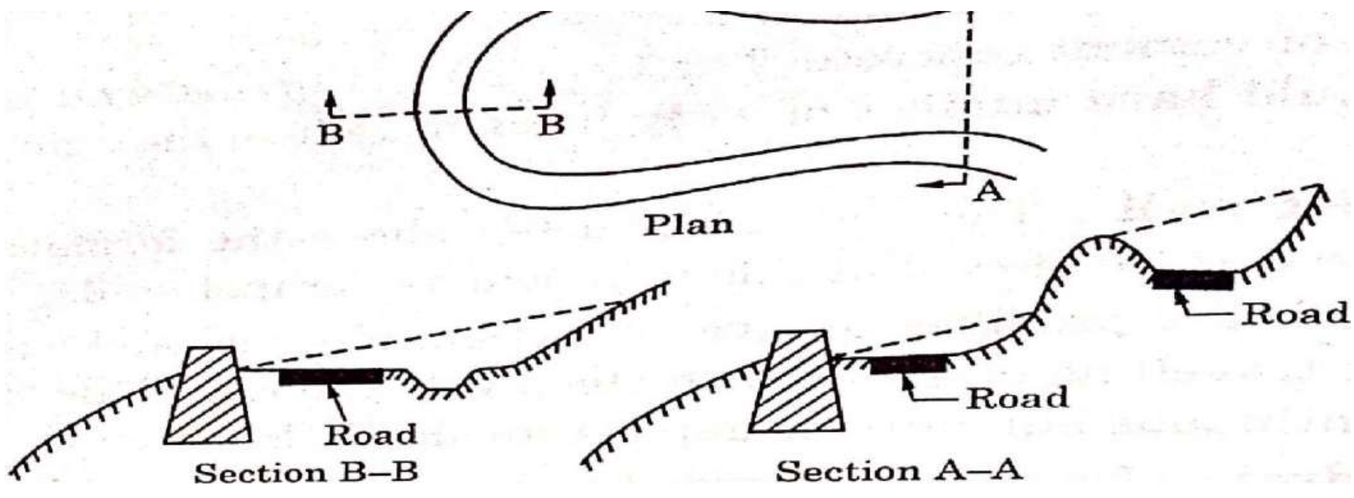
(1) Hair-pin curves

(2) Re-entrant curves

(3) Salient curves

(i) Hair-pin curves : The curve in a hill road which changes its direction through on angle of 180° or so, on the same side down the hill is known as hair-pin

Curve.

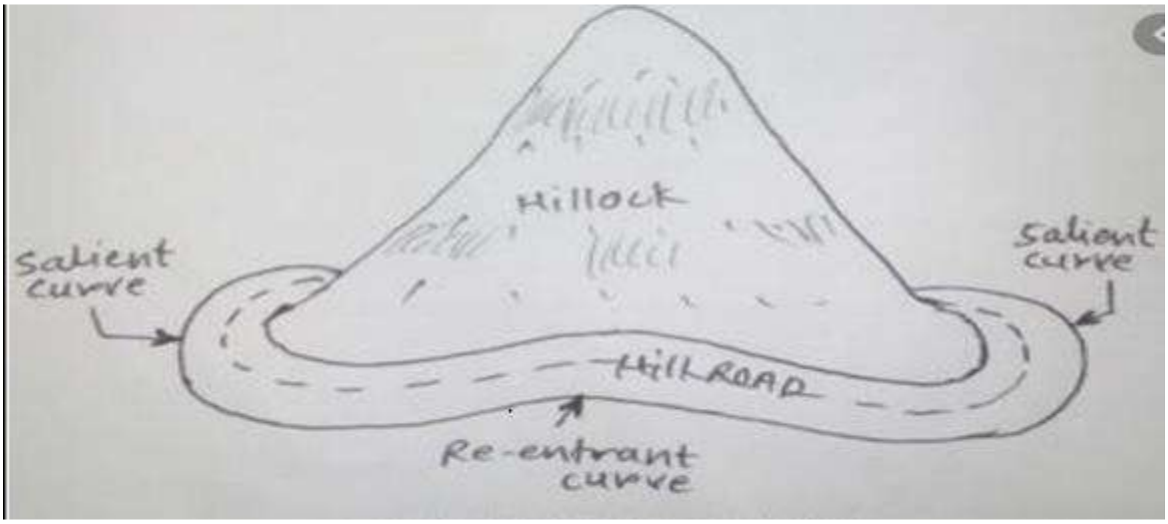


Hair-pin curves

The curve is so called because it conforms the shape of a hair-pin. The bend so formed at the hair-pin curve in a hill road is known as hair-pin bend. A hair-pin bend is 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. Hairpin bends with long arms and farther spacing are preferred to reduce construction problem and expansive protective works.

(ii) **Re-entrant curves:** The curves having their convexity on the inner edge of a hill road are known as re-entrant curves. The centre of curvature of a re-entrant curve lies away from the hill side. It is provided to negotiate a deep but narrow valley, forming an open bend. Re-entrant curves provide adequate visibility and are less dangerous.

(iii) **Salient curves:** The curves having their convexity on the outer edges of a hill road are called salient curves.



The centre of curvature of this type of curve lies towards the hill side. The bend formed by the salient curve in a hill road is known as corner bend. These curves are very dangerous as they do not provide adequate visibility. A parapet wall is provided at the outer edges of this type of curve to prevent the vehicles from falling down the hill slopes.

TYPICAL CROSS SECTIONS OF HILL ROADS

The typical cross-sections of hill roads giving all the details of construction aria shown below:

(a) Cross-section of a hill road in cutting: Hill roads in cutting are constructed when the hill side slope is very steep. The roads in cutting are generally constructed in half tunnels as the roads through full tunnels are very costly.

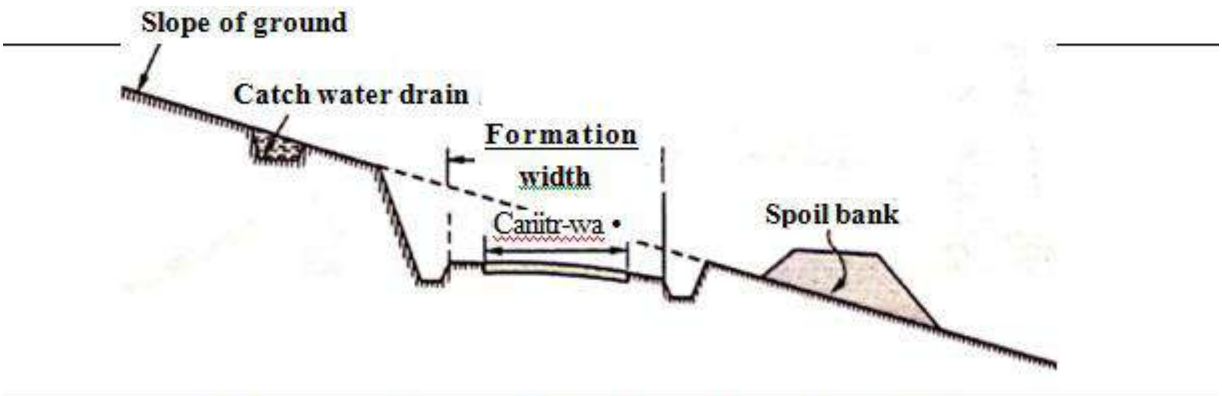
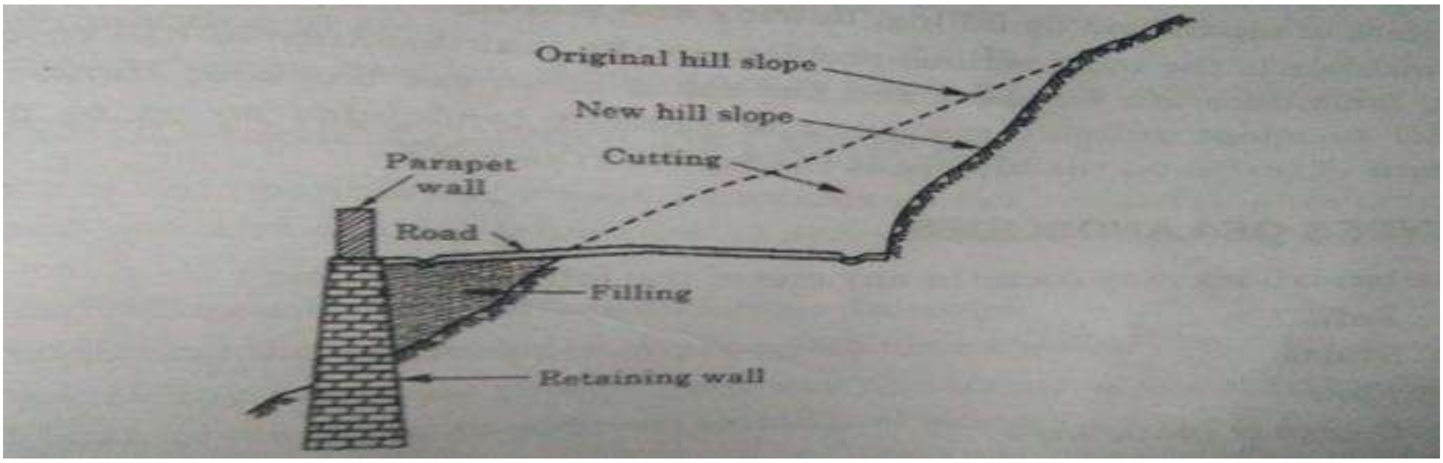


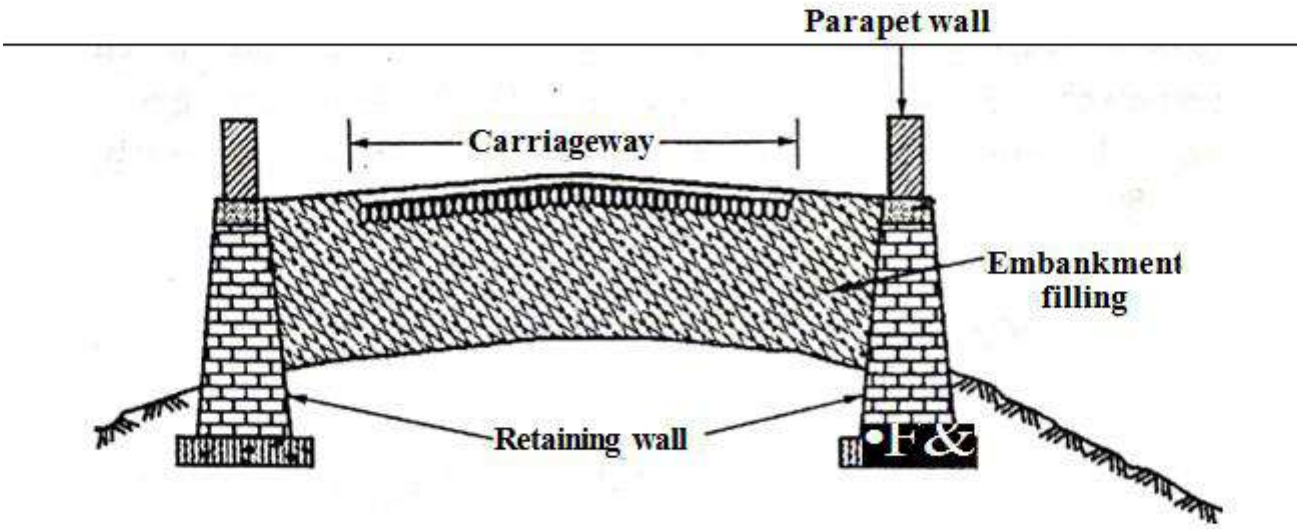
FIG. 6.4 : CROSS-SECTION OF A HILL ROAD IN CUTTING

(b) Cross-section of a hill road partly in cutting and partly in filling : Hill roads are generally constructed partly in cutting and partly in filling. These type of hill roads are constructed when the hill side slope is not very steep and cost of rock cutting is not too much.



CROSS SECTION OF A ROAD PARTLY IN CUTTING AND PARTLY IN FILLING

(c) Cross-section of hill road in filling: Construction of hill road in embankment is very costly and generally should be avoided. This type of construction becomes necessary when a depression comes in between the road alignment. In this case, two retaining walls will have to be constructed one on each side of the road.



CROSS-SECTION OF A ROAD IN FILLING

LANDSLIDES

Landslide is downward and outward movement of slope forming materials under the influence of gravity. The material involved in a landslide may consist of naturally deposited soil, artificial fills or combination of two. Landslides move along the surface of separation by falling, flowing and sliding.

Landslide is the most serious problem in the maintenance of hill roads. In rainy season, landslides are frequent and the roads often get blocked. Hence it becomes essential to adopt suitable measures to prevent landslides so as to provide free movement of traffic on the hill roads throughout the year.

TYPES OF LANDSLIDES

The landslides may occur in any one of the following forms :

- **(i)** Fall
- **(ii)** Slides
- **(iii)** Flow
- **(iv)** Complex landslides

(1) **Fall**: It includes free fall and rolling of rocks and debris down the hill slope. This type of landslide occurs due to tension failure.

(2**) Slides**: It is the movement of slope forming material along one or several surface down the hill slope.

(3**) FLOW** : The type of land sliding in which rock mass flows like a viscous material without any shear resistance is termed as flow.

(4) **COMPLEX LANDSLIDES :** The landside as a result of combination of one or more of failure

is termed as a complex landslide.

CAUSES OF LANDSLIDES

The following are causes of landslides :

(i) Hair-cracking due to alternate swelling and shrinkage of soil mass.

(ii) Formation of faults in bedding planes of the strata due to vibrations caused by rock blasting or earthquakes.

(iii) Increase in water content and consequent increase of pore pressure of soil mass.

(iv) Increase in load due to traffic movement or accumulation of snow on the road surface.

(v) Due to seepage pressure of percolating ground water.

(vi) Undermining caused by man-made excavations and burrowing animals or due to soil erosion.

(vii) Due to failure of a retaining wall or breast wall.

(viii) Deforestation of area.

(ix) Large scale construction of buildings or hotels on ridges or hill

PREVENTION AND CONTROL OF LANDSLIDES

Though it is not possible to prevent landslides caused by earthquakes etc. yet can surely prevent and control landslides to some extent by adopting the following measures:

i) By providing efficient surface and drainage.

ii) By reducing the earth slopes or providing breast walls.

iii) By providing adequate protective works like construction of retaining walls and buttresses at to improve stability of slopes.

(iv) By slope treatment (by turfing, stone pitching, cement grouting etc.) to minimize the erosion and to improve the stability of hill slopes.

(v) By prohibiting cutting of trees in forest areas and excavations at the bases

of slopes.

(vi) By preventing construction of unauthorised buildings at hill tops.

DRAINAGE WORKS ON HILL ROADS

One of the main problem in hill road drainage system is the surface water from the hill slope that flows towards the roadway. If the water from the hill slope flows into the road side drains, the water will flow over across the roadway surface and consequently cause severe damages to the roadway and the pavement. Therefore, the water flowing from the hill side towards the road side drain should be got intercepted at a higher level by catch-water drains' and then taken across the hill road through suitable cross drainage structures such as culverts or scuppers,

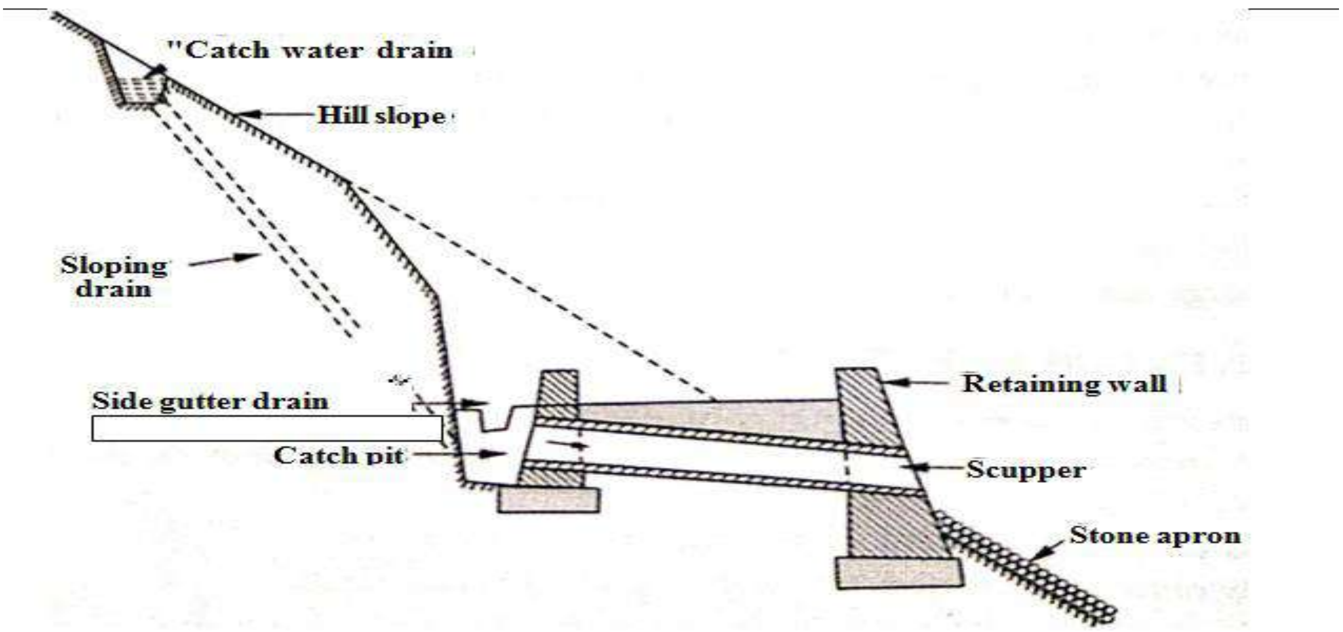
The surface drainage system of hill road consists of the following component

(i) Catch water drains

(ii)Sloping drains

(iii) Road-side drains

(iv) Cross drainage structures (such as culverts or scuppers)



CROSS-SECTION OF HILL ROAD SHOWING CATCH WATER DRAIN, SIDE GUTTER DRAIN AND SCUPPER

1. Catch water drains : These drains are provided higher up in the hill parallel to the alignment of road to intercept all the drainage water running down from the hill side and to discharge it into nearby valley. Catch water drains may be 60 cm wide and 45 cm deep with pitched bed and sides Catch water drains are given gradient of 1 in 50 to 1 in 33 to avoid high velocity of flow of water and possible wash out.

2. Sloping drains : These are the drains connecting catch-water drains and catch pit. Water from the catch water drains is diverted by sloping drains to catch pit at suitable intervals depending on the anticipated quantity of water to be diverted.

3. Road-side drains or Side gutter drains : These road-side drains are provided on one side of the road, usually on the side facing hill. The drains are of smaller size than the catch water drains and are constructed to collect drainage water from the surface of road only.

4. Cross drainage structures: Cross drainage structures are essential part of the hill road drainage system. These are provided to take the water collected through 'catch water drain' and side drain' to down the hill on the other side the roadway. Cross drainage are taken under the road and at right angle to it. At the head of the cross drains small catch pits must be provided to collect, the stones, soil and rubbish and to prevent scour. The floor level of the catch pit should he deeper than the sill of the culvert or cross drain by at least 0.3 m.

SOIL EROSION

The wearing out of rocks by the combined action of weathering agencies known as soil erosion. Water, wind and snow are the main agents of soil erosion Soil erosion also depends upon the type of soil, height and angle of slope of soil.

EFFECTS OF SOIL EROSION

Following are the major effects of soil erosion in hilly areas

(1)Soil erosion from the slopes of embankment destabilizes the soil stability.

(2) Soil erosion causes landslides which blocks the movement of traffic on hillroads.

(3) Soil erosion due: to surface water flow leads to more harmful effects in case of earthen roads.

METHODS TO CONTROL SOIL EROSION

The soil erosion can be controlled by adopting the following measures :

1. By providing turf: The soil mass is protected from soil erosion by providing turf (by growing grass) on the side slopes of embankments,

It also reduces dust nuisance on the road side and increases physical appearance of road.

2. By providing ground cover : The method to control soil erosion by water and wind is providing a ground cover to the slopes and other road side areas by growing low woody plants or shrubs. Properly selected plants will prevent headlight glare during night and their low height would not affect sight distance considerations.

3. Mulching : Mulching is a method in which straw, hay (grassy matter), falling leaves, saw dust etc. are spread uniformly over the soil surface. Mulching retards washing of soil, binds the soil particles together and provides a favorable condition for the growth of native plants.

SNOW CLEARANCE

In cold hilly region, large amount of snow accumulates in large amount during winter months. Because of snow accumulation, most of the hill roads situated at high altitudes get closed to traffic movement during winters. For the smooth movement of traffic on these roads, it is must that these roads be cleared off the snow accumulated. This process is known as snow clearance.

METHODS OF SNOW CLEARANCE

For the effective snow clearance, it is first necessary to locate the position of the roads generally coming under the attack of snow cover. After this, 'snow markers' which are like wooden poles are erected on the roadside before the snowfall starts. These indicator poles with metre scale marked on them give clear indication about the thickness of snow cover.

Generally following methods are employed for snow clearance in hill roads

1. Blasting for removal of snow

2. Snow cutting by machines

3. Removal of snow by manual labour

Blasting is only employed when ice crust is very thick and explosion does no affect the structures in the vicinity. Snow cutting by machines is most commonly employed in hill roads. Wheel dozer, motor graders and large trucks equipped with blade plows are effectively employed for this purpose. In regions, where snowfall is less, manual labour is employed for snow clearance. Snow is removed from the roads and thrown to the road side. When the snowfall is heavy, it is generally loaded into the trucks and hauled away.

SNOW AVALANCHE

Snow avalanche is defined as a hurtling mass of snow descending from a mountain side. 'Snow avalanche' may also be referred as a 'snow slip' occurring on a large scale in hilly regions. Snow avalanche is a much more serious problem as it may prove dangerous for road users.

CONTROL OF SNOW AVALANCHES

In hilly areas, snow avalanches can be controlled by the following measures :

1. Construction of galleries

2. Construction of snow fences

3. By detonating explosives

1. **Construction of galleries** : These are special protective structures constructed in R.C.C. and covered with earth on roof. These structures are constructed above the road. These structures permit snow mass to slide over the gallery roof without disturbing the flow of traffic on the hilly roads.

2. **Construction of snow fences** : Snow fences consist of wooden pickets about 1.25 m long woven with galvanised wire located on the windward side at right angle to the prevailing wind. Snow fences are placed before the ground freezes and are removed in the spring. These are very effective to minimise the formation of snowdrifts across the roadway.

3. **By detonating explosives**: By detonating explosives at the avalanche slab, snow is brought down in pieces. This method gives adequate warning and minimizes the damage to the road structures.

FROST

In hill roads, where the temperature of soil water falls below the freezing point, alternate cycles of freezing and thawing of water in the voids take place. This phenomenon which is known as frost action is very harmful to the road pavement.

This phenomenon can be understood as follows:

When the soil temperature decreases below the freezing point, water in the larger voids freezes. This raises the level of overlying pavement. This is known as frost heave'. During spring, with increase in temperature melting or thawing of ice crystals take place. This results in softening of road bed and causes settlement of road surface. Thus alternate cycle of freezing and thawing of ice causes raising and lowering of road pavement.

Remedies to control frost action : Frost action can be controlled by the following steps :

1. Providing proper surface and subsurface drainage system to lower ground water.

2. Replacing the soil subjected to capillary action with a granular non capillary material below the frost line.

3. Providing capillary cut off or an impervious seal (such as asphaltic membrane) to cut-off the flow of capillary water.

LAND SUBSIDENCE

Land subsidence is defined as the lowering of land surface. Many different factors can cause the land surface to subside. Subsidence can occur due to a sinkhole or underground mine collapse or during a major earthquake.

Land subsidence can lead to many problems including changes in elevation, damage to structures such as storm drains, sanitary sewers, roads, structural damage to public and private buildings. Subsidence is known for causing an increase

in the potential for flooding.

GEOSYNTHETICS

Geosynthetics are synthetic products used to stabilize terrain. They are generally polymeric products used to solve civil engineering problems. This includes different products like georids, geotextiles, geonets, geosynthetic, geofoam, geocomposites etc. The polymeric nature of the products make them suitable for use in the ground where high levels of durability are required. These are available in wide range of forms and materials. These products have a wide range of applications and are currently used in many civil, geotechnical, transportation, geoenvironmental, hydraulic applications.

Geosynthetics are generally designed for a particular application by considering the primary function that can be provided. Following are the five primary functions:

1. Separation

2. Reinforcement

3. Filtration

4. Drainage

5. Containment

1. Separation : is the placement of a flexible geosynthetic material between dissimilar materials so that the integrity and functioning of both materials can remain intact or even be improved, Paved roads, unpaved roads are common applications.

2. Reinforcement: is the improvement of a total system's strength created by the introduction of a geotextile, georids or geocell (all of which are good in tension) into a soil (that is good in compression) or other disjointed and separated material. Applications of this function are in mechanically stabilized and retained earth walls and steep soil slopes.

3. Filtration : is the equilibrium soil-to-geotextile interaction that allows for adequate liquid flow without soil loss, across the plane of the geotextile. Filtration applications are highway underdrain systems, retaining wall drainage etc.

4. Drainage : is the equilibrium soil-to-geosynthetic system that allows for adequate liquid flow without soil loss. Drainage applications are retaining walls, sport fields, dams, canals reservoirs etc.

5.Containment : involves geomembranes which function as liquid or gas barriers. Landfill liners and covers make use of these geosynthetics

RCC DESIGN & DRAWING

SUBJECT CODE – 220751

BY– SUMIT KUMAR

Reinforced Concrete Design

Compressive Strength of Concrete

- f_{cr} is the average cylinder strength
- f'_c compressive strength for design
- f'_c ~2500 psi - 18,000 psi, typically 3000 - 6000 psi
- E_c estimated as: $E_c = 33w^{1.5}\sqrt{f'_c}$

where w = weight of concrete, lb/ft^3

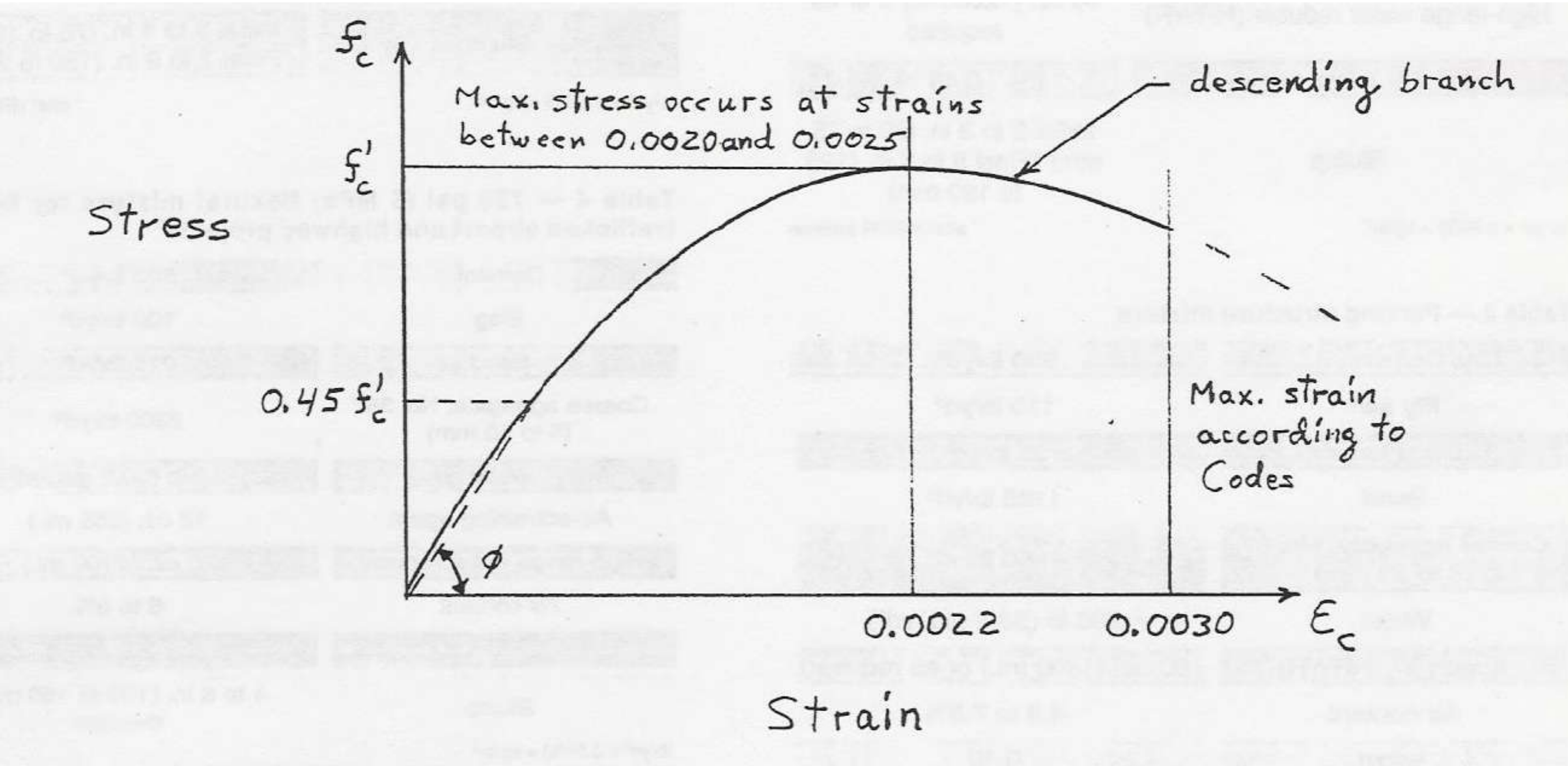
f'_c in psi

E in psi

for normal weight concrete ~145 lb/ft3

$$E_c = 57{,}000\sqrt{f'_c}$$

Concrete Stress-Strain Curve



For short term loading. Over time concrete will creep and shrink.

Concrete Strain

Strain in concrete will be caused by loading, creep, shrinkage, and temperature change.

For scale, consider a 20’ section of concrete, f'_c = 4000 psi, under a stress, f_c = 1800 psi. Determine the change in length.

Tensile Strength of Concrete

- Tensile strength of concrete is about $\frac{f'_c}{10}$
- ~300 – 600 psi
- Tensile strength of concrete is ignored in design
- Steel reinforcement is placed where tensile stresses occur

Where do tensile stresses occur?

Tensile Stresses

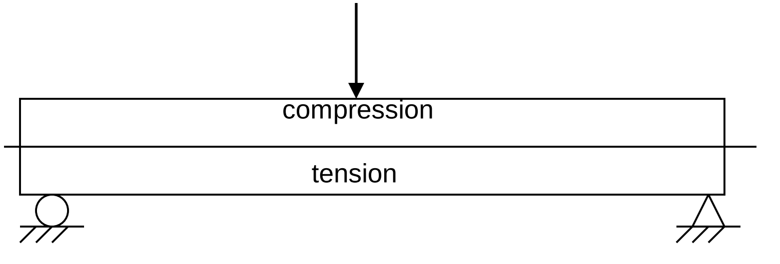
Restrained shrinkage

slab on grade 

shrinkage strain, $\varepsilon = 0.0006$

$\sigma = \varepsilon E = 0.0006 \times 3600 \text{ ksi} = 2.16 \text{ ksi}$

Flexural member

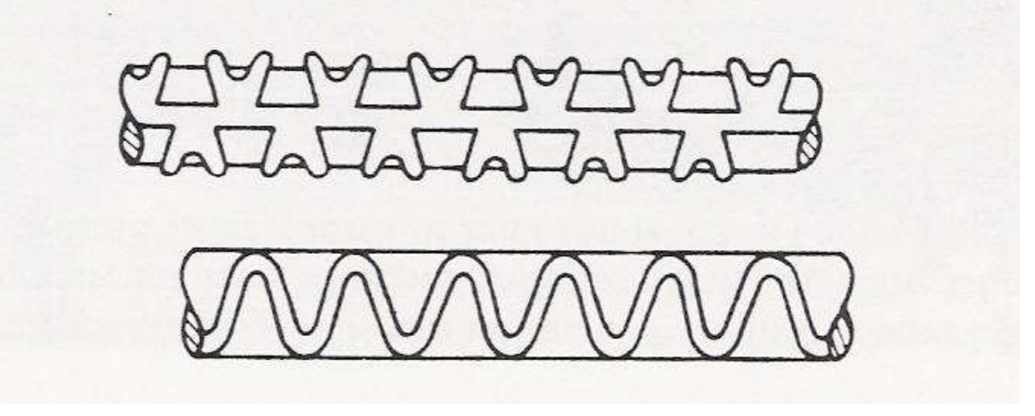


Reinforcing Steel

- Deformed steel reinforcing bars
- Welded wire fabric
- 7-strand wire (for pre-stressing)

Deformed Steel Reinforcing Bars
Rebar

- Grade 60 (most common in US)
- Sizes #3 → #18 (number indicates diameter in ⅛ inch)



Welded Wire Fabric

Readily available fabrics

	mm^2/m
6 x 6 - W1.4 x W1.4	59
W2.0 x W2.0	85
W2.9 x W2.9	123
W4.0 x W4.0	169
W5.5 x W5.5	233

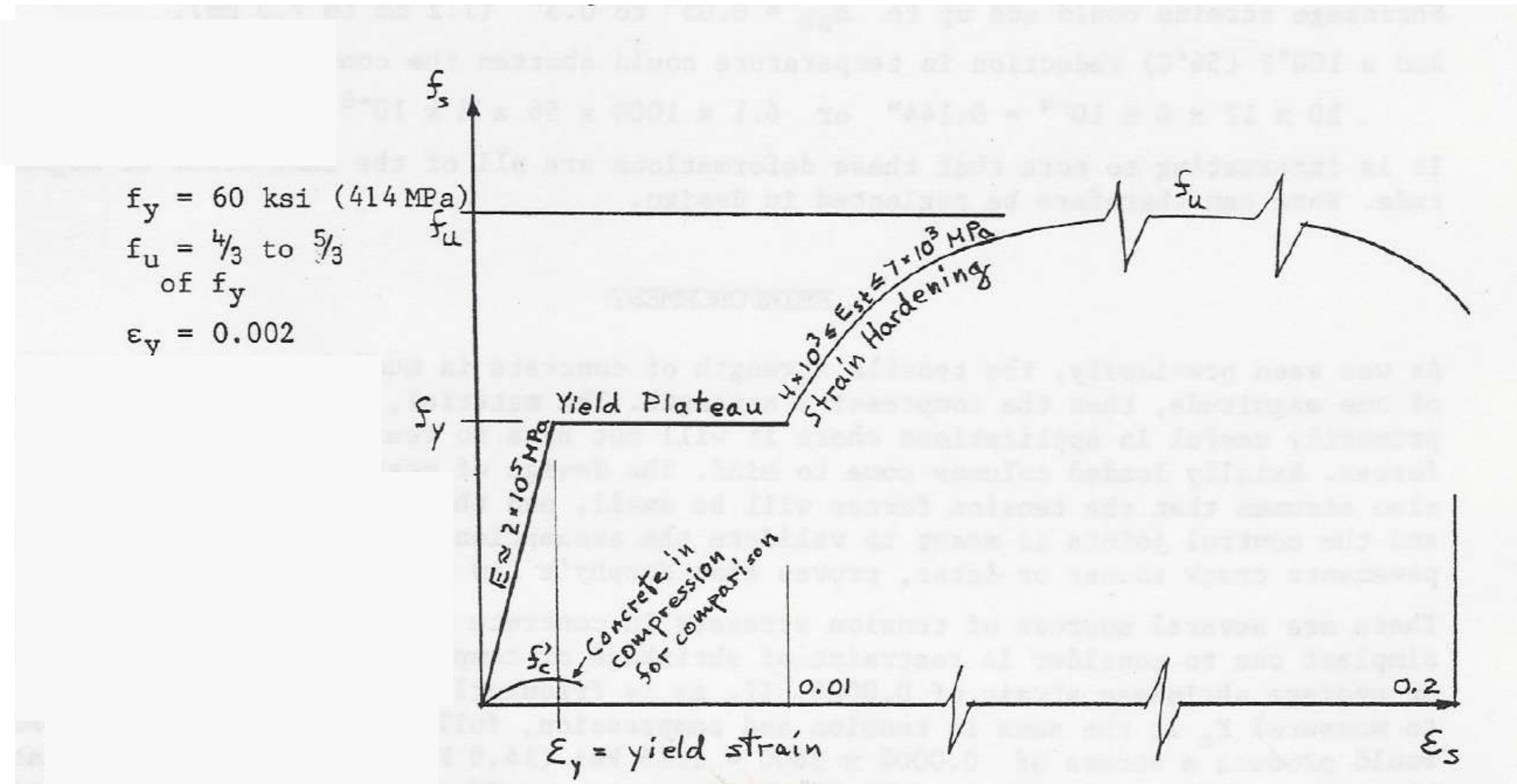
	mm^2/m of slab width
4 x 4 - W1.4 x W1.4	90
W2.0 x W2.0	127
W2.9 x W2.9	184
W4.0 x W4.0	254

Designation:

longitudinal wire spacing x transverse wire spacing –

cross-sectional areas of longitudinal wire x transverse wires in hundredths of in^2

Stress-Strain Curve, Steel and Concrete



Reinforce Concrete Design

Two codes for reinforced concrete design:

- ACI 318 Building Code Requirements for Structural Concrete
- AASHTO Specifications for Highway Bridges

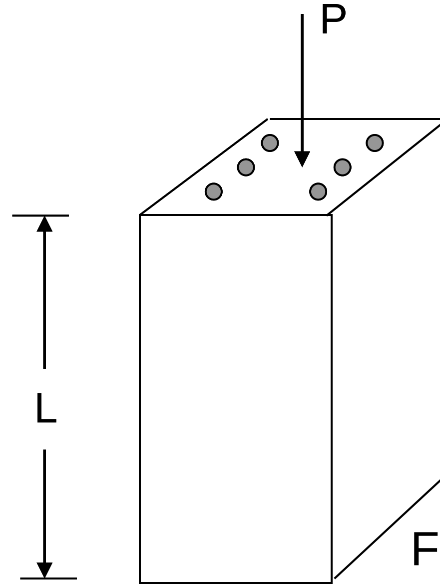
We will design according to ACI 318 which is an 'LRFD' design. Load and resistance factors for ACI 318 are given on page 7, notes.

Short Reinforced Concrete Compression Members

- Short - slenderness does not need to be considered – column will not buckle
- Only axial load

Cross-sectional Areas:
A_s = Area of steel
A_c = Area of concrete
A_g = Total area

F_s = stress in steel
F_c = stress in concrete



From Equilibrium:
$P = A_c f_c + A_s f_s$

If bond is maintained $\varepsilon_s = \varepsilon_c$

Short Concrete Columns

For ductile failure – must assure that steel reinforcement will yield before concrete crushes.

- Strain in steel at yield ~0.002
- $\varepsilon = 0.002$ corresponds to max. stress in concrete.
- Concrete crushes at a strain ~ 0.003

Equilibrium at failure: $P = A_s F_y + A_c f'_c$

Reinforcement Ratio

- $\rho = A_s/A_g$
- ACI 318 limits on ρ for columns:

  $0.01 \le \rho \le 0.08$ (practical $\rho_{max} = 0.06$)
- Substitute $\rho = A_s/A_g$ and $A_g = A_s + A_c$ into equilibrium equation:

  $P = A_g[\rho f_y + f'_c(1 - \rho)]$

Short Concrete Columns

$$P = A_g[\rho f_y + f'_c(1 - \rho)]$$

Safety Factors

- Resistance factor, $\Phi = 0.65$ (tied), $\Phi = 0.70$ (spiral)
- When $f_c > 0.85f'c$, over time, concrete will collapse
- Stray moment factor for columns, K_1
  - $K_1 = 0.80$ for tied reinforcement
  - $K_1 = 0.85$ for spiral reinforcement

$$\Phi P_n = \Phi\, K_1\, A_g[\rho f_y + 0.85f'_c(1 - \rho)]$$

Short Column Design Equation

$\Phi P_n = \Phi\ K_1\ A_g[\rho f_y + 0.85 f'_c (1 - \rho)]$

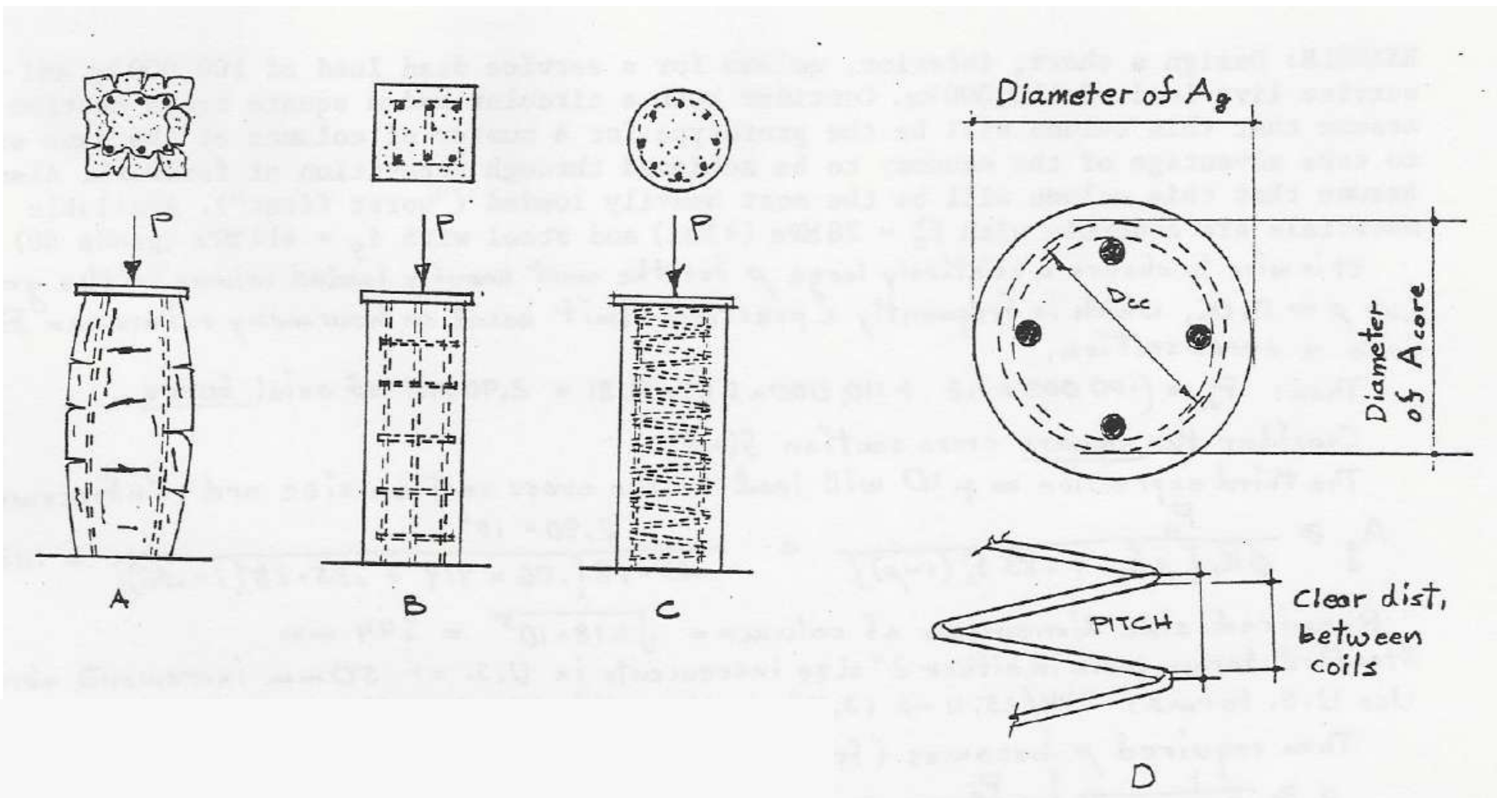
for design, $P_u \leq \Phi P_n$

$$\rho \geq \frac{1}{(f_y - 0.85 f'_c)} \left[\frac{P_u}{\phi K_1 A_g} - 0.85 f'_c \right]$$

$$A_g \geq \frac{P_u}{\phi K_1 \left[\rho f_y + 0.85 f'_c (1 - \rho) \right]}$$

Transverse Reinforcement

Used to resist bulge of concrete and buckling of steel



Concrete Cover

Used to protect steel reinforcement and provide bond between steel and concrete

¾"	(20 mm) for interior slabs, pan joists, and other light floor systems, protected against deleterious substances;
1½"	(40 mm) for most interior exposures, including main members;
2"	(50 mm) for normal exterior exposures, with additional cover recommended for particularly aggressive environments;
3"	(75 mm) for concrete cast against earth.

Short Concrete Column Example

Design a short, interior, column for a service dead load of 220 kips and a service live load of 243 kips. Consider both a circular and a square cross section. Assume that this column will be the prototype for a number of columns of the same size to take advantage of the economy to be achieved through repetition of formwork. Also assume that this column will be the most heavily loaded ("worst first"). Available materials are concrete with $f'_c = 4$ ksi and grade 60 steel.

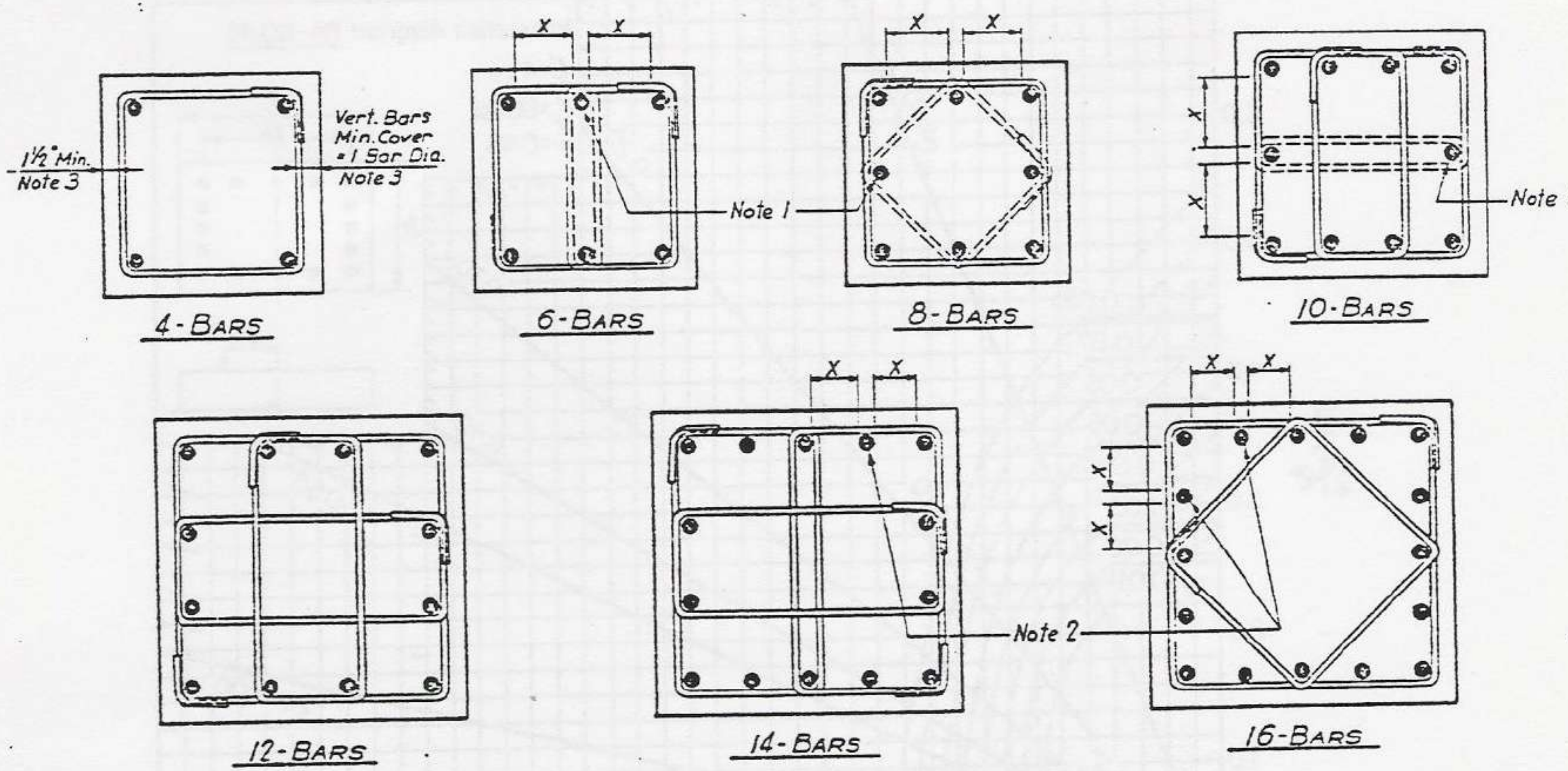
Available Steel Reinforcing Bars

ASTM standard reinforcing bars				
		Nominal dimensions—Round sections		
Bar size, designation	Weight, lb/ft	Diameter, in.	Cross-sectional area, $in.^2$ (mm^2)	Perimeter, in.
#3 (10)	0.376	0.375	0.11 (71)	1.178
#4 (13)	0.668	0.500	0.20 (127)	1.571
#5 (16)	1.043	0.625	0.31 (198)	1.963
#6 (19)	1.502	0.750	0.44 (285)	2.356
#7 (22)	2.044	0.875	0.60 (388)	2.749
#8 (25)	2.670	1.000	0.79 (507)	3.142
#9 (29)	3.400	1.128	1.00 (645)	3.544
#10 (32)	4.303	1.270	1.27 (817)	3.990
#11 (36)	5.313	1.410	1.56 (1010)	4.430
#14 (43)	7.65	1.693	2.25 (1450)	5.32
#18 (57)	13.60	2.257	4.00 (2580)	7.09

ACI 318. MAXIMUM NUMBER OF BARS THAT CAN BE ACCOMMODATED IN A COLUMN FACE, USING BEARING SPLICES OR RADIAL LAP SPLICES

Column side dimension, in.	#3 ties, 1½ in. cover					#4 ties, 1½ in. cover		
	#6	#7	#8	#9	#10	#11	#14	#18
10	3	3	3	2	2	2	—	—
12	4	4	3	3	3	2	2	—
14	5	4	4	4	3	3	2	—
16	6	5	5	4	4	4	3	2
18	7	6	6	5	5	4	3	3
20	—	7	7	6	5	5	4	3
22	—	—	7	7	6	5	4	3
24	—	—	8	7	6	6	5	4
26	—	—	—	8	7	6	5	4
28	—	—	—	9	8	7	6	4
30	—	—	—	—	8	7	6	5
32	—	—	—	—	9	8	7	5
34	—	—	—	—	10	9	7	5
36	—	—	—	—	10	9	8	6
38	—	—	—	—	11	10	8	6
40	—	—	—	—	12	10	9	7
42	—	—	—	—	12	11	9	7
44	—	—	—	—	13	11	10	7
46	—	—	—	—	13	12	10	8
48	—	—	—	—	14	13	11	8
50	—	—	—	—	15	13	11	8

*Does not include allowance for increased diameter at couplers.



1½" Min.
Note 3
Vert. Bars
Min. Cover
= 1 Bar Dia.
Note 3
4-BARS
X
X
Note 1
6-BARS
X
X
8-BARS
X
X
Note 1
10-BARS
12-BARS
X
X
14-BARS
X
X
X
X
Note 2
16-BARS

MAXIMUM SPACING OF COLUMN TIES*

Vertical bar size	Size and spacing of ties, in.		
	#3	#4	#5
#5	10	—	—
#6	12	—	—
#7	14	—	—
#8	16	16	—
#9	18	18	—
#10	18	20	—
#11	†	22	22
#14	†	24	27
#18	†	24	30

*Maximum spacing not to exceed least column dimension.
†#3 ties not permitted.

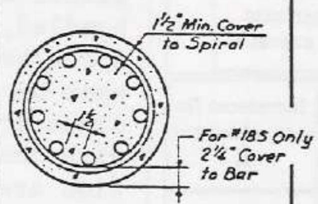
Minimum diameters to which standard spirals can be formed and minimum diameters which are considered collapsible are shown below for various sizes of spiral bars. Add 3" or more to find Least dia. of col.

Spiral bar diameter, in.	Minimum outside diameter which can be formed, in.	Minimum outside diameter of collapsible spiral, in.
3/8	9	14
1/2	12	18
5/8	15	24
3/4 (special)	30	—

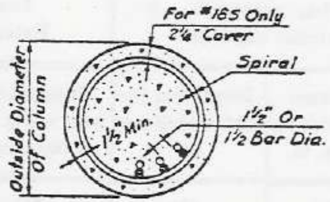
clear spacing between spiral turns should not exceed 3 in. or be less than 1 in. or 1-1/3 times the maximum size of coarse aggregate used.

MAXIMUM NUMBER OF BARS PERMITTED IN ROUND COLUMNS

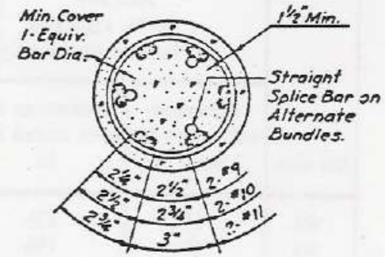
CASE I— BUTT SPLICES



CASE II— RADIALLY LAPPED SPLICES



CASE III— CIRCUMFERENTIALLY LAPPED SPLICES



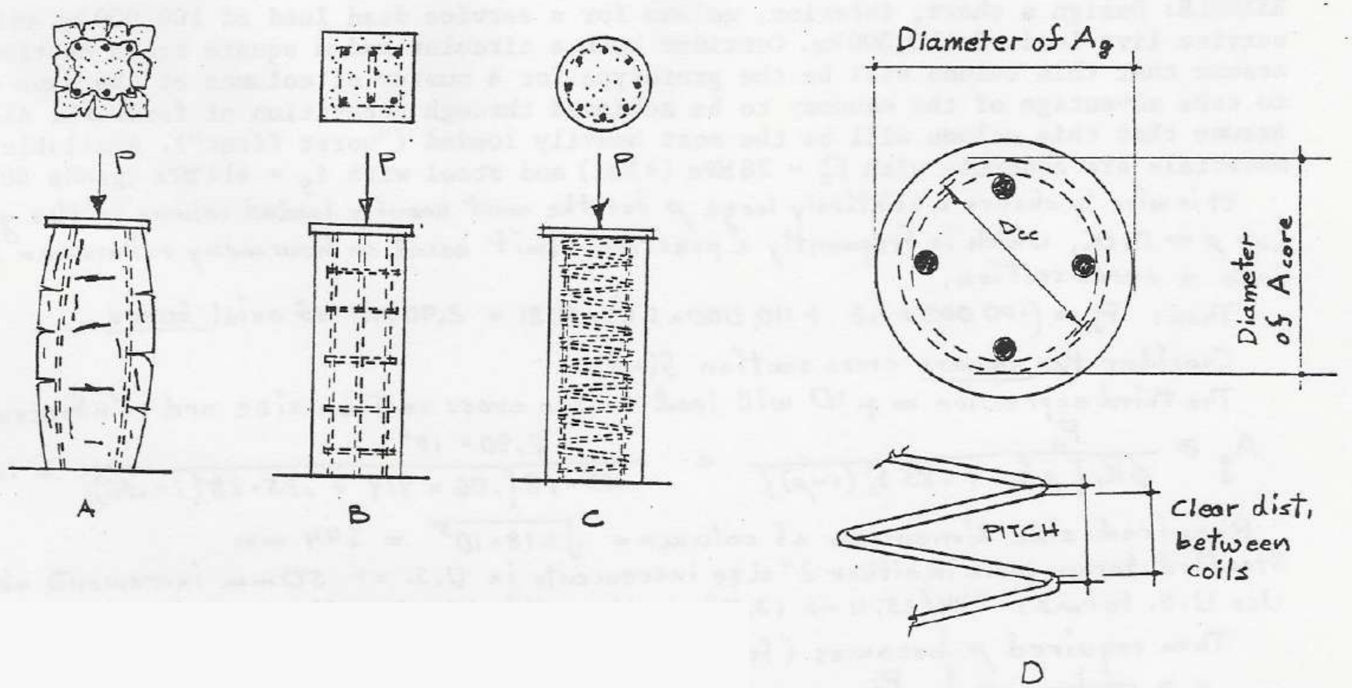
Column diameter, in.	CASE I— BUTT SPLICES						CASE II— RADIALLY LAPPED SPLICES									CASE III— CIRCUMFERENTIALLY LAPPED SPLICES								
	Bar Size						Bar Size									Bar Size								
	#8	#9	#10	#11	#14S	#18S	#5	#6	#7	#8	#9	#10	#11	#14S	#18S	#5	#6	#7	#8	#9	#10	#11	#14S	#18S
10†	6	–	–	–	–	–	6	–	–	–	–	–	–	–	–	6	6	–	–	–	–	–	–	–
11†	7	6	–	–	–	–	8	7	6	–	–	–	–	–	–	7	7	6	–	–	–	–	–	–
12‡	9	7	6	–	–	–	9	8	7	6	–	–	–	–	–	8	7	7	6	–	–	–	–	–
13‡	10	9	7	6	–	–	10	9	8	7	6	–	–	–	–	9	8	8	7	6	–	–	–	–
14	11	10	8	7	–	–	12	11	10	9	7	6	–	–	–	11	9	9	8	7	6	–	–	–
15	12	11	9	8	6	–	13	12	11	10	8	7	6	–	–	12	11	10	9	8	7	6	–	–
16	14	12	10	9	7	–	15	13	12	11	9	8	6	–	–	13	12	11	10	8	7	6	–	–
17	15	13	11	10	8	–	16	15	14	12	11	9	7	6	–	14	13	11	11	9	8	7	6	–
18	16	14	12	11	9	–	18	16	15	14	12	10	8	6	–	15	14	12	11	10	9	8	6	–
19	17	15	13	12	10	–	19	18	16	15	13	11	9	7	–	16	15	13	12	11	9	8	7	–
20	19	16	14	13	10	6§	21	19	18	16	14	12	10	8	–	17	16	14	13	12	10	9	7	–
21	20	18	15	14	11	7§	22	20	19	17	15	13	11	8	–	18	17	15	14	12	11	10	8	–
22	21	19	16	15	12	7§	23	22	20	18	16	14	11	9	–	20	18	16	15	13	12	10	8	6
23	22	20	17	15	13	8§	25	23	21	20	17	15	12	10	6	21	19	17	16	14	12	11	9	6
24	24	21	18	16	13	9§	26	24	22	21	18	16	13	11	7	22	20	18	17	15	13	11	9	6
25	25	22	19	17	14	9§	28	26	24	22	19	17	14	11	7	23	21	19	18	16	14	12	10	7
26	26	23	20	18	15	10	29	27	25	23	20	18	15	12	8	24	22	20	19	16	14	13	10	7
27	28	24	21	19	16	11	31	28	26	25	21	19	16	13	8	25	23	21	20	17	15	13	11	8
28	29	25	22	20	16	11	32	30	28	26	22	20	17	13	9	26	24	22	20	18	16	14	11	8
29	30	26	23	21	17	12	33	31	29	27	23	21	17	14	9	28	25	23	21	19	16	15	12	8
30	31	28	24	22	18	12	35	32	30	28	25	22	18	15	10	29	26	24	22	20	17	15	12	9
31	33	29	25	23	18	13	36	34	31	29	26	23	19	16	10	30	27	25	23	20	18	16	13	9

Design of Spiral Reinforcement

- A_{sp} = cross sectional area of spiral bar
- D_{cc} = center to center diameter of spiral coil
- A_{core} = area of column core to outside of spiral coils
- Pitch = vertical distance center to center of coils

$$\text{Pitch of spiral} \leq \frac{A_{sp} \pi D_{cc} f_y}{0.45 f'_c (A_g - A_{core})}$$

with the limit: 1” ≤ clear distance between coils ≤ 3”



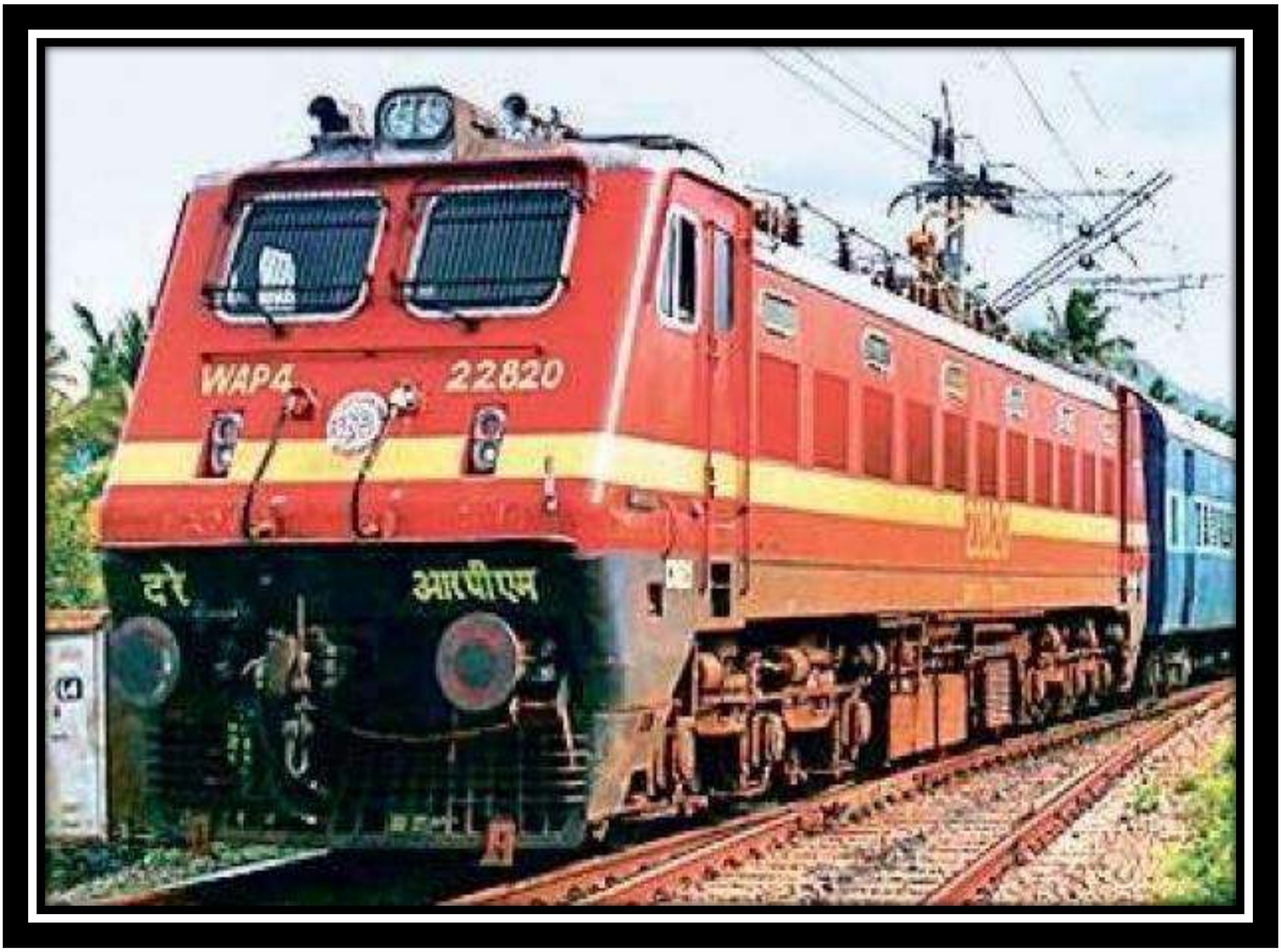
P
P
P
A
B
C
Diameter of A_g
Dcc
Diameter of A_core
PITCH
Clear dist, between coils
D

RAILWAYS, BRIDGES &TUNNELS

SUBJECT CODE – 220753

BY–AMIT KUMAR

RAILWAY BRIDGES AND TUNNELS



BY: - CIVIL ENGINEERING DEPARTMENT

B.K.N. GOVT. POLYTECHNIC NARNAUL

CONTENT COVERED

1. INTRODUCTION

There are different modes of transport for frequent movement from one place to other. Even mode has their own significance, but among all Railway has great utility and influence on our day to day life.

The concept of railway is very interesting in old days when horse driven vehicles moved over wooden planks these are termed as tram ways, however when wooden planks are replaced by iron plates, these were termed as plate way and presently iron plates are being replaced by iron angles known as rails. One thing is common among the old days horse driven vehicles that is horse worked as Engine and Cart worked as bogie (Rail Compartment). With the advancement of technology shape of railway changed; George Stephenson was first man to invent the steam locomotive. which is being used till date to drive rail compartments.

‘With the passage of time, development in technology replaces these steam engines with Diesel Engines as well as Electrically operated Engines.

Railways impart great economy in the development of country Developing countries like India, railway plays integral role in the development as well as national integrity of the nation.

DEVELOPMENT OF RAILWAYS IN INDIA

Railway development was not an easy task but great efforts were made to make it compatible and finally it is proved that the efforts made for the developments of Railways lead great success, it was continuous and regular efforts. If we go through the history of railway it is evident that attention were made in 17th century and finally George Stephenson resulted in the running the first train of the world on 27th September 1825 between Stockton and Darlington.

Britishers were the first to introduce the system of railways in India. In India the first railway line was laid in 1853 and run first train on 16th April 1853 between Bombay to Thane.

1854 –Second railway line from Howarh to Pandooa was opened

1855- 1862 – North India was constructed with help of 8 companies

1879 – India has a total of 14920 kms railway line.

1880 – The recommendation of 8000 km of new railway line

1881 - Lord Hartington formulated the rules for railway construction

1881 -1897 - New contracts were given to the 7 New Companies tor development of Railway.

1901 - Special Attention was given by appointing Mr. Thomas Robertson to investigate into Railway administration, organization and

System.

1905 - Railway Board was established under the department of Commerce and Industries

1907 - Mckay Committee was appointed to examine the railway problems

1908 - Railway Board was re-organised to improve the railway

1914-1921- Railway kilometrage was increased up to 58,776 kms

1922-1939 - Kilometerage was increased up to 65,850 kms.

1947-48 - Due to Partition of India, Indian Railways suffered great. loss.

1948-50 - Government acquired control over all railways except few pro companies.

The entire Railway system comprising of 35 Railway Administrations before April, 1951 was re-grouped into the following nine zones :

- Eastern Railway (E.R.).
- South-Eastern Railway (S.E.R.)
- Northern Railway (N.R.).
- MI North Eastern Railway (N.E.R.)
- Southern Railway (S.R.).
- Central Railway (C.R.).
- Western Railway (W.R.).
- North East Frontier Railway (N.F.R).
- South Central Railway (S.C.R.). .

After this, there was a rapid development of Railways in India which was achieved through the following five year plans :-

First Five Year Plan (1951-56) : In this plan, the total investment on Railways was Rs. 423 crores. This plan considerably helped India in achieving self sufficiency. Chitrarjan Locomotive Works and Tata Engineering and Locomotive boosted up their production during this plan.

Second Five Year Plan (1956-61) : In this second five year plan, a total provision was increased up to 1.044 crores, for ,the development of Railways in India. This plan made the country self sufficient in railway equipment and transportation.

Third Five Year Plan (1961-66) : In this plan, a sum of Rs. 1,686 crores was increased for the development of Indian Railways. During this plan, many locomotives wagons and coaches were acquired. It also provided for doubling of track, complete track renewals, etc., Besides this, many bridges, staff quarters, railway stations and other facilities were undertaken. This plan helped the railways in building infra structures.

Fourth Five Year Plan (1969-74) : In fourth five year plan, a sum of Rs. 1.557 crores was retained for the development of Indian Railways. During this plan, more attention was given on addition and replacement of rolling stock.

Fifth Five Year Plan (1974-79) : In this plan, a sum of Rs. 2,350 crores was kept for the development of Indian Railways In order to have the uni-gauge over the large area, conversion of Metre gauge to Broad gauge (B G.) was Ta ken in hand during this Five Year Plan. As in the case of earlier plans. the main objective of this plan was to provide capacity for freight and passenger traffic was anticipated during the Precious Plans, keeping in view for the developments of the country and national economy.

SYSTEMS OF RAILWAYS

The Railways can be provided on, above and below the ground surface, suiting to the topography of the area. Further, the Railways below ground surface can be constructed just below the ground level or at greater depths.

There are the following four systems of Railways :-

1. Surface railways ;
2. Elevated railways ;
3. Under ground railways ;
4. Tube railways.

1. Surface Railways

The railways provided over the ground surface are known as surface railways.

Suitability : This system of Railways is most extensively used throughout the world because this is the best system for transporting people andgoods. In surface railways, the various means like *level crossings over-bridge or under-bridge are to be provided for crossing of the railway and road traffic safely and efficiently.

2. Elevated Railways

The railways provided at higher or elevated portion, above the ground surface are called "high level" or "elevated railways".

In this system of Railways, a continuous viaduct supported on piers, columns, etc. [i5] constructed and the track is carried on its steel deck. This system is very costly because buildings like stations, waiting halls, offices are to be constructed at high levels requiring stair cases, escalators, etc. But elevated railways cause little obstruction due to piers, columns supporting the, track,

3 . Under Ground Railways

The railways provided just below ground level are called "low level or underground railways.

In this system of Railways, tunnels are constructed for carrying tracks through them and a over-bridge is necessary at every road-crossing to carry the road traffic over the railway traffic. Due to ventilation problem in tunnels, electricity is the only source of power for traction in under ground railways.

Advantages :-

(i) This system provides rapid and unobstructed transportation.

(ii) This system helps in reducing traffic congestion problems.
(iii) This system provides safety during aerial attack in war.

Suitability : Under ground railways are suitable in the heavily congested urban areas where the traffic intensity on roads is heavy.

Tube Railways

The railway provided underground at a greater depth of about 18 m or more (upto 52m) are called tube railways.

This system of Railways is so called as the section of the underground tunnels, carrying the track, is circular like a tube. The main purpose of providing tube railways is to avoid the interference of the tracks with water and gas pipes, sewerage systems and oil or drainage pipes, etc.

Some important feautures of the tube railways are given below :

(i) The railways stations have to be of cylinderical form.
(ii) Escalators or moving stair Cases are to be constructed to reach the tube railways.
(iii) Only electric traction is to be uses to avoid the smoke and ventilation problems.
(iv) Automatic signalling system is to be used.
(v) Such a mechanism of the train is to he used that it cannot start until all the doors are closed, and it automatically stops, if the signal is at 'STOP' position.

ADVANTAGES OF RAILWAYS

Railway imparts great significance on over day to day life. These may be classified as :

1. Political significance
2. Social significance
3. Economic significance

Political Significance

(i) Railway unites the people of different caste, religion, customs thus helps integrity of the nation.
(ii) With the help of railway networking central administrative control become easy and effective.
(iii) The role of railways for mobilizing troops and war equipment cannot be denied during emergencies.

(iv) Railway Network easy migration of people thus impart political stability to the nation.

Social Significance

1. Railway has made movement of people easy thus social integrity results due to railway networking.
2. Railway does not made restriction on the movement of caste, race etc thus feeling of humanity increased by travelling in rail compartments.

3. Railway has made the Journey's of religious places easier thus strengthens the social advantages among the people.

4. Railways journey's increases social outlook of masses as it provide easy way to meet the people's of different part of the Country.

Economic Advantages

1. The mobility of masses contributed to industrial development.
2. Transportation facility for raw as well as finished goods from the factories helped rapid growth of industrial development.

3. Railway has great employment thus solving the problem of unemployment up to great extent.

4. Easy movement of goods helps the nation against inflation problem of the country.

FEATURES OF INDIAN RAILWAY

Railway is one of the most important mode of transportation. In the modern era rail transport is the index feature of nation's economic, social, political as well as industrial development. In Developing country like India rail transport is the backbone of the country Railway transport is an economical means of transportation in India for commercial as well as passanger's per's movement Some of the main features arc discussed below

1. Indian Railways are the biggest undertaking in the world

2. Indian railway contributes major employment opportunity among the world.

3. Indian railways are the cheapest mode of transportation among the other modes of transportation.

4. Railway has its unique way of movement thus keeps easy movement without traffic congestions.

5. Development of electric railway keeps in protecting environment against pollution.

6. Railway need less traction to move it in comparison to its weight.

7. The rate of accidents are minimum in case of railways.

2. RAILWAY SURVEY

INTRODUCTION

To get the optimum position of railway rout, before laying is called railway survey on the ground and giving direction to the railway track is only possible through the operation of railway survey. The location of this railway track is also called alignment of track. Broadly alignment of railway track comprises of win two components

1. Horizontal components

2. Vertical components

1. Horizontal Components: It includes straight path, its width, curves an deviations in width.
2. Vertical Components: It includes changes in vertical curves and gradients. Both these components plays vital role while ascertaining optimum railway track or setting out alignment of railway track. While determining the alignment of railway track every care should be taken, and numbers of factor relating to setting out alignment should carefully be studied which & directly or indirectly affects the rail route. A little mistake in alignment of track can prove un-economical in construction as well as maintenance of track and operation in movement of vehicles. It is obvious that once the track is constructed it is impossible to alter the track because it involves large initial cost of construction and it is nearly impossible to change the track so while setting out alignment various factors should be considered in mind and proper survey should he carried out to get most economical track alignment.

FACTORS INFUUENCING THE RAILWAY ROUTE

While determining railway route or alignment it is kept in mind that it should be straight between the two terminal stations, but this condition is not always be possible because of available topographical conditions of the area to be surveyed, such as intermediate obstruction, steep quotients, construction problems etc. along route.

It is observed that the route which is most economical in initial cost does not prove economical in operations. It means that same times operation list on such alignment prove costlier than other available alternative routes. Thus it is concludes that all requirements does not met simultaneously so following are some factors which should be kept in mind while aligning the track :-

1. **Religious Places** : The track which is to be determined should never cross trough religious buildings or structure. If these types of obligations comes in the way the track or alignment must be deviated.
2. **Areas of flood/snow fall** : The rail alignment also effected if such area like flood prone or heavy snowfall comes across the alignment which cause considerable problem in operations of railways. Thus alternative possible routes are find out for the alignment.

3. Obligatory Points : Railways alignments should be determined keeping in view of some obligatory points which have some importance like defence importance, intermediate towns, towns of commercial importance etc.

4. Future Traffic Growth - The route should be such that it will incorporate future growth of traffic so that initial cost for future can be minimized for future.

5. Geometric Design : It is the vary important factor which affect the route of railway while determining the alignment it should be carefully studied. geometric design of railway alignment covers gradients, curves factors. For gradient it should be below 3% i.e. it should be normal or ruling gradient where as in case of curves should he maximum possible radii.

6. Topography of Area - Topography means the geographical conditions of the area where the railway should be aligned. This is most serious factor of railway track alignment and seriously affect the railway route considerably. So while considering optimum railway track it should be seriously studied according to topography There may be three types of alignments

1. Valley alignment

2. Cross country alignments

3. Mountain alignment

Depending upon the conditions available in the region any suitable alignment is adopted to set up the track. Further to achieve the development, to limit the gradient upto ruling gradient the length of the alignment is increased first between the two extreme ends of elevation. This development is achieved by

1. Zig-Zag development

2. By switch back development

3. Spiral or complete loop development

7. Economic Considerations It is the most important factor of determining the railway route it includes working out the economics, the initial cost, cost of maintenance and vehicle operation cost. The best alignment would be one which gives maximum annual return. It also includes that it should not involve in excessive cutting or embankment etc.

8. Drainage : A railway route should always be away from those areas which cause drainage problems.

9. Boundaries : There should be away form the boundaries of neighboring countries.

RAILWAY SURVEY FOR TRACK ALIGNMENT

The need for constructing a railway line may arise from one of the follow considerations.

1. For the development of an area. The existing transportation facilities may inadequate.

2. To develop an area which may be rich in mineral; resources or other nature wealth like timber resources.

3. For development of existing industries.

4. For shortening an existing railway line.

5. For connecting a sea port with its hinter land.

6. To serve as feeder or line for an existing railway line

The whole survey work is divided in four stages:

(A) Traffic survey

(B) Reconnaissance survey

(C) Preliminary survey

(D) Location survey

TRACK ALIGNMENT

The route survey and track alignment are interdependent parameters. It is not possible to go in for a detailed survey which involves considerable amount of effort, money and time. At the same time the alignment cannot he decided without getting field data for taking a tentative decision in respect of one or two routes. A working compromise in respect of these two interdependent elements is achieved by deciding one or two routes in the office on the basis of contoured map of the area between the starting and terminating stations. A comparative statement of the various possible routes is arrived at. On the basis of a rapid go over the area in the form of reconnaissance survey followed by preliminary survey.

The location survey or detailed survey is finally taken for the chosen alignment only. While finalizing the alignment the following points should be considered

1. Shortest route

2. As low construction cost as possible

3. Low maintenance cost

4. Easy curves

5. Easy gradients

6. It should serve the towns and cities falling in the alignment.

7. The alignment should afford good scenery on the way.

It is, however, not possible to have an alignment which would satisfy all the requirements. The one to he decided therefore would be the one that meets maximum requirements. In addition to the above stated guiding principles, the special features of the track which also influence the alignment are as below :

(i) Obligatory points namely bridge sites.

(ii) Climatic condition of the region.

(iii) Location of tunnels if the track is in hilly area or undulating country.

(iv) Highest Flood Level in case of stream crossings.

(v) Topography of the country.

(vi) Gauge of the track.

(vii) Crossing rail-road or other crossings.

SURVEY FOR TRACK ALIGNMENT

Work may be divided into the following parts :

(i) Traffic survey
(ii) Reconnaissance survey
(iii) Preliminary survey
(iv) Location survcy

Traffic Survey:

The purpose of the traffic survey is to give field data to the Administrative Authority to judge the suitability of the project under reference. The economical considerations of the project such as availability of funds and the return that the line would yield on completion in the form of earnings from passengers and goods traffic have to be studied in detail.

The following information is collected in the traffic survey :

(i) Particulars of towns and villages within a distance of ten to twenty kilometers on either side of the proposed track. If for a considerable distance on either side of the track, there is no existing communication system (road or railway), the distance on either side of the track would extend to say 20 kilometers otherwise to say 10 km.

(ii) Location of existing and potential industries with brief description and scope of development consequent to the opening of the new track.

(iii) Estimate of traffic in terms of passengers and goods wagons.

(iv) Occasional rush periods on religious festivals.

(v) Possibility of opening export aspects or development of natural resources.

(vi) Pilgrimage places, if falling on the way.

(vii) The details in respect of population, type of people and trade facility of

the starting and terminating stations and of the obligatory stations.

Reconnaissance Survey

Having studied the general configurations of the area from available survey ma along with aerial photographs where available, a few tentative alignments are propose and minimum data required for compilation of comparative study of the various possible alignments are made. This survey should be as quick as possible and involve minimum expenditure but at the same time the important feature of each of the possible alignments should be properly investigated so that a comparative statement based on cost of construction and utility can be prepared. For this purpose the reconnaissance survey should furnish the following information in respect of each of the propose alignments:

(a) Location of natural features such as ridges, valleys, streams, and rivers.

(b) Soil classification

(c) Existing water sources along with their minimum and maximum discharge.

(d) Topography of the area

(e) Approximate elevation of the area along the proposed track.

In order to get the above information without going into the details alignment, the following instruments are used for determination of elevation, direction and distance.

(i) Aneroid barometer for determining relative heights.

(ii) Abney Level for gradient

(iii) Primatic compass for magnetic bearing.

(iv) Binocular for long distance observation.

(v) Pedometer for determing length traversed by person

Preliminary Survey :

The number of possible alignments is reduced to a few alternative alignments the basis of the reconnaissance survey. Sometimes the choice of alignment may be such that the one proposed is the only feasible track alignment. In such cases reconnaissance and preliminary surveys both may be done away and only the data survey carried out. At other times, the reconnaissance survey may reveal the feasible of only one alignment. In this case the preliminary survey and the final location survey can be merged into one detailed survey. As a rule the preliminary survey is limited two or three possible alternate, routes only.

The sequence of field work and office work involved in the finalisation of the preliminary survey is given below :

A. Field work

(i) A traverse is prepared covering a strip of 100 to 150 metre width on either side of the alignment depending upon the nature of the terrain and existing development of the area. A plane-table survey in the form of open traverse using chain and compass is quite adequate for this purpose.

(ii) The details of the levels along the alignment and on important points in the 100 to 150 metre belt mentioned in (1) above are obtained by using a tacheometer or level and chain.

(iii) Details of crossings of rivers and streams.

The location of the crossings are indicated in the traverse along with a record of the available detailed information in respect of the following, which are specified in the field book :

(1) Name of the stream.

(ii) Maximum and minimum discharge.

(iii) Cross-section upstream, downstream, and at the point of crossing indicating therein the HFL. LWL, scour depth, flow direction and geological details of foundation.

(iv) Details of existing bridges, tunnels or culverts in case an existing track is to be improved.

(v) Details of canal crossing.

(vi) Details of proposed level crossing.

(vii) Availability of local resources such as construction material, man power etc. Type of land whether owned by Central or State Government or its departments, cultivated or barren along with details of other property which may have to be acquired. This will help in the approximate estimation and of the cost compensation for acquiring the right of way for the track.

(x) Climatic condition along the routes.

B. Office work

From the field data collected as described in (A) above the following drawings are prepared.

(1) Longitudinal section.

(ii) Typical cross-sections.

(iii) Profiles of crossings with rives, streams, canals and railroad crossings.

(iv) Rough design of maximum and minimum breadths. Based on these minimum required drawings, a comparative statement bringing out the following is prepared :

1. Length of the track.

2. Ruling and excessive gradients.

3. Cost of subgrade and formation (other things being common such as track, equipment, filling etc.

4. General.

The various instruments used for preliminary survey are given below :

(i) Plane-table with accessories.

(ii) Dumpy level for levelling.

(iii) Prismatic compass for bearings.

(vi) Theodolite/ tacheometer.

Location Survey

On the basis of the preliminary survey the final alignment of track is decided and the project estimate for the complete project is taken in hand. This survey is undertaken only in respect of such projects which are to be taken in hand immediately or in the near furture, It consists of depth field work data collection of all the work done under the preliminary survey. At the same time the final location is transferred from paper to the ground. This transferring of alignment from paper to ground is done by fixing 15 cm pegs at 30 metre intervals Every tenth peg is marked by 60 cm pegs. In addition to this, pegs are fixed to demarcate the centre line of the track at the starting and terminating points of a curve. At every kilometre length masonry pillars are constructed. These pillars serve primarily as bench marks. Sometimes the distance of the centre line is indicated on these pillars. In addition to ground demarcation by means of pegs, the following additional points are marked on the ground :

(i) Demarcations of land width. This is done either by erecting R.C,C. boundary posts or by tracing the edge of the boundary line by digging.

(ii) Centre line of waterways of culverts.

(iii) Centre line of tunnel.

(iv) Position of different components of the station complex such as station buildings, station yards, signal loco shed etc.

The field data collected during the final location survey is as given below :

(i) Precise levels along the centre line of the track at every 30 m centres and cross-sections at every third station or 90 metre centrers. From these levels longitudinal sections and cross-sections of the track are prepared in the office.

(ii) The magnetic bearings of the centre line from all stations connected by straights.

(iii) Geological data along the alignment. This is obtained by taking borings wherever the nature of the ground changes.

In the case of important river crossings the following information is obtained from field observation to enable the design office to finalise bridge design.

(i) Cross-sections at every bridge site as well as 1 to 1 5 km upstream and downstream of the bridge site along with longitudinal section of the bed of the stream upto the extreme limits to which cross-sections have been taken. The H.F.L. and L.W.L. are marked on the cross-sections.

(ii) Current velocities and scour depths.

(iii) Soil survey and geological exploration along the cross sections taken upstream and downstream. On the basis of the field observations the following data are compiled in the office.

(i) Maximum discharge.

(ii) Type of foundation to be adopted.

(iii) Length of span.

The following instruments are used for carrying out detailed survey,

(i) Dumpy level.

(ii) Theodolite.

(iii) Steel tape.

(iv) Plane table and auxiliary equipment.

The detailed estimate of the project, which is the basis for the Administrative Approval and the execution of the project is prepared from the following drawings.

These drawings are prepared from the field data collected during the final location survey.

(i) Index of the drawing.

(ii) Site plan- This is a contoured map of the area showing the proposed alignment and adjoining available details of transportation such as railways, roads navigable channels etc. The R.F. for the plan is1/20,00,000.

(iii) Index map- This is developed from the site plan and enlarged with a view to provide additional detail in respect of alignment R.F for this may be is1/25,00,000.

(iv) Detailed section of the track formation- These are the basic documents for calculation of earth work quantities. The quantities of earth work in cutting and filling; are worked out in the same way as explained for road work.

(v) Details of river/ stream crossing.

(vi) Plan and design details of stations and yards. R.F. = 1/5000 for plan and 1/100 design details.

(vii) Detailed drawings of all structures R.F = 100

These documents are submitted along with the Project Report which highlights all the salient features of the Project under the following heads :

(i) Introduction : Under this a brief background of the project starting from the initiation of the proposal and ending with the finalization of the detailed location survey and the detailed estimate is given. A brief description of alternate routes along with reason for rejection is given.

(ii) Alignment : Under this the various stages involved in the finalization from reconnaissance survey to final location survey are given. A brief description of important towns and names of the villages and places of interest along which the alignment passes is given.

(iii) Elements of alignment : The design elements of a railway project are given below

(a) Gauge.

(b) Gradients.

(c) Curves.

(d) Obligatory points.

(e) Length and levels of different sections along which there is a change of gradient.

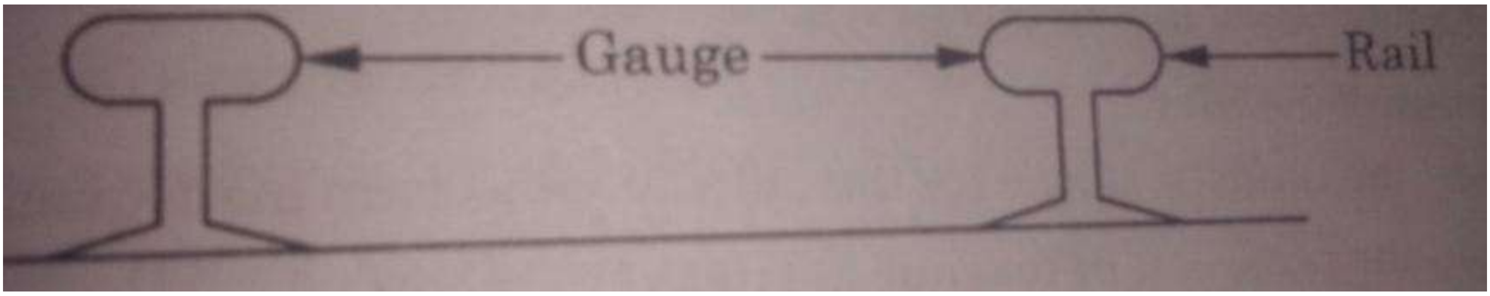
(iv) Design standards : It is presumed that the standards for various elements of construction detailed under the respective standard has been followed in the design details of the trade, equipment, structures and buildings. However, in case a watering down in respect of any of then is proposed, the same 'is' brought to the notice of the competent authority.

(v) Phasing of the Project: If it is proposed to take the execution of the work in phases, it is specified. The alternate to this phasing out is to divide the main project into a number of smaller ones and get separate approvals for the same as and when desired. It is, however, better to combine the entire work under one project and divide the sequence of construction into various phases.

(vi) Remunerative aspect of the project: This aspect of the Project is considered from two aspects. Firstly, the in depth investigation of the financial aspect strengthens the merit of the project. If during a period of a few years, the cost of construction along with the running cost of the project is paid back, the project under consideration would be readily accepted. Secondly, a comparative study in respect of the other alignments, which have been rejected would justify such a rejection, if the route rejected was less remunerative.

3. RAIL GAUGE

GAUGE: Gauge is defined as the minimum horizontal distance between the inner faces of the two rails of a track.



There are many method of gauge measurement as.

In India it is measured the clear distance between the running faces of rails of a track. In European countries it is taken as 14 mm below the rail table where as in Japan it is taken 16mm below the rail table, while in U.S it is taken as 15.88 mm below the rail table. In British railways the gauge was 5'0", and this gauge is used by most of world.

GAUGE PRACTICES IN VARIOUS COUNTRIES

Types of Gauges used in India :

Indian railway has own importance among the world due to India's geography. Different types of gauges are in practices. Mainly following three types of gauges being used in India.

1.Broad Gauge (1676 mm)

2.Metre Gauge (1000 mm)

3.Narrow Gauge (760 mm and 610 mm)

1. Broad Gauge (1676 mm) : The clear horizontal distance between the inner faces of two parallel rails forming a track is 1676 mm (5'-6"), the gauge is called Broad gauge (B.G.).

It is also known as standard gauge and is the broadest gauge of the world.It is also being used by Pakistan, Bangladesh, Ceylon, Brazil, Argentine, etc. 50% India's railway tracks have been laid to this gauge

Broad gauge is suitable.

(i)When sufficient funds are available for the railway project.

(ii)When the prospects of revenue are very bright.

Broad gauge is used for tracks in plain areas which are densly populated intensities and at place which are centres of industry and commerce importance.

2.Metre Gauge : When the clear horizontal distance between the inner faces of two parallel rails forming a track is 1000 mm the gauge is known as Metre gauge (M.G).

Meter gauge are being used by France, Switzerland, Argentine, etc. 40% of India'5 railway tracks have been laid to this gauge.

Meter gauge is suitable

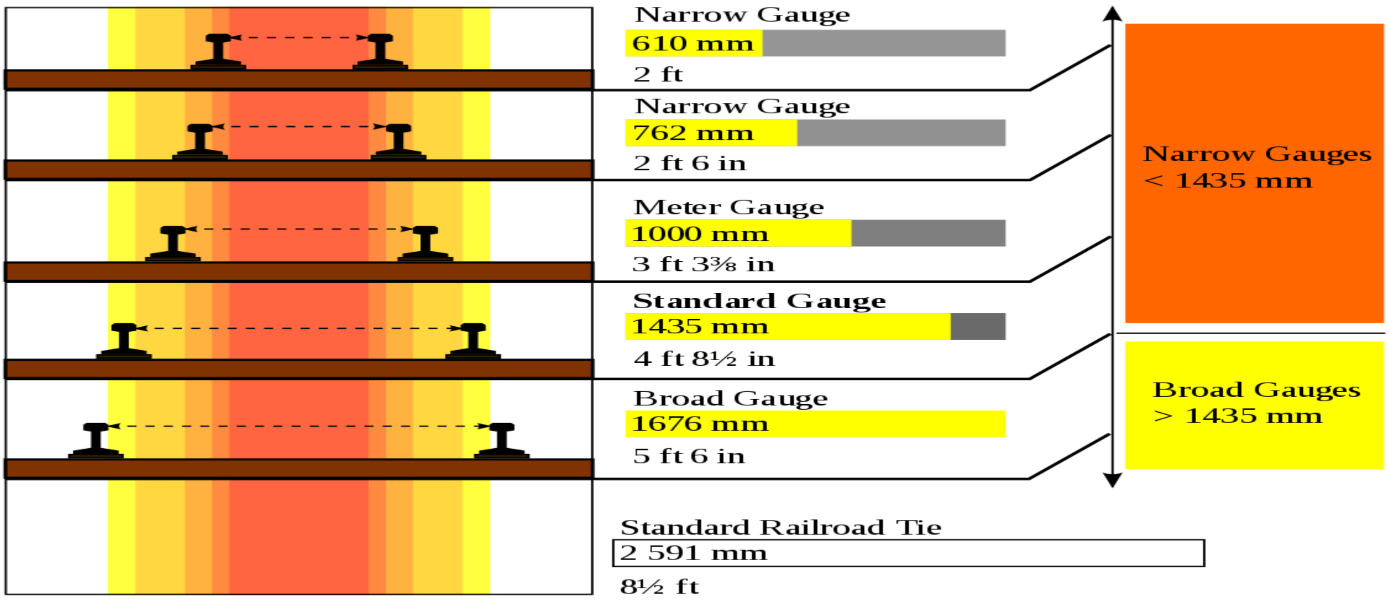
(i)When the funds available for the railway project are inadequate.

(ii)When the prospects of revenue are not very bright.

This gauge is, therefore, used for tracks in under-developed areas and in interior areas where traffic intensity is small and prospects for future development are not very bright.

3.Narrow Gauge (760 mm and 610 mm) : When the clear horizontal distance between. The inner faces of two parallel rails forming a track i.e. either 762 or 610 mm is called Narrow gauge. The gauge of 610 mm is also feeder gauge or light gauge. It is being used by Britain, South Africa etc.

N.G. is suitable, when there is no possibility in construction of wider gauge due to geographic conditions as well as revenue prospects are very weak. It is in hilly and thin populated areas. N.G is commonly used for feeding raw materials.



Uniformity of Gauges

Uniformity of gauge means uniform gauge throughout the country

It is very important aspect of construction that uniformity of gauge is economical. This system is highly beneficial to the rail uses.

Gauge to he used in a particular country should be uniform as far as possible, Because it will avoid difficulties experienced in a non-uniform system and will result in he following advantages :

1. The delay, cost and hardship in transshipping passengers and goods from the vehicles of one gauge to another is avoided.

2. Transshipping is not required, so there is no breakage of goods.

3. Loading and unloading is avoided and labour expenses are saved.

4. Chances of thefts and misplacement, are nil because there is no transshipping.

5. Sheds to store goods are not required.

6. Labour strikes, etc. do not affect the service and operation of trains.

7. Surplus wagons of one gauge cannot be used on another gauge. This problem will not arise if gauge is uniform.

8. Locomotive can be used on all the tracks if a uniform type of gauge is adopted.

9 Duplication of platforms, sanitary arrangements, clocks, etc. is avoided, Thus saves extra expenditure.

10. Military movement during emergency, no time is wasted in changing personnel and equipment if gauge is uniform.

11. It is quire expensive to convert one gauge into another at a later stage as it may require new rolling stock, fresh construction and widening of bridges and tunnels. etc.

12. In uniform gauge this the late arrival of trains is prohibited upto large extend.

13. Porter charges are increased when passengers have to changes compartment due to a different gauge. This is avoided if gauge is uniform.

4. RAILS

RAILS

"Rails may be defined as the rolled steel sections laid in two parallel lines over the sleepers to form the track are known as rails."

Rails are the main part of permanent way on which wheels of rolling stock move. These are continuous girders which carry axle load.

FUNCTIONS OF RAILS

Rails in the railway track serve the following purpose :

(i) Rails provide a hard, smooth surface for passage of heavy moving loads with a minimum friction between the rails and wheels.

(ii) Rails bear the stresses developed due to heavy vertical loads, lateral and braking forces and thermal stresses.

(iii) The rail material gives minimum wear to rails.

(iv) Rails transmit load to sleepers and consequently reduce pressure on ballast and formation.

COMPOSITION OF RAIL STEEL

1) For Ordinary Rails : High carbon steel with following composition is used :

Carbon (C) - 0.55 to 0.6 percent.

Manganese (Mn) - 0.65 to 0.90 percent

Silicon (Si) - 0.05 to 0.3 percent

Sulphur (S) - 0.05 per cent or below

Phosphorus (P) - 0.05 per cent or below.

(ii) For Rails on points and crossing : Medium carbon steel With following composition is used :

Carbon (C) - 0.5 to 0.6 percent

Manganese (Mn) - 0.95 to 1.25 percent

Silicon (Si) - 0.05 to 0.203 percent

Sulphur (S) 0.06 %

TYPES OF RAILS

The rails which are used for railway track should be such that every part of the rail can withstand against maximum allowable stress. The design/cross sectional area of rail should be economical. There are three types of rails are used in the construction of a railway track

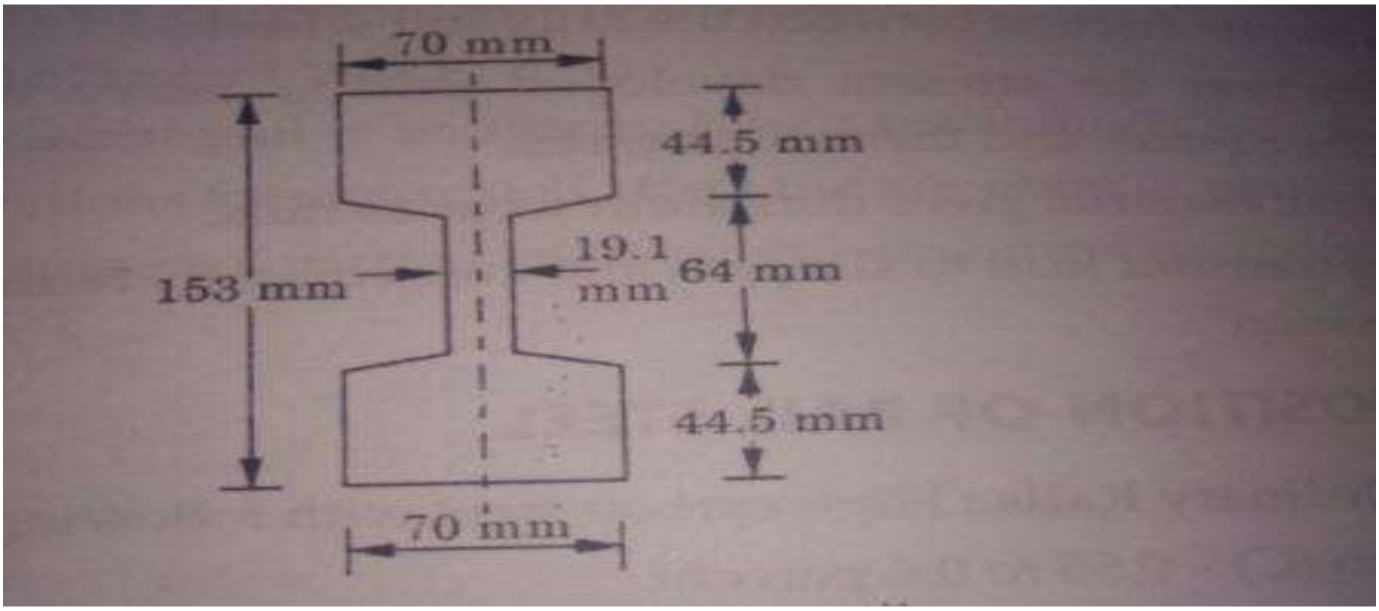
1.Double headed rails.

2.Bull headed rails.

3.Flat footed rails.

Double Headed Rails

Double headed rails having rail section i.e. head and foot of same dimensions are termed as double headed rails. Double headed rail sections were used in the early stages of railway These are designed with a point of view that when top of (head) which get wear out during the movement of traffic should be replaced with foot, to reuse it when reseeded because head and foot have identical dimensions, thus life of rail can be increased by inverting the rail and reuse it.



Bull Headed Rails

The rail sections having their head and foot of different dimensions, are termed as Bull headed rails. In this section head is kept nearly as in double head rail but foot is modified so that minimum required section is kept. These rails are result of the defects arrises in D.H. rails. Foot sections is kept just to bear the stresses of moving wheels loads.

The double headed rails were therefore replaced by Bull headed rails. The rails are fixed to the sleepers by means of chairs. The head is larger than the foot and the foot is so shaped that it should hold the wooden keys with which the rails are secured to the cast iron chairs. Two cast iron chairs per sleeper are required with these rails. These rails are extensively used in England and other European countries. These rails are commonly used in indian railway.

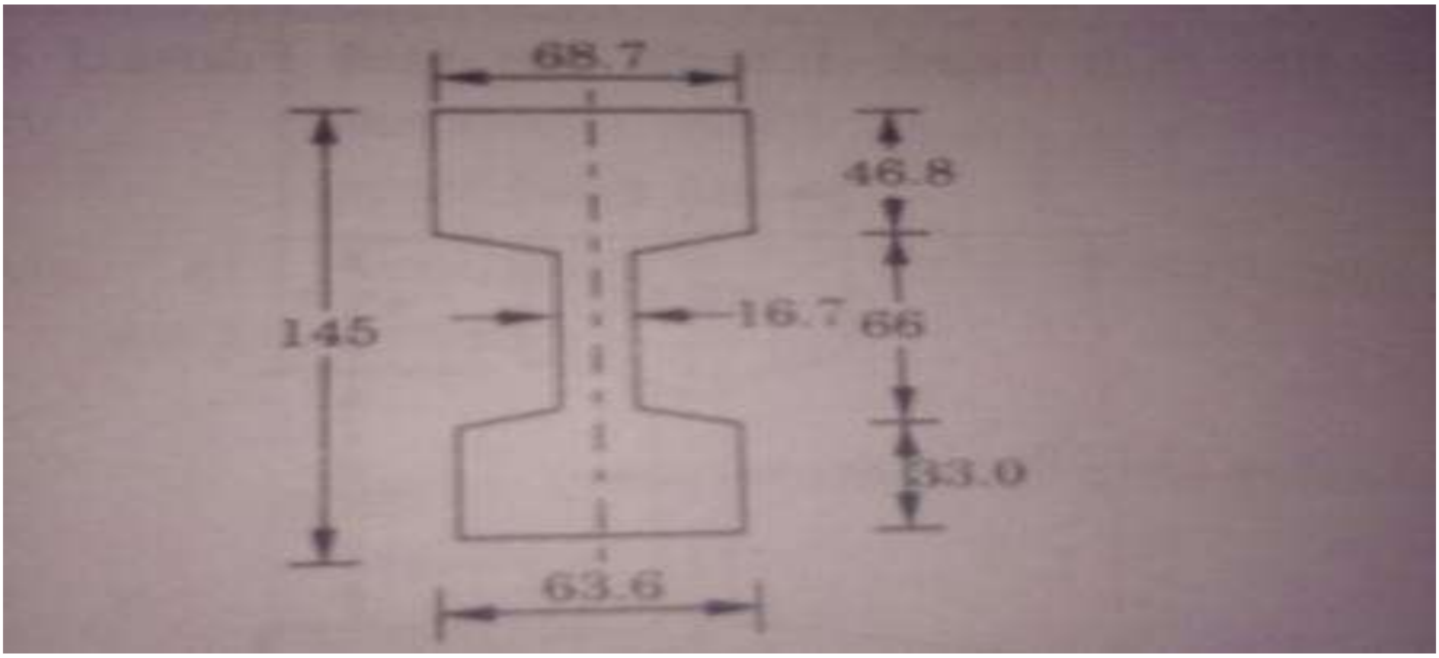
The salient features of Bull headed rails are as given below :

These rails required chains for fixing it to the sleepers, this is the great drawback of this rail. Despite this, there are some features of B.H. rails given below

(i) Heavy cast iron chairs provide large bearing area with sleepers and thereby the life of the sleepers is increased. This adds stability to the track.

(ii) The rails are not directly connected to the sleepers so can be easily disconnected.

(iii) Due to rigidity of the connections, the track alignment is maintained. The provision of heavy C.I. chairs results in heavy construction and maintenance cost.

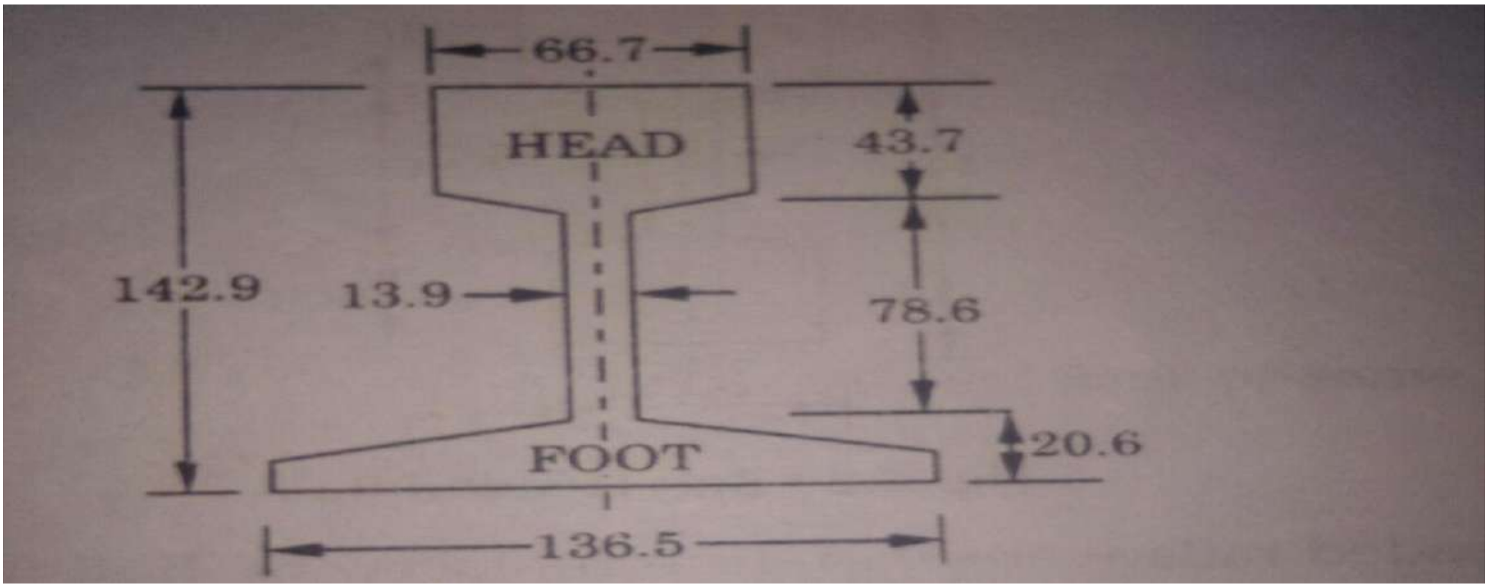


Flat Footed Rails : The rail section having their foot flat and head is kept nearly as in Bull headed rail. These rails are designed to remove the draw backs. Charles Uigneeles in 1836 invented flat footed rail. These rails can be directly used on sleepers with fine fastenings. Later on steel bearing plates are used in between the sleepers and F.F rail in order to avoid sinking of rails in to sleepers. These are used in Indian railway due to its lateral stability. As compared to the Bull headed rails the Flat Footed Rails have the following advantages:

(i) Better rigidity and stiffness to resist vertical and latera forces.

(ii) Simpler fittings. No chairs or keys are required.

(iii) Points and crossings are simpler as compared to the B.H. rails.



RAILS SECTIONS AND WEIGHTS

Rails are provided to perform the following functions :-

(i) They provide hard, smooth and strong surface for train movements.

(ii) Due to heavy wheel loads, braking action etc. stresses produced and rails take up all these stresses safely.

(iii) Wheel load is safely transmitted to the ballast and formation by distributing the same uniformly.

Keeping in view the above said factors, therefore it is desired to use proper rail sections so that they are in a position to take up

1. Wheel loads

2. Stresses produced

3. Speed of trams etc.

The rail sections adopted are normally designated by weight. For example for Broad gauge rail sections weighting 55,45 and 35 kg per meter length are used. For meter gauge rails sections weighing 35,30 and 25 kg/meter length are adopted whereas 25 kg/meter length rail is used for narrow gauge.

So the reasons for the preference to heavier sections is given below

(i) With the introduction of diesel and electric traction, higher speeds are being achieved and hence need for heavier section.

(ii) It is more economical to have heavier rail sections with comparatively larger sleeper spacing from the point of view of maintenance costs.

(iii) The depression between two sleepers is less in the case of heavier rails and hence less pulling power is required for traction.

(iv) The selection of the rail to be adopted in a particular case are governed by the following factors

(i) Gauge of the track.

(ii) Axle load and nature of traffic.

(iii) Spacing of sleepers.

(iv) Speed of the train.

(v) Availability of standard section.

LENGTH OF RAILS

From the view of maintenance cost and efficient functioning of the track the longer the rail, the better it is. Long rails have less number of joints and hence lesser fittings which result in reduction in the cost of construction and maintenance. Longer rails also provide a better travel comfort to the passengers as the less number of joints results insmooth running of the train. The length of the rail is therefore limited by the following consideration :

(i) Facility for economical length from the point of view of its manufacture

(ii) Facility for being transported by wagons.

(iii) Facility for lifting and handling of the rail.

(iv) Provision of expansion joints.

Taking the above factors into consideration the Indian Railways adopted 12.8 metres (42 feet) and 11.89 metres (39 feet) as standard rail lengths for the Broad Gauge (B.G.) and Metre Gauge (M.G.) respectively. The standard rail lengths adopted in America, England, France and Germany are 11.89 metres, 18.30 metres, 24 metres and 30 metres respectively.

RAIL CORRUGATION

The appearance of weavy surface on the head of rail is termed as rail corrugation. Corrugation is the result due to defects in the laying out or defects in maintenance of the track, or due to steep gradient of the resulting in sudden application of brakes, the heads of the rails develop a wavy surface. Rails which develop this defect are known as Corrugated Rails. When the trains pass over such rails, a' roaring noise is created and for this reason these rails are known as Roaring Rails as well.

These defects generally develop in the following rail locations :

(i) At starting and terminating points of the track due to braking action.

(ii) On electrified sections due to high speeds.

(iii) In long tunnels due to presence of humidity.

(iv) On yielding formations or rails laid on soft material like brick ballast.

The development of corrugations in rail results in overall deterioration of the track. It also loosens rail fastenings, fittings and anti creep devices.

How to avoid corrugation ?

The only remedy for rail corrugations is to grind the corrugation by special machines. In India corrugated rails are replaced by new rails.

CORROSION OF RAILS

The gradually destruction of rails in the presence of dampness is called corrosion of rails.

It is eating away of rails or wasting away of rails in the presence of damp condition. The presence of damp conditions causes corrosion of rails. The effect is seen particularly in tunnels, near ash-pits and in the vicinity of industrial areas. As a result of this corrosion, the strength of the rail is reduced because of reduction in effective resisting area. If immediate remedial treatment is not given to the rails the strength of the rail may get reduced to such an extent that it may lead to failure of the rail.

The prevention of this defect can be done either by using specially fabricated rails prepared from special steel alloy or by coating the surface with non-corrosive material. The practice in Indian Railways is to apply one coat of zinc chromate over a red oxide priming coat. The surface is finished with three coats of bituminous emulsion.

Coning of Wheels : If the distance between the inside edge of the flanges is kept equal to the gauge distance the flanges of the wheel would rub against the inside face of the rail. To prevent this the distance between the inside edge of the flanges is kept less than the gauge distance.

If the rim of the wheels rests flat on the rails there would be lateral movement of the axle resulting in damage to the inside edge of the rails. This is prevented by sloping the wheels at a slope of 1 in 20 as shown in Fig. The foot of the rail resting on the sleeper is also tilted to a slope of 1 in 20. This sloping of the wheel from the vertical axis is known as CONING OF WHEELS.

When the wheel negotiates a curve, the outer wheel has to cover a greater distance than the inner wheel. The axile therefore shifts laterally towards the outer rail and since there is coning of the wheels, the tread at outer rail increases and that at the inner rail decreases. The outer wheel therefore is able to cover the additional distance without any 'slipping' taking place.

One of the undesired effects of 'Coning of wheels' is that the pressure of the wheel is always towards the inner edge of the rail.

WELDING OF RAILS

Welding is the process of uniting the similar metals. A railway track which consists of rail were rolled in short lengths due to difficulties in rolling and transportation operations. The rail joint is the weakest section of the rail and is unavoidable. The lengths of the rails can be increased by welding the rail joints.

Purposes

(i) To increases the length of rail thus reduce the number of joints which leads the economy.

(ii) To restore the worn out or damaged rail section.

(iii) To repair damaged or worn out points and rails along the curves.

(iv) To restore the burnt sections of head of the rail or to repair any other defect.

Advantage of Welding of Rails

1. Reduction in the number of joints resulting in saving in construction and maintenance cost.

2. Increase in the life of the rail due to reduction in wear at the end.

3. Increased travelling comfort due to reduction of joints.

4. Reduction in creep.

5. Increase in carrying capacity of the track.

6. Saving in fuel due to reduction in tractive effort.

7. Reduction in theft and sabotage.

8. Increase in the stability and stiffness of the track.

METHODS OF WELDING OF RAILS

1. Electric arc welding.

2. Oxy- acetylene welding

3. Flash butt welding.

4. Chemical or thermit welding.

These methods are briefly described below

1. Electric Arc Welding : Heat is generated by passage of an electric current across a gap between two conductors. A metal electrode is energised by an electric voltage and brought close to another metal object. This produces an arc of electric current. The heat generated in the process causes fusion of the two rail ends which get welded. This method can be used only in the workshop where facilities of electric current are available. Because of the evident limitations, this method is not popular with Indian Railways.

2.Oxy-Acetylene Welding : The heat required for welding is produced by the combination of oxygen and acetylene gas and hence the name of the process. The rail ends to be welded are brought in contact and heat is applied through a blow pipe which connects the oxygen and acetylene gas cylinders. The rail metal at the ends melts and fusion takes place at a temperature of 3300°C. The weld produced by this method is not very satisfactory and hence the method is not popular in Indian Railways, for welding the rail joints.

3**. Flash Butt Welding** : In this method the two rails to be welded are clamped into two jaws of the welding machine. The gap between the two rail ends is adjusted by adjusting the rail held by the movable jaw. The other jaw of the machine is stationary. The rail ends are brought near each other. An electric current of about 5 volts and 35,000 amperes is allowed to pass between the inner faces of the two rails. The passage of electric current generates lot of heat at the rail ends. The ends of the rails are moved to and fro till the fusion temperature of 1000°C to 1500°C is reached. At this stage a pressure of about 37 tonnes is applied and the rails get pressed together. The process is so regulated that any steel which may be oxidised during preheating is eliminated. The time taken for welding each set of rails is from 2.5 to 3.3 minutes and upto 20 mm length of rail is lost in each weld. As compared to other methods of welding the cost of welding by this method is less and the quality of the weld is very good.

4.Chemical or Thermit Welding of Rails : This method was first developed by Gold Schmidt of Germany towards the end of 19th century.

When a mixture of finely divided Aluminium and Iron oxide known as THERMIT mixture" is ignited, a chemical action takes place. Heat is produced during this reaction and iron and aluminium oxides are formed

Fe_20_3 + 2A1= Al_20_3 + 2Fe + Heat

The iron released from the reaction is in a molten state. This molten iron welds the rail ends which are kept enveloped by mould boxes. The aluminium oxide being lighter floats on top and forms slag.

WEAR OF RAILS

The gradual reduction in cross-sectional dimensions of rail is called wear of rail. Wear of rail occurs due to heavy loads move on rails with high speeds, Due to these movements of wheel loads the rails gets worn off. This wear is also the result of weather conditions like temperature, sand, snow, and rain, maintenance of track also cause vertical and lateral wear on rails. Therefore wear of rails can be classified keeping in view the location and position of wear.

Location of Wear

1. Where steep gradient is provided.

2. On curves.

3. Near railway stations, where acceleration and de-acceleration has to take place.

4. Near sea and Industrial areas due to saltish water.

5. In tunnels due to gases.

6. Track sections where maintenance is not proper.

Position of Wear

On straight and curved tracks the rails may get worn off near

(a) Heads of Rails

(b) Ends of Rails

(c) Sides of Rails

Wear of Head of Rails on Straight Track:

(1) On rails, heavy wheel loads move with high speeds which cause the metal to low on sides so as to form burrs which is simply a projection formed out of metal. These Projections get removed when wheel flanges move on rails.

(ii) Due to application of brakes.

(iii) Due to change in gradients.

(iv) Due to abrassion.

(v) Sanding is adopted to produce friction on rails where dampness is more. This i also responsible for wear of rails.

(vi) Due to bad quality ballast and loose packing.

(vii) Near sea and Industrial areas due to saltish waters.

(a) Wear of Head of Rails on Curved Tracks

(1) Due to skidding of wheels— when the wheels travel linear distance without revolving.

(ii) Due to slipping of wheels— when the wheels travel no linear distance however they go on revolving.

(iii) Due to less area of contact between the wheels and rails, while providing super elevation, some mistake is committed while providing proper tilt.

(iv) When the amount of super elevation provided is less or more than the require amount.

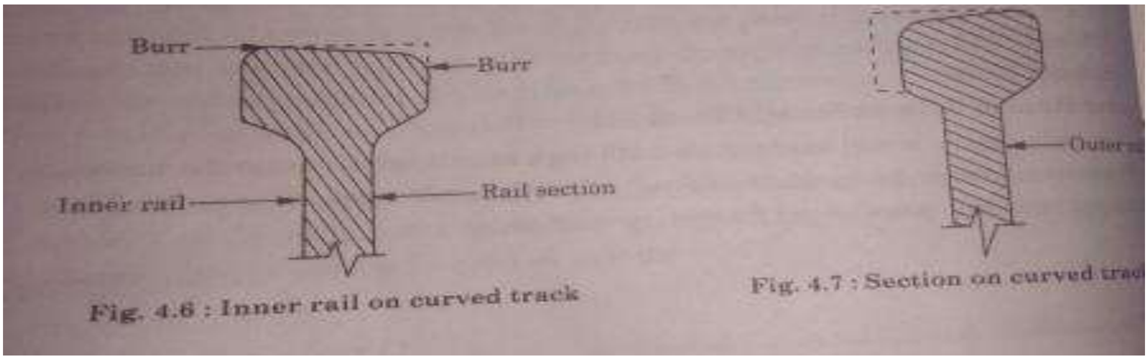


Fig. 4.6 : Inner rail on curved track

Fig. 4.7 : Section on curved trac

(b) Wear of ends of Rails:

At rail joint, the rail with wheel loads is depressed and the facing rail ends is in normal position. This way the ends of rail sections get battered, metal flows towards the gap and ultimately get chipped off, Thus blow of moving wheels at the joint are responsible for the wear of rails at their ends. However if joints provided are proper, with good quality sleepers and ballast, good fixtures, proper drainage facilities and overall proper track maintenance will reduce the wear of rail ends.

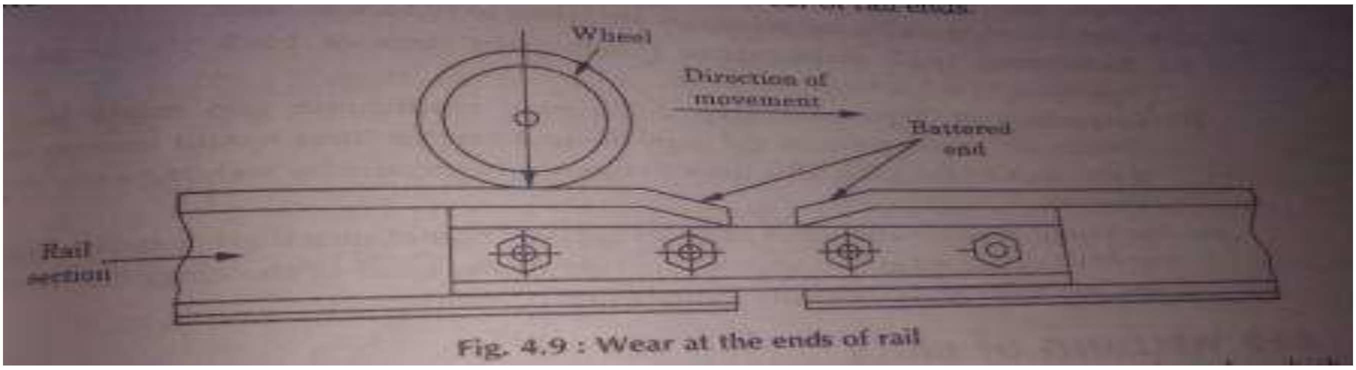


Fig. 4.9 : Wear at the ends of rail

(c) Wear of Rails on sides:

This type of wear only occurs on curved tracks which night occur due to

(i) Wheel flanges bite the rail sides, when the wheels do not properly accept the curved track.

(ii) Due to the centrifugal forces flanges rub on the inner side of the outer rail.

(iii) Slipping of wheels is also responsible for wear of sides of rails.

Methods to Reduce wear of Rails

(i) By providing proper super elevation on curved tracks.

(ii) Coning of wheels to a slope of 1 : 20 and similarly tilting of track rails to till same slope of 1 : 20 also helps in reducing the wear of rails.

(iii) Use better quality alloy steel rails, where the wear expected is more.

(iv) Give proper gradient to the Railway track which is recommended by I.R.C.

(v) Number of joints be less and in addition to this they should be provide properly and well maintained.

(vi) Sleepers provided are of good quality and ballast is packed tightly.

(vii) Near the Rail Road crossings, points and crossings and curved tracks, provide, check-rails where-ever necessary. Widening of gauge also helps.

(viii) Lubricating the jails off and on also reduces the wear of rails.

(ix) By replacing the outer rails by the inner rails on curved tracks.

(x) Maintenance of track should be proper, change the battered and worn our parts.

The following additional measures are taken to reduce the wear.

(a) Satisfactory track maintenance: The main item of track maintenance tightening of fish bolts at the joints.

(b) Inspection of Expansion Gap : Whereas inadequate gap might lead derailment, the increase in the gaps beyond certain limit would increase we of the ends of the rails. This defect is partly overcome by welding some of the ,rail joints.

(c) Exchange of inner and outer rails on curves : Sometimes there is heavy wean top head of the inner rail and on the side of the head of the outer rail. In such cases the inner and outer rails can be interchanged.

WELDING OF RAILS

These days the rail sections are being welded. Five rails are welded together make a total length of 64 m. This process not only makes the journey comfortable II passengers but also reduces the maintenance cost from 20% to 50%.

Purposes and Advantages of Welding of Rails

1. Discomfort of passengers is reduced, as the number of joints is also reduced.

2. Maintenance cost of track is reduced from 20% to 50%.

3. Life of points and crossings is increased.

4. The rail head is burnt at certain places due to slipping of wheels. That portion of rail head can be repaired by welding.

5. As the rail joint is the weakest part of the track, their number can be reduced by welding the joints.

6. Creep of rails is also reduced, as the overall expansion reduced and more over number of joints also gets reduced.

7. On bridges, full rail lengths equal to span can be used. This also reduces the intensity of high frequency vibrations.

8. Where electrified tracks are used, circuiting of tracks becomes easy due to welding of rails.

TILTING OF RAILS

The way of placing the rails to an inward slope of 1 in 20 is termed as tilting of rails. Tilting of rails is done because the tread of wheels one coned to an out ward slope of in 20. In case rails are placed in vertical positions the top surface i.e. head of rail will not come in full contact with the tread of wheels of a train due to coning. Thus rails will wear out sharply. To avoid this sharp wear and to make the head of rail in full contact of treated of wheels of train tilting is made by providing an inward slope in the same ratio as in coning is termed as tilting of rails.

The object of tilting of rails is to minimize the wear of rails in a track.

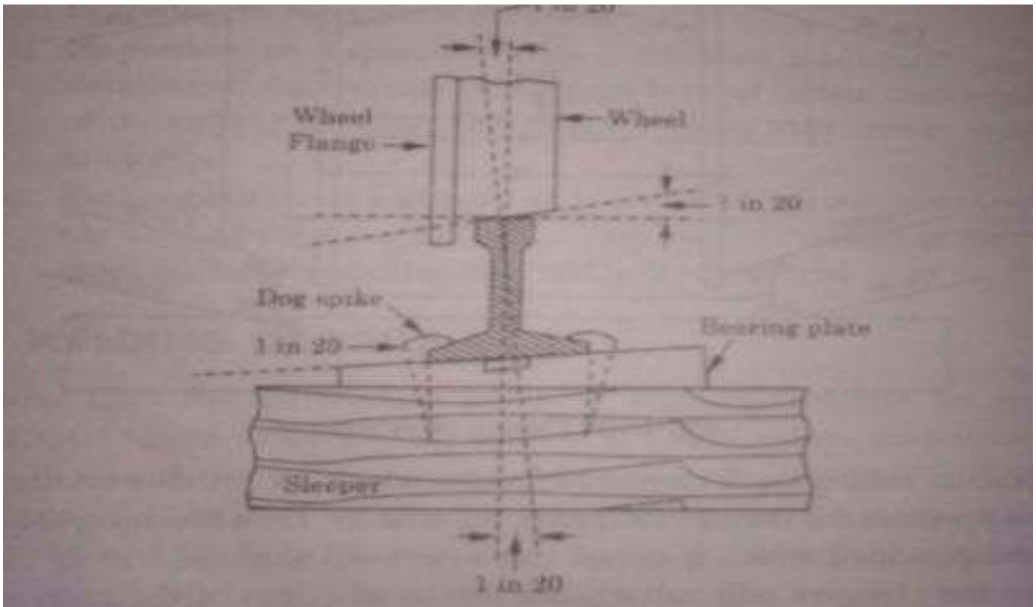


Fig. 4.11 : Tilting of Rails

Advantages :

(i) The gauge is properly maintained.

(ii) Tilting result the wear of the rail head uniform.

(iii) The life of rails and sleepers increase due to tilting of rails.

FAILURE OF RAILS

The appearance of splits, cracks or fissures in the rails due manufacturing defects slipping or skidding of wheels etc., is called failure of rails.

The failure of a rail is due to defect in its manufacture, other causes like slipping of wheels, skidding of wheels, inadequate support at the rail end, etc. may also result failure of rails. Rails are made under rigid quality control and hence sudden failure, of rails are very unusual occurrence. When ever it occurs it is purly manufacturing defect.

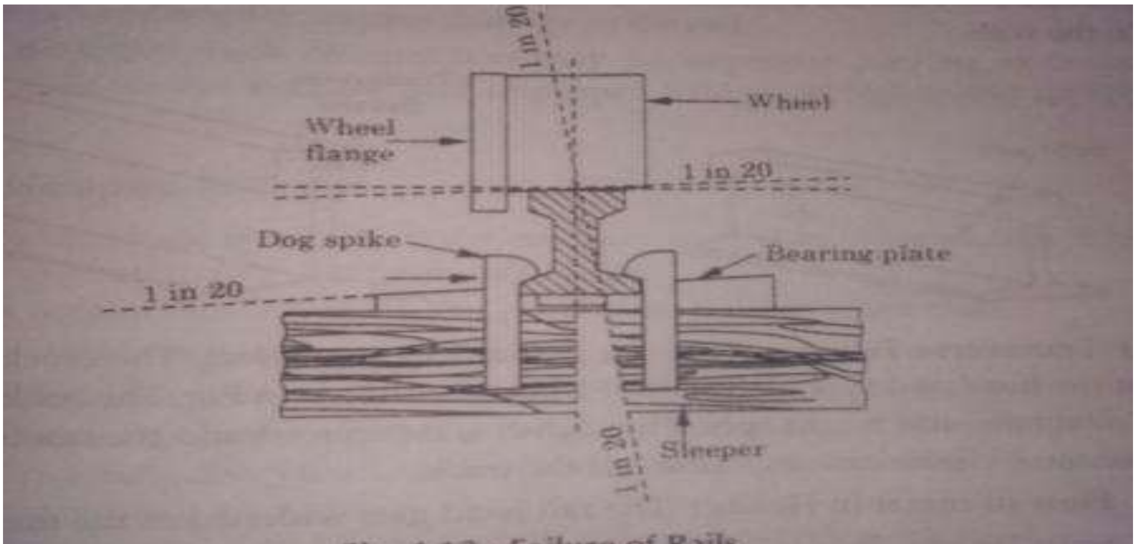
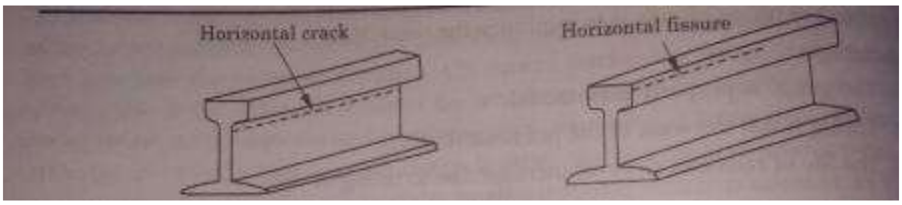


Fig. 4.12 : Failure of Rails

Type of Failures

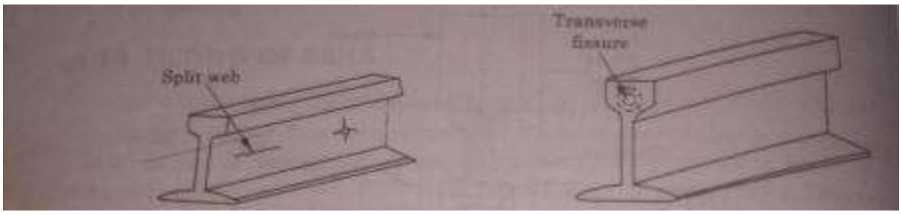
As discussed rails are made under stiff quality control, but rail failure may he the result of following causes

(i) Horizontal cracks : This defect occurs at rail ends, when worn fish plates are used for joining the rails or when the ballast is not properly packed. The crack develops due to shearing stresses, at the critical section that is junction between the rail head and the web. This defect is located on Indian Railways by means of SONIRAIL DETECTOR.



(ii) Horizontal Fissure : It is caused due to defective rail head. The rail develops a horizontal crack.

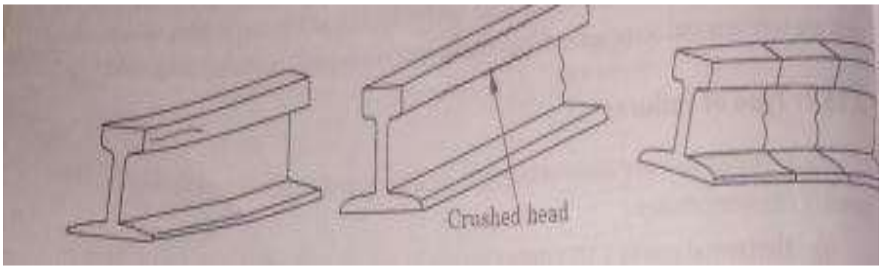
(iii) Split Web : This is another horizontal crack between the bolt holes in the web. It may start from strained bolt hole. The cracks may be horizontal radiating from the bolt holes in the web.



(iv) Transverse Fissure : This is a manufacturing defect. The crack starts from the centre of the head and spreads round the head as shown in Fig. The broken surface has a smooth oval or round bright spot. This defect is dangerous and the rail breaks before the defect becomes visible causing failure of the track.

(v) Flow of metal in Heads : The rail head gets widened as the metal is forced out.

(vi) Split Head : This is also manufacturing defect crack on the top as illustrated in Fig. is an indication of this defect. When opened, the crack has on the top as illustrated in When opened, the crack has smooth appearance and is dark in colour. Such a defective rail is known as PIPED RAIL.



(vii) Crushed Head : The head gets sagged or flattened. This defect may be due to (a) Skidding of wheels (b) Slipping of wheels Weak end support.The end support may become weak due to loose fish plate. (d) Defect of manufacture.

Damaged Rails

The rail failure described above, results in damage to the route. In addition to above failures, the rail may be damaged due to defective track construction, or due to improper maintenance or due to over load or bad application of the brakes. Improper unloading and careless handling also causes damage to the rail.

The defective track construction may be improper packing of ballast, improper fixing of rails to the sleepers and improper fixing and tightening of bolts, nuts and fixtures.

Hogged Rail

When rails bent vertically at the ends are termed as Hogged rails. It is very serious defect of poor rails joints and loose fish plates.

There defects can be reduced by proper remedial measures like

(i) By replacing the hogged rail

(ii) If hogging is small, it can be rectified by shovel packing.

(iii) The hogged rail can be improved by welding the worn out ends.

(iv) By cutting the rail ends about one meter length and fresh holes are provided for fish plates.

(v) Hogging can also be reduced by using de-hogging machine.

Buckling of Rails

Buckling of rail means the displacement of track from its original position. Buckling is the result of excessive compressive forces on the track due to insufficient expansion gaps in the track. Bucking leads the track out of its original position or alignment.

The following are the main cause of buckling :

(1) Due to excessive creep leads the track out of its original position.

(ii) Due to fish plates being bolted so tight that rails are not allowed to expand or slip.

(iii) Due to loose fittings.

(iv) Inadequate ballast on track also leads buckling because stresses are not counter balanced.

(v) Welding of rails on weak track also lead buckling.

Remedial Measures

(i) Numbers of welded rails should be decreased.

(ii) By providing anti creep fastenings to the rails.

(iii) The Ballast, sleeper and rail section should be redesigned.

(iv) Lubrication should be done properly and timely to fish plates, bolts at regular intervals.

(v) Sufficient expansion gap should be provided between rails joints.

(vi) To allow proper expansion and contraction fish bolts should neither be lighted so tight nor so loose.

(vii) Proper prevision for steel sleepers should be made.

PERMANENT WAY

A permanent way is the back bone of railway traffic. Permanent way is the combination of rails, sleepers, ballast etc. permanent way is the term which is used to define or distinguish between temporary and permanent track used for various operations in rail track construction. The function of permanent way is facilitating easy movement of traffic for passenger as well as goods to the desired destination without any disturbances."The permanent way may be defined as the railway track which provides easy and safe movement to traffic". Permanent tracks are of permanent in nature. Permanent way consists of the following components:-

(a) Formation or sub grade,

(b) Ballast,

(c) Sleepers,

(d) Fixtures and fastenings.

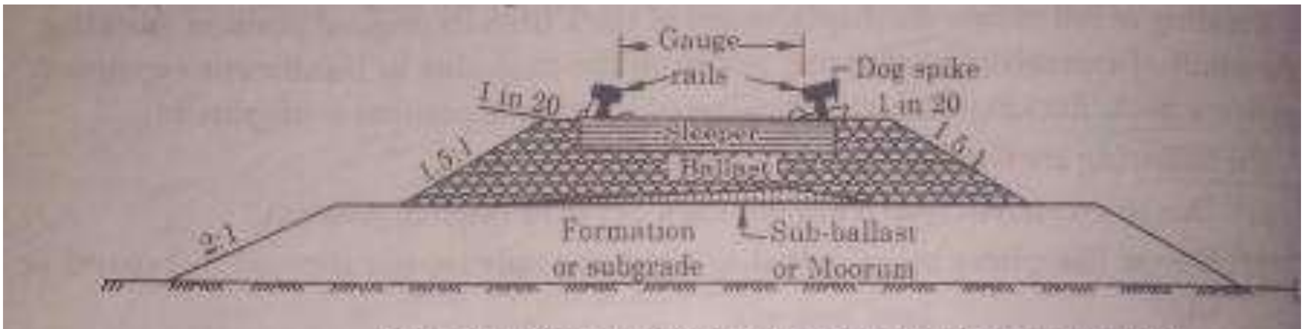


Fig. 4.13 : Diagram showing components of permanent way

Requirements of permanent way : An ideal permanent way must have the following requirements for the easy movement of the traffic,

1. Permanent way must have uniform and correct gauge throughout the way.

2. The permanent way must have uniform gradient throughout the length.

3. The permanent way must follow the required amount of super elevation where necessary.

4. The rails of permanent way should be at the same perfect balanced level.

5. The permanent way should be sufficiently strong and durable enough to take lateral forces and withstand against weathering actions.

6. Permanent way should be such that it will provide ease to renewal and maintenance of parts in track when necessary.

7. Permanent way should be designed in such a way that it allows proper drainage.

8. All the points and crossings among the permanent way must be designed properly and carefully installed.

9. The permanent way should be designed in such a way that the loads of traffic should be distributed on both the rails properly.

10. The permanent way must be free from excessive joints.

11. The permanent way must have elastic enough against impacts of moving loads of traffic.

CREEP OF RAILS

Creep of rails is the result of longitudinal movement of rails with respect to sleepers. Some times creep may occur due to longitudinally movement with respect to rails. First type of creep is possible if the toe load of fastenings on the rails is less than the force due to creep. The sleepers will move longitudinally with the rail if the resistance of the ballast to such movement is less than the creeping force. The creep behave different under static and dynamic conditions due to toe load of fastening on the rail foot and the ballast resistance get considerably reduced because of high frequency vibrations caused by dynamic loading at high speeds.

"Creep of rails may be defined as the longitudinal movement of rails in a track is known as creep of rails"

Causes of Creep

The causes of creep are explained by following principal theories:-

1. Wave Action or wave theory

2. Percussion theory

3. Drag theory

1. Wave action or wave theory : According to this theory, a the rail gets depressed by the wave motion due to moving wheel loads. The train wheels cause depression under them forming lifts or crests immediately at the rear and front of the wheel. The wheels have to push a tendency to push the waves in the direction of traffic, with the successive forward motion of the wheel the creep is carried forward. Thus the rails are pushed forward which cause creep in the forward direction.

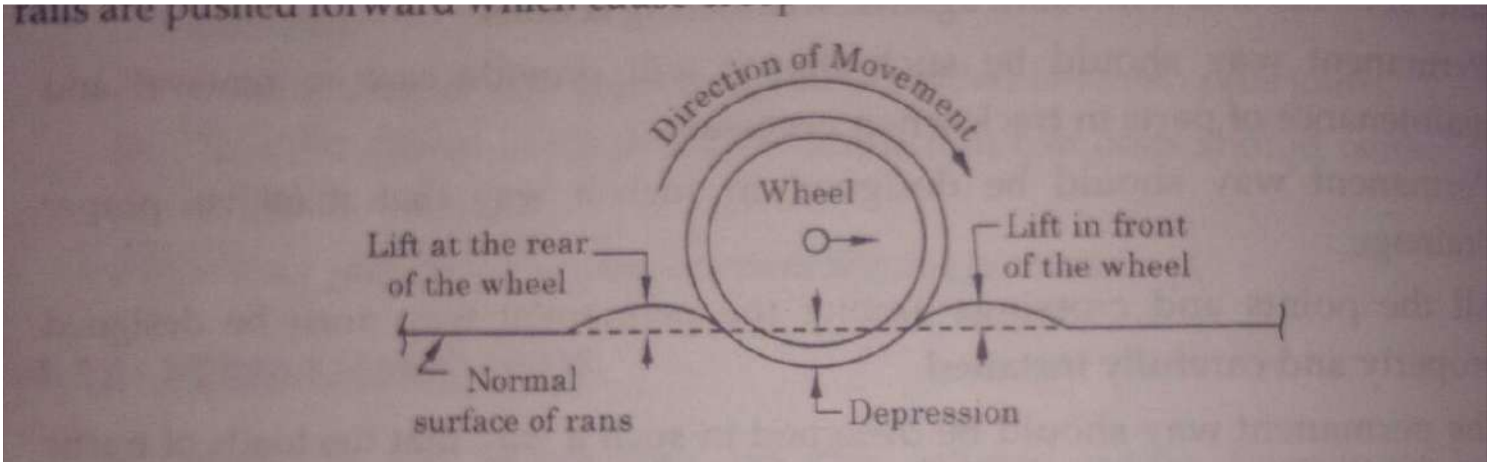


Fig. 4.14 : Wave theory of creep

It has been found that pitch and depth of wave is governed by

(a) Stiffness of track and stability of the formation. These are the properties which go together. Stiffness of track depends upon the type of rails and rigidity of joints and fastenings. The stability of the formation depends upon the character of the formation soil and packing of ballast.

(b) Track modulus : Track modulus is an index of measurement of resistance of deformation. It is defined as the load in kg per cent of the rail length required to produce one centimeter depression of the rail table. The stiffer is the track higher is the track modulus and vice versa.

2. Percussion Theory : According to this theory the rail creep is due to impact of wheel at the end of rail face or ahead of the joints gives rise to creep in the rails. When the wheels passing over these joints the trailing rail depresses and the wheel gives impact to the end of facing rail, which results creep in forward direction

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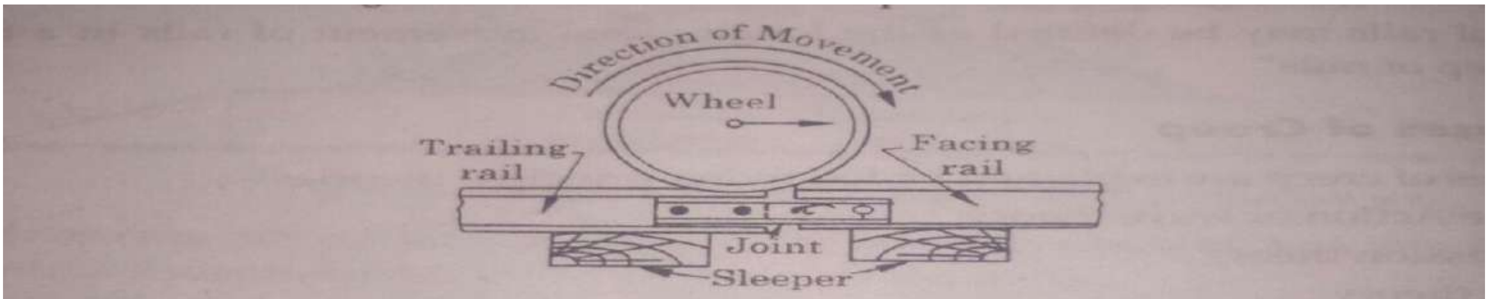


Fig. 4.15 : Percussion theory of creep

3. Drag theory : According to this theory the rails are pushed off in back direction by the driving force of wheel of locomotives of the train while the remaining wheels of locomotive and the train push the rail in the direction of travel. As a result of this creep takes place along the direction of travel.

Following are the other factors which give rise to creep:-

(a) Variation of temperature : The amount of creep depends upon the range of temp, location of track and adjoining areas.

(b) Starting, stopping and change in speed : when the train is starting or being accelerating speed, the backward thrust tends to push the rails in backward direction, on the other hand when train are bringing slow down or brakes are applied the braking effect pushes the rails in forward direction.

(c) Track alignment : on the curves creep is more.

(d) Track gradient : on steeper gradient creep is higher.

(e) Creep is also more rapid during the hot weather.

(f) Old rail sections are liable to higher creep.

(g) Un balanced traffic i.e. in case of single line heavy traffic moves in both direction so creep is negligible if the traffic is unidirectional in case of double line creep is higher.

(h) Creep is more on embankments.

Effects of Creep

The following are the effects of creep:-

1.Creep cause difficulties in removal and fixing of rail parts and maintenance of rail fastenings for repair purposes.

2. Due to creep ballast is forced out.

3.The points and crossings get pulled or pushed out due to creep. Irti b

4.Due to creep it became difficult to operate switches and interlocking system.

5..Creep causes the rail joints jammed and prevent expansion to some extent but cause difficulty in removal and maintenance of track.

6.Due to creep rail joints are opened to their maximum limit at some places and thus excessive stresses are induced in fish plates and bolts due to jumping action of the moving wheel loads which may break and cause derailment of train.

7. Sleepers are move out of the position due to creep.

8. Creep disturbed the track thus movement of traffic gets affected.

Measurement of Creep

Creep is measured by following way:-

The creep is measured by creep indicator by erecting creep posts at every kilometer on either side of the track and position of joints should be marked on one side of the post. The arrangement of creep post or creep indicator is shown in fig below.

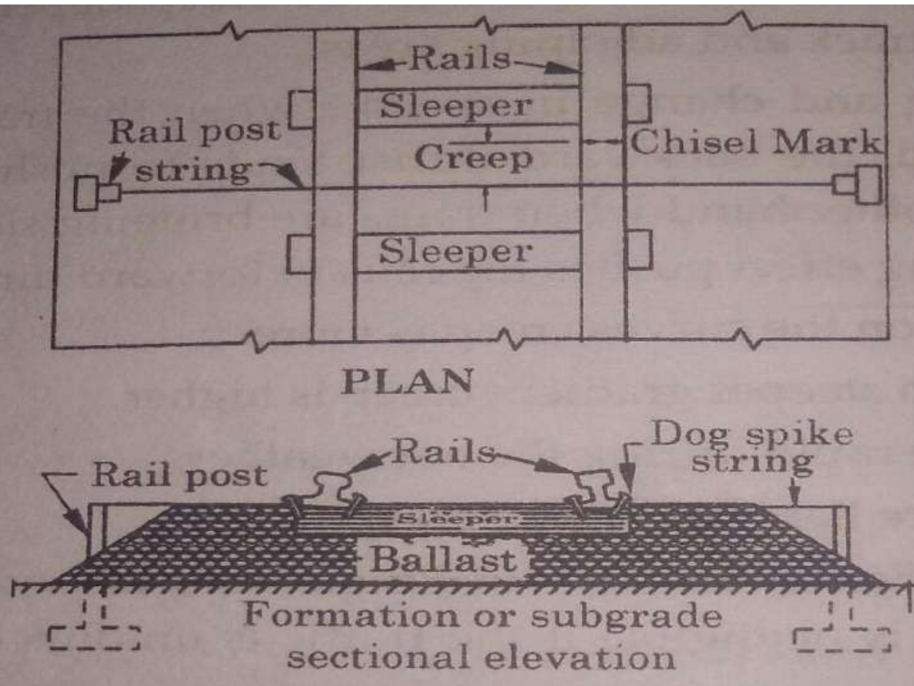


Fig. 4.16 : Showing creep indicator

Method of measuring the creep : After the track is laid, two small posts of rails are erected on both sides of the track so that the line joining the centers of these two rail post is perpendicular to the centre line of the track. Their top level is kept in level with the level with the top surface of sleepers. A chisel mark is made at the bottom flange of the rail between the centers of the two sleepers. Two rail posts are fixed such that the line joining their centers passes through the chiseled marks on the rails. The top of these rails posts are at the top level of the sleeper as shown in fig. A tight string is stretched below rails on the marks of the indicator and horizontal displacement of the rail marks from the stretched string gives the amount of creep.

Adjustment of Creep

When creep exceeds 15 cm the same should be adjusted by pulling the track. Expansion gaps should be carefully handled. Creep should be adjusted by following preventive measure:-

1. Pulling back the rails : When creep is visible than it is best to pull the rails to their back to their original position with the help of crow bars.

2. By providing anti creepers devices : To prevent the creep on railways anti creep devices/anchors are provided to minimize the creep. Anchors are fixed on the foot of the rails in the opposite direction of creep. The number of anti creeper/anchor depends upon the amount of creep occurring in the track. Anchors are fixed by wedging or by spring grip or by clamping.

3. Use of steel sleepers : The use of steel sleepers in location prone to creep found very effective. In addition to use of good quality sleepers, number of sleepers can also helps in preventing creep.

4. By providing good drainage system creep can minimized.

5. By using good quality and sufficient of ballast can also helps in preventing creep.

6. Creep can also be minimized or prevented by proper maintenance of joints.

5. RAILS FASTENINGS:

The devices which are used to make connections between rails to rail as well as, to fix the rails to sleepers to make track to fulfill technical aspects are termed as fixtures and fastenings.

The fixtures are used to make to make connections between rail to rail to rail sleeper to fix the rail track are termed as fixtures. e.g. spikes, bolts, keys. There are used to fix the fastenings with rail and sleepers to get track. On the other hand the fastenings which are bearing plates, fish plates, chairs. etc which are used to fix the rail to rail and to fix to sleepers to form in full length of rail is terms of track.

Functions:

1. To achieve required tilt of rails.

2. To fix the rails to sleepers.

3. To maintain gauge.

4. To maintain rail alignment.

5. To maintain properly the rail joints .

TYPES OF FIXTURES AND FASTENINGS

: These are classified as

1. Fish plates

2. Bearing plates

3. Chairs.

4. Fastening

(1) Spikes

(ii) Bolts

(iii) Keys and cotters.

(iv) Anchors and anti-creepers.

(A) Fixtures : These are described as.

(1) FISH PLATES : Fish plates is the device which used to maintain the lull length of rail by joining the rails end to end with M.S. plates are called fish plates.

The fish plates are so designed that they fit the underside of rail head and the top of the rail foot. Fish plate have same strength as the rail section Fish plates have sizes 457 mm long with four numbers 31.70 mm dia holes 114 mm c/c, the depth of the fish plate is equal to depth of web of the rail.

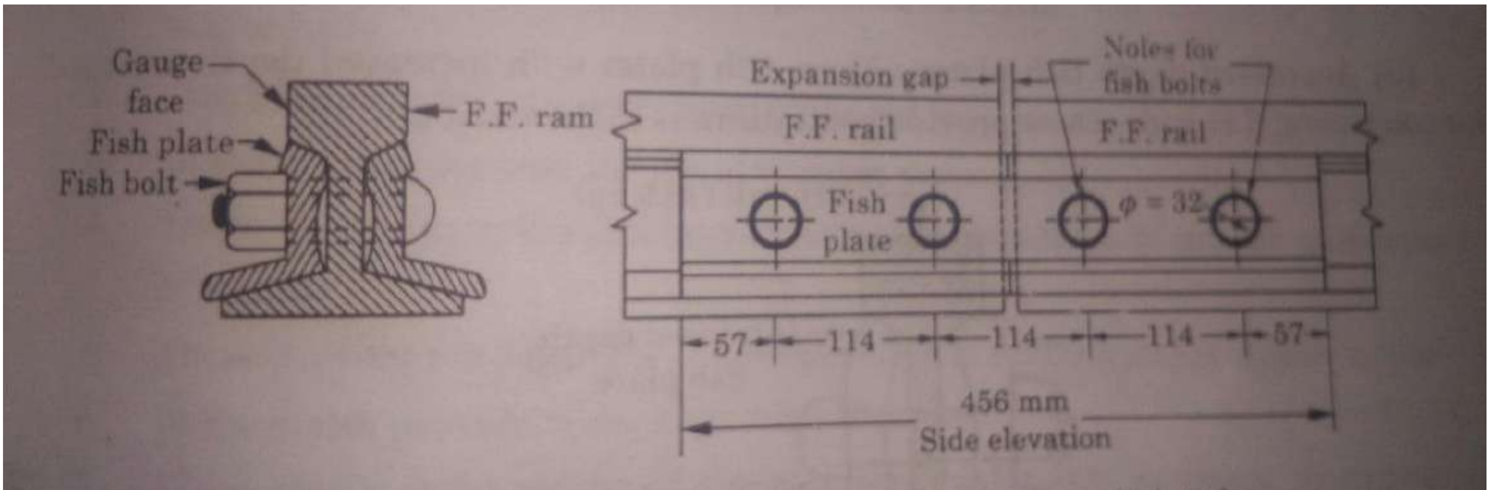


Fig. 5.1 : Rail Joint Showing the Position of Fish Plates and Fish Bolts

Functions of Fish Plates

Following are the functions of fish plates in a railway track :

(i) To maintain continuity of rails in a track

(ii) Allow expansion and contraction of the rails due to temperature variations.

(iii) Helps in maintaining the alignment of track and rail joints.

(iv) These helps in renewal and replacement of rails.

Types of Fish Plates

Fish plates are manufactured so as to join the flat footed (F.F) as well as headed (B.H) rails sections, so broadly these are of the two types.

(1) Bone shaped fish plates.

(ii) Increased depth fish plates.

(1) Bone Shaped Fish Plates : These are used for connecting F. Footed rails, can take the stresses due to impact of moving wheel loads.

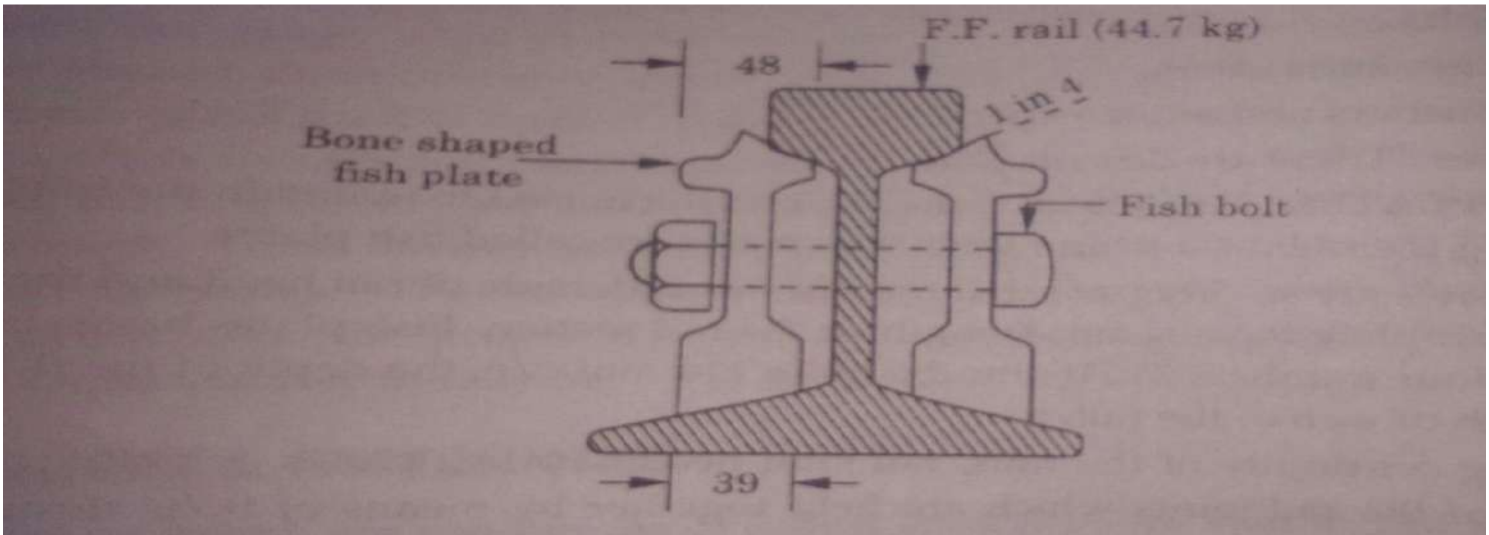


Fig. 5.2 : Bone Shaped Fish Plates

(ii) Increased depth fish plates : These fish plate with increased depth are used for connecting B.H rails. These provides good stiffness to the rail joints.

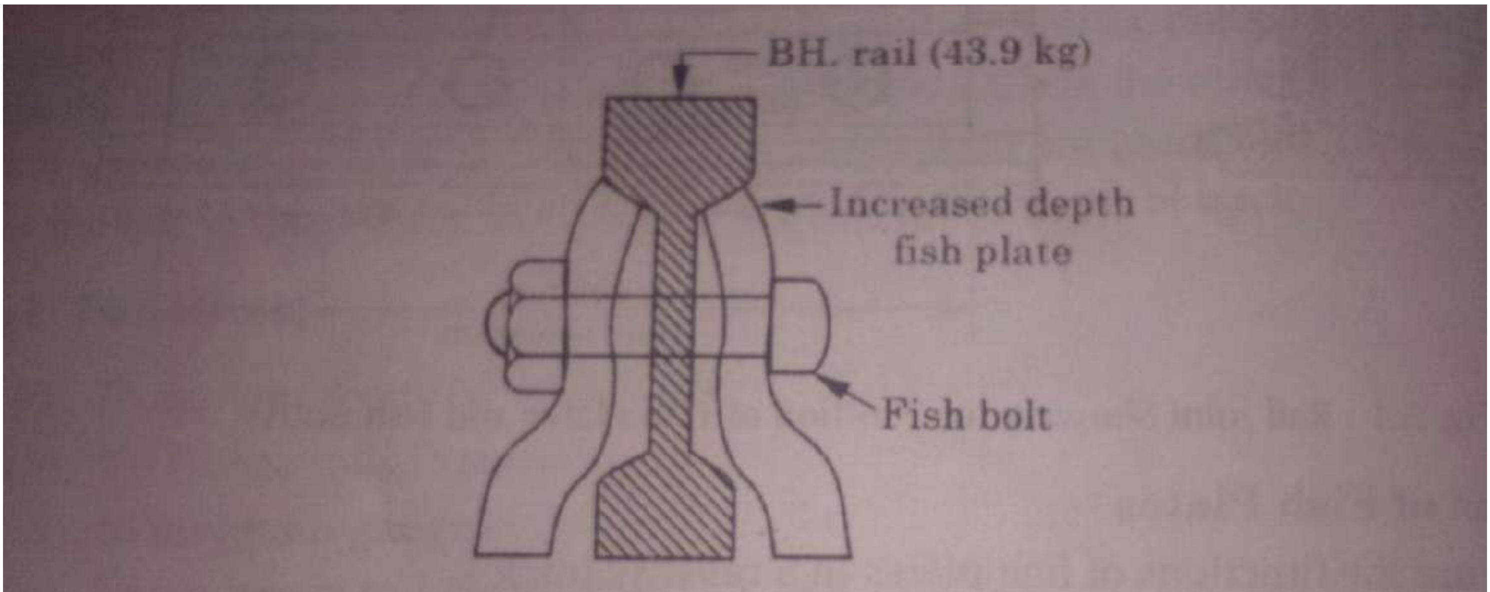


Fig. 5.3 : Increased Depth Fish plates

Requirements of Fish Plates :

1.The fish plates such that they provide perfect Joint both vertically as well as horizontally.

Rails Fastenings Fish plates should be such that they properly fit in the webs of adjoining rails at each rail joint.

3. The fish plates should be such that they allow free expansion and contraction of rails at rail joints.

4. They should able to resist all types of near.

5. These should provide easy replacement and renewal of rails.

Fish plates should be designed in such a way that they helps in maintaining the alignment of track.

The most important requirement of fish plate is that it should provide strength to the rail joints.

(ii) Bearing Plates

The plates which are used to prevent the sinking of flat footed rails in to the wooden sleepers due to heavy loads are termed as bearing plates.

Advantages

1. They increase the bearing area time distribute the intensity of loads uniformly.

2. There helps in maintaining gauge of the track.

3. Bearing plates increase the life of wooden sleepers.

4. There keeps the spikes and keys remain tight thus helps in smooth movements of trains.

5. These prevent rail cutting of the sleepers due to rubbing action of rails at seat.

6. These plates provide better alignment at curves.

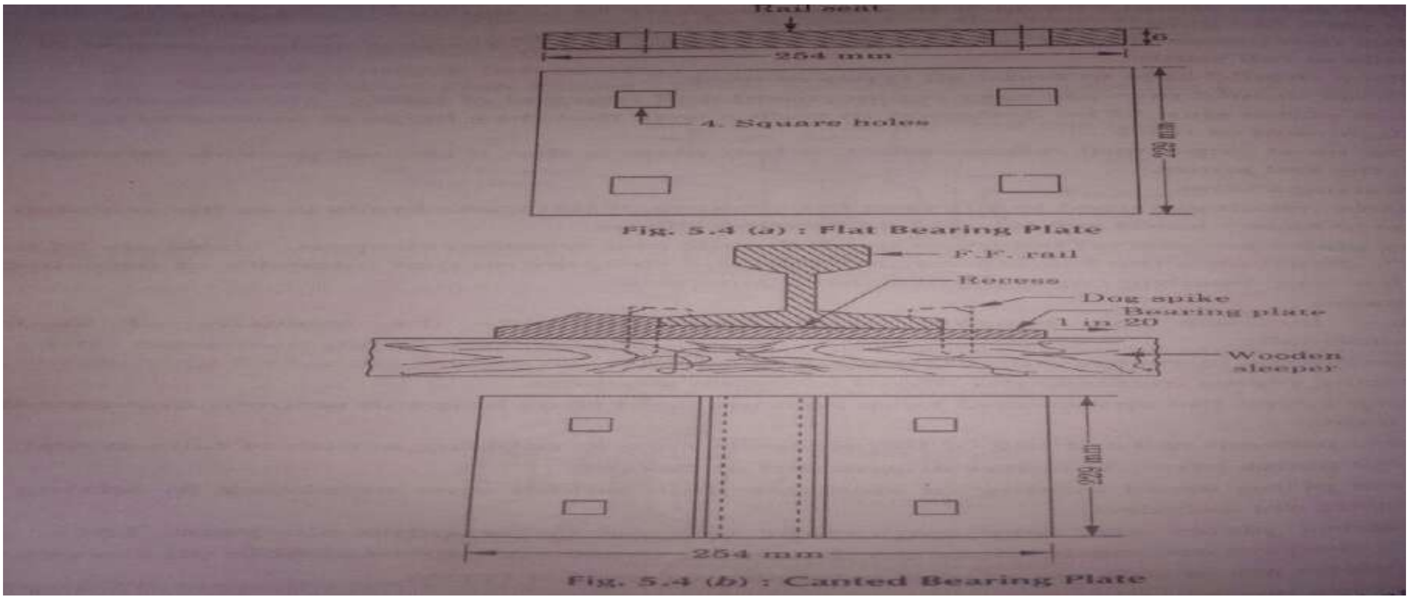


Fig. 5.4 (a) : Flat Bearing Plate

Fig. 5.4 (b) : Canted Bearing Plate

(iii) CHAIR: Chair is the device which are used to hold the rails to fix in position with sleeper.

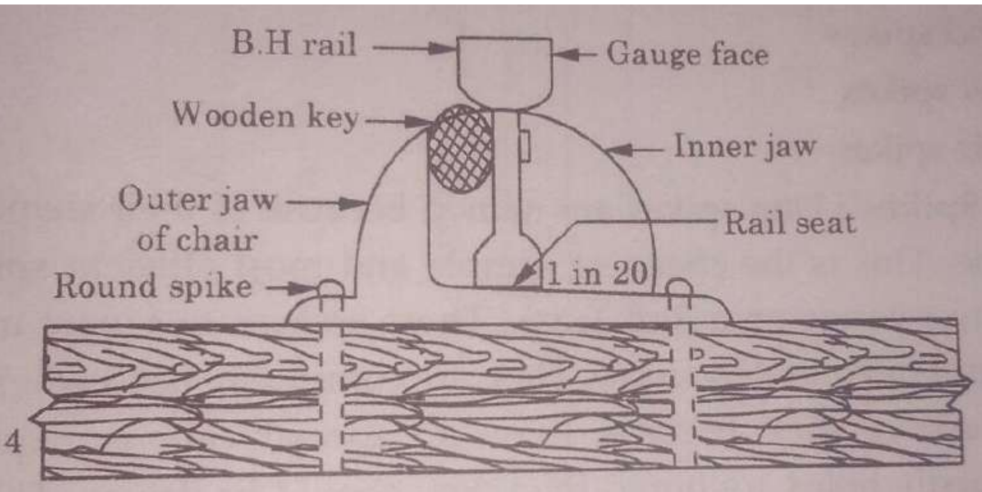


Fig. 5.5 (a) : C.I. Chair with Wooden Key

FASTENINGS : These are described below

(i) SPIKES : Spikes are the fixing devices which are used to fix the rails, bearing plates and chairs to the wooden sleepers. Following are the characteristics of good spikes:

(i) They should be cheep and easily available.

(ii) They should be strong enough to hold the rails, bearing plates, and chair in position.

(iii) They should be easy in fixing and removing for easy maintenance of track

Types of Spikes

(I) Dog spikes

(ii) Round spikes

(Iii) Screw spikes

(iv) Elastic spikes

I) Dog Spikes : Dog spikes are named because of their shape of head. There are simple in shape. This is the cheapest, simple and most efficient spike which holds the rails to the correct gauge on a Rail Track. These spikes are square in section with lower end pointed blunt or chiseled shape

They are commonly used where F.F. rails are used due to wave action they become loose so special care is required towards their maintenance- Firstly holes are bored then they should be driven.

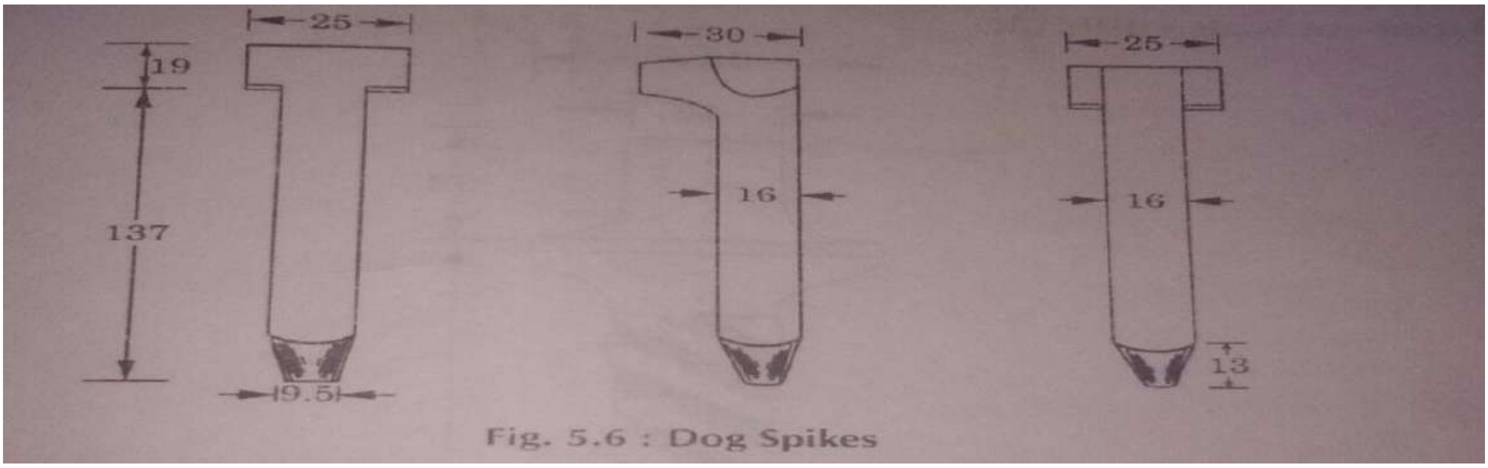


Fig. 5.6 : Dog Spikes

2. Round Spikes : These spikes are also known as rough spikes. Round spikes are 19 mm in diameter with 38 mm diameter head, either cylindrical or hemispherical. The length of these spikes varies with the gauge of the track and their end is blunt. Round spikes are used for fixing chairs of B.H. rails to wooden sleepers and for fixing slide chairs of points and crossings on wooden sleepers. These are fixed to sleepers as dog spikes are fixed.

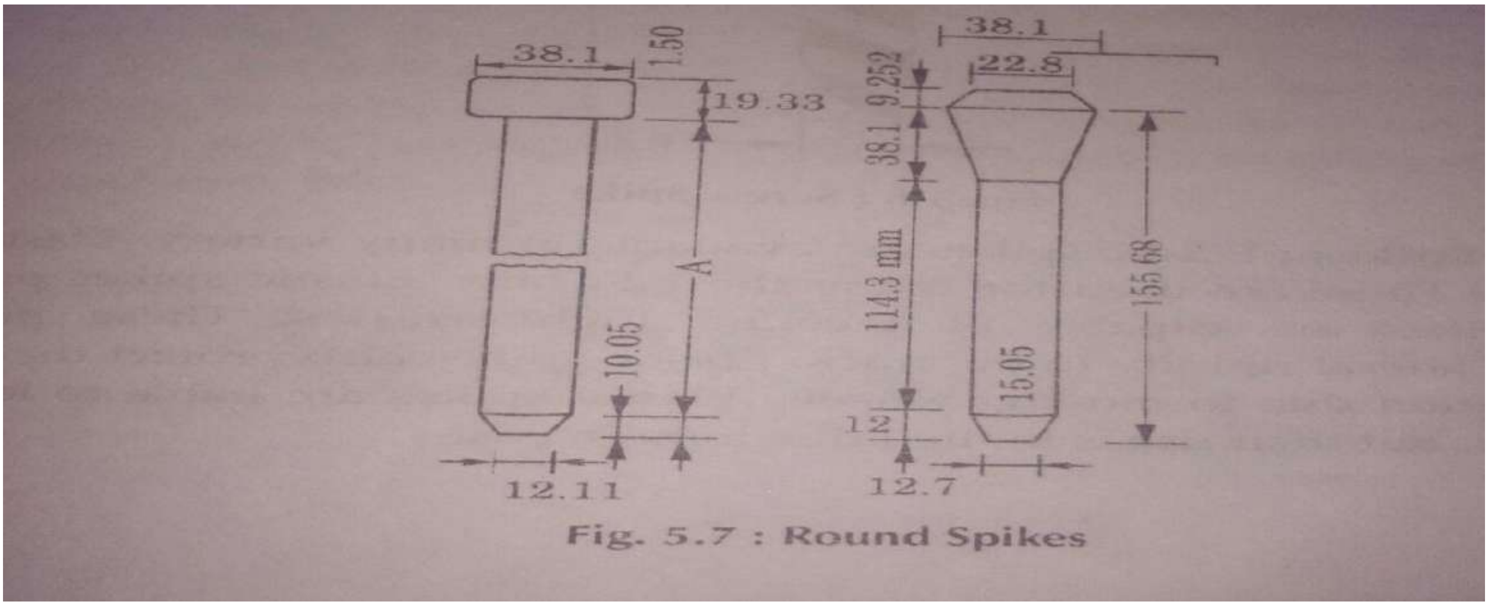


Fig. 5.7 : Round Spikes

SCREW SPIKE

These spikes have their head circular and length of these spike depend upon in gauge of track.

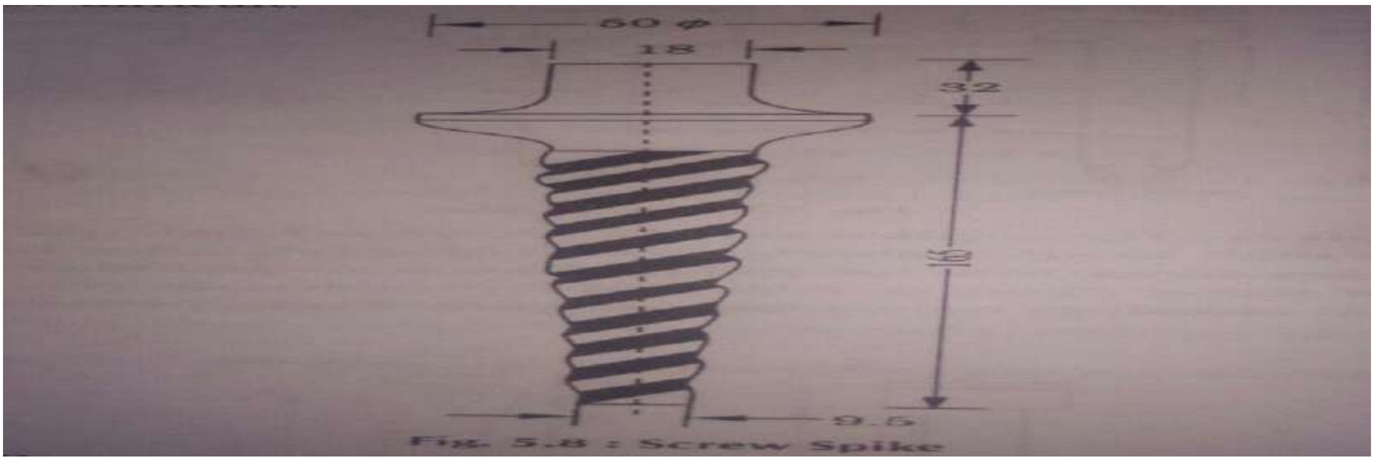


Fig. 5.8 : Screw Spike

Elastic Spikes

Elastic spikes are available in many variety. Elastic spikes are of special shape. These are used for fixing the F.F. rails. Elastic spikes provide better grip, Elastic spikes are capable of meeting high stresses. These provide or longitudinal and lateral rigidity to the track. Elastic spikes also protect the track against. shocks and vibration due to moving wheels. Elastic spike are liable to less creep an' produce low riser, but their use is limited due to high cost.

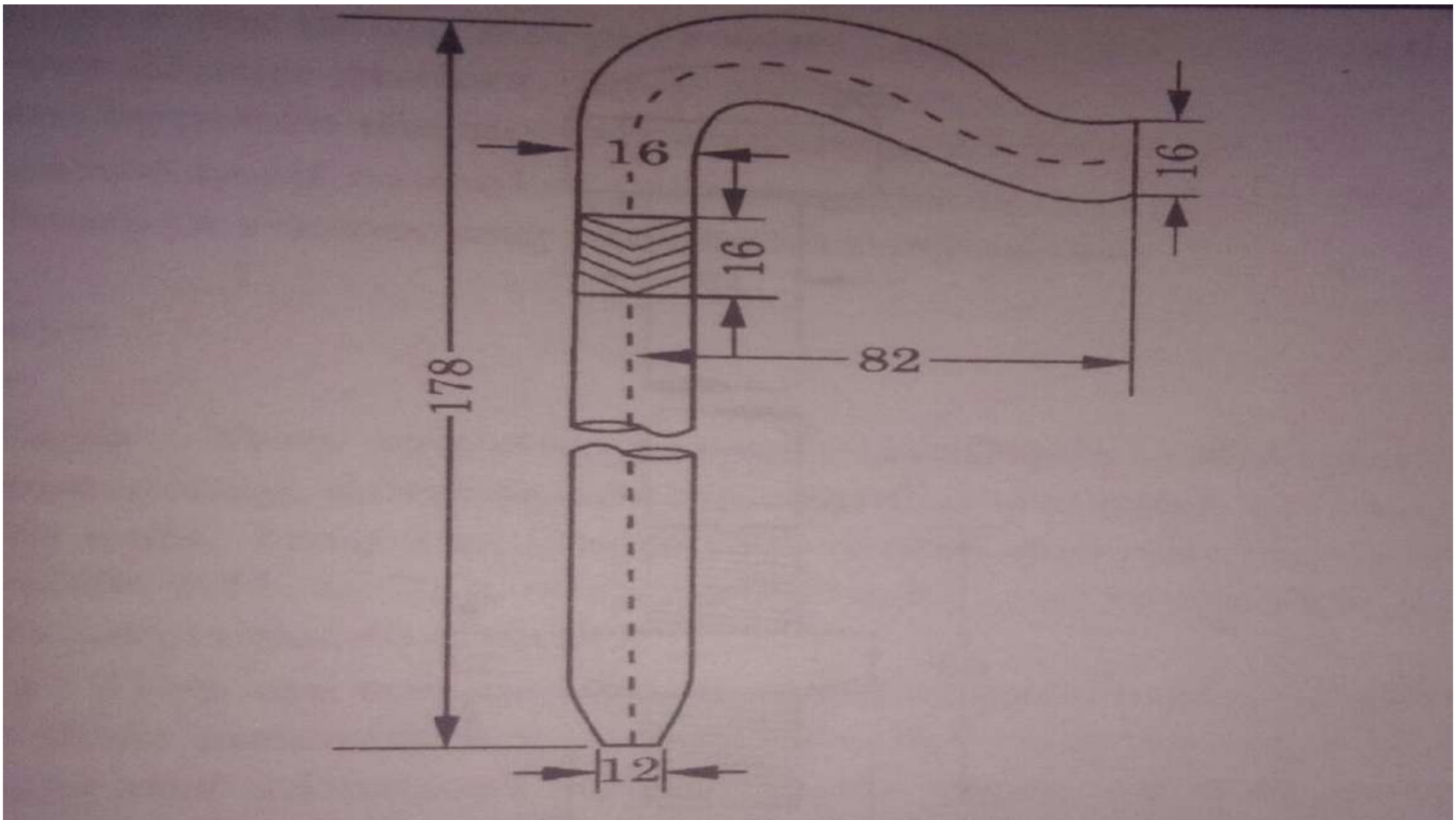


Fig. 5.9 : Elastic Spike

Bolts : Bolts art. used for connecting fish plates to the rails at each mil joint, chairs to sleepers and bearing plates etc. There are different types of bolts available And being used h Indian railways as per the need these may be classified as

(i) Fish Bolts : These are used to Connect the fish plates to the rails at rail point. Each pair of fish plate is joined by tour fish bolts, two on either side of the joint These bolts are very heavily stressed and hence they are made from medium or high carbon steel. Since they get loosened due to vibrations, they are tightened form- tune to time Over-tightening however prevents the free expansion of rail and is prohibited

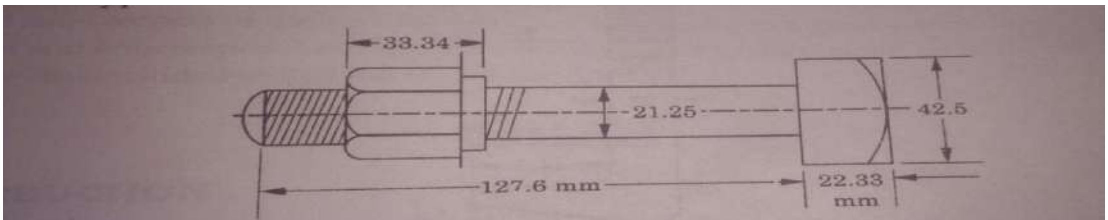


Fig. 5.10 : Fish Bolt

(ii) Fang Bolt : Fang bolts can be used for chair with sleeper .They may be used instead of round spike.But their use is limited due to their high cost.

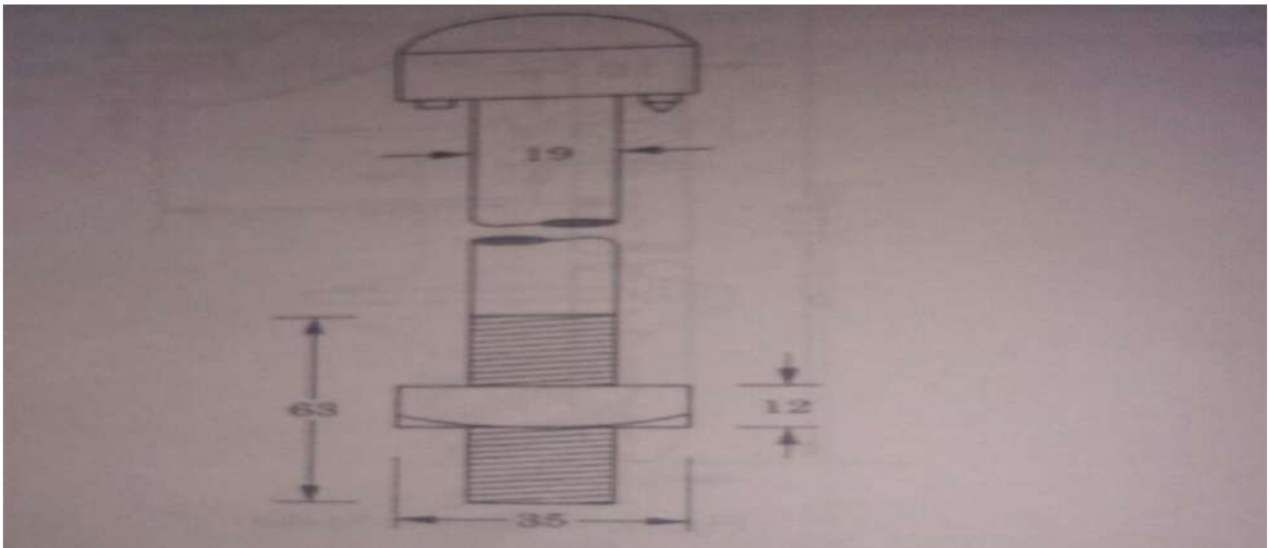


Fig. 5.11 : Fang Bolt

(iii) Hook Bolt :Hook bolt are used for fixing sleeper with bridge girder where sleeper have to be placed directly over bridge.

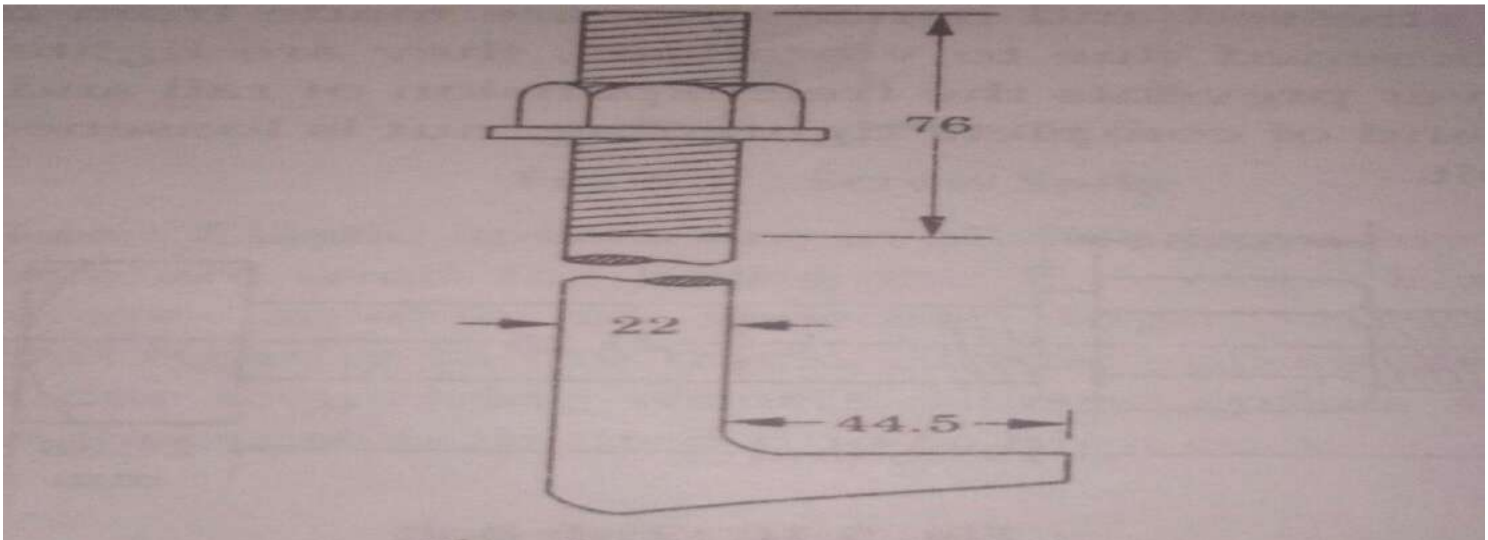


Fig. 5.12 : Hook Bolt

KEY:

Key are used to make rail connection. These are timber or steel pieces used to fix rails to chair or connecting rails to bearing plates.

Types:

1. Wooden Keys

2. Metal Keys

1.Wooden keys : They are cheap easily available ,easily prepared but at the same time they are not strong durable and resistant to weathering action. they can also be attacked by white ants.

2.Metal Keys : They are commonly used for connection and joints. Though they are more costly. but their maintenance cost is low, they are strong and durable and can take up heavy stresses and vibration under heavy loads.

BALLAST

It may be defined as the granular form of materials spread on the formation of railway track upon which the sleepers one to be rested is known as ballast.

Functions of Ballast

Following are the functions of ballast when used for Railway track

(i) To distribute the load uniformly from sleepers to large area of formation

ii) To provide hard and elastic bed for sleepers.

(iii) To hold the sleepers tightly against any lateral and longitudinal movements,

(iv) To provide elasticity to track. It therefore become such as alignment and gradient.

(v) Weed growth to prevent.

(vi) A level of the two rails can be easily maintained, corrected and changed if and when necessary.

(vii) To drain the rainwater from the track properly, so as to protect the surfaced formation.

Characteristic of Good Ballast

Good ballast should have the following characteristic

(i) It should be strong durable, non brittle under heavy loads of moving trains.

(ii) It should be resistant to abrasion and weathering action.

iii) it must be free from dust and mud.

Requirement of Good Ballast

To satisfy the main functions, the ballast should fulfill the following requirement

(i)It should resist crushing under ,dynamic loads while doing packing under sleepers

(ii) It should have angular and rough surface so as to provide good lateral and longitudinal stability to the sleepers.

(iii) It should allow for easy and quick drainage of the track.

iv) It should not have any chemical effect on rails and metal sleepers.

TYPES OF BALLAST

The following materials are used as ballast on Indian Railways

1. Broken stone

2. Gravel

3. Ashes or cinders

4. Sand

5. Moorum

6. Kankar

7. Brick ballast

8. Blast furnace slag

9. Selected earth.

1. Broken Stone : This is the best material for the ballast because it fulfils all the requirements of good ballast. The stone which is non-porous, hard, angular and does not flake when broken, should be used as ballast. Granite, quartzite and trap are used as ballast. broken stone, of 5 cm to 2 cm size provide maximum stability to the track. This type is the most expensive in its initial cost but is cheaper in the long run.

Suitability : This type of ballast is most preferred for high speed tracks.

2. Gravel : The second best material for use as ballast, and being next in rank to broken stone due to its suitability. It consists of smooth, rounded fragments, obtained, from river beds. The gravel, obtained from pits, usually contains earth which should be removed by washing before use. The smooth pieces, greater than 6 cm size, are broken to the required size to increase their interlocking action.

Advantages :

(i) Gravel is a cheaper material than broken stone.

(ii) Its drainage property is excellent. Disadvantages : Following are the disadvantages of using gravel as ballast :

(i) Gravel easily rolls down due to vibrations and thus results in early loosening of packing under sleepers.

(ii) The variation in size and quality is considerable and hence, it requires screening of small size fragment, .breaking of large size and smooth pieces and washing of gravel obtained from pits.

Suitability : This type of ballast is also used in large quantity in India and other countries.

3. Ashes or cinders : The residue obtained form coal used is known as ash

It is a by-product of every railway, using coal as fuel. It is preferred being economical ballast material in its initial cost, available in large quantity When eve required, has excellent drainage properties, and provides easy handling. In emergency such as destruction of track by floods, this can be used for repairing formation as well for packing track. This is suitable for station yards, sidings, foot paths. But it should not be used in main lines because it is very soft and turns in powder under loads and having corrosive properties thus carried steel sleepers and for rails.

4. Sand : It is also good material for ballast. If no other material is available for some unimportant track, then sand or some selected type of earth may he tried as ballast material. It is cheap, easily available but of poor strength and with poor drainage properties.

These type of ballast is good for packing pet sleepers.

5. Moorum : It is formed by decomposition of lateral. It has red or yellow color it is soft ballast material it can be used formerly track, it has good drainage properly. moorum is used for unimportant tracks because it is soft in nature and turns in powder also maintenance of rack, laid with moorum is difficult, so it should be used for unimportant tracks.

6. Kankar : It is a lime agglomerate and is commonly found in certain clayey soil. It is found in many places in the form of nodules of varying size, where stone is not available it is being used as ballast because Kankar is a cheap variety of ballast. It has good drainage characteristics.

7. Bricks Ballast: Where no stone or substitute is available for use as ballast, over burnt brick are broken into small size and used, It powders easily and produces dusty rack. Rails in tracks laid on brick ballast many a time get corrugated. Brick ballast however, is fairly good for drainage.

8. Blast furnace slag: It is by- product obtained in the manufacture of iron. Slag forms cheap ballast. Obtain from molten slag ,It has got good drainage properties.

9. Selected earth : There are indurated clay and decomposition rock material which are used as ballast .these are used as ballast.

6. SLEEPERS

SLEEPERS

Sleepers are the members which are laid under the rails to hold the rails required gauge as well as to support the rails. Sleepers is the main component of track. These are laid transversely to the rails.

Functions of Sleepers

1. To support the rails properly.

2. To maintain the gauge distance.

3. To distribute the loads on the formation through ballast.

4. To provide cushion between the rail sections and ballast thus absorbing the shock of moving loads.

5. To provide easy replacement of rails.

6. To maintain the rail track alignment.

Requirements of and ideal Sleeper

1. Sleepers used for track should be able to maintain proper gauge.

2. Sleepers should be able to provide good bearing area for rails.

3. Sleepers should be such that they can take moving load, and not too heavy that cause problem in handling and transportation.

4. Sleepers should be durable.

5. Material used for sleepers should be such that it does not get damaged during packing and tamping process.

6. Sleepers have some scrap value after their rejection which indicate the good quality of sleepers.

7. The design of sleepers should be such that rails can easily fixed and taken out when need arise.

TYPES OF SLEEPERS

Indian Railways used various types of sleepers in the formation of track, depending upon the easily availability of the material and the topography of the area. These are

1. Wooden sleepers

2. Metal sleepers

(a) Steel sleepers

(h) Cast-iron sleepers

3. Concrete sleepers

(a) Re-in forced cement concrete sleepers

(b) Pre-stressed concrete sleepers

1. Wooden sleepers : Timber is the natural and easily available source for wooden sleepers. As the name wooden sleepers are made from timber or wood and are termed as wooden sleepers, with the invention of railways initially wooden sleepers being used by. Indian railways in track formation. In those days timber was chief and easily available source for making sleepers and hold the max requirement of good sleeper qualities. Teak, deodar, sal and chir sleepers are being used. Among all sal is the best timber for wooden sleepers it is the cheapest one, Teak and chir are used where these are easily and cheaply available. Care should be taken before making timber sleepers. Timber should be well seasoned before using as sleepers to protect them from weathering action and from the attack of white ants. The timber used for wooden sleeper should be free from defects like center heart, split ends, knots, wraps and crops grains etc.

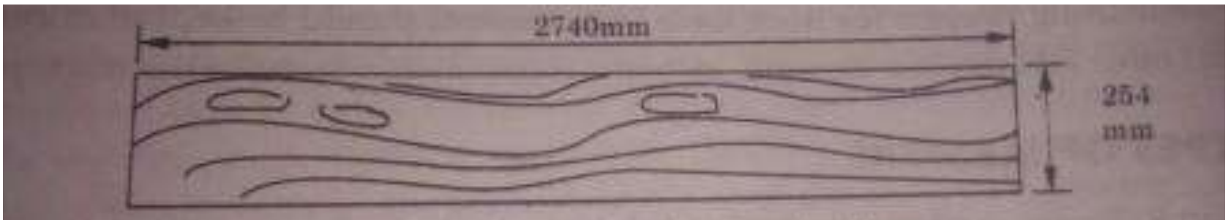


Fig. 6.1 : Plan Showing Wooden Sleeper

Advantages

1. These are easily available in all parts of India.

2. The initial cost of wooden sleepers is low.

3. Wooden sleepers are simple in design.

4. Wooden sleepers require less numbers of fastenings.

5. Wooden sleepers are easy in handling.

6. These facilitate easy replacement of rail sections.

7. Wooden sleepers are suitable for every type of ballast.

8. Track circuiting proves best in case of timber sleepers.

9. Wooden sleeper can be used for all types of rail sections.

Disadvantages

1. These are liable to decay due to vermin attack.

2. In case of wooden sleeper it proves to be difficult in maintaining of pric gauge.

3. These are liable to get fire.

4. The life of wooden sleepers is less as compare to other sleepers, it is generally 10-15 years.

5. These require skilled labour to provide adzing of sleeper to provide in ward tilt.

(2) METAL SLEEPERS

Later an wooden sleepers are replaced with metal sleeper as the shortage timber in the country increasing day by day, also with other disadvantages like maintenance of track, life of wooden sleeper etc. pushed the adoption of steel sleepers. Steel and cast iron are normally used for manufacturing of metal sleeper.

Advantages

1. More life nearly 35-50 years.

2. There sleepers are strong and durable as compared to wooden sleepers.

3. Maintenance cost is less.

4. Gauge can be properly maintained.

5. More track stability.

6. Scrap value is more.

Disadvantages

1. There sleepers are liable to decay early due to rusting and other chemical effects.

2. Steel sleepers require more quantity of ballast for the their laying.

3. There sleepers require more fittings for the proper track formation.

4. Track circling become difficult in case of metal sleepers.

6. There sleepers are unfit in case of bridges and level crossings.

Metal sleepers are future classified in two type

(i) Steel sleepers

(ii) Cast Iron sleepers

(i) Steel Sleepers : The sleepers made of steel are termed as steel sleepers.

These sleepers are made or manufactured with 6mm thick special plate. Both ends of the sleepers are bent down to check the running out ballast. These sleepers are pressed in such a way that give proper tilt to the sleeper for the inward slope to the rail sections. Standard length of the steel sleepers is 2680 mm or 2.68 meter.

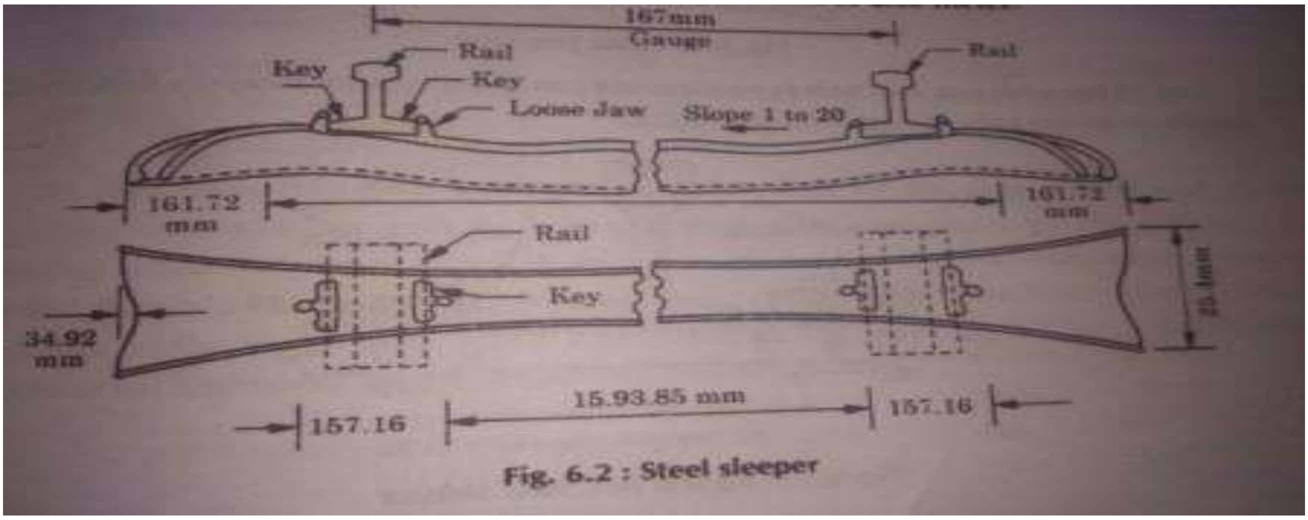


Fig. 6.2 : Steel sleeper

Steel sleepers are of following two types :

(a) Key type sleepers.:

(b) Clip with nut and bolt type sleeper.

(a) Key type sleepers : In this type of sleepers keys are used for holding the rails in pressed up lugs that is why these are known as key type sleepers Lugs are specially formed to hold the rail with the help of keys. Keys are used to fill the space left between the lugs and rail practices proved that key type sleepers cause damage and due to keys they got weakens and to counter this problem loose jaw type Sleepers formed.

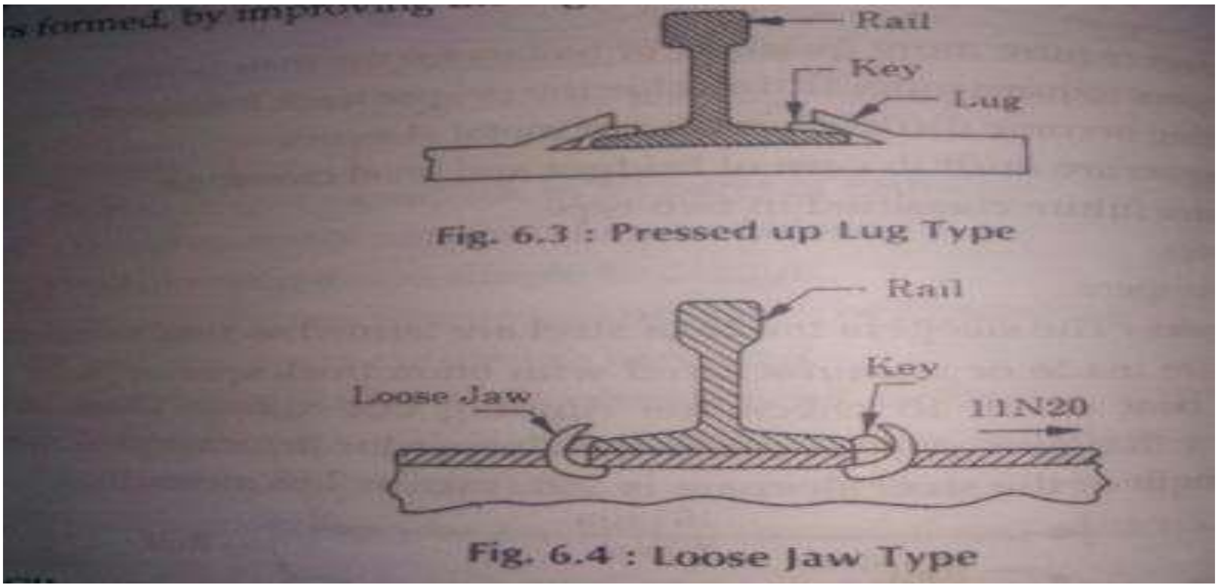


Fig. 6.3 : Pressed up Lug Type

Fig. 6.4 : Loose Jaw Type

(b) Clip with nut and bolt type sleepers : In these type of sleepers rails are held in sleepers with the help of clips, nut and bolts .

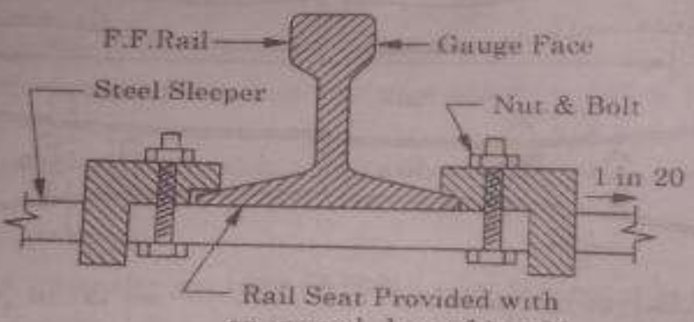


Fig. 6.5 : Clip and Bolt Steel Sleeper

Advantages

1. These sleepers are capable for maintaining proper gauge.

2. The strap value of there sleepers are more.

3. The life of sleepers are more in comparison to wooden sleepers.

4. These sleeper helps in preventing creep up to large extent.

5. These sleepers provide lateral and longitudinal rigidity to the track.

6. These sleepers are easy to transport as they are light in weight.

7. These sleepers require less fastenings.

Disadvantages

1. These are not suitable for every type of ballast used for track.

2. Initial cost of these sleepers are high.

3. These sleeper does not meets the requirements of track circuiting.

4. These sleepers are liable to corrosion.

5. Crakes are developed in rail seats after some time.

(b) Cast iron sleepers : Sleepers which are made with cast iron are teemed as cast iron sleepers.

These are becoming more important for Indian railway track and are widely used. Cast iron sleepers are of following types.

(i) Pot or bowl sleepers

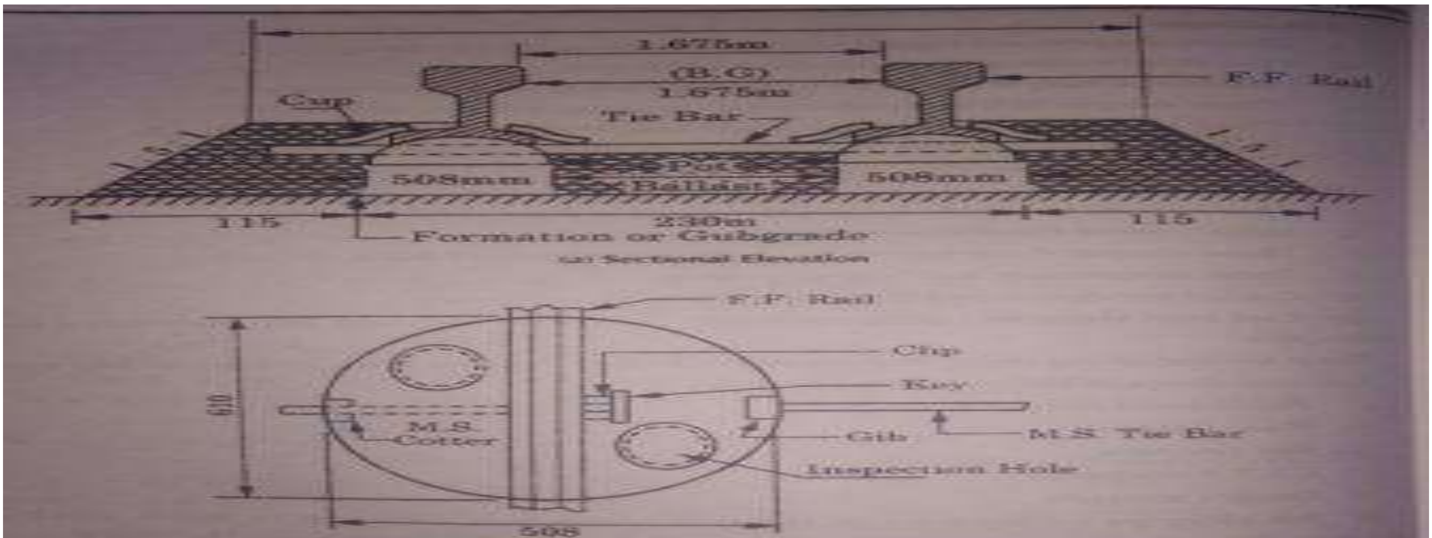
(ii Plate sleepers

(iii)Box sleepers

(iv) C.S.T.9 sleepers

(v) Duplex sleepers

(i) Pot sleepers : This type of sleepers consists of two pots or bowls which are connected with a tie bar with the help of cotters, gibs, clips and keys. The effective area of both pot in a sleepers is kept 0.46 m^2. i.e. as of wooden sleepers. Two inspection holes are also provided on the sides, Ballast can be checked with the help of holes. Seat is -provided on the top of pot in such a way that an inward slope tit 1 in 20 can he given Weight of such sleepers are approximately 113.50 kg.



(b) Detail of Fixing F.F. Rail with an Oval Shaped C.I. Sleeper

Fig. 6.6 : Pot or Bowl Type C.I. Sleeper

(ii) Plate sleeper : This is another type of cast iron sleeper is plate sleeper. Plate sleeper consist of two plate 860x300 mm plate with sidealso as 300.

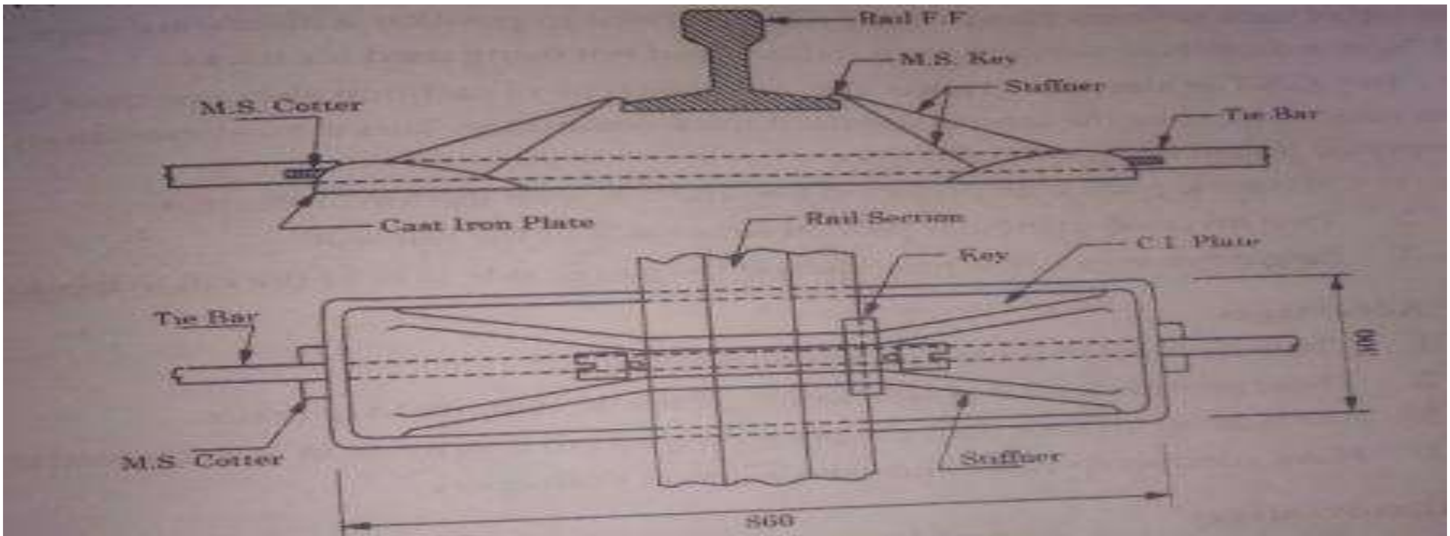


Fig. 6.7 : Details of Plate Sleepers

(iii) Box sleepers : these are similar to plate sleepers. In this case box is provided on the top of each sleepers plate, where rails are fixed in position with inward slope of I in 20. Now a days these sleepers are out dated and not being used for tracks.

(iv) C.S.T 9 sleepers : This is also an other type of cast iron sleepers. these sleepers was standardized by the central standard track committee. This is most extensively used sleeper on Indian Railway it consist of

I. A central plate with projected key and a box on the top of the plate.

2. Two inverted triangular pots on either side of the rail seat.

3. Single two way key is provided on the gauge side to hold the rail to the sleeper.

Advantages

1. These sleepers provide firm support to the rail.

2. These provide lateral as well as longitudinal stability to the rails.

3. The bearing area for both the plate is equals to 0.46 m2 as in wooden sleeper.

4. Have good scrap value and can re-cast in to sleepers.

Disadvantages

1. The rail seats wears out quickly causing keys to work out loose.

These sleepers are subjected to vibration due to moving loads so it has limited longitudinal and lateral strength.

3. The suitability of rails is reduced because these provide rigid fastenings.

Due to aforesaid disadvantages these sleepers are improved upon in the form of C.S.T.-10,11,12 and 13 sleepers.

The CST-9 are extensively used in the Indian Railways is modified to confirm to CST-13, which has been designed with a view to meet the requirements.

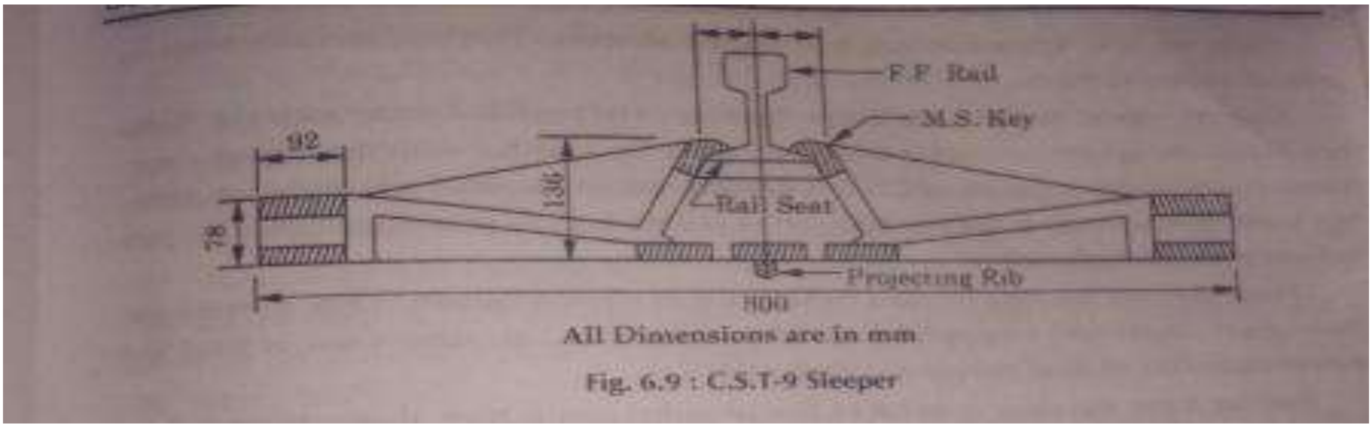


Fig. 6.9 : C.S.T-9 Sleeper

3. Concrete Sleepers

The sleepers which are made of concrete as major constituent are known as concrete sleepers.

In the early stages wooden sleepers were being used as timber was easily available at that time. With the development wooden sleepers were replaced with C.1 sleepers, further advancement in concrete technology, C.I. sleepers were replaced with concrete sleepers. These sleepers are firstly used and invented by France. In India these were introduced in 1925.

Advantages of concrete sleepers

1. Gauge maintenance proves satisfactory in concrete sleepers.

2. These sleepers found to good for track circuiting.

3. These sleepers have long life.

4. These sleepers are free from fire hazards.

5. These sleepers are durable.

6. These sleepers proves less creep in the track.

7. These sleepers require less number of fitting.

8. Maintenance cost of these sleepers proves very less.

9. There sleepers can withstand against stress induced with high speed traf because of heavy track modulus.

Disadvantages

1. These sleepers have nil scrap value.

2. The initial cost of concrete sleepers are high.

3. The are difficult to handle and transporting due to their heavy weight.

4. During the derailment there sleeper proves heavy damage.

5. The renewal work of track laid with these sleeper is difficult.

There are two main types of concrete sleeper

1. R.C.C sleeper

2. Pre-stressed concrete sleepers

SLEEPER DENSITY

Sleeper density means the number of sleeper used per rail length on a track. This may vary on different tracks. The density of sleepers depend upon following factor:

1. Importance of track

2. Speed of train

3. Expected axle load which a track can carry

4. Type of joint provided ,their strength as well as curve of the track.

1. BRIDGE-ENGINEERING

INTRODUCTION

A Bridge is a structure providing passage to cross an obstacles like a stream or a river or a low ground etc without closing the way beneath. The bridges are made to provide passage for a railway, a rood, a canal or a pipe line etc

BRIDGE ENGINEERING

It is the art of civil engineering which deals with the construction, maintenance as well as design of bridges.

Development of Bridges

The development of bridges has great part depending upon the necessity of the life, easeness of human nature compels the development stages. The development period of ridge construction is associated with the history of human civilization. Still the exact period of development of bridges in different countries of the world con not be predicted, but bridge development was very fast in some countries where as it is very slow in under developed countries. It is evident that the idea of developing a particular type of came to man by many instances of natural behaviour.

There are four major types of bridges

(A) Arch Bridges
(B) Suspension Bridges
(C) Simply Supported Bridges
(D) Truss and Girder Bridges

TECHNICAL TERMS :

Bridge Engineering : The branch of Civil Engineering which deals with the design, planning, construction, maintenance etc. of bridges in known bridge engineering.

Culvert : It is a small bridge having maximum span of 6 metres or less.

Span : It is the centre to centre distance between two supports.

Clear Span: It is the clear distance between two supports.

Pier: It is the intermediate support of a bridge superstructure.

Abutments : These are end supports of the super-structure of a bridge.

Approaches : These are construction woks which carry the highway or railway track upto the bridge.

Wing walls : These are the. walls constructed on both sides of the abutments to retain the earthen banks and protect them from the wave action of water, if necessary.

Foundations : Abutments, wingwalls and piers rest on structural foundations which transfer the load from the stricture over a large area of sub-soil below.

Economic span : The bridge length is divided into number of suitable spans. The span, for which the total cost of the bridge structure is minimum, is called economic span.

Long Span Bridge : It is a bridge having length more 120 metres.

Major Bridge : It is a bridge having length between 30 to 120 metres.

Minor Bridge : It is a bridge having length more than 6 in. and less than 30 metres.

Vent Way : It is a culvert having length less than 1 metre.

High-level or Non-submersible Bridge : It is a bridge, other than a culvert, which allows all the flood water to pass below it. e•g All highway or railways bridges.

Submersible or Low level Bridge : It is a bridge, which allows normal flood to pass through its vents, but heavy flood to pass over it thereby submerging the communication route.

H.F L. (Highest Flood Level) : It is the level of the, highest flood ever recorded of a river OR stream.

O• F. L. (Ordinary Flood Level) : It is the flood level which generally occurs a river OR stream every year..

L. W. L. (Low Water Level) : It is the minimum water level in the dry weather.

Natural Water-way : It is unobstructed sectional area available at bridge site for flow of water

Water-way : The area of opening which allows max. flood discharge to pass under the bridge without increasing the velocity to a dangerous limit is called waterway.

Artificial Water-way : It is area of opening provided under the bridge super-structure through which water flows.

Afflux (see Fig.) : It is, rise in water level due to, obstruction by the bridge in the flow of water.

Scour : It is the vertical cutting of the dyer bed.

Run-off : It is the portion of rainfall on a catchment area, which flows to water course.

Freeboard : The difference between the H. F. L. and the level of the crown of the road at its lowest point is called freeboard.

Clearance : It is the minimum distance between boundaries at specified posit° of a bridge structure.

In case of road or Railway bridge it is the distance available for traffic. The Vertical clearance' is the- distance between the afflux and the lowest point of the bridge superstructure.

Head-room : The distance between the highest point of a vehicle and the lowest point of any protruding member of the bridge is called headroom.

Foot Bridge : It is a bridge used for carrying pedestrians, cycles, animals etc., only across any obstruction or depression.

Cause Way : It is a "pucca dip" which allows flood water to pass over it.

Abutment Pier : In bridges with arches to support the flooring sometimes, some of the intermediate supports are made if stronger section which are called Abutment Pier.

COMPONENTS OF BRIDGE

Bridge structure is combination of two major parts

(1) Sub-structure

(2) Super- structure

1) sub-structure: : The lower most part of bridge which supports the entire structure made from abutments, piers etc, including superstructure is called sub- structure.

The function of sub-structure is similar to that of foundations, columns and walls etc of a building. Sub-structure supports the super-structure and distribute the loads to the soil through foundation. Substructure of abridge consists of following components.

(1) Foundations

(ii) Piers

(iii) Wing walls

(iv) Abutments

(v) Approaches.

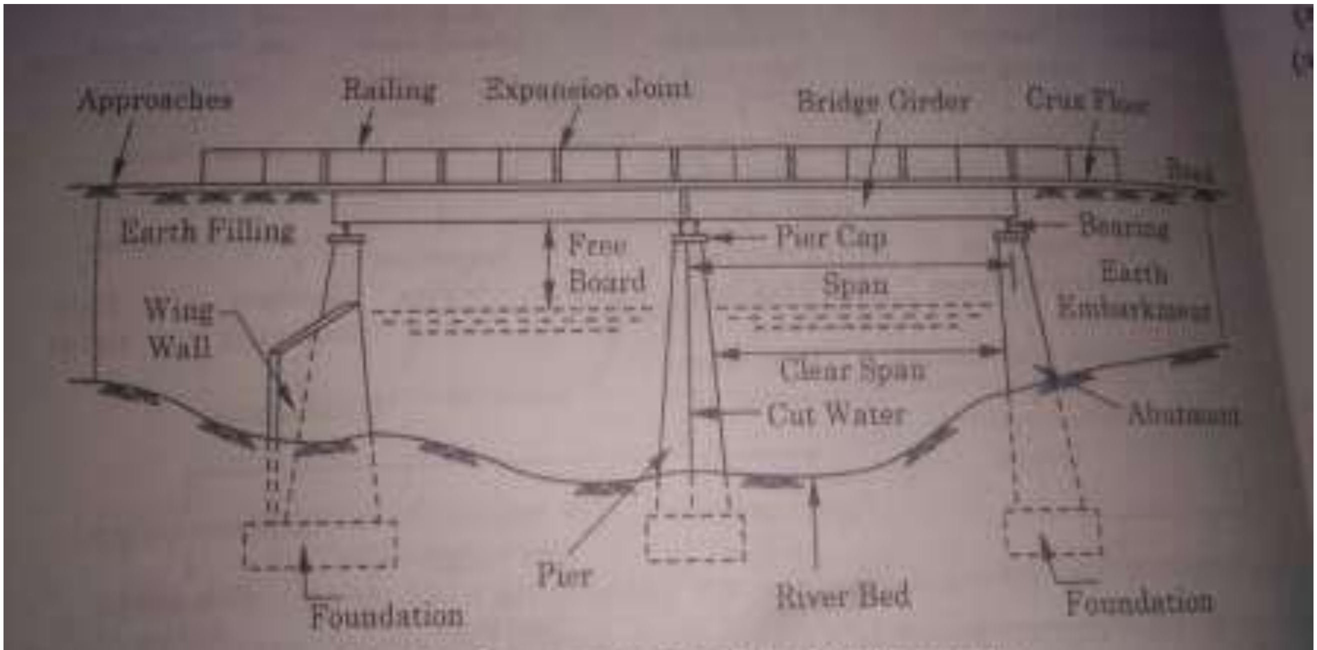
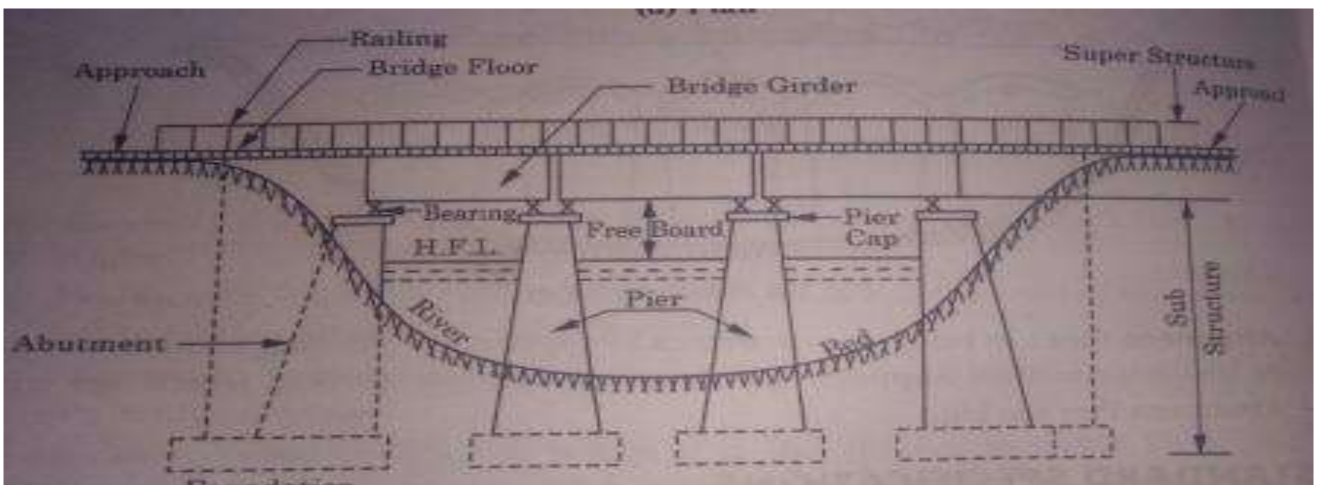


Fig. 1.1 : Component parts of the Bridge structure



(b) Section

Fig. 1.5 : Component Parts of a Bridge

(i) Foundations It is the lowermost part of bridge substructure is called foundation. The main function of foundations is to take" the loud of superstructure and transfer the load to the subsoil through foundations.

(ii) Piers : Piers are the intermediate support of the various spans of a bridge.

Piers are designed in such a way so that they can safely transfer the load from the superstructure to the sub soil through foundations. Piers also helps to divide the length of a bridge in to suitable numbers of span.

(iii) Wing walls : The walls constructed on both side of abetments to retain the earth banks of the river are called wing walls.

Wing walls serves the functions to protect the earth banks against the action of water and also to retain the earth banks of approaches.

(iv) Abutments : The end supports of bridge super-structure are known as abutments. They transmit the load from bridge to the foundations and gives final Formation level to the bridge super structure and also retain earth filling.

(V) Approaches : Approaches are the portions of roadway or railways on both the ends, Which connect the route with the bridge proper are termed as approaches.

The main function of approaches is to enable the traffic to run over road or railway back.

(2) Super Structure : It is that part of the bridge over which the traffic moves safely. It consists of road way. girders, arches etc over which road is supported.The basic function of super striation is to provide carriage way.

Between Bridge and Culverts

(A) Bridge : It is a structure made to cross obstacles providing passage over an opening without closing the same. The required passage may be for road, railway, canal pipe line etc. The total length of a bridge between the faces of its abutments is always more than 6 m.

The classes of crossing

(a) River crossing

(b) Via doct (bridge across a deep valley),

(c) Grade separation.

CULVERT

Culvert is define as a small bridge constructed over a stream which remain dry most part of the year .A culvert is a cross drainage work having a total length not exceeding 6m between the face of abutment.

Culvert are provided:

1. For driving small pockets and also where the height of the bank is small.

2. For small streams with rigid boundary or semi-rigid boundary.

CLASSIFICATION OF BRIDGES

The bridges are mainly classified according to:

1. According to life- 1. Permanent

2. Temporary

2. According to road level – 1. Deck

2. Through

3. Semi- Through

3. According to material – 1. Timber

2. Masonary

3. Steel

4. R.C.C

5. Prestressed Concrete

4. According to position of high flood level – 1. Submersible

2. Non – Submersible

5. According to Alignment – 1. Strength

2. Skew

6. According to Structural Form —

1. Beam type bridges R.C.C, Tee beam, balanced cantilever, steel girder, plate and box girder, portal frame bridges, truss .

2. Arch type bridges - open spandrel, filled spandrel, rib type bridges etc.

3. Suspension type - Ramp, trestle and sling bridges.

According to Loading —

1. Class A bridges

2. Class B bridges

3. Class AA bridges

According to Function —

1. Foot bridge

2. Highway

3. Railway

4. Viaduct

5. Aqueduct

According to span:

1. Culvert

2. Minor bridges

3. Major bridges

4. Long span bridges

10. According to Clearance in Navigation Channels — 1. Movable 2. Transporter

11. According to Level of crossing of Highway or Railway — 1. Over-bridges 2. Under-bridges

The classification of steel bridges may also by done as follows :

(i) Riveted Bridges

(ii) Welded Bridges

(iii) Pin-jointed (or Bolted) Bridges

Permanent & Temporary Bridges

The bridges which are constructed and maintained at low cost and have short span of life are called Temporary Bridges

Temporary or Low Cost Bridges

These bridges are constructed for short time e.g.

(i) During construction of Darns.

(ii) Permanent bridges.

(iii) In crossing river during Meals.

(iv) During repair work of permanent bridges

(v) During survey work for projects.

(vi) For transporting timber from one bank to another in forests.

These bridges are dismantled when the object of their construction is fulfiled, hence the name. Permanent or High Cost Bridles

These are bridges which are constructed and maintained at high cost and have long span of life.

These bridges are built to last for centuries.

Straight & Skew Bridges

The bridge which is at right angles to the axis of water is called straight bridge.

Skew Bridge : The bridge which is constructed at some other angle than 90^0 to flow of water is known as skew bridge. It is better, always to avoid a skew bridge

Disadvantages of Skew Bridges

(i) The foundations are likely to be s covered.

(ii) Construction of skew arches is difficult.

(iii) Maintenance is costly and difficult.

(iv) The piers have to resist additional water pressure, as whirls are produced.

Hence special care must be taken that the pie: is parallel to the current. If the alignment of the central line of a bridge is in a curve, then it has to 'resist additional forces due to centrifugal action. Therefore alignment must have smooth entry and exit. On very important routes, where traffic is heavy and temporary bridges are ,unsuitable, permanent bridges are constructed to cross the rivers or streams.

Deck, Through And Semi Through Bridges

The flooring of bridge which carries the traffic may be supported at top, bottom or at some intermediate level of the superstructure.

When the plateform of a carriage communication route is supported at the top of the superstructure it is known as deck bridge.

When it is suspended at the bottom of the super structure the bridge is called a through bridge. If it is supported at some intermediate level, the bridge is a Semi Through Bridges.

Over and Under Bridges

The bridge constructed to allow a road to pass under is known as Under Bridge.

The bridge constructed to allow a highway to pass route is called an Over Bridge.

Class A, B and AA Bridges

(i) Class A bridges : are bridges which are designed and constructed for 1.R.C. class A loading.

(ii) Class B bridges : are bridges which are designed and constructed for I.R.C. class B loading e.g. weight of a lorry.

(iii) Class AA bridges : which are designed and constructed for I. R C. class AA loading. e.g. tracked vehicles having total. weight 70 Tones, refer Fig. Standard loading for design of bridges as per I.R.C.

Submersible and Non-Submersible Bridges

(i) Submersible or Low Level Bridge : It is the bridge which allows the highest flood to pass over its superstructure. These bridges are generally constructed on unimportant routes and when sufficient funds are not available. In this case storm water runs only for a short period of the year. The stream remains dry for the rest period of the year or little quantity of storm water runs under the bridge.

(ii) Non Submersible or High Level Bridge : It is a bridge which does not allow the high flood water to pass over the floor carrying the communication route.

This type of bridge is of permanent nature. It is constructed on important highways and to carry an unobstructed traffic throughout the year. Moreover sufficient funds should be available for its construction.

FACTORS AFFECTING THE SELECTION OF TYPE OF A BRIDGE

The various factors which may affect the selection of type of a bridge are :

1. Nature of the river. 2. Type of bed soil.

3. Volume of traffic. 4. Funds available. 5. Time limit.

6. Foundation conditions.

7. Facilities during construction.

8. Length of the bridge.

9. Economic span of the bridge.

10. Level of H. F. L.

11. Availability of workers. Nature of Traffic.

12. Bearing capacity of bed soil.

13. Materials available.

14. Climatic conditions.

15. Physical features of the site.

16. Width of the bridge. 17. Live loads on the bridge.

2. SITE SELECTION AND COLLECTION OF DATA

SELECTION OF BRIDGE SITE

The selection of site for bridge is done keeping the engineering, economic as well as soil and geographic aspects of the area. It is not be possible that bridges always have a wide choice of bridge sites, serially in case of urban area. In order to select an economical site for bridge construction following are the characteristics for ideal site :

(i) A straight reach of the river : At bridge silt there should be straight reach of stream or a river. A straight reach/flow will not tend to change its path thus bridge can be withstand for a long period/designed period, because it reduces scour near the bridge.

(ii) Narrow channel with firm banks : Well defined banks of upstream and down stream provide a safe guard against the river changing its course. River or stream at bridge site should be as narrow as possible. This leads economy and least possible length to the bridge thus resulting economy in the initial cost.

(iii) High banks above H.F.L on each side : The site selected for bridge should have high and stable banks near the bridge thus prevent the overflowing of the streams during flood, preventing scouring and increasing the life period.

(iv) Foundation : A bridge site should have hard, non erodable bed at short depth for providing foundation for the bridge. This feature add economy to labour, time, material for providing piers, abutments etc.

(v) Right Angle crossings : At bridge site the axis of stream should be right angle to the centre line of the route as far as possible. This provide economy in bridge construction.

(vi) Obstruction in waterways : Minimum obstructions in waterways provide le afflux, so while selecting bridge site there should be no or minimum obstruction in the way.

(vii) Absence of expensive river training works : Site which is to be selected hr bridge should have free from training works. River training works are very costly and used for controlling river water so absence of river training works at bridge site results in economy in initial cost.

(viii) Absence of scouring and silting : Absence of scouring and silting needs less maintenance cost, so while selecting site for bridge it should be kept in mind that bridge site should be free from scouring and silting.

(ix) Minimum under water construction : The site which is selected for bridge, should be such that the minimum construction under water should be needed so that to avoid under water construction work for the yield of the bridge as well as economy in the initial

(x) Availability of labour, and material : The site selected for bridge construction should be carefully selected so that at site there should be easy availability of labour and material to make the bridge economical in initial cost of construction and maintenance.

(xi) Absence of sharp curves and approaches : The bridge site should have free from sharp curves and have straight approaches. Since it is difficult to construct and maintain the bridges at sharp cruves. So while selecting site for bridge it should be free form sharp curves.

DATA COLLECTION

Preliminary Data To Be Collected

The engineer in-charge of the investigation for a bridge should collect the following information :

(i) Name of the river, road and location of the probable bridge sites.

(ii) Present and anticipated future volume and nature of traffic on the road of the bridge site.

(iii) Location of the nearest Great Trigonometric Survey (G. T. S.) bench mark " its R. L. (reduced level).

(iv) Soil profile along the probable bridge sites.

(v) Navigational requirements, if any for the river.

(vi) Hydraulic data pertaining to the river This may include ordinary flood level, highest flood level and low water level. site, shape, slope and nature of the catchment, frequency and intensity of rainfall in the catchment etc.

(vii) Availability, quality and location of the nearest quarries for stones, for masonry and for concrete aggregates.

(viii) Nearest place of availability of cement, steel and timber.

(ix) Means of Transport for materials.

(x) Availability of Electric power.

(xi) Availability of skilled and unskilled labour for different trades required for construction.

(xii) Facilities required for housing labour during construction.

(xiii)Earthquake disturbances of the site.

Preliminary Drawings

The drawings prepared at the time of investigation are -

(i) An index map

(ii) A contour survey plan.

(iii) A site plan.

(iv) A cross section

(v) A longitudinal

(vi) Additional cross-section

(vii) Catchment area map.

(viii) Soil profile

(i) An Index Map : An index map is drawn to a suitable scale (generally 1/50,000). It should show the proposed location of the bridge, general topography of the area, existing communications, important towns, existing bridges etc. in the vicinity.

(ii) A contour Survey Plan : It may be drawn to a suitable scale i.e. 1/1000 to 1/5000. Contour plan of the stream showing all topographical features for a sufficient distance on U/S and D/S of the site must be completed. All sites worth considering most be shown on the plan.

iii) Site Plan : It may be drawn to a suitable scale (usually 1/500 to 1/11000). This Should give details of the selected site and details of the stream or river to a of 150 to 200 metres up-stream and down-stream of the selected site.

Details to be indicated on the Site Plan

(a) Name of the stream or river, road and nearest distance marker.

(b) Direction of flow of water.

(c) North direction.

(d) The alignment of existing approaches and proposed crossing with approaches.

(e) Location and reduced level of the bench mark used as datum.

(f) Angle and direction of skew, if the proposed alignment is on a skew.

(g) Name of the nearest village or town at either end of the crossing.

(h) Width of roadway over the bridge.

(i) Location of trial pits and boring holes with their indentification number.

(j) Location of all nallahs, buildings, wells or other obstructions to a road alignment.

(k) Locations of the longitudinal section and x-sections of road and stream taken

within the area of the plan.

(iv) Cross Section : A cross section of the stream at the proposed bridge site to a scale about 1/1000 horizontally and about 1/100 vertically.

The x-section should indicate the following information :-

1. Name of the stream, road and chainage.

2. Nature of sub-soil.

3. River bed line with banks up to a level above the highest flood level.

4. Formation level.

5. Depth of cutting or filling on the approaches.

6. Low water level, normal flood level and the highest flood level.

(v) Longitudinal Section : Suitable scale may be used for horizontal distance but vertical scale must not be less than 1/1000, L-Section of the stream showing site of the. bridge with the L. W. L., 0. F. L. and bed levels at suitable intervals along tile-- approximate centre line of the deep water channel should be drawn.

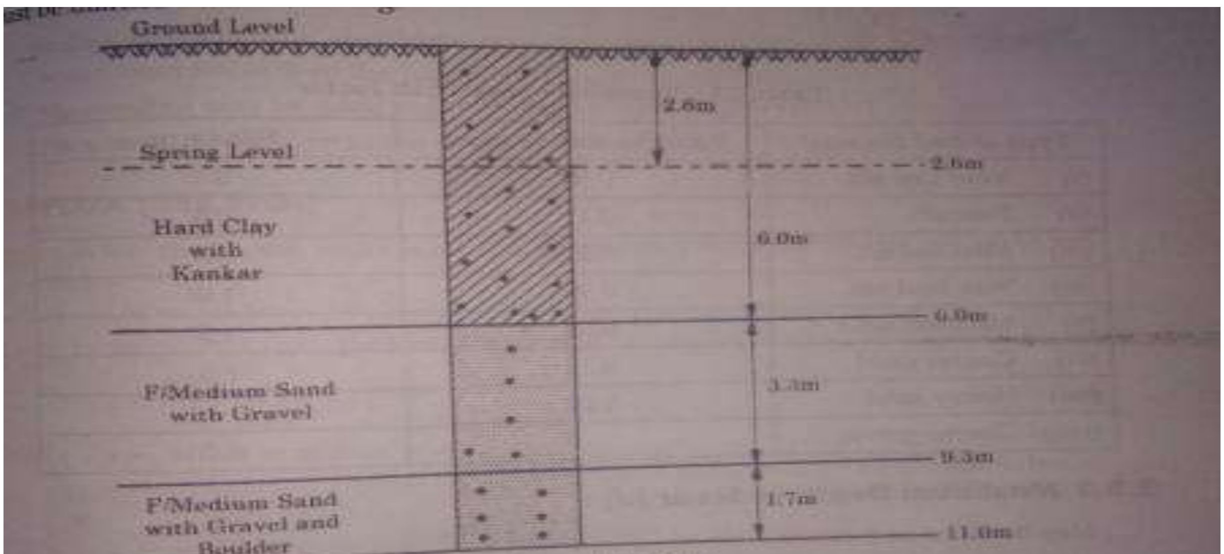


Fig. 2.1 : Soil Profile

(vi) Additional Cross-Sections : These may, be drawn of the stream or river, suitable distance both U/S and D/S of the proposed bridge site.

(vii) Catchment area Map : It is prepared for the stream or river at the proposed, of bridge by tracing the line of the ridge of the watershed from the topographical of survey of India drawn to a scale 1/50,000.

(viii) Soil Profile : The soil profile must show the bed and banks, of levels of layer and classification of the sub soil. It should be found along bridge alignments by sub soil exploration.

SCOUR

cutting of bed or deepening of river due to action of water is called scouring. More over horizontal widening of river is called 'Erosion.

Scour 0f stream bed occurs during the passage of a flood discharge. Firstly scouring will be at the nose of the piers and at bends, then it will start in the foundation. Due to reduction in bearing capacity piers will sink down, hence causing the failure of the bridge.

Maximum and Normal Depth of Scour

In India, Lacey's equation is commonly uscd for finding normal depth of scour for natural streams in alluvial beds.

if d = normal depth of scour below H. F. L. in rn.

Q = discharge in m^3/sec. f= Lacey's silt factor Then $d = 0.473\ (Q/f)^{0.33}$

Maximum Depth of Scour (d) : May be taken as follows:-

(i) for straight reach = 1.27d

(ii) for moderate bend = 1.50d

(iii) At a severe bend = 1.75d

(iv) For a right angled bend = 2.00d

(v) For noses of piers = 2.0d

(vi) For U/S noses of guide banks = 2.75d

Prevention of Scouring The measures taken are as under

(i) Shape of piers should be such that it may not cause currents, eddies water.

(ii) The bridge site must have stream line flow.

(iii) Pitching of heavy stones must be done on U/S and D/S of the bridge

(iv) Bed particles of the bridge should be such that these may stand the high velocity of water.

(v) Sufficient water way should be provided under the bridge, so that velocity of water must not exceed the limit alter which scouring starts.

(vi) Sheet- piling may be done to prevent scouring in sandy beds.

(vii) Piles should be driven in the stream or river bed to avoid scouring.

RUN OFF

It is the portion of rain-fall on a catchment area which flow to the water course depends on the following factors

(i) Duration of rain-fall.

(ii) Intensity of rain-fall.

(iii) Area and type of catchment area.

(iv) Slope of catchment area.

(v) Shape of catchment area.

(vi) Initial state of catchment area regarding wetness.

(vii) Type of soil in catchment area i.e. porosity etc.

Calculation of Run-Off

The following are the usually used empirical formulae for calculating the rum If Q it., discharge in cum/ sec.

C = constant, value depends upon nature of catchment area

A area of catchment in sq.-km.

then (i) According to Dicken's formula

$$Q= CA^{3/4}$$

According to Ryve’s tormula

$$Q= CA^{2/3}$$

Economical Span

The span for which the total cost of the bridge will be minimum is called economic span of the bridge.

The most economical span length is that for which the cost of superstructure...(of substructure. This condition may be found as under :-

Let L = total linear water-way.

I = length of one span.

n = No. of spans = L/l

A = Cost of approaches.

B = Cost of two abutments, including foundations.

Z = Cost of one pier, including foundations.

C = total cost of bridge.

Assume that cost of superstructure of one span is proportional to square of the s, length.

(1) Then total cost of superstructure = $n\ k\ 1^2$ where k is a constant.

(ii) Cost of flooring, railing etc. is proportional to the total length of bridge' may be taken as K'L.

For minimum cost dC/dl= 0

By differentiating, putting n = L/l and equaling result = 0

we have : $Z=k1^2$

Hence for economic span, the cost of superstructure of one span= cost of substructure of the same span. I.R.C. recommendations for small culverts and bridges are :-

(i) For R. C. C. slab bridge—economic span= 1.5 H where H Heigh above the foundation.

(ii) For Masonry Arch Bridge — Economic span = 2H, where H = height of pier above foundation up to springing line.

Length of Bridge

After calculating the economic span length, water way, the length of bridge is found. More over piers are designed and their sizes are noted.

Then Length of Bridge =Water way + width of all piers.

Width of Carriage Way

The minimum width of carriage way for one lane is 3.8 m. For every additional lane, a minimum of 3.0 m must be allowed.

The width of carriage way will depend on the volume and intensity of traffic anticipated to use. the bridge. In urban areas it is desired to provide separate cycle tracks, foot paths etc. Bridges should have carriage way of two, four or multiples of two lanes.

As per I. R. C. (Indian Road Congress) recommendations it is required to provide a carriage way of 7.5 metres instead of 6.8 m for two lane traffic.

Bridge Alignment

The location of centre line of a communication route to be carried by the bridge at the selected site is called bridge alignment.

While locating the alignment of a bridge following points to be considered

(i) The alignment for bridge is free from curves because it cause difficulty in construction as well as maintenance of a curved bridges. Curved alignment of bridges are also liable to traffic accidents.

(ii) The center line of the bridge should always be at right angle to the axis of river. This type of bridges are easy in construction and moreover helps in economic constructions.

(iii) The most important point while making bridge alignment is that it should be avoided from skew bridge because skew bridge are difficult in construction also obstruct the water way.

FOUNDATION

INTRODUCTION

Foundation is the lower-most part of the sub-structure. It transfer load from the super-structure of a bridge. Piers and abutments are provided with foundations. All the loads that came on the bridges, the forces are to be transmitted to the foundations. Excessive settlements or shear failure of the foundations damage the bridge. The depth of foundations should be such that they shall be located below the depth of maximum scour so that these are not damaged.

BRIDGE FOUNDATION

The lowermost parts i.e. piers, abutments etc. which supports the bridge and helps transferring loads safety to the sub-soil are termed as bridge foundation.

Function of Foundation

Foundations serve the following purposes :

(I) Transmit the loads from the superstructure and substructure over a bearing area in such a way that keep the maximum stress within the permissible bearing capacity of the soil.

(ii) Prevent of tilting and overturning of piers and abutment,

(iii) Stabilization of the supporting material of the river bed in order to prevent sinking of the pier

(iv) Provide of a level base for the construction of substructure above the foundation.

(v) Prevention of settlement of the structure by transmission of the load to the bearing strata uniformly.

(vi) It prevents heaving up of the soil under applied load.

(vii) It provide stability to the structure/bridge.

Requirement of a Foundation

There are the three basic requirements of a foundation,

1. Location

2. Stability

3. Settlement

1. Location : The location of foundation structure should be so that it is able to resist influences which may adversely affect its performance. This aspect requires careful judgment of an engineer.

2. Stability : The foundation structure should be stable or safe against any possible failure.

3. Settlement The foundation should not settle to such an extent so as to impair its usefulness. It is however, difficult to define the amount of settlement. It is seen that the differential settlement cause damage to the structure. So it should be avoided.

The term differential settlement is used to indicate the non-uniform settlements of different points of the same foundation or of two independent foundations. It is mainly due to prevailing foundation bed conditions at site.

BRIDGE FOUNDATION CLASSIFICATIONS

Bridge foundations are classified in three major categories.

1. Land foundations ;

2. Foundations constructed on soil having wager at shallow depths ;

3. Under water foundations.

1. Land Foundations : The foundations constructed on a dry land are known as land foundations.

Land foundations can be easily constructed because they are mostly shallow and do not require any special provision for their construction.

Land foundations are further classified as :

(a) Spread or open foundations ;

(b) Raft foundatlions ;

(c) Grillage foundations ;

(d) Inverted arch foundations ;

(e) Pile foundations.

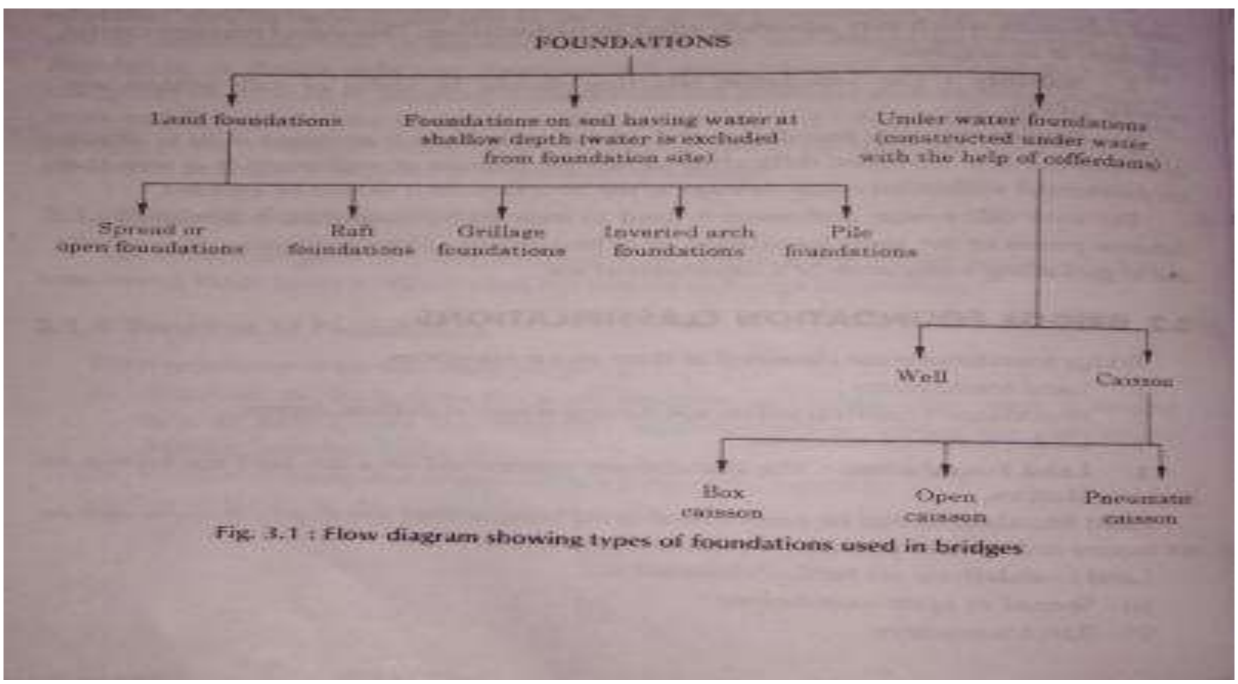
1. Shallow foundations : The foundations which are constructed at shallow depths on hard and firm strata are known as shallow foundations.

2. Foundations Constructed on Soil Having Water at Shallow Depths : These foundations are constructed when there are suitable arrangements are made to exclude water from the site.

3. Under Water Foundations : These foundations are constructed under water. These are also known as deep foundations. In such types of foundations cofferdams are Made to exclude water from site. These are of following types

(i) Well foundations

(ii) Caisson foundations.



GRIP LENGTH

Unless the foundations are rested on rock, proper grip length below the maximum scour level must be provided. As per I.R.C., the minimum req uired grip length is recommended as one-third the maximum scour depth for road bridges and one-half of maximum scour depth for railway bridges. The advantage of grip length is to ensure stability under heavy flood conditions.

Factors Affecting Depth of Foundation

(As per I.R.C.) :According to I.R.C. Bridge Code the factors affecting depth of foundation are as under :

(i) The minimum depth of foundation below H. F. L. must be 1.33 D, where : D = anticipated max. depth of scour below H. F. L.

(ii)The foundation must be taken below the scour level and to the level at which there is little variation in the water content of the subsoil.

(iii) The forces due to wind and seismic forces when considered, the intensity of load must not exceed the safe bearing capacity of the subsoil by more than 25%.

(iv) In well foundations, the effect of skin friction should be considered on the portions below the maximum depth of scour.

Skin friction is the frictional resistance of the surrounding soil on the outer surface of steining of wells or well caissons.

(v) For deciding the depth of well foundation grip length must he considered as per I.R.C. recommendations.

Rankin's Formula For Calculating Minimum Depth of Foundation

If p = safe bearing capacity of the subsoil in tonnes/m2

w = specific weight of the subsoil in tonnes/ m3

Q= Angle of repose or friction of subsoil in degrees.

Then minimum depth of foundation $=h=p/w(1-\sin Q/1+\sin Q)^2$

Factors which influence Bridge Foundation

Following three factors influence the design of bridge foundations :

1. Bearing capacity of soil
2. Frictional resistance
3. Scour.

1. Bearing capacity of soil : The bridge foundations should be kept to such a depth that the soil at that depth has sufficient safe bearing capacity to withstand the load without any settlement. If W is the total load on bridge foundation and A is the area of bridge foundation, the W/A should be less than or equal to the safe bearing capacity of soil.

2. Frictional resistance : Some foundations resist the load coming upon them by the friction offered by the surrounding soil. in such cases, the bridge foundations should be taken upto suitable depth so that enough frictional resistance is developed to resist the load coming on the bridge foundations.

3.Scour : -The term scour is used to indicate the increase in depth in vertical direction of the bed of river. Such increase in depth mainly occurs due to the currents of flowing water, bed material, alignment of river, flood discharge, bed slope, direction of flow, shape of pier, etc. The scouring action of the current is not uniform all along the bed width. It is not so even in straight reaches. There is deeper scour than normal at the piers or other obstructions and also at bends. Hence, it is necessary to determine the maximum scour depth and the bridge foundations should be taken beyond this maximum depth of scour. The term scour should not be confused with erosion which indicates the horizontal widening of river.

Factors Affecting the Selection of Bridge Foundation

The following are the factors which effect the selection of foundation :

(i) Type of soil.

(ii) Nature of. soil.

(iii) Type of the bridge.

(iv) Velocity of water.

(v) Superimposed load on the bridge

Types of Bridge Foundations with their Suitability

Following are the different types of bridge foundations which are suitable according to nature and depth of bridge,

(i) Spread foundations

(ii) Raft foundations

(iii) Grillage foundations

(iv) Inverted arch foundations

(v) Pile foundations

(vi) Well foundations (vii) Caisson foundations

(i) Spread or open foundations : It is best suited at such places where hard soil is available within 1.5 to 3.5 m below the bed level of river and scouring is minimum. This types of foundations are also suitable in dry areas where hard soil is available.

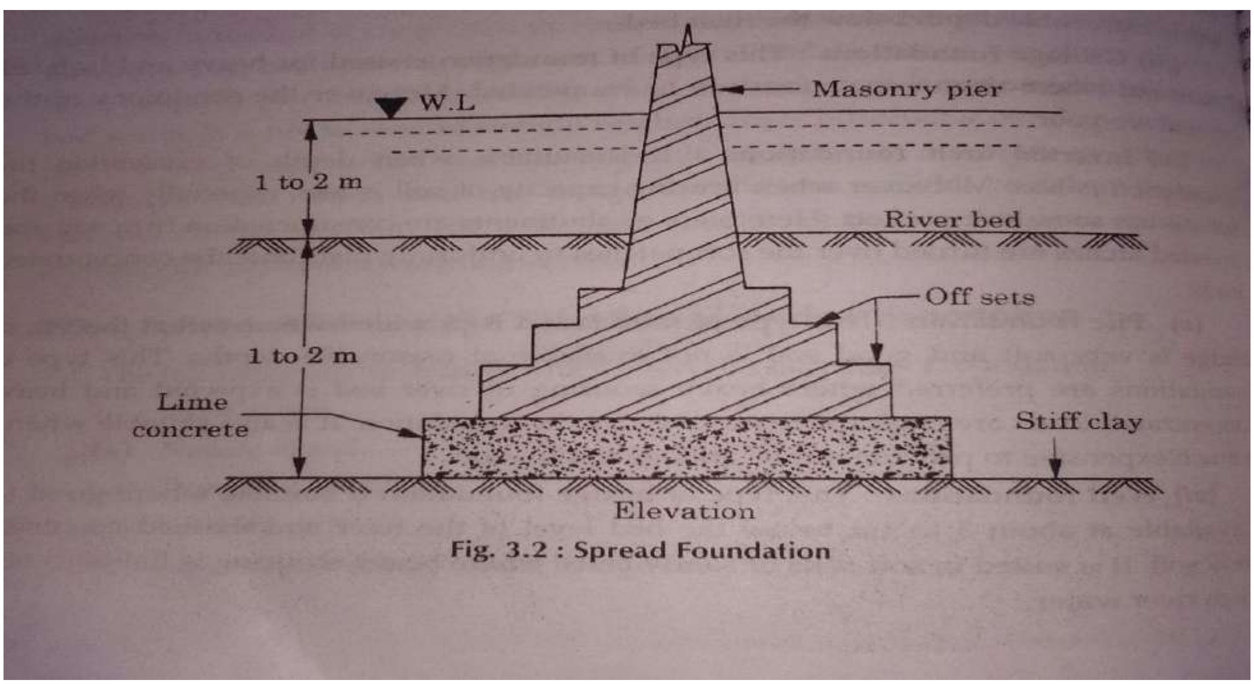
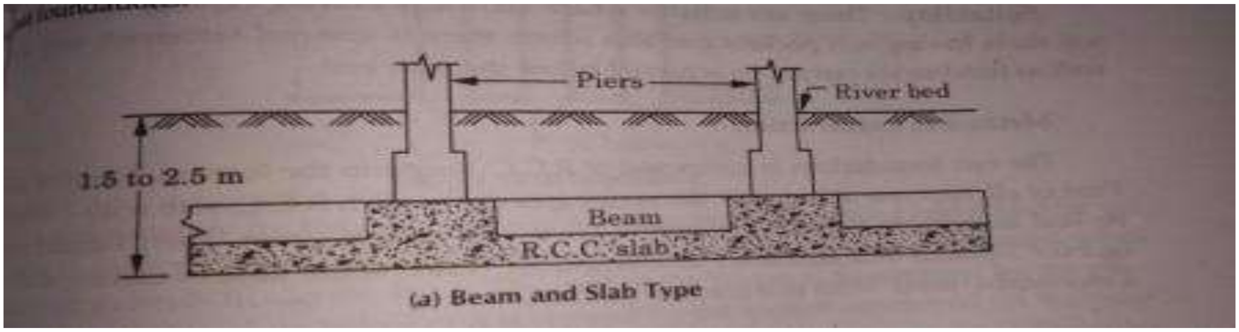


Fig. 3.2 : Spread Foundation

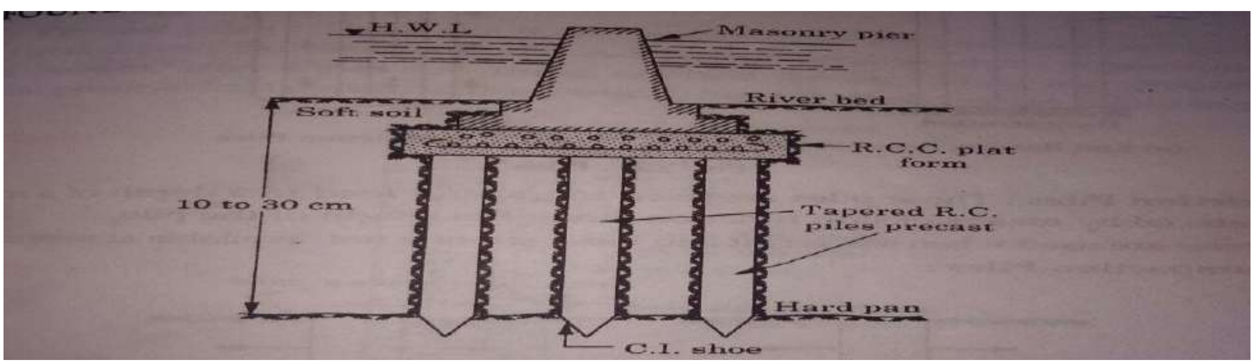
(ii) Raft foundations : It is provided where bed soil is having less hearing capacity Raft foundation is suited when bed contains soft clay or silt and good soil is not available within a reasonable depth. It is suited when bride are heavy and soil has soft pockets and liable to unequal settlement. This type of bridge foundation is suitable when the bed of the water course consists of soft clay and silt and the hard soil is not available within reasonable depth below the river bed.



(iii) Grillage foundations : This type of foundation is used for heavy and isolated loads and where deep excavations are to he avoided. Moreover the conditions of the 'Subsoil are-poor.

iv) Inverted arch foundations : It is suitable when depth of excavation for foundation is less. Moreover when bearing capacity of soil is less, especially when the subsoil has some soft pockets. Here piers or abutments are constructed on firm soil and inverted arches are turned over the soft patches to uniformly distribute the concentrated loads.

v) Pile foundation : This type of foundation is provided where soil at the site. of bridge very soft and good soil is not available at reasonable depths. This type of foundations are preferred where heavy scouring of river bed is expected and heavy concentrated loads are expected to be taken by the foundation. It is also suitable when it is much expensive to provide raft or grillage foundation.



(vi) Well foundations : This type of bridge foundation is suitable where good soil about 3 to 4 m below the bed level of the river and the bed consists of sandy soil. It is suited in soft soil or sandy beds, where heavy scouring is liable to occur due to river water.

Pile Foundations

Pile and functions of Piles

(a) Pile : It is a column support which is driven into the ground vertically or in an inclined position to improve the bearing capacity of a soil. It takes up the load of the structure and either directly distribute it on the hard stratum (rock) or balances the same with skin friction.

b) Functions of Piles :

1. It protect the foundation against slipping.

2. It transfer the load through a soft soil to a hard stratum (rock).

3. It transfer the loads to a weak subsoil by means of skin friction.

4. Compact the granular soils, hence, increasing their bearing capacity.

5. It helps the foundation to withstand against scour.

PILE FOUNDATION

It is a construction for the foundation of a bridge pier or abutment supported on the piles. This is a deep type of land foundation. This type of foundation is adopted when the loose soil extends to a great depth. The load of the bridge is transmitted by the piles to hard stratum below or it is resisted by the friction developed on the sides of R.C.C. or steel-piles are generally used for bridge construction. The piles cast in site or precast.

TYPES OF PILES

(A) According to Functions :

(i) End Bearing Piles.

(ii) Friction Piles.

(iii) Compaction Piles.

(i) End Rearing Piles : These piles are used to transfer load through soft soil to a suitable bearing stratum.

(ii) Friction Piles : These piles are used to transfer load to a depth of a friction load , carrying material by means of skin function along the length of the pile. These piles are used when soil is soft and hand strata is not available at reasonable depth.

(iii) Compaction Piles : These piles are used to compact the loosen soils by this bearing capacity of soil increased . These piles, do not carry load themselves. In this care pile tube, driven to compact the soil is gradually taken out and sand is filled in its space. In this way sand pile is formed.

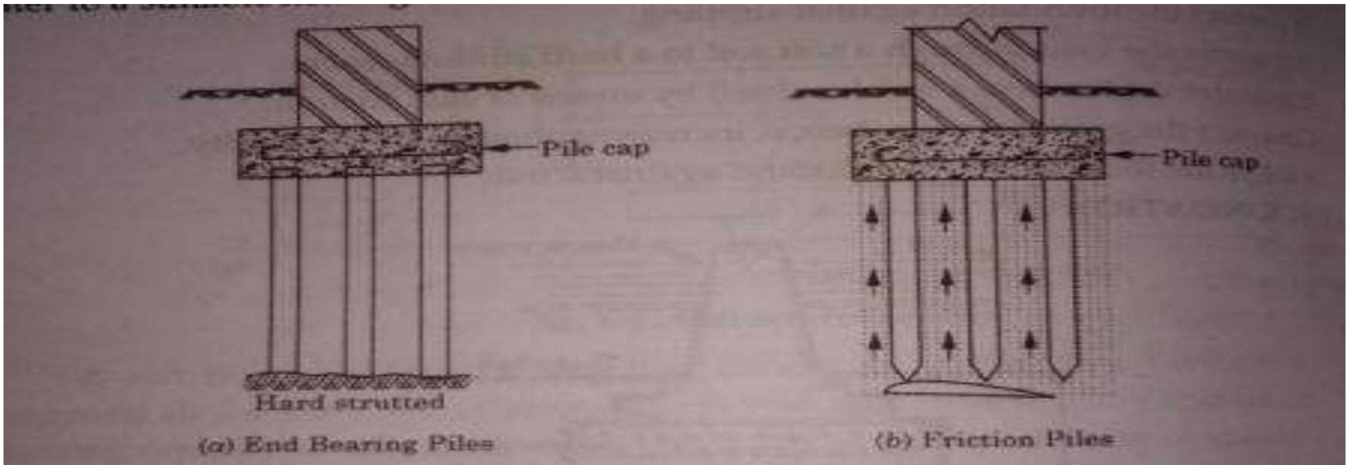


Fig. 3.6 : Piles

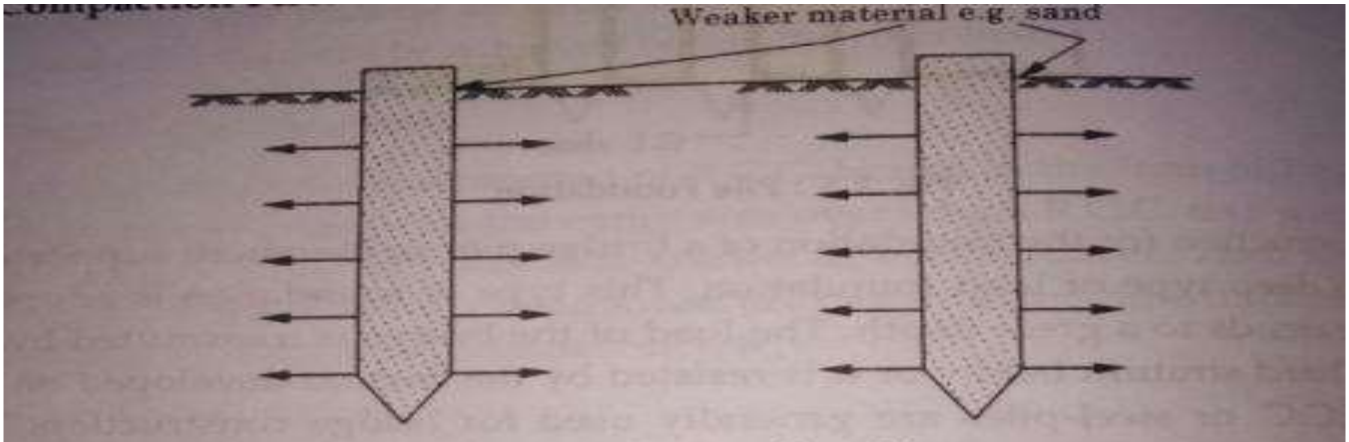


Fig. 3.7 : Compaction Pile

According to material

(1) Timber piles : The piles which are made of timber are known as timber piles. These piles are economical. There piles should be free from defects and decays. Top of these piles are provided with iron ring to prevent it from splitting against hammer blow. These are circular in shape.

(ii) Concrete piles : The piles made of cement concrete are called concrete piles. These are strong and durable and can take more load than timber piles. These piles are fire-proof. Concrete piles are of two types :

(a) Pre-cast piles

(b) Cast-in-situ piles

(1) Pre-cast piles : These are R.C.C. piles. After constructing and curing, they are handled and driven like wooden piles Additional reinforcement is provided both at the top and bottom. Iron shoes are fitted at their bottom. They are generally cast in a horizontal position and cured on the ground. Length of such piles varies from 2 to 30 m.

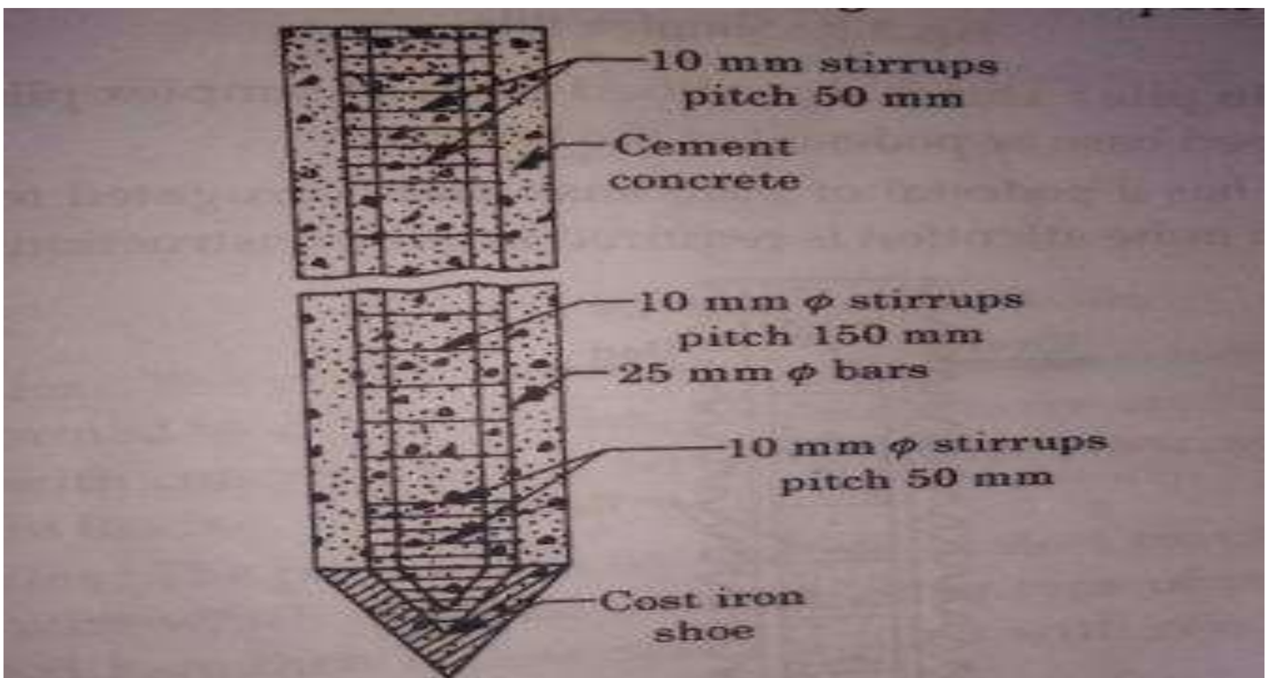


Fig. 3.8 : Pre-Cast Pile

ii). Cast-in-situ piles : The concrete pile constructed at site. The operation consists in boaring a hole, filling it with concrete or steel reinforcement and concrete.Some of the cast-in-situ concrete piles are :

(a) Simplex pile : It is very simple in its construction. For constructing such a Pile, hollow cylindrical steel pipe, fitted with a detachable metal base is driven into the ground to the required depth. The hole is then filled with concrete and pipe is gradually withdrawn.

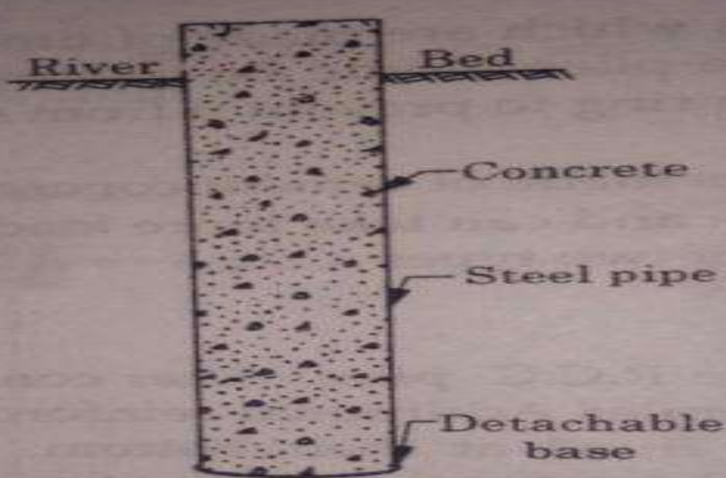


Fig. 3.9 : Simplex Pile

(b) Pedestal or bulb pile : This is a modified from of simplex pile. It is constructed by providing a bulb shaped base or pedestal at the bottom.

(c) Franki pile : It has a pedestal or bulb base and corrugated tem. the method of formation is difficult and more attention is required in the construction.For constructing a Franki pile, a steel pipe casing is placed vertically. Rich cement concrete is then poured to the bottom of the casing and a concrete plug is formed. the concrete plug is then driven with the help of a drop hammer. When the plug has been forced sufficiently, the other charge of concrete is poured into the pipe and rammed. At this stage reinforcement is inserted vertically, if needed. Similarly, the concrete is poured. Each layer is rammed properly.

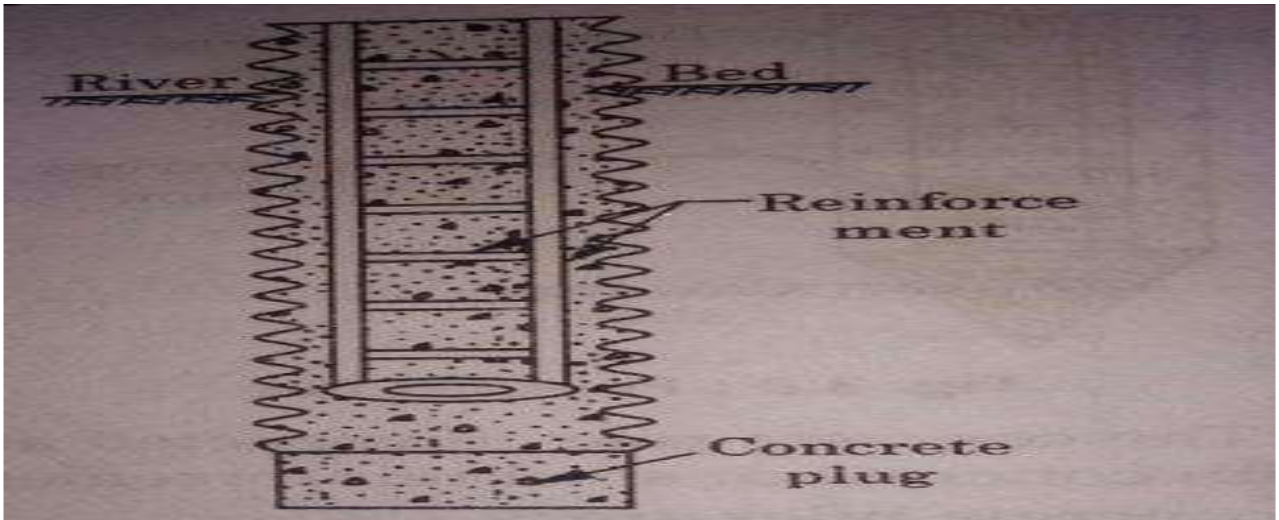


Fig. 3.10 : Franki Pile

(d) Raymond concrete pile : It is most used concrete pile for bridge foundations. It is cone shape and cast in situ concrete pile. It is made by driving the cone shape steel shell into the ground then is filled with R.C.C. or concrete.

(iv) Steel piles : The piles which are consists of steel are called steel piles. These are special types of piles which are used when no other type of pile is suitable. These piles are derived in soil bare then hollow space is filled with concrete to take heavy loads. These are of following types.

(a) Steel pipe piles

(b) Shat piles

(c) Disc piles

Total load capacity of Pile Group.

Pg = nFpf

where, n = number of piles.

F = efficiency of pile-group.

pf = Load carried by each friction pile.

Suitability of Pile Foundation :

(i) When soil is very soft to a considerable depth.

(ii) Heavy concentrated loads are coming on the structures.

(iii) Raft or Grillage foundation either not possible to construct or uneconomical

(iv) When buildings are constructed on a sloping ground under lying a laver of clayey soil to safeguard slipping.

(v) Structures on sea shore to avoid scouring.

Determination of Allowable Load on a Pile

It is difficult to find the bearing capacity of a pile driven into the ground and it is generally estimated by employing the empirical formulae based on long experience or by carrying out load tests. The "Engineering News Formula" is simple and used very widely. It was proposed by A.M. Wellington (1888) in the following general form :

$P_a = WH / F(S + C)$

where P. = allowable load

W = weight of hammer

H = height of fall of the hammer

S = average penetration in cm/blow for the last 5-10 blows for gravity hammer and the last 10-20 blows for others.

C = empirical constant

F = Factor of safety = 6.

If we denote W in kg. S in cm,

H is on there,

C = 2.5 cm for drop hammer.

C = 0.25 cm for single and double acting hammer

i. For Drop hammer

$$P_a = WH/6(S + 2.5)$$

For single acting hammer (Steam/Air)

$$P_a = WH /6(S +0.2)$$

3. For Double acting hammer (Steam/ Air)

$$P_a = (W + a \times p)H/6(S + 3.25)$$

where a = effective area of piston in cm^2

p = mean effective pressure at the hammer in kg/cm^2

WELL FOUNDATIONS

The foundations in which a well is slinked under each abutment or pier to take loads of the structure is known as well foundations. Well foundation is the most commonly adopted bridge foundation in India. The foundation may consist of a single large diameter well or of a group of smaller wells of circular or other shapes.

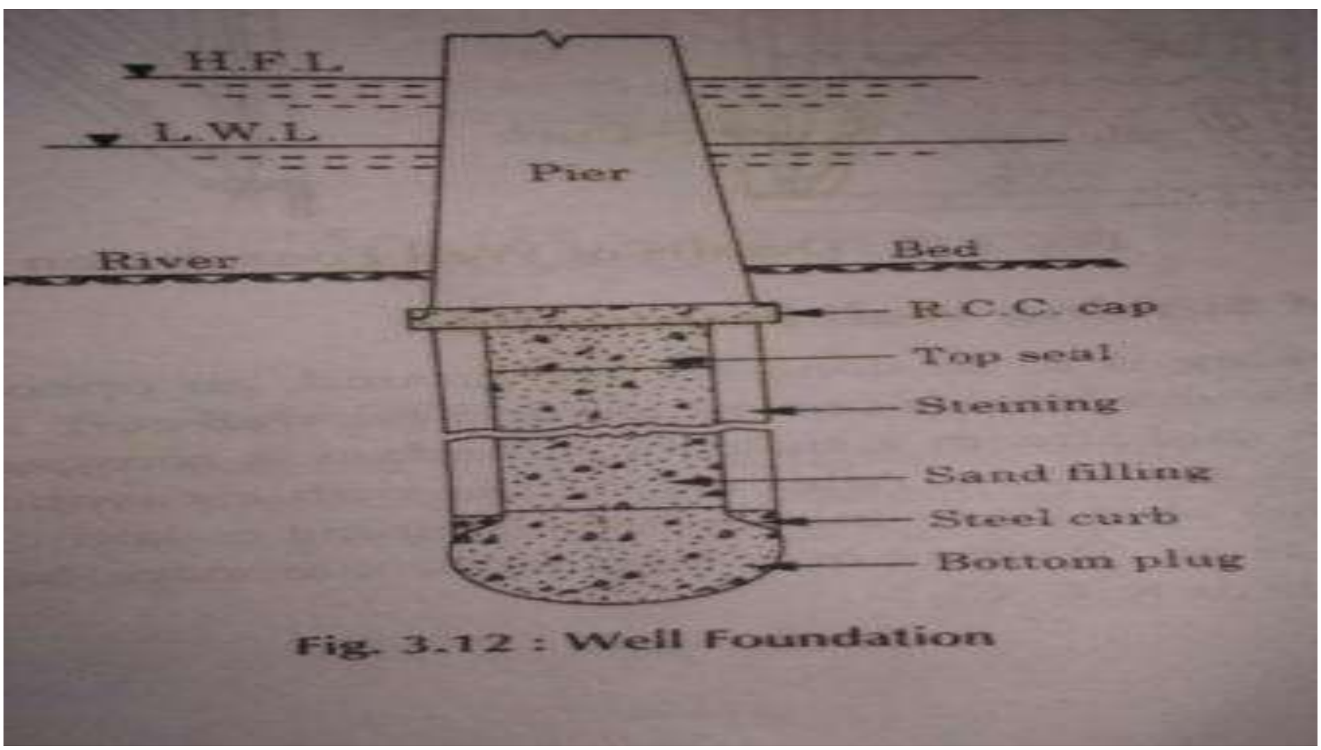


Fig. 3.12 : Well Foundation

Types of Well Foundations

1. Deep wells foundations

2. Shallow wells foundations •

1. Deep wells foundations : The foundations in which wells are sunk deeper than, the maximum possible depth of scour are called deep well foundations. This system of known Punjab system, since this type of foundations is most commonly employed under bridge piers in Northern India, particularly in Punjab.

Advantages : of well foundations is that, No need of bed floors and curtain walls for their protection thus economical in maintenance.

These foundations do not interfere with the natural flow of water thus they will not result afflux and scour and maintain stability of the foundations. It has disadvantages like these foundations are difficult to construct.

Deep well foundations are useful for alluvial rivers in pain country, having heal) discharge and are liable to scour.

2. Shallow well foundations : The foundations in which wells are not sunk deeper than the maximum possible depth of scour are called shallow well foundations. This system of foundations is known as Madras system, since this type of well foundation is most commonly employed under bridge piers in South India, particularly in Madras.

Main advantages of Shallow foundations are that shallow well foundations are easy in construction. These foundations are cheaper due to shallow depth.

Disadvantages of Shallow foundations are :

Shallow well foundations require additional floors and curtain walls for their protection against scour and are difficult to maintain.

These foundations interfere with the natural flow of water and thus they will cause afflux and scour.

Component Part of a Well Foundation and Their Functions

The different component parts of a well foundation and their functions

Shape of Wells : Wells constructed for foundations may be any one of the followift: shapes

i) Circular shape

ii) Rectangular shape

iii) Dumb-well shape

iv) Twin Hexagonal shape Twin circular shape Twin octagonal shape

v) D-shape

vi) Double D-shape

CAISSON FOUNDATIONS

The foundations which is made by sinking a box like structure made of R.C.C. called caisson through water at desired depth, and filling the caisson with concrete or masonry is known as caisson foundation.

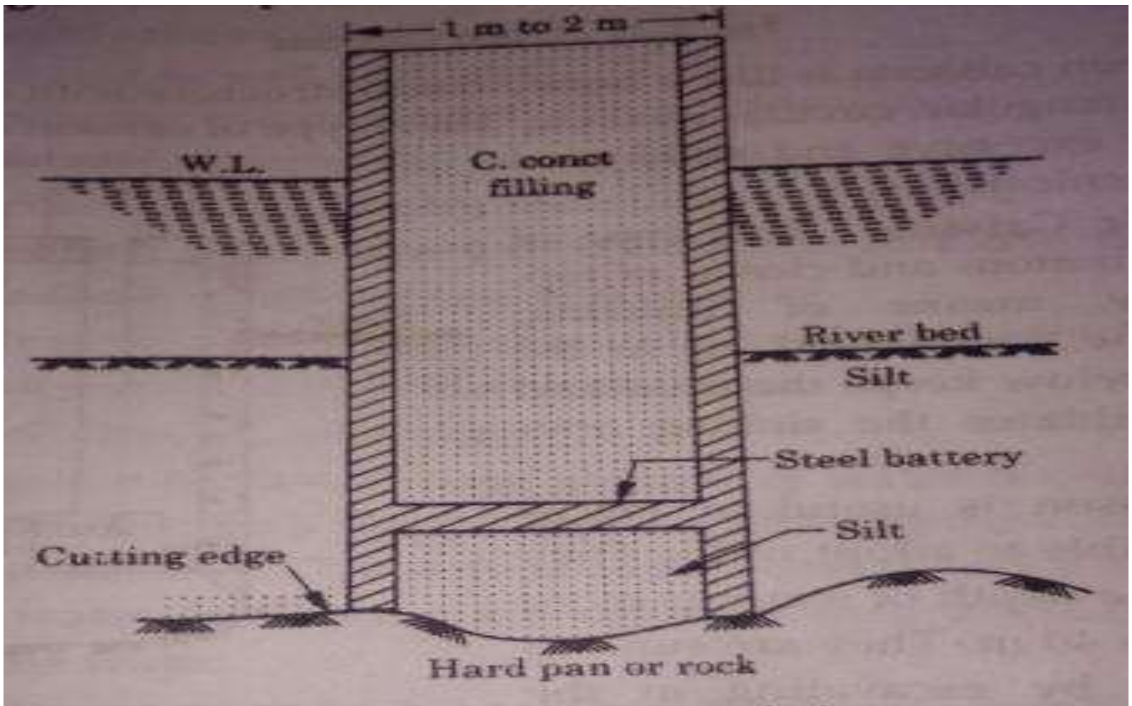


Fig. 3.20 : Caisson Foundation

Types of Caisson : `These are as under :

(i) Box caissons.

(ii) Open or Dredging caissons.

(iii) Pneumatic caissons.

(1) Box Caissons : These are strong water tight vessels open at top and close at bottom. Box caissons are generally made of timber masonry or concrete, and are used where little excavation is required. To place the caisson in position, it is launched and floated to pier site where it is sunk in position. Then it is filled with concrete or masonry to serve as foundation for a structure like bridge pier. This type of caisson is suitable for constructing bridge foundations under water, when the depth of water is considerable but a firm ground or rocky base is available immediately below the river bed. In its case, little excavation is required for preparing the site to provide and uniform bearing to the caisson.

(ii) Open or Dredging Caissons : This type of caisson is open both at the top and at the bottom. Open caissons are generally made of steel, masonary or concrete and a; sunk like masonary wells. They form the most common type of deep foundations bridges in India.

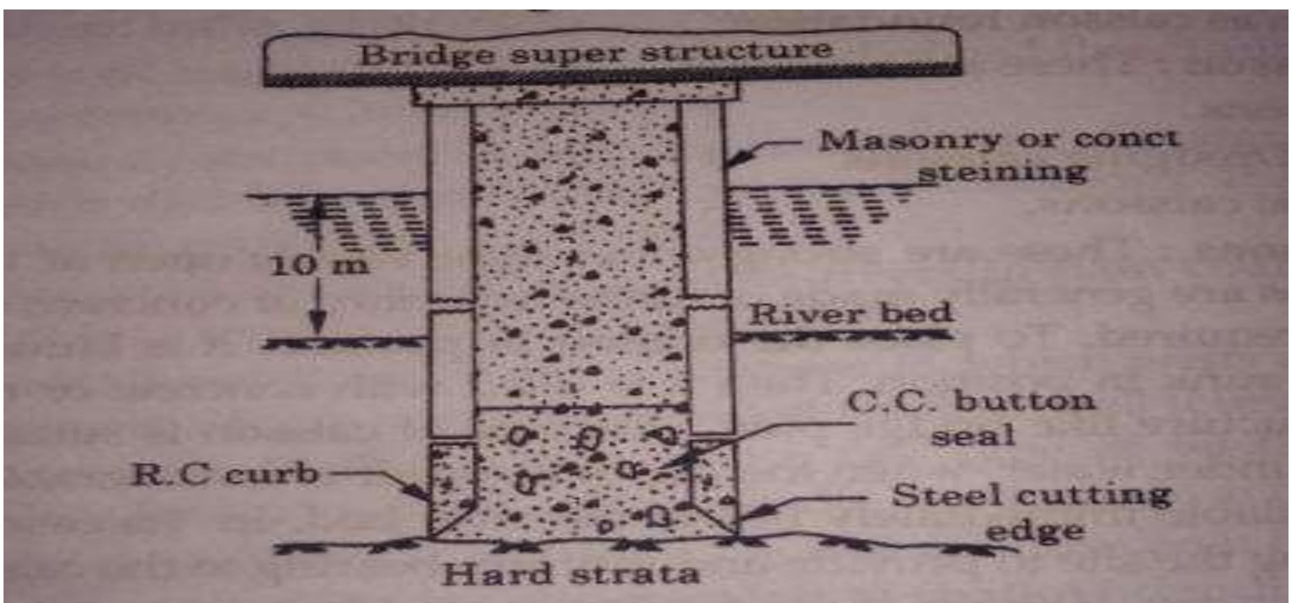


Fig. 3.21 : Open Caissons

These caissons are used on sandy soils liable to scour and where no firm bed,is available for large depth below the surface. Steel or R. C. C. curbs are many times provided for easy sinking of open masonary caissons. After laying the foot of caisson on hard pan it is filled with concrete throughout and the structure over it.

(iii) Pneumatic Caisson : This type of caisson is open at bottom and closed at top. It is driven by means of utilizing, compressed air. The compressed air in the working chamber below keeps the mud and water out and facilitates the sinking operation. Pneumatic caisson is useful at places where it is not possible to adopt wells. They are suitable when the depth of water is more than 12 m and up to 40 m. They are sunk to the required depth by excavating in the working chamber. The working chamber is about 2.5 m high . Two vertical shafts for the passage of men and put constructed over opening in the roof of this chamber The max. pressure are allowed at a depth of 40 m is 4 kg/cm2. A normal workman can work for eight hours under a pressure of 1.25 kg/cm2. For higher pressures the working time is reduces. When the desired depth is reached the caissons are partially or wholly filled with concrete and the bridge structure built on top of them. There are Generally laying' where there is water depth is more than 15 metre and foundations have to laid at great depths.

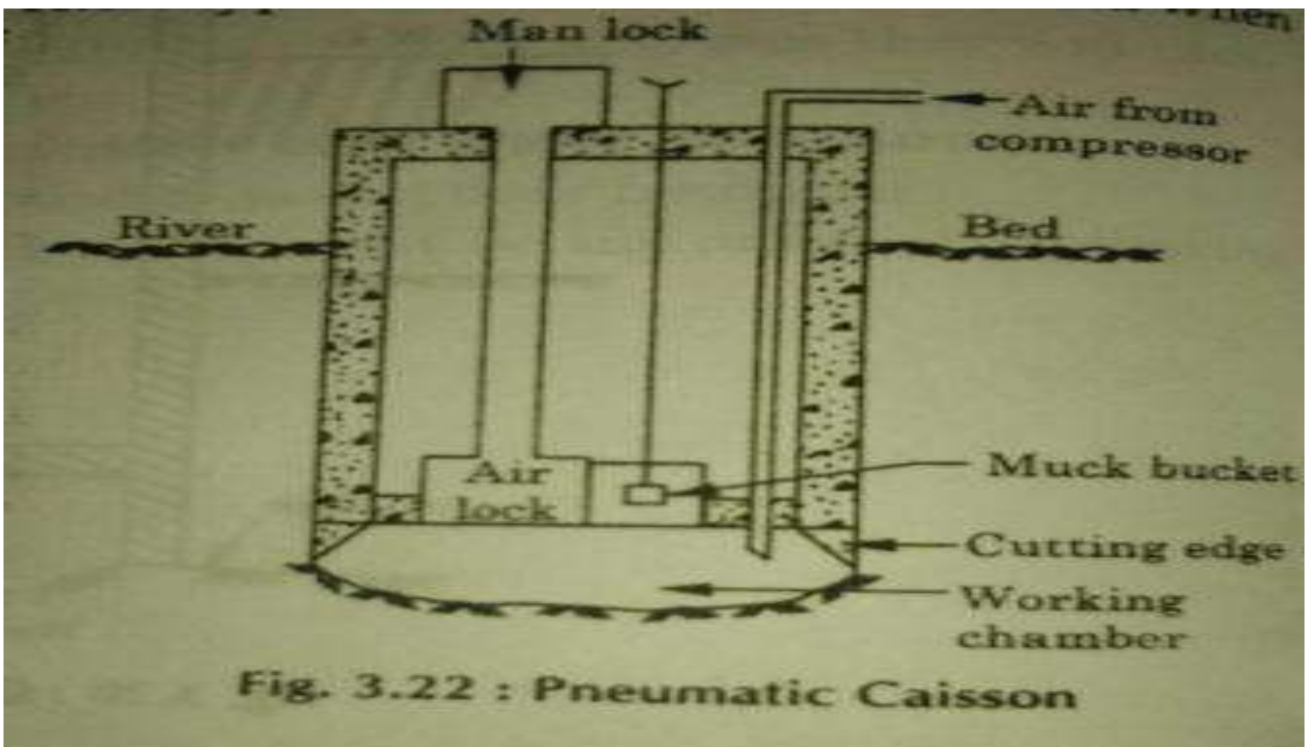


Fig. 3.22 : Pneumatic Caisson

Caisson Disease : Workers suffer from this disease during the construction of pneumatic caisson. when the workers are working under compressed air, they suffer from this disease when they return to atmospheric pressure. When workers are subjected to compressed air, nitrogen is absorbed along with oxygen by the tissue fluid of the man. The 0_2 is dissolved in blood while nitrogen is kept in suspension because it is not soluble in blood. The main symptoms of this disease are headache, dizziness pain in legs, trouble in speaking etc. This may results in paralysis, loss of consciousness or even fatal accidents.

Precautions to avoid caisson disease :

(1) Main locks should be well ventilated.

(ii) Rate of compression and decompression must be properly controlled.

(iii) Workers with strong hearts may be employed.

(iv) Temperature of working chamber should be kept at 25°C.

(v) A medical chamber or dispensary should be provided near the work site.

(vi) Every worker should work for one shift in a day.

(vii) A stand by air compressing plant should be kept ready for emergency.

(viii) Good circulation must be provided at the work.

BRIDGE

COFFER DAMS

Cofferdams are made to construct the foundations, abutments or piers under water i.e. to make constructions under water. These are temporary structure which are removed from the site after the constructional work is completed.

A temporary structure constructed to prevent the water to enter an area where permanent structure is to be built up are known as cofferdams".

These are generally required for projects like dams, docks etc. The selection of the cofferdam to be made at site of construction mainly depends upon bed of upriver, type of soil etc.

Requirements of a Cofferdam

(i) It should be easy in construction.

(ii) It must be water tight.

(iii) The design. must be such that total cost of construction and maintenance should be minimum.

(iv) Cofferdam should be sufficiently stable against overturning, sliding and bursting under floods.

(v) As far as possible it should occupy less area.

(vi) It should provide least obstruction to the flow of water.

(vii) Its height must be sufficiently higher than highest flood level in the river.

(viii) It should be so planned as to facilitate easy dismantelling and reuse of materials.

Factors Affecting Selection of a Type of Cofferdam

(i) Depth of water to be dealt with.

(ii) velocity of flowing water.

(iii) Extent of an area to be protected by a cofferdam.

(iv) Type of construction material available near site of work.

(v) Skilled labour available at site of work.

(vi) Transportation facilities available.

(vii) Nature of the river bed on which the cofferdam is to rest.

(viii) The possibility of overtopping by tides or floods.

(ix) The possibility of scour due to reduction of water-way caused by the construction of cofferdam.

Types of Cofferdams

The most common material used for cofferdam is steel sheet due to its water

Tightness and structural strengths. But depending upon the situations during the construction i.e. depending upon the nature of structure and economy in construction cofferdams may be classified as.

(i) Earth cofferdams

(ii) Rock-fill cofferdams

(iii) Rock fill crib cofferdams

(iv) Single wall cofferdams

(v) Double wall cofferdams

(vi) Cellular wall cofferdams

(i) Earth Cofferdams : The cofferdams in which earth is main material which is put around the site is known as earth cofferdam. In this cofferdam Only earth or rock fill material is used where depth of still or running water is not more than 2 metres . The dia/side of the area enclosed should atleast he 3 metres more than that of the structure to be built. In case the velocity of the running water is more. Adequate stone pitching is done to prevent erosion. After enclosing the area by a suitable sloped embankment, it is then dried by pumping water to make i.e. dry for construction of suitable foundation.

Fig. 3.23 : Earth Cafferdom

(ii) Rock Filled Dams : The cofferdams which are made of broken stone at the site in the shape of embankment along the streams are known as rock-filled dams These dams are similar to earth dams but having steeper slopes up to 1 in 1.25

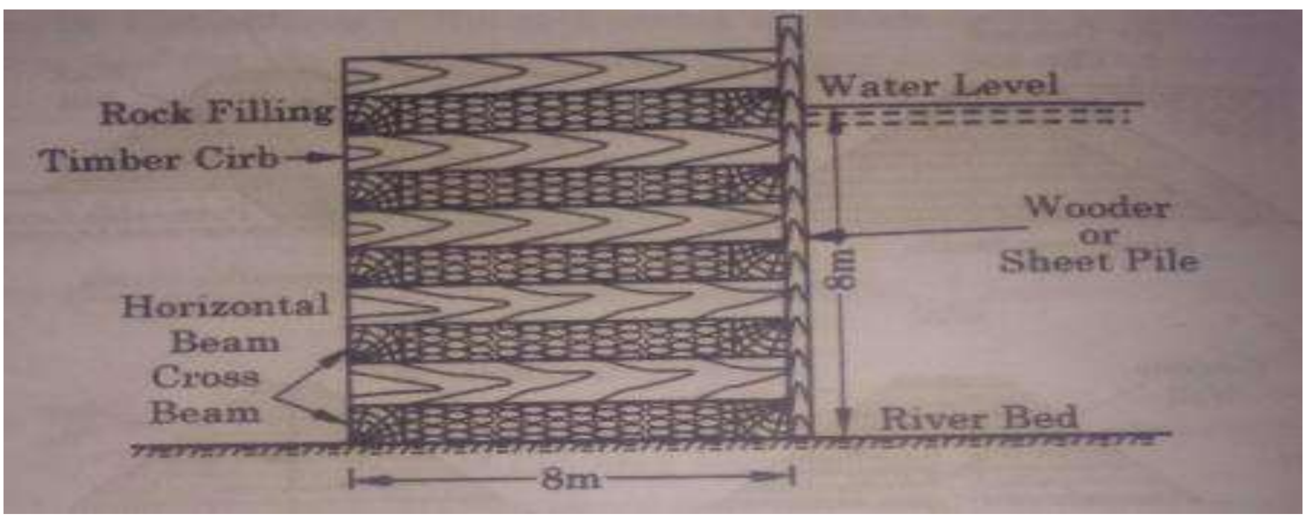
These dams are made impervious in nature by placing impervious layer of earth on the outer face of the cofferdam.

These type of cofferdams are cheap. and easy to construct. These dams has isadvantage that it cannot be made water tight as the junctions between rock and ver bed is always susceptible to leakage and it is difficult to locate the seepage and hence dewatering become costly.

Rock : This type of cofferdam is generally constructed at the site, where Efficient rock is easily and cheaply available.

Rock-fill cofferdam can withstand the overtopping of water without any serious mage. These are suitable for depths of water up to 3 m and even in the case of swift water.

(iii) Rock-fill crib cofferdams : The type of cofferdam in which cribs are filled With rock or gravel or earth at the site according to availability are known as rockfill crib cofferdams.



Cribs is a framework of horizontal and cross beams made of timber laid in alternate layers is called crib. In this type of cofferdam, the crib base is prepared on the shore and then floated to the position and is sunk hr further budding up its top portion and filling rock in the alternate layers, Generally, the width of crib is made equal to the depth of water in the river. To make the cofferdam watertight a layer of impervious earth or timber planks is provided on the water side. To make crib more water-tight, heavy, bituminised canvas is provided over the crib and is nailed to it.

Suitability : Rock-fill crib cofferdam is suitable •-

(i) When the river has a hard bed.

(ii) When the depth of water is high.

(iii) When the current of water is swift.

(iv) When the working space is limited.

(v) When there is danger of overtopping.

(vi) When the timber is cheaply and easily available at the site.

(iv) Single Wall Cofferdam : This type of cofferdam is used where aenclosed is comparatively small and the depth of water ranging from 3 metres to 6 meters. These are also known as single wall sheet pile cofferdams.

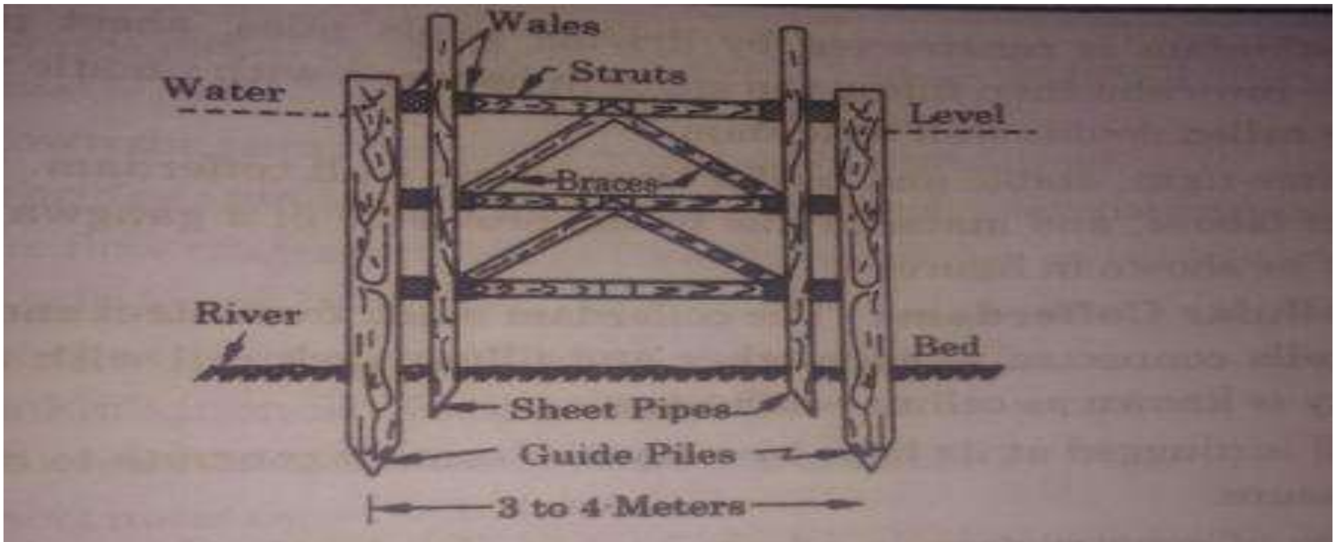


Fig. 3.27 : Single wall sheet pile

Ordinary timber piles strong enough are driven first into the bed at 3to 4 metres apart and to form one unit these are connected by horizontal members called wales. Such a row of piles will serve as guide piles.A single row of wooden sheet piles abutting against wale pieces is driven into the bed with water proof joints. To strengthen this enclosure of sheets struts and braces are inserted in between the opposite walls. As an alternative either earthen embankment or sand bags are dumped all around its inside. The area so enclosed is worked usual way after dewatering.

Guide piles are the vertical members which are embedded in river bed to support sheet piles. These are made of timber or steel.

Sheet piles are thin sheets made of steel, or timber of R.C.C. etc driven into ground to make enclosed area to be water tight.

(v) Double Wall Cofferdams : When the current of water is swift and also the depth is from 6 metres to 12 metres, a single sheet pile coffer dam cannot Withstand the hydraulic pressure. In this case two rows of single sheet piles at a distance of 3 to 5 metres apart depending upon the depth of water are driven in a similar way as explained below. The inner space between the two rows of sheet piles is filled with earth. The area is then dewatered and construction started.

This cofferdam is constructed by driving guide piles, sheet piles along with wales in two rows and then filling the space in between with puddle to form a water tight wall is called double wall cofferdam.

It is water-tight, stable and useful than single wall cofferdam. It provides movement of labour, and material due to the provision of a gangway.

(vi) Cellular Cofferdams : The cofferdam made from steel sheet piles forming a series of cells connected to each other and filling each cell with clay or sand for their stability is known as cellular cofferdam.

Each cell is plugged at its base by a layer of cement concrete to make it resistant to water pressure.

Such type of construction is adopted when the depth of water ranges from 15 metres to 20 metres. These have been explained under steel sheet piles. Such cofferdams consist of series of cells connected to each other and are filled with earth to prevent dislocation or overturning. These are suitable when larger area is required to be enclosed. Various other types are :—

(i) Diaphragm type

(ii) Circular type

TUNNELS

TUNNEL ENGINEERING:

It is the branch of civil engineering which deal with the construction design and maintenance of tunnel.

Tunnel engineering is very complicated and large.

TUNNEL

Tunnels are artificial underground passage construction for the transportation purpose . Without disturbing the ground surface.

CHRONOLOGICAL DEVELOPMENT OF TUNNELING

B.C. 2000 : First tunnel built in Babylon. It was 900 meters long With3.5 x 4.5 m section.

A.D. 50 : Roman Emperor built the first Roman tunnel, 6 km long With 3 x 1.8 m section.

1679 A.D.: First Navigational tunnel constructed by France about 160 m long.

1853 A.D.: First Highway tunnel constructed in Hungry and was 350 m long.

1949 A.D. : In Great Britain first underground railway tunnel wasconstructed which is about 15.20 km long.

Advantages of Tunnels

(1) Tunnels are used for transportation of men, materials, goods and water.

(2) Tunnels are used for conveying water for hydro power plants to generate power.

(3) Tunnels are used for carrying sewerage, gas etc.

NECESSITY OF TUNNELS

Necessity of tunnels arise any or combination of the following factors.

1. To Reduce the costs of Operations :

(i) In case of surface routes profiles of ground are followed which needs gradients in alignment. In the absence of such gradients tunnels are constructed to reduce the operation costs.

(ii) Tunnels also reduces lengths of surface routes thus results in economy of fuel, time and cost of operation.

2. To reduce the cost of construction i.e. when depth of open cut is more than 20 m it is advisable to adopt tunnels.

3. When surface route for reaching the other end become much longer therefore

costlier in construction, alternate route of through tunneling is provided.

4. When there is possibility that tunnel cost in some cases under the river is much cheaper than to construct a bridge over the river.

5. In case of congested towns it is cheaper to construct the tunnel than surface route due to non availability of land.

6. Sometimes tunnels are work out to be cheaper than open channels for conveying water because of their short and direct routes.

7. When high mountain ridges are required to be crossed.

8. When an open cut threatens the stability of a near by structure a tunnel may he provided.

9. Traffic facilities in tunnels are protected from hazards caused by snow, rain land slide, warfare etc.

10. Traffic in underground tunnels does not interfere with surface traffic, and provide easy movements.

REQUISITES OF TUNNEL

Requisites of tunnel are :

(i) Construction of the tunnel should be avoided on curves.

(ii) Shafts should be driven at regular intervals in such a way that the load for the materials is less.

(iii) Alignment of the tunnel should be straight.

(iv) Tunnel construction is considered to be the best if it runs through hard rock as no lining will be needed in this case.

(v) Tunnel should be given as steep slope as possible in longitudinal direction. It will increase the velocity of transporting material and will need less cross-sectional area.

Advantages and Disadvantages of tunnels are described below :-

(A) Advantages :-

(i)Tunnels connects two terminals by the shortest possible route.

(ii) Tunnels helps in avoiding the holding up of traffic due to congestion and

provide easy movements of traffic in big cities.

(iii) Tunnels proves economy in construction and operational cost when open

cut is more than 20 m.

(iv) Tunnels carry public utilities like water, gas etc across the river /

mountains very economically.

(v) Tunnels avoid dangerous open cuts likely to be subjected to snowfall DI'

land slides etc.

(vi) Tunnels protects the acquisition of valuable land.

(vii) Tunnels facilitate conduction of water to generate power

DISADVANTAGES

(i) It requires special equipment for their construction.

(ii) It require skilled labour and supervision in their construction.

(iii) These proves costlier in comparison to open cut.

(iv) It requires more time for their construction and completion.

COMPARISON BETWEEN TUNNEL AND OPEN CUT

S.No.	Tunnel	Open Cut
1.	Excavation required is less.	Excavation required is more.
2.	More time is needed.	Less time is required.
3.	Extra facilities are required like light, ventilation etc.	No such facilities are required.
4.	More costlier. It is about 11 to 15 times that of open cut.	Cost is less.
5.	Timbering and lining is required.	Timbering and Lining is not required in open cut.
6.	Saves cost of land acquired.	Increases the cost of land to be acquired.
7.	Avoids diversion of property.	Diversion of property cannot be avoided in open cut.
8.	During construction there is no obstruction to traffic.	During construction, there is obstruction during execution of work.
9.	Provides protection during aerial warfare and bombing.	Does not provide protection during aerial warfare and bombing.
10.	Natural water ways are not interfered.	natural water ways are interfered.
11.	Cheaper where water connections or gas lines are to be provided.	Not cheaper where water or gas lines are to be carried.

TUNNEL INVESTIGATION : A number of problems are involved in the construction of tunnels. The conditions vary from tunnel to tunnel. It is very tough to establish standards of construction. But certain assumptions are made during the design stage.

When it has been decided to provide tunnel in a particular case, the next step is to conduct tunnel investigations which comprise of

(a) Geological Survey

(h) Alignment of Tunnel or setting out the centre line of the tunnel on the surface.

(c) Selection of the tunnel to be constructed i.e. size and shape of the tunnel.

(a) Geological Survey :

It is set of information required about the nature and type of strata by conducting investigations upon which tunneling is to be done.

It is very important to know the nature and type if strata through which tunneling is to be done, because the selection of tunnel depends upon the information gathered by these investigation and most important is the method of tunneling which is to be decided by these investigations.

The data collected through geological survey used to prepare geological maps, which helps to anticipate the problems comes during the process of tunneling. Another object of geological survey is to locate underground rivers, fault plane and zones of shattered rock etc.

Hence geological survey is done to know the nature and type of strata through which tunneling is to be done. It also helps us to decide the method of tunneling. Moreover it also helps us to locate the fault plane. Zone of shattered with as well as water under the rock etc.

(b) Alignment of Tunnel or Setting out the centre line of the tunnel on the surface : In tunnel surveying, main work consists of alignment of the centre line on the surface, its transfer in to the tunnel and good levelling work inside and outside the tunnel. This work is to be done with extreme accuracy and progress of the work is to be checked again and again.

Generally the surface control points of tunnels are not visible from each other. By the method of reciprocal ranging the points can be established. For conveying two given points normally a tunnel follows straight alignment. But sometimes curves are introduced in tunnel alignment to avoid difficult tunneling zones. For this route survey is done with great precision survey instruments.

When the ground which is to be tunnelled is accessible from surface, the centre line of tunnel can be set on the surface. In such cases tunnel driving can be aided by digging vertical shafts along the path of tunnel. The vertical shafts provide extra working faces and ventilation to the tunnel. Centre line from surface to inside of proposed tunnel is transferred through the shaft by means of plumb bobs. Two plumb bobs 3 meters apart are suspended from a steel wire into the shaft to indicate centre line of tunnel. In line with these plumb bobs spuds or dogs are fixed on ceiling of tunnel with the help of transit theodolite.

Fig. 1.1 : Tunnel Driving With Help of Vertical Shafts

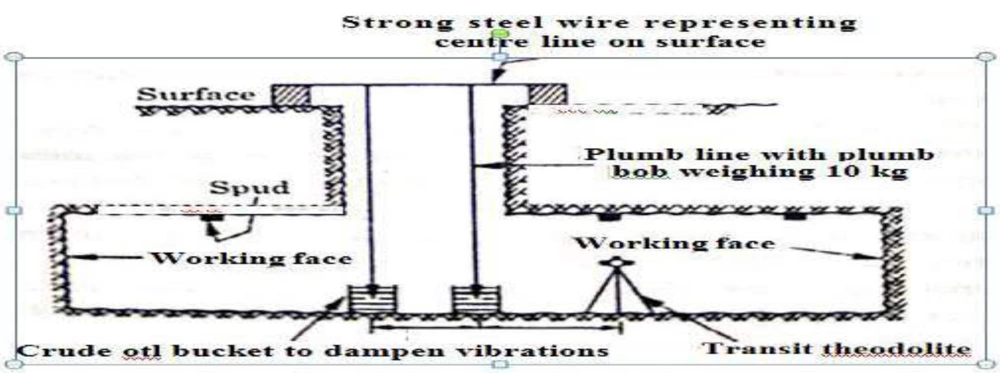
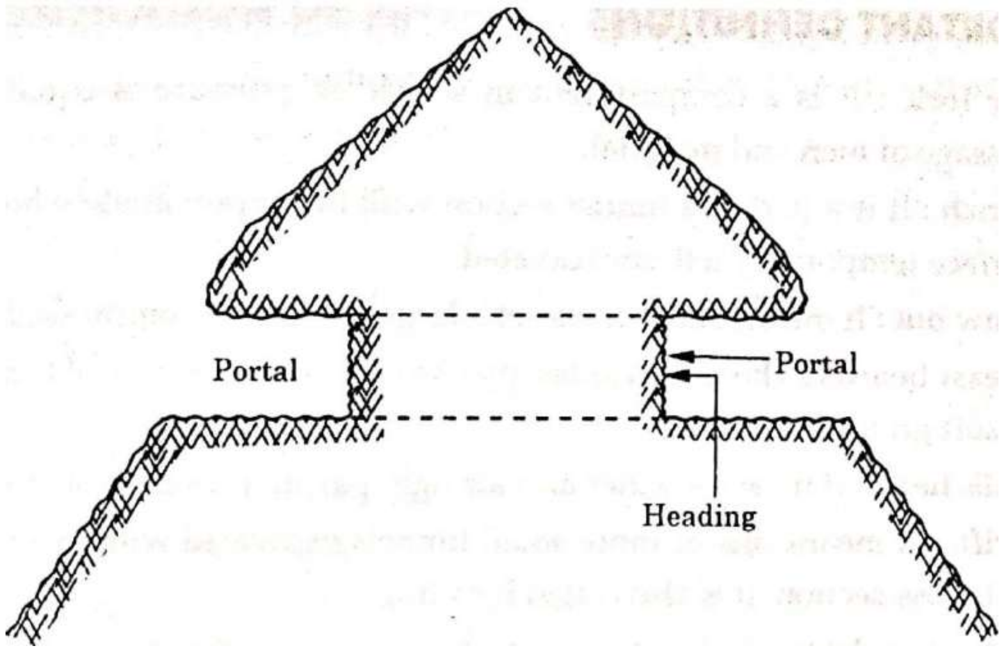


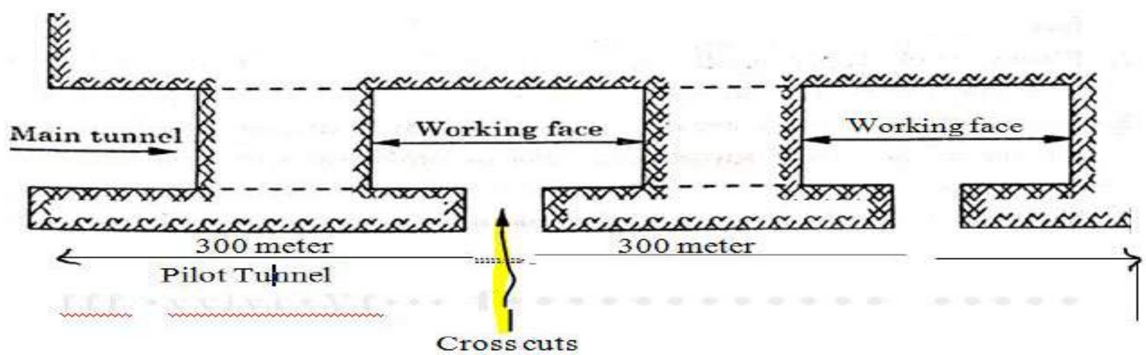
fig. 1.2 : Transfer of Alignment From Surface to Tunnel

In case of tunnels under mountains, vertical shafts are out of question. In such case, tunneling is started, from both ends as shown in fig. Line of tunneling is advanced by transit theodolite as the work progress. Accuracy of survey is so high that engineers surprised if there is an error of even one centimetre in alignment when two headings meet.



Portal Driven Tunnel

In case of large tunnels there may be driving by pilot tube method. This method involves driving a small tunnel. This method is quick and convenient and later on pilot tunnel may be used for drainage. This method is costly because lot of expenditure is incurred on construction of pilot tunnel.



Plan Piloy-Tube Method

(c) Selection of tunnel to be constructed

After geological investigation and selection of alignment of the tunnel is completed. Next is to decide its shape and size which serves the functions. The shape and size depends upon the nature of the ground through which is driven out.

IMPORTANT DEFINITIONS

1. Air lock : It is a compartment in which air pressure is equalised to permit passage of men and material,

2. Bench It is a part of a tunnel 4ection with the approximately horizontal upper surface temporarily left unexcavated.

3. Blow out : It means sudden loss of a large amount of compressed air.

4. Breast boards : These are timber planks to support the face of tunnel excavation in soft ground.

5. Bulk head : It means a water and air tight partition usually of steel.

6. Drift. : It means one or more small tunnels excavated with in and ahead of the full cross-section. It is also caned Heading.

7. Face : It is the vertical surface at the head of a tunnel excavation.

8. Liner plate : It is a steel plate segment generally provided to support a tunnel excavation.

9. Lining : It means temporary or permanent concrete structure in order to secure and finish the tunnel interior.

10. Mucking : It means removal of material excavated or blasted from the tunnel face.

11. Pilot tunnel : It is a small tunnel excavated over the whole length or over part of a tunnel to explore sub-soil conditions and assist in final excavation.

12. Poling boards : These are timber or steel planks driven into the soft ground at the tunnel face over supporting steel or timber sets to hold back soil during excavation.

13. Scaling : It means removing loose pieces of rock from the tunnel surface after blasting.

14. Shaft : It is a vertical excavation to gain access to tunnels or mines from the

surface.

15. Shotcrete : It is a concrete mixture sprayed on to the rock surface,

16. Wall plate : It is a footing placed on the rock shelf to temporarily support arch ribs of tunnel sets.

17. Adit : It is a short transverse tunnel connecting two parallel tunnels or an entry from the face of the slope to a side hill tunnel.

CLASSIFICATION OF TUNNELS

Tunnels are classified according to purpose for which they are constructed such as

(A) According to Service

1. High way tunnels

2. Railway tunnels

3. Rapid transit tunnels

4. Underground Caverns

5. Shafts

6. Special Tunnels

7. Aqueducts and Sewers

(B) According to locations

1. Under water tunnels

2. Mountain Tunnels

3. Shallow Tunnels

(C) According to Soil Type

1. Rock Tunnels

2. Soft ground tunnels

3. Mixed face tunnels

(D) According to Alignment

1. Saddle and base tunnels : When track is led through valleys, for reducing tunnel length, as long as the natural slope of the valley does not become steeper than the ruling gradient of the route, the tunnel is referred as saddle and base tunnels.

2. Spiral tunnels : These are those tunnels in which loop formation takes place into the interior of mountain. These are provided in narrow valleys in order to obtain additional length for minimum permissible radius.

3. Off-spur tunnels : These are those tunnels which are made to short cut minor local obstacles. Such tunnels have very short lengths.

4. Slope tunnels : These are constructed to ensure safe operation and protection to railway and highway routes in steep mountains. They have also been found suitable from economic point.

(E) Miscellaneous tunnels all other types of tunnel come under this group such as

(i) Tunnels carrying gas, sewage, oil, telephone or electric cables etc.

(ii) Approach tunnels to underground installations and tunnels for defence purposes.

(iii) Tunnels for pedestrian traffic

SIZE AND SHAPE OF TUNNELS

Size of Tunnels

Size of a tunnel is governed by the purpose of tunnel. The tunnel should be large enough to discharge its function satisfactorily. Since lining reduces the size of tunnel, allowance for lining is kept for deciding the size of tunnel to he actually driven.
Shape of tunnel (sectional profile) is largely governed by the type and nature of ground through which tunnel is driven. It is also influenced by purpose of tunnel. Shape of tunnel should fulfill following requirements.

(a) Walls and roof of tunnel should be able to withstand external end internal pressures to which they are likely to be subjected.

(h) Shape should be advantageous for the function of tunnel.

(c) Shape should be such that complicated tunnel supporting arrangements are avoided.

Shapes of Tunnels

The shape of tunnel depends upon the type and nature of ground through which the tunnel is to be driven. Its shape also depends upon the purpose for which it is to be served. Shape of tunnels should be such that they are able to serve the purposes for which they are constructed, more over shapes of tunnels must be such that they are not liable for complicated frame work. The most important requirement is that shape of tunnel should be able to with stand the pressures. Depending upon the requirement and nature of the area, following shapes are commonly adopted

Shapes of Tunnels

(i) Poly-centric Tunnels (ii) Circular Tunnels (iii) Horse shoe Tunnels (iv) Egg-shaped Tunnels (v) Elliptical Tunnels (vi) Box-type Tunnels (vii) Segmental Tunnels

TUNNELING AND LINING

TUNNELING

The art of constructing a tunnel is known as tunneling.

Tunneling is very difficult and require skilled labour for their construction process. Tunneling methods depends upon the type and nature of strata. Tunneling is classified as

(A) Soft ground Tunneling

(B) Hard Rock Tunneling

(A) Soft ground or Soft Rock Tunneling

In this case of tunneling, after the excavation, it require immediate supporting to support grounds as soon as possible. Excavation in soft rock is easy and cheap. The various ways in which temporary supports are provided are

(i) Suitably spaced bent of wood

(ii) Suitably spaced bents of steel

(iii) Liner plates

(iv) Fore poling placed to retain the material between adjacent bents

In order to achieve economy, temporary supports are designed for higher working stresses. Temporary supports are later on replaced by permanent lining. The face of cannel in soft soil is attacked by excavating small bores at different places. These bores arrangement thee enlarged to give full section of tunnel position of such bores, timbering arrangement and method of enlargement of small bores, is different in different countries and are named after the countries in which the have been developed.

Tunneling in Hard Rock

In case of hard rock tunneling less timbering is required but need special care for their excavation work. This case tunneling is comparatively costly but safe. These require explosion during construction and progress of work is more. It require heavy and costly equipment for constructing hard rock tunnels.

Methods of Tunneling in Soft Rock :

These are following methods of tunneling in soft rock.

(i) American Method

(ii) English Method

(iii) German Method

(iv) Belgian Method

(v) Italian Method etc

These are named because of their timbering arrangement and methods ()I enlargement of small bores depending upon country to country and hence named because of adoption of these methods by different countries.

Apart from these methods there are

(i) Fore poling method

(ii) Needle beam method

(iii) Linear plate method

(iv) Shield tunneling method

(v) Mechanical Tunnelling i.e. Mole Method

Shield tunnelling method become more popular in these days. But mole method is.. latest and known as mechanical method of tunnelling.

Needle Beam Method

This method is suitable for such ground which can stay unsupported for a few minutes. The method derives from its name. The timber beams are used for supporting the excavation temporarily.

The constructional procedure is explained in steps given below :

(1) A monkey drift about one meter deep is driven near the roof of tunnel.

(2) The root of monkey drift is supported with the help of trench jacks

(3) Needle beam is now inserted in drift. The rear end of beam is strutted as in fig

(4) The load of roof support is transferred to needle beam through a trench jack

(5) Now the drift is enlarged side ways and the new excavation is supported fig c shows widening of drift on left side.

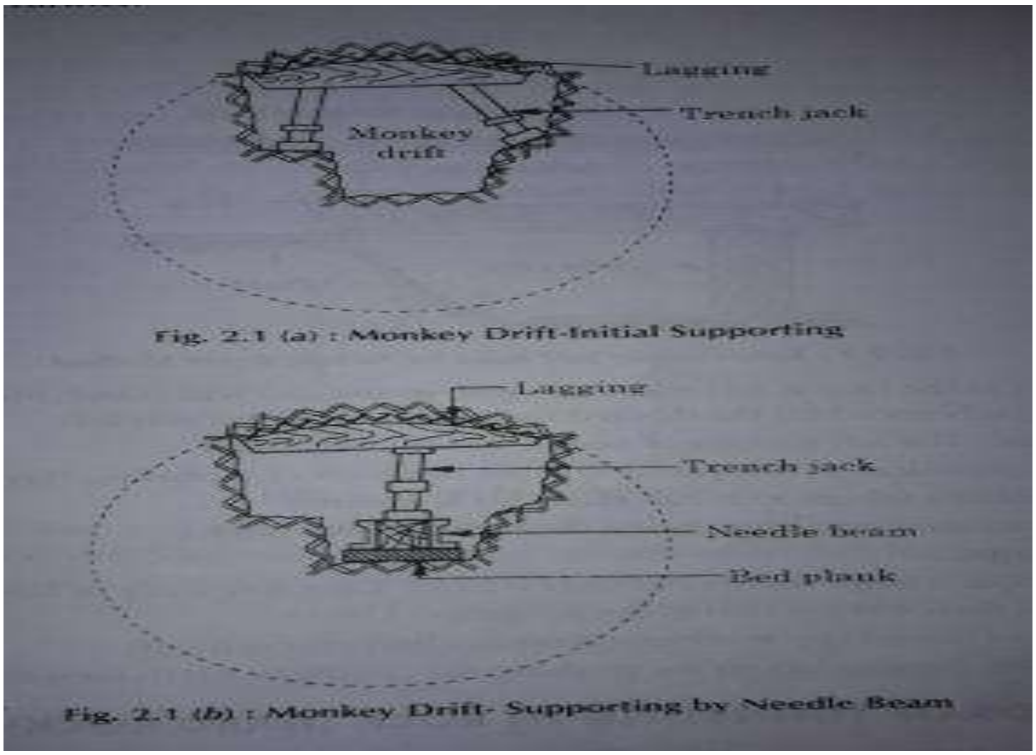


Fig. 2.1 (a) : Monkey Drift-Initial Supporting

Fig. 2.1 (b) : Monkey Drift- Supporting by Needle Beam

(6) When full section is excavated, new monkey drift is made for advancing the tunnel further.

Excavation at the face is advanced as steep as the soil will stand. Steps are repeated and the beam is advanced till the desired excavation work is complete.

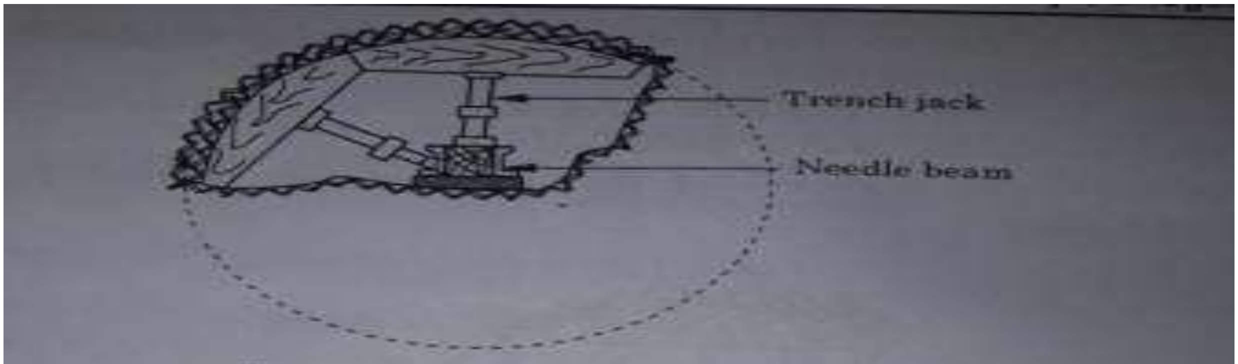


Fig. 2.1 (c) : Enlarging of Monkey Drift

Fig. 2.2 : Tunneling in Soft Rock by Needle Beam Method

Advantages : The advantages of needle beam method are :

(i) It is economical as compared to other methods of tunneling through soft soils.

(ii) It is suitable where soils can stand for sometime.

(iii) It is suitable method for lining the tunnels with bricks.

Disadvantages :

(i) This require large number of trench jacks. Thus efficiency of labour is decreased due to their obstruction in the progress of work.

(ii) Lining of tunnels by mechanical means becomes difficult.

(iii) It require manual labour for pushing the needle beam in forward direction.

METHODS OF TUNNELING IN ROCK (HARD ROCK)

The methods to be adopted depends upon the shape, size and available equipment.

a) Traditional Methods

(b) Excavation by Tunneling Methods

(A) Traditional Methods : This method involves drilling and blasting Operations. Depending upon the type of strata, size of the tunnel and the method adopted, excavation is supported by temporary wooden supports or permanent steel supports. There are different methods of tunneling given below :-

(i) Full face Method : This method is suitable for firm soils, where the excavated portion can hold itself for sufficient time to permit mucking and supporting operation to be completed. The method of construction is shown in fig. The excavation to be done is divided into three sections. The top section is cut and removed followed by similar operation in section II and section III. After completing excavation of one section, work in second section is started. The method is recommended for tunnels of small size.

(ii) Top Heading and Benching : Where the excavated portion cannot hold itself by the time muckin8 and supporting operations are carried out the heading is excavated and supported to the full length or part length of the tunnel before benching is started. The heading is always ahead of benching.

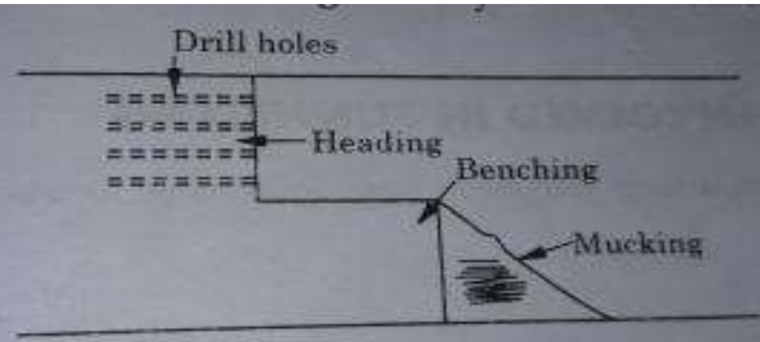


Fig. 2.4 : Heading and Benching Method

This method is adopted where the tunnel section is very large but rock structure is not sound.

(iii) Bottom Heading and Stoping : This method is suitable where the section of the tunnel is very large and rock structure is sound.

(iv) Drift Method : In this case large size tunnels a pilot tunnel or drift is made in the side or at the centre of the tunnel. The drift is then widened by drilling holes on its faces. Drift provides suitable .arrangement for supporting the excavation.

Depending upon the position of the drift, the method of tunneling may be done either.

(v) Wall plate drift : This method is adopted where rock is so bad. Wall plates of sufficient lengths are provided to support the top ribs.

(B) Side Drift : It is adopted where size of tunnel is large and excavations needs to be supported before mucking.

(C) Multiple Drift Method : This is the combination of side drift and top drift method. This is frequently employed to get through crushed rock in fault zones which may be behave like earth.

OPERATIONS INVOLVED IN TUNNELING

The hard rock tunneling method has following sequence of operation for construction of tunnel.

(1) Drilling

(2) Loading of holes

(3) Blasting

(4) Scaling

(5) Mucking

(6) Secondary Blasting

(7) Tunnel Supporting

(8) Grouting and Lining

(1) Drilling Tunneling with explosive requires drilling of holes in to rock. These holes are drilled. A drill holes are made with drills worked by compressed air. The depth of the bore holes varies from 2.5 m to 3m. Holes are made by using Tack drills either by jack hammer or drifter.

Generally holes are made along joints to loosen the rock material. The number of holes to be drilled depends upon the area and nature of rock.

(2) Loading of Holes : Charging the holes with explosives is known as loading of holes. It is the operation performed to loosen the rock, each hole is charged and loaded with explosive. Explosives are used in the shape of cartridges. These cartridges are fixed with detonators. These cartridges are known as primer cartridges. Each hole needs one primer cartridge. Leads from detonators of various holes are suitably connected to shot firing cable.

The quantity of explosive depends upon the type of strata to be blasted, kind of explosive method of explosive.

(3) Blasting : After loading the holes neat step is blasting. A blasting lead is taken up to safe, distance where it is connected to an exploder. Warning signals are sounded for safety. After blasting a trained worker locate misfire, if any, and reblasts it.

(4) Scaling : At the end of blasting some rock fragments hang loosely from ceiling and walls of tunnel. These rock pieces may fall off without warning and cause accidents during the operations. Removal of such loose rock fragments and hammering off projecting pointed rock is known as scaling. It is done with the help of steel rods and Water jets.

(5) Mucking : It refers to the operation of loading and removing the excavated or blasted material and dumping it at the selected place. Mucking is the operation of loading the rock, earth or any other excavated material. It may be done either by Hand or by Machines.

The blasted debris is known as muck. Removal of muck and its disposal is mown as mucking. Mucking involves

(i) Loading of Muck

(ii) Hauling

(iii) Unloading

Muck loaders are called muckers the operation of mucking is done either by I manual labour, belt conveyor or mechanical shovels. A mucker is a mechanical device.

Hauling of muck is done by mine cars. Mine cars are pulled with locomotives., Carts may be used on small jobs.

Unloading was done previously by means of hands but now a days it is done by self tipping mine cars.

(6) Secondary Blasting : Main blasting may not gives desired profile to the tunnel. Therefore to achieve proper shape of tunnel the process of secondary blasting is done. This blasting is of smaller scale.

(7) Tunnel Supporting : The interior surface of the blasted portion is supported by timbering, to avoid accidents immediately after mucking.

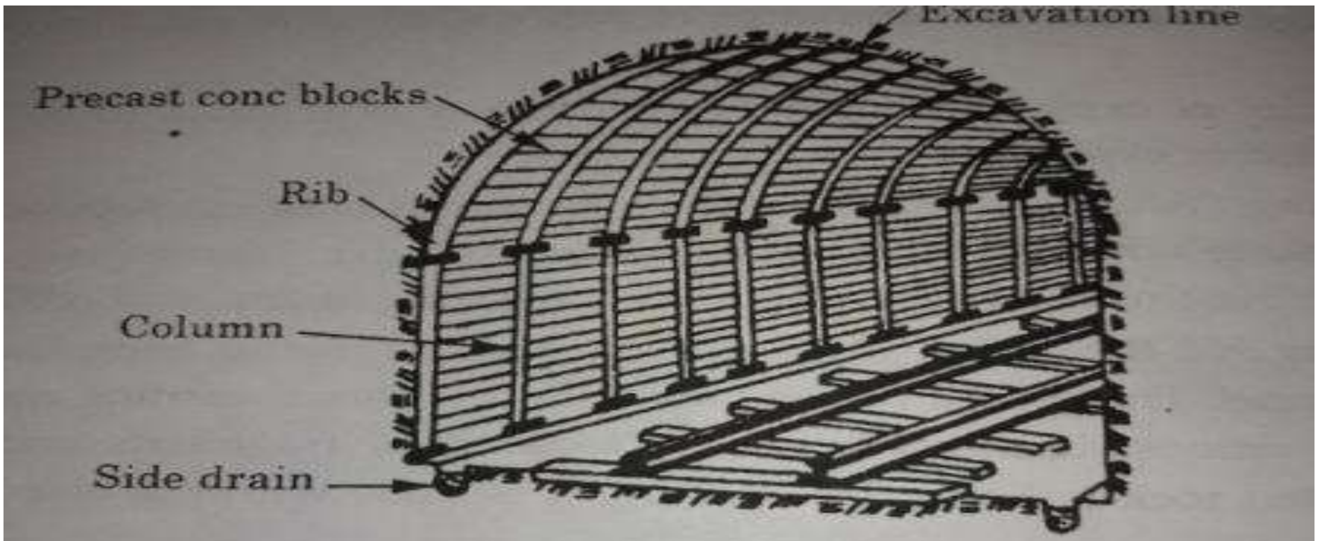


Fig. 2.6 : Method of Supporting the Tunnel

The design of the supporting structure depends upon the nature of rock through which the tunnel is driven. A common timbering arrangement consists of ribs, supported on columns as shown in fig. The ribs are usually are made of mild steel in the form of H-section

For supporting the tunnel after mucking, frames are erected at suitable spacing with columns and ribs. The portion between the two adjacent frames is filled with precast concrete blocks. Ribbing is done to get uniform profile of the tunnel.

(8) Grouting and Lining : Before the tunnel is finally lined, it is necessary to grout the weaker sections with cement slurry so that the weaker strata is stabilized. Finally the tunnel is lined.

EQUIPMENTS FOR DRILLING

(a) Drills : Following type of drill are in common use.

1. Jack Hammer : It is a light drill weighing 20 to 40 kg. It can be held in hands or mounted on a stand while operating. It can drill 3 to 4 m. dia holes up to 2 meters deep.

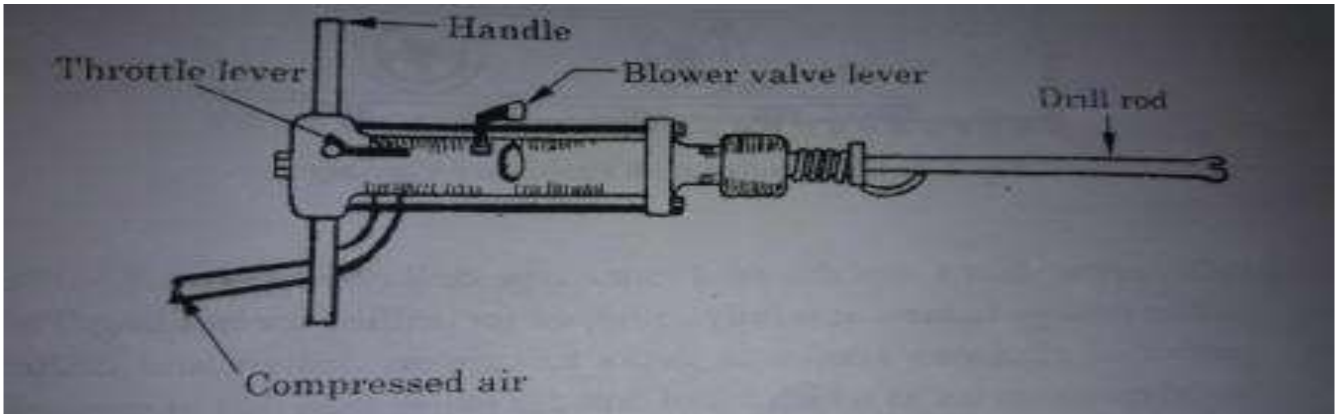


Fig. 2.7 : Jack Hammer

2. Drifter : It is heavier than jack hammer weighing 50 to 100 kg. It is mounted on stand. Holes up to 6 metres deep can be made with drifter..

(b) Drill carrying equipment :

(1) Support for mounting drills : Steel pipe supports strutted between roof and floor or walls of tunnel are used for mounting drills in small tunnels.

Drill Carriage : Carriage mounted drills are used for drilling in small find medium tunnels.

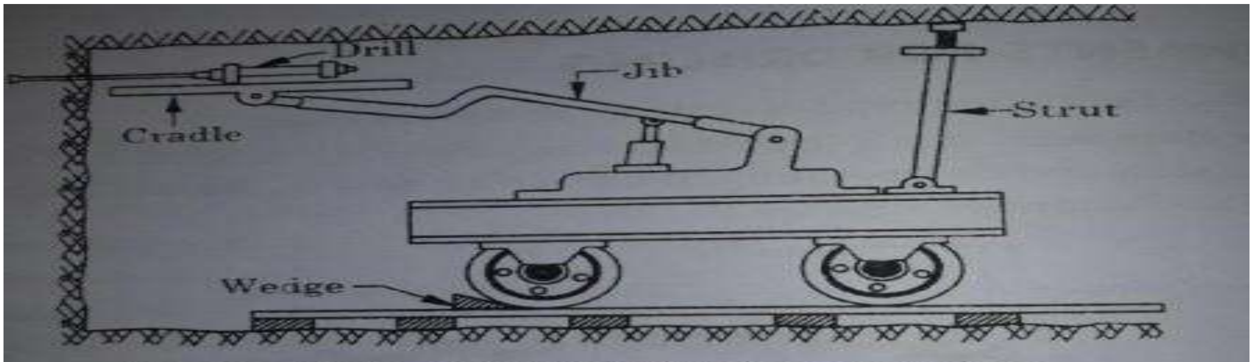


Fig. 2.9 : Jib Mounted Drill Fitted on a Carriage

(iii) Drill Jumbo : It is a movable steel frame type drill carriage commonly used for drilling in large tunnels. It is fully equipped for drilling for heading. There are a number of platforms known as decks to support drillers and drilling steel. jumbo moves on tracks which are of broader gauge than that of mine cars.

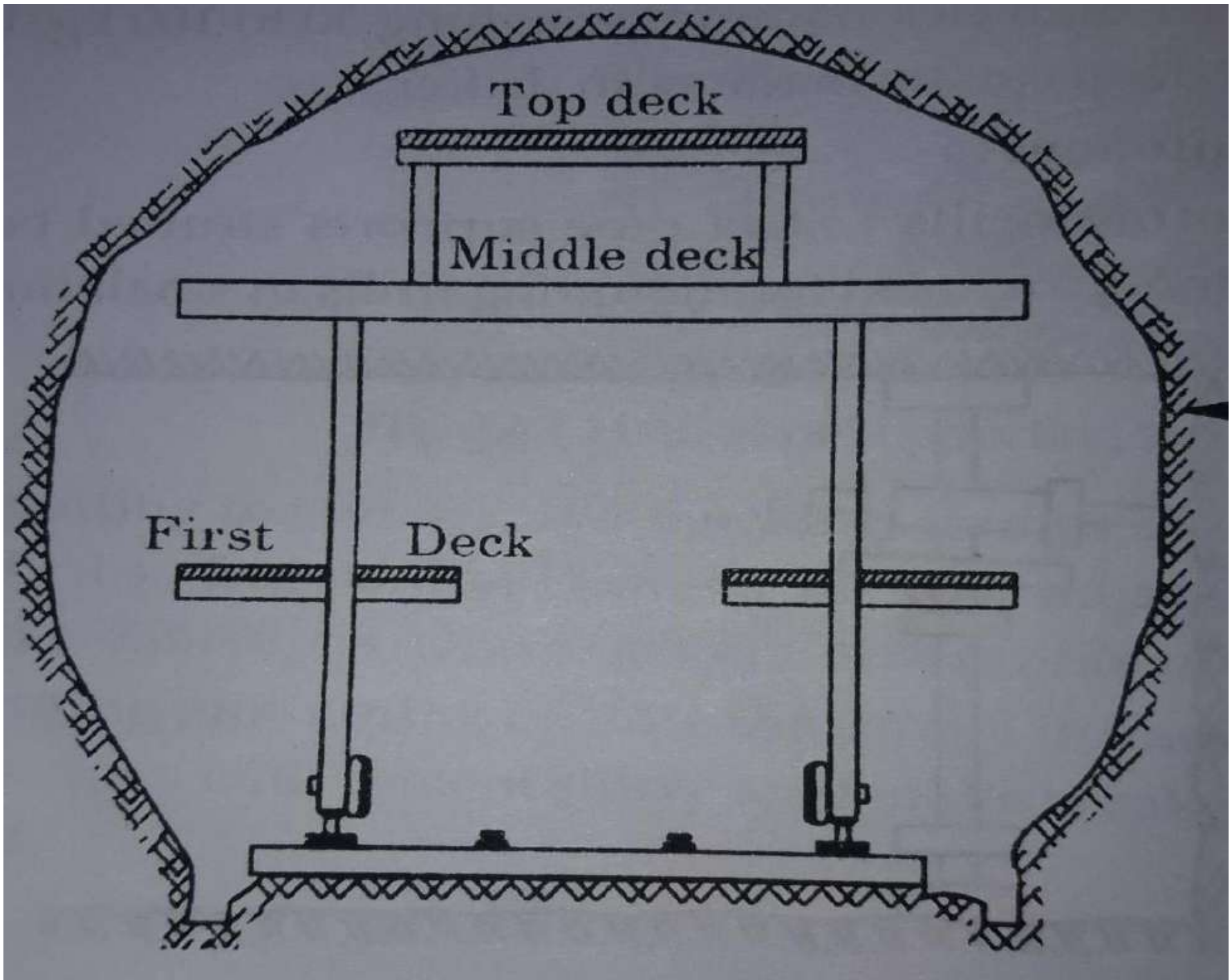


Fig. 2.10 : Drili Jumbo

PLUMBING SERVICES

BY–VINAY YADAV

Department of Civil Engineering

Plumbing Services

Sanitary Fittings and Accessories

Sanitary fittings

- The fittings or appliance used for collection and discharge of soil waste or waste matter is termed as sanitary fittings.
- Different types of sanitary fittings are required in a building to perform different type of function.
- These fittings are glazed chinaware.
- These fittings are so designed and shaped that they have non absorbent surface which can be easily cleaned.

Types of Sanitary Fittings used in a Building

- Wash Basin.
- Sink.
- Bathtub.
- Urinals.
- Water Closet.
- Flushing Cisterns.
- Shower.
- Faucet

Wash Basin

- A Wash Basin is used for washing hands, face etc.
- A Wash Basin is usually made of porcelain or enameled iron etc, sometimes they are also made of pressed steel or plastic.
- There are two types of wash basins- The flat back and The angle back.
- An ordinary Wash Basin is mounted on brackets fixed on wall. While a pedestal type basin are mounted on pedestal rising from wall.
- The type of Wash Basin normally used in a house has an oval shaped bowl with an overflow slot at top.

- The flat back Wash Basin have provision for making holes for installing taps. Normally two pillar taps are provided one for cold and the other for hot water.
- It has a circular waste hole for draining out waste water from the basin.
- A metallic strainer is provided in the waste hole which is connected to a waste pipe either directly or through a bottle trap for discharge of waste water into the floor trap.
- The top of Wash Basin should be kept at a height of 75 to 80 cm from the floor.

- Standard size for flat back Wash basins are

  25 inch by 17 inch

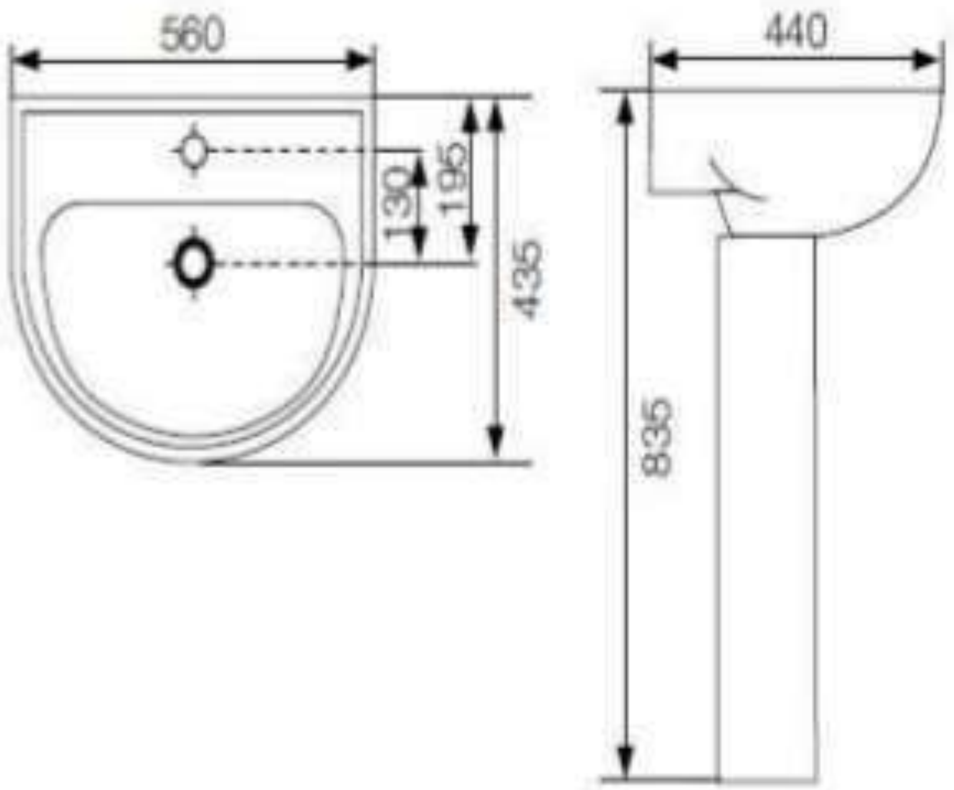
  21 inch by 15 inch

  17 inch by 12 inch

- Standard sizes for angle back Wash basins are

  24 inch by 18 inch

  15 inch by 15 inch


560
130
195
435
440
835

- Flat back Wash Basin

- Angle back Wash Basin

Placement of Wash Basin

- Wall mounted
- Table mounted
- Pedestal

Wall Mounted

Table Mounted

Pedestal

Types of Table Mounted Wash Basin

- Table top basin

- Under Countertop Wash Basin

Sink

- A sink is a rectangular basin used in kitchen or laboratory for cleaning utensils and glass ware.
- These may be made of glazed fire clay, stainless steel, plastic, marble, R.C.C.
- The sink has an outlet(waste hole) usually of about 40mm diameter.
- The waste hole is provided with gratings so that the entry of coarse solid substances is prevented.
- The outlet pipe discharges water over a floor trap or nahni trap.

Types of sink

- Top mount
- Under mount
- Farmhouse or apron
- Double bowl
- Single bowl
- Corner sink

Type -Single bowl
Material -Marble sink

Type - Farmhouse
Material-Glazed fire clay sink

Type - Double bowl
Material - Plastic sink

Type - Undermount
Material - Stainless steel sink

Top mount

Corner sink

- Common sizes for kitchen sinks

    600 x 400 x 150 mm

    600 x 450 x 250 mm

    750 x 450 x 250 mm

- Common sizes for laboratory sink

    400 x 250 x 150 mm

    450 x 300 x 150 mm

    600 x 400 x 200 mm

Bathtubs

- A Bathtub is a large or small container for holding water in which a person or animal can bathe.
- A Bathtub is usually made of enameled steel gel coated fiber glass, reinforced enameled porcelain, reinforced concrete finished with terracotta or marble finishes.
- Modern bathtub have overflow and waste drain and may have taps mounted on them.
- There are two types of bathtub:- Eastern style and Western style.

Eastern style bathtub

- In this the bather lies down and these bathtubs are typically shallow and long.

Western style bathtub

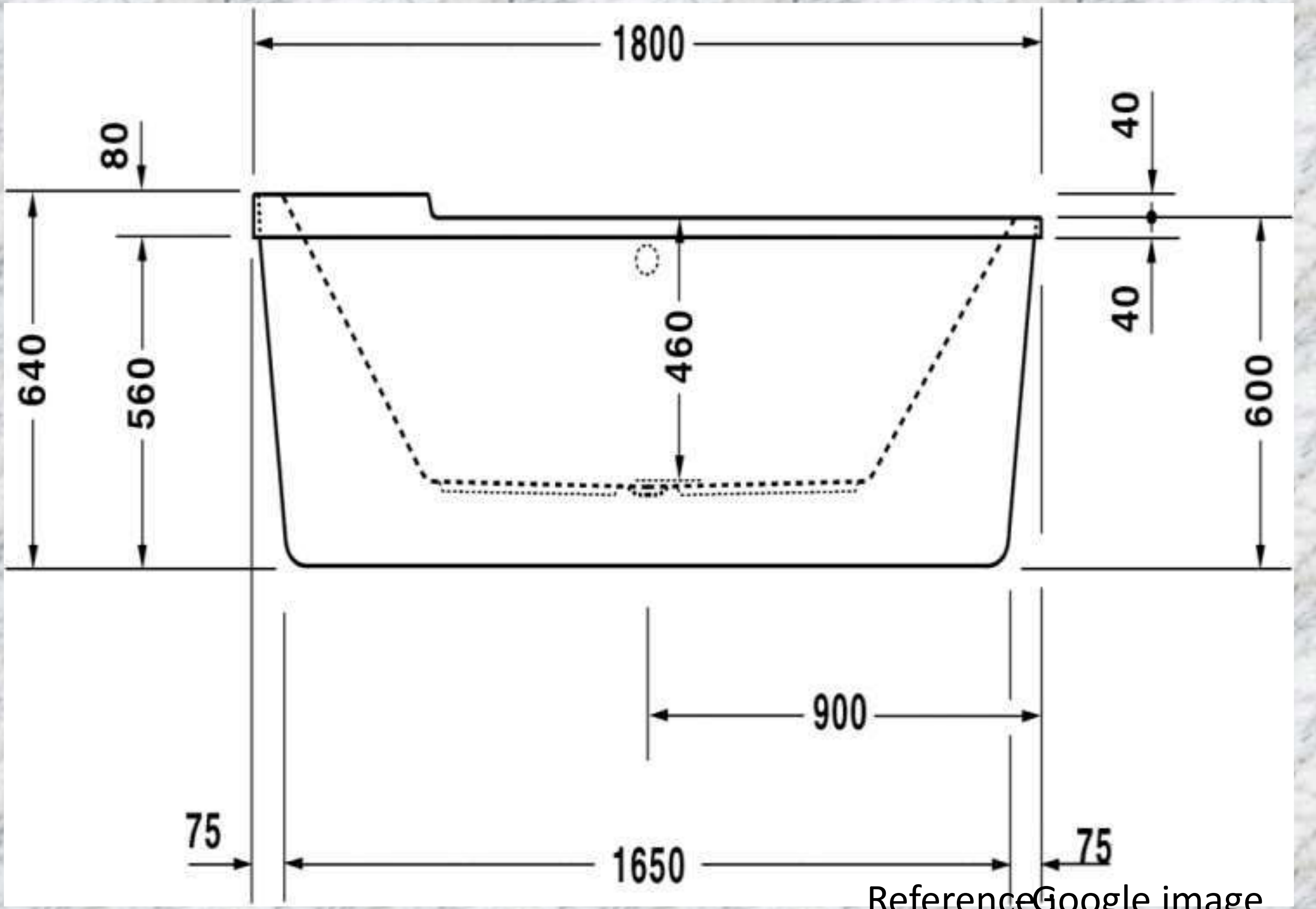
- In this the bather sits up and are typically short and deep.

- the usual dimensions of bathtub are:

length: 1.7 to 1.85 m

width: 0.70 to 0.75 m

depth: 0.6 m



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Classification of bathtubs

- FREE STANDING BATHTUBS
- CLAW FEET BATHTUBS
- DROP IN BUTHTUBS
- WHIRLPOOL BATHTUBS
- WALK IN BATHTUBS

Free Standing Bathtub

Claw Feet Bathtub

Drop In Bathtub

Whirlpool Bathtub

Walk In Bathtub

Urinals

- It fall under the category of soil appliance and the discharge from urinals is connected to soil pipe either directly or through trap provided with gun-metal or brass domed shaped removable grating.
- From hygienic considerations it is desirable to provide glazed tiles on walls of urinals preferable upto door height.
- Urinals consume less water while flushing as compared to W.C.
- Urinals are generally made of stainless steel and glazed earthen ware, fire clay or white vitreous chinaware.

Types of urinals

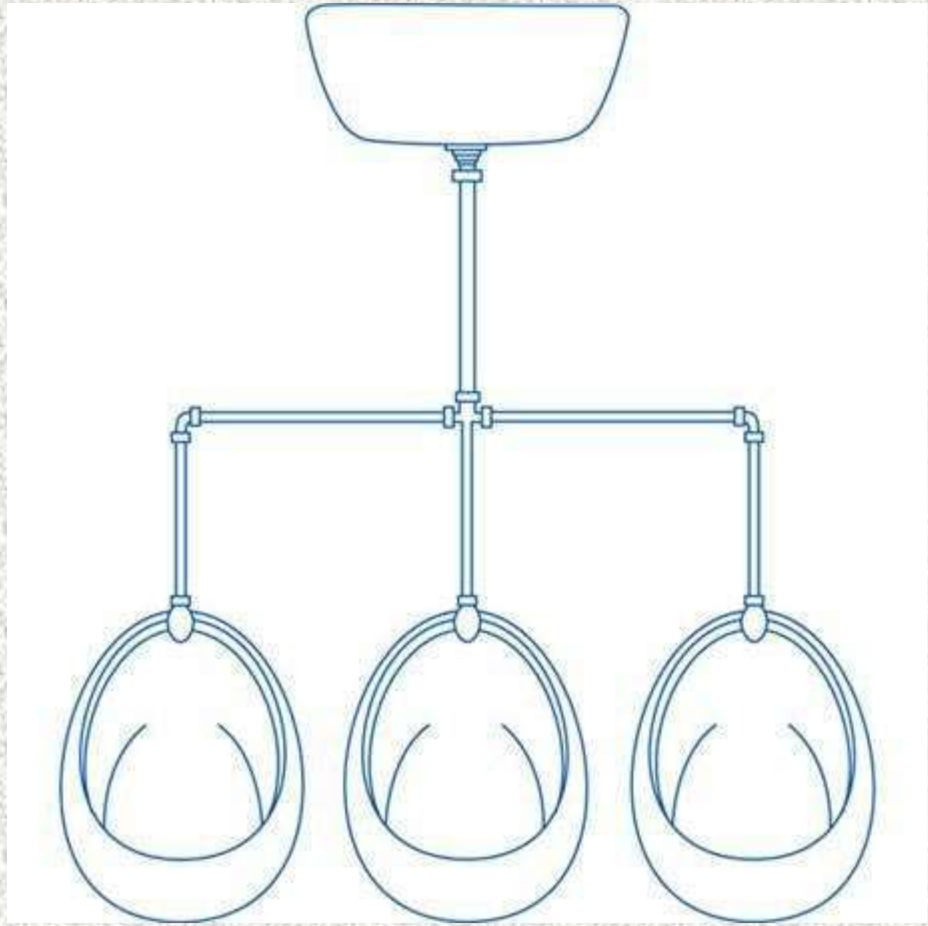
- Bowl type

This is a one piece construction with integral flushing box rim having 12 hole suitably distributed for proper flushing.

The urinal has an outlet horn at bottom for connection to the trap.

In case number of urinals are required to be installed in a row , it is necessary to provide vertical partition between them.

Bowl Type Urinal



- Stab or stall type

These are manufactured as a single unit or as a range of two or more units.

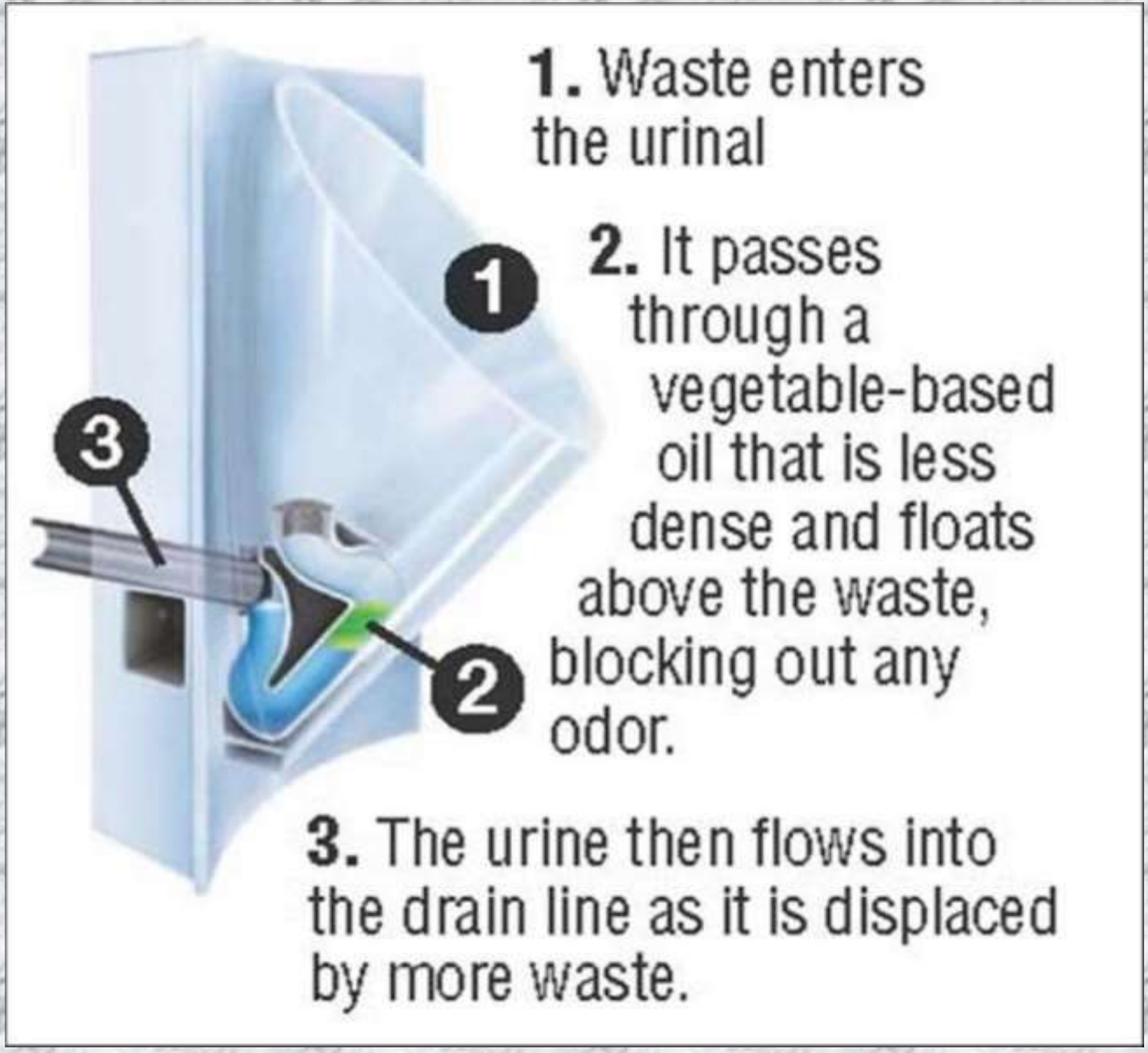
The width of single unit should be at least 2’6”.

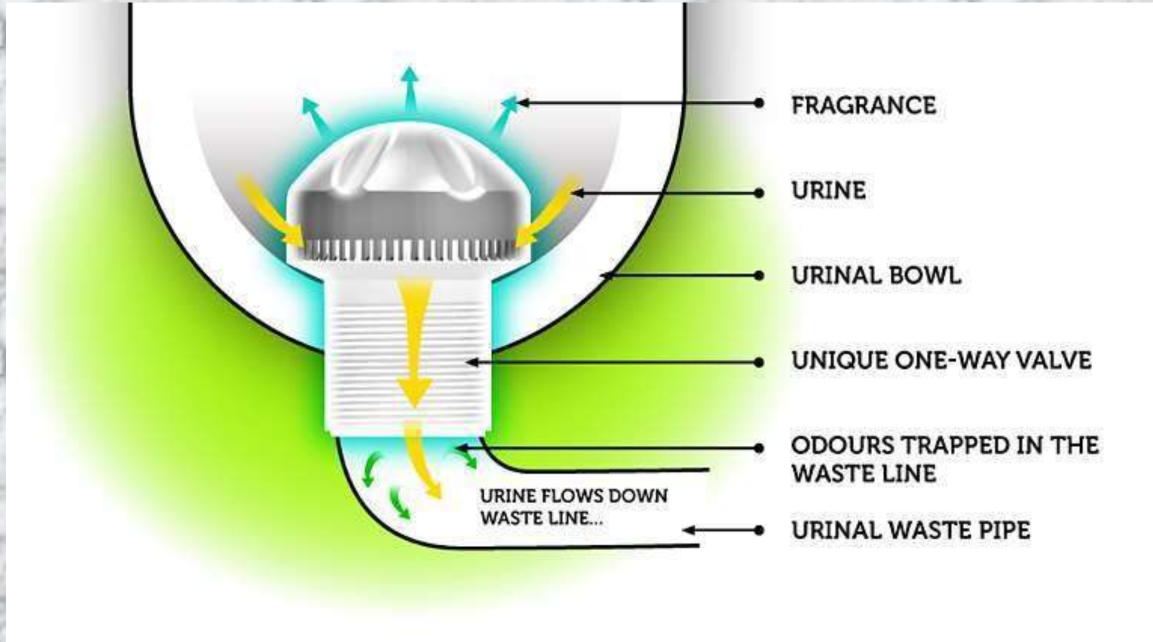
The flushing is carried out using automatic flushing cistern which operates at regular interval of 10 to 15 minutes.

The discharge from series of stall in a row is usually carried through a glazed semi circular drain which has sharp fall toward the trap from where it is discharged into the soil pipe.

Slab or stall type urinal

Waterless urinal



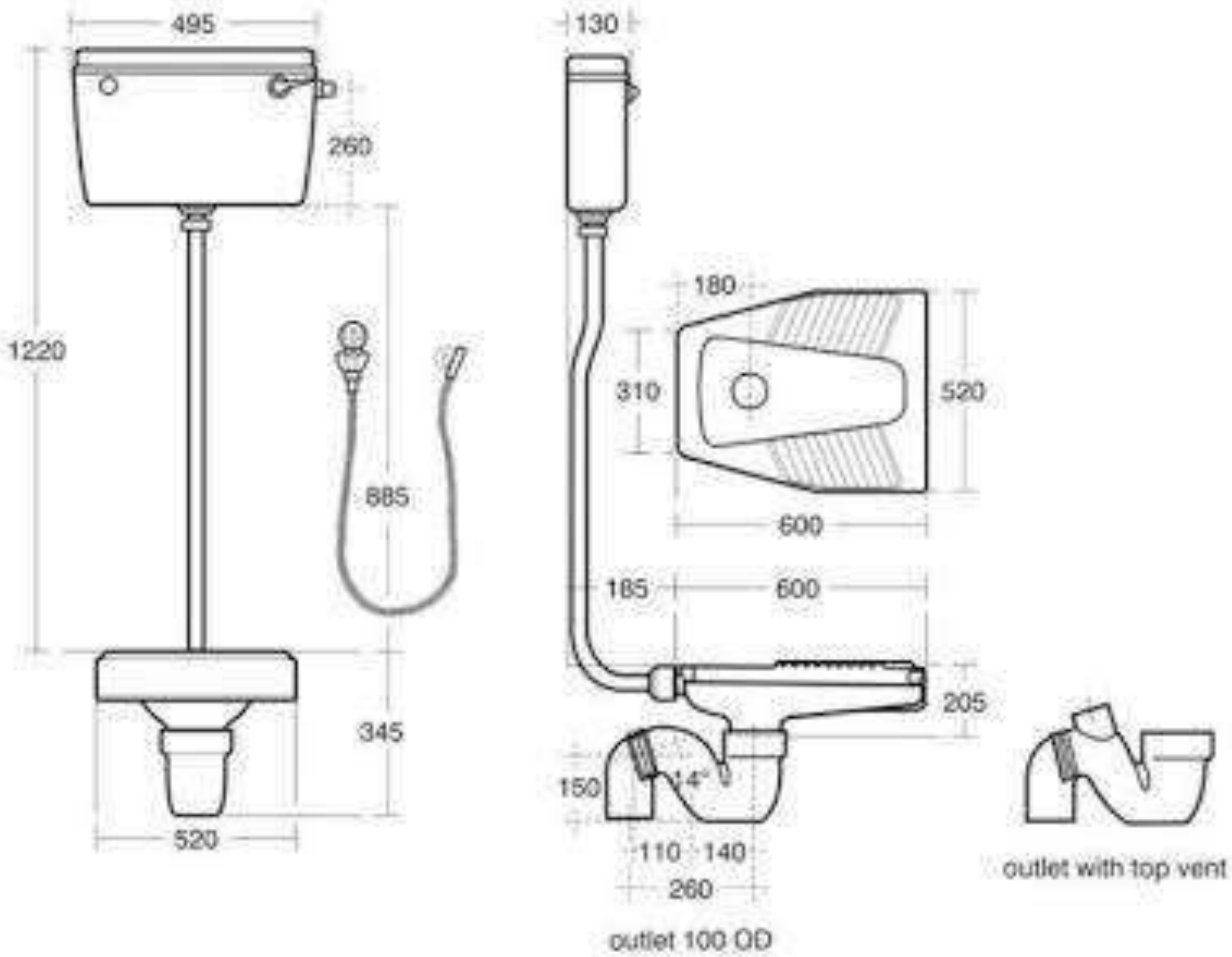


Water closet (W.C.)

- A water closet is a sanitary fitting which is designed to receive human excreta directly and convey to the septic tank or underground sewer through a trap.
- W.C. is connected to flushing cistern to flush the excreta from the closet to the soil pipe.
- W.C. is usually made of glazed earthen ware, fire clay or white vitreous chinaware.
- Types of W.C. :-   Indian or squatting type, European type, Anglo Indian type.

Indian or Squatting type

- This type of W.C. is used in squatting position.
- The W.C. consists of two pieces, i.e. porcelain pan and a P or S trap.
- The W.C. pan along with the trap is fixed flush with the floor.
- Footrest are provided on sides of the pan and the pan has an inbuilt flushing rim having a number of holes through which the flushing water from the cistern is discharged.
- The content of the pan are removed by the gravity flush of water.


495
260
1220
885
345
520
130
180
310
520
600
185
600
205
150
14°
110
140
260
outlet 100 OD
outlet with top vent

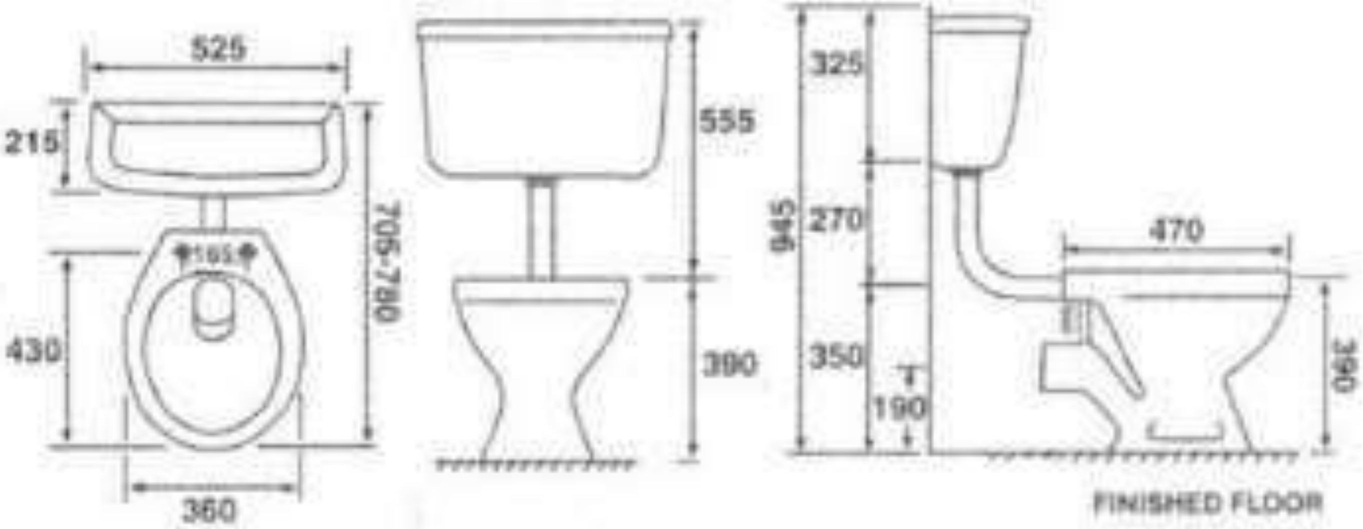
European type W.C.

- Tis type of W.C. is used in sitting position over a plastic seat hinged to the appliance.
- This is a pedestal type of appliance with a pan and a trap in a single piece.
- The flushing rim of pan is connected to the cistern which may be of a high level type () or low level type (30 cm above the W.C. or resting on the W.C.) for getting flushing water.
- Types of European W.C. :- Wash down type and siphonic type.

Wall hung W.C.

Pedestal W.C.

CLOSE COUPLED PAN & CISTERN



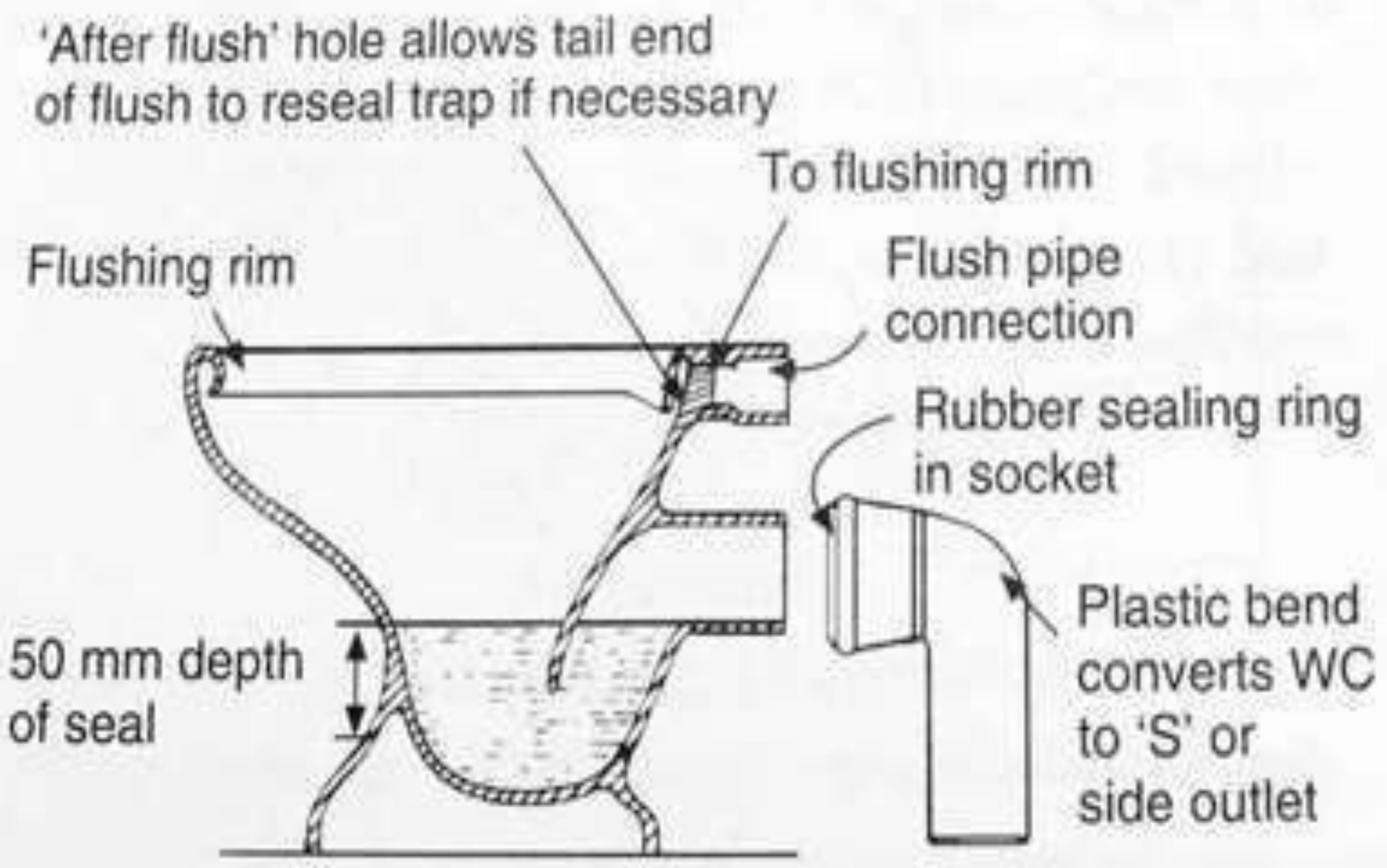
LOW LEVEL PAN & CISTERN

Wash down type

- This is the most commonly used pattern in which the content are removed by the gravity flush of water discharges into the pan through the flushing rim of the pan.
- Usually for ground floor the WC having S trap (outlet pointing vertically down) is used.
- Whereas for installation on upper floor WC ending up with P trap is preferred

Siphonic type

- In this type, the content of the pan are removed by siphonic action when the cistern is flushed and water passes through the pan.
- It has a special type of trap inbuilt within the pan is so shaped as to set up siphonic action when the water passes over the pan.
- Due to siphonic action the entire water along with waste get emptied from the pan into the soil pipe.
- The W.C. has small after flush chamber inbuilt in the appliance, water from which re-seals the trap.
- It may have one trap or two traps.


'After flush' hole allows tail end
of flush to reseal trap if necessary
To flushing rim
Flushing rim
Flush pipe
connection
Rubber sealing ring
in socket
Plastic bend
converts WC
to 'S' or
side outlet
50 mm depth
of seal

★ Difference of Washdown and Siphonic Toilet ★

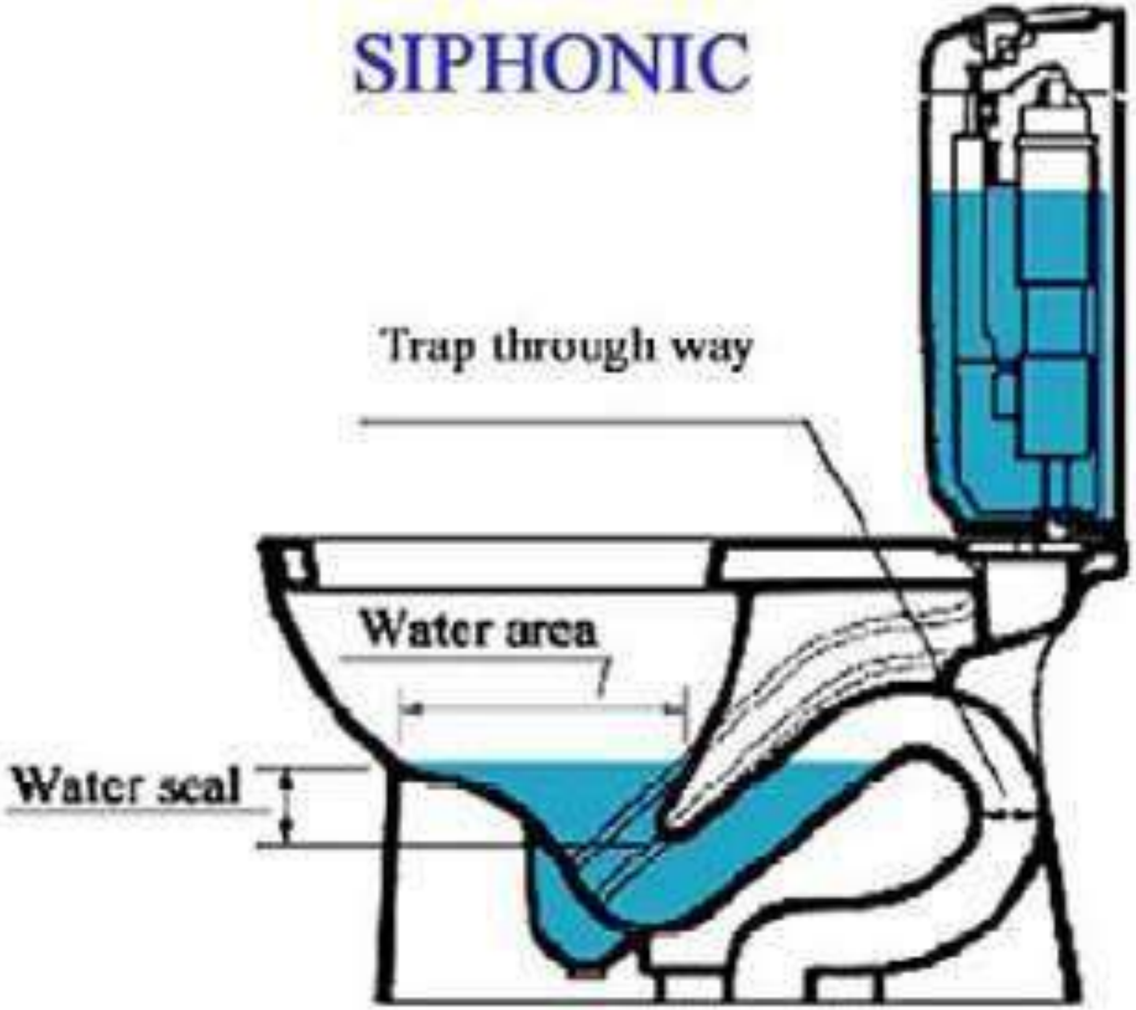
Washdown Toilet

Discharge pipe of washdown toilet is wide and radian is small.

Siphonic Toilet

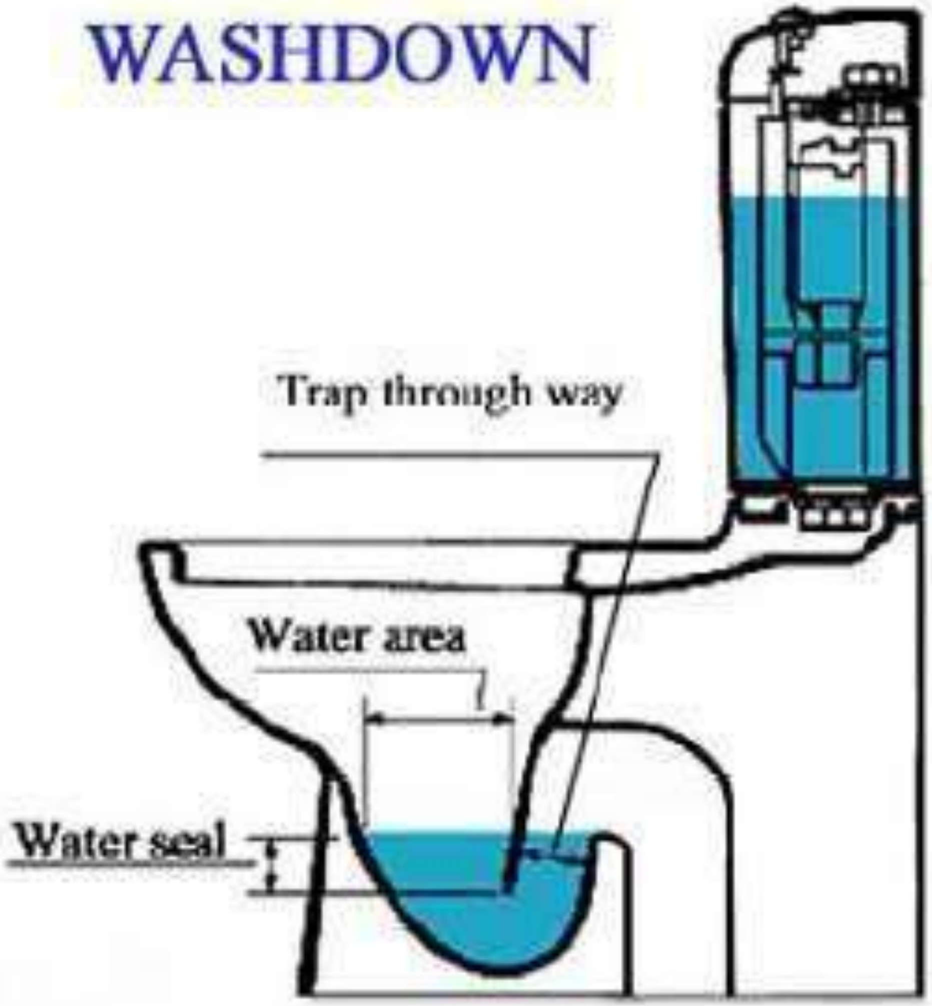
Discharge pipe of siphonic toilet is narrow and radian is large.

SIPHONIC



Siphonic system

WASHDOWN



Washdown system

Anglo Indian W.C.

- This type of W.C. can be used both in squatting as well as in sitting position .
- It is pedestal type and has an inbuilt trap .
- The top of W.C. is provided for footrest to permit it to be used in squatting position.
- To use it as an European type W.C. the plastic seat is hinged on to the top of the pan to use it in sitting position.
- In this design the fouling area of pan is less and the waste falls in water of trap and is flushed out as in European W.C.


Flushing cistern

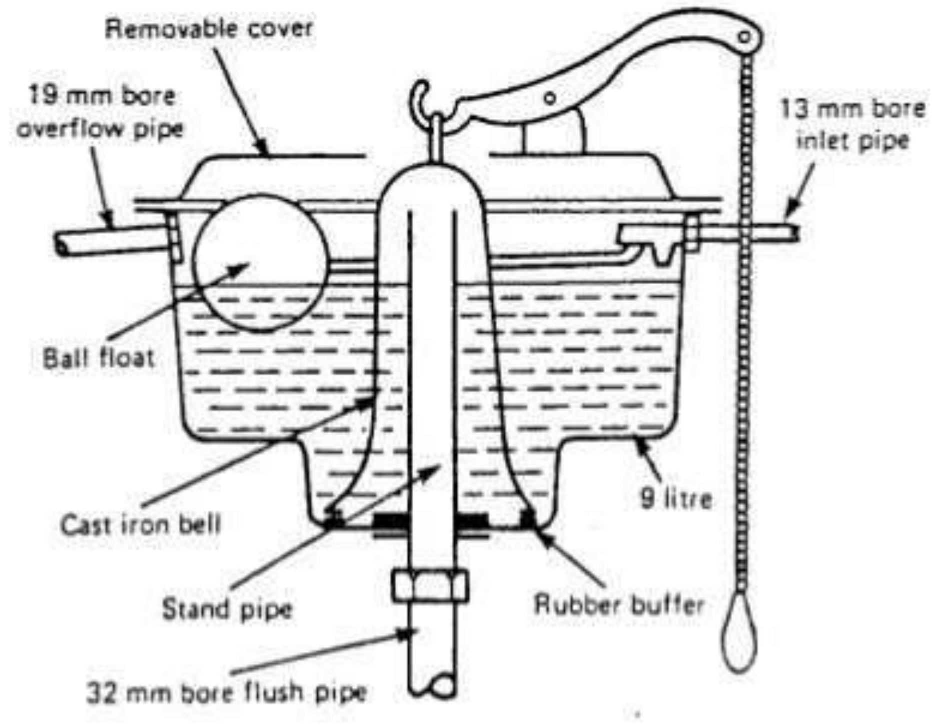
- It is used for storage and discharge of water for flushing of W.C. or urinals.
- It is made of cast iron vitreous china or pressed steel plates or plastic.
- The capacity varies from 10 to 15 liters.
- When the cistern is fixed at a height of 1.8 to 2 m from floor it is termed as high level cistern made of cast iron.
- The European W.C. is generally provided with low level cistern made up of porcelain and it operated at a height of not more than 30 cm between top of pan and under side of cistern.

Types of Flushing Cisterns

1. Valve less siphonic type or bell type.
2. Valve fitted type or piston type.
3. Automatic flushing type.

Valve less siphonic type or bell type

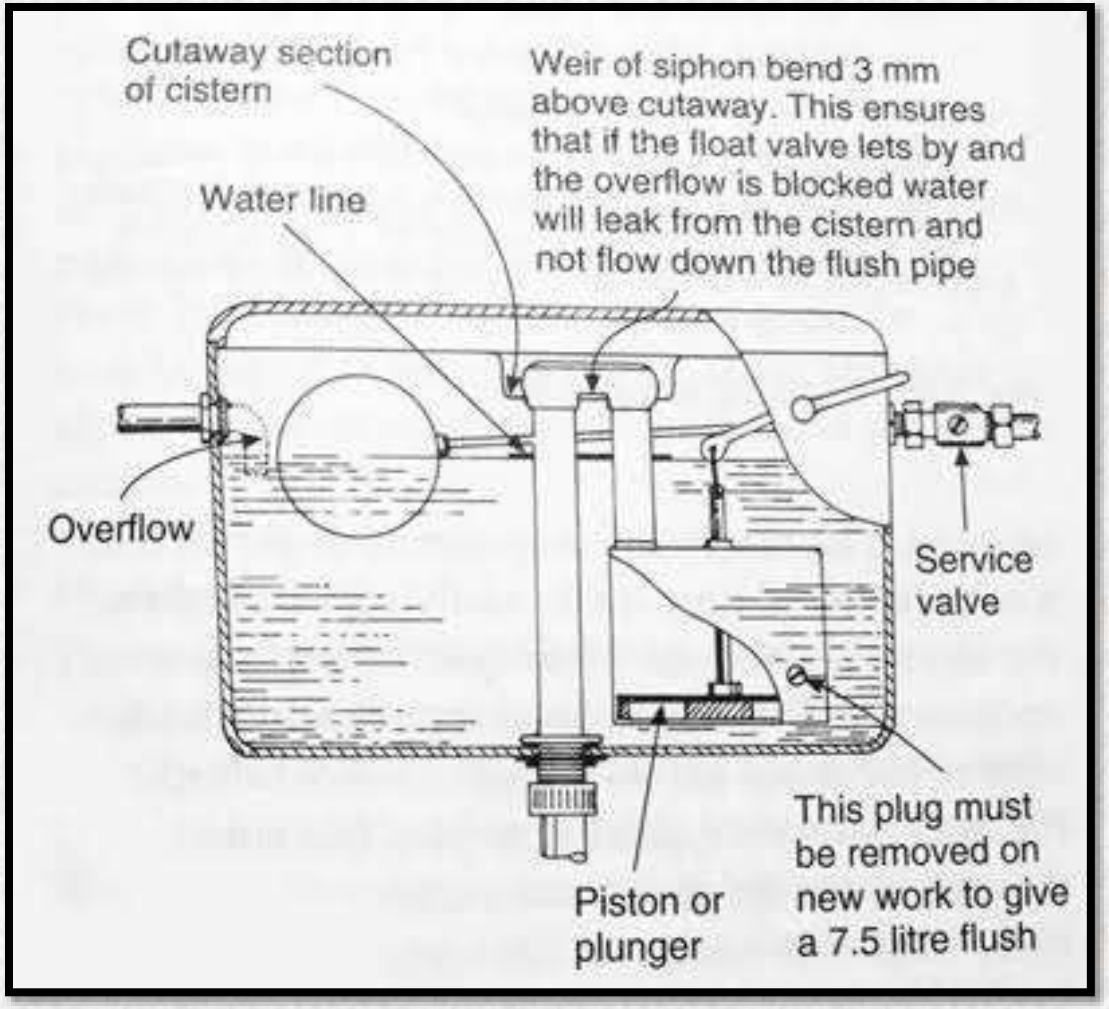
- The bell type flushing cistern is rather noisy but may be used in factories and schools.
- The cistern is operated by chain being pulled over which lifts the bell.
- When the chain is released the bell falls thus displacing water under the bell down the sand pipe.
- Siphonic action is then created which empties the cistern.



Bell type flushing cistern

Valve fitted or piston type cistern

- When the lever is depressed sharply, the piston is lifted which displaces water over the siphon.
- Water discharging down the flush pipe takes some air with it and creates a partial vacuum in the siphon.
- The greater air pressure acting upon the water in the cistern forces water through the siphon until air is admitted under the piston which breaks the siphonic action.



Automatic flushing cistern

- Automatic cistern are designed to discharge its contents of water at regular intervals into a urinal.
- The rate at which the water will flush depends upon the rate at which the water is fed into the cistern and for a single installation this should not exceed ten liters per hour.
- These flush water automatically once in 10-15 minutes.
- To prevent wastage of water from these cisterns, at times when cistern is not used such as at weekends, an auto matic dlow cut off device should be used.


electroflo


tissino

Faucet

- A small diameter, directly or indirectly, manually or automatically operated valve from which water is drawn.
- Types of faucet

1. Ball faucet
2. Disc faucet
3. Cartridge faucet
4. Compression faucet

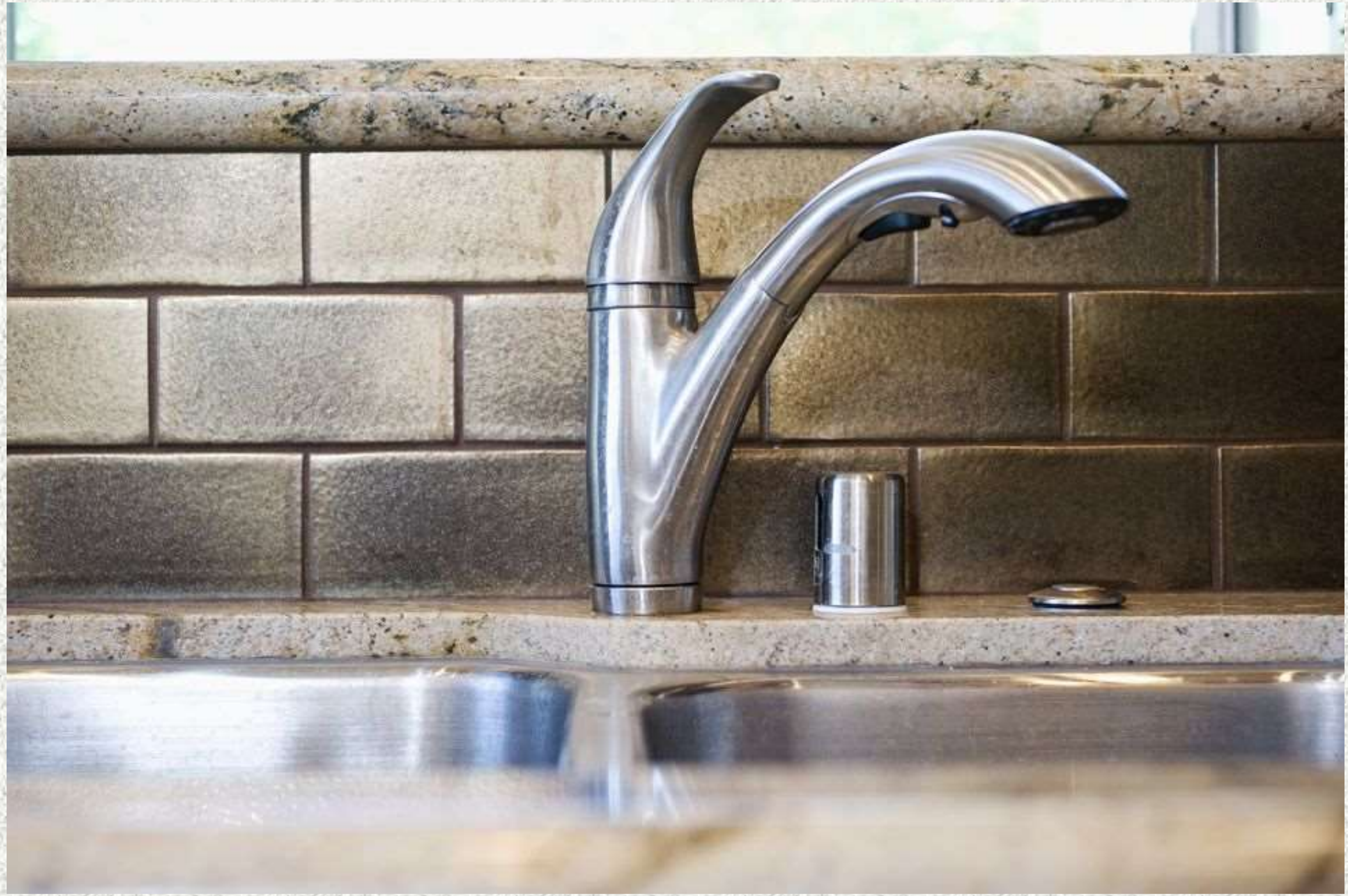
The first three are type of washerless faucets since they do not use rubber or neoprene washer. And the latter is very much basic washer faucet.

Ball faucet

- Ball faucets are very common in kitchen sinks and were the first type of washerless faucet.
- They are identifiable by their single handle which moves over a rounded ball-shaped cap right above the base of the faucet spout.
- The ball faucet has a single handle which controls a special plastic or metal ball inside the faucet body.

Disk faucet

- They are identifiable by their single lever over a wide cylindrical body.
- The disk faucet mixes hot and cold water inside a mixing chamber called a pressure balance cartridge.
- Two ceramic disks at the bottom of the chamber will raise and lower to control the volume of water flow.
- Temperature is controlled by a side-to-side rotation of the handle.
- These faucets are high quality, are very reliable and do not need repair more very often



Cartridge faucet

- They are identifiable by how they feel when they operate than how they look.
- As opposed to a ball faucet that you push back to turn on, a single handle cartridge faucets operate in an "up/down" motion to adjust water volume and a "left/right" motion for temperature

Compression faucet

- Compression washer faucets are identifiable by their separate hot and cold water handles and their action requiring you to tighten the handles down to close off the water flow

Shower

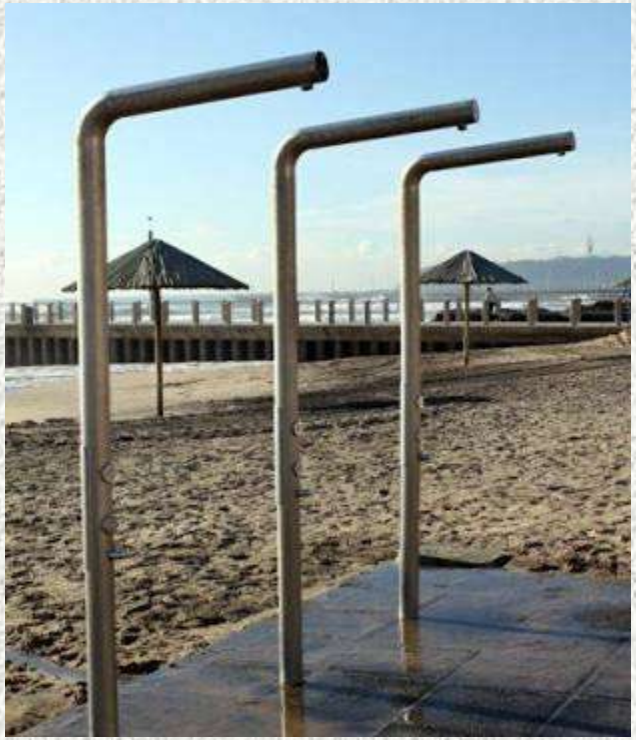
- A shower is a place in which a person bathes under a spray of warm or cold water indoors. there is a drain in the floor.
- Most showers have temperature, spray pressure and adjustable shower head nozzle.
- Most common showers have a rod connecting nozzle aiming down on user.
- Bathing in shower is more efficient when compared to a bathtub because a shower uses less water.
- There are three types of showers :- Public, Domestic, Wetroom

Domestic Shower

- These are most commonly stall shower or shower over bathtub.
- It has a dedicated area which uses a door or curtain to contain water spray.
- Mostly domestic showers have a single head which may be adjusted.
- Cubicle shower has more than one shower head which provides luxury bathing expirence.

Public Shower

- Many modern athletic and aquatic facilities provide shower for use by participants,
- These can be in the form of individual stalls shielded by curtains or by a door or communal shower rooms.
- Open showers are often provided at swimming pools and at popular beaches.



Wet room

- A wet room is a bathroom without internal dedicated or raised area which has an open shower.
- Structurally a wet room requires the bathroom to have a gradient or slope towards a drain hole and foul air trap connecting the floor to the waste pipe.

Bathroom Accessories

Bathroom accessories upgrade your bathroom's look and functionality

Towel bars

- Towel bars are an essential part of any bathroom, bringing both style and functionality to the room.

Bathroom shelves

- Bathroom shelves can offer fashionable storage options for bathroom or dressing area.

Shower Basket

- Shower baskets ensure that the shower stays organized and safe. Available in one and two-tier designs and fitting snugly in the corner of shower.



Toilet paper holder

- It is used to hold toilet paper and it is mounted near the W.C.

Toilet brush holder

Soap dispensers

Toothbrush holder

Bathroom hooks

Bathroom water heaters

Bathroom mirrors

No matter how much you decorate your bathroom, the beauty remains incomplete without an elegant bathroom mirror.

Types of Bathroom Mirrors

1. Shadow Box mirror
2. Framed Mirror
3. Frameless Mirror
4. Pivot Mirror
5. Venetian Mirror
6. Extension Mirror
7. Lighted Mirror
8. Wood Mirror
9. Makeup Mirror

Shadow Box mirror

Framed Mirror

Frameless Mirror

Pivot Mirror

Venetian Mirror

Extension Mirror

Lighted mirror

- . It is surrounded by light so as to give you bright light for makeup.

wood mirror

- Wood mirror can be just the thing to accentuate the luxurious, rich look.

Makeup mirror

- This type of mirrors find in hotels, spa, doctors offices and even movies.

REPAIR AND MAINTENANCE OF BUILDINGS

BY–AMIT KUMAR

Repair and Maintenance

Maintenance And Repair Of Buildings.

What is maintenance ?

- It is the work undertaken to restore or improve every facility in every part of a building , its services and surroundings to currently accepted standards and to sustain utility values of the facility.

Objectives Of Maintenance :

- To preserve in good condition buildings and services.
- When deterioration occurs due to any reason it is inevitable to restore it to its original standard.
- To make improvements whenever required.
- To sustain utility value.

A good maintenance team has to ensure

1. **Safety**
2. **Efficiency**
3. **Reliability**

Maintenance operations have many facets such as :

1. Condition based maintenance :
   - It is the work initiated after inspection.
2. Fixed time maintenance :
   - Activities repeated at predetermined intervals.
3. Preventative maintenance :
   - This is intended to preserve by preventing failure and detecting incipient faults.
4. Opportunity maintenance :
   - Work done as and when possible within the limits of operational demand.
5. Day to day maintenance :
   - Its involves maintenance that has to be performed daily.
6. Shutdown maintenance :
   - Through overhaul and maintenance after closing.

Maintenance operations have many facets such as :

- **Emergency maintenance** : Necessitated by unforeseen breakdown damage or a damage caused by natural calamity like earthquakes, floods ,etc.

Before

Before

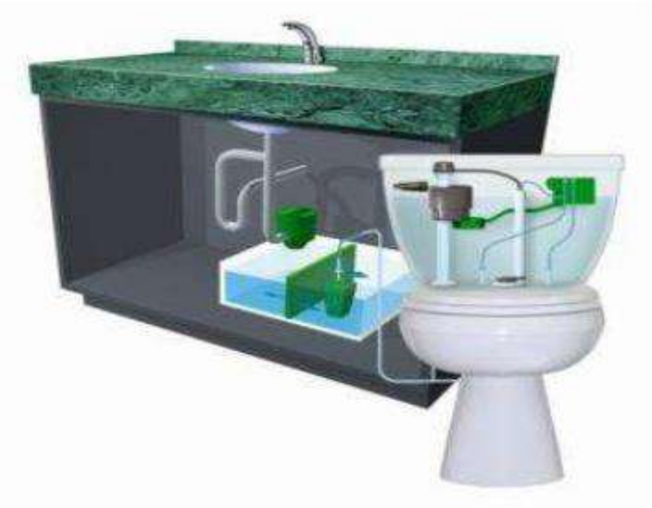
After

After

Examples of some common maintenance works in a building are as follows : -

- **Maintenance Survey for water supply and sanitary system :**

  In case of water supply and sanitary system , periodic surveys are necessary to observe how the system is functioning. Normally inspection should start from the top and proceeded downwards. Drawings which indicate various services as laid should be obtained to facilitate survey.



Maintenance of Electrical Installations :

The electrical installation is made safe by getting it installed and maintained through licensed persons. Its necessary that the installation is checked periodically and a proper record of such work is maintained. Recommended periodicity of checking is as follows :

1. Earthing test - Once a year
2. Insulation - Twice a year
3. Polarity - Once in five years.

Maintenance of Elevators

In multistoreyed buildings vertical transportation is an essential service. The vertical transportation is effected by lifts which could be of various types such as passenger lifts , goods lifts special lifts in hospitals , etc. Without adequate vertical transportation the entire activity in the multistoreyed building would come to a standstill.

Lift maintenance should cover :

1. All mechanical equipments such as sheaves , buffers door closers , floor selectors , limit switches , door hangers ,etc.
2. Interlocks – mechanical fastenings to the base and latching head is locked securely when door is closed. The electrical contact should not get made unless the door is fully closed and locked.
3. Hoist and governor ropes for wear and rust
4. Travelling cables – Make sure that they are properly hung and outer wrapping is not worn out to avoid short circuit.
5. Rails – Alignment , tightness of all plates brackets.

Maintenance of walls to avoid efflorescence

Efflorescence is caused due to entry of moisture into the brickwork and soaking it to saturation. Once the moisture has entered it moves upward due to capillary action; reasons for entry of moisture are-

- Porous nature of structure
- Cracks in the wall
- Existing voids left due to bad workmanship
- Small trees and plants in the wall
- Nonexistence of damp proof course or failure of DPC

EFFECTS OF EFFLORESCENCE

- Dry rot of woodwork
- Disintegration of masonry
- Damage to furniture
- Crumbling of plaster

STEPS TO AVOID EFFLOROSCENCE

Eradication of efflorescence is quite difficult and it is often termed as cancer of buildings .The first step to check efflorescence is to check the ingress of moisture in buildings if there is no failure of DPC efflorescence can be checked easily .

- Step one- ingress of water is checked
- Step two- plaster is removed both inside and outside and is left to dry
- Step three- voids in the wall are filled
- Step four- walls are washed with tamarind water to remove stains
- Step five- walls are replastered with cement mortar not leaner than 1:4 and a water proofing admixtures

What is repair ?

It is defined as the process of restoration of a broken, damaged, or failed device, equipment, part, or property to an acceptable operating or usable condition or state.

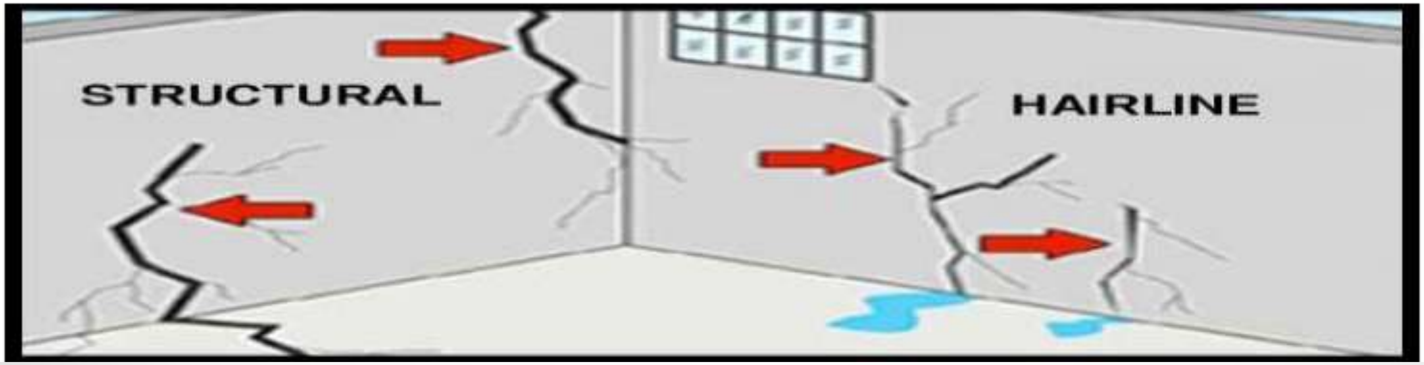
Some common types of repairs are as follows :

1. Patching up of defects such as cracks and fall of plaster.
2. Repairing doors, windows, replacement of glass panes.
3. Checking and repairing electric wiring.
4. Checking and repairing gas pipes, water pipes and plumbing services.
5. Re-building non-structural walls, smoke chimneys, boundary walls, etc.
6. Re-plastering of walls as required.
7. Rearranging disturbed roofing tiles.
8. Relaying cracked flooring at ground level.
9. Redecoration — whitewashing, painting, etc.

Examples of some common repair works in a building are as follows : -

REPAIR OF CRACKS IN WALLS

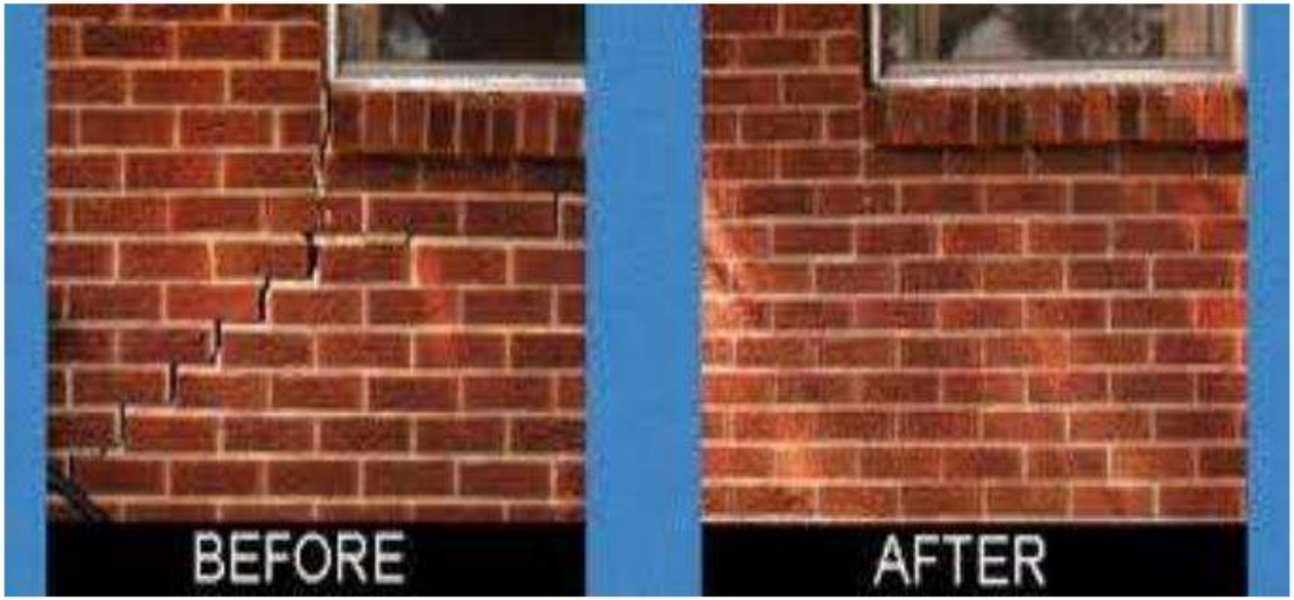
Cracks are signs of distress in structural and non-structural members caused due to separation of joints , development of fissures , shearing, separation of members built with different materials . Cracks may be at different locations like – vertical, horizontal, inclined ,separation at the roof level just below the junction of RCC slab and masonry wall , in parapet , at junctions of RCC columns etc. They may be wide narrow or hairline and can be of varying depths. They are classified broadly as structural and non structural cracks; with structural cracks forming due to incorrect design faulty construction, and non structural cracks forming due to internal stresses .



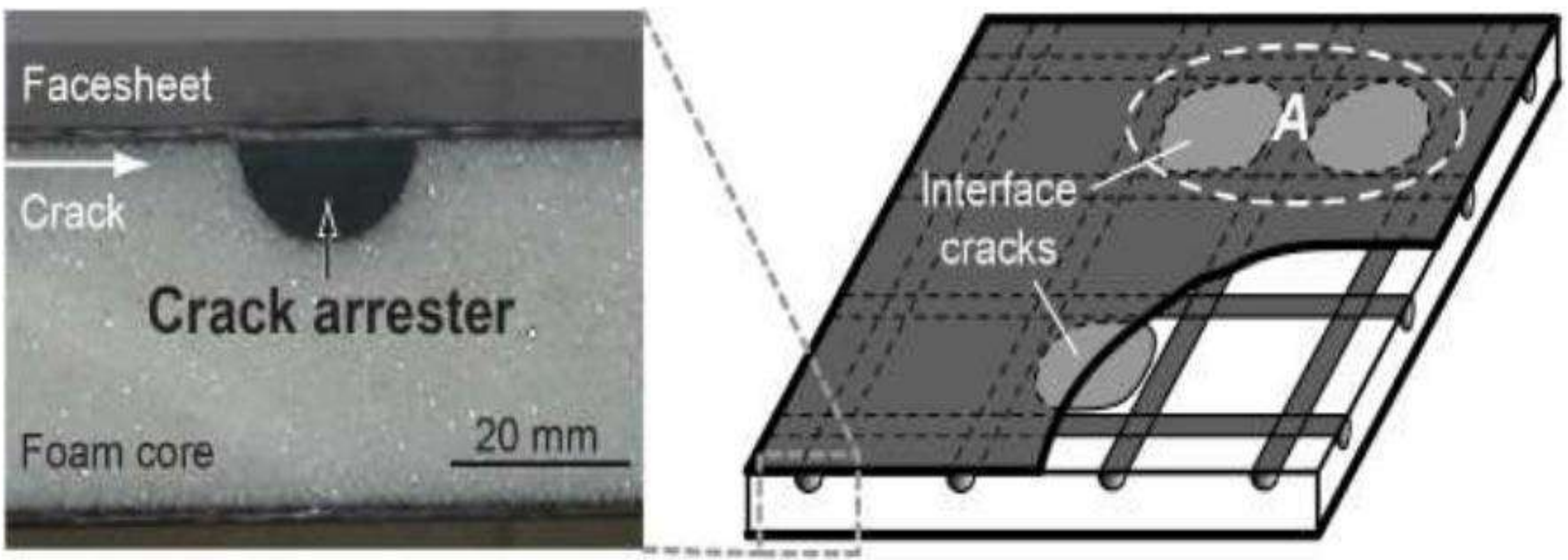
DIFFERENT METHODS OF REPAIR OF CRACKS

1. Non structural or surface cracks -They do not require elaborate measures as they prevail on the surface only. After removal of the rendering, cracks if observed in masonry are cut v shaped upto a depth of 12-30 mm and filled with cement mortar 1:4and then the surface is replastered.

2. Very heavy cracks – If there are very heavy cracks all over the external load bearing wall along with signs of settlement, the wall is considered beyond repair and needs replacement. The load carried by the wall is supported on props , the old wall is demolished part by part and then rebuilt either in brickwork or suitable RCC framework.



3. RCC band (crack arrestor) – an active crack in progress may be arrested by providing an RCC band along the line of crack. RCC band helps in checking further cracking and provide adequate strengthened sections for brickwork. The brickwork has to be opened on either side of the crack upto a depth of 100 to 150mm or one third the thickness of the wall ; the exposed surface is roughened and cleaned , the reinforcement mesh is placed and filled with good concrete . The procedure is repeated on both sides of the wall



3. Cracks over arch openings – In old buildings we can see cracks over arch openings . It indicates that the arch has reached the limit of its load transfer mechanism. If the cracks are not severe they are repaired by driving metallic wedges from below.

4. Stitching – stitching is done to repair cracks of brickwork.

5. Cracks observed at junctions of two different materials RCC columns and masonry walls
   a. RCC columns and masonry wall - cracks appear due to difference in thermal coefficients of the two materials and can be prevented by inserting GI butterfly ties between RCC column and brickwork. The ties are provided at alternate layers of brickwork.
   b. In buildings having this problem and water entering from the crack and causing dampness of thewall , the external plaster on the outer face 100mm on either side of the crack may be taken out and replastered after fixing chicken wire mesh over the crack. In all cases of junctions rendering should be one after fixing chicken wire mesh.