# ARYAN SCHOOL OF ENGINEERING & ECHNOLOGY

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# LECTURE NOTE

SUBJECT NAME- RAILWAY & BRIDGE ENGINEERING

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## Terminology:-

**Ballast:-** Ballast is the granular material packed under and around the sleepers to transfer loads from sleepers to ballast. It helps in providing elasticity to the track.

**Ballast Crib:** The loose ballast between the two adjacent sleepers is known as 'ballast crib'.

**Bearing plates:-** To reduce the intensity of pressure, particularly on soft variety of sleepers, a rectangular plate of mild steel or cast iron is introduced between the rails and the sleepers. This plate is called bearing plate. It distributes the load over a large area of timber sleepers.

**Blocks:** To provide the required gap between the two rails, steel pieces called blocks or 'Heel blocks' are used. Such blocks are used between main rails and check or ground rails.

**Boxing:** The process of filling the ballast around the sleeper is called boxing of the ballast. This ballast boxes the sleeper.

**Broad Gauge:** The gauge of a track in which the distance between the running faces of two track rails is 1.676 meters, is termed as Broad Gauge.

**Buckling of Rails:** The railway track gets out of the original position due to buckling if the expansion of rails due to rise in temperature is prevented during hot weather. This is known as buckling due to rise in temperature rails.

**Bull Headed Rails:** (B.H. Rails) B.H. Rails are those in which head is made little thicker and stronger than lower part i.e. foot by adding more metal at the top.

**Cant 'or' Superelevation:-** On curves, to counteract the effect of centrifugal force, the level of outer rail is raised above the inner rail by a certain amount. This raising of outer rail over the inner rail is called superelevation or cant.

**Cant Deficiency-** The equilibrium cant is provided on the basis of the average speed of different trains on the track. This equilibrium cant or superelevation will fall short of that required for speeds higher than average speed. This shortage of cant is called cant deficiency.

**Chairs:** C.I. chairs are used to hold the bull-headed and double-headed rails. These chairs are fixed to sleepers by round spikes.

**Check rails:** Check rails are provided on the opposite side of the crossing locations for guiding one wheel of the vehicles and thus to check the tendency of another-wheel to climb over the crossings.

**Coaches or Vehicles:-** The passenger compartments are called coaches. They are meant for sitting and sleeping of passengers. Latrines and washing facilities are provided in coaches. They are well lighted; 1st class coaches have more comfortable seats and better amenities than 2nd class coaches, Now-a-days even air-condition coaches are also used.

**Coning of wheels:** The wheels are coned at a slope of 1 in 20 to prevent from rubbing the inside face of the rail head and to prevent lateral movement of the axle with its wheels. This is known as coning of wheels.

**Creep of Rails:** Creep is the longitudinal movement of rails in a track. It occurs due to several reasons. The effect of creep tends to drag the track if ballast is insufficient to hold the rails.

**Crossing clearance:** The clear distance between the wing rail and the crossing rail is known as crossing clearance. This clearance is theoretically same as clearance at the throat but in practice it is slightly greater than at the throat.

**crossing Number:** The number of crossing is defined as the ratio of spread to the length of crossings are designated by this number i.e. (N).

**Crossing stations:** In a single line system, the stations at which up and down trains can pass each others are called crossing stations.

**Cutting:** When the ground has to be cut, it is called cutting. Cutting is termed as shallow cutting when the depth is 3m or less and is called deep cutting when depth is more than 3m.

**Double headed Rails:** These are the rails which have double headed. The bottom and top of the rails are of the same cross-section.

**Drop Pits:** They are rectangular drop pits in which wheels of the locomotive are taken out of for repaire.

**Embankments:** The raised structure above the ground level for carrying the railway track is called embankment. When height of the embankment is more, the sides sleepers are stepped for better stability of slopes.

**Equilibrium Cant or Superelevation:** If the cant or superelevation on the curved track is provided on the basis of Average or Equilibrium speed of the trains running over that section, then such a cant is called Equilibrium cant.

**Facing directions:** A point is called a facing points when a train runs in facing direction only. In this case, the wheels pass over the switches first and then over the crossing.

Fish plates: These plates, resembling in shape of to a fish, are used to provide the continuity between the two rails at the rail-joints. They also provide the required gap for expansion and contraction of rails due to temperature variations. They are made of steel.

Flangeway clearance: This is the distance between the adjacent faces of the stock rails or running rails and the check or guard rails. It is provided for free movement of the wheel flanges.

Flangeway Depth:- It is the vertical distance between the top surface to the running rails ~~and~~ or stock rails top to the surface of the heel block which is used between stock rail and the check rail.

Flare: It is the gradual or tapered widening to the flangeway which is formed by bending and splaying the end of check rail or wing rail away from the gauge line.

F.F. Rails: F.F. Rails have wider or flatter bottom, so that they can be fixed directly on the sleeper, avoiding the necessity of chairs. They are also called Vignole's rails.

Formation: Formation is the prepared subgrade ready to receive the ballast.

Gauge: The gauge of a track in India is measured as the minimum distance between the inner running or gauge faces of the two rails.

Gradient: Any departure of the railway track from the level is known as grade or gradient. It is called an upgradient when the track rises in the direction of motion and a down gradient when track falls below in the direction of movement.

Grade compensation: The amount of gradient is reduced, whenever a curve and gradient have to be provided together. The reduction in grade is known as grade compensation on curves.

Guard Rails: Guard rails are extra rails provided over bridges to prevent damage and danger in case of derailment occurring on the bridges.

Heel: Tapered rails at location where they are fixed to the main rails is called Heel.

Heel Divergence:- Heel Divergence is the distance between the running faces of the stock rail, i.e. gauge faces of stock rail and gauges faces of the tongue rails, when measured at the heel of the switch.

Hogged Rails: Those rails which get battered due to impact action of wheels over the end of the rails are called hogged rails. These rails get bent down and deflected at the ends.

Keys:- Keys are the tapered pieces of timber or steel to fix the rails to the chairs or metal sleepers.

Kinks: The lateral movement of the ends of the rails out of its original position due to several causes such as loose joint, defective gauge etc. from shoulders, are called kinks.

Lead or Crossing Lead:- It is the distance from the heel of the switch to the Theoretical Nose of Crossing (T.N.C.), the distance being measured along the straight.

Left Hand Turnout:- A turnout is called a left hand turnout when the directions is towards the left of the main track in facing direction.

Level crossing: When a railway line and a road cross each other at the same level, it is called a level crossing.

Locomotive:- It is a machine which transfers chemical energy of fuel into mechanical energy of motion. Fuel may be water and coal or diesel a electricity.

Steam Locomotives are designated by the type and number of wheels such as 4-6-2 type locomotive

Metal sleepers: sleepers made of cast iron or steel are called metal sleepers. C.S.T.9 sleeper is most commonly used on Indian Railway.

Metre Gauge: The gauge of a track in which distance between the running faces of two track rails is one metre.

Momentum Gradient:- It is the rising gradient, which takes advantages of a falling gradient in developing the momentum and kinetic energy to negotiate this rising gradient.

Narrow Gauge: The gauge of track in which the distance between the running faces of two track is either 0.762 metre or 0.61 meter.

Negative Cant or Negative Superelevation:

When the turnout or branch lines off from a mainline on the curve on the opposite side, then at a point from where both the track bifurcate or diverge, it is not possible to provide cant for both the tracks at the same place. In such cases, on the branch line where the outer rail is below the inner rail is said to have negative cant or superelevation.

Packing:- The process of ramming the ballast underneath the sleeper is known as 'packing'.

Permanent Track: It is the track which is of permanent nature and handles the normal commercial traffic for which it is meant. It is also called permanent way.

platform:- A raised level surface from where passengers board and alight from trains at the stations is called platform.

Points and Crossings: Points, Crossings, cross-overs and turnout, etc. are contrivances or arrangement by which different routes either parallel or diverging are connected to afford for the train to move from one track to another.

Pusher Gradient: The gradient which requires one or more additional locomotives for hauling the load over the rising gradient is called a pusher gradient.

Rails: Rails are steel girders which provide the hard and smooth surface for movement of wheels of a locomotive and railway vehicles.

Railway Engineering:
Railway engineering is that branch of civil engineering which deals with the construction and maintenance of the railway track for safe and efficient movement of trains on it.

Railway Track: Railway track is the structure provided by rails fitted on sleepers, resting on ballast and subgrade for passage of wheels.

Railway Zones: For improved operations and administration, the Indian Railway have been divided into 9 zones viz- Southern, Central, Western Northern, North-Eastern, Eastern, South Eastern, North-East Frontier and South Central.

Relaying of Tracks: changing of rails, sleepers and fittings is called relaying of track.

Ruling gradient: It is the max^m ~~gradient~~ rising gradient which is provided keeping in view the power of the locomotive.

Siding: When a branch starting from a main line terminates at a dead end with a buffer stop or sand hump, it is known as a siding.

Sleepers: Sleepers are the members laid transversely under the rails which are meant to support the rails over them and transfer the load from rails to ballast.

Sleeper Crib: A track is temporarily supported for repairs and alteration work by girders, piers, etc. over a stack of timber sleepers called sleeper crib. This is adopted on small bridges and culverts where dry bed is available

Sleeper Density: Sleeper density represents the number of sleepers per rail length in metere

Stock Rail: The position of the straight alignment against which the tongue rails fits is known as the stock rails.

Studes!- These are bent plates fixes between the stock rail and tongue rail to prevent the lateral bending of the tongue rail. They are fitted to the web of the stock rails by bolt.

Switch: A switch consists of a stock rail and a tongue rail. Switches are tapered rails with the thicker end known as the heels, fixed to the main track while thinner end known as the toe is kept movable.

Switch angle: This is the angle formed between the running face of stock rail and tongue rail.

**Through Packing:** It is the process of ~~packing~~ replacing the whole track periodically to maintain it in good running condition which otherwise gets disturbed by moving traffic. This through packing is done on programme basis taking the precaution that on each day only that portion should be opened which can be effectively repacked before closing the work on that day.

**Terminal station:** Stations at which the continuity of a main line terminates is called a terminal station.

**Throw of switch:** It is the distance through which the toe of the tongue rails rotates sideways, with heel of tongue rail as the centre of rotation.

**Toe:** Toe is the movable end of the tapered or tongue rail, by means of which the flanged wheels of the train are diverted from one track to another.

**Tongue Rail:** A tongue rail is tapered having toe at one end and heel at the other end. It is fixed at heel end and can move or rotate about this point.

**Track Alignment:** The direction and position given to the centre line of the railway track on the ground is called the track alignment.

**Track Circuit:** The length of track, which is connected by electric circuit to signal cabin, block telegraph apparatus, etc. required for indication of light or bell, is called a track circuit.

**Trailing Direction:** When the switches are seen facing while standing at the crossing, the direction is called trailing direction.

**Transition Curve:** A parabolic curve is introduced between straight and a circular curve or between two branches of a compound curve. For the sake of ease, comfort and safety of movement of trains during transition use is why this is called a transection curve. This curve results in smooth transition due to gradual change in rading.

**Turnout:** A complete set of points and crossing with the intervening lead rails is called a turnout.

**Wagons:** For transportation of goods, wagons are provided in goods train. For transporting different types of goods such as food grains, building material, animals, clothe, coal, sugarcane, petrol, chemicals, oils, explosives automobiles, perishable goods, etc. ~~there are~~

**Wear of Rails:** Due to movement of very heavy loads at high speeds, the concentrated stresses often exceed the elastic limit of metal, resulting in the metal flow. This flowed material of rails is chipped off by the striking of wheels. The rails is then called worn out and this happening is called wear of rails.

## Advantages of Railways

Railways have brought about many political, social and economic changes in the life of Indian people.

### (a) Political Advantages

→ Railways have united the people of different castes, religions customs and traditions.

→ With the adequate network of railways, the central administration has become more easy and effective.

→ Railways have contributed towards development of a national mentality in the minds of people.

→ The role of railway during emergencies in mobilising troops and war equipment has been very significant.

→ Railways have helped in the mass migration of the population.

### (b) Social Advantages

→ The feeling of isolation has been removed from the inhabitants of the Indian Villages.

→ By travelling together into the compartment without any restriction of caste, the feeling of caste difference has disappeared considerably.

→ The social outlook of the masses has been broadened through railway journeys.

→ Railway has made it easier to reach ~~people~~ places of religious importance.

→ Railways provide a convenient and safe mode of transport for the country.

### (c) Economic Advantages

→ Mobility of people has increased, thereby the congested areas can be relieved of congestion and the sparsely populated areas can be developed.

→ Mobility of labour has contributed to industrial development.

→ During famines, railways have played the vital role in transporting food and clothing to the affected areas.

→ Growth of industries has been promoted due to transportation of raw materials through railways.

→ Speedy distribution of finished product is acheived through railways.

→ Railway provide employment to millions of people and thus helps in solving the unemployment problems of the country.

→ Trade developed due to railways thereby has increased the earnings and standard of living of Indian people.

→ Land values have increased due to industrial development which ultimately result in the increase of national wealth.

→ Due to mobility of products through railways, the price stabilisation of commodities could be possible.

→ Commercial farming is every much helped by the railway network throughout the country.

### (d) Techno-Economic Advantages

→ Cost saving in transportation of long haul bulk traffic.

→ Energy Efficiency (railways consume one-seventh of fuel used by ther road sector)

→ Environment friendliness.

→ Higher safety (fatal accidents one-tenth of road sector in India)

→ Efficient Land use and ease in capacity expansion.

## Classification of Indian Railways

Railway Broad has classified the Indian Railway lines on the basis of the importance of route, traffic carried and maximum permissible speed on the routes, into the following 3 main catogories

i) Trunk Routes
ii) Main Lines
iii) Branch Lines

Railway Board has given the following specifications for these lines

(I) Trunk Routs: The following 6 routes of B.G. and 3 routes of M.G. have been classified as trunk routes.

On B.G.
1. Delhi - Mughalsarai - Howarch
2. Delhi - Kota - Mumbai
3. Delhi - Jhansi - Chennai
4. Howrah - Bagpur - Mumbai
5. Mumbai - Guntakul - chennai
6. Howrah - Vijyawada - chennai

On M.G.
1. Lucknow - Gorakhpur - Guwahati
2. Delhi - Jaipur - Ahmedabad
3. chennai - Madurai - Trivandrum

The following track standards for trunk routes have been specified.

| Items | B.G. | M.G. |
|---|---|---|
| 1. Max^m. Permissible speed | 120 kmph | 80 kmph |
| 2. Rail section | 52 kg/m or heavier | 37.2 kg/m (i.e. 75R) |
| 3. sleeper density | (n+7) | (n+7) |
| 4. Ballast cushion | 25cm below sleeper | 25cm. below sleeper |
| 5. Degree of curvature | $7\frac{1}{2}$° | suitable degree |
| 6. Design speed for new track | 160 kmph | 100 km.p.h. |

(II) Main Lines: All lines other than trunk routes carrying 10 Gross Million Tonnes (G.M.T.) per annum or more for B.G. and 25 G.M.T. for M.G. or where maximum permissible speed allowed is 100 km.p.h. for B.G. and 75 km p.h. for M.G. are classified as main lines.

The following specifications have been laid down for main lines by Railway Board:

| Items | B.G. | M.G. |
|---|---|---|
| 1. GMT | ≥ 10 | ≥ 2.5 |
| 2. Max^m. Permissible speed | 100 kmph | 75 kmph |
| 3. Track relaying period | 20 years | 30 years |
| 4. Rail section | 52 kg/m | 37.2 kg/m (or 75R) |
| 5. Design speed for new track | 120 km.p.h | 75 km.p.h. |

(iii) Branch Lines:
These are classified on the basis of following criteria. All those B.G. lines which carry less than 10 Gross Million Tonnes (G.M.T.) per annum and have maximum permissible speeds less than 75 km.p.h. are classified as Branch Lines.
The track specifications would vary depending upon the requirements of traffic subject to the following conditions
(i) B.G. locomotive (WG/WP type) and Bobs wagons would be allowed to operate over all branch lines at a reasonable speed.
(ii) M.G. engines (YG/YP type) and wagons with a maximum axle load of 12 tones would be permitted to operate on all branch lines at a reasonable speed.
(iii) No new rails will normally be used on branch lines.

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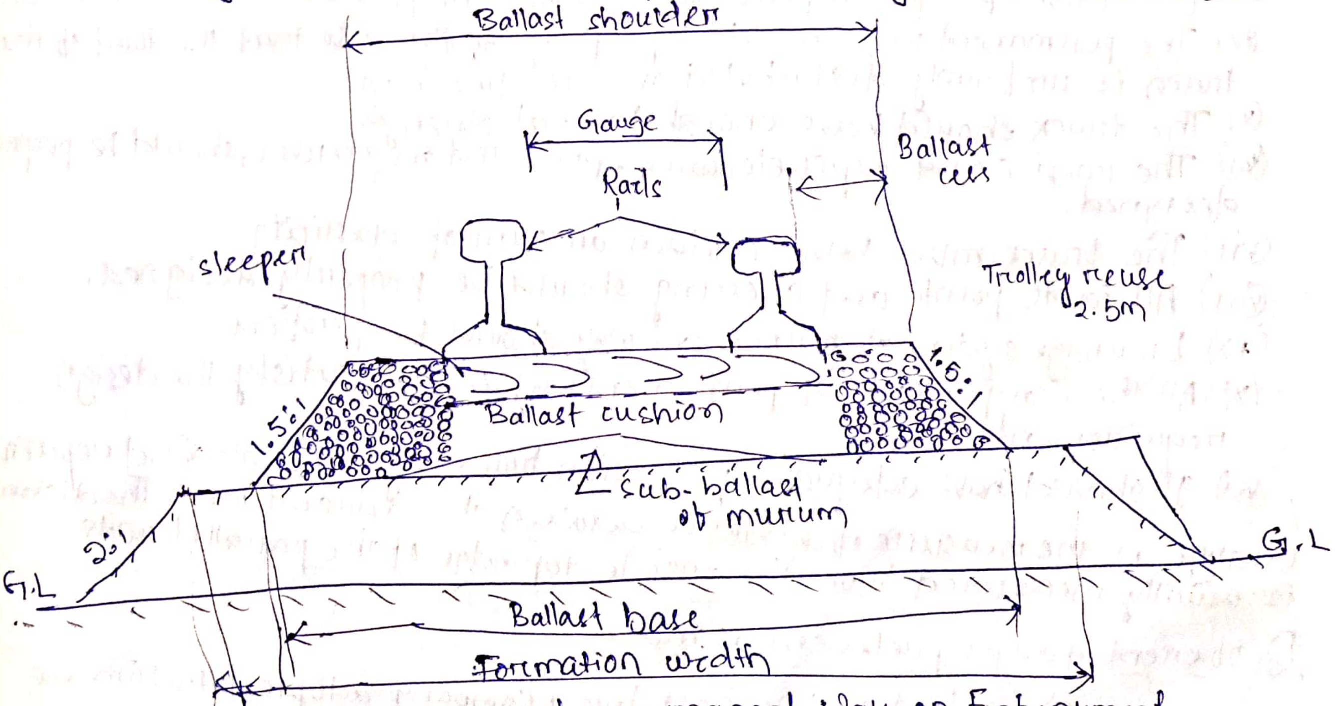
## Railway Track (Permanent Way)

The combination of rails, fitted on sleepers and resting on ballast and subgrade is called the railway track or permanent way. Sometimes temporary tracks are also laid for conveyance of earth and materials during construction works. The name permanent way is given to distinguish the final layout of track from these temporary track. Fig. shows a typical cross section of a permanent way on an embankment.




Typical Cross-sections of a permanent way on Embankment

In a permanent way, the rails are joined in series by fishplates and bolts and then they are fixed to sleeper by different types of fastenings. The sleepers properly spaced, resting on ballast, are suitably packed and boxed with ballast. The layer of ballast rests on the prepared subgrade called the formation.

The rails act as girders to transmit the wheel load to the sleepers. The sleepers hold the rails in proper position with respect to the proper tilt, gauge and level, and transmit the load from rails to the ballast.

The ballast distributes the load over the formation and holds the sleepers in position.

On curved tracks, super-elevation is maintained by ballast and the formation is levelled. Minimum ballast cushion is maintained at the inner rail, while the outer rail gets kept more ballast cushion. Additional quantity of ballast is provided on the outer cess of each track for which the base width of the ballast is kept more than for a straight track.

## Main Components of a Permanent Way

Following are the important of a permanent way

(i) Sub-grade or formation
(ii) Ballast
(iii) Sleeper
(iv) Rails
(v) Fixture and Fastenings

## Requirements of An ideal sleeper :-

Following are the basic requirements of a permanent way

(i) The gauge should be uniform and correct
(ii) Both the rails should be at the same level in a straight track
(iii) On curves proper superelevation should be provided to the outer rail.
(iv) The permanent way should be properly designed so that the load of the train is uniformly distributed over the two rails.
(v) The track should have enough lateral strength.
(vi) The raddii and superelevation, provided on curves, should be properly designed.
(vii) The track must have certain amount of elasticity.
(viii) All joints, points and crossing should be properly designed.
(ix) Drainage system of permanent way should be perfect
(x) All the components of permanent way should satisfy the design requirements.
(xi) It should have adequate provision for easy renewals and repairs

Gauge is the measure of distance between the railroad rails. The distance is usually measured from the inside top edge of the parallel rails.

## Different gauges prelevent in India

→ In India, the East India Company adopted 1.676m i.e. broad gauge or standard gauge.

→ In 1871, in order to build cheap railways for the development of the country (India) the govt. adopted a meter gauge i.e. 1m.

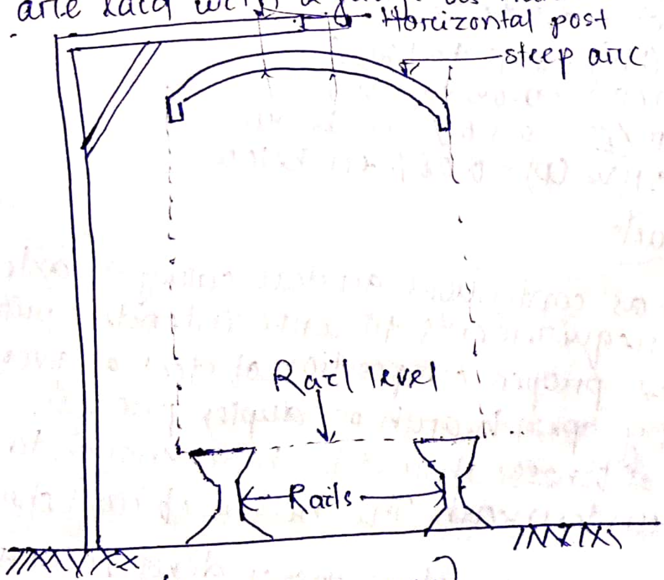
→ In hilly areas or poor areas, generally narrow gauge and feeder gauge is adopted

## Gauges in India

| Types of Gauge | | Gauge Width |
|---|---|---|
| 1. B.G. → | Standard Gauge/ Broad Gauge | 1.676m |
| 2. M.G → | Meter Gauge | 1.00m |
| 3. N.G → | Narrow Gauge | 0.762m |
| 4. L.G → | Feeder Gauge/ Light Gauge | 0.610m |

### Suitability of these gauges under different conditions

1. Traffic condition → If the intensity of traffic on the track is likely to be more, a gauge wider than the standard gauge is suitable.
2. Development of poor areas → The narrow gauges are laid in certain parts of the world to develop a poor area and thus link the poor area with the outside developed world.
3. Cost of track → The cost of railway track is directly proportional to the width of gauge. Hence, if the funds available is not sufficient to construct a standard gauge, a meter gauge or a narrow gauge is preferred rather than to have no railways at all.
4. Speed of movement → The speed of a train is a function of the diameter of wheels which in turn is limited by the gauge. The wheel diameter is usually about 0.75 times the gauge width and thus, the speed of a train is almost proportional to the gauge. If higher speeds are to be attained, the B.G. track is preferred to the M.G. or N.G. track.
5. Nature of Country → In mountainous, it is advisable to have a narrow gauge of track since it is more flexible and can be laid to a smaller radius on the curves. This is the reason why some important railways, covering thousands of Kilometers, are laid with a gauge as narrow as 610mm.




(Loading gauge)

# Rails

The rails on the track can be considered as steel girders for the purpose of carrying axle loads. They are made of high carbon steel to withstand wear and tear. Flat footed rails are mostly used in railway track.

## Functions of Rails

Rails in the railway track serve the following purposes:

→ Rails provide a hard, smooth and unchanging surface for passage of heavy moving loads with a minimum friction between the steel rails and steel wheels.

→ Rails bear the stresses developed due to heavy vertical loads, lateral and breaking forces and thermal stresses.

→ The rail material used is such that it gives minimum wear to avoid replacement charges and failures of rails due to wear.

→ Rails transmit the loads to sleepers and consequently reduce pressure on ballast and formation below.

## Composition of rail steel

(a) For ordinary Rails: High carbon steel with following composition is used

Carbon (C) – 0.55 to 0.68%
Manganese (Mn) - 0.65 to 0.90%
Silicon (Si) - 0.05 to 0.3%
Sulphur (S) - 0.05% or below
phosphorus (P) - 0.06% or below

(b) For Rails on Points and Crossings: Medium carbon steel with following composition is used

Carbon (C) - 0.5 to 0.6%
Manganese (Mn) - 0.95 to 1.25%
Silicon (Si) - 0.05 to 0.20%
Sulphur (S) - 0.06% or below
phosphorus (P) - 0.06% or below

## Requirements of Rails

Rails act as continuous girders carrying axle loads. They should meet the following requirements to serve intended purposes.

→ They should be proper composition of steel as given above and should be manufactured by open hearth or duplex process.

→ The vertical stiffness should be high enough to transmit the load to several sleepers underneath. The height of rail should, therefore, be adequate.

→ Rails should be capable of withstanding lateral forces. Large width of the head and foot endows the rails with high lateral stiffness.

→ The head must be sufficiently deep to allow for an adequate margin of vertical wear. The wearing surface should be hard.

→ Web of rails should be sufficiently thick to bear the load coming on it and should provide adequate flexural rigidity in horizontal plane.

→ Foot should be wide enough so that rails are stable against overturning, especially on curves.

→ Bottom of the head and top of the foot of rails should be so shaped as to enable the fish-plates to transmit the vertical load efficiently from the head to the foot at rail joint.

→ Relative distribution of material of rail in head, web and foot must be balanced, for smooth transmission of loads.

→ The centre of gravity of the rail section must lie approximately at mid-height so that maximum tensile and compressive stresses are equal.

→ The fillet radii must be large to reduce the ~~connection~~ concentration of stresses.

→ The tensile strength of the rail piece should not be less than 72kg/cm$^2$

→ The rail specimen should withstand the blow of 'Falling Weight Test or Tup Test" as specification by Indian Railway standard without fracture.

## Length of rails:

From the consideration of strength of the track maximum possible length is advisable as it will reduce the number of the joints, less number of fittings and textures and economical maintenance. But in practice the following factors are considered to decide the length of rails.

(i) Ease of transportation
(ii) Reasonable cost of manufacture
(iii) Ease in loading into the available wagons
(iv) Development of temperature stresses

Indian Railways have adopted the following length of rails in practice.

(i) For BG tracks = 13m (42')
(ii) For MG & NG tracks = 12m (39')

## Types of Rail sections

There are three types of rail sections

(a) Double headed rails
(b) Bull headed rails
(c) Flat footed rails

### (a) Double-Headed Rails

These rails have used in the early stages of rail road development. They are divided into three sections

- Upper table
- Web
- Lower table

The upper table and lower table were identical, and they were introduced in the hopes of doubling the rail's lifespan. When the upper table wears out, the rails can be placed on the chair upside down and reversed, allowing the lower table to be used.

However, this plan quickly proved to be incorrect since the continuous contact of the lower table with the chair caused the lower table's surface to become rough, making smooth train operation impossible. As a result, this type of rail is almost obsolete. These rails are now available in lengths ranging from 20 to 24 feet.

b) Bull headed rails:

This type of rail is made up of three pieces

- The head
- The web
- The boot.

Steel was used to construct these rails. The head is larger than the boot and the boot holds the wooden keys that fasten the rails in place. As a result, the boot's sole purpose is to provide the required strength and rigidity to rails.

When these rails are used, two cast iron chairs are required for each sleeper. Their weight ranges from 85 to 95 pounds, and they can grow up to 60 feet long.

c) Flat-footed rails:

These rails were first invented in 1836 by Charles Vignoles and so are also known as Vignoles rails. They are divided into 3 section.

- The head
- The web
- The foot

This type of rail has grown in popularity to the point where it now makes up over 90% of all railway lines in the world.

The benefits of flat-footed rails are as follows

→ They don't require a chair and can be spiked or keys to the sleepers directly.

→ They are thus cost-effective. They're less expensive than bull-headed rails

→ Both vertically and laterally, they are substantial stiffeners for curves, lateral rigidity is crucial.

→ They are less prone to kinking and have a more consistent top surface than bull headed rails.

The weights from train wheels are distributed over a large number of sleepers and hence a broader area, resulting in increased track stability, longer rail and sleeper life, lower maintenance costs, less rail failure and fewer traffic delays

Rail Wear

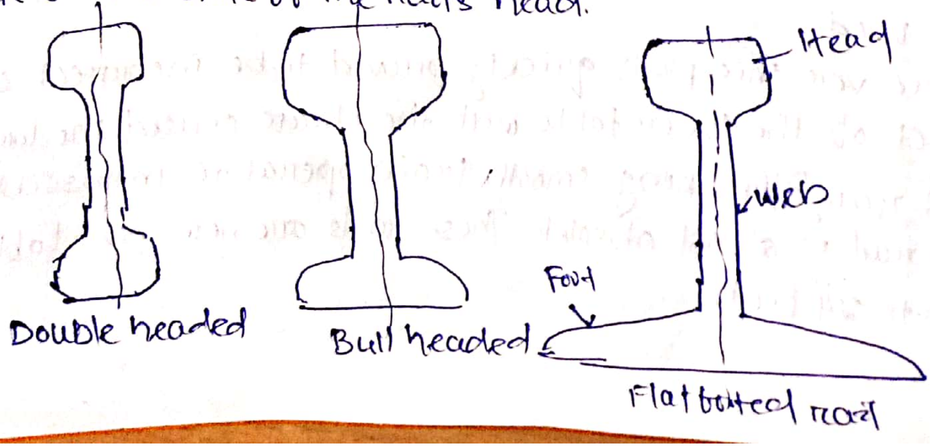
Wear is defined as the abrasion or cutting of rail owing to friction and abnormally high loads.

There are 3 different types of rail wear

→ Wear on the top of the rails

→ Wear on the head of the rails at the end of the rails

→ Wear on the side of the rails' head.



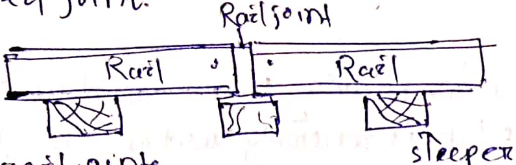
# Rail joints

Rail joints are necessary to hold the adjoining ends of the rails in the correct position, both in the horizontal and vertical planes.

Following are the types of rail joint

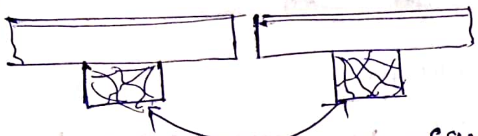
(a) Supported rail joints:

When the rail ends rest on a single sleeper it is termed as supported joint. The duplex joint sleeper with other sleepers is an example of the supported joint.



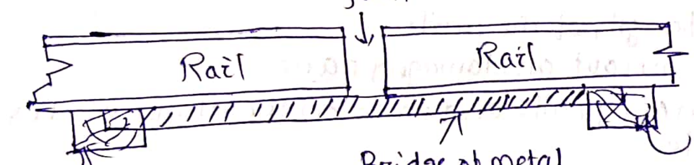

(b) Suspended rail joints

When rail ends are projected beyond sleepers it is termed as suspended joint. This type of joint is generally used with timber and steel through sleeper




(c) Bridge joint:

When the rail ends are projected beyond sleepers as in the case of suspended joint and they are connected by a flat or corrugated plate called as bridge plate it is termed as a bridge joint



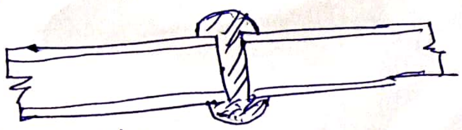

(d) Insulated joint:

When an insulating medium is inserted in a rail joint or stop the flow of current beyond the track circuited part then that type of joint is called an insulated joint

(e) Compromise joint:

Where two different rail sections are required to joined together it is done by means of fish plated which fit both rails and this joint is termed as compromise joint.

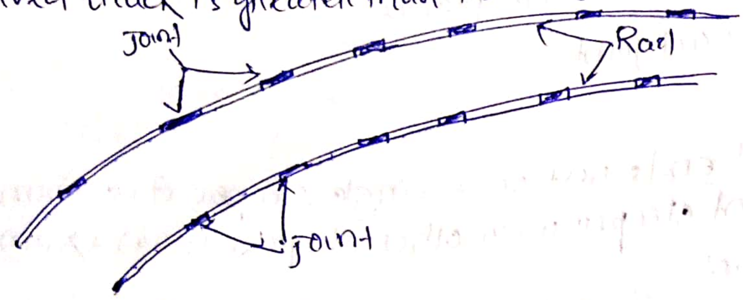
(f) Welded joint:. These are the best joints as they fulfil nearly all the requirements of an ideal or perfect joint.



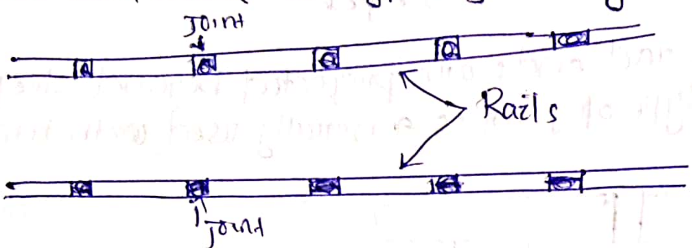
(g) Staggered/broken joint:

The joints on railway track are not directly opposite to the joints of the rail tracks.

→ These joints are generally provided on curves, where the length of outer curved track is greater than the length of inner curved track.




(h) Square or Even joint: The joint of the one railway track are directly opposite to the joints of other rail track. This type is generally used on straight track.




square joint

(i) Expansion joint: In bridges, provision for expansion and contraction is kept for girders and rails both.

Purpose of welding rails:

→ To increase the length of the rails
→ To repair the worn out or damaged rails
→ To build up worn out points and rails on the sharp curves

Advantages of welding rails:

→ Reduces the creep and friction due to increase in length of rail.
→ Expansion effects due to reduction in temperature.
→ Increase the life of the rails due to decrease in wear
→ It facilitates track circuiting on electrified tracks
→ The cost decrease because as the length increase automatically the number of joints decreases.
→ High frequency vibrations due to heavy moving loads are decreased due to the heaviness of the rails.

Creep of Rail:

It is defined as a longitudinal movement of rail with respect to sleeper. Rail have the tendency to gradually move in the direction of dominant traffic. The creep of rail is common to all railway tracks and its value varies from almost nothing in some causes to about 130 mm/month in creep.

Causes of creep:

(a) Accelerating or starting of train

At the time of acceleration, wheel gives lateral thrust which causes creep of rail.

(b) Deaccelerating or stopping of train:

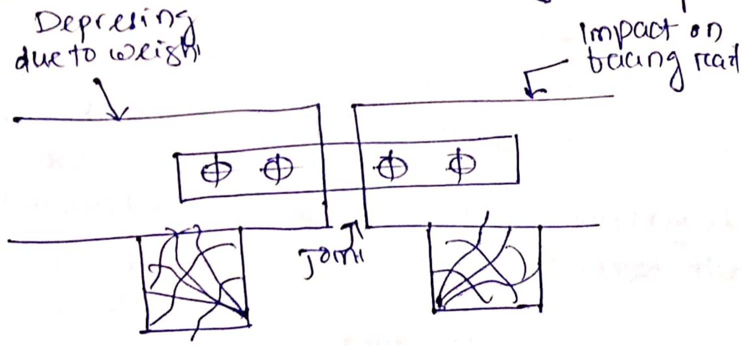
If sudden stopping of train takes place, braking effect tends to push the rail forward and thus causes creep in forward direction.

(c) Wave action or Wave Theory:

As train is passing under the rolls the portion under the rolling wheels is compressed and depressed slightly due to wheel loads. As more the wheel moves this depression also moves and the portion which is under depression previously comes back to its original position.

(d) Percussion Theory:

This type of creep of rail occurs due to impact of load. In this type, when the wheels of rail passes over the joint, the trailing rails gets depressed down and the wheel gives impact to the facing of rail.




In addition to this creep of rail may also be caused due to following reason.

→ Insufficient numbers of sleepers is laid
→ Uneven spacing of sleepers
→ Improper expansion joints
→ Use of improper and faulty sleepers
→ Rails too light for the traffic carried by them.
→ Poor drainage work
→ Improper maintenance of track gauge and joints.

Effect of creep:

→ The results of creep are of very serious nature and hence great care should be taken to detect and repair the creep.

→ The suspended joints starts becoming supported joints and rails ends get battered.

Scanned by CamScanner

→ The sleepers move out of their position and hence the rail gauges is disturbed and also the rail level. This result in bad running of train.

→ Due to creep the position of point and crossing will be disturbed and it will difficult to maintain a correct gauge and alignment.

→ The interlocking mechanism of the signal are disturbed due to creep.

→ Rail joints get opened out resulting in bolts holes getting elongated and premature fracture of fishplates and bolts.

Measurements of creep:

Creep posts should be erected by every kilometer on either side of the track and the position of joints should be marked on one of the posts. The measurement of creep should be taken frequently at an interval of about 3 months in a prescribed register to be maintained by the P.W.I. creep in excess of 150mm (6 inches) should not be permitted on standard track and at one location not more than six consecutive rails should be found jammed in single rail track. In approaches of points & crossings, there should be no creep.

# Sleepers

Sleepers are the transverse ties that are laid to support the rails. They have an important role in the track as they transmit role in the track as they transmit the wheel load from the rails to the ballast.

## Function of sleepers:

→ To hold the rails to correct gauge and alignment
→ To give a firm and even support to the rail
→ To transfer and distribute the axle load through rail over a sufficiently large area of ballast.
→ To act as an elastic medium between the rails and ballast to absorb vibrations and blows of the moving wheels.
→ To maintain the alignment of the track
→ To provide insulation for the electrified track.
→ To provide a proper grade, longitudinal and lateral stability to the track.
→ To provide means for easy replacement of rail fastening without disturbing the traffic during the service life.

## Requirement of An Ideal sleeper:

→ It should be economical
→ The fitting of the sleepers should be such that they can be easily adjusted during maintenance.
→ They should not be too heavy or excessively light in weight.
→ They should have long life.
→ They should be able to maintain the correct gauge
→ They should be quite durable.
→ The bearing area of sleepers should be enough to resist crushing.
→ They should faciliate easy removal and replacement of ballast
→ They should be capable of resisting shocks and vibrations due to heavy moving loads.
→ They should be suitable for track circuiting if required
→ The design of sleepers should be such that they are not pushed out easily due to moving trains.
→ They should have high scrap value.

## Different types of sleepers:-

According to the use of materials, railway sleepers are classified into the following categories

(1) Timber or wooden sleeper
(2) Metal sleeper (a) steel sleeper
(b) Cast Iron sleeper
(3) Concrete sleeper (a) R.C.C sleeper
(b) Prestressed sleeper

## 1 Wooden sleeper :-

These are commonly 254mm wide by 127mm thick in cross section by 2600mm long. The sleepers are first seasoned and treated with preservative. Creosote is an oil generally used/sprayed on the surface. They are either hardwood or softwood typ.

Wooden sleepers are the ideal type of sleeper. Hence they are universally used. The utility of timber sleepers has not diminished due to the passage of time

### Advantages of wooden sleepers

→ They are easily liable to attack by vermin and weather
→ They are susceptible to fire
→ It is difficult to maintain gauge in case of wooden sleepers
→ Scrap value is negligible.
→ Their useful life is short about 12 to 15 years.

## 2 Metal sleeper

Sleepers are beds in the railway tracks. The main reason to use metal sleepers are because of insufficiency of wooden sleeper. Metal sleepers use widely in the modern construction of railway tracks. The main role of sleeper is to transfer load from rails to the ballast. The metal sleepers are cast iron and steel.

### Advantages :-

→ Metal sleepers are uniform in strength and durability
→ For metal sleepers no frequent renewal requires
→ It is economical and have longer life
→ Low maintenance and easier repair
→ Gauges are easy to maintain and adjustable.
→ Easy in manufacturing and laying.
→ The fittings operation is better and it makes less occurrence of creep.
→ It is fireproof
→ It is reusable and have a good scrap value
→ The manufacturing of sleepers is a simple process.
→ The fixtures of the sleepers are less in number and simple in nature.

### Disadvantages

→ More ballast requires for metal sleepers
→ Difficult to maintain due to rust and other chemical gents in atmosphere.
→ And it is more likely subjects to corrosion/rusting.
→ As a good conductor of electricity it interfaces with track circuitings
→ It is not suitable for level crossing and bridges.
→ Unsuitable in case of pointing.
→ Creep occurs frequently
→ It subjects easily to deform and bend due to heavy moving loads in it.
→ Suitable only for stone ballaste.
→ Cracks develop easily in metal sleeper seats through the holes of bolts
→ More care has to take to maintain steel sleepers.

(iv) steel sleepers:

→ Steel ties are used where wood or concrete is not favorable, for example in tunnels with limited headway clearance.

→ They are also used in heavy curvature prone to gage widening.

→ This type of steel ties can cause problem to signals control system.

Advantages

→ It is more durable. Its life is about 35 years

→ Lesser damage during handling and transport

→ It is not susceptible to vermin attack.

→ It is not susceptible to fire.

→ Its scrap value is very good

Disadvantages

→ It is liable to corrosion.

→ Not suitable for track circuiting

→ It can be used only for rails for which it is manufactured.

→ Cracks at railseats develop during the service.

→ Fittings required are greater in number.

C.I. sleepers

Advantages:

→ Service life is very long

→ Less liable to corrosion.

→ Form good track for light traffic up to 110 kmph as they form rigid track subjected to vibrations under moving loads without any damping

→ Scrap value is high.

Disadvantages

→ Gauge maintenance is difficult as tie bars get bent up.

→ Not suitable for circuited track.

→ Need large number of fittings

→ Suitable only for stone ballast.

→ Heavy traffic and high speeds (> 110 kmph) will cause loosening of keys and development of high creep.

3 Concrete sleeper

Advantages:

→ It is more durable having greater life (upto 50 years)

→ It is economical as compared to wood and steel

→ Easy to manufacture

→ It is not susceptible to vermin attack

→ It is not susceptible to fire

→ Good for track circuited areas

Disadvantages

→ It is brittle and cracks without warning.

→ It cannot be repaired, and required replacement.

→ Fittings required are greater in number

→ No scrap value.

(a) Reinforced Concrete sleeper:- (Fig 9.12)

There are of two types

(i) Through type, (ii) Composite or Block and tie type.

In through type, when concrete sleeper is stressed, cracks on the tension side are inevitable. Though the cracks are very small and almost invisible but they tend to enlarge with repetition of the impact loadings of the fast trains. This is the main cause of the failure of these sleepers.

These composite or block and tie type of sleepers are not subjected to same degree of tensile stress and have given excellent results in France where a steel tie of inverted T-section is used. It is not in use, at present

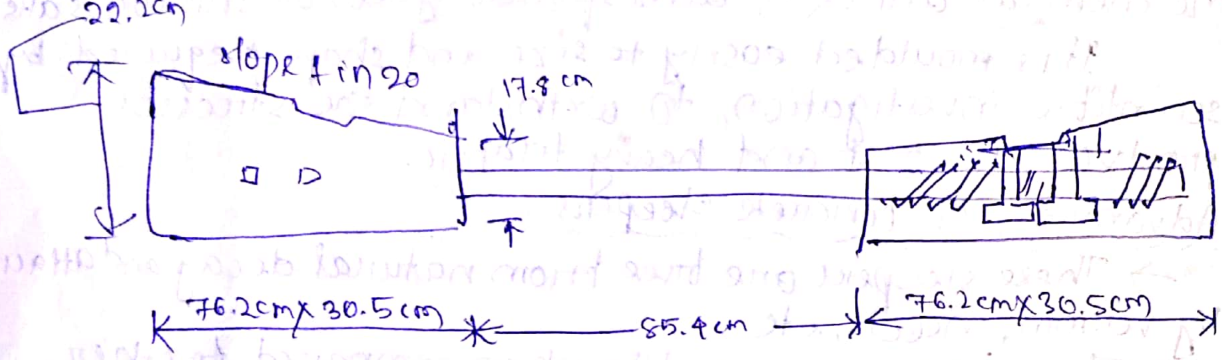



Fig 9.12 Reinforced Concrete sleeper (Composite Type)

(b) Pre-stressed Concrete Sleepers (Fig 9.13)

All the disadvantages of reinforced concrete sleepers have been eliminated by prestressing technique for sleepers. In prestressed concrete sleepers, the concrete is put under a very high initial compression. The design is based on

(i) The max^n permissible compressive strength of 211 kg/cm².

(ii) The minimum cube crushing strength of concrete in the sleeper is 422 kg/cm² at 28 days, and

(iii) The pre-stressed wires are stressed to an initial stress of 8.82 kg/cm².

Disadvantages of Pre-stressed Concrete sleepers.

(i) There are heavily damaged in case of derailments.

(ii) The bed of the ballast is specially prepared.

(iii) These are uneconomical.

(iv) The standard of maintenance for the track, where these sleepers are used, is to be kept very high.

(v) They are more rigid in nature.

(vi) The design and construction is complicated but even then the desired strength is not developed at the centre of sleeper. (9)

Comparision of different types of sleepers

| S.No. (1) | Point of Comparision (2) | Wooden sleeper (3) | C.I. sleeper (4) | steel sleeper (5) | Concrete sleeper (6) |
|---|---|---|---|---|---|
| 1. | Cost per sleeper | Low | Medium | High | Depends upon design |
| 2. | Life | 10 to 15 years for untreated sleepers. 20 to 25 years for treated sleepers. | 35 to 50 yrs | 35 to 50 yrs | 40 to 60 yrs. |
| 3. | Weight per sleeper for B.G. track | Low | Heavy | Medium | Depends upon design but heavier than others |
| 4 | Maintenance cost | Higher than other sleepers | Minimum | moderate | moderate |
| 5. | Overall economy | cheaper in the initial cost but expensive in long run | costlier in first cost but cheaper in long run | same as for C.I. | Under trail |
| 6. | Handling | Not liable to break under rough handling | Liable to break under rough handling | Not liable to break, if clip and bolts are used | with improved design, not liable to break |
| 7. | Track fittings | Requires less fittings | Requires more fittings | Requires less fittings | Requires less fittings |
| 8. | Elasticity | Good | Not so good | Not so good | Not good |
| 9. | Laying and Relaying | Easiest | Difficult due to large number of fittings | Easy due to light weight | Difficult by manual labour. Easy if mechanical devices are used |
| 10. | Rigidity of Track | Poor both laterally and longitudinally | Better than timber sleeper | Better than timber sleeper | Best because of heavy dead weight |
| 11. | Suitability of Track | Generally suitable in all locations except areas of vermins and white ants. Specially suitable for point | | | |

2(a) Cast-Iron sleeper :- Cast Iron sleepers have been extensively used in India and on a small scale in South America. They are of following types.
(1) pot or Bowl sleepers (2) plate sleepers, (3) Box sleepers.
(4) C.S.T-9 sleeper (combination of plate and box type),
(5) Rail free duplex sleeper.
(1) pot or Bowl sleeper :- They consist of two bowls or pots placed inverted on the ballast.
(2) plate sleeper :- This sleeper consists of rectangular plates about 86.5cm x 30.5cm in size with 30.5cm side parallel to the rails and of projecting ribs under the plates for lateral stability. The plates are held in position with tie bars, the connection being similar to that with pots, gibs and cotters, distance pieces and keys or keys alone being used.

It provides the effective bearing area of 0.464 sq.m per sleeper on Broad Gauge. Both, pot and plate sleepers, can be used with flat-footed and bull headed rails, but they have to be casted accordingly, Jaws form an integral part of the casting in case of bull-headed rails. A rail seat or chair is provided to hold the Flat-footed or Bull-Headed rails respectively with 1 in 20 cant.

The various types of cast iron plate sleepers are being used such as (i) DO plate sleeper, (Denham and Olphert's sleeper), (ii) Laidly Pedestral, (iii) The lines patent (iv) N.W.R type, (V) L.K. type, (vi) K.K. type, (vii) 3S/T.S. (viii) C.S.T. 4, (ix) C.S.T. 4A, (x) C.S.T. 9, (xi) Rail free duplex sleeper.

Out of the above types, the cast iron sleeper currently used is known as the C.S.T-9, (Being 9th of the series produced by Central standard office) in which the cast iron component has a shape combining the pot, bowl and plate. This C.S.T-9 plate sleeper has been standardin and widely used on Indian Railways.

(3) Box sleeper :- This sleeper is out of use these days and therefore, it is not discussed over here.

(4) C.S.T.-9 sleeper :

This sleeper was standardised by Track standard Committee. It has been extensively used on Indian Railways for the last thirty years and moreover, its comparative satisfactory behaviour has resulted in the withdrawal of all the previous designs.

It has a triangular inverted pot on either side of the rail seat, a plate with the projecting rib and a box on the top of the plate.

(5) Rail Free Duplex sleepers :-

A joints sleeper of cast iron known as rail free duplex sleeper has been used as rail joints in conjuction with C.S.T-9 sleepers. These sleepers are used to prevent the ~~ends~~ cantilever action between the two supports of the sleeper with any fitting. Duplex sleepers give added strength to the rail near the joint. Their use is not very popular due to the fact that rail ends supported on this sleeper gets ~~very~~ severely battered. (Fig 9.7)

# Ballast

## Definition

It is a layer of broken stone or any other such gritty material laid and packed below and around sleeper.

## Functions of ballast

→ To distribute the loads uniformly over the subgrade.
→ To provide good drainage for the track structure.
→ To provide elasticity and resilience to track for getting proper riding comfort.
→ To held the track structure to line and grade.
→ To reduce dust.
→ To prevent growth of brush and weeds.

## Requirements of Good Ballast

→ It should be tough and should not crumble under heavy loads.
→ It should not make the track dusty or muddy.
→ It should offer resistance to abrasion and weathering.
→ It should not produce any chemical reaction with rails and sleepers.
→ The materials should be easily workable.
→ It should retain its position and should not be distributed.

## Materials used as ballast

1. Broken stone:- Broken stone is one of the best materials for railway ballast to be used on the railway tracks. Almost all the important railway tracks are provided with broken stone. The stone to be used as railway ballast should be hard, tough nonporous and should not decompose when exposed to air and light. Igneous rocks like quartzite and granite forms the excellent ballast materials. When these are not available then lime stone and sandstone can also be used as good ballast material.

Advantages:-
→ It holds the track in position
→ It is good for heavy traffic
→ It can serve high speeds equally well.

Disadvantages
It expensive in its initial cost

2 Gravel:-
Gravel ranks next in its suitability for use as material for ballast and is used in many countries of the world in very large quantities. Gravel consists of worn fragments of rocks occurring in natural deposits. Gravel or shingle may be obtained from river bed or it may be dug out from gravel pits.

Advantages
→ It is cheaper in its cost as it has not to be broken as like stone ballast.
→ It has got excellent drainage properties, if properly cleaned.

Disadvantages
→ It easily rolls down under the vibrations and packing under the sleepers gets loose.
→ The variation in size is considerable and hence requires screening before use.
→ Gravel as obtained from gravel pits, is full of earth and hence requires proper cleaning if proper drainage of the track is to be done.

## 3 Cinders or Ashes:-

The residue from the coal in locomotives or other furnaces is called cinder or ashes. It is one of the universal forms of ballast as it is a byproduct of all the railway which use coal as a fuel.

### Advantages:

→ Handling of the material is not cumbersome this materials can be handled easily

→ Cost is very low and hence can also be used for sidings.

→ It has got fairly good drainage properties.

→ Large quantities of this material can be made available at short notice.

→ In case of emergence such as caused by the destruction of portions of railway track during floods

This material proves to be very useful and is used in the formation repairing as well as for packing of track.

### Disadvantages

→ It is highly corrosive and cannot be used where steel sleepers are fixed.

→ The foot of the rails get affected due to use of this type of material as ballast.

→ It is very soft and can easily be reduced to powder under vibrations and hence the track becomes very dusty. This is objectionable particularly in dry weather.

## 4 Sand:-

Sand is another good materials for railway ballast, coarser sand is to be preferred to finer sand and the best sand is that which contains a quantity of fine gravel varying in size from $\frac{1}{8}$ upwards.

### Advantages

→ If the sand is free from earth and vegetation then it has good excellent properties to drain off water immediately

→ It is cheaper if available in nearby locality

→ It produces very silent track and hence are suitable for packing cast iron pot sleepers.

### Disadvantages

→ Its gets easily disturbed under vibrations and hence its maintenance is very difficult.

→ The sand can be easily washed off or blown away and hence requires frequent renewal.

→ The sand particles may get into the moving parts of the vehicles and produces friction. This leads to heavy wear of vehicles.

## 5 Kankar:-

Kankar a lime agglomerate is found in many places in the form of nodules of varying sizes

### Advantages

→ Kankar is suitable materials for ballast when other good material for ballast is not available or if available. uneconomically.

→ Kankar is good for light traffic on metre and narrow gauges

### Disadvantages

→ It is a very soft and can be reduced to powder form easily, hence, making the track dusty.

→ The maintenance of track is very difficult

6. Moorum: The decomposition of laterite results into the formation of moorum. It has red and sometimes yellow colour. The best moorum is that which contain large quantities of small laterite stones.

Advantages

→ Moorum is good materials for ballast when other materials for ballast is not available

→ Moorum can be safely used on newly laid track and acts as a soling when broken stones are laid afterwords.

→ Moorum has got good drainage properties

Disadvantages

→ Moorum is very soft and reduce to powder and hence to dust form in short time.

→ Maintenance of tracks laid with this materials is difficult.

7. Brick Ballast or Brick Bats:

Sometimes the broken pieces of over burnt bricks, called brick ballast are used as materials for ballast.

Advantages

→ It has got excellent drainage properties

→ They can be used as good ballast materials where suitable material for ballast is either unavailable or uneconomical.

Disadvantages

→ Brickbats turn down into powder from easily and hence the track becomes dusty.

→ Maintenance of the track laid with this material as ballast is very difficult.

→ Rails are often corrugated on the tracks laid with this materials as ballast

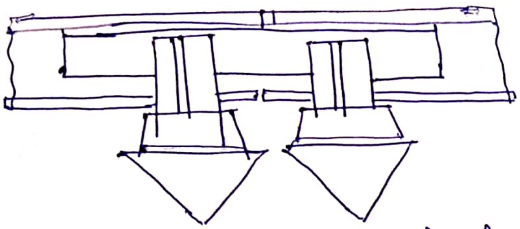
8. Earth Selected → Selected earth may be used as materials for railway ballast for sidings and also for newly laid tracks.

# Track fixtures for B.G.

**Fastening:** A rail fastening system is a means of fixing rails to railroad ties. The terms rail anchors, tie plates, chairs and track fasteners are used to refer to parts or all of a rail fastening system. Various types of fastening have been used over the years.

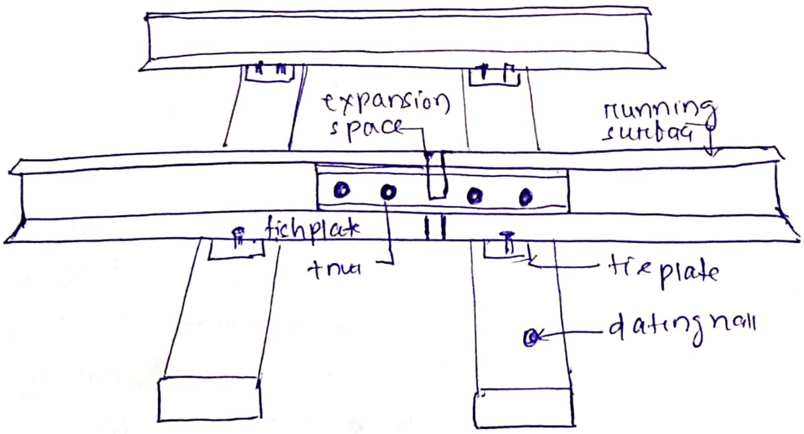
**Fishplates:**

In rail terminology, a fishplate, splice bar or joint bar is a metal bar that is bolted to the ends of two rails to join them together in a track. The name is derived from fish, a wooden bar with a curved profile used to strengthen a ship mast. The top and bottom edges are tapered inwards so the device wedges itself between the top and bottom of the rail when it is bolted into place. In rail transport modeling, a fishplate is often a small copper or nickel silver plate that slips into both rails to provide the function of maintaining alignment and electrical continuity.

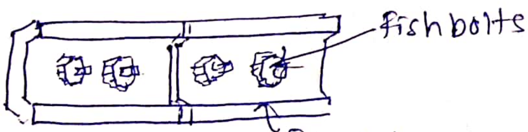


Fish as specified

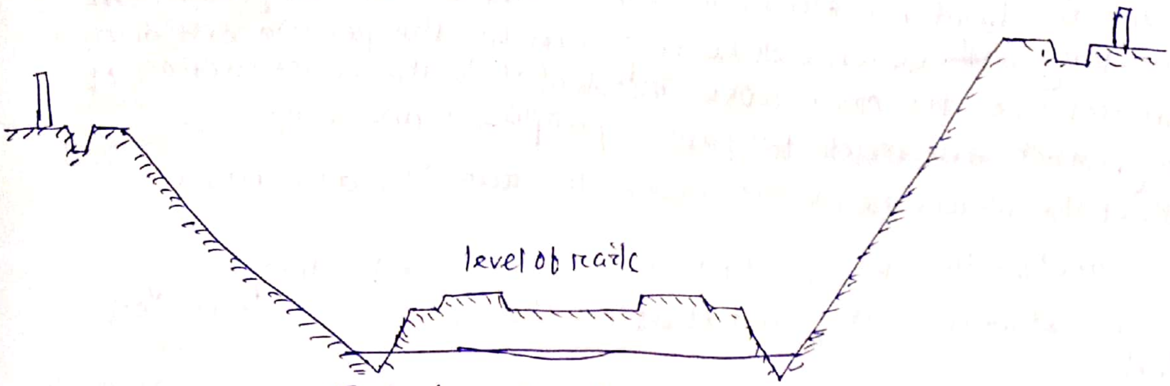
The first railway fishplate



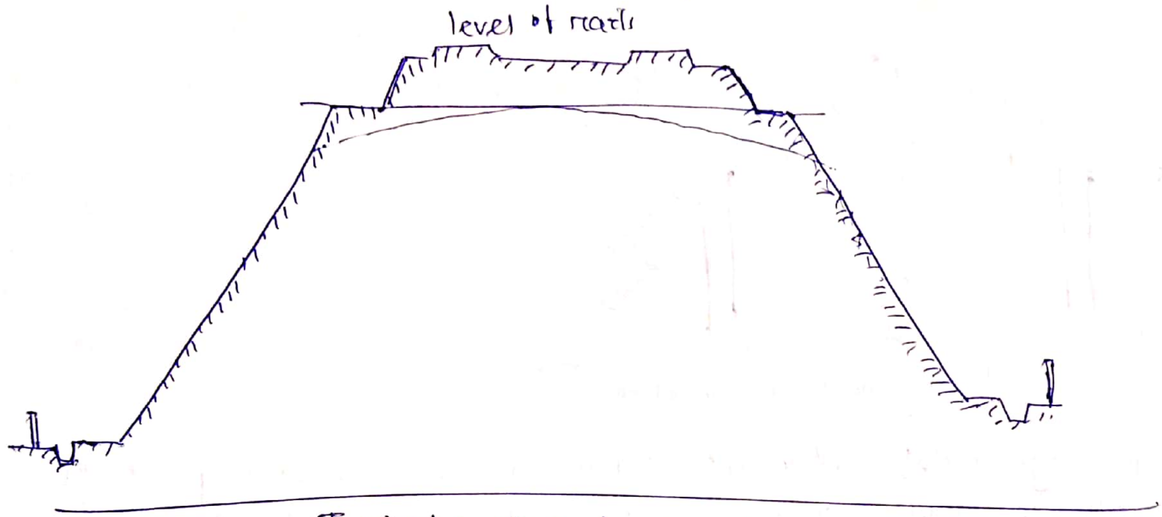

RAIL-TO-RAIL Fastenings



## Geometric for Broad Gauge




Typical section of Railway in cutting




Typical section of an embankment

**Landwidth:-** With a view to determine what the ~~displacement~~ disposition of the land will probably be on the completion of the work for which it had been acquired, the classification given in ~~paragraph~~ ~~etc~~ etc adopted.

On railways, land is divided into two classes etc.

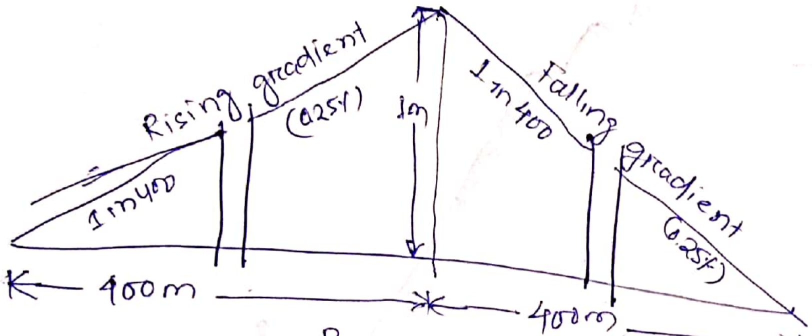
(a) Permanent landwidth and

(b) Temporary landwidth

**Permanent landwidth:-** is land which will be required permanently after the railway is open for traffic and the work of construction is complete. Under this head will be included all land to be occupied by the formation of the permanent line of railway width side slopes of banks and cuttings and the berms connected therewith, catchwater drains and borrow pits or such parts of them as it is necessary to retain, the entrances to tunnels and shafts belonging to them, the sites of bridges and protection or training works: stations yards, landing places for railways terrace, ground to be occupied by works belonging to the railway such as gas works, arrangements for water supply, septic tanks, collecting pits, filter beds and pumping installation & churches, plantation gardens and recreation grounds, sites for station, offices, workshops, dwelling houses and other buildings required for the purposes of the railway, or the accommodation of the staff, with the grounds, yards, roads & c. appertaining thereof. Under this head will also be included land outside the permanent railway boundary, ~~with~~ which will be required for the permanent diversion of roads or river, or for other works incidental to the construction of the railway, which are made for public purposes and will not on completion of the works be maintained by the railway authorities.

**Temporary landwidth:** It is land which is acquired for temporary purposes only, and which is disposed of after the work of construction is completed.

**Gradients for drainage.**




Rising and falling gradient

Drainage is defined as interception, collection and disposal of water away from track. Drainage is the most important factor in track maintenance and for stability of banking/cuttings. When water seeps into the formation, it weakness the bonds between the soil particles, soften the soil and results in creation of ballast pockets. On one hand, ingress of water into bank/cuttings adds to weight of soil mass trying to slide thereby increasing propensity for slope-slide, on the other hand, it reduces shear strength of soil, thereby decreasing factor of safety for stability of slope. Therefore, quick disposal of water from formation top slopes is very essential. Drainage system should be effective in preventing the stagnation of water and allow quick disposal of water. At present, the drainage is not being given its due importance in field. Provisions relating to drainage have been detailed in various guidelines issued by RDSO from time to time, however, the present Guidelines highlights the salient features of drainage arrangement in embankment as well as cutting.

**Conventional drainage system**

- surface drainage
- Side drains
- catch water drains
- Subsurface drain

## Superelevation:.

Cant or superelevation:- is the amount by which one rail is raised above the other rail. It is positive when the outer rail on a curved track is raised above inner rail and is negative when the inner rail on a curved track is raised above the outer rail.

Equilibrium speed:- It is the speed at which the centrifugal force developed during the movement of the vehicles on a curved track is exactly balanced by the cant provided.

Cant deficiency:- Cant deficiency occurs when a train travels around a curve at a speed lower than the equilibrium speed. It is the difference between the actual cant and the theoretical cant required for such a lower speed.

Cant excess: Cant excess occurs when a train travels around a curve at a speed lower than the equilibrium speed. It is the difference between the actual cant and the theoretical cant required for such a lower speed.

Maximum permissible speed of the curve: It is the highest speed which may be permitted on a curve taking into consideration the radius of the curvature, actual cant, cant deficiency, cant excess and the lengths of transitions. When the maxm permissible speed on a curve is less than the maximum sectional speed of the section of a line, permanent speed restriction becomes necessary.

Cant gradient: and cant deficiency gradient indicate the amount by which cant or deficiency of cant is increased or reduced in a given length of transition e.g. 1 in 1000 means that cant or deficiency of cant of 1mm, is gained or lost by every 1000mm of transition length.

Rate of change of cant: or rate of change of cant deficiency is the rate at which cant or cant deficiency is increased or reduced per second, at the maximum permissible speed of the vehicle passing over the transition.

Superelevation, Cant deficiency and cant excess

(1) superelevation

(a) The equilibrium superelevation/cant necessary for any speed is calculated from the formula

$$C = \frac{GV^2}{127R}$$

where $e$ is cant/superelevation in mm, G is the gauge of track + width of rail head in mm

R is radius of curve

Necessity of superelevation:-

When a main line is on a curve and has turnout of contrary flexure leading to a branch line, the superelevation necessary for a average speeds to trains running over the main line curve cannot be given.

If the combination of lateral displacement of the centre of gravity provided by the superelevation, velocity of the rolling stock and radius of curve is such that resulting force becomes centered between and perpendicular to a line across the running rails the downward pressure on the outside and inside rails of the curve will be the same.

The superelevation that produces this condition for a given velocity and radius of curve is known as the balanced or equilibrium elevation.

## Limits of superelevation and cant deficiency

Superelevation should be provided in such a way as to accomodate various trains running with different speeds from time to time. There are limits to the amount of superelevation which may be provided safely.

Normally, the maximum permissible values of superelevation according to the Railway Board is $\frac{1}{10}$th of gauge. Therefore, the maximum permissible values in India for different gauges are

Limits of superelevation

| Gauges | Max^m S.E. when $V \leq 100$ kmph | | Max^m S.E. for high speeds is $V \geq 120$ kmph | | |
|---|---|---|---|---|---|
| | Under ordinary conditions | Under special permissible chief Engineer | 120 kmph | 160 kmph | 200 kmph. |
| B.G. | 14.0 cms | 16.5 cms | 16.5 cms | 18.5 cms | 18.5 cms |
| M.G. | 9.0 cms | 10.0 cm | Not specified | — | — |
| N.G. | 6.5 cm | 7.6 cms | — | — | — |

(i) Max^m S.E for B.G. = $\frac{1}{10} \times 1.65m = 0.165m = 16.5cm$

(ii) Max^m S.E for M.G. = $\frac{1}{10} \times 1m = 0.1m = 10cm$

(iii) Max^m S.E. for N.G. = $\frac{1}{10} \times 0.76m = 0.076m = 7.6$ cm

| Gauge | cant deficiency for speed upto 100 kmph | cant deficiency for speed higher than 100 kmph |
|---|---|---|
| B.G. | 76 | 100 |
| M.G. | 51 | Not specified |
| N.G. | 38 | Not specified. |

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Q1 If a 8° curve track diverges from main curve of 5° in an opposite direction in the layout of a broad gauge yard, the cant to be provided for the branch track for maximum speed of 45 km/h on the mainline and 'G' = 1.676 m is permitted.

Ans Main Line

$D = 5°$

$V = 45$ Km/h

B.G. yard $G = 1.676$

$R = \frac{1720}{D} = \frac{1720}{5} =$

Superelevation $(e) = \frac{GV^2}{127R} = \frac{1.676 \times 45 \times 45}{127 \times 1720} \times 5$

$= 7.76$ cm

cant deficiency for B.G. = 7.6 cm

so, Negative cant = 7.76 - 7.6 = 0.16 cm

Branchline

$D = 8°$

so that cant for maintrack = 0.16 cm

Therefore cant to be provided in branch track = 0.16 cm

cant for branch line = 7.6 + (-0.16)

= 7.44 cm

$\therefore 7.44 = \frac{1.676 \times V^2 \times 8}{127 \times 1720}$

$\Rightarrow V^2 = \frac{7.44 \times 1.27 \times 1720}{1.676 \times 8} = 1212.107$

$\Rightarrow V = \sqrt{1212.107} = 34.81$ kmph

$= 35$ kmph

Q.2 A 5° curve diverges from a 3° main curve in reverse direction in the layout of B.G. yard. If the speed on the branchline is restricted 35 kmph, determine the restrict speed on the mainline.

Ans Branchline

$D = 5°, V = 35$ kmph

B.G. yard (G) = 1.676 m

$R = \frac{1720}{5} = 344$

$e = \frac{GV^2}{127R} = \frac{1.676 \times 35^2 \times 5}{127 \times 1720} = 4.69$

cant deficiency for B.G. = 7.6 cm

so, Negative cant = 4.69 - 7.6 = 2.91 cm

cant to be provided on maintrack = 2.91 cm

Main Line

$D = 3°$

cant of main track = 2.91 + 7.6 = 10.51

$\therefore 10.51 = \frac{1.676 \times V^2 \times 3}{127 \times 1720}$

$\Rightarrow V = \sqrt{\frac{10.51 \times 127 \times 1720}{1.676 \times 3}} = 67.51$ kmph.

## Necessity of geometric Design of a railway track:-

Most of the train derailments are due to the following reasons. (i) Track defects (ii) Vehicular defects, (iii) Operational defects.

The Civil Engineer is mainly concerned with track defects. He should be aware of the track defects and how to remove these defects so that no derailment takes place. Railway track should be designed, suiting to load and speed of the train and meeting the safety and economy requirements.

A train may derail on the straight track due to the following defects in the track:

(i) Defective cross-levels (ii) Defective alignment
(iii) Defective Gauge, and (iv) Low joints

In addition to this, on curved track, the derailment may occur due to the following reasons:

(i) Gaping joints
(ii) Lifting of toe of switch due to inadequate fittings
(iii) Improper assembly of crossing, loose crossing bolts or wing rails than the crossing nose.
(iv) Excessive wear in switches
(v) Tight gauge and defective check clearance at the nose of crossing.

Therefore, if all the above elements are properly designed, the possibility of derailments due to defects in the track can be avoided.

Cross levels, alignments, gauge and joints have already been discussed in previous chapters, the study will be confined to the following that follows. In this chapter, the study will be confined to the following elements of a railway track:

(1) Gradient and Grade compensation (2) Speed of train
(3) Radius or Degree of the curve (4) Cant or superelevation
(5) Curves (6) Widening of Gauges on curves

## Limits of Superelevations and Cant-Deficiency:

As discussed in the previous articles, superelevation should be provided in such a way as to accomodate various train running with different speeds from time to time. There are limits to the amount of superelevation which may be provided safety.

Normally, the maximum permissible values of superelevation, according to the Railway Board is 1/10th of gauge. Therefore, the maximum permissible values in India for different gauges are:

Table 151 Limits of Superelevation

| Gauge | Max^m S.E. When V ≤ 100 Kmph | | Max^m S.E for high speeds i.e V ≥ 120 kmph. | | |
|---|---|---|---|---|---|
| | Under ordinary conditions | Under special permissible chief Engg. | 120 Kmph. | 160 Km.ph. | 200 Kmph. |
| B.G. | 14.0 cms | 16.5 cms | 16.5 cms | 18.5 cms | 18.5 cms |
| M.G | 9.0 cms | 10.0 cms | Not specified | Not specified | Not specified |
| N.G | 6.5 cms | 7.6 cms | - DO - | - DO - | - DO - |

i) Maximum S.E. for B.G. $= \frac{1}{10} \times 1.65m = 0.165m = 16.5cm$
(ii) Maximum S.E for M.G. $= \frac{1}{10} \times 1m = 0.1m = 10cm$
(iii) Maximum S.E for N.G. $= \frac{1}{10} \times 0.76m = 0.076m = 7.6cm$
In Britain max^m S.E = 19cm (i.e. 7.5")
In America max^m S.E = 15.2cm (i.e 6") } for 4'-8½" gauge

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## Necessity of points and crossing

Points and crossings are provided to help transfer railway vehicles from one track to another. The tracks may be parallel to, diverging from or converging with each other.

Points and crossings are necessary because the wheels of railway vehicles are provided with inside flanges and therefore, they requires this special arrangement in order to navigate their way on the rails. The points or switches aid in diverting the vehicles and the crossings provide gaps in the rails so as to help the flanged wheels to roll over them.

The provision of points and crossings is essential for achieving the following objects

- To receive the trains at the alloted platform of the railway station.
- To enable the train to occupy the specified track leads to the destination station
- To facilitate shunting operation
- facilitate marshalling of trains from and to the washing lines, sidings etc.

## Turnout

It is a mechanical device that used to guide the trains from one rail track to another. As an important part in rail construction, turnout helps to enable the trabbicability of the rail.

It's the simplest combination of points and crossings which enables one track either a branch line or a siding, to take off from another track. So the object of turnout is to provide facilities for safe movement of trains in either direction on both the tracks.

Following parts of a turnout

- A pair of points or switches (ABCD and EFPQ)
- A pair of stock rails.
- A vee crossing (GHIJ)
- Two check rails
- Four lead rails.
- Switch tie-plate or "gauge tie chair" and crossing tie plate
- Studs or stops
- Bearing plates, slide chairs, stretcher bars etc
- For operating the points - Rods, cranks, levers, etc.
- For locking system - locking box, lock bar, plunger bar etc.

Important terms Used in points and crossing

(i) Facing direction: If someone stands at toe of switch and looks towards the crossing, then the direction is called "Facing Direction" (as shown in Fig 16-1)

(ii) Trailing direction: If someone stands at the crossing and looks towards the switches, then the direction is called 'Trailing Direction'

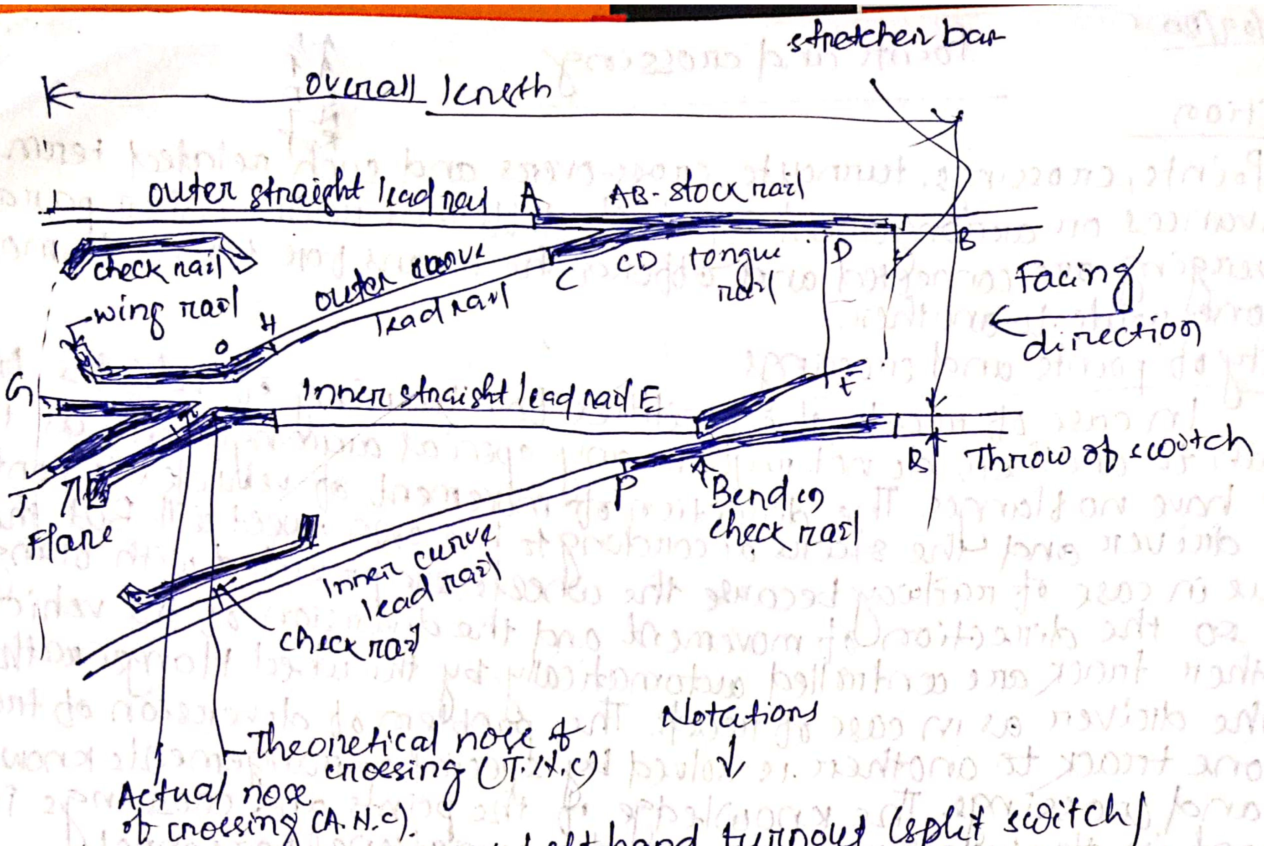


Fig. 16.1 Left hand turnout (split switch)

(iii) Facing Points of Turnouts are those where trains pass over the switches first and then they pass over the crossings. These are important to specify when the direction of movement of trains is reserved for facing direction.

(iv) Trailing points of Turnouts are those on the opposite side of facing points in which the trains pass over the crossing first and then over the switches. These are important to specify when the direction of movements of trains is reserved for trailing direction only.

So every points may be of a 'facing' or 'trailing' point or both, depending upon the directions of movements of trains.

(v) Right-Hand and Left-Hand Turnouts :- If a train from main track is diverted to the right of the main route in the facing direction then this diversion is known as Right-Hand turnout. (Fig 16.2)
If a train from main track is directed to the left of the main route in the facing direction, then the diversion is known as Left-Hand turnout. (Fig 16.3)

(vi) Right-Hand and Left-Hand Switches
These are termed as left-hand or right-hand switches depending upon left or right, when seen from the facing direction i.e. stand at the points and look towards the crossing. Fig 16.2 and 16.3

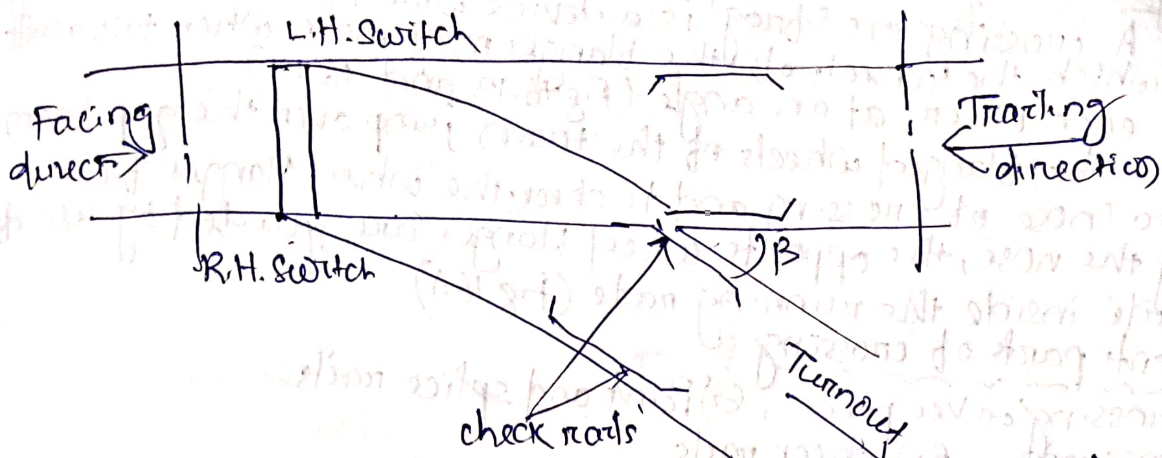


Fig 16.2. Line Diagram of Right-hand Turnout

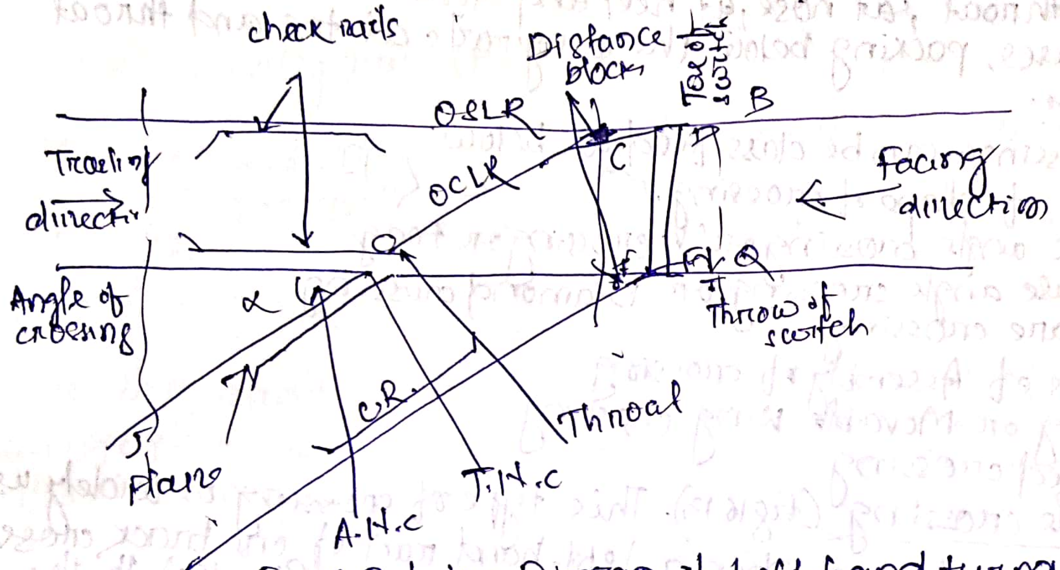


Fig 16.3. Line Diagram of Left-hand turnout

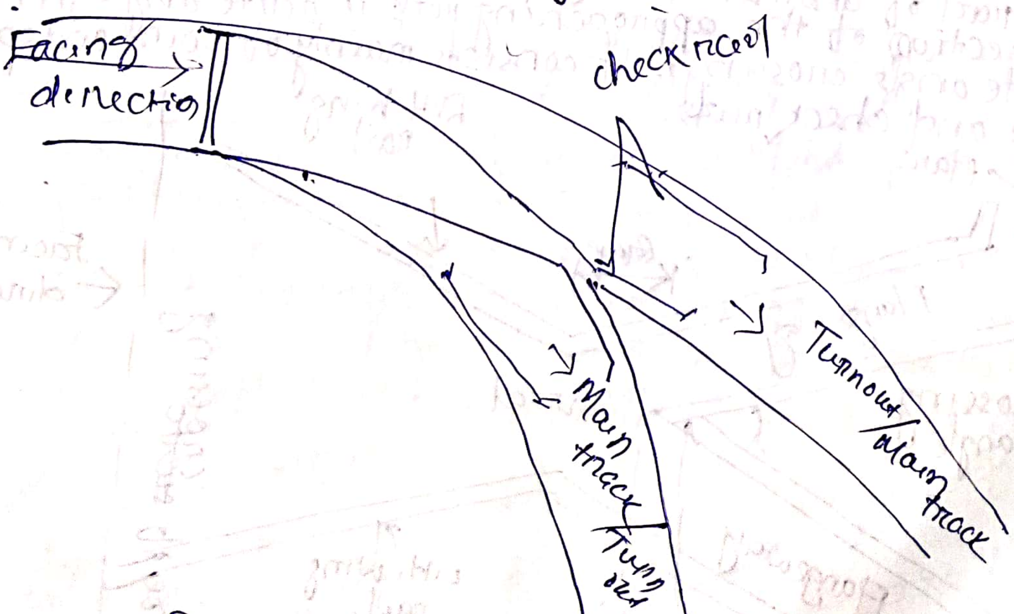


Fig 16.4 Turnout from curved Main track

## Crossings:

A 'crossing' or 'frog' is a device which provides two flangeways through which the wheels of the flanges may move, when two rails intersect each other at an angle (Fig 16.13 and 16.14)

The flanged wheels of the train jump over the gap from 'throat' to 'nose' of crossing and to check the wheel flanges from striking the nose, the opposite wheel flanges are guided by use of 'check rails' inside the running rails (Fig 16.1)

### Component parts of crossing:

(i) A crossing or Vee piece, (ii) Point and splice rails
(iii) Wing rails, (iv) check rails
(v) chairs at crossing, at toe and at heel.
(vi) Blocks at throat, at nose, at heel and distance block.
(vii) In some cases, packing below the wing rails at toe and throat.

### Type of crossings:

Crossings can be classified as below:

(A) On the basis of shape of crossing.
 (1) Acute angle crossing or 'V' crossing or frog
 (2) Obtuse angle crossing or Diamond crossing.
 (3) Square crossing

(B) On the basis of Assembly of crossing
 (1) Spring or Movable wing crossing.
 (2) Ramped crossing.

(A)(1) Acute angle crossing (Fig 16.13). This type of crossing is widely used. This crossing is obtained when a left-hand rail of one track crosses a right-hand rail of another track or vice versa. (Fig 16.1) If the angle of intersection of the approaching rails is acute angle, it is termed as Acute angle crossing. It consists mainly of point and splice rails, wing rails and check rails.

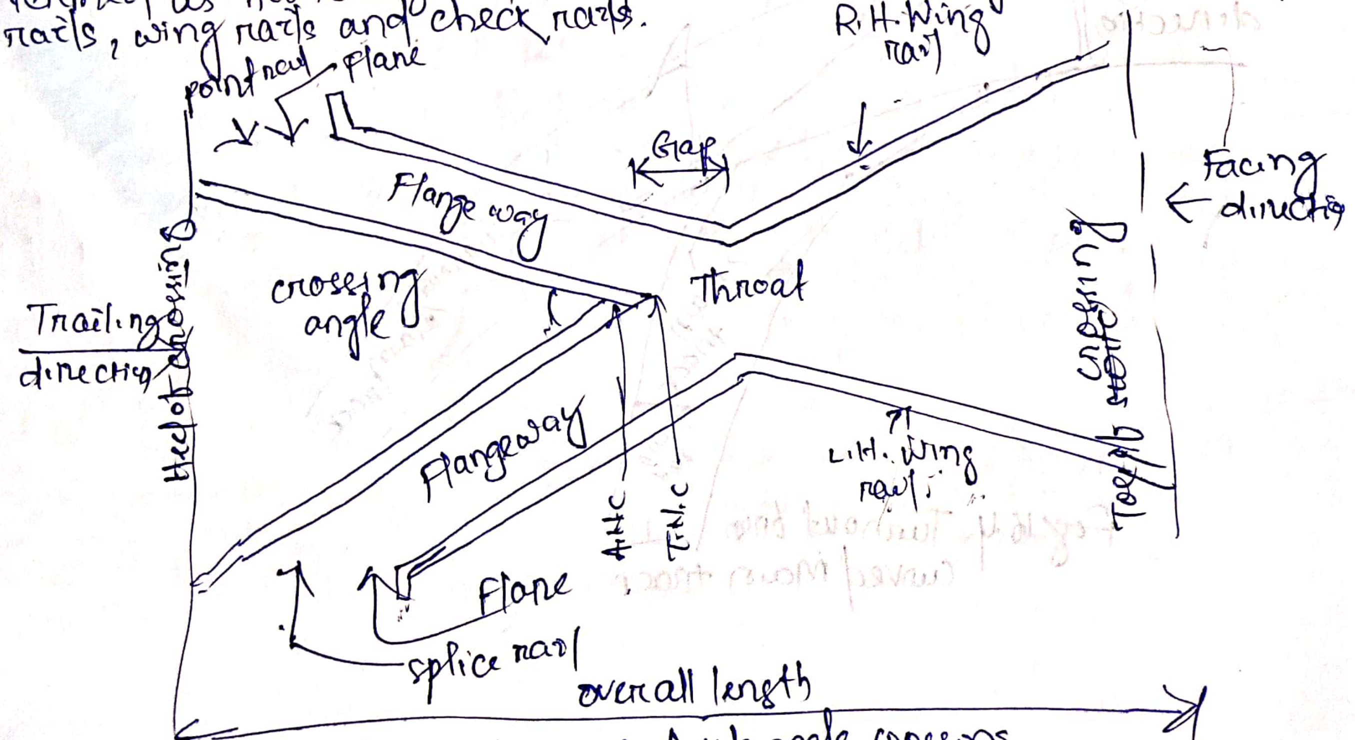


Fig 16.13. Acute angle crossing.

7. (a) Point and splice rails :- An acute angle is formed either by a point rail and a splice rail or by combination of two point rails. These are made of a special steel (i.e. alloy steel such as carbon steel or manganese steel) as shown in Fig. 16.14 and 16.15.

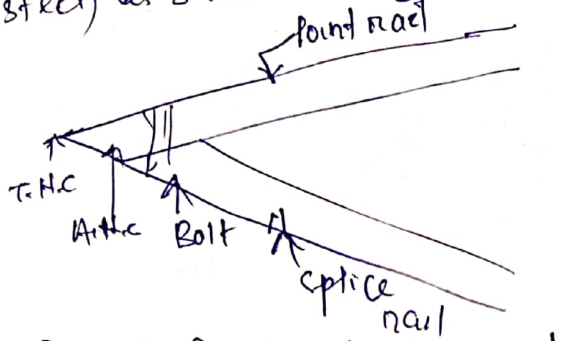


Fig 16.14 Point and splice Joint

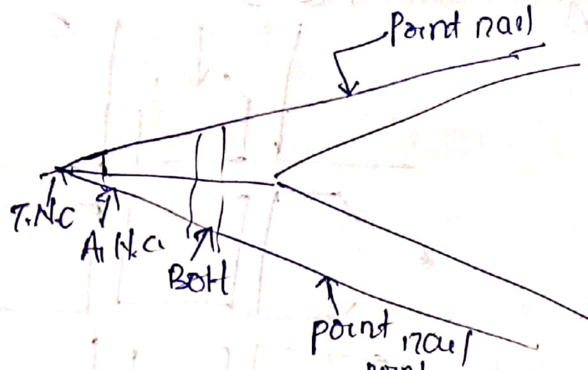


Fig. 16.15. Two point rail joint

(b) A pair of wing rails (Fig 16.13) :-

These are bent at the ends. One end of the wing rails is connected to lead rails whereas the other end is flared. This flaring is done to facilitate the entry and exit of flange wheels to the gap.

(c) A pair of check rails (Fig 16.1)

These are subsidiary rails parallel to the running rails. They are flared at end for guiding the wheel flanges. They are provided on the opposite sides of the crossing angle to serve the following purposes

(i) To guide the wheel flanges
(ii) To prevent wear and rocking of wheels
(iii) To prevent derailment at level crossing.

(A) → Obtuse angle crossing (Fig 16.16) :- This crossing is obtained when left-hand rail of one track crosses right-hand rail of another track or vice versa at an obtuse angle.

In diamond crossing, a pair of special crossing is used which is called "obtuse crossing". In case of obtuse angle crossing the long wing rails do not carry the wheels as in case of acute angle crossing, rather act as check rails.

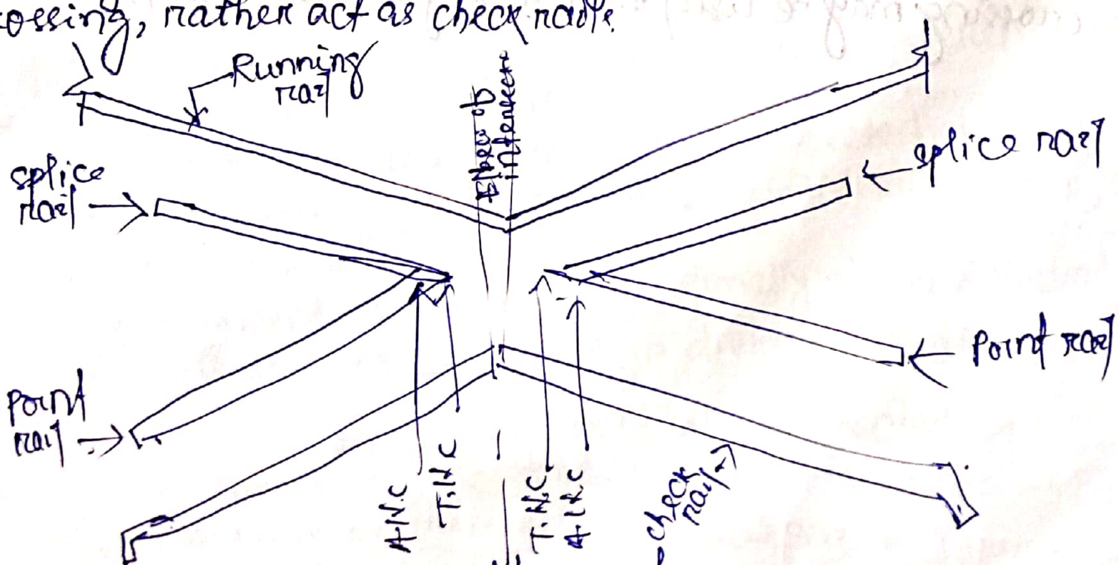


Fig 16.16 Obtuse angle crossing

A-(3) Square crossing :- When two straight tracks cross each other at right angles, they give rise to square crossing. This type of crossing must be avoided on main lines because there is heavy wear due to dynamic loads. [Fig 16.17]

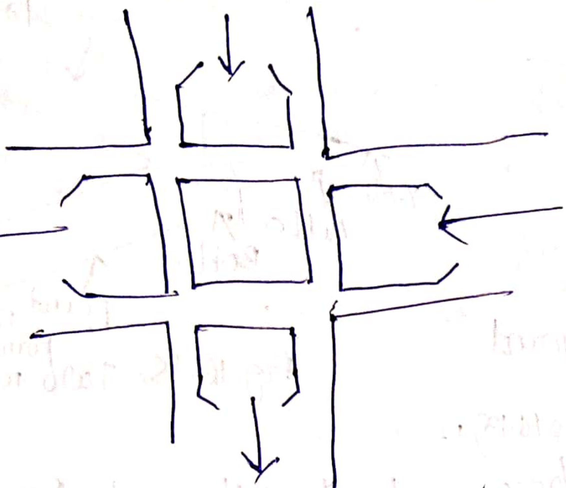

Fig 16.17 Square crossing

(B)-(1) Spring or Movable crossing (Fig 16.18) In such a crossing the Vee of the one wing rail is movable, and is held against the Vee of the with a strong helical spring. By doing so, it makes the main track continuous and this crossing becomes very useful when there is high speed traffic on main tracks and light speed traffic on the branch line or a turnout. This type of crossing is used in U.S.A. but in India spring crossing is not favoured because there is a danger of accident in case of spring failure.

(B)-(2) Ramped crossing: In case of complicated yard layout with heavy but slow speed traffic, the throat to nose clearance is negotiated by use of special manganese steel blocks over long distance. The wheel flanges roll over this distance extending from a little beyond the throat to little beyond the nose. The top level of these special blocks is so arranged that the tread of the wheel is taken off the table by the wheel flanges riding the blocks. So the entire wheel load comes on the flange and this type of crossing may be used with safety for slow speeds.

## Types of switch

Switches are of two types namely 'stud switches' and 'split switch'.

In 'stud switch' no separate tongue rail is provided and some portion of the track is moved from one side to the other side.

∴ In 'split switch' a pair of stock rail and pair of tongue rail ~~finishes at the heel of the switch to enable movement of the free end of the tongue rail~~ are present split switches are two types.

(1) Loose Heel Type.

→ In this type of split switch, the switch or tongue rail finishes at the heel of the switch to enable movement of the free end of tongue rail.

→ The fish plates leading at the tongue rail may be straight or highly bent.

→ The tongue rail is fastened to the stock rail with the help of a fishing fit block and four bolts.

→ All the fish bolts in the lead rail are tightened while those in the tongue rail are kept loose or snug to allow free movement of the tongue.

→ As the discontinuity of the track at the heel is a weakness in the structure, the use of these switches is structures, the use of these switches is not performed.

(2) Fixed Heel Type.

In this type of split switch the tongue rail does not end at the heel of the switch, but extends further and is rigidly connected. The movement at the toe of the switch is made possible on account of flexibility of tongue rail.

# Methods of lying & Maintenance of track

## Essential of Track Maintenance

1. The gauge should be correct or within the specified limits.
2. There should be no difference in cross levels except on curves, where cross levels vary in order to provide superelevation.
3. Longitudinal levels should be uniform.
4. The alignment should be straight and kink free.
5. The ballast should be adequate and sleepers should be well packed.
6. The track drainage should be good formation should be well trained.

Railway track can be maintained either conventionally by manually labour or by the application of modern methods of track maintenance. Such as mechanical tamping or measured shovel packing. The major maintenance operations performed in a calender year (12 months) are as follows for acheiving the above mentioned standards.

(i) Through packing
(ii) systematic overhauling
(iii) picking up slacks

## I Through packing:

Through packing is carried out in a systematic and sequential manner as described as follows:-

→ Opening of road

The ballast is dug out on either side of the rail seat for a depth of 50mm (2") below the bottom of the sleeper with the help of a shovel with a wire claw. On the outside, the width of the opening should extend up to the end of the sleeper.

On the inside it should extend from the rail seat to a distance of 450mm (18") in case of BG, 350mm (14") in case of MG, and 250mm (10") in case NG

→ Examination of rails, sleepers and fastenings:

The rails, sleepers and fastening to be used are throughtly examined. Defective sleepers are removal and loose fastenings are tightened. Any kinds in rails are removed.

→ Square of sleepers:

(a) To do this one of the rails is taken as the slighting rail and the correct sleeper spacing is marked on it.

(b) The position of the sleepers is checked with reference to the second rail with the help of a T-square.

(c) The sleeper attended to after this defects have been established which may include their being out of square or at incorrect spacing.

→ Alignment the track:

(a) The alignment of the track is normally checked visually where in the rail is visually assessed from a distance of about four rail length or so.

(b) Small errors in the alignment are corrected by slewing the track after loosening the cores at the ends and drawing out sufficient ballast at the ends of the sleeper.

(c) Slewing is carried out by planting crowbar into the ballast at an angle not more than 30 from the vertical.

Advantages of Track Maintenance

i) If the track is suitably maintained, the life of the track as well as that of the rolling stock increases since there is lesser wear and tear of their components.

ii) Regular track maintenance helps in reducing operating costs and fuel consumption.

iii) Small maintenance jobs done at the appropriate time, such as tighting of a bolt or key, hammering the dog spikes, etc. help in avoiding loss of concerned fittings and thus saving on the associated expenditure.

iv) When track maintenance is neglected for along time, it may render the track beyond repair, calling for heavy track renewals that entail huge expenses.

Gauging:-

The gauge should be checked and an attempt should be made to provide a uniform gauge within permissible tolerance limits.

2. Systematic overhauling:-

The systematic overhauling of the track should normally commence after the completion of one cycle of through packing. It involves the following operation in sequence.

(a) shallow screening and making up of ballast section.
(b) Replacing damaged or brother fittings
(c) Including all items in through packing
(d) Making up the cess.

3. Picking up slacks:-

Slacks are those points in the track whose the running of trains is faculty. slacks generally occurs in the following cases

(a) stretches of yielding formation
(b) Improperly aligned curves
(c) Portions of track with poor drainages
(d) Approaches to level crossing, girder bridges etc.

No through packing is done during the raining season and slacks are only picked up in order to keep the track safe and in good running condition.

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## Duties of a permanent way Inspector (PWI)

The PWI is generally responsible for the following

→ Maintenance and inspection of the track to ensure satisfactory and safe performance.

→ Efficient execution of all works incidental to track maintenance including track relaying work

→ Accounts and periodical verification of the stores and tools in his or her charge.

→ Maintenance of land boundries between stations and at important stations as may be specified by the administration.

The PWI also carries out inspection of the following facts of a track

(a) Testing the track

(b) Inspection of track and gauge

(c) Level crossing inspection

(d) Point and crossing inspection.

(e) Curve inspection

(f) safety of track

In addition to the inspections, a PWI also carries out following duties

(a) Check the proximity of trees that are likely to damage the track and get them removed

(b) check the night patrolling at least once a month by train as well as by trolley.

(c) Takes the necessary safety measures while executing maintenance work that affects the safety of the track.

(d) Periodically inspect and respective LWR tracks to ensure the safety.

(e) Ensures the cleanliness of station yards

(f) Keeps proper records of the training out of ballast

# Bridge Engineering

1. Bridge: A structure is faciliating a communication route for carrying road traffic or other moving loads over a depression or obstruction such as river, stream, channel, road or railway. The communication route may be a railway track, a tramway, a roadway, footpath, a cycle track or a combination of them.

2. High Level Bridge or Non-submersible Bridge: The Bridge which does not allow the high flood water to pass over them. All the flood water is allowed to pass through its events. In other words, it carries the roadway above the highest flood level of the channele.

3. Submersible Bridge: A submersible bridge is a structure which allows fold water to pass over bridge submerging the communication route. Its formation level should be so fixed as not to cause interruption to traffic during floods for more than three days at a time nor for more than six times in a year.

4. Causeway: It is a pucca submersible bridge which allows floods to pass over it. It is provided on less important routes in order to reduce the construction cost of cross drainage structure. It may have vents for low water flow.

5. Foot Bridge: The foot bridge is a bridge exclusively used for carrying pedestrain, cycles and animals.

6. Culverts: When a small stream crosses a road with linear waterway less than about 6 metres. The cross drainage structure so provided is called culverd.

7. Deck bridge: These are the bridge whose floorings are supported at top of the structure.

8. Through Bridge: These are the bridges whose flooring are supported or suspended at the bottom of the superstructure.

9. Semi-Through Bridges: These are the bridges whose floorings are supporte at some intermediate level of the superstructure

10. Simple Bridges: They include all beam, girder or truss bridges whose flooring is supported at some intermediate level of structure.

11. Cantilever bridge: Bridges which are more or less fixed at one end and free at other. It can be used for spans varying from 8m to 20m.

12. Continues Bridges: Bridges which continue over two or more span. They are used for large span and where unyielding foundation are available

13. Arch Bridge: These are the bridges which produce inclined pressure on supported under vertical loode. These bridges can be economically used up to spane about 20 metres. The arches may be in the barrel from or in the form of ribe.

14. Rigid Frame Bridges: In these bridges the horizontal deck slab is made monolithic with the vertical abutments walls. These bridges can be used up to span about 20 metres. Generally this type of bridge is not found economical for spans about 20 metres. Generally, this

type of bridge is not found economical for spans less than 10 metre.

15. Square bridge: These are the bridges at right angle to axis of the river.

16. Squares Bridges: These are the bridges not at right angles to axis of the river.

17. Suspension bridge: These are the bridges which are suspended on cables anchored at ends.

18. Under-bridge: It is a bridge constructed to enable one from of land communication over the other.

19. Over bridges: It is a bridge constructed to enable one from of land communication over the other.

20. Class AA bridges: These are bridges designed for IRC class AA load and checked for class. A loading they are provided within certain municipal limits, in a certain existing or contempled industrial area, in other specified areas, and along certain specified higher

21. Class A bridges These are permanent bridges designed for I.R.C. class A loading.

22. class B bridges: These are permanent bridges designed for IRC class B loading.

23. Viaducts: It is a long continuous structure which carries a road or railway like Bridge over a dry valley composed of series of span over trestle bents instead of solid piers.

24. Apron: It is a layer of concrete, masonry stone etc. placed like flooring at the entrance or out of a culvert to prevent scour.

25. Piers: They are the intermediate supports of a bridge superstru and may be solid or open type

26. Abutments: They are the end supports of the structure.

27. Curtain walls: It is a thin wall used as a protection against scouring action a stream.

28. Effective span: The centre to centre distance any two adjacent supports is called as the effective span of a bridge

## Components of a bridge

The major parts of a bridge

1) Substructure
2) Superstructure
3) Adjoining structure

### 1 Substructure:-

The structure of the bridge below the level of bearings is known as the substructure. It consists of the following

(a) Abutments
(b) piers
(c) Wing walls

### 2 Superstructure:

The components of the bridge above the bearing are known as superstructure.

(a) Beam and girders
(b) Bearings
(c) Arch and cables
(d) Parapet wall and Handrail
(e) Flooring

### 3 Adjoining structures

(a) Approaches
(b) Guard stones

1.(a) Abutments:- It is a structure mostly used for bridges and dams as a substructure at the ends of a bridge span or dam and on that superstructure is rest. Bridge with a single span has two abutments that offer vertical and lateral support. It also plays the role of retaining walls to resist lateral movement of the earthen fill of the bridge approach.

The abutment can also be defined by the structure supporting one side of an arch, or masonry used to resist the lateral forces.

1.(b) Piers: Piers provide intermediate support between two bridges spans. Bridge piers mainly support the bridge superstructure element and transfer the load to the foundation.

Pier must be strong to handle the horizontal as well as lateral Piers are known as compression members of the bridge.

1.(c) Wing walls: It is one of the earth retaining structures in the bridge. They are located adjacent to the abutments and act as retaining walls. Wing walls retains soil for abutment, roadway and approach embankment, which can be at a right angle to the abutment or splayed at different angles.

2.(a) Beams and girders:

Both have a similar function to support the roadway and prevent bending. Girder is also one type of beam support. Where loads are heavy girders are used instead of beam support.

Beam has a rectangle cross-section, whereas girders have composed of I-shaped cross-section with two load-bearing flanges and a web for stabilization.

2.(b) Bearings.

A bearing is provided between the bridge girder and the pier cap. The main function of bearing to allow free movement or vibration of the top ~~surface~~ superstructure and reduce effect stress to reach the bridge foundation.

2.(c) Arch and Cables:

Arched and cable both have specified used. Arches are used for arch bridge construction and cable is used for suspension, cable-stayed bridge etc. For different types bridge construction arches and cables play a vital role.

2.(d) Parapet Wall and Handrail -

The parapet is one of the safety components of any bridge which prevent the vehicle from falling off where there is a drop. It is also useful for restricting views, preventing rubbish from passing below and acting as noise barriers.

2.(e) Flooring:

Its top surface of bridge roadway on vehicle travel. It is made of concrete or bituminous road.

3.(a) Approaches:

It is structured constructed at the starting or ending of any bridge. Its main function is to provide smooth and easy entry or exit from the bridge.

3.(b) Guard stone.

They are ~~restrict~~ used to restrict traffic on a particular lane or sometimes as road railing but are generally positioned to protect a specific object such as a corner of a street or the side of a gate.

Classification of bridge:

The bridges may be classified depending upon the following factors

-> Their function or purpose as railway, highway foot bridges, aqueduct etc.
-> Their material of construction used as timber masonry, R.C.C. steel, prestress concrete etc.
-> Nature of life span such as temporary permanent bridges etc.
-> Their relative position of floor such as deep bridges, through bridges etc.
-> Type of superstructure such as deep bridge, through bridges etc.
-> Loadings: Road Bridges and culverts have been classified by I.R.C. into class AA, class A, class B bridges according to the loadings they are designed to carry.
-> Span Length: Under this categories the bridges can be classified as
  - Culverts (span less than 8m) i.e. Box Type; Hume pipe Type
  - Minor Bridge (span length = 8 to 30m) i.e. Box type, Girder type
  - Major Bridge (span length = above than 30m)
-> Degree of redundancy: Under this the bridges can be classified as indeterminate bridges
-> Types of connection: Under this category the steel bridges can be classified riveted or welded bridges

Requirement of a bridge:

An ideal bridge meets the following requirements to fulfil the three criteria of efficiency, effectiveness and equity.
-> It serves the intended function with utmost safety and convenience.
-> It is aesthetically sound.
-> It is economical.

The site characteristics of an ideal bridge has been discussed below

1) The stream at the bridge site should be well defined and as narrow possible.
2) There should be a straight reach of stream at bridge site.
3) The site should have firm, permanent, straight and high banks
4) To flow of water in the stream at the bridges site should be in steady regime condition. It should be free from whirls and cross-current.
5) There should be no confluence of large tributaries in the vicinity of bridge site.
6) It should be reliable to have straight approach roads and square alignment i.e. right-angled crossing.
7) There should be minimum obstruction of a natural waterway so as to have minimum afflux.
8) In order to acheive economy there should be easy availability of labour, construction material and transport facility in the vicinity of bridge site.
9) In order to have minimum foundation cost, the bridges site should be such that no excessive work is to be carried inside the water.
10) At bridge site it should be possible to provide secure and economical approaches.
11) In case of curved alignment the bridge should not be on the curve, but preferably on the tangent since otherwise there is a greater like hood of accident as well as an added centrifugal force which increases the load effect on the structure and will require modification of design.
12) There should be no adverse environment input.
13) The bridge site should be such that adequate vertical height and waterway is available.
14) Underneath the bridge for navigational use.

## Bridge Alignment:

Depending upon the angle which the bridge makes with the axis of the river, the alignment are of two types

(a) Square Alignments:- In this the bridge is at right angle to the axis of the river.

(b) Skew Alignments:- In this the bridge is at some angle to the axis of the river which is not a right angle.

Note:- As far as possible, it is always desirable to provide the square alignment, the skew alignment suffers from the following disadvantage

i) A great skill is required for the construction of skew Bridges. Maintenance of such type of Bridges is also difficult.

ii) The water pressure on piers in case of skew alignment is also excessive because of non-uniform flow of water underneath the bridge superstructure.

iii) The foundation of skew bridge is more susceptible to scour action.

## Flood Discharge

One of the essential data for the design is fair assessment of the maximum flow which could be expected to scour at the bridges site during the design period of the bridge. The conventional practice in India for determination of flood discharge is to use a few conventional formulae or past records.

Note: This faulty determination of flood discharge which led to failure of many hydraulic structures.

As per I.R.C. recommendation the maximum discharge which a bridge on a natural stream should designed to pass determined by the following methods:

(a) From the rainfall and other characteristics of the catchment

(i) By use of an empirical formula applied to that region, or

(ii) By a rational method, provided it is possible to evalute for the region concerned the various factors employed in the method.

(b) From the hydraulic characteristics of the stream such as cross-section area, and slope of the stream allowing for velocity of flow.

(c) From the records available, if any, of discharge observed on the stream allowing for velocity of flow.

## Empirical Methods for Estimation of Flood discharge

In these methods are of basin or catchment is considered mostly. All other factors which influence peak flow are merged in a constant.

A generally equation may be followed in the form

$$Q = CM^n$$

Here, Q = peak flow or rate of maximum discharge
C = a constant for the catchment
M = area of catchment and 'n' is an index

The constant for catchment is arrived at, after taking the following factors into account:

(A) Basin characteristic

(a) Area
(b) shape
(c) slope

(B) storm characteristic

(a) Intensity
(b) Duration
(c) Distribution

Limitations

These methods donot take frequency of flood into consideration.
These methods cannot be applied universally.
Fixing of constant is very difficult and exact theory cannot be put forth for its selection.

1) Dicken's formula

$$Q = C.M^{3/4}$$

Here, Q = Discharge in cu.m/sec
C = a constant
M = area of catchment in sq.Km

2) Ryves's formula

$$Q = C.M^{2/3}$$

Here, Q = Discharge in cu.m/sec
C = 6.74 for area within 24km from coast or,
C = 8.45 for area within 24-161km from coast or
C = 10.1 for limited hilly areas.

In worst cases C goes upto 40.5
M = area of catchment in sq.km.

3) Ingli's formula

This formula used only Mahastra state and here there different cases are taken into consideration

(a) for small areas only (It is also applicable for fan-shaped catchment)

$$Q = 123.2\sqrt{M}$$

(b) For areas between 160 to 1000 square km.

$$Q = 123.2\sqrt{M} - 2.62(M - 259)$$

(c) For all types of catchment

$$Q = 123.2M/\sqrt{M+10.36}$$

In all equation, M = area of catchment in sq. km,

4) Newab Jang Bahadur's formula

$$Q = C(M/2.59)(a - b\log A)$$

Here a, b and c are constant
a = 0.993 and b = 1/14
C = 59.5 for North India, or
= 481 for South India

5) Creager's Formula:

$$q = C \cdot M^n$$

Here q = the peak flow per sq. km of a basin
M = area of catchment in sq. km and 'n' is some index
By multiplying both sides of the above equations are of the basin M, we get

$$Q = C \cdot M^{n+1}$$ where Q is peak value

Equation given by Creager, Justin and Hinds is

$$Q = 46. CM^{(0.849M - 0.048)}$$

6) Khosla's Formula

It is a rational formula. It is based on the equation
P = R + L
or
R = P − L
Here, R is round off, P is rainfall and L is losses.
L = 4.82 Tm, where L is in mm and Tm is in centigrade
R = P − 4.82 Tm

7) Besson's formula

This formula is very rational and can be used in any case.

$$Q_m = (P_m \times Q_R)/(P_R)$$

Here, $Q_m$ = peak flow expected
$Q_R$ = some observed peak flow
$P_R$ = observed rainfall
$P_m$ = expected rainfall

Rational Methods for Estimation of flood discharge

This method is applicable for determination of flood discharge for small culverts only. In order to arrive at a rational approach, a relationship has been established between rainfall and runoff under various circumstances. The size of flood depends upon the following factors.

(i) Climate or Rainfall factors. This include
(a) Intensity (b) Distribution and (c) Duration of Rainfall
(ii) Catchment Area factor. This include
(a) Catchment Area (b) its slope (c) its shape, (d) porosity of soil
(e) Vegetable cover, (f) initial state of wetness

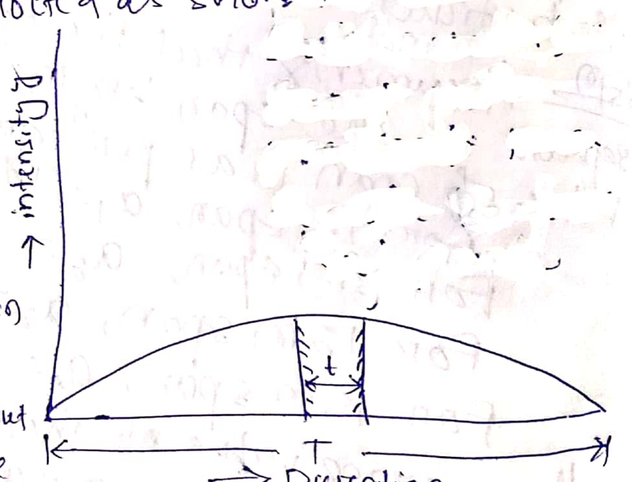
In order to establish a relationship between the intensity and duration of a storm, a curve has been plotted as shown.

Let, in an individual stream:
F = total rainfall in cm
T = duration of rainfall in hours
I = mean intensity of rainfall in cm/hour taken over the duration of the storm

Then $I = F/T$

If i = intensity of rainfall in cm per hour, obtain for small interval 't' as shown in fig 31.1

Since the intensity is not uniform throughout the mean intensity 'i' obtained over the time interval 't' will be higher than the mean intensity 'I' taken over the whole period 'T'.




31.1 Rainfall intensity duration curve

The intensity of a storm is some inverse function of its duration. It has been reasonably well established that:

$$\frac{i}{I} = \frac{T+C}{t+c}$$

$$\Rightarrow i = \frac{F}{T}\left(\frac{T+C}{t+c}\right)$$

Here C = a constant
T = total rainfall

# Waterway

The area through which the water flows under a bridge superstructure is known as the waterway of the bridge. The linear measurement of this area along the bridge is known as the linear waterway. This linear waterway is equal to the sum of all the clear span. This may be called an artificial linear waterway.

Due to this construction of a bridge the natural waterway gets contracted thereby increasing the velocity of flow under a bridge. This increased velocity results into heading up of water on the upstream of the river or stream known as Afflux.

Economic span: the economic span of a bridge is the one which reduces the overall cost of a bridge to be minimum. The overall cost of a bridges depends upon following factors

a) Cost of material and its nature.
b) Availability of skilled labour
c) Span length
d) Nature of stream to be bridged
e) climatic and other conditions

# Afflux

When a bridge is constructed, the structure such as abutments and piers cause the reductions of natural waterway area. The contraction of stream is desirable because it leads to tangible saving the the cost specially for alluvial stream whose natural surface width is too large than required for stability. Therefore, to carry the maximum flood discharge, the velocity under a bridge increases. This increased velocity gives rise to sudden heading up of water on the upstream side of the stream. The phenomenon of heading up of water on the upstream side of the stream is known as Afflux.

Afflux is calculated by one of the following formula

(A) Marriman's Formula.

$$h_a = \left(\frac{V^2}{2g}\right)\left\{\left(\frac{A}{ca}\right)^2 - \left(\frac{A}{A_1}\right)^2\right\}$$

Here, $h_a$ = Afflux in meters
$V$ = velocity of approach in meters per second
$A$ = Natural waterway area at the site
$a$ = contracted area in square meter
$A_1$ = The enlarged area upstream of the bridge ~~stru~~ square meter
$C$ = Coefficient of Discharge $= 0.75 + 0.35(a/A) - 0.1(a/A)^2$

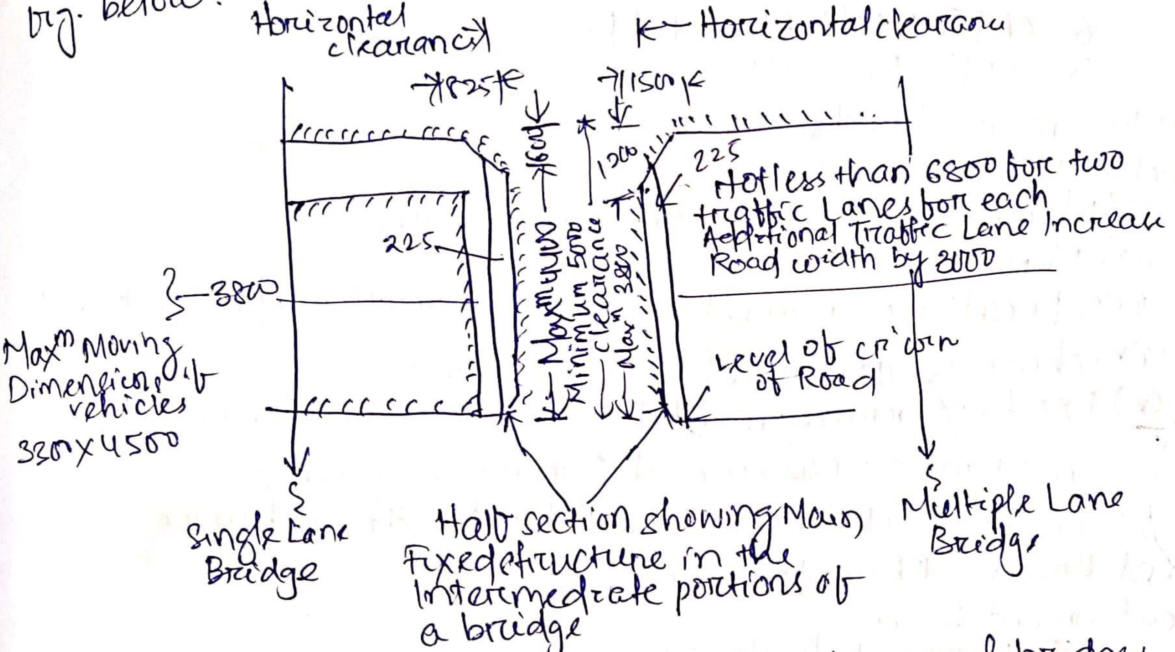
(A) Molesworth's Formula.

$$h_a = \left(\frac{V^2}{17.9} + 0.015\right)\left(\frac{A}{a}^2 - 1\right)$$

Here V, A and a have the same meanings as in Marriman Formula

## Clearance

To avoid any possibility of traffic striking any structural part clearance diagram are specified. The horizontal clearance should be the clear width and vertical clearance of the clear height, available for the passage of vehicular as shown in the clearance diagram in the fig. below.




Clearance diagram for road bridges

## Free Board

Freeboard is the vertical distance between the designed high flood level, allowing for the afflux, if any, and level of the crown of the bridge as its lowest point.

It is essential to provide the free board in all types of heights for the following reasons.

→ Free board is required to allow floating debris, fallen tree trunks and approaches waves top pass under the bridge.

It is essential to provide the free board in all types of bridge for the following reasons:

→ Freeboard is required to allow floating debris, fallen tree trunks and approaches waves top pass under the bridge.

→ Freeboard is also required to allow for the afflux during the maximum flood discharge due to contraction of waterway.

→ Freeboard is required to allow the vessels to cross the bridges in case of navigable rivers. The value of free board depends upon the types of the bridges.

## Collection of bridge design data:-

For a complete and proper appreciation of the bridge project the engineer in charge of the investigation should carry out studies regarding its financial, economic, social and physical feasibility. The detailed information to be collected may cover loading to be used for design based on the present and anticipated future traffic, hydraulic data based on stream characteristics, geological data, subsoil data, climatic data, alternatives sites, aesthetics, costs etc.

The following drawing containing information as indicated should be prepared

1. INDEX MAP
2. CONTURE SURVEY PLAN
3. SITE PLAN
4. CROSS-SECTION
5. LONGITUDINAL SECTION
6. CATCHMENT AREA MAPS
7. SOIL PROFILE

Design data for major bridge:

A – General data:

(i) Name of the road and its classification
(ii) Name of the stream
(iii) Location of nearest G.T.S. bench mark and its reduced level
(iv) chainage at centreline of the stream
(v) Existing arrangement for crossing the stream.
(a) During Monsoon, (b) During dry season
(vi) Liability of the site to earthquake disturbance

B – Catchment Area and Runoff Data:

(i) catchment Area
(a) Hilly Area (b) In plain
(ii) Maximum recorded intensity and frequency of rainfall in catchm
(iii) Rainfall in cementer per year in a reason
(iv) Length of catchment in Kilometres
(v) Width of catchment in Kilometre
(vi) Longitudinal slope of catchment.
(vii) cross slope of catchment
(viii) The nature of catchment and its shape

C – Data Regarding Nature of stream

Sub-surface Investigation

Sub-surface investigation is essential for to know the properties of the bridge site soil. The field and laboratory investigations required to obtain the necessary soil data for the design are called soil exploration.

The principal requirements of a complete investigation can be summarized as follows

1. Nature of the soil deposits up to sufficient depth.
2. Depth, thickness and composition of each soil stratum.
3. The location of ground water
4. Depth to rock and composition of rock.
5. The engineering properties of soil and rock strata that affect the design of the structures.

In exploration programme the extent of distribution of different soils both in the horizontal and vertical directions can be determined by the following methods.

1. By use of open pits
2. By making bore holes and taking out samples
3. By soundings
4. By use of geophysical methods

Equipments for laboratory work:-

The disturbed soil sample as taken from bed level to scour level at every one meter interval or at depth wherever strata changes are tested to determine the following properties.

1. Liquid limit, plastic, Limit, and plasticity Index
2. Organic Content
3. Harmful salts
4. Sieve Analysis
5. Silt factor

The undisturbed soil samples as taken below the scour level to a level where the pressure is about 5% of the pressure at the base are tested to determine.

1. Particle size analysis
2. Values of cohesionless and angle of internal friction by shear test
3. Compression index and pre-consolidation pressure by consolidation test
4. Density specific gravity and moisture content.

Advantage of subsurface Investigation:

There are manifold advantages of carefully planned investigation programme. These can be summarized as below:

1. A suitable and economical solution can be worked out.
2. The construction schedule can be properly damaged.
3. The extent and nature of difficulties likely to be met with can be determined
4. The rate and amount of settlements can be determined.
5. The variation on the water-table of the pressure of artesian pressure can be found out

## Depth of Scour:

Depth of scour (D) is the depth of the eroded bed of the river, measured from the water level for the discharge considered. Well-laid foundation is mostly provided in road and railway bridges in India over large and medium-sized rivers. The age-old Lacey Inglis method is used for estimation of the design scour depth around bridge elements such as pier, abutment, guide bank, spur and groyne. Codal provision are seen to produce too large a scour depth around bridge elements resulting in bridge sub-structure that lead to increased construction costs. Limitations that exist in the codes of practice are illustrated in this paper using examples. The methods recently developed for estimation of the scour are described. New railway and road bridges are required to be built in large numbers in the near future across several rivers to strengthen such infrastructure in the country. It is strongly felt that provision in the existing codes of practice for determination of design scour depth require immediate review. The present paper provides a critical note on the practices followed in India for estimating the design scour depth.

Indian practices on estimation of design scour depth:

1. Lacey-Inglis method
2. Comments on Lacey's method

- The probable maximum depth of scour for design of foundation and training and protection works shall be estimated considering local condition.
- Wherever possible and especially for flashy rivers and those with beds of gravel or boulders, sounding for purpose of determining the depth of scour shall be taken in the vicinity of the site proposed for the bridge. Such soundings are best taken during or immediately after a flood before the scour holes have had time to split up appreciably.

In calculating design depth of scour, allowance shall be made in the observed depth for increased scour resulting from:

(i) The design discharge being greater than the flood discharge observed.

(ii) The increase in velocity due to the construction of waterway caused by construction of the bridge.

(iii) The increase in scour in the proximity of piers and abutment.

- 4.6.3 In the case of natural channels flowing in alluvial beds where the width of waterway provided is not less than Lacey's regime width, the normal depth or scour (D) below the foundation design discharge ($Q_f$) level may be estimated from Lacey's formula indicated below.

$$D = 0.473 \left(\frac{Q_f}{f}\right)^{1/3}$$

where D is depth in meters, $Q_f$ is in cumecs and 'f' is Lacey's regime width for $Q_f$ or where it is narrow and deep as in the case of incised rivers and has sandy bed, the normal depth of scour may be estimated by the following formula:

$$D = 1.338 (Q_f^2/f)^{1/3}$$

where '$Q_f$' is the discharge intensity in cubic meter per second per meter width and f is silt factor. The silt factor 'f' shall be determined for representative sample of bed material collected from scour zone using the formula: $f = 1.76\sqrt{m}$ where m is weight mean diameter of bed material particles in mm.

Values of 'f' of different types of bed material met with are given below:

| Types of bed | Material weighted mean dia. of particle (mm) | Value of 'f' |
|---|---|---|
| (i) coarse silt | 0.04 | 0.35 |
| (ii) Fine sand | 0.08 | 0.50 |
| | 0.15 | 0.68 |
| (iii) Medium sand | 0.3 | 0.96 |
| | 0.5 | 1.24 |
| (iv) coarse sand | 0.7 | 1.47 |
| | 1.0 | 1.76 |
| | 2.0 | 2.49 |

The depth of calculated (vide clause 4.6.3 and 4.6.4 above) shall be increased as indicated below, to obtain maximum depth of scour for design of foundation protection works and training work.

| Nature of the river | Depth of scour |
|---|---|
| In a straight reach | 1.25D |
| At the moderate bend conditions e.g. along apron of guide bund | 1.5D |
| At a severe bend | 1.75D |
| At a right angle bend or at nose of piers | 2.0D |
| In severe wines e.g. against mole head of guide bund | 2.5D to 2.75D |

## Bridge Foundation

A foundation is the part of the structure with which is in direct contact with the ground. It transfers the load of the structure to the soil below. Before deciding upon its size, we must ensure that:

(i) The bearing pressure at the base does not exceed the allowable soil pressure.

(ii) The settlement of foundation is within reasonable limits

(iii) Differential settlement is to limited as not to cause any damage to the structure.

(iv) Broadly, foundation may be classified under two categories i.e.

1. Shallow Foundation.
2. Deep Foundation.

**Shallow Foundation:** According to Terzaghi's, a foundation is said to be shallow if its depth is equal or less than its width.

**Deep Foundation:** According to Terzaghi, a foundation is said to deep, the depth is greater than its width and it cannot be prepared by open excavation.

## Types of Bridge Foundation:

The selection of foundation type suitable for a particular site depends on the following considerations

1) Nature of subsoil
2) Nature of and extent of difficulties e.g. presence of boulder buried tree trunks etc. Likely to be met with and
3) Availability of expertise and equipment

Depending upon their nature and depth, bridge foundation can be categories as follows

1. Open foundation
2. Raft foundation
3. Pile foundation
4. Well foundation

## 1 Open Foundation in bridges:

1) An open foundation or spread foundation is a type of foundation and can be laid using open excavation by allowing natural slopes on all sides.

2) This type of foundation is practicable for a depth of about 5m and is normally convenient above the water table.

3) The base of the pier or abutment is enlarged or spread to provide individual support.

4) Since spread foundations are constructed in open excavation therefore, they are termed as open foundation

5) This type of foundation is provided for bridges of moderate height built on sufficiently form dry ground.

6) The piers in such cases are usually made with slight batter and provided with footings widened at bottom. Where the ground is not stiff the bearing surface is further extended by a wide layer of concrete at bottom

## 2 Raft foundation:

1. A raft foundation or mat is a combined footing that covers the entire area beneath a bridge and supports all the piers and abutments.

2. When the allowable soil pressure ~~below~~ is low, or bridge loads are heavy, the use of spread footing would cover more one-half of the area, and it may prove more economical to use of raft foundation

Scanned by CamScanner

3) They are also used where the soil mass contains compressible lenses so that the differential settlement would be difficult to control.

4) The raft tends to bridge over the erratic deposits and eliminate the differential settlements.

5) Raft foundation is also used to reduce the settlement above highly compressible soils by making the weight of bridge and raft may undergo large settlement without causing harmful differential settlement. For this reason, almost double settlement of that permitted for footing is acceptable for rafts.

6) Usually when hard soil is not available within 1.5 to 2.5m raft foundation is adopted.

7) The raft is composed of reinforced concrete beams a relatively thin slab underneath i.e.-

3) Pile foundation in Bridges:

1. The pile foundation is constructions for the foundation of a bridge pier or abutment supported on piers.
2. A pile is an element of construction composed of timber, concrete or steel or combination of them.
3. Pile foundation may be defined as a column support type of foundation which may be cast-in-situ or precast.
4. The piles may be place separately or they may be placed in form of a cluster throughout the length of the pier or abutment.
5. This type of construction is adopted when the loose soil extends to great depth.
6. The load of the bridge is transmitted by the piles on hard stratum below or it is resisted by the friction developed on the sides of piles.

classification of piles:

Piles are broadly classified into two categorie

i) classification based on the function

ii) classification based on the materials and composition

classification based on the function

→ Bearing pile
→ Friction pile
→ Screw pile
→ Compaction pile
→ Uplift pile
→ Batter pile
→ sheet pile.

classification based on the materials and composition

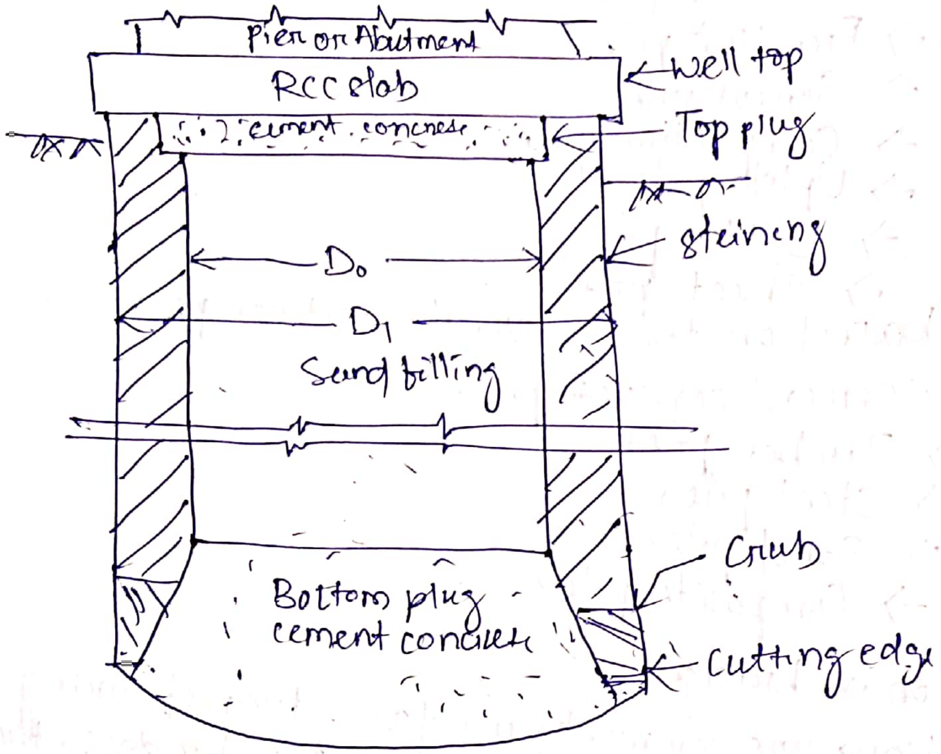
→ cement concrete piles
→ Timber piles
→ steel piles
→ Sand pile
→ Composite pile

(iv) Well Foundation in bridges

(a) Well foundations are commonly used for transferring heavy loads to deep strata in river or sea bed for bridges, transmission towers and labour structures. The situation where well foundations are resorted are as below as) Wherever consideration of scour or bearing capacity require foundation to be taken to depth of more than 5M below ground level open foundation becomes uneconomical. Heavy excavation and dewatering problem coupled with effort involve in retaining the soil makes the open foundation costlier in comparesion to other type of foundation

(b) Soil becomes loose due to excavation around the open foundation and hence susceptible to scouring. Thes is avoided in well foundation can always be left hollow thereby considerably reducing bearing pressure transmitted to the foundation material. This is very important in soils of poor bearing capacity particularly in clayey soils. In other type of foundation, the soil displaced is occupied by solid masonry concrete which are heavier than the soil displaced and hence this does not give any relief in respect of adjusting bearing capacity. However in case of well foundation this is easily acheived because of cellular space left inside the well.

Caission :-




The caisson is a structure used for the purpose of placing as foundation in correct position under water. The term caisson is derived from the French word 'caisse' meaning a box. It is a member with hollow portion, which after installing in places by any means is filled with concrete or other material. Caisson are prepared in sandy soils the caissons can be divided in the following three groups.

a. Box Caissons
b. Open caissons or Wells
c. Pneumatic Caisson

Well components and their function

→ Cutting edge :- It provides a comparatively sharp edge to cut the soil below during sinking operation. It is usually consists of a ~~solid~~ mild steel equal angle of side 150 mm.

→ Curb :- It has a two-fold purpose. During sinking it acts as an extension of cutting edge and also provides support to the well steining and bottom plug while after sinking it transfers the load to the soil below. It is made up of reinforced concrete using controlled concrete of grade M200.

→ **Steining**: It is the main body of the well. It is serves dual purpose. It acts as a cofferdam during sinking and structural member to transfer the load to the soil below afterwards. The steining may consists of brick masonry or reinforced concrete. The thickness of steining should be less than 4.5cm not less than that given by equation.

$$t = K\{(H/100) + (D/100)\}$$

Here t = minimum concrete steining thickness
H = well depth below bed
D = External diameter of well
K = a constant which is 1.0 for sandy strata

→ **Bottom plug** – Its main functions is to transfers load from the steining to the soil below.

→ **Sand plug**: Its utility is doubtful. It is supposed to afford some relief to the steining by transforming directly a portion of load from well cap to bottom plug.

→ **Top plug** :– The opinion is divided about the top plug. it, at least, serves as a shuttering for laying well cap.

→ **Reinforcement** :– It provides requisite strength to the structure during sinking and service.

→ **Well cap** :– It is needed to transfer the loads and moments from the pier to the well or wells below. The shape of well cap is similar to that of the well with a cantilever of about 15cm. Whenever 2 or 3 wells of small diameter are needed to support the substructure, the well cap designed as a slab resting over the well or wells with partial fixity at the edges of the wells.

→ **Depth of well foundation** :– As per I.R.C. Bridges code (part-II), the depth of well foundations is to be decided on the following consider.

1) The minimum depth of foundation below the H.F.L should be 1.33 D, where D is the anticipated max. Depth of scour below H.F.L. Depth should provided proper grip according to some rational formula.

2) The max bearing pressure on the subsoil under the foundation resulting from any combination of the loads and forces except wind and seismic forces should not exceed the safe bearing capacity of the subsoil after taking into account the effect of scour.
With wind and seismic forces in addition, the max. Bearing pressure should not exceed the safe bearing capacity

of the subsoil by more than 25%.
3) While calculating max. Bearing pressure on the foundation bearing layer resulting from the worst combination of direct forces and overturning moments, the effects of a passive resistance of the earth on side of the foundation structure may be taken into account below the max. depth of the scour only.
4) The effect of skin friction may be allowed on the portion below the max depth of scour. Accordingly for deciding the depth of well foundation, we required correct estimation of the following

1. Max. scour depth ✓
2. Safe bearing capacity ✓
3. Skin friction ✓
4. Lateral earth support below max. scour level

It is always desirable to fix the level of a well foundation on a sandy strata with adequate bearing capacity. Whenever a thin stratum of clay occurring between two layers of sand is met with, in that case well must be pierced through the clayey strata, if at all foundation has to be laid on clayey layer it should be ensured that the clay is stiff.

Design loads and forces: The forces acting on a bridge structure, to be considered for the design of a well foundation are as follow

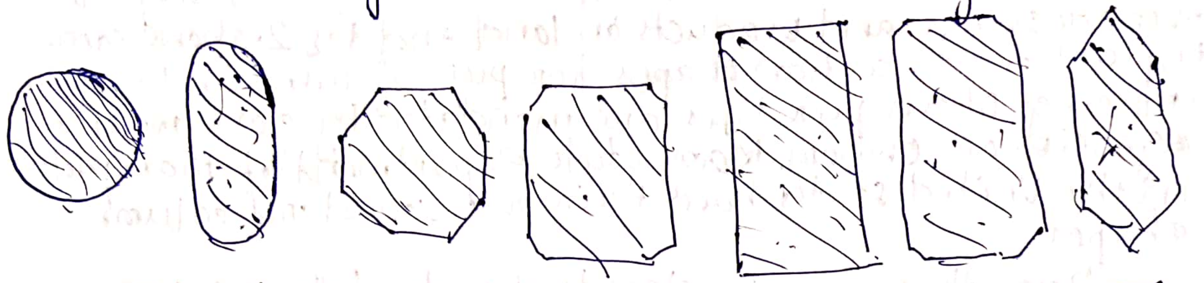
vertical
(i) Dead load
(ii) Live load
(iii) Buoyancy

Horizontal
(i) Wind force
(ii) Force due to water currents
(iii) Longitudinal forces caused by the tractive effort of vehicle or by braking effect of vehicles
(iv) Longitudinal force on account of resistance of the bearing against movement due to variation of temperature
(v) Seismic force
(vi) Earth pressure
(vii) Centrifugal force

The I.R.C. Bridge code II stipulates the magnitude of above loads and forces. The magnitude, direction and point of application of all the above forces can be resolved into two horizontal force P and Q and a single vertical force W under the worst possible combination.

## Piers:-

Piers provide vertical supports for spans at intermediate points and perform two main functions: transferring superstructure vertical loads to the foundations and resisting horizontal forces acting on the bridge. Although piers are traditionally designed to resist vertical loads it is becoming more and more common to design piers to piers high lateral loads caused by seismic events. Even in some low seismic areas designers are paying more attention to the ductility aspect of the design. Piers are predominantly constructed using reinforced concrete. Steel, to a lesser degree, is also used for piers. Steel tubes filled with concrete (composite) columns have gained more attention recently.



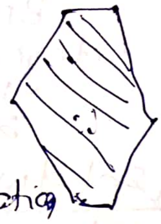
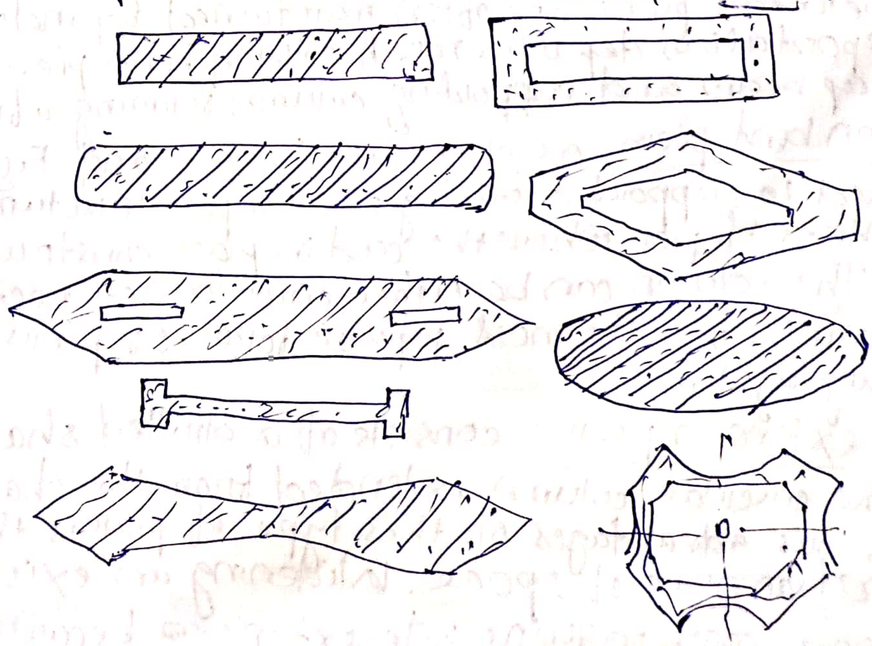


Fig. 1: Typical cross-section shapes of piers for overcrossing or viaducts on land

Pier is usually used as a general term for any type of substructure located between horizontal spans and foundation. However, from time to time, it is also used particularly for a solid [illegible]

[illegible] wall in order to distinguish it from columns of bents. From a structural point of view, a column is a member that resists the lateral force mainly by flexure action whereas a pier is a member that resists the lateral force mainly by a shear mechanism. A pier that consists of multiple columns is often called a bent.



There are several ways of defining pier types. One is by its structural connectivity to the superstructure, monolithic or cantilever. Another is by its sectional shape, solid or hollow, round, octangonal, hexagonal or rectangular. It can also be distinguished by its framing configuration single or multiple columns bent, hammerhead or pier wall. Selection of the type of piers for a bridge should be based on functional, structural and geometric requirement. Aesthetics is also a very important factor of selection since modern highway bridge are part of a city's landscape. Fig 1 shows a collection of typical cross-section shapes for overcrossings and viaducts on land and Fig 2 shows some typical cross-section shapes for piers of rivers and waterway crossing. Often pier types are mandated by government agencies or owners. Many state department of transportation in the United states have their own standard column shapes.

∴ Broadly piers are classified under following two categories

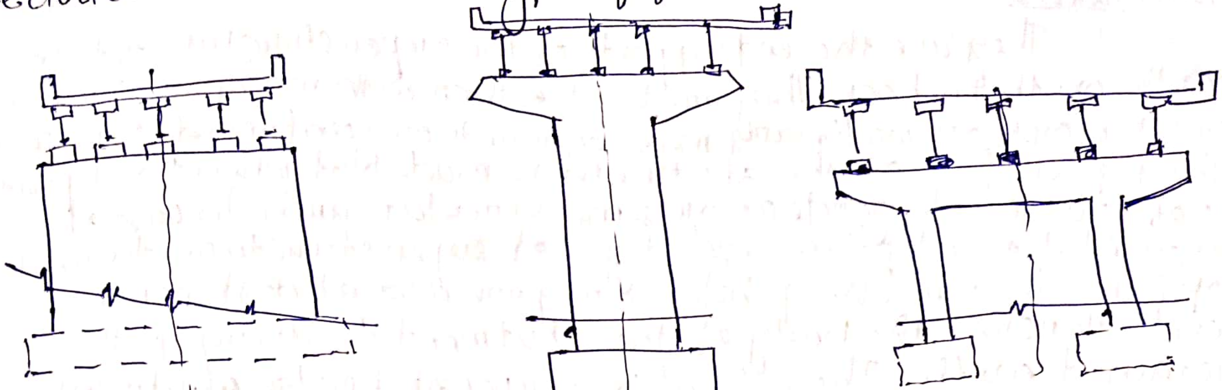
1. Solid piers
2. Open pier

Solid wall piers as shown in Fig 3a and 4 are often used at water crossing since they can be constructed to proportion that are both slender and streamlined. These features lend themselves well for providing minimal resistance to floods

Hammerhead piers as shown in Fig 3-b are often found in urban areas where space limitation is a concern. They are used to support steel girder or precast prestressed concrete superstructures. They are aesthetically appealing. They generally occupy less space, thereby providing more room for the traffic underneath. Standards for the use of hammerhead piers are often maintained by individual transportation department. A column bent piers consists of a cap beam and supporting column forming a frame.

Column bent piers as shown in Fig 3-c and Fig 27.5 can either be used to support a steel girder superstructure or to be used as an integral pier where the cast-in-place construction technique is used. The column can be either circular or rectangular in cross-sec. They are by far the most popular forms of piers in the modern highway system.

A pile extension pier : consists of a drilled shaft as the foundation and the circular column extended from the shaft to form substructure. An obvious advantages of this type of pier is that it occupied minimal amount of space. Widening an existing bridge in some instances may require pile extension because limited space precludes the use of other types of foundation.



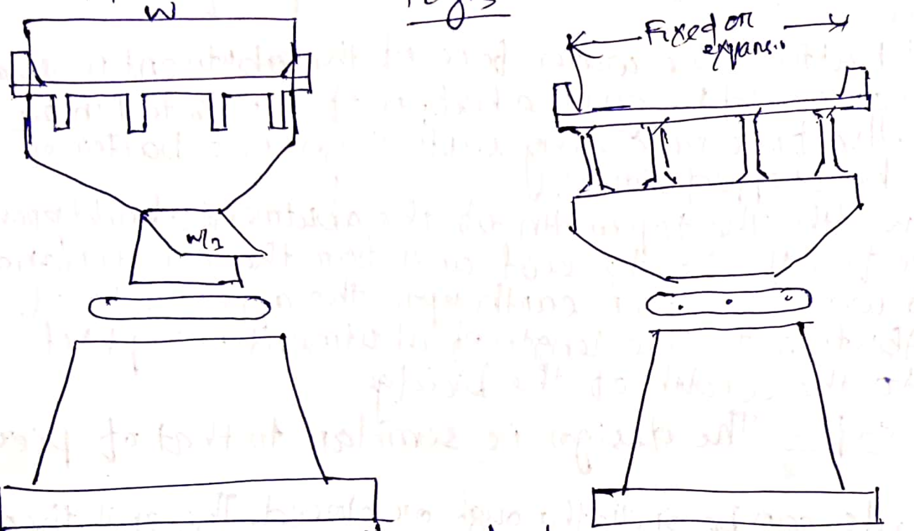
(a) Solid wall pier

(b) Hammerhead pier

(c) Riged frame pier

Fig.3

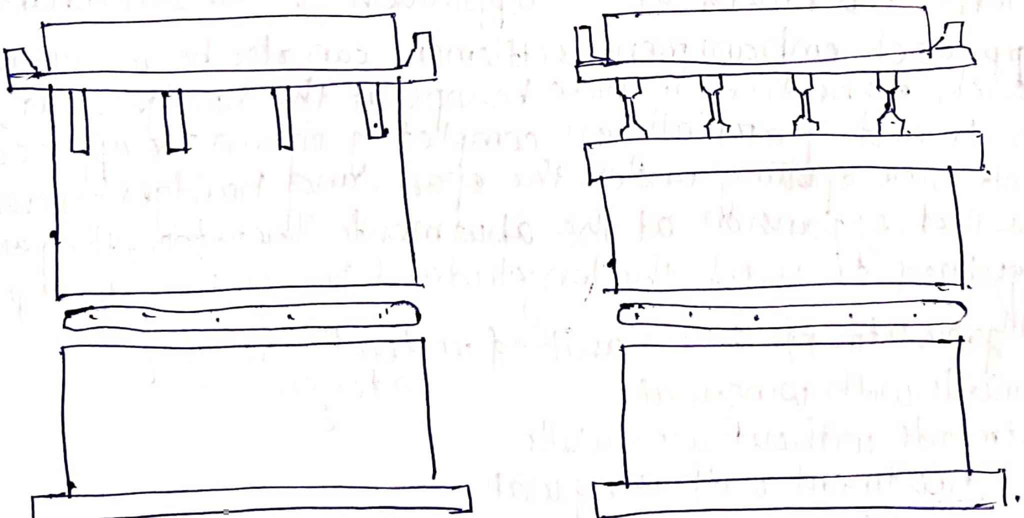
MONOLITHIC




Monolithic

Hammerhead (rectangular shaft)

Fixed or expaneion



solid wall (b)

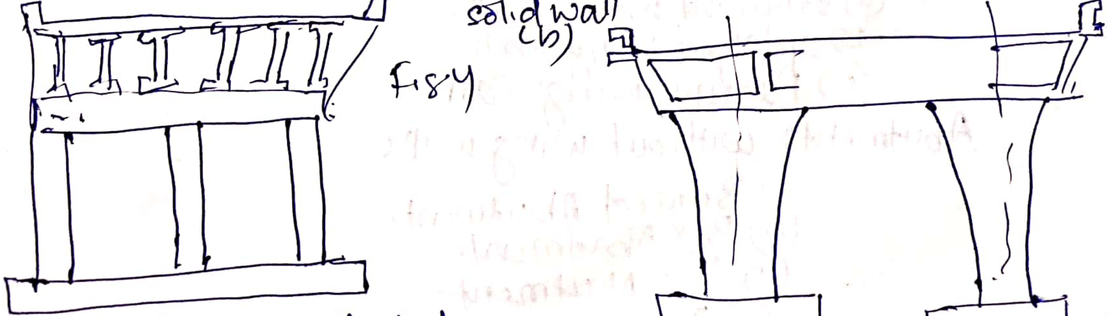


Fig.4

(a) Bent for precast girder.

(b) Bent for cast-in-place gerder

## Abutments:

They are the end supports of the superstructure, retaining earth on their back. They are built either with masonry, stone or brick work or ordinary mass concrete or reinforced concrete. The top surface of the abutment is made flat when the superstructure is of trusses of girders or semi-circular arch. In case of segmental or elliptical arch types of superstructure, the abutment top is made skew. Weep holes are provided at differential levels through the body of the abutment to drain of the retained earth. The salient features of bridge abutments are listed below:

(a) Height: The height of the abutments is kept equal to that of the piers.

(b) Abutment batter: The water face of the abutment is usually kept vertical or could be given a batter of 1 in 12 to 1 in 24 as of piers. The face retaining earth is given a batter of 1 in 6 or may be stepped down.

(c) Abutment width: The top width of the abutment should provide enough space for the bridge seat and for the construction of a dwarf wall to retain earth upto the approach level.

(d) Length of Abutment: The length of abutment is kept at least equal to the width of the bridge.

(e) Abutment cap: The design is similar to that of pier cap.

Abutments can be spill-through or closed. The spill through abutment generally has a substantial berm to help restrain embankment settlement at the approach of the structure.

Approach embankment settlement can also be accompanied by approach slabs to eliminate bumps at the bridge ends, closed abutments partially or completely retain the approach embankments from spilling under the span, and bridges of several spans required expansion at the abutments. Therefore, they are usually required to resist the longitudinal forces that develop.

Broadly, abutments are classified under the following category

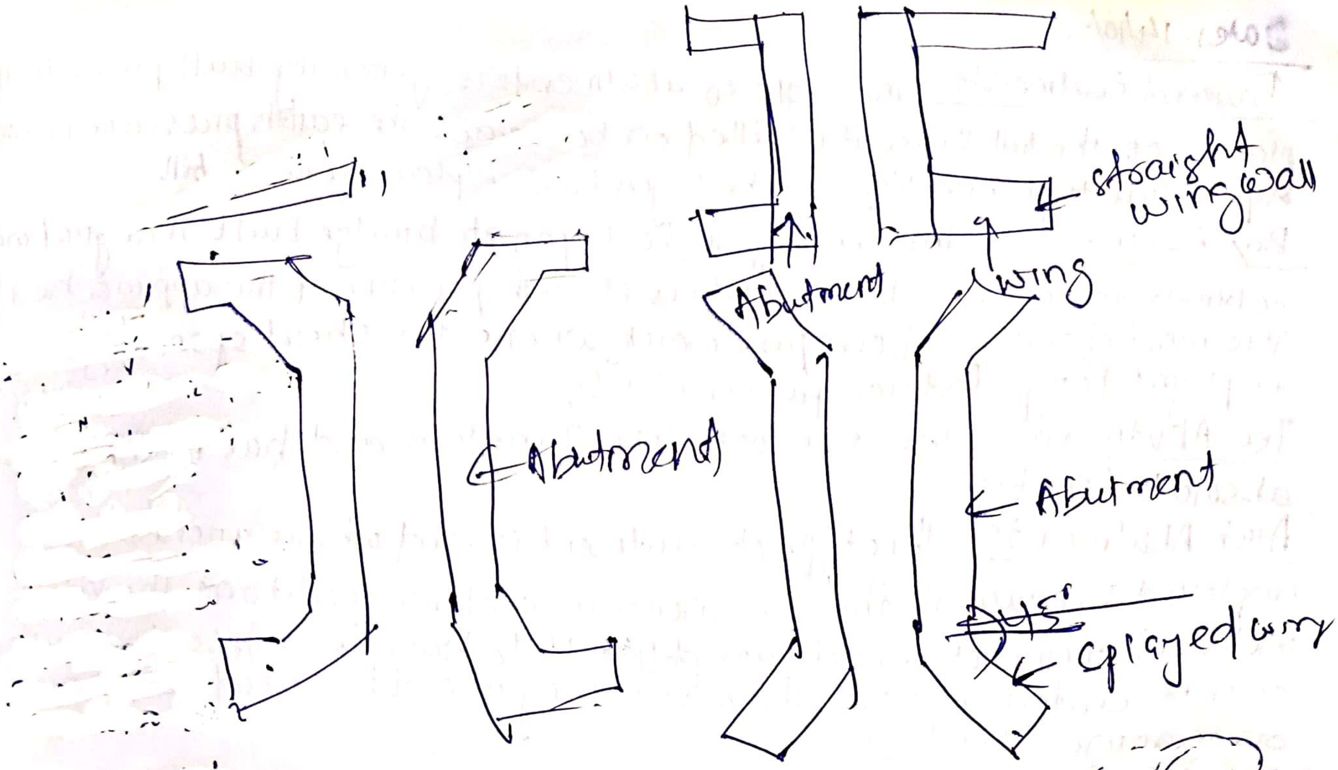
1. Abutments with wing walls
2. Abutments without wing walls

**Abutments with wing wall**

(a) Straight wing wall.
(b) Splayed wing wall
(c) Return wing wall

**Abutments without wing walls**

(a) Buried Abutment.
(b) Box Abutments
(c) Tee Abutment
(d) Arch Abutment



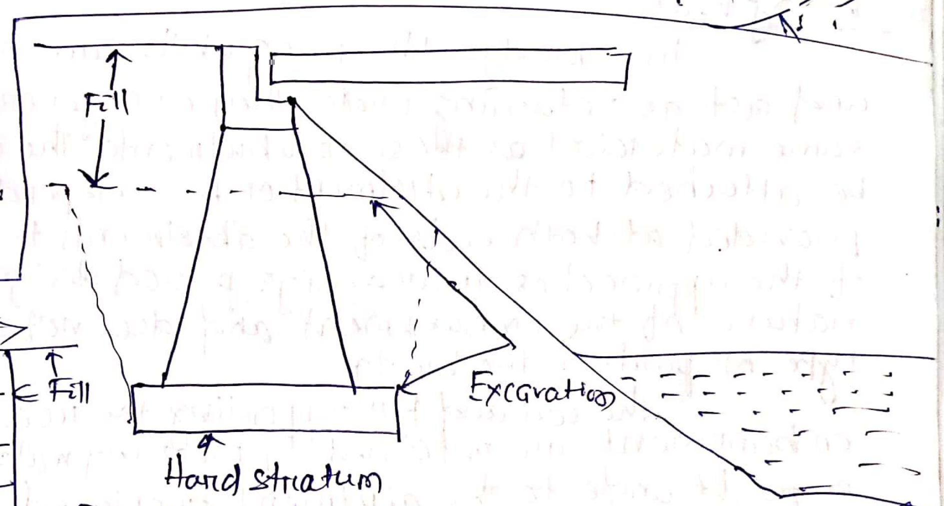




Fig. Buried Abutment

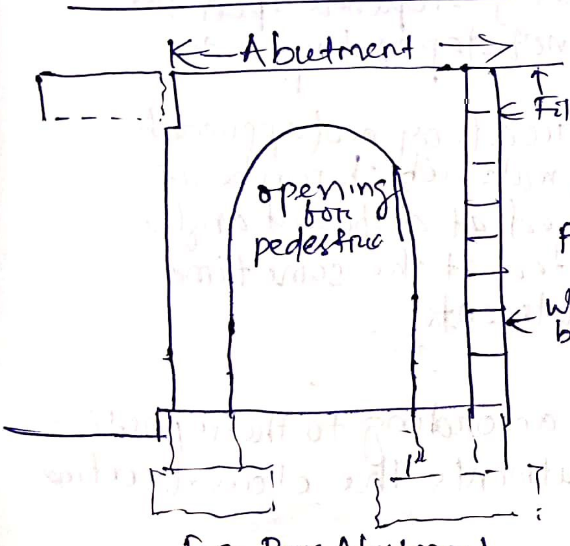



Fig. Box Abutment

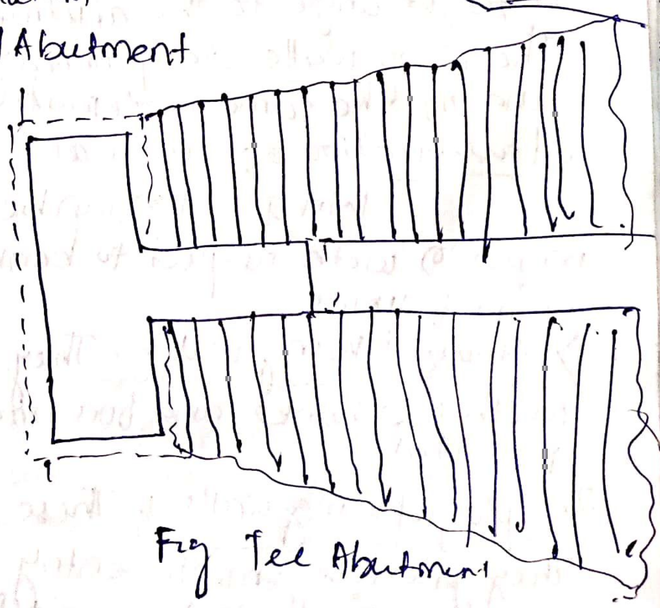


Fig Tee Abutment


Arch Abutment

Date: 14/10/20

**Buried Abutments:** This type of abutments is generally built prior to placing of the fill. Since it is filled on both sides the earth pressure is lo... superstructure erection can be begin before placement of fill.

**Box Abutments:** These employs a short span of bridge built integral wi... columns to act as a frame and resist earth pressure of the approaches. It is most often used overpass work where the short span may be employed for pedestrian passage (see fig)

**Tee Abutments:** These type looks like T in plain and has now become absolute (see fig)

**Arch Abutments:** These type of abutment is used where arches are employed because of their economy in certain conditions. The high inclined skewback thrusts are difficult to handle unless the abutment can be seated in rock. Therefore, they are often used for span over gorges (see fig)

**Wing Wall**

In a bridge, the wing walls are adjacent to the abutments and act as retaining walls. They are generally constructed of the same material as those of abutments. The wing walls can either be attached to the abutment or be independent of it. Wing walls are provided at both ends of the abutments to retain the earth filling of the approaches. Their design period design depends upon the nature of the embankment and does not depend upon the type or parts of the bridge.

The soil and fill supporting the roadway and approach embankment are retained by the wing walls, which can be at a right angle to the abutment or splayed at different angles. The wing walls are generally constructed at the same time and of the same materials at the abutments.

**Classification of wing walls**

Wing walls can be classified according to their position in plan with respect to banks and abutments. The classification is as follows

1) **Straight Wing walls:** They are used for small bridges, on drains with low banks and for railway bridge in cities (weep holes are provided)

2) **Splayed wing walls:** These are used for bridges across rivers. They provide smooth entry and exit to the water. The splay is usually us. Their top width is 0.5m, face batter 1 in 12 and back batter 1 in 6, weep holes are provided.

3) **Return wing walls:** They are used where banks are high and hard or firm. Their top width is 1.5m and face is vertical

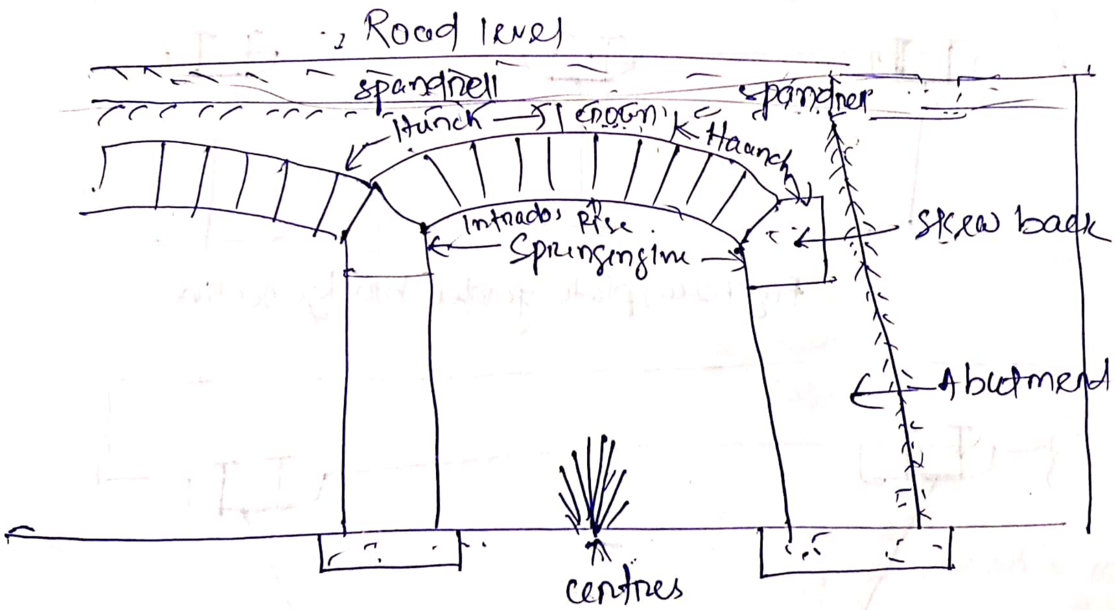
and back battered 1 in 4. Scour can be a problem for wing walls and abutments both, as the water in the stream erodes the supporting soil.

## ch-11

## Permanent Bridges

### Masonry Bridges:

Bridges unit the spandrel, which supports the bridge roadway. The spandrel is made from gravel or crushed stone backing held in by lateral (side) walls made of concrete masonry or stonework or in the form of an open main load bearing structure are made of natural stone, brick or concrete blocks. Such a bridge is always arched, with massive supports. The main load-bearing element of a masonry bridges is the arch, over which is structure of small arches resting on crosswalls. The advantages of a masonry bridges are its archetectural attractiveness and its durability. Masonry bridges are known that have been in use for more than 1,000 years. The basic short coning that limit the use of masonry bridges are their complexity and labor intensiveness of construction. Their simplicity, economy and ease with which pleasing appearance can be obtained make them suitable for this purpose




### Classification of steel bridges

steel bridges are classified according to

- the type of traffic carried
- the type of main structural system
- the position of the carriage way relative to the main structural system

These are briefly discussed in this section

classification based on type of traffic carried

Bridges are classified as
- Highway or road bridges
- Railway or rail bridges
- Road-cum-rail bridge

Classification based on the main structural system

Many different types of structural systems are used in bridges depending upon the span, carriageway width and types of traffic. classification, according to makeup of main load carrying system, is as follows

i) Girder bridges :- Flexure or bending between vertical supports is the main structural action in this type. Girder bridges may be either solid web girders or truss girders or box girders. plate girder bridges are adopted for simply supported spans less than 50m and box girders for continuous spans up to 250m. cross-sections of a typical plate girder and box girder bridges are shown in Fig 7.2(a) and Fig 7.2(b) respectively. Truss bridges [See Fig 7.2(c)] are suitable for the span range of 30m to 375m. Cantilever bridges have been built with success with main spans of 300 to 550m. They may be further, subdivided into simple spans, continuous spans and suspended and - cantilevered spans as illustrated in Fig 7.3

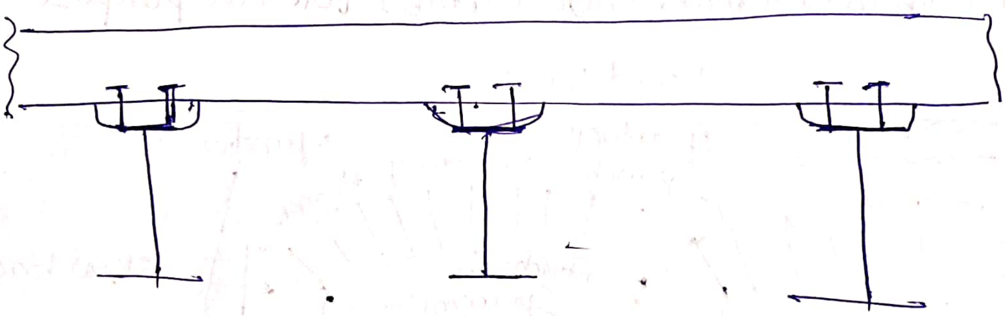


Fig 7.2(a) plate girder bridge section

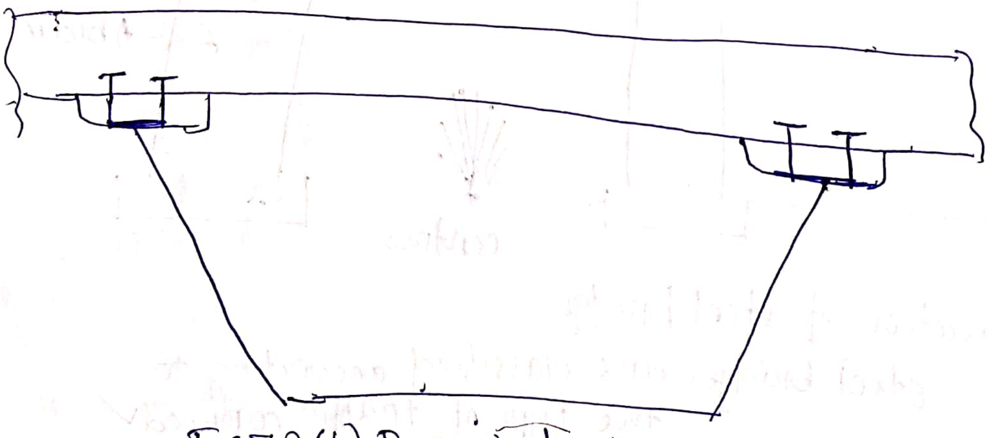


Fig 7.2 (b) Box girder bridge section

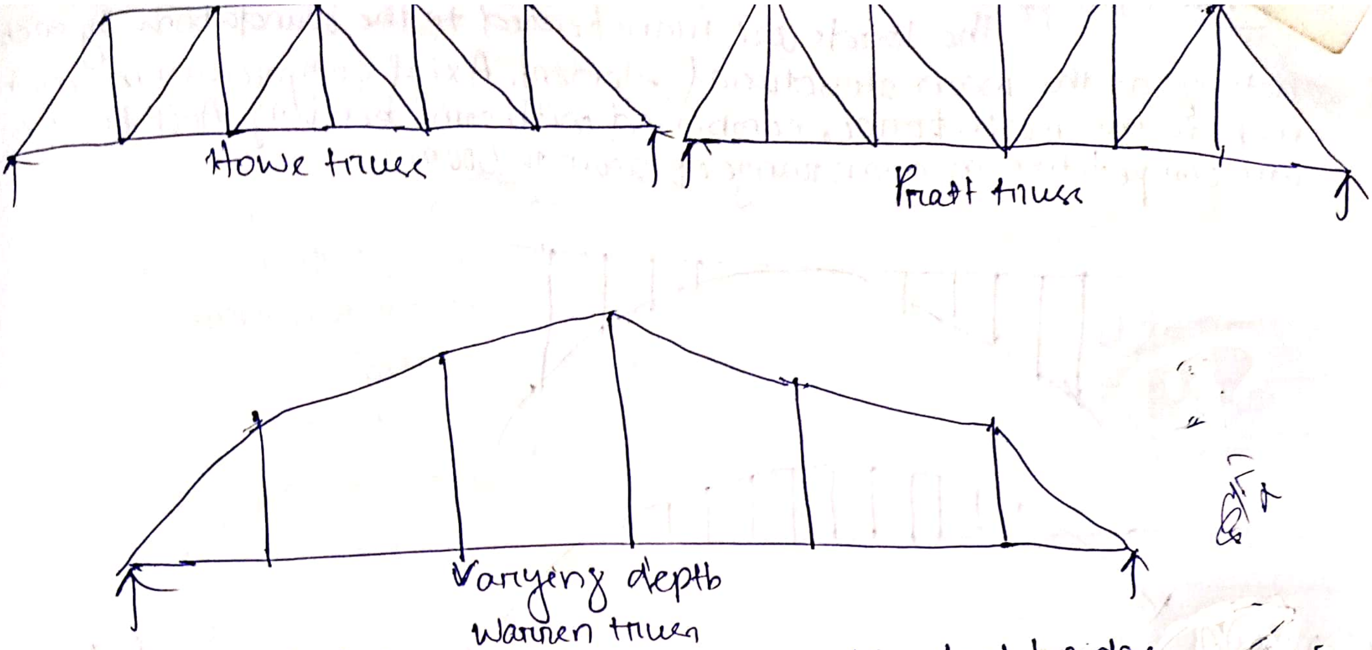



Fig 7.2 (c) Some of the trusses used in steel bridges.

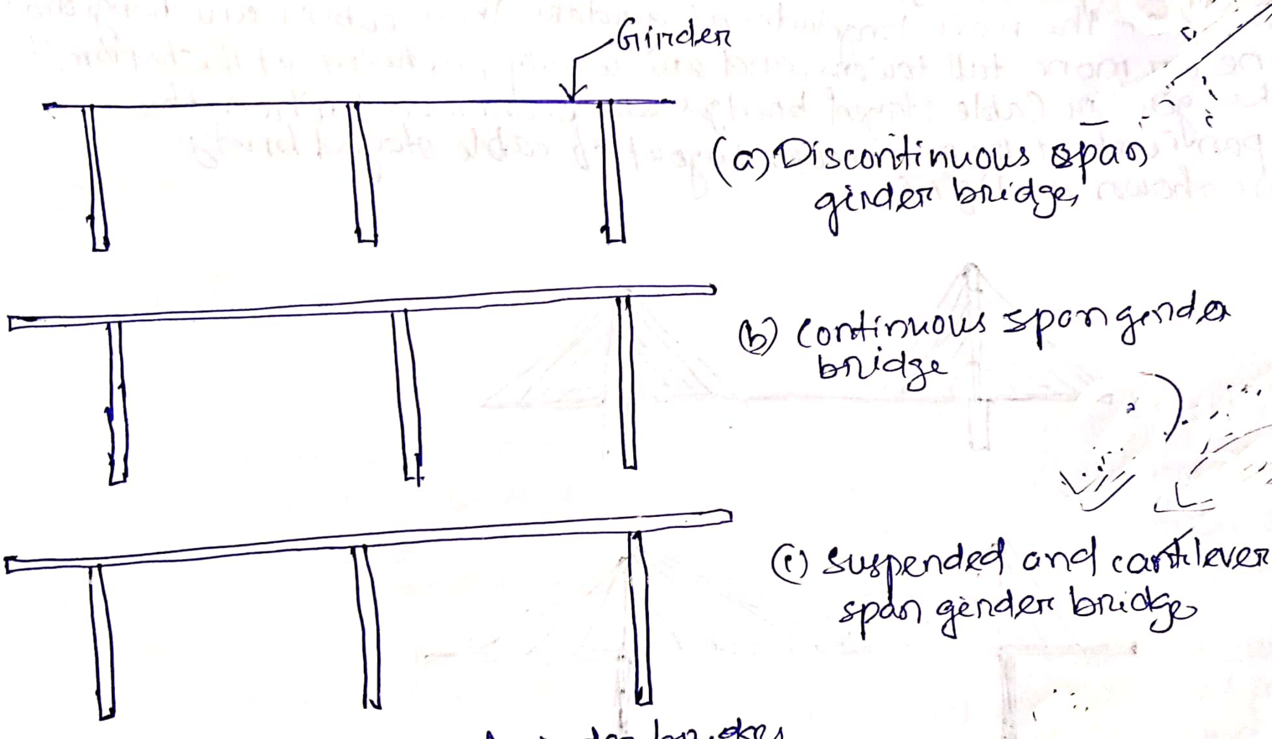



Fig 7.3 Typical girder bridges

(ii) Rigid frame bridges:- In this type, the longitudinal girders are made structurally continuous with the vertical or inclined supporting member by means of moment carrying joints [Fig 7.4]. Flexure with some axial force ic the main forces in the member in this type. Rigid frame bridges are suitable in the span range of 25 to 300m.

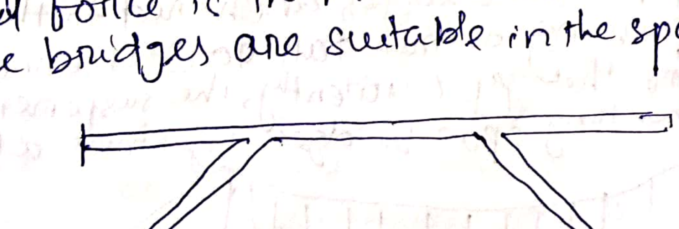
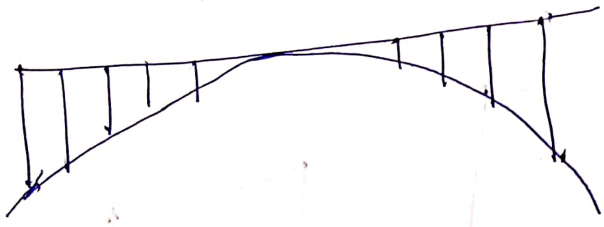
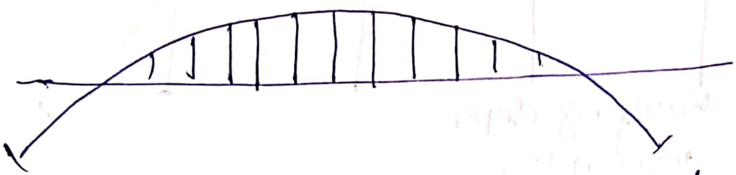


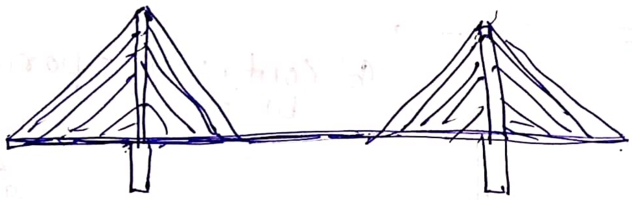
Fig 7.4 Typical rigid frame bridge

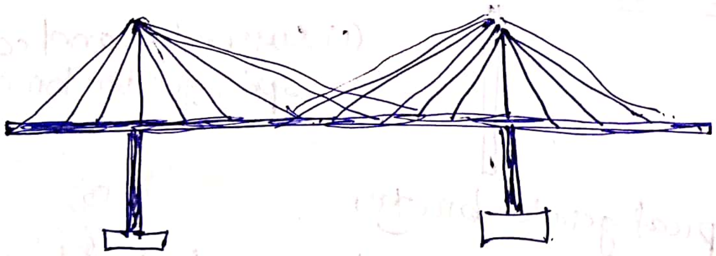
(iii) Arch bridges The loads are transferred to the foundations by an arch acting as the main structural element. Axial compression in arch rib is the main force, combined with some bending. Arch bridges are competitive in span range of 200m to 500m.





(iv) Cable stayed bridges:- Cables in the vertical or near vertical plane support the main longitudinal girders. These cables are hung from one or more tall towers, and are usually anchored at the bottom to the girders. Cable stayed bridges are economical when the span is about 150m to 700m. Layout of cable stayed bridge are shown in Fig 7.6





Layout of cable stayed bridge

(v) Suspension bridges. The bridges deck is suspended from cables stretched over the gap to be bridged, anchored to the ground at two ends and passing over tall towers erected at or near the two edges of the gap. Currently, the suspension bridge is best solution for the long span bridges. Fig shows a typical suspension

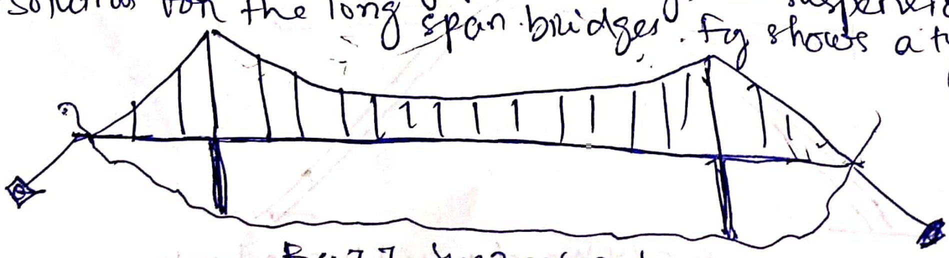
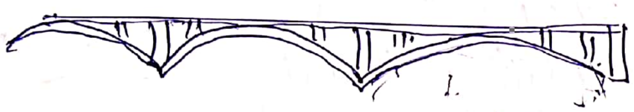


Fig 7.7. Suspension bridge

Date:- 19/10/20 Types of concrete bridges

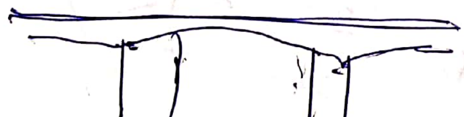
## Arch Bridges:

Arch bridges derive their strength from the fact that vertical loads on the arch generate compressive forces in the arch ring, which is constructed of materials will able to withstand these forces. The compressive forces in the arch ring result in inclined thrust at the abutments, and it is essential that arch abutments are well founded or buttressed to resist the vertical and horizontal components of these thrusts. If the support spread apart the arch falls down. Traditionally, arch bridges were constructed of stone, brick or mass concrete since these materials are very strong in compression and the arch could be configured so that tensile stresses did not develop. Modern concrete arch bridges utilize prestressing or reinforcing to resist the tensile stresses which can develop in slender arch rings.



## Reinforced slab bridges

For short spans, a solid reinforced concrete slab generally cast-in-situ rather than precast, is the simplest design. It is also cost-effective, since the flat, level soffit means that false work and formwork are also simple. Reinforcement, too is uncomplicated. With larger spans, the reinforced slab has to be thicker to carry the extra stresses under load. The extra weight of the slab itself then becomes a problem which can be solved in one of two ways. The first is to use prestressing technique and the second is to reduce the deadweight of the slab by including voids, often expanded polystyrene cylinder. Upto about 25m span, such voided slabs are more economical than prestressed slabs.



**Beam and slab bridge:** Beam and slab bridges are probably the most common form of concrete bridges in the UK today, thanks to the success of standard precast prestressed concrete beams developed originally by the Prestressed concrete Development Group (cement & concrete association) supplemented later by alternative designs by others culminating in the Y-beam introduced by the Prestressed Concrete Association in the late 1980s.

They have the virtue of simplicity, economy, wide availability of the standard sections, and speed of erection. The precast beams are placed on the supporting piers or abutments, usually on rubber bearings which are maintenance free. An in-situ reinforced concrete deck slab is then cast on permanent shuttering which spans between the beams.

The precast beams can be joined together at the supports to form continuous beams which are structurally more efficient. However, this is not normally done because the costs involved are not justified by the increased efficiency.

Simply supported concrete beam and slab bridges are now giving way to integral bridges which offer the advantages of less cost and lower maintenance due to the elimination of expansion joints and bearings.

Techniques of construction vary according to the actual design and situation of the bridge, there being three main types.

1. Incrementally launched
2. span-by-span
3. Balanced cantilever

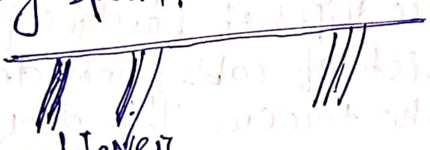
Incrementally launched:

As the name suggests, the incrementally launched technique creates the bridges section by section, pushing the structure outwards from the abutment towards the pier. The practical limit on span for the technique is around 75m.

Span-by-span:

The span-by-span method is used for multi-span viaducts where the individual span can be up to 60m.

These bridges are usually constructed in-situ with the false work moved forward span by span, but can be built of precast sections put together as single spans and dropped into place, span by span.



Balanced cantilever

In the early 1950s, the German engineer Ulrich Finsterwalder developed a way of erecting prestressed concrete cantilever segment by segment with each additional unit being prestressed to those already in position. This avoids the need for false work and the system has since been developed.

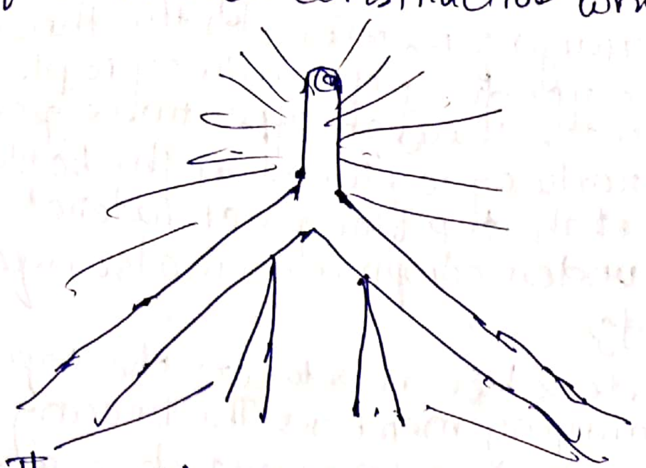
Whether created in-situ or using precast segments the balance cantilever is one of the most dramatic ways of building a bridge. Work starts with the construction of the abutment and piers. Then, from each pier, the bridge is constructed in both direction simultaneously. In this way, each pier remains stable - hence 'balanced' - until finally the individual structural elements meet and is connected together. In every case, the segments are progressively tied back to the piers by means of prestressing tendon or bars threaded or bars through each unit.

4. Integral Bridges

One of the difficulties in designing any structure is deciding where to put the joints. These are necessary to allow movement as the structure expands under the heat of the summer sun and contracts during the cold of winter. Expansion joints in bridges are notoriously prone to leakage. Water laden with road salts can then reach the tops of the piers and the abutments, and this can result in corrosion of all reinforcement. The expansive effects of rust can split concrete apart. In addition, expansion joints and bearings are an addition of cost so more and more bridges are being built without either. Such structures called integral bridges can be constructed with all types of concrete deck. They are constructed with their decks connected directly to the supporting piers and abutments and with no provision in the form of bearings or expansion joints for thermal movements. Thermal movements of the deck is accommodated by flexure of the supporting piers and horizontal movement of the abutment, with elastic compression of the surrounding soil.

Already used for lengths upto 60m, the integral bridges is becoming increasingly popular as engineers and designers find other ways of dealing with thermal movement.

Cable-stayed bridge:- For really large spans, one solution is the cable-stayed bridge. These types of bridges first developed in West Germany. They consists of cables provided above the deck and are connected to the towers. The deck is either supported by a number cables meeting in a bunch at the tower or by joining at different levels on the tower. The multiple cables would facilities smaller distance between points of supports for the deck girder. This result in reduction of structure depth. The cables can arrange in one place or two point plane. The two plane system requires additional width to accommodate the towers and deck anchorages. Singly plane systems requires less width of deck. Where all elements are concrete. the design consists of supporting tower carrying cables which support the bridges from both sides of the tower. Most cable-stayed bridges are built using a form of cantilever construction which can be either insitu or precast



The cable stayed bridges are similar to suspension bridge except that there are no suspenders in the cable stayed bridges and the cables are directly stretched from the towers to connect with decking. No special anchorages is requirecked for the cables as increase of suspension bridges because the anchorage at one end is done in the girder and at the other on top of tower. The cable-stayed bridges have been found economical for upto span 800m. However due to cantilever effect their deflection is rather high and hence they are not preferred for very long span in railways.

Suspension bridges:

Concrete plays an important part in the construction of a suspension bridge. suspension bridge are ideal solution for bridging gaps in hilly areas because of their construction technology and capacity of spanning large ~~span~~ gaps. There will be massive foundations, usually embedded in the ground that supports the weight and cable anchorages. The cables takes shape of catenary between two points of suspension. The flooring of bridge supported by the cable by virtue of tension developed in its cross section. The vertical members are known as suspenders are provided to transfer load from bridge floor to suspension cable. There will also be the abutments, again probably in mass concrete, providing the vital strength and ability to resist the enormous forces and in addition the slender superstructure carrying the upper ends of the supporting cables are also generally made from reinforced concrete.

bridges. Typical deck, through and semi-through type truss bridges.

(ii) Through Types Bridge:- The carriageway rests at the bottom level of the main load carrying member. In the through type plate girder bridges, the roadway or railway is placed at the level of bottom flanges. In the through type truss girder bridge, the roadway or railway is placed at the bottom chord level. The bracing of the top flanges or lateral support of the top chord under compression is also required.

(iii) Semi through Types Bridge:-

The deck lies in between the top and the bottom of the main load carrying members. The bracing of the top flanges or top chord under compression is not done and part of the load carrying system project above the floor level. The lateral restraints in the system is obtained usually by the U-frame action of the vertical and cross beam acting together.

Concrete bridges:-

They can be divided into the following main classes
(1) Unstiffened suspension bridges
(2) stiffened suspension bridges

Un-stiffened suspension Bridge: In case of un-stiffened suspension Bridges the moving load is transferred into direct to the cables by each suspender. These are used for light construction such as foot bridges forest train structures etc. Where span is very long and the ratio dead to moving load intensity is to great to render stiffening unnecessary.

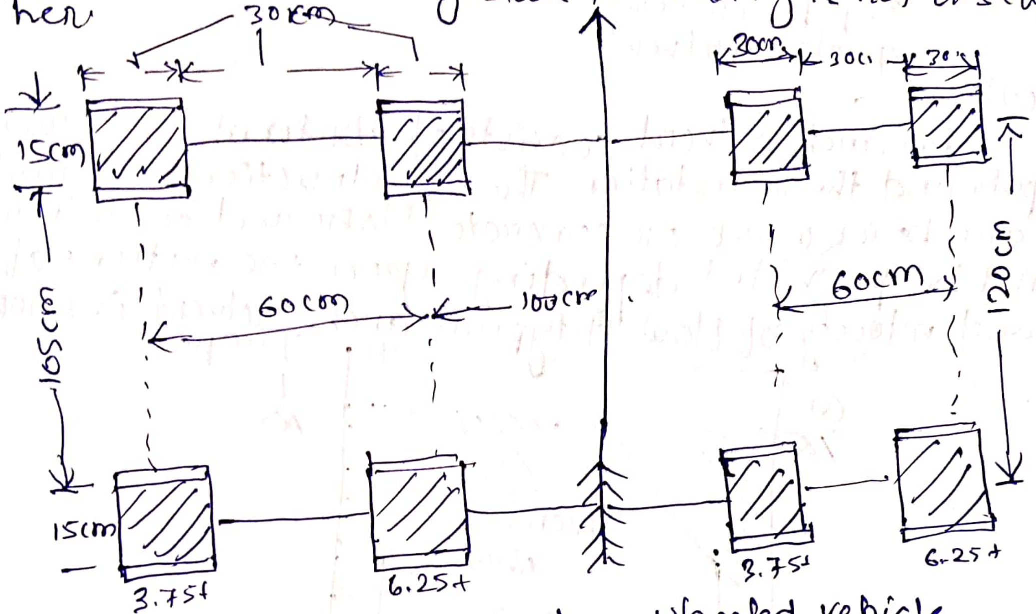
stiffened suspension Bridges: In stiffened type suspension Bridges moving loads are transformed to the cables through medium of trusses called stiffening girders. The stiffening girder assists the cables to become more rigid and prevent change in shape and gradient of roadway platform. It is therefore adopted for heavy traffic.

IRC Bridge loading:-

The public roads in India are managed and controlled by the Government and hence bridges to be constructed for roads to be designed as per standards set up by standard authorities. For highway bridges, standard specifications are contained in the Indian Road Congress (I.R.C) Bridges code. In India highway bridges are designed in accordance with IRC bridge code. IRC: 6 - 1966 - section II gives the specifications for the various loads and stresses to be considered in bridges design. There are three types of standard loadings for which the bridges are designed namely.
(a) IRC class AA loading (c) IRC class B loading
(b) IRC class A loading

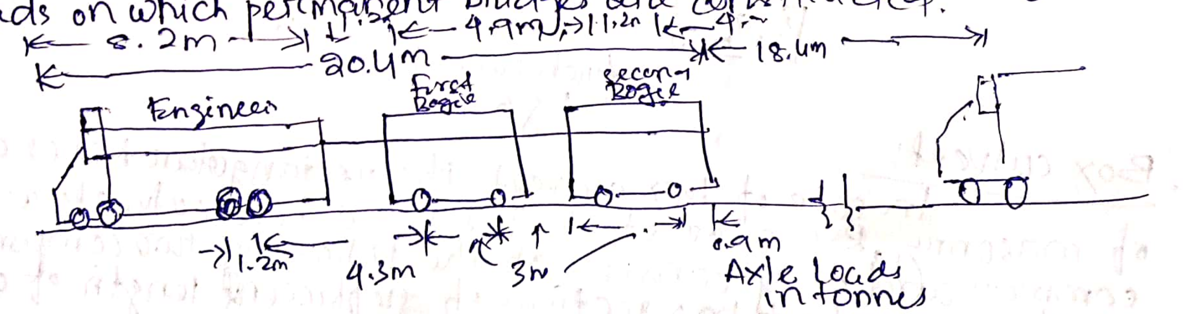
IRC class AA loading:-

IRC class AA loading consists of either a tracked vehicle of 70 tonnes or a wheeled vehicle of 40 tonne with dimension as shown in Fig. The units in the figure are mm for length and tonnes for load. Normally bridges on national highway and state highway are designed for these loadings. Bridges designed for class AA should be checked for IRC class A loading also, since under certain condition larger stresses may be obtained under class A loading. Sometimes class 70R loading given in the Appendix-1 of IRC 6-1966 section II can be used for IRC class AA loading class 70 R loading is not discussed feature here




IRC class AA loading - wheeled vehicle

IRC class A loading:- class A loading is based on heaviest type commercial vehicle consists of a wheel load train composed of a driving vehicle and two trailers of specified axle spacings. This loading is normally adopted on all roads on which permanent bridges are constructed.




IRC class A and class B loading

IRC class B loading is adopted for temporary structures and for bridges in specified areas. For class A and class B loadings reader is referred to IRC 6-1966 - section II

20/10/20

**Culverts** :- A culvert is defined as small bridged constructed ~~across~~ over a stream which remains dry most part of the year. It is across drainage work having total length not exceeding 6m between faces of abutment.

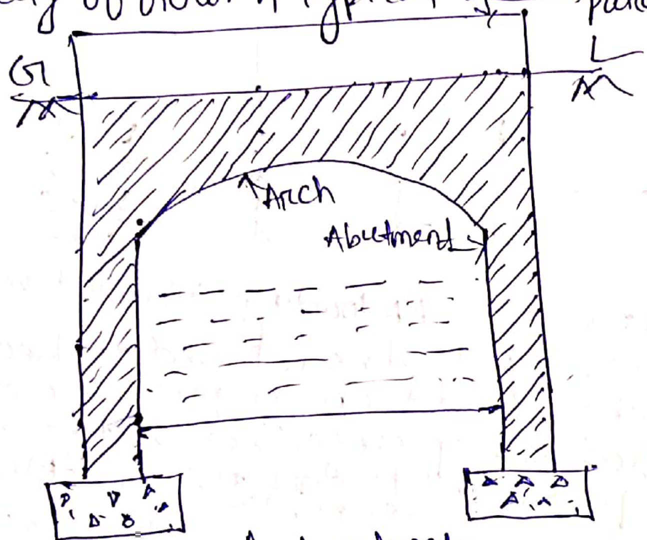
Types of Culverts:-

The following are four different types culvert

1. Arch culvert
2. Box culvert
3. pipe culvert
4. slab culvert

**1. Arch culvert** :-

An arch culvert consists of abutments wing walls, arch parapets and the foundation. The construction materials commonly used are brick work or concrete. Floor and curtain wall may or may not be provided depending upon the nature of foundation soil and velocity of flow. A typical arch culvert is shown in fig



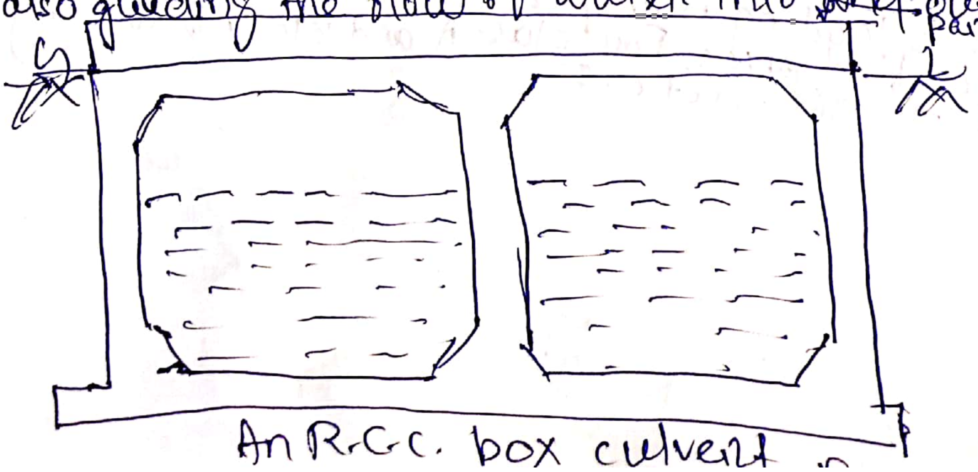

Arch culvert
Fig 6-1

**2. Box culvert** :-

In case of box culvert the rectangular boxes are formed of masonry, R.C.C. or steel. The R.C.C. box culverts are very common and they consist of the following two component

i) The barrel or box sections of sufficient length of accommodate the roadway and the kerbs

ii) The wing walls splayed at 45 for retaining the embankment and also guiding the flow of water into and out of the barrel.




An R.C.C. box culvert

Fig 6.2 shows an R.C.C. box culvert with two opening. Following points should be noted,

(i) Foundation:- The box culverts prove to be safe where good foundation are easily available

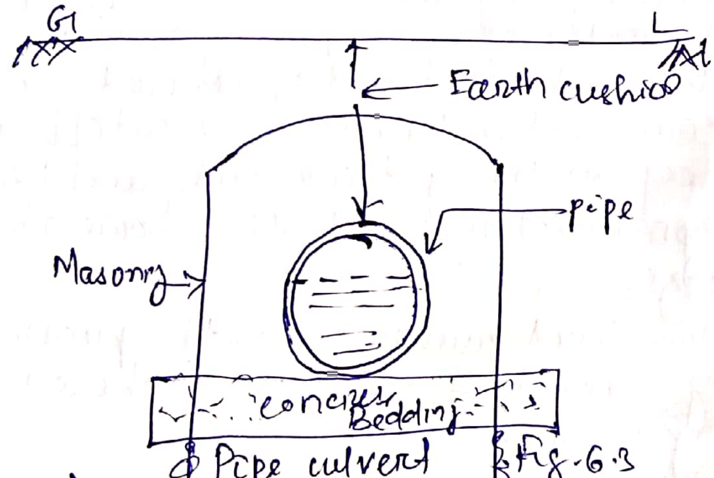
(ii) Height:- The clear vent height i.e. the vertical distance between top and bottom of the culvert rarely exceeds 3 meter.

(iii) Sop:- The box culverts are provided singly or in multiple units with individual span exceed about 6m or so. if requires thick section which will make the construction uneconomical

(iv) Top:- Depending upon the site condition, the top level of box may be at the ~~level~~ road level or it can even be at a depth below road level with filling of suitable material.

3. Pipe culvert:-

They are provided when discharge of stream is small or when sufficient headway is not available. Usually one or more pipes of diameter not less than 60cm are placed side by side. Their exact number and diameter depend upon the discharge and height of bank. For easy approach of water splayed type wing walls are provided in fig. 6.3 shows a Hume pipe culvert of single pipe. The pipes can be built of masonry, stone ware, cement concrete, cast iron or steel. Concrete bedding should also be given below the pipes and earth cushion of sufficient thickness on the top to protect the pipes and their joints. For economic reason road culverts should have non-pressure heavy duty pipes of type IS1 class HP3 conforming to IS:458-1961. As far possible the gradient of the pipe should not be less than 1000.




Pipe culvert Fig-6.3

4. Slab culverts

A slab culverts consists of stone slabs or R.C.C. slab suitably support on masonry walls on either side. as shown in fig. 6.4. The slab culverts of simply type are suitable up to a max^m span of 2.50m or so. However the R.C.C. culverts of deck slab type can economically be adopted up to span of about 8m. However the thickness of slab and dead weight may sometimes prove to be limiting factors for deciding the economical span of this type of culverts.

The construction of slab culverts in relatively simple as the frame work can easily be arranged reinforcement can be suitably placed and concreting can be done easily. This type of culverts can be used for highway as well as Railway Bridg. Depending upon the span of culvert and site conditions the abutments and wing walls of suitable dimension may be provided. The parapet or hand rail of at least 750mm height should be provided on the slab to define the width of culvert.

Causeways:-

A road causeway is a pucca dip which allows floods to pass over it. It may or may not have opening or vents for low water to flow. If it has vents for low water to flow then it is known as high level causeway or submersible bridge otherwise a low level causeway.

Types of Causeway

(A) Low level causeway:

It is also known as Irish Bridge. The beds of small rivers or stream, which remain dry for most part of the year are generally passible without a bridge. This involves heavy earth works in cutting for bridge approaches. Banks of such types of streams are cut down at an easy slope. For streams of rivers in plains having sandy beds. It is often sufficient to lay bundles of grass over and across the sandy track. The bundles may be of 20 to 25cm in diameter whose ends are secured by longitudinal fascines pegged down by stakes.

For crossings important from traffic point of view is essential to lay a metal or pucca paving of stone or brick set in lime mortar on a substantial bed of concrete. To prevent against possible scour and undermining a cut off or dwarf wall usually 60cm deep on the upstream side and 120 to 150cm downstream side is provided fig 5.3.1 below shows the details of a typical Irish bridge.

The low level causeway could be provided with openings formed by concrete Hume pipes if there is a continuous flow stream during the monsoon periods.

(B) High level Causeway:

A high level causeway is submersible road bridge designed to be overtopped in floods. Its formation level is fixed in such a way as not to cause interruption to traffic during floods for more than three days at a time not for more than six times in a year. A sufficient numbers of openings are provided to allow the normal flood discharge to pass through them with the required clearance. They are provided with abutments and piers, floors and slabs or arches to form the required number of openings. The slope of the approache is kept as 1 in 20. When the velocity is high and stream bed is soft the aprons could be of concrete or harder masonry upto a certain distance. Similarly, the road can be formed of a cement concrete slab or stone blocks set in cement mortar. A typical type of high level causeway is shown in fig. If railing are provided in the bridge, they should be of collapsible type. Temporary causeways used for an emergency military operations are formed either by using timber stringers and planking over cribs used as piers by constructing a culvert using pipe.

Ex.36.1 A bridge has a linear waterway of 150 metres constructed across a stream whose natural linear waterway is 220 metres. If the average flood discharge is 1200 $m^3/sec$. and average flood depth is 3 metres, calculate the afflux under the bridge.

Ans The natural waterway area at the site

$$= A = 220 \times 3 = 660\, m^2$$

Contracted waterway area $= a = 150 \times 3 = 450\, m^2$

The velocity of approach $= V = Q/A$

Here, Q = Flood discharge = 1200 $m^3/sec$.

$$V = 1200/660 = 1.83\, m/sec.$$

Using Molesworth formula, the afflux can be given by

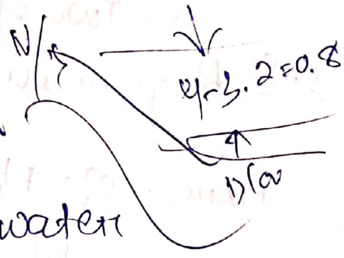
$$h_a = \left(\frac{V^2}{17.9} + 0.015\right)\left\{\left(A/a\right)^2 - 1\right\} = \left(\frac{(1.83)^2}{17.9} + 0.015\right)\left\{\left(\frac{660}{450}\right)^2 - 1\right\}$$

$$= (0.187 + 0.015)\{(660/450)^2 - 1\}$$

$$= 0.202 \times 1.15 = 0.232\, m$$

Ex.36.2 Calculate flood discharge of a river at the bridge site. Given the following data:

(i) Unobstructed width of river = 80m
(ii) Linear waterway of the bridge = 60m
(iii) The upstream depth of water = 4m
(iv) The downstream depth of water = 3.2m




Soln Afflux = Upstream depth of water − D/s depth of water

or $h = h_1 - h_2$

or Afflux = 4 − 3.2

$h = 0.8m$

Therefore $\frac{h}{h_2} = \frac{0.8}{3.2} = \frac{1}{4}$

This is a borderline case, where afflux is just equal to 1/4th of the downstream depth of flow. Therefore, both broad crested weir and drowned orifice formula will be applied and the higher value of the two be taken as flood discharge.

Broad Crested Weir Formula

$$Q = 1.70\, C_W L \left(h_1 + \frac{V^2}{2g}\right)^{3/2}$$

Here, L = Linear waterway = 60 m

W = unobstructed width = 80 m

$h_1$ = 4 m.

$C_W$ = 0.98 from table 3.1.1

If V is velocity approach, then discharge just U/s of the bridge

$$Q = W \times h_1 \times V$$
$$= 80 \times 4 \times V$$

Therefore. $Q = 320V$.

The discharge through bridge

$$Q = 1.70 \times 0.98 \times 60 \left(4 + \frac{V^2}{2 \times 9.8}\right)^{3/2}$$

=

Ex. 3.4.1 A bridge is proposed to be constructed across an alluvial stream carrying a discharge of 300 m³/sec. Assuming the value of silt factor = 1.1, determine the maximum scour depth when the bridge consists of

(i) Two spans of 35 m each, (ii) Three spans of 30 m each

Soln Regime surface width of the stream is given by

$$W = 4.8\sqrt{Q}$$

Here, Q = Flood discharge = 300 m³/sec.

$$W = 4.8\sqrt{300} = 83\text{ m}$$

Case I Since the proposed bridge consists of two spans of 35 m each.

Therefore, $L = 2 \times 35 = 70\text{ m} < W$

i.e. the waterway is contracted. Normal scour depth can be given by eqn 3.4.2

$$d_1 = d\left(W/L\right)^{0.61}$$

Here, d = Regime depth = $0.473\left(Q/f\right)^{1/3}$

f = silt factor = 1.1

$$d = 0.473\left(\frac{300}{1.1}\right)^{1/3} = 3.02\text{ m}$$

$\therefore \quad d_1 = 3.02 \left(\frac{83.1}{70}\right)^{0.61}$

$= 3.1 m$

As the bridge has got two spans, therefore it will have one pier and two end support.

Since, the maximum scour depth will occur at noses of piers, therefore

Maximum scour depth $= 2d$

$= 2 \times 3.1 = 6.2 m.$

Case.II Since the bridge consist of three spans of 30m each

$L = 90 m > W$

Therefore, Normal scour depth = Regime depth

or, $d = 0.473 (Q/f)^{1/3}$

$= 0.472 \left(\frac{300}{1.1}\right)^{1/3} = 3.02 m$

The maximum scour depth in this case too will occur at noses of pier.

Therefore, Maximum scour depth $= 2d = 6.04 m$.

Ex 3.3.1 The following are the costs of one pier and one superstructure span of multiple span bridge for various span lengths. The cost of superstructure span excludes the costs of railing and flooring system. Calculate the economic span.

| | | | | |
|---|---|---|---|---|
| span in metres | 4 | 8 | 12 | 15 |
| superstructure cost in Rs. | 1700 | 7000 | 16000 | 24500 |
| substructure cost Rs. | 22200 | 23200 | 23000 | 23600 |

Sol^n Assuming that the cost of superstructure varies as the square of the span length, the constant of variation a for various value of span is as per equation 3.3.1

for 4m span, $a_1 = 1700/16 = 106.2$

For 8m span, $a_2 = 7000/64 = 109.2$

For 12m span, $a_3 = 16000/144 = 111.1$

For 15m span, $a_4 = 24500/225 = 109.0$

An average value of this constant of variation $a$,

$$a = \frac{a_1 + a_2 + a_3 + a_4}{4}$$

$$= \frac{106.2 + 109.2 + 111.1 + 109.0}{4} = 108.875$$

The average cost of a pier

$$P = \frac{22200 + 23200 + 23000 + 23600}{4} = 23000$$

Therefore,

Economic span, $l = \sqrt{\frac{P}{a}} = \sqrt{\frac{25000}{108.857}} = 14.6 m$

## Afflux :

When a bridge is constructed, the abutment and pier structure as well as approaches on either side cause the reduction of natural waterway areas. The contraction of stream is desirable because it leads to saving in the cost especially of alluvial streams whose natural surface is too large than that required for stability. Therefore to carry maximum flood discharge within bridge portion the velocity under the bridge increases.

Afflux should be as small as possible and generally shall not exceed 0.6m. When the floods spread over the banks is large, use of average velocity for calculating the afflux will give an erroneously low afflux. In such cases, the velocity in the main channel/compart. should be used. The permissible afflux will be governed by the submergence effect on adjoining structure field etc. upstream side. Afflux is catchmented by the following formula.

(a) Afflux at H.F.L by Molesworth formula (in case of high level bridge)

$$\text{Afflux } (h_a) = \left[\frac{V^2}{17.88} + 0.0153\right]\left[\left(\frac{Q}{Q_i}\right)^2 - 1\right]$$

where V = Mean velocity in m/s.

Date: / /

Railway Engineering objectives & long.

No1 Railways were first introduced to India in the year 1853

2. First from Bombay to Thane.

3. On 23 April 2014, Indian Railways introduced a mobile app system to track schedules.

4. What are the advantages of railways:
Ans (i) Economic Advantages
(ii) Political Advantage.
(iii) Social Advantage.

5. What are the classification of Indian Railway
Three classes
(i) class I - Railways with gross annual earnings of over Rs. 50 lakhs (Rs. 5,00,00,000)
(ii) Class-II - Railways with gross annual earnings of between Rs. 10 and 50 lakh
(iii) class-III - Railways with gross annual earnings under Rs. 10 lakh

6. The finished or complete track of railway line is commonly known as Permanent Way.

7. It consists of 3 parts (a) Rails. (b) sleepers, (c) Ballast

8. In India, the gauge of a railway track is defined as the clear minimum perpendicular distance between the inner faces of the two rails.

9. Name the different types of gauge and their length
(a) Broad Gauge: Width 1676 mm to 1524 mm
(b) Standard Gauge: Width 1435 mm and 1451 mm.
(c) Meter Gauge: Width 1067 mm, 1000 mm and 915 mm
(d) Narrow Gauge: Width 762 mm and 610 mm.

10. What are the suitability of these gauges under movement conditions:

Ans 1. Traffic condition:→ If the intensity of traffic on the track is likely to be more, a gauge wider than the standard gauge is suitable.

2. Development of poor areas:→ The narrow gauges are laid in certain parts of the world to develop a poor area and thus link the poor area with the outside developed world.

3. Cost of track:→ The cost of railway track is directly proportional to the width of gauge. Hence, if the funds available is not sufficient to construct a standard gauge a meter gauge or narrow gauge is preferred rather than to have no railways at all.

4. Speed of movement:→ The speed of a train is a function of the diameter of wheels which in turn is limited by the gauge. The wheel diameter is usually about 0.75 times the gauge width and thus, the speed of a train almost proportional to gauge. If the higher speeds are to be attained, the BG track is preferred to the M.G. or N.G. tra

5. Nature of Country:→ In mountainous country, it is advised to have a narrow gauge of track since it is more flexible and can be laid to a smaller radius on the curves. This is the reason why some important railways, covering thousands of kilometers, are laid with a gauge as narrow as 610mm.

11. What are the function of rails?

Ans → To transmit the moving loads to the sleepers

→ To provide strong, hard and smooth surface for the train journey

→ To bear the stresses developed in the track due to temperature changes and loading pattern.

→ To serve as lateral guide to the running wheels.

→ To resist breaking forces caused due to stoppage of train.

12. What are the requirements of an ideal Rail.?

Ans → The rail section consists of three components: head, web and foot. It should be designed for optimum nominal weight to provide for the most efficient distribution of metal in its various components.

→ The bottom of head and top of the foot should be given such shapes that fish-plates can easily be fitted.

→ The C.G. of the rail section should be located very near to the centre of height of rail so that maximum tensile and compressive stresses are more or less th

same
→ The depth of head of rail should be sufficient to allow for adequate margin of vertical wear.
→ The rail should possess adequate lateral and vertical stiffness same.
→ There should be balanced distribution of metal in the head web and foot of rail so that each of them is able to fulfill its assigned function.
→ The surface of rail table and gauge face of rail should be hard and should be capable of resisting wear.
→ The thickness of web of rail should be sufficient to take safely the load coming on the rail.

13 What are the types of rail section?
Ans (a) Double headed rails, (b) Bull headed rails (c) Flat footed rails

14 What is the double headed rails?
Ans These were the rails which were used in the begining, which were double headed and consisting of a dumb-bell section. The idea behind using these rails was that when the head was worn out in course of time, the rail can be inverted and reused. But as time passed indentations were formed in the lower table due to which smooth running over the surface at the top was impossible.

15 What is bull headed rails?
Ans In this type of rail the head was made a little thicker and stronger than the lower part by adding more metal so it, so that it can withstand the stresses.

16 Flat footed :- These rails are also called as Vignole's rails. Initially the flat footed rails were fixed to the sleepers directly and no chairs and keys were required. Later on due to heavy train loads problem arose which lead to steel bearing plate between the sleeper and the rail at rail joints and other important places these are the rails which are most common used in India.

17 What is length of rails?
Ans From the consideration of strength of the track maximum possible length is advisable as it will reduce the number of the joints, less number of fittings and fixtures and economical maintenance. But in practice the following factors are considered to decide the length of rails.
(i) Ease to transportation
(ii) Reasonable cost of manufacture
(iii) Ease in loading into the available wagon
(iv) Development of temperature stresses

18 What is rail joints?
Ans Rail joints are necessary to hold the adjoining ends of the

# Railway objective Questions

No1 In a shunting signal if the red band is inclined at 45° it indicates proceed.

No2 The nominal size of ballast used for points and crossings is 25mm.

No3 The standard length of rail for Broad Gauge and Meter Gauge are respectively 13m and 12m.

No4 Number of keys used in CST-9 sleeper is 2

No5 Gauge is the distance between running faces of rails.

No6 Normally the limiting value of cant is (where G is the gauge) G/10.

No7 Tensile strength of steel used in rails should not be less than 700 MPa.

No8 Largest dimension of a rail is its height.

No9 For the purpose of track maintenance, the number of turn out equivalent to one track km are 10.

No10 Due to battering action of wheels over the end of the rails, the rails get bent down and are deflected at ends. These rails are called Hogged rails.

No11 Yellow lighthand signal indicate proceed cautiously.

No12 Consider the following statements about concrete sleepers.
1. They improve the track modulus, 4. They maintain the gauge quite satisfactorily

No13 Consider the following statements.
Automatic Signalling system results in (2) higher efficiency (4) avoidance of block inst...

No14 Minimum composite sleeper index prescribed on Indian Railways for a track sleeper is 783.

No15 The distance through which the tongue rails moves laterally at the toe of the switch for movement of trains is called throw of the switch.

No16 The type of bearing plate used in all joints and on curves to give better bearing area to the rails is mild steel canted bearing plate.

No17 Standard size of wooden sleeper for Broad Gauge track is 275X25X13 cm.

No18 Maximum value of 'throw of switch' for Broad Gauge track is 115 mm.

No19 The purpose of providing fillet in a rail section is to Avoid the stress concentration.

No20 A Broad Gauge branch line takes off as a contrary flexure from a main line. If the superelevation required for branch line is 10mm and cant deficiency is 75mm, the superelevation to be actually provided on the branch line will be 65 mm.

No21 The sleeper resting directly on girder are fastened to the top flange of girder by hook bolts.

No22 A triangle is used for changing the direction of engine.

No23 Cant deficiency occurs when a vehicle travels around a curve at speeds higher than equilibrium speed.

No24 The cross-sectional area of 52kg flat footed rail is 6615 mm².

No25 Which of the following mechanical devices is used to ensure that route cannot be changed while the train is on the point even after putting back the signal? Lock bar.

No26 Switch angle depends on heel divergence, length of tongue rail.

No27 The reception signal is outer signal, home signal.

No28 In a scissors cross-over, the crossings provided are 2 obtuse angle crossing, 6 acute angle crossing.

No29 Which of the following factors govern the choice of the gauge? physical features of the country.

No30 The formation width for a railway track depends on the (i) type of gauge, (ii) number of tracks to be laid side by side.

No31 Study the following statements regarding creep.
(i) creep is greater on curves than on tangent railway track
(ii) creep in new rails is more than that in old rails.

No031 Study the following statements regarding creep railway track
(i) creep is greater on curves than on tangent railway track.
(ii) creep in new rails is more than that in old rails.

No032 Creep is the longitudinal movement of rail.

No033 Number of cotters used in CST-9 sleepers is 4.

No034 One degree of curve is equivalent to (where R is the radius of curve in meters) 1750/R.

No035 The rail is designated by its weight per unit length.

No036 Lead of crossing is the distance from the heel of the switch to the theoretical nose of the crossing.

No037 The treadle bar is provided near and parallel to inner side of one of the rails.

No038 A tradle bar is used for interlocking points and signal.

No039 Flange-way clearance is the distance between the adjoining faces of the running rail and the check rail near the crossing.

No040 The total gap on both sides between the inside edges of wheel flanges and gauge faces of the rail is kept as 19mm.

No041 Heel divergence is always greater than flange-way clearance.

No042 On a single rail track, goods trains loaded with heavy iron material run starting from 'A' to 'B' and then empty wagons run from 'B' to 'A'. The amount of creep in the rails will be more in the direction of A to B.

No043 staggered joints are generally provided on curves.

No044 The side slope of embankments for a railway track is generally taken as 2:1

No045 Loose jaws of steel trough sleepers are made of spring steel.

No046 For a Broad Gauge route with M+7 sleeper density, number of sleeper per rail length is 20.

No047 ~~Which~~ Wooden sleeper is preferred on joint.

No048 Vertical curves are provided where algebric difference between grades is equal to or more than 4mm/m.

No049 If a is the angle of crossing, then the number of crossing 'N' according to right angle method is given by cot(a).

No050 Crushed head one of the following rail failures is caused by loose fish bolts at expansion joint.

No051 The main function of a fish plate is to join the two rail together.

No052 For a sleeper density of (n+5), the number of sleeper required for constructing a broad gauge railway track of length 650m is 900.

No53 A train is hauled by 2-8-2 locomotive with 22.5 tonnes and on each driving axle. Assuming the coefficient of rail wheel friction to be 0.25, what would be the hauling capacity of the locomotive 22.5 tonnes.

No54 The limiting value of cant gradient for all gauges is 1 in 720.

No55 The correct relation between curve lead (CL), switch lead (SL) and lead of crossing (L) is given by L = CL − SL.

No56 The object of providing a point lock is to ensure that each switch is correctly set.

No57 Flat mild steel bearing plates are used for points & crossings in the lead portion.

No58 The height of the rail for 52kg rail section is 156 mm.

No59 Head width of 52kg rail section is 67mm.

No60 Largest percentage of material in the rail is in its head.

No61 A train is hauled by 4-8-2 locomotive. The number of driving wheels in this locomotive is 8.

No62 For developing thinly populated areas, the correct choice of gauge is Narrow Gauge.

No63 The slipping of driving wheels of locomotive on the rail surface causes wheel burns.

No64 Wear of rails is maximum in weight of tangent track.

No65 At points and crossings, the total number of sleepers of sleepers for 1 in 12 turnouts in Broad Gauge is 70.

No66 For a 8° curve track diverging from a main curve of 5° in an opposite direction in the layout of a broad gauge yard, the cant to be provided for the branch track for maximum speed of 45km/h on the main line and 'G' = 1.676 m is (permitted cant deficiency for the main line = 7.6cm) −0.168cm.

No67 Normally maximum cant permissible in Meter Gauge is 90mm

No68 1 in 8½ most commonly used for good train on Indian Railways

No69 When semaphore and warner are installed on the same post then the stop indication is given when both arms are horizontal

No70 Traverser is used to transfer the wagons or locomotives to and from parallel tracks without any necessity of shunting.

*—*

17/10/20

No1 At bridge site water flows from cut water to ease water.

No2 The length of bridge is (n*l)*b+(n-1) if distance between two pier is called l, No of span=n, width of pier=b Length of bridge =(n*l)+(n-1)*b

No3 Vertical distance between designed high flood level allowing for afflux and to allow vessels to cross the bridge free board

No4 The Economic span of bridge is 14.5m if the Average cost of pier(p) is Rs 23000 and Average value of constant (a) is 109

No5 A bridge to convey water over an obstacle, such as a river Aqueduct

No6 A bridge composed of several small spans for crossing a valley dry or wetland viaduct.

No7 A road causeway is a pucca dip which allows floods to pass over it. It may have opening or vents for low water to flow submersible bridge.

No8 End support of a bridge substructure is known as abutment.

No9 For general understanding the span < 8 m is known as culvert.

No10 For general understanding the span 8 to 30m is classified as Minor bridge.

No11 For general understanding the span 30 to 120m is classified as major bridge.

No12 For general understanding the span > 120m is classified as Long span bridge.

No13 Based on your engineering skill suggest best suitable bridge for deep valley provided it shall be Economical and light in weight suspension bredge.

No14 Rocker bearing are suitable for spans upto more than 20 m

No15 Fixed plate bearing plates are suitable for spans upto 12m.

No16 As far as possible the alignment of a bredge should be square

No17

A. Causeway — 1. Movable bridge
B. Culvert — 2. Bridge over a dry valley
C. Viaduct — 3. Flush with bed of stream
D. Bascule bridge — 4. Span less than 6m

No18 Rocker bearings are suitable for spans upto more than 20m.

No19 Tap paper bearing is used for < 8m.

No20 The type of Elastomeric bearing is Neoprene rubber bearing

No21 In a bridge construction the expansion joint is provides having width 25 mm.

No22 Erection of steel girder for bridge, the site having depth of water in the river is shallow, suggest suitable method erection by staging.

No23 Erection of steel girder for bridge, the site having deep water in the river, suggest suitable method erection by floating Depth of water in the river is more

No24 Forces acting on substructure of bridge earth pressure, Buoyancy uplift pressure.

No25 Forces due to geometry and atmosphere temperature stresses, erection stresses, seismic loads.

No26 Forces acting of super structure and substructure Dead load live load, wind load.

No27 Suggest the suitable method for weakening of foundation of bridge strengthening by underpinning

No28 Suggest the suitable method for scouring in bridge repairing of foundation

No29 Assessment of safe load carrying capacity of bridge the method are Theoretical method, correlation method, load testing.

No30 To know the fatigue life of bridge, the test required is stress history test.

No31 (A) Behaviour Test — (3) Verify the results of any method of analysis
(B) Proof Test — (4) Test done on new structure
(C) Ultimate load test — (2) determine ultimate load carrying capacity
(D) Diagnostic test — (1) Monitor the cause of damage

No32 To stabilize the river channel along a certain alignment with certain ~~alignment~~ cross section is known as River training.

No33 The objectives of river training is
→ To prevent the river from changing its course
→ To prevent from changing its cross section
→ To prevent flooding of surrounding area
→ To provide minimum depth for navigation purpose

No34 In river training work for bridge the spur is constructed transverse to river flow.

No35 In river training work for bridge the vibro-flotation is used when soil is cohesionless.

No36 In river training work for bridge, pitched islands is artificially created island, protected by stone.

No37 Nal and Neel was the first Bridge Engineer in ancient time.

No38 The linear measurement of water way between the two edge of flow of water perpendicular to the direction of abutment is Linear waterway.

No39 The unobstructed area of the river through which water flow at the bridge site is called natural waterway.

No40 The free board for high level bridge should not be 600mm

No41 The full form of IBMS Indian Bridge Management system

No42 The depth of bridge foundation below maximum scour depth is called grip length.

No43 The most economical span length in bridge is cost of super structure = cost of substructure

No44 A Bridge is provided when the normal flood discharge is relatively smaller than the high flood discharge and the blockage of the traffic for smaller duration of high floods is economically less important than the cost of high level bridge submersible bridge.

No45 The end of pier in up stream side is known as cut water.

No46 ~~The end of pier in down stream side is known as~~.
In a Arch bridge having number of span, the failure of an arch due to earthquake can be localized if it is provided with Abutment pier after every fourth or fifth pier.

No47 Abutment with return wing wall also known a U-Abutment.

No48 For Bridges of National highway and state highway the class of loading is considered as per IRC AA

No49 In a proof testing of bridge, the load shall be applied in stage of W/4, W/2, 3W/4.

Date: 18/11/2020

No1 Mr. W. Simms, the consulting Engineer to the Government of India recommended the gauge for Indian railways 1.676 m as a compromise gauge

No2 If absolute levels of rails at the consecutive axles A, B and C separated by 1.8 meters are 100.505m, 100.530m and 100.525m respectively, the unevenness of rails, is 0.065m

No3 A CST-9 sleeper consists of
→ two inverted triangular pots on either side of rail seat
→ a central plate with a projected key and box on the top of plate
→ a tie bar and 4 cotters to connect two cast iron plate
→ a single two way key provided on the gauge side to hold the rail to sleeper.

No4 Charles Vignoles invented the flat footed rails in 1836.

No5 To design a cross-over between parallel tracks, the required components are: two switch points, two acute angle crossing and four check rails.

No6 The first Indian railway was laid in 1853.

No7 The weight of the rails depends upon gauge of the tracks, speed of trains, spacing of sleepers, nature of traffic

No8 Pick up correct statement from the following
→ Rails are directly laid over hard wooden sleepers and fixed with spikes.
→ Adzing is done on hard wooden sleepers
→ Bearing plates are used on soft wooden sleeper
→ Chairs are used for bull headed rails.
All the above correct

No9 Pick up the incorrect statement from the following
→ Fish plates fit the underside of the rail head
→ Fish plates fit the top of the rail foot
→ Fish plates fit the web of the rail section
→ cross sectional area of fish plates, is normally the same as that of the rail section.

No10 Minimum depth of ballast prescribed of B.G. trunk lines of Indian Railways, is 25cm.

No11 Boxing of ballast is done at the rails.

No12 Best ballast contains stones varying in size from 2.0cm to 5 cm

No13 For holding a rail in position, no chairs are used for flat footed rails

No14 Distance between the inner rail and check rail provided on sharp curve, is 44mm.

No15 Coal ash (or cinder) is used in initial stages of a new construction of railway for wooden sleepers.

No16 Pot sleepers are in the form of two bowls placed under each rail and connected together with a tie bar.

No17 In railways a triangle is mainly provided for changing direction of engines through 180°

No18 A kink is made in stock rails, ahead of the toe of switch at a distance of 15cm.

No19 If L is length of rail and R is the radius of a curve the versine h for the curve, is $h = \frac{L^2}{8R}$

No20 Rails are bent to correct curvature if the degree of curve is more than 4°.

No21 In India the rails are manufactured by open hearth process duplex process.

No22 Rail section first designed on Indian railways, was ~~double~~ double headed.

No23 A scissors cross-over consists of four pairs of points, six acute angle crossings and two obtuse angle crossing.

No24 To prevent percolation of water into formation, moorum is used as a blanket for black cotton soil.

No25 Distance between inner faces of the flanges, is kept slightly less than the gauge distance.

No26 Wooden sleepers used on the girders of bridges, are generally made of teak.

No27 If $L_1$ and $L_2$ are the actual and theoretical lengths of a tongue rail, d is heel divergence and t is thickness of tongue rail at the the switch angle α is $\sin^{-1}\frac{d-t}{L_1}$

No28 If D is distance between centres of two parallel track of gauge then, total length of cross-over (from the point of commencement to the point of termination) with an intermediate straight portion and N crossing is given by $DN + G(3N + \sqrt{1+N^2})$

No29 If a 0.7% upgrade meets a 0.65% downgrade at a summit and the permissible rate of change of grade per chain length is 0.10%, the length of the vertical curve, is 14 chains.

No30 Overall depth of a dog spike, is 120.6mm.

No31 Best wood for wooden sleeper teak.

No32 The rail section which is not used on Indian metre gauge track, is 40R.

No33 Dimensions of a plate girder, are: 851mm x 254mm

No34 Rail joint supported on a single sleeper, is known supported rail joint

No35 Maximum wheel base distance provided on Indian B.G. track is 6.096 m.

No36 The tread of wheels is provided an outward slope of 1 in 20

No37 On a straight railway track, absolute levels at point A on two rails are 100.550 m and 100.530 m and the absolute levels at point B 100 m apart are 100.585 m and 100.515 m respectively the value of twist of rails per metre run, is 0.5 mm.

No38 Bearing plates are used to fix flat footed rails to the wooden sleepers.

No39 Safe speed (V) on a curve of radius 970 metres provided with two transition curves on Board Gauge track is 132 km/hour.

No40 ~~Safe speed (V) on a curve of~~ A welded rail joint is generally suspended.

No41 pick up the incorrect statement from the following
→ sleepers hold the rails at proper gauge on straight
→ sleepers provide stability to the permanent way.
→ sleepers act as an elastic cushion between rails and ballast
→ sleepers transfer load of moving trains to ballast.
→ None of these ✓

No42 If α is switch angle and R is radius of the turnout, the length of the tongue rail, is R tan α/2.

No43 The quantity of stone ballast required per metre tangent length, is 1.11 m³.

No44 The type of switch generally used for B.G. and M.G. track is over riding.

No45 The difference in the lengths of two diagonal of a rail diamond is $\frac{2G}{\sin\alpha}[\cos\alpha/2 + \sin\alpha/2]$

No46 For flat bottom sleepers, maximum size of ballast is 50 mm.

No47 Coning of wheels
→ prevent lateral movement of wheels
→ provide smooth running of trains
→ avoid excessive wear of inner faces of rail
→ All the above. ✓

No48 The sleepers which satisfy the requirements of an ideal sleeper are wooden sleepers.

No49 Arrangement made to divert the trains from one track to another is known as turnout.

No50 At a rail joint, the ends of adjoining rails, are connected with a pair of fishplates and 4 fish plates.

No51