GOVT. POLYTECHNIC MAYURBHANJ

DEPARTMENT OF CIVL ENGINEERING

Railway & Bridge Engineering

5TH SEMESTER

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RAILWAY ENGINEERING

CHAPTER:-01 [INTRODUCTION]

- **Introduction:** **Amongst the different modes of transport, Railways have their greatest utilization in the transport of large volumes of heavy and bulk commodities and passengers over long distances with safety, comfort and convenience.**

History of Railways:

In India first railway was built between Mumbai and Thane in 1852 and the first passenger train ran between the two stations, covering a distance of 34 km, on April 16, 1853.

Railway Terminology

- **ADHESION OF WHEELS**: It is resistance offered by the friction proper between the metal surfaces of the rail and the wheel. This is one of the factors which imposes limitation in raising the speeds beyond certain limit and depends upon the condition of the wheel and rail surfaces, speed of train and the load.

- **ADVANCE STARTER SIGNAL**: It is the last stop signal of semaphore type for an outgoing train.

- **ADZING OF SLEEPERS**: To provide a cant of 1 to 20 in the rails, wooden sleepers have to be cut to this slope at rail seat. This process of cutting the wooden sleeper at 1 in 20 slope is known as adzing of sleepers.

- **AUDIBLE SIGNALS**: Sometimes a Container containing suitable explosive is put on the top of the rail so that there is explosion with a loud voice when wheels pass over the rails. This arrangement is called audible or fog signal or a detonator.

- **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".

- **BUCKLING OF RAILS**: **The railway track gets out of the original position due to buckling if the expansion of rails is occurred due to rise in temperature.**

- **BUFFER STOP**: **The dead end of a railway line is provided with a barrier erected across the track to prevent the vehicles running off the track.**

- **BULL HEADED 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.**

- **CAPACITY OF TRACK: Capacity of the track is the number of trains that can run safely on a track per hour.**

- **CENTRALIZED TRAFFIC CONTROL SYSTEM: (C.T.C.) In this system, control operations of all the points and signals at various stations on a section of the railway, are performed at a central place under the responsibility of a single official.**

- **Centre Bound Sleepers: The repeated applications of load on the ends cause greater depression at the end as compared to portion of shaper, so the sleeper is said to be centre bound.**

- **CHAIRS: 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 location for guiding one wheel of the vehicle and thus to check the tendency of another wheel to climb over the crossing.

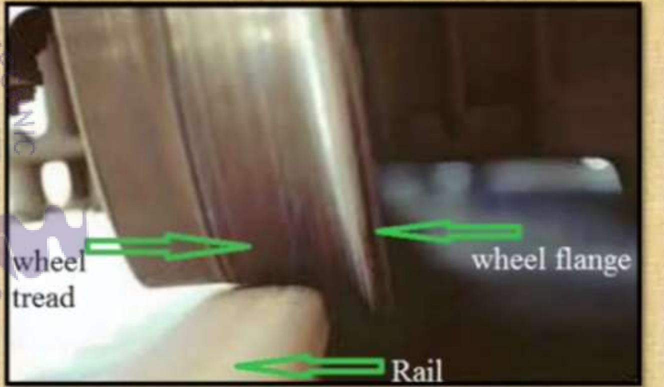
- **COACHES**: The passenger compartments are called coaches. They are meant for sitting and sleeping of passengers. Latrines and washing facilities are provided in coaches.

- **COACHING STOCK**: All types of vehicles that form passenger trains carrying passengers are called "coaching stock".

- **CO-ACTING SIGNALS**: When the line of sight to main signal is not clear due to presence of any obstruction such as tunnel, over bridge, sharp curve, etc., then a duplicate signal is provided on the same main post but at lower level. This duplicate signal is called co-acting signal.

- **COLOUR LIGHT SIGNALS**: These are high intensity beam colour light signals, particularly used on electrified railways, both during day and night time.

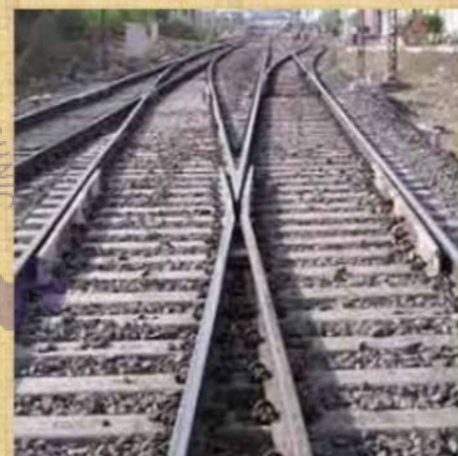
- **CONING OF WHEELS**: The wheels are coned at a slope of 1 in 20 to prevent from rubbing the inside face of the rail head and to prevent lateral movement of the axle with its wheels.



- **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.

- **CROSSING NUMBER**: The number of crossing is defined as the ratio of spread (i.e. distance between the point and splice rails at the leg of crossing, generally 30 cm) to the length of crossings are designated by this number i.e. 'N'



- **DERAILMENT**: Derailment occurs when moving wheels of a train or bogie get out of the rails. It causes by an accident and often results in loss of lives or property damage

- **DETECTOR**: A detector is a safety device to ensure lowering of the correct signal for a set route, where a track diverges.

- **DISC SIGNALS**: Disc signals consist of circular disc with broad red band, which are used for setting points for shunting operation of engines.

- **DIVERSION (Temporary): It is a temporary shifting of track alignment from its original position if some heavy 'or' time consuming works like repairing breaches, track wash out in floods, rebuilding of bridge etc. are to be done on original track.**

- **DOUBLE HEADED RAILS: These are the rails which have double head. The bottom and top (i.e. foot and head) of the rails are of the same cross-section.**

- **DROP PITS: They are rectangular deep pits in which wheels of the locomotives are taken out for repairs.**

- **FISH PLATES: These plates, resembling in shape 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.**

- **FLAG STATIONS: Station without sidings, where trains do not stop is called a flag station. On such stations there are no fixed signals to control the trains.**

- **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.**

- **FLAT FOOTED RAILS: F.F. rails have wider or flatter bottom (or foot), so that they can be fixed directly on the sleeper, avoiding the necessity of chairs.**

- **FORMATION: Formation is the prepared subgrade ready to receive the ballast.**

- **FOULING MARK: Where two tracks converge, the limiting position upto which a train can stand for safe movement on the adjacent track is demarcated by a mark called fouling mark.**

- **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.

- **GOODS STOCK**: Wagons for movement of goods, heavy and bulky commodities, are called goods stock.

- **GOODS YARD**: A yard in which goods wagons are shunted and sorted for loading and unloading is called a goods yard.

- **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, wherever a curve and gradient have to be provided together. The reduction in grade is known as grade compensation on curves.

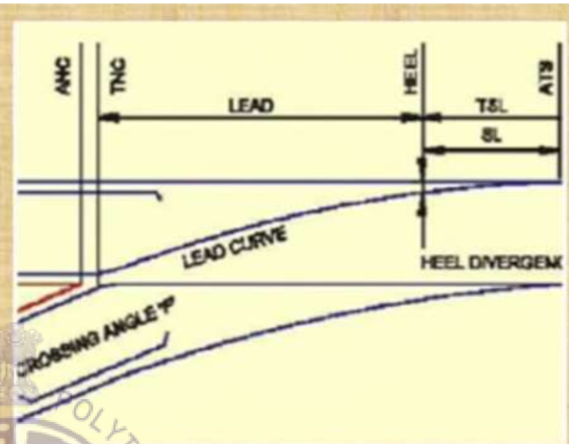
- **GUARD RAILS**: Guard rails are extra rails provided over bridges to prevent damage and danger in case of derailment occurring on the bridge.

- **JUNCTION STATION**: When two or more railway lines meet at a station it is called a junction station. The lines may be of same gauge or of different gauges.

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

- **KINKS**: The lateral movement of the ends of the rails out of its original position due to several causes such as loose joints, 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, the distance being measured along the straight.



- **LEAD RAILS:** In a turnout, lead rails are the length of rails from the heel of the tongue rail to the toe of the crossing. These rails are of the normal rail sections.

- **LEFT HAND TURNOUT**: A turnout is called a left hand turnout when the direction is towards the left of the main track in facing direction.

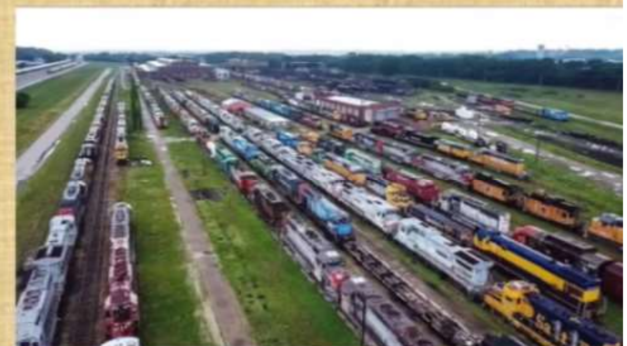
- **LEVEL CROSSING**: **When the Railway line and a road cross each other at the same level, it is called a level crossing.**

- **LINKING GANG**: **The labour who fixes rails to the sleepers links the rails together with fish plates, is called linking gang.**

- **LOADING GAUGE**: **It is a device consisting of vertical posts with a cross beam, generally situated at the exit of goods yard. This is used to ensure that open wagons are not loaded beyond the specified height and the width.**

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

- **LOCOMOTIVE YARD**: Yards in which locomotives are kept, repaired, and where coaling, watering, maintenance and servicing are done, are called locomotive yards.



- **LOOP**: When a branch line starting from a main line again terminates at the same main line it is called a loop line.

- **POWER SIGNALLING: Power signalling implies signalling with the utilization of track circuiting, colour light signal and operation of points and signals through electric power or electro-pneumatic power.**

- **PUMPING JOINT: In rainy season, the dust in the ballast becomes mud and comes up by suction from below the rail joint. Such joint is called a pumping joint.**

- **PUSHER GRADIENT: The gradient which requires one or more additional locomotives for hauling the load over the rising gradient is called a pusher gradient.**

- **STATION YARD**: It is the system of tracks laid within prescribed limits for various purposes such as storing, sorting, dispatching of vehicles and making up trains.

- **STOCK RAIL**: The position of the straight alignment against which the tongue rail fits is known as the stock rail.

- **STRETCHER BAR**: The toes of the two tongue rails are connected together by means of a bar, known as stretcher bar, so that each tongue rail moves the same distance on the gap while changing the points.

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

- **TURN TABLE**: Turn table is an arrangement for turning the engine by supporting it over a centrally pivoted girder set.

Advantages of Railways:

- Railways provide a comfortable and safe means transportation.
- Its speed over long distances is more than any other mode of transport, except airways.
- Railway transport is economical, quicker and best suited for carrying heavy and bulky goods over long distances.
- Railway is the safest form of transport. The chances of accidents and breakdown of railways are minimum as compared to other modes of transport.

CLASSIFICATION OF INDIAN RAILWAYS:

According to Indian Railway specifications, the railways be classified as under,

1. Broad gauge routes

All the broad gauge routes of Indian Railways have been classified based on speed criteria in the following five groups.

Group	Sanctioned speed
A	160 kmph
B	130 kmph
C	Suburban sections of Mumbai and Kolkata
D	100 kmph
E	Other sections and branch lines

2. Metre gauge routes

All the metre gauge routes of Indian Railways were classified, based on their importance, the traffic carried and the maximum permissible speed in the following three main categories,

a. Trunk routes b. Main lines c. Branch lines

In 1984, these metre gauge routes are re classified as under,

i. Q routes The routes on which traffic density is more than 2.5 GMT with maximum permissible speed more than 75 mph.

ii. R routes The routes on which traffic density is more than 1.5 GMT with a speed potential of 75 kmph.

iii. S routes The routes on which traffic density is less than 1.5 GMT with a speed potential less than 75 kmph.

END

RAILWAY ENGINEERING

CHAPTER:-02 [PERMANENT WAY]

Definition: The combination of rails, fitted on sleepers and resting on ballast and subgrade is called the railway track or permanent way.

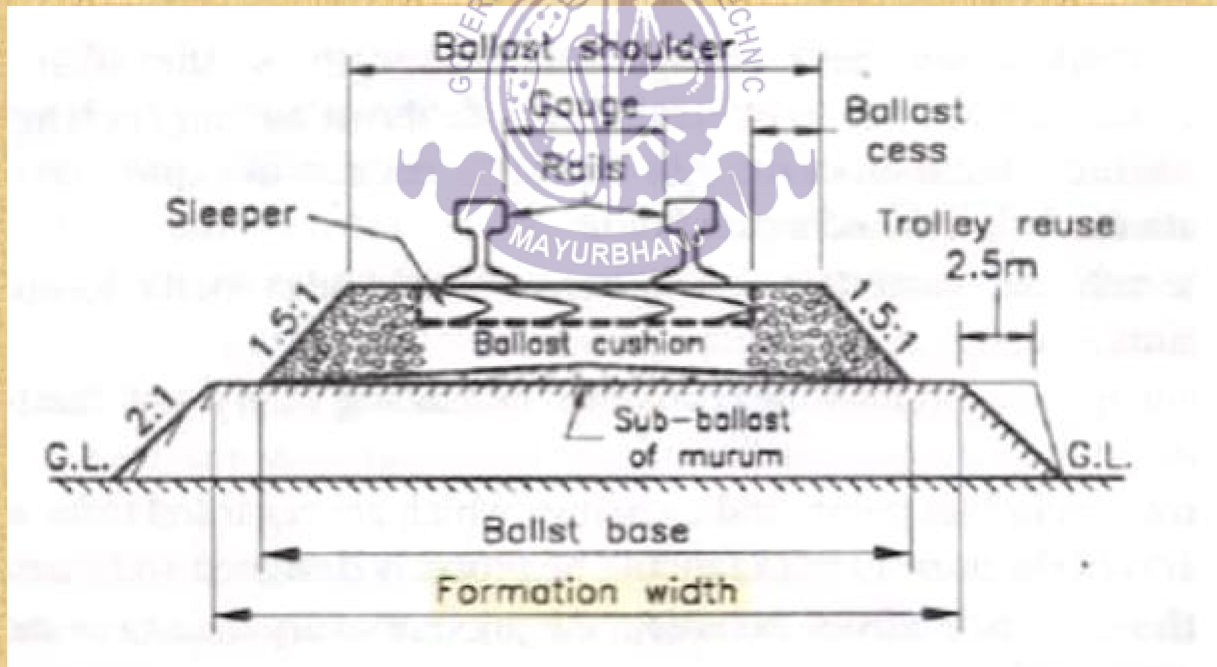


Fig. 3.1 Typical Cross-section of a Permanent Way on Embankment.

Various component of permanent way are:

Rails, Sleepers, Ballast, Fixtures and Fastenings.

A permanent way should serve the following requirements:

(i) Both rails should be at the same level.

(ii) Curves should properly designed.

(iii) Proper super elevation should be provided.

(iv)Track should be elastic to reduce hardship of impact between rails and the moving wheels.

(v) Joints should be properly designed.

(vi)Components (rails, sleepers, ballast, fixture and fastening) should be properly designed.

(vii) Even, uniform and correct gauge should be provided.

(viii) Should be strong enough to resist lateral forces.

(ix) On straight portions both rails should be at the same level.

(x) Tractive resistance should be least.

(xi) All points and crossings should be properly designed.

(xii) Proper drainage should be provided.

(xiii) Repairs and renewals should not present any difficulty.

GAUGES IN RAILWAY TRACK:

Definition: The 'Gauge' of railway track is defined as the clear distance between inner or running faces of two track rails (Fig. 3.1). The distance between the inner faces of a pair of wheels is called the "wheel gauge''.

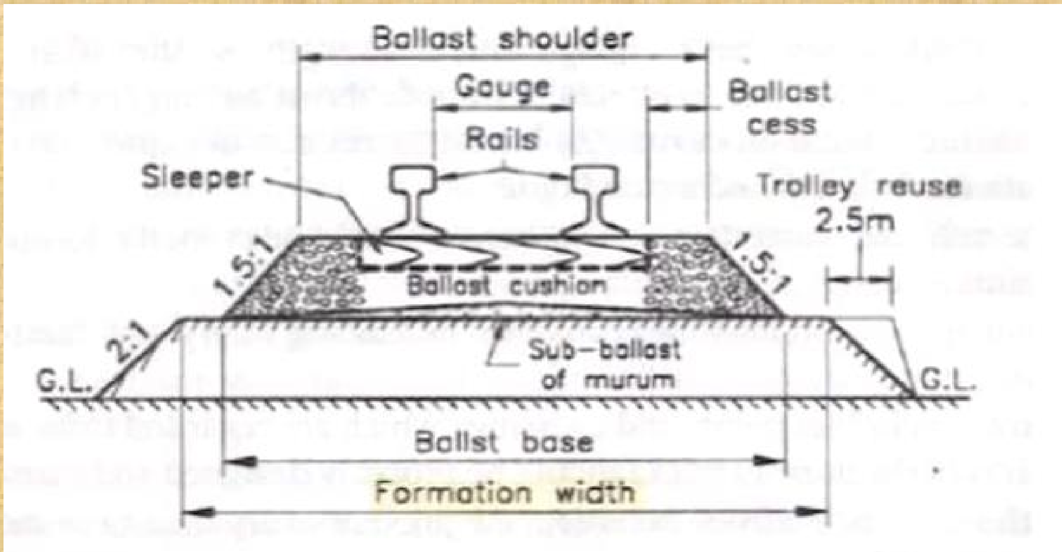


Fig. 3.1 Typical Cross-section of a Permanent Way on Embankment.

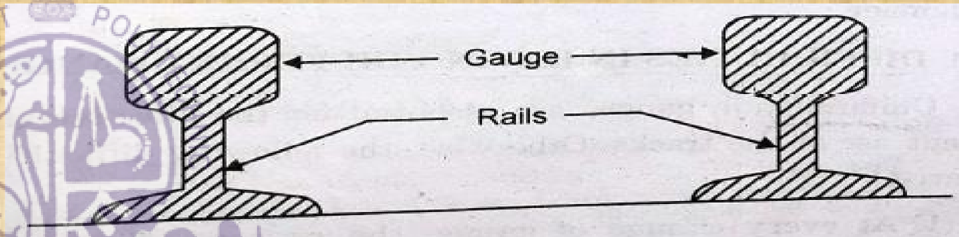


Fig. 3.1 Rail gauge

Classifications of Gauge:

Type of Gauge	Gauge Width
1. Broad gauge (B.G.)	1.676 m
2. Metre gauge (M.G.)	1.000 m
3. Narrow gauge (N.G.)	0.762 and 0.610 m.

1. Broad gauge (BG): In India, the East India company adopted 1.676m gauge as the standard gauge. It is known as broad gauge. For greater the gauge, higher is the speed. Hence for higher speeds, broad gauge is preferred. Also broad gauge is more acceptable if the intensity of the traffic is more as it is cheaper.

2. Metre gauge (MG): In order to build cheap railways for the development of the country, the government introduced metre gauge (i.e.) 1.0 m wide. If the intensity of traffic is more, metre gauge is not recommended.

3. Narrow gauge (NG): In hilly areas and thinly populated areas, narrow gauge is introduced whose width is 0.762m and 0.610m respectively. On steeper gradients and sharper curves narrow gauge may be adopted.

Selection of Gauge:

(1) Cost of Construction. **There is little increase in the initial cost if we select a wider gauge (say B.G.), this is due to following reasons:**

(a) The cost of bridges, tunnels, station buildings, staff quarters, signals, cabins and level crossings is the same for all the gauges.

(b) The cost of earth work, (in making embankments and cuttings) ballast, sleepers, rails, etc. would proportionally increase with increase in gauge width.

(c) There is little proportional increase in the acquisition of land for permanent track with increase in gauge.

(d) The cost of rolling stock is independent of the gauge used for the same volume of traffic.

We can, therefore, conclude that there is not an appreciable increase in cost due to increase in width of gauge.

(2) Volume and Nature of Traffic. It is evident that with greater traffic volume and greater load carrying capacity, the trains should be run by a better traction technique or by better locomotive. For heavier loads and high speed, the wider gauges are required because subsequently the operating cost per tonne-km is less for higher carrying capacity.

(3) Development of the Areas. Narrow gauges can be used to develop the thinly populated areas by joining the under developed areas with developed or urbanized areas.

(4) Physical Features of the Country. Use of Narrow gauge is warranted hilly regions where broad and metre gauge is not possible due to steep gradients and sharp curves. In plains also, where high speed is not required and the traffic is light, N.G. is a right choice.

(5) Speed of Movement. The speed of a train is almost proportional to the gauge. Speed is the function of diameter of wheel, which in turn is limited by the gauge. The wheel diameter is generally 0.75 times that of the gauge. Lower speeds discourage the customers, and so for maintaining high speeds, the Broad gauge is preferred. ***END***

RAILWAY ENGINEERING

CHAPTER:-03 [TRACK MATERIALS]

{RAILS}

Definition: **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:

(i) 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.

(ii) Rails bear the stresses developed due to heavy vertical loads, lateral and braking forces and thermal stresses.

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

(iv) Rails transmit the loads to sleepers and consequently reduce pressure on ballast and formation below.

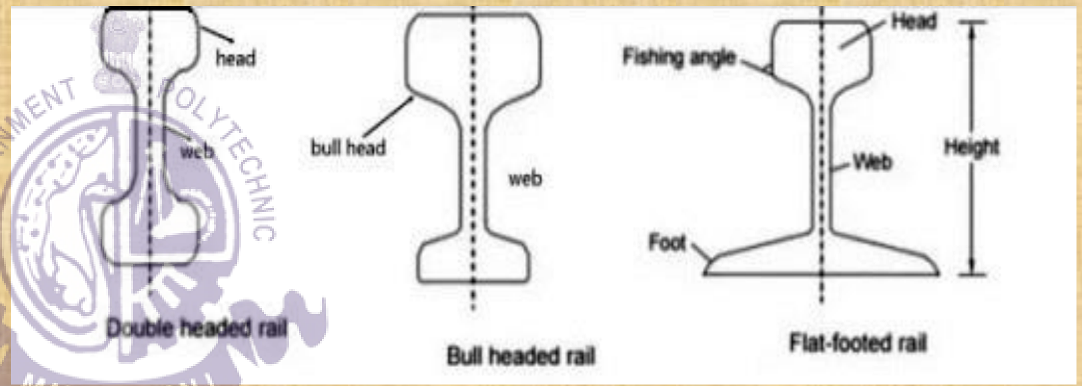
TYPES OF RAILS

Rails can be classified into the following categories:

1. Double headed rail

2. Bull headed rail

3. Flat footed rail



1. Double-headed rail:

Originally double-headed rail was designed in which both the head and foot have the same cross-section. For fixing, each rail require one chair per sleeper. The object of this type of rail was that

when the head had worn out, the rail could be inverted and be used. In practice, it was found that due to impact, the lower head got dented. The lateral stability was also very poor and hence, could not be used as head. This lead to the development of bull-headed rail.

2. Bull-headed rail:

Bull headed rail is similar in shape to double headed rail but with more metal added to head to permit wear. The foot was just sufficient in size to bear the stress induced in it by the moving loads. The foot of the rails are fastened to chairs by wooden key. Each rail required one chair per sleepers for fixing. It also had poor lateral rigidity.

3. Flat-footed rail:

Flat-footed rail has the shape of inverted ‘T’. It is stronger than bull-headed rail. It needs no chair and the foot of the rail may be spiked directly to the sleeper. The main advantages of this type of rail is its lateral rigidity. The heavy train load tends to sink the rail into the sleepers. This causes loosening of the spikes when the flat footed rails are sinked directly to the wooden sleepers. To avoid this sinking and for distributing the load on wider areas, steel bearing plates are used between sleepers and rails.

ADVANTAGES OF FLAT FOOTED RAILS

1. For fixing flat footed rails to sleepers, no chairs are needed. The foot of the rail may be spiked direct to the sleepers. This effects economy to a great extent.

2. For the same weight, this rail is stronger vertically and laterally both than Bull headed rails.

3. It is cheaper than Bull headed rails.

4. It requires less fastening than BH rails.

5. F.F. rails give better stability to the track as these rails distribute rolling stock load over larger number of sleepers.

6. F.F. rail develop less kinks and maintain a more regular top surface than B.H. rails.

7. F.F. rails give longer life to the track and reduce maintenance cost.

The F.F. rails have been widely accepted throughout the world. About 90% track length of the entire world has been laid with F.F. rails. It has also been standardized on Indian railways.

COMPARISON OF RAILS:

Sl. No.	Item of comparison	Flat-footed rails	Bull-headed rails
01	Initial cost	Less	More
02	Strength and stiffness	More for the same weight, both laterally and vertically.	Less

03	Laying and relaying	Fixing is simple and no chairs are required.	Fixing is difficult and chairs are required.
04	Maintenance cost	Less	Heavy
05	Replacement of Rails	Difficult	Easy
06	Inspection	Daily inspection is not necessary.	Daily inspection is necessary.
07	Arrangement at points and crossing	Simpler	Complicated
08	Alignment and stability of track	The impact of rolling stock affects the fitting.	Provide a more solid and smoother track and keep better alignment.
09	Suitability	More suitable due to their stability. economy and strength.	More suitable when lateral loads are more important rather than vertical loads.

REQUIREMENTS OF RAILS:

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

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

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

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

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

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

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

(vii)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 joints.

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

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

(x)The fillet radius must be large to reduce the concentration of stresses.

(xi) The tensile strength of the rail piece should not be less than 72 kg/m².

(xii) The rail specimen should withstand the blow of "Falling Weight Test or Tup Test" as specified by Indian Railway Standards without fracture.

LENGTH OF RAILS:

For B.G. = 12.80m. (42ft) (say 13m)

For M.G. = 11.89m. (39ft) (say 12m)

RAILWAY ENGINEERING

CHAPTER:-03 [TRACK MATERIALS]

{RAIL JOINTS}

Definition: **Rail joints are necessary to hold together the adjoining ends of the rails in the correct position, both in the horizontal and vertical planes. Rail joints form the weakest part of the track. It is observed that strength of a rail joint is only 50 percent of the strength of a rail.**

REQUIREMENTS OF AN IDEAL JOINT:

An ideal or perfect rail joint is one which provides the same strength and stiffness as the other rail section of the track. *The following requirements should be met by an ideal joint:*

(i) The two rail ends should remain true in line both laterally and vertically when trains move on the track. This is necessary to avoid wheel jumping or changing its correct path of movements.

(ii) The rail joint should be as strong and stiff as the rail itself and should be elastic both laterally and horizontally.

(iii) The rail joint should provide enough space for free expansion and contraction to account for the effect of temperature variations.

(iv) A good joint should be easily disconnectable so that it can be easily taken out without disturbing the whole track for the purposes of changing rail or a fish plate, and lubricating the contact faces.

(v) It should not allow rail ends to get battered in any case.

(vi) The joint should fulfill the above requirements with the minimum of initial and maintenance cost (i.e., it should be economical).

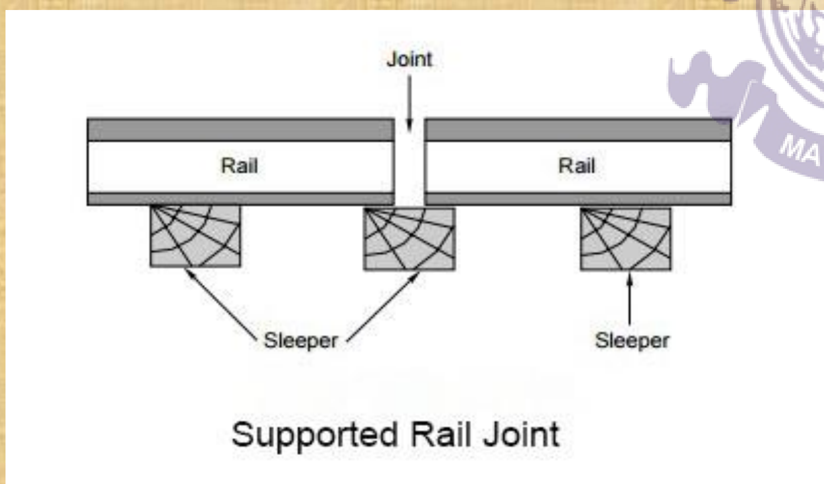
TYPES OF RAIL JOINTS:

The following types of joints are commonly used on Indian and foreign railways:

(1) Supported Rail Joint:

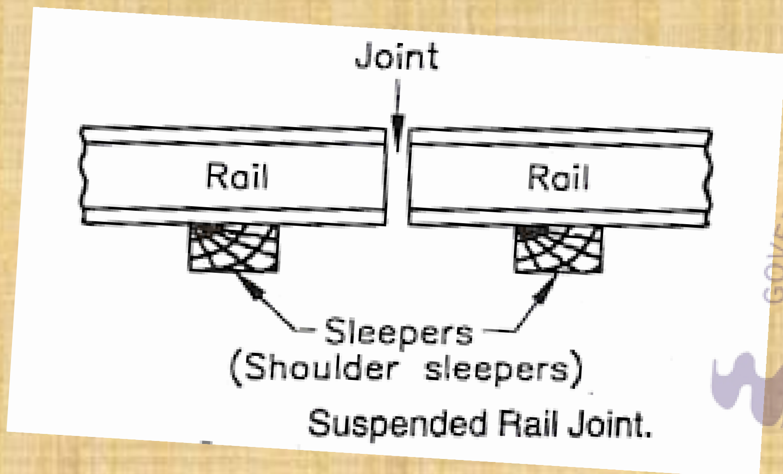
When the rail ends rest on a single sleeper called a "joint sleeper", it is termed as "supported joint". The duplex joint sleeper with other sleepers is an example of the supported joint.

Three sleeper support with long fish plate, i.e., combined supported and suspended joint is most objectionable. Because in this case when the packing under the outer sleeper gets loose, undue load comes on central sleeper and in turn the loose central sleeper converts this joint into a weak suspended joint.



(2) Suspended Rail Joint:

When rail ends are projected beyond sleepers called “shoulder sleeper", it is termed as suspended joint. This type of joint is generally used with timber and steel trough sleepers on Indian and foreign railways.



Suspended Rail Joint.

(3) Bridge Joint:

When the rail ends are projected beyond sleepers as in case of suspended joint and they are connected by a flat or corrugated plate called a "bridge plate", it is termed as a bridge joint. This type of joint is not used on Indian Railways.

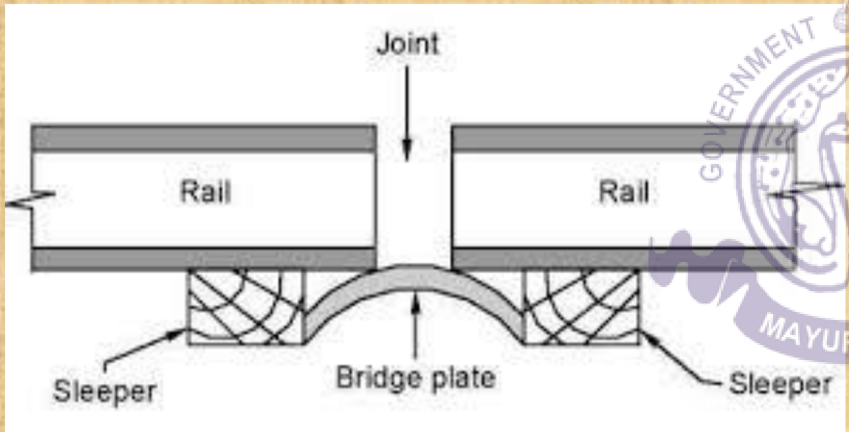


Fig. 16.3 (b) Bridge joint with bridge plate

(4) Base Joint:

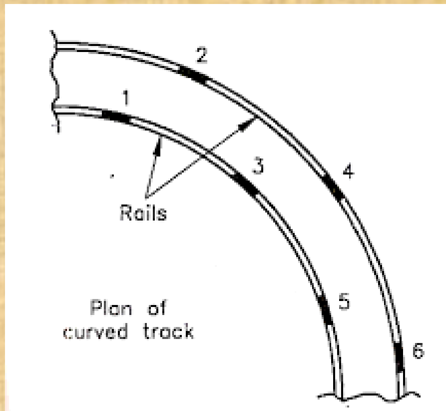
This is similar to the bridge joint, with the difference that the inner fish plates are of bar type and outer fish plates are of the special angle type, in which the horizontal leg is further extended over the sleepers to be bolted to both bridge plate and sleeper. Due to complicated design, this is not generally used.

(5) Welded Rail Joints:

These are the best joints as they fulfill nearly all the requirements of an ideal or perfect joint. Welding of rails provides very strong rail joint with many advantages. Various methods are used for welding of joints are; Electric Arc Welding, Gas pressure Welding, Flash Butt Welding & Chemical Welding.

(6) Staggered or Broken Joint:

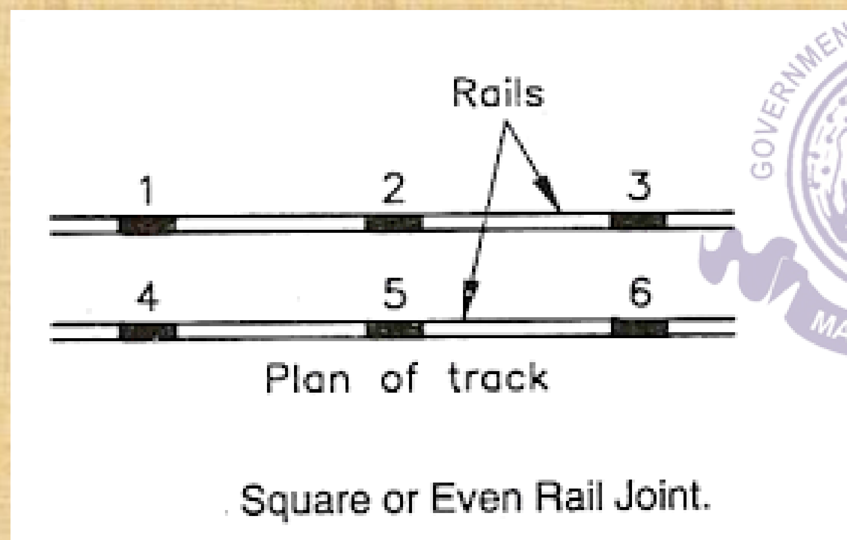
In this, position of joints on railway track is the basis of its nomenclature. In this type of joint, the joints of one rail track are not directly opposite to the joints of the other rail track. These joints are generally provided on curves, where the length of outer curved track is greater than the length of inner curved track.



Staggered Rail Joint.

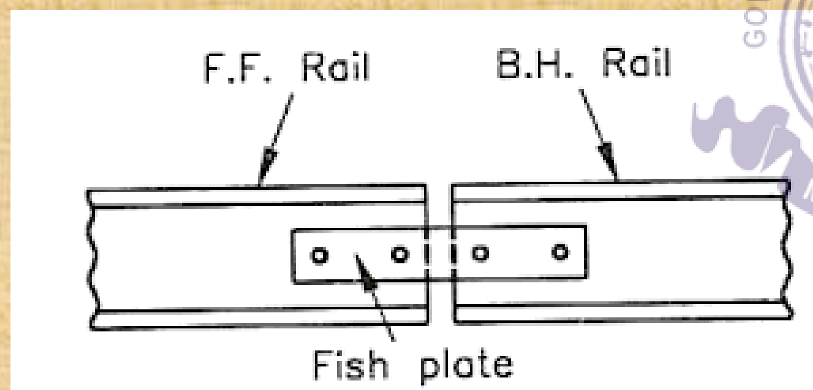
(7) Square or Even Joint:

In this also, the position of rail joint is the basis of its nomenclature, the joints of one rail track are directly opposite to the joints of other rail track. This type is generally used on straight tracks.



(8) Compromise Joint:

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



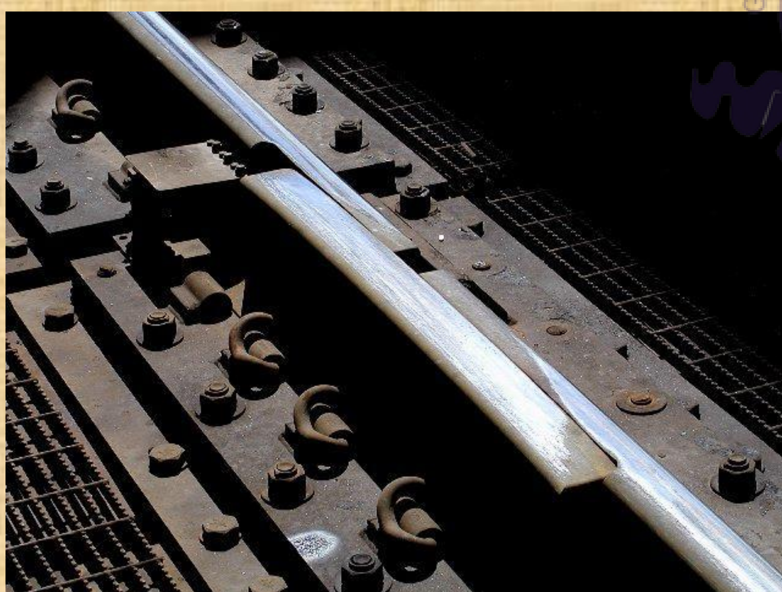
. Compromise Joint.

(9) Insulated Joint:

When insulating medium is inserted in a rail joint to stop the flow of current beyond the track-circuited part, it is called insulated joint.

(10) Expansion Joint:

In bridges, provision for expansion and contraction is kept for girders and rails both. This gap is 2.2 cm in case of "mitred" joint and 7.2 cm for "Halved Joint".



{WELDING OF RAILS}

Definition: **Rail joints are provided to join two adjacent rails. They are weakest parts of the track and should therefore be strictly constructed as per requirements of an ideal joint. The number of Joints can be reduced by welding of rails. Welding of rails provides very strong rail joint with many advantages.**

PURPOSE OF WELDING:

Welding of rails serves the following purposes:

(i) To increase the length of the rail by joining two or more rails and thus to reduce the number of joints and requirements of fish plates, which lead to economy and strength.

(ii) To repair the worn out or damaged rails and thus increase their life.

(iii) To build up worn out points and rails on the sharp curves.

(iv) To build up the bust portion of rail head which is caused due to slippage of wheels over the rails or other defects or spots in rail steel.

ADVANTAGES OF WELDING RAILS:

(1) It satisfies the condition of a perfect joint and hence increases the life of the rail, as also the reduction in maintenance cost of track by about 20 to 40 percent.

(2) It reduces the creep due to increase in the length of rail and in turn friction as well.

(3) Expansion effect due to temperature is reduced which in turn also reduces the creep.

(4) **Due to discontinuity of joints, a source of track weakness is reduced. The defects, such as hammering at rail joints, displacement of joints, disturbance in alignment and running surface, which result in bad riding quality, are eliminated.**

(5) **Long rail lengths being heavier, dampen the intensity of high frequency vibrations due to moving loads.**

(6) **Welding increases the life of rails due to decrease in the wear of rails at joints.**

(7) **Welding facilitates track circuiting on electrified tracks.**

(8) **Welded rails provides on large bridges for the span length are helpful as they result in better performance.**

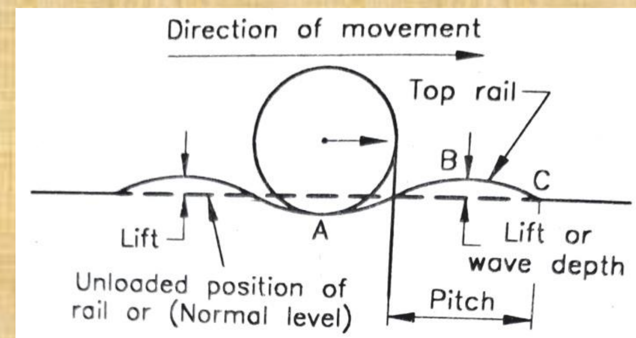
(9) **Welded rails provision on curves is under investigation. However, maximum curve length may be welded depending upon resistance and Lateral displacement of track.**

(10) **The cost of track construction by welding of rails decreases due to less number of rail joints.**

RAILWAY ENGINEERING

CHAPTER:-03 [TRACK MATERIALS]

{CREEP}



Definition: **Creep is defined as the longitudinal movement of the rails in a track in the direction of motion of the locomotives. It is common to all railway tracks, but varies considerably in magnitude.**

INDICATIONS OF CREEP

Creep occurrence may be noticed by:

1. Closing of successive expansion spaces at rail joints in the direction of creep and opening out of joints at the point from where creep starts.

2. Marks on rail flanges and webs made by spike heads due to scratching as the rails slide.

CAUSES OF CREEP

Following are the main causes of the development of creep:

1. Wave Action or Wave Theory. Wave motion is set up by moving loads of wheels. The vertical reverse curve *ABC* is formed in the rails ahead of the wheels, resulting from the rail deflection under the load, is the chief cause of creep. The wheels push the wave with a tendency to force the rail in the direction of traffic. On a particular rail, the joint action by several wheels causes creep. As the wheels move, the lift in front of the moving load is thus carried forward by the wheels and causes creep, whereas the lift at the rear of the wheel gets back to its normal position.

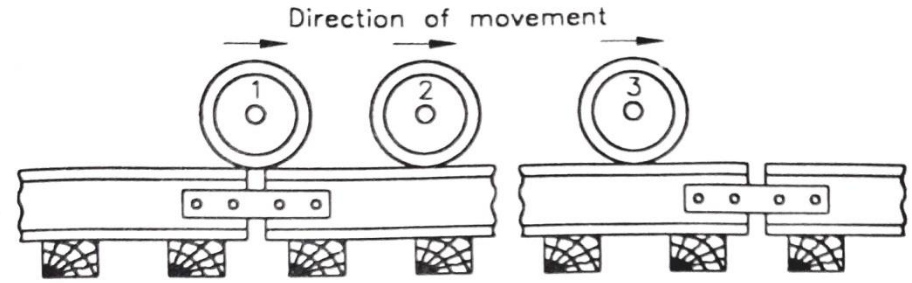


Fig. 8.1. Wave Theory of Creep.

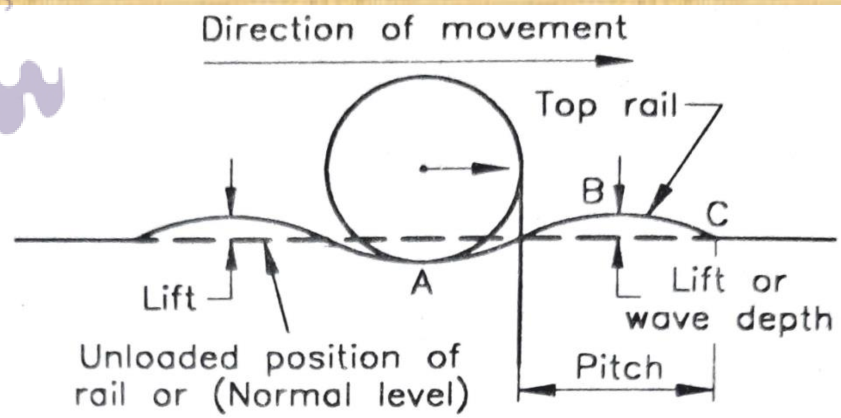
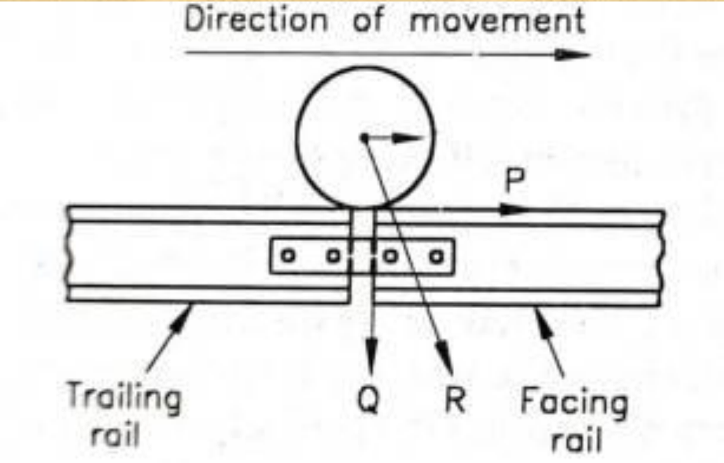


Fig. 8.2. Wave Theory of Creep (Formation of Wave)

2. Percussion Theory. This theory states that the creep is due to impact of wheels at the rail end ahead at joints. The horizontal component *'P'* of *'R'* tends to cause creep while the vertical component tends to bend down the rail end vertically, i.e., to make a battered rail end. Hence as and when the wheels leave the trailing rail and strike the facing rail end at each joint, it pushes the rail forward resulting in creep. Though the creep is very small in single impact but cumulative effect of number of wheels in quick succession results in sufficient creep.



3. Drag 'or' Dragging Theory. It states that backward thrust on driving wheels of the locomotive of train has got a tendency to push the rail off the track backward while the other wheels of the locomotive and the vehicles (i.e. wheels of coaches and wagons) push the rail in the direction of travel as explained in Wave Action Theory and they have greater effect (as compared to drag effect). This results in creep of rails in the direction of movement of trains.

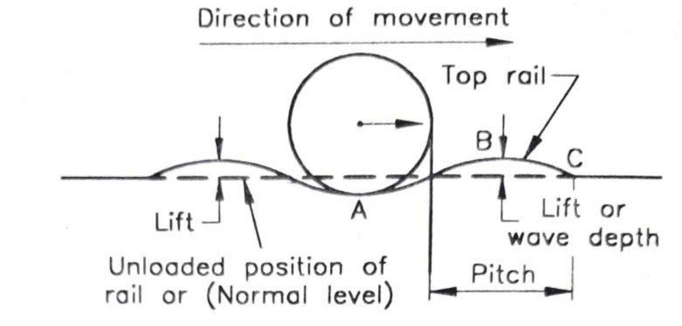


Fig. 8.2. Wave Theory of Creep (Formation of Wave)

4. Starting, Accelerating, Slowing down or Stopping of a Train. When a train is starting or accelerating, the backward thrust of the engine driving wheels tends to push the rails backward. When it is slowing down (i.e. decelerating) or coming to a stop, the braking effect tends to push the rails forward.

5. Expansion or Contraction of Rails due to Temperature. Creep also occurs due to variation in temperature. The creep in this case is influenced by the range in temperature variation, location of track, whether exposed or shady surroundings, etc.

6. Unbalanced Traffic.

(a) In a single line system if heavy equal traffic (both in number and load) runs in both directions, the creep is almost balanced. Otherwise, heavy traffic in one direction will cause creep, which is partly balanced by light traffic in opposite direction.

(b) In the double line system, trains on a particular line being unidirectional, creep occurs in both the lines.

EFFECTS OF CREEP

(i) Sleepers move out of square and out of position. This affects the gauge and alignment of track. As sleepers move, naturally the surface is also disturbed and finally results in an uncomfortable riding.

(ii) Rail-joints are opened out of their limit in some cases and stresses are set up in fish-plates and bolts due to which the bolts sometimes break. The rails are also battered at ends due to excessive gap at joints. While at other places, joints are jammed and prevent required expansion due to temperature variation.

(iii) Points and crossings get distorted and it becomes very difficult to keep them to correct gauge and alignment. The movement of switches is made difficult (i.e., difficult to operate the switches) and interlocking is thrown out of gear.

(iv) If any rail is removed from the track for any purpose, it becomes difficult to fix it again at proper position because by the time gap becomes too short or too long due to creep.

(v) Besides these effects, smashing of fish-plates and fish-bolts, bending of bars, kinks at joints of rails and forging of ballast ahead, are common effects of creep.

PREVENTION OF CREEP

Prevention is always better than cure. If creep is not prevented in time, it will result in derailment. Following are the common methods adopted to prevent creep.

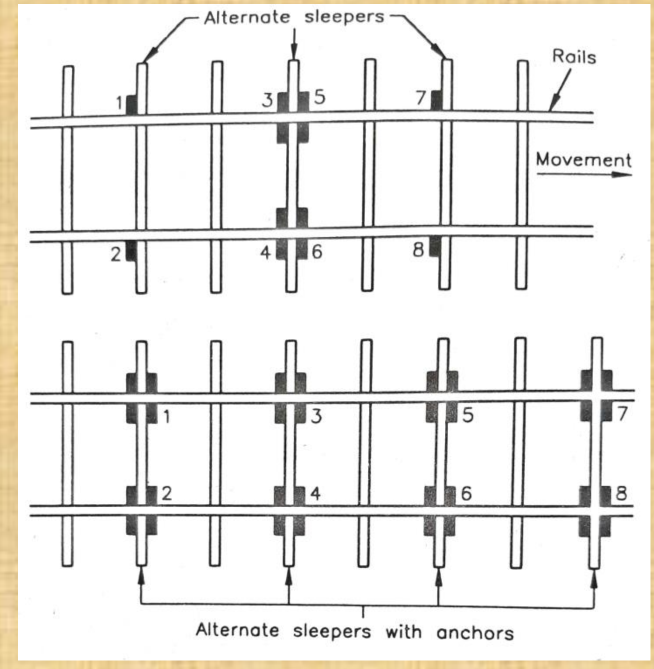
(1) Pulling Back the Rails. If creep is distinctly visible, the remedy is pull back the rails to their original position. For doing this, first inspect the track, note the extent of pulling back distance and determine the point from which to begin. Now start pulling the rails back to their original positions by means of crow bars and hooks provided through the fish bolt holes of rail. In pulling back, the positions of joints relative to sleepers must be maintained, and both the rail joints must be in their relative positions.

Pulling back the rails is a very slow and tedious process and is only possible when a small length is to be dealt. It has, moreover, been noticed that rails start creeping immediately after pulling back.

(2) Provision of Anchors or Anticreepers. The creep of the track can be prevented by use of Anchors and sufficient crib ballast. For creep of 7.5 cm to 15 cm, in a month 4-anchors per rail and for creep of 22.5 cm to 25 cm.6-anchors per rail are used in the Indian practice.

Anchors are fastened to the foot of rail and kept in perfect contact with the side of the sleeper being the side opposite to the direction of creep. If creep occurs in both directions, anticreepers are provided on both the sides of sleepers, starting from the centre of the rail and should never be fixed near the joints.

(3) Use of Steel Sleepers. Sleepers should be of such a type and with such fittings that they effectively prevent the rail from creeping on them. Secondly, the sleepers must have a good grip with the ballast to resist the movement of the sleepers in the ballast. Steel trough sleepers are the best for this purpose. Increase in the number of sleepers will, therefore, also help in the prevention of creep.



RAILWAY ENGINEERING

CHAPTER:-03 [TRACK MATERIALS]

{SLEEPERS}

Definition: **Sleepers are members generally laid transverse to the rails on which the rails are supported and fixed, to transfer the loads from rails to the ballast and subgrade below.**

FUNCTIONS OF SLEEPERS

Sleepers perform the following functions:

(i) To hold the rails to correct gauge (exact in straight and flat curves, loose in sharp curves and tight in diamond crossings).

(ii) To hold the rails in proper level or transverse tilt i.e., level in turnouts, cross-overs, etc., and at 1 in 20 tilt in straight tracks, so as to provide a firm and even support to rails.

(iii) To act an elastic medium in between the ballast and rails to absorb the blows and vibrations of moving loads.

(iv) To distribute the load from the rails to the index area of ballast underlying it or to the girders in case of bridges.

(v) To support the rails at a proper level in straight tracks and at proper superelevation on curves.

(vi) Sleepers also add to the longitudinal and lateral stability of the permanent track on the whole.

(vii) They also provide means to rectify track geometry during service life.

REQUIREMENTS OF SLEEPERS

For good performance of sleepers to fulfil the above functions or objectives an ideal sleeper should possess the following characteristics.

(i) The sleepers to be used should be economical, i.e., they should have minimum possible initial and maintenance costs.

(ii) The fittings of the sleepers should be such that they can be easily adjusted during maintenance operations such as easy lifting, packing, removal and replacement.

(iii) The weight of sleepers should not be too heavy or excessively light. i.e., they should have moderate weight, for ease of handling.

(iv) The design of sleepers should be such that the gauge, alignment of track and levels of the rails can be easily adjusted and maintained.

(v) The bearing area of sleepers below the rail seat and over the ballast should be enough to resist the crushing due to rail seat and crushing of the ballast underneath the sleeper.

(vi) The sleeper design and spacing should be such as to facilitate easy removal and replacement of ballast.

(vii) The sleepers should be capable of resisting shocks and vibrations due to passage of heavy loads of high-speed trains.

(viii) The design of the sleepers should be such that they are not damaged during packing processes.

(ix) **The insulation of rails should be possible for track circuiting, if required, through sleepers.**

(x) **The design of sleepers should be such that they are not pushed out easily due to moving trains especially with steel sleepers with rounded ends.**

(xi) **An ideal sleeper should also have an anti-sabotage and anti-theft qualities.**

CLASSIFICATION OF SLEEPERS

Sleepers can be classified according to the materials used in their construction, in the following categories:

1. **Wooden sleepers**
2. **Metal sleepers**
   - **(a) Cast iron sleepers**
   - **(b) Steel sleepers**
3. **Concrete sleepers**
   - **(a) Reinforced concrete sleepers**
   - **(b) Prestressed concrete sleepers**

1. Wooden sleepers: **Wooden sleepers are regarded to be best as they fulfil almost all the requirements of an ideal sleeper. The life of timber sleepers depends upon their ability to resist (i) Wear, (ii) Decay, (iii) Attack by Vermin, i.e., white ants and (iv) Quality of the timber used.**

Advantages :

(i) Timber is easily available in all parts of India.

(ii) Fittings for wooden sleepers are few and simple in design.

(iii) These sleepers are able to resist the shocks and vibrations due to heavy moving loads and also give less noisy track.

(iv) Wooden sleepers are easy to lay, relay, pack, lift and maintain.

(v) These wooden sleepers are suitable for all types of ballast.

(vi) They are best for track-circuited operations and moreover, wooden sleepers are over-all economical.

Disadvantages:

(i) The sleepers are subjected to wear, decay, attack by white ants, spike killing, warping, cracking, end splitting, rail cutting, etc.

(ii) It is difficult to maintain the gauge in case of wooden sleepers.

(iii) Track is easily disturbed, i.e., alignment maintenance is difficult.

(iv) Wooden sleepers have got minimum service life (12 to 15 years) as compared to other types of sleepers.

(v) Maintenance cost of wooden sleepers is highest as compared to other sleepers.

2. Metal sleepers: Due to the growing scarcity of wooden sleepers, their high cost and short life, metal sleepers are now being widely adopted in India. Metal sleepers are either of steel or cast iron. Cast iron is in greater use than steel for sleepers because it is less prone to corrosion.

Advantages :

(i) Metal sleepers are uniform in strength and durability.

(ii) In metal sleepers, the performance of fittings is better and hence lesser creep occurs.

(iii) Metal sleepers are economical, as life is longer and maintenance is easier.

(iv) Gauge can be easily adjusted and maintained in case of metal sleepers.

(v) For metal sleepers, frequent renewal is not required.

(vi) They have good scrap value, easy in manufacturing and not susceptible to fire-hazards.

Disadvantages:

(i) More ballast is required than other type of sleepers.

(ii) Fittings required are greater in number, and difficult to maintain and inspection.

(iii) Metals, C.I., or steel, are liable to rusting/corrosion.

(iv) Metal being good conductor of electricity interferes with track circuiting.

(v) Metal sleepers are unsuitable for bridges, level crossings and in case of points and crossings.

(vi) These sleepers are only suitable for stone ballast and for rails for which they are manufactured.

(a) Cast iron sleepers: On Indian Railways cast iron sleepers have been used extensively. At present about 45% track consists of cast iron sleepers. Cast iron sleepers have been extensively used on Indian Railways due to their long life and non susceptibility to corrosion.

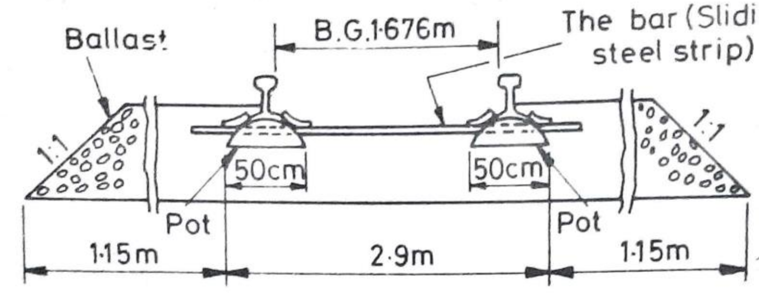


Fig. 9.4. Cross-section of Pot Sleepers.

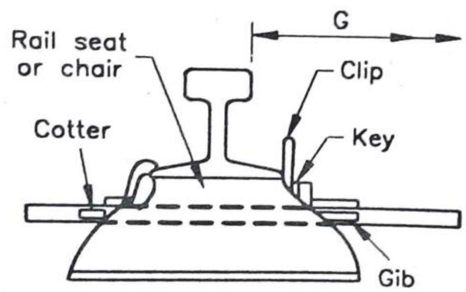


Fig. 9.5. Longitudinal View of Pot sleepers.

Classification of cast iron sleepers:

Cast iron sleepers can be divided into two categories as follows:

1. Cast iron pot type sleeper
2. Cast iron plate type sleeper

1. Cast iron pot type sleeper: This type of sleepers consist of two hollow pots or bowls of circular or elliplical shape placed inverted on the ballast section.

2. Cast iron plate type sleeper: These consists of rectangular plates if size about 860 mm × 305 mm with projecting ribs under the plates for their lateral stability. The tie bars can be fixed to the plates by keys, gibs and cotter, distance pieces etc.

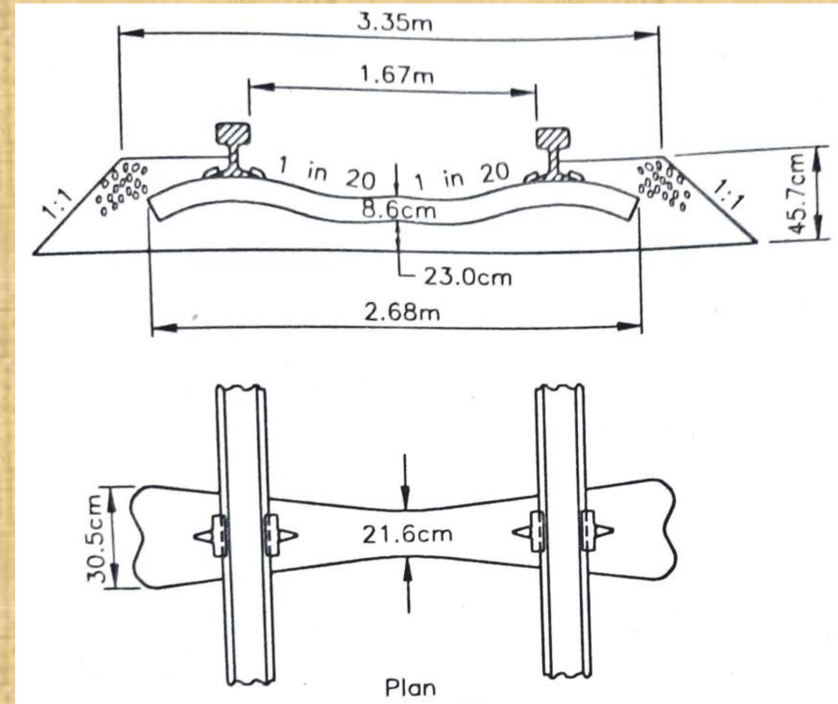
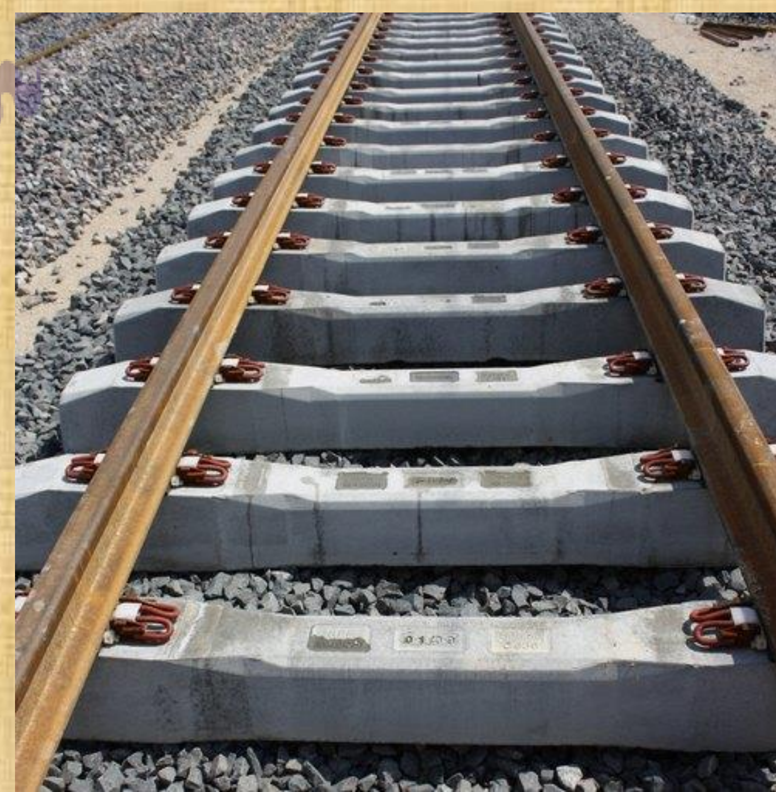


Fig. 9.8. Steel Sleepers.

(b) Steel sleepers: The increasing shortage of good timber in the country and other economical factors are mainly responsible for the use of steel and concrete sleepers on the Indian Railways. About 27% of the track on Indian Railways is laid on steel sleepers. India uses the metal sleepers more than any country of the world.



3. Concrete sleepers: These sleepers were ended due to chronic shortage of good wooden sleepers and need for better design and economy of sleepers on sustainable basis.

Advantages:

(i) These sleepers are free from natural decay and attacks by vermin, insects, etc.

(ii) They have maximum life when compared to other sleepers, the life under normal conditions is 40 to 60 years (as compared to 15-20 years for wooden sleepers).

(iii) This is not affected by moisture, chemical action of ballast, cinder and sub-soil salt.

(iv) There is no difficulty in the track-circuiting, required for electrifying the track.

(v) The high weight of sleepers helps in minimising joint maintenance by providing longer welded lengths (i.e. use of LWR), greater stability of the track and better resistance against temperature variation.

(vi)The sleepers have higher elastic modulus and hence can withstand the stresses induced by fast and heavy traffic.

(vii) Concrete sleepers in the elastic fastenings offers an ideal track in respect of gauge, cross-level and alignment.

Disadvantages:

(i) The weight of concrete sleeper is as high as 2.5 to 3 times of wooden sleeper, requiring the mechanical appliances for handling.

(ii) These sleepers require pads and plugs for spikes.

(iii) They damage the bottom edge during the packing.

(iv) The scrap value is almost nil.

(v) The damages to the concrete sleepers is very heavy in case of derailment.

Classification of concrete sleepers:

These sleepers are mainly of two types:

(a) Reinforced concrete sleepers.

(b) Pre-stressed concrete sleepers.

(a) Reinforced concrete sleepers: **Sleepers made of reinforced concrete are called R.C. sleepers. There are two types of R.C. sleepers.**

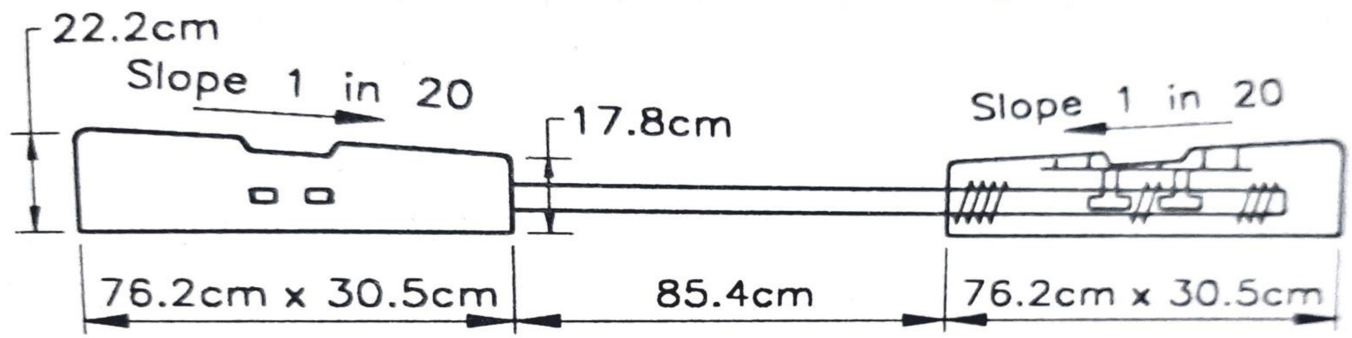


Fig. 9.12. Reinforced Concrete Sleeper (Composite Type).

a. A single piece like a wooden sleeper.

b. Has two R.C. slabs joined together by means of a tie bar generally of a T-section.

(b) Pre-stressed concrete sleepers: All the disadvantages of reinforced concrete sleepers have been eliminated by pre-stressing technique for sleepers. In pre-stressed concrete sleepers, the concrete is put under a very high initial compression.

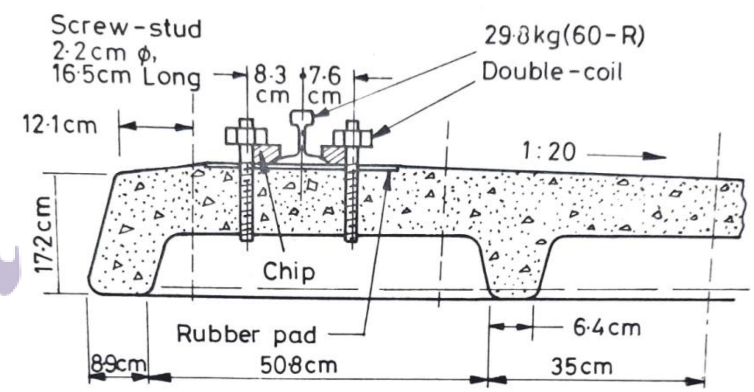


Fig. 9.13. Pre-stressed Concrete Sleeper.

RAILWAY ENGINEERING

CHAPTER:-03 [TRACK MATERIALS]

{BALLAST}

Definition:

- **Ballast is the granular material usually broken stone or brick, shingle or kankar, gravel or sand placed and packed below and around the sleepers to transmit load (due to the wheels of the train) from sleepers, to formation and at the same time allowing drainage of the track.**
- **It provides a suitable foundation for the sleepers and also hold the sleepers in their correct level and position, preventing their displacement by lateral or longitudinal thrusts.**

FUNCTIONS OF BALLAST

Ballast performs the following functions:

(i) It transfers the load from the sleeper to the subgrade and then distributes it uniformly over a larger area of the formation.

(ii) It holds the sleepers in position and prevents the lateral and longitudinal movement, due to dynamic loads and vibrations of moving trains.

(iii) It imparts some degree of elasticity to the track.

(iv) It provides easy means of maintaining the correct levels of the two lines of a track (i.e., level in straight portions and correct super-elevation on curves) and for correcting track alignment.

(v) It provides good drained foundation immediately below the sleepers and helps to protect the top surface of the formation. This is achieved by providing coarse and rough aggregates with plenty of voids.

REQUIREMENTS OF THE GOOD BALLAST

To perform the above mentioned functions, the ballast should have the following characteristics :

(i) It should be able to withstand hard-packing without disintegrating. In other words, it should resist crushing under dynamic loads.

(ii) It should not make the track dusty or muddy due to powder under dynamic wheel loads but should be capable of being cleaned to provide good drainage.

(iii) It should allow for easy drainage with minimum soakage and the voids should be large enough to prevent capillary action.

(iv) It should offer resistance to abrasion and weathering.

(v) It should retain its position laterally and longitudinally under all conditions of traffic, particularly on curves, where it should be able to prevent transverse displacement of sleepers.

(vi) It should not produce any chemical action with rail and metal sleepers.

(vii) The size of stone ballast should be 5 cm for wooden sleepers, 4 cm for metal sleepers and 2.5 cm for turnouts and crossovers.

(viii) The materials should be easily workable by means of the implements in use.

(ix) The ballast should be available in nearby quarries so that it reduces the cost of supply. It should also fulfil the requirements of quality, amount of traffic, life and maintenance cost.

TYPES OF BALLAST

(1) Broken Stone. This is the best material for the ballast and almost all important tracks are provided with stone ballast. The best stone for ballast is a nonporous, hard and angular, which does not flake when broken. Igneous rocks such as hard trap, quartzite and granite, make excellent ballast and are used in large quantities for high speed tracks in India.

(2) Gravel or River Pebbles or Shingle. Gravel comes next in rank for its suitability for use as ballast and is used in large quantities in many countries. This is obtained either from river beds or from gravel pits. The smooth pebbles are broken, otherwise they are liable to displace the sleeper due to smoothness of its particles and the packing does not hold.

(3) Ashes or Cinders. It has excellent drainage proper ties as it is very porous. It is cheap and is largely used in sidings but cannot be used for main lines as it is very soft and gets reduced to powder under wheel loads and makes the track very dusty. It is excellent for station yards and for footpaths particularly in rainy weather as it does not retain water and is not slippery.

(4) Sand. It is reasonably good material as ballast as it is cheap and provides good drainage. Sand ballast also produces a silent track and has been found to be particularly good for packing pot sleepers. The great drawback of the sand is its blowing effect due to vibration.

(5) Moorum. It is the soft aggregate and is the result of decomposition of laterite and has a red or sometimes a yellow colour. It is recommended as a ballast for sidings and main tracks when they are newly laid and the embankments are not sufficiently consolidated. When moorum is finally laid on the track, it forms a soling or blanket under the stone ballast.

(6) Kankar. It is lime agglomerate which is common in certain clayey soils and is dug out of the ground. Where stone is not easily available, it is used as road metal and as ballast for railway tracks. It is soft in nature and reduces to powder under loads. It is used for M.G. and N.G. tracks with light traffic and where a better type of the ballast is not available.

(7) Brick Ballast. Where no stone or substitute is available for use as ballast, overburnt bricks are broken into small sizes and used. It powders easily and produces a dusty track. Rails of tracks laid on brick ballast many a time get corrugated. Brick ballast, however, is fairly good for drainage.

(8) Blast Furnace Slag. Which is a by-product in the manufacture of pig iron forms a suitable ballast material. It should, however, be hard, of high density and free from gas holes.

(9) Selected Earth. For sidings, earth, if of suitable quality, is sometimes used as ballast. It is also sometimes used on new formation as a temporary measure. Indurated (i.e. hardened) clay and decomposed rock are suitable materials.

RAILWAY ENGINEERING

CHAPTER:-04 [GEOMETRIC DESIGN FOR BROAD GAUGE]

Introduction:

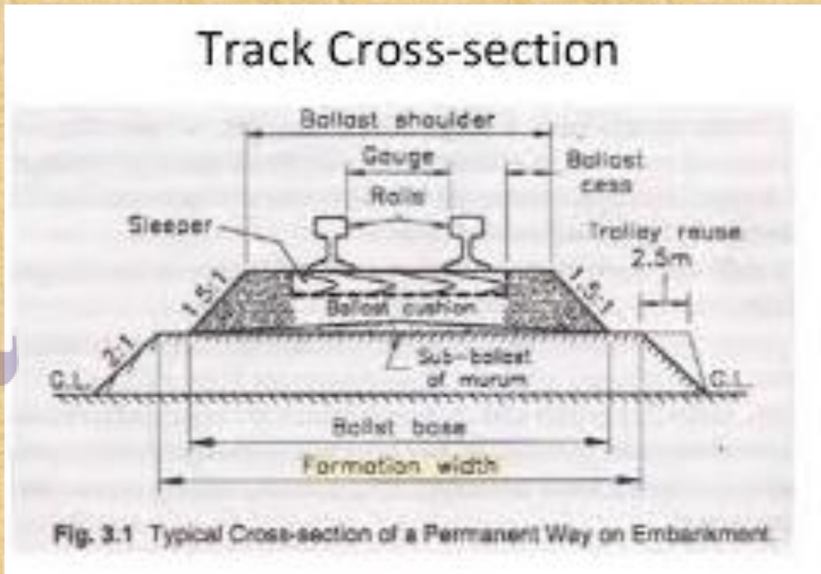


Fig. 3.1 Typical Cross-section of a Permanent Way on Embankment

- The geometric design of a railway track is the most important aspect of the railway track.
- The geometric design should be such as to Provide maximum efficiency in the traffic operation with maximum safety at reasonable cost.
- The success or failure of the track depends upon its geometric design.
- The safety to the traffic depends on the control of derailments which occur mostly due to (a) defects in track (b) Defects in vehicles

  (c) Defective operations etc.

REQUISITE OF GOOD TRACK:

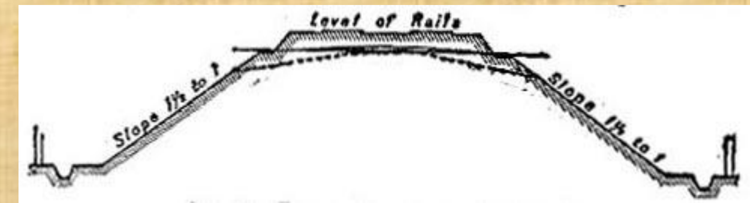
1. It should have proper gradient.
2. It should remain dry throughout the year.
3. It should have good drainage.
4. It should have proper curves.
5. It should have proper points and crossings.

On railways, land is divided into two classes,

(i) Permanent land width

(ii)Temporary land width

Typical Section of Railway in Cutting.



Typical Section of an embankment.

(i) Permanent land width:

- It 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 with side slopes of banks and cuttings, the sites of bridges, and protection or training works; station yards, etc.

- Under this head will also be included land outside the permanent railway boundary, which will be required for the permanent diversion of roads or rivers, 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.

(ii) Temporary land width: **Temporary land width is land which is acquired for temporary purposes only, and which is disposed of after the work of construction is completed.**

Gradients:

- Gradients are provided to negotiate the rise or fall in the level of the railway track.

- A rising gradient is one in which the track rises in the direction of the movement of traffic and a down or falling gradient is one in which the track loses elevation in the direction of the movement of traffic.
- A gradient is normally represented by the distance travelled for a rise or fall of one unit. Sometimes the gradient is indicated as percent rise or fall.
- For example, if there is a rise of 1 min 400 m, the gradient is 1 in 400 or 0.25%, as shown.

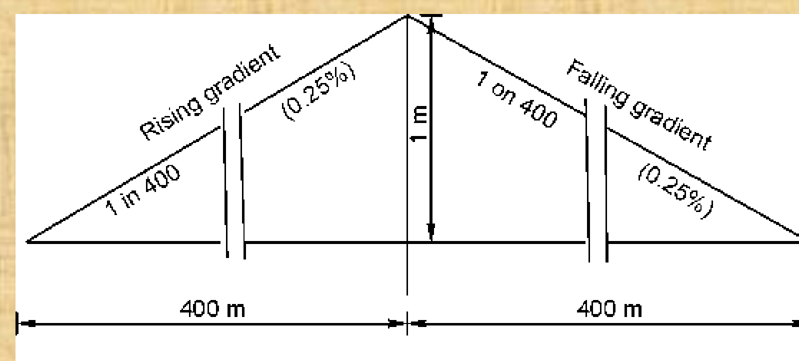


Fig. 12.1 Rising and falling gradient

Gradients are provided on the tracks due to the following reasons:

(i) To provide a uniform rate of rise or fall as far as possible.

(ii) To reach the various stations located at different elevations, and

(iii) To reduce the cost of earth work.

The following types of gradients are used on the railways;

(1) Ruling gradient.

(2) Momentum gradient.

(3) Pusher or Helper gradient.

(4) Gradients at station yards.

(1) Ruling gradient:

- The ruling gradient is the steepest gradient that exists in a section.
- It determines the maximum load that can be hauled by a locomotive on that section.
- While deciding the ruling gradient of a section, it is not only the severity of the gradient but also its length as well as it position with respect to the gradients on both sides that have to be taken into consideration.
- The power of the locomotive to be put into service on the track also plays an important role in taking this decision.

- Generally, the following ruling gradients are adopted on Indian Railways when there is only one locomotive pulling the train;

  In plain terrain: 1 in 150 to 1 in 250

  In hilly terrain: 1 in 100 to 1 in 150

(2) Momentum gradient:

- The momentum gradient is steeper than the ruling gradient and can be overcome by a train because of the momentum it gathers while running on the section.
- In valleys, a falling gradient is sometimes followed by a rising gradient.
- In such a situation, a train coming down a falling gradient acquires good speed and momentum, which gives additional kinetic energy to the train and allows it to negotiate gradients steeper than the ruling gradient.
- In sections with momentum gradients there are no obstacles provided in the form of signals, etc., which may bring the train to a critical juncture.

(3) Pusher or Helper gradient:

- **In hilly areas, the rate of rise of the terrain becomes very important when trying to reduce the length of the railway line and, therefore, sometimes gradients steeper than the ruling gradient are provided to reduce the overall cost.**
- **In such situations, one locomotive is not adequate to pull the entire load, and an extra locomotive is required.**
- **When the gradient of the ensuing section is so steep as to necessitate the use of an extra engine for pushing the train, it is known as a pusher or helper gradient.**

(4) Gradients at station yards: ***The gradients at station yards have to be sufficiently low due to the following reasons:***

(i) To prevent the movement of standing vehicles on the track due to the effect of gravity combined with a strong wind and/or a gentle push.

(ii) To prevent additional resistance due to grade on the starting vehicles, which is about twice at the start than vehicle in motion.

Generally, yards are not levelled completely and certain flat gradients are provided in order to ensure good drainage. The maximum gradient prescribed in station yards on Indian Railways is 1 in 400, while the recommended gradient is 1 in 1000.

RAILWAY ENGINEERING

CHAPTER:-04 [GEOMETRIC DESIGN FOR BROAD GAUGE]

Continue....

SUPER ELEVATION ON CURVES OR CANT

Definition: **It is defined as the difference in height between the inner and outer rails on the curve. It is provided by gradually raising the outer rail above the inner rail level.**

Functions of super elevation or cant. ***Following are the main functions of super elevation.***

(a) It provides better load distribution on the two rails.

(b) It reduces the wear and tear of rails and rolling stock.

(c) It neutralises the effect of lateral forces.

(d) It provides smooth running of trains and comforts to the passengers.

Equilibrium speed: Actually equilibrium speed is the speed at which the effect of centrifugal force is exactly balanced by the super elevation provided.

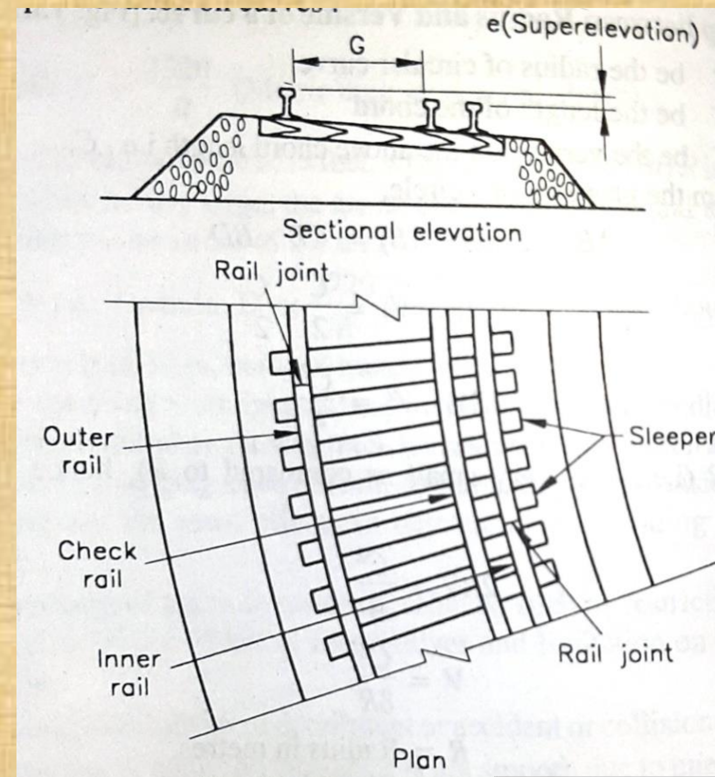


Fig. 15.2. Superelevation

Maximum permissible speed: This is the highest speed which may be allowed or permitted on a curved track taking into consideration the radius of curvature, actual cant or super elevation, cant deficiency, cant excess and the length of the transition curve. When the maximum permissible speed on the curve is less than the maximum sanctioned speed of the section of a line, permanent speed restrictions become necessary on such curves.

Cant deficiency (Cd): When a train travels on a curved track at a speed higher than the equilibrium speed, then cant deficiency occurs. It is the difference between the theoretical cant required for such higher speeds and the actual cant provided.

Cant excess (Ce): When a train travels on a curved track at a speed lower than the equilibrium speed. then cant excess occurs. It is the difference between the actual cant provided and the theoretical cant required for such lower speeds.

Cant gradient and cant-deficiency gradient: These indicate the amount by which a cant or deficiency of cant is reduced or increased in a given length of transition. For example a gradient of 1 in 500 means that cant or deficiency of cant of 1 mm is attained or lost in every 500 mm length of transition

Rate of change of cant or cant deficiency: This is the rate at which the cant or cant deficiency is increased while passing over the transition curve. 40 mm per second means that a vehicle when travelling at a maximum speed permitted will experience a change in cant or deficiency of cant of 40 mm in each second of travel over the transition.

In metric units the equilibrium super elevation

$$e = GV^2/127\,R$$

where,

e = Super elevation in mm

G = Gauge in mm + width of rail head in mm

V = Speed in kmph

R = Radius of curve in metres

Negative superelevation: **When the main line is on a curve and has a out of contrary flexture leading to a branch line, the superelevation necessary for the average speeds of trains running over the main line cannot be provided.**

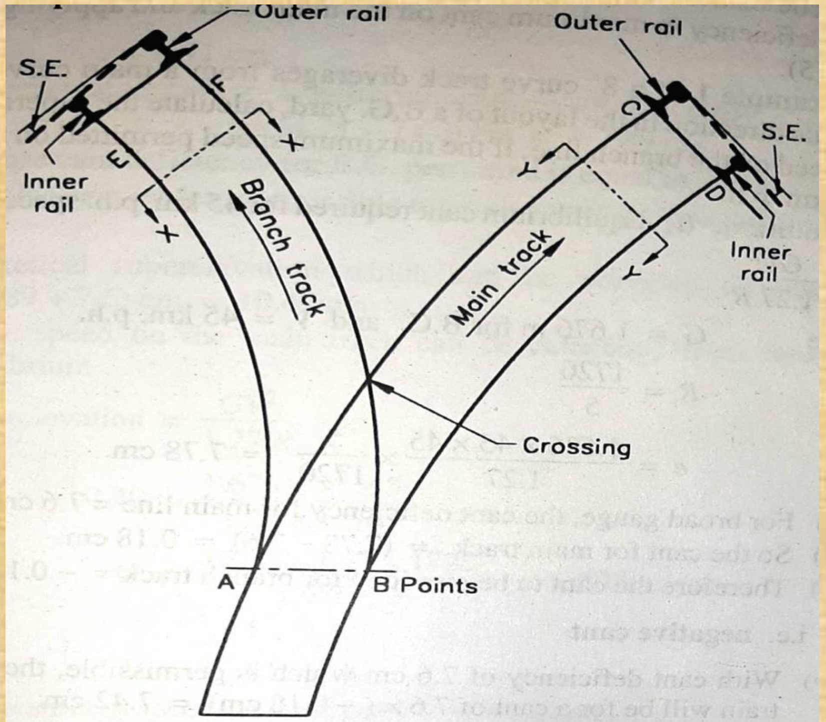


Fig. 15.4. Negative Superelevatic

- **AC which is the outer rail of the main line curve must be higher than inner rail BD or in other words, the point A should be higher than point B.**
- **For the branch line, however, BF should be higher than AE or the point B should be higher than points A.**
- **These two contradictory conditions cannot be met at the same time within one layout. So instead of outer rail BF on branch line being higher, it is kept lower than the inner rail AE. In such cases, the branch line curve has a negative superelevation and therefore speeds on both tracks must be restricted, particularly on branch line.**

end

RAILWAY ENGINEERING

CHAPTER:-05 [Points and crossings]

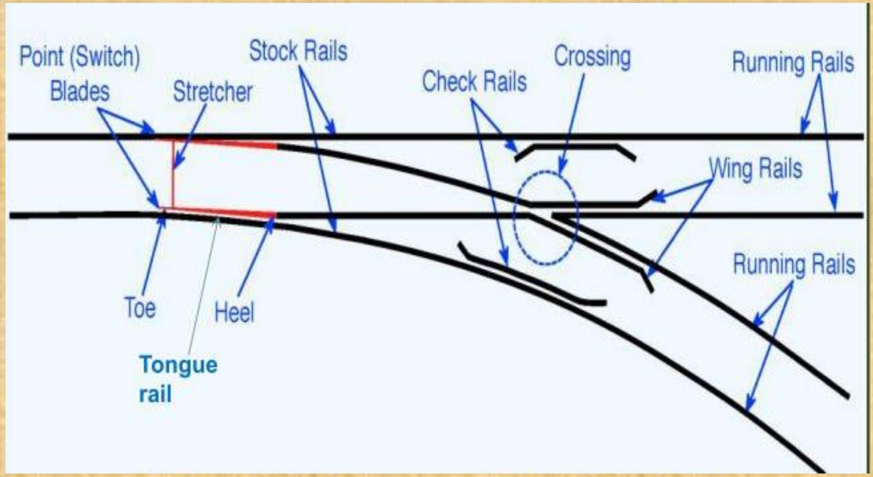
Introduction: To divert the trains from one track to another track some special arrangements are needed due to the inside flanges on the wheel which can move on a definite track. These special arrangements are called points and crossings.

Necessity:

i. Points and crossing are provided to help transfer railway vehicle from one track to another.
ii. The track may be parallel to diverging from or converging with each other point and crossing are necessary because the wheels of railway vehicles are provided with inside flange and therefore they require this in special arrangement in order to navigate their way on the rail.
iii. The points or switches aid in diverting the vehicles and the crossing provide gaps in the rails so as to help the flanged wheels to roll over them.
iv. A complete set of points and crossings, along with lead rails is called a turnout.

SOME IMPORTANT DEFINITIONS

(a) Turn out. A complete set of points and crossing along with lead rails is known as turn out. With the help of this arrangement rolling stock may be diverted from one track to another track.



(b) Tongue rail. It is a tapered movable rail made of high carbon or manganese steel to with stand wear. It is attached at its thicker end to a running rail. Sometimes it is also called switch rail.

(c) Stock rail. It is the running rail against which a tongue rail operates.

(d) Switch. A pair of tongue and stock rails with necessary connections and fittings form a switch. It is the device used to divert the rolling stock from one track to another track.

(e) Points. A pair of tongue rails with their stock rails is known as point. In other words a set of switches is known as point.

(f) Crossing. A crossing is a device introduced at the junction where two rails cross to permit the wheel flange of a railway vehicle to pass from one track to another track.

(g) Switch angle. **It is the angle formed between the gauge face of the stock rail and that of tongue rail at the theoretical toe of the switch in its closed position. It is the function of the heel divergence and the length of tongue rail.**

TURNOUTS

A complete set of points and crossings along with a lead rail is known as a *turnout*. Depending upon the direction of diverting the train, turnout is known as left hand or right hand turnout.

The following are the parts of a Turnout:

(i) A pair of points or switches (ABCD and EFPQ).

(ii) A pair of stockrails.

(iii) A Vee crossing (GHIJ).

(iv) Two check rails.

(v) Four lead rails.

(vi) "Switch tie-plate' or "gauge tie chair" and crossing tie-plate,

(vii) Studs or stops.

(viii) Bearing plates, slide chairs, stretcher bars etc.

(ix) For operating the points-Rods, cranks, levers etc.

(x) For locking system-locking box, lock bar, plunger bar etc.

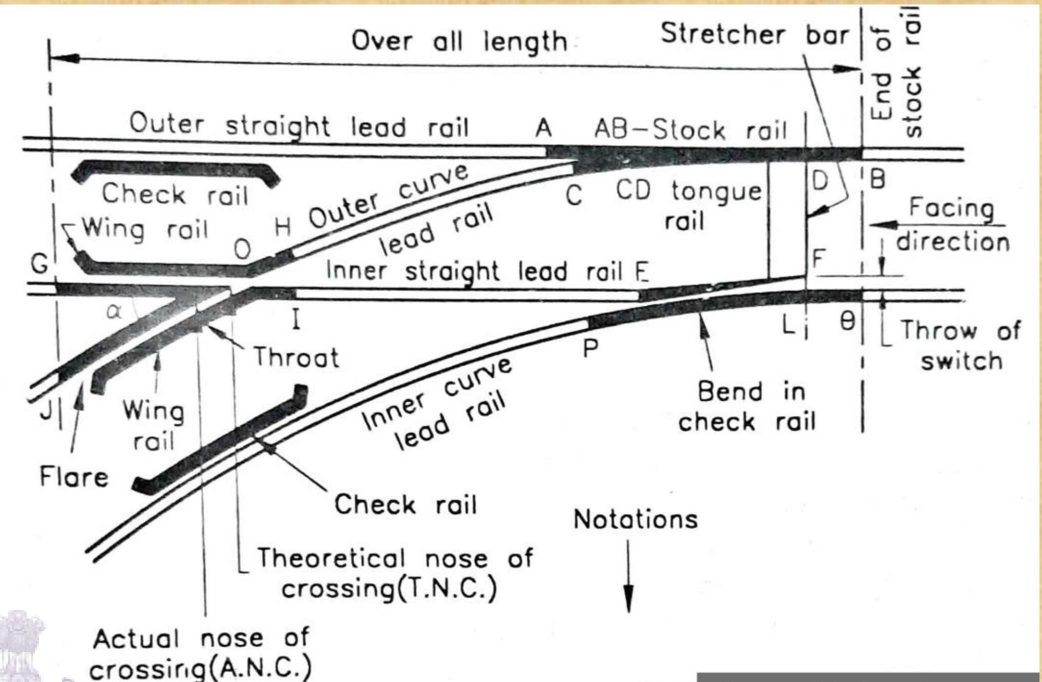


Fig. 16.1. Left hand turnout (Split

Important Terms Used in Points and Crossings

(i) Facing Direction. If someone stands at toe of switch and looks towards the crossing, then the direction is called "Facing Direction"(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) .

(iii) Facing Points of Turnouts are those where trains pass over the switches first and then they pass over the crossing. 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 movement of trains is reserved for trailing direction only.

(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).

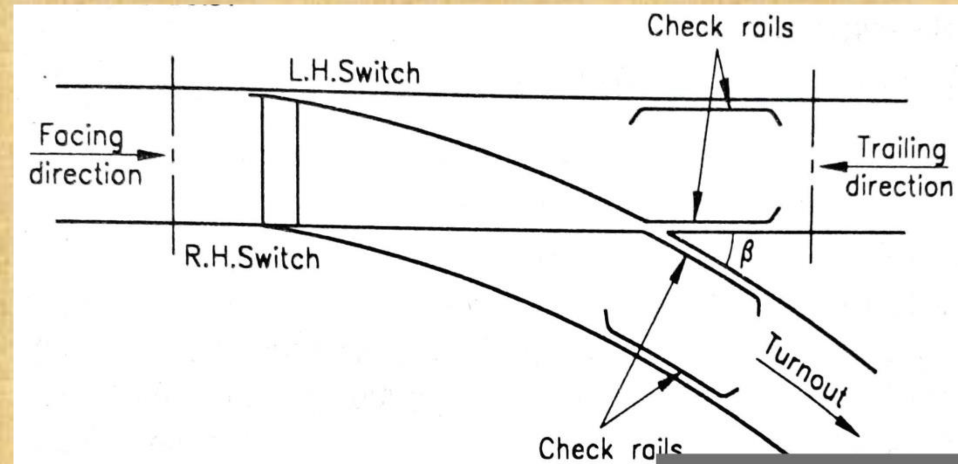


Fig. 16.2. Line Diagram of Right-hand

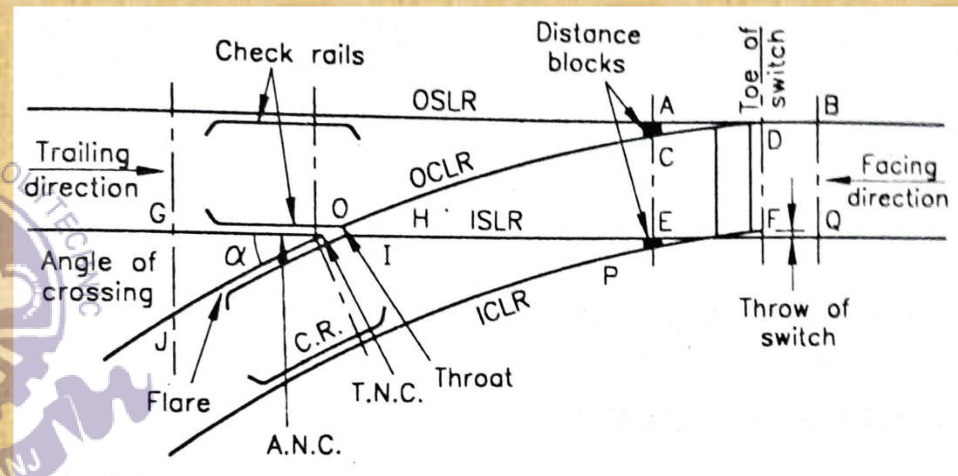


Fig. 16.3. Line Diagram of Left-han

(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, (Figs. 16.2 and 16.3).

POINTS or SWITCHES

- **A switch consists of a stock rail and a tongue rail. A set of switches or points consists of a left-hand switch and a right-hand switch (Fig. 16.5).**
- **Switches are tapered rails with the thicker end known as *the heel* fixed to the main track and thinner end known as *the toe* movable by means of which the flanged wheels of the train are diverted from one route to another.**

The various component parts of the switches are as below:

(i) A pair of stock rails.

(ii) A pair of tongue rails.

(iii) Heel block or distance block.

(iv) Stretcher bars.

(v) Switch tie plate or gauge tie plate.

(vi) Slide chairs or sliding plates.

(vii) Studs or stops.

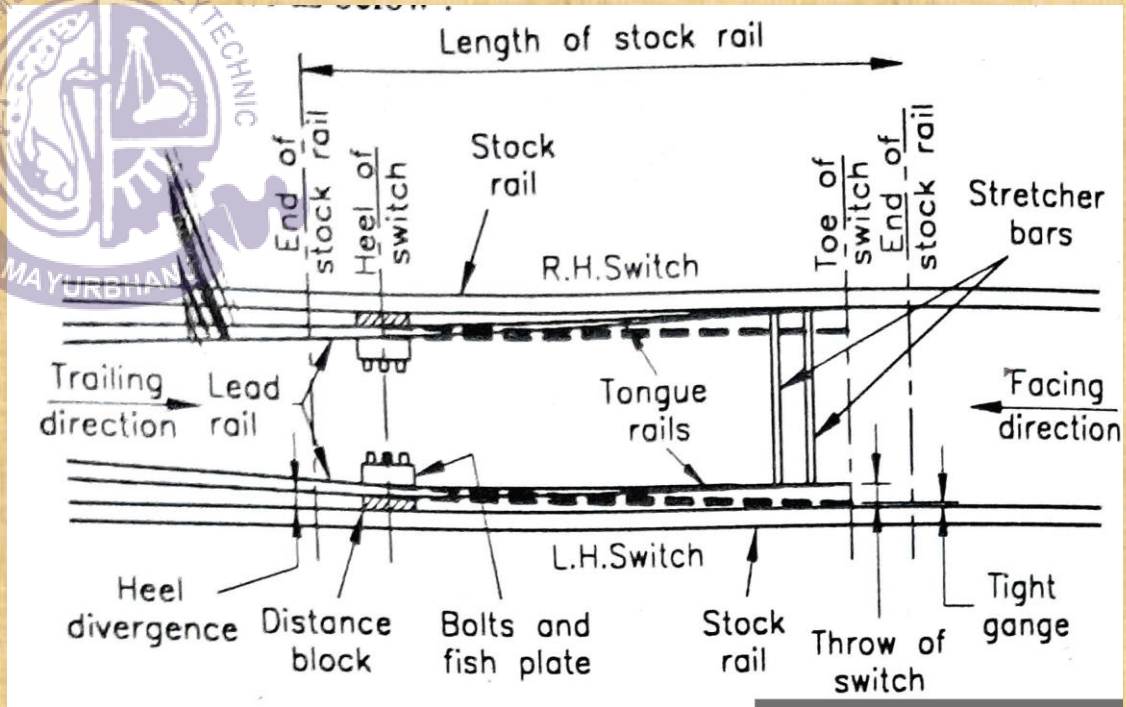


Fig. 16.5. . Fixed Heel Type

(i) A pair of stock rails. They are the main rails of the track to which the tongue rails fit closely against them. They are made of the rail steel and have the same dimensions (i.e. rail section) as for other rails in the track (Fig. 16.1 AB and PQ) where PQ has bend in rail and AB is straight.

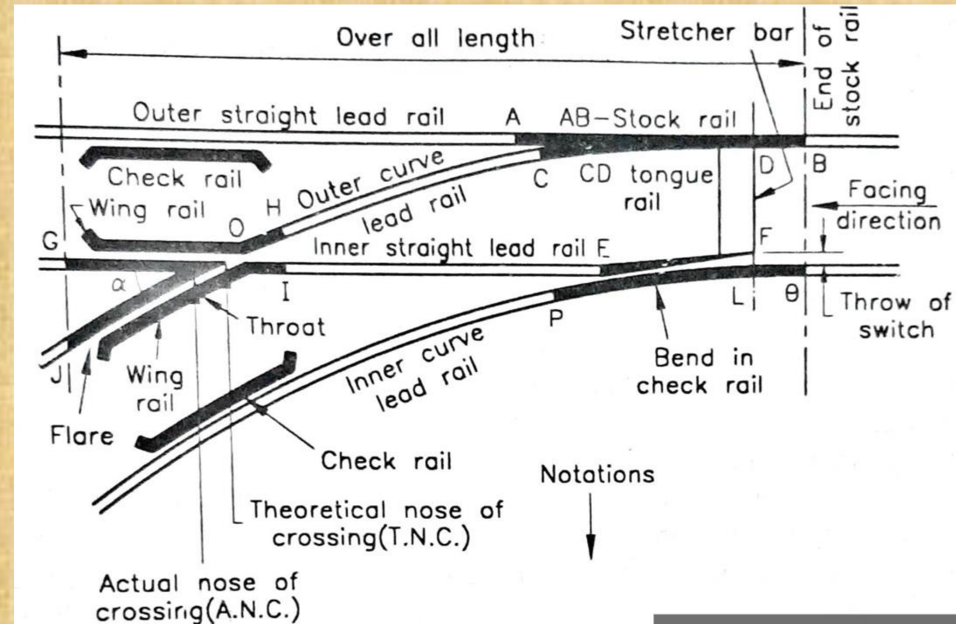


Fig. 16.1. Left hand turnout (Split

(ii) A pair of tongue rails. Tongue rails are supported on sliding plates and each pair of tongue rails is connected by stretcher bars near the toe of switch so that both the tongue rails move together through the same distance or gap and maintain the gauge. This gap (i.e., FL—Fig. 16.1) is known as throw of switch.

(iii) Heel blocks or Distance blocks.

- These blocks are inserted between the heel of the tongue rail and stock rail. These are made of C.I. and are used to provide a clear gap for the wheel flange (i.e., to maintain proper heel divergence).

- **The distance block is same as heel block but it is used to provide a distance or gap for flange way between the running rail and the check rail, hence termed as distance block.**

(iv) Stretcher bars.

- **The toes of both the tongue rails are connected together by means of stretcher bars, so that each tongue moves through the same distance or gap while changing the points.**
- **Generally two or three bars are used near and behind the toe.**

(v) Switch tie plate (or Gauge tie bar or plate).

- **This is provided below the slide chairs at the toe. There are two butt straps (also known as 'stops') at the ends to ensure the definite location of slide chairs and hence of the rails.**
- **These are used to hold the track rigidly to the definite gauge at the toe of switches.**

(vi) Slide chairs (or sliding plates). These are the special plates which are provided under the stock and tongue rails. These are essential because tongue rails have to move towards or away from the stock rail.

(vii) Studs or stops. These are fixed between the stock rails and tongue rails. These are used to prevent the lateral bending of the tongue rail and subsequently maintain correct alignment when the wheels roll over the points.

TYPES OF SWITCHES

There are two types of switches

(1) Stub switch (2) Split switch

(1) Stub switch. This is the earliest type of switch. No separate tongue rail is provided and some portion of the track is moved from side to side. This type is no more in use on Indian Railways.

(2) Split switch.

This is the modern type of switch. It consists of a stock rail and a tongue rail. It is further sub-divided into,

a. Loose heel type b. Fixed heel type

a. Loose heel type switch (Fig. 16.7). In this type, tongue rails are joined to lead rails by means of fish plates. The two front bolts are kept loose to allow the throw of switch and these bolts are kept tight when the tongue is open. This is suitable for short length switches.

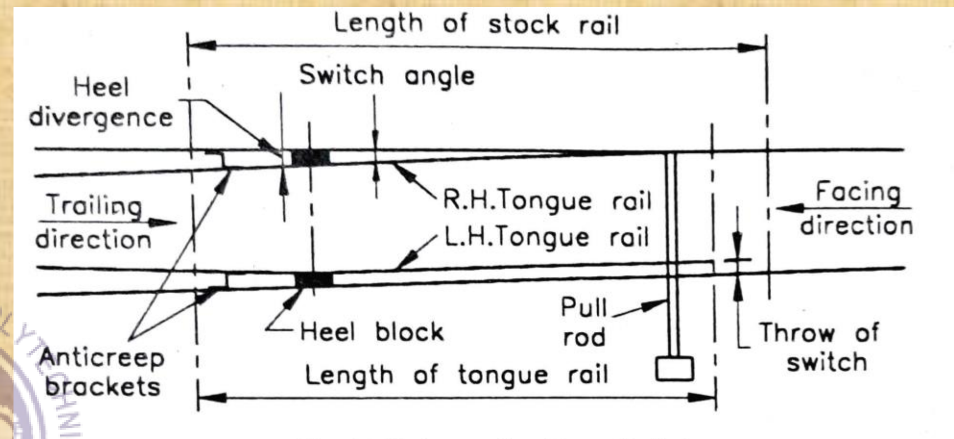


Fig. 16.7. Loose heel type Switc

b. Fixed Heel type (or Spring type or Flexible type) switch (Fig. 16.6). This switch is an improvement over loose heel type switch. In this, all the four bolts are tight when the tongue is closed. So fixed heel type switch is suitable with long tongue rails only.

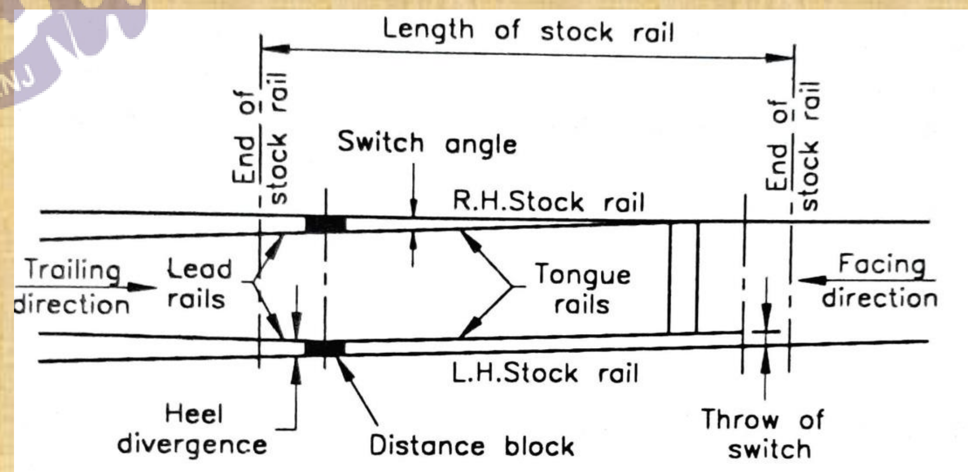
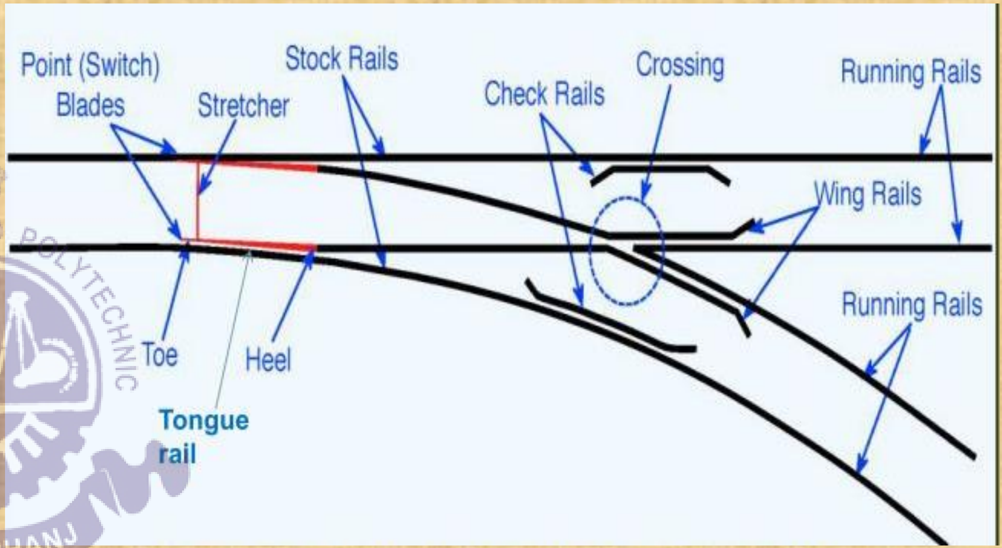


Fig. 16.6. Line Diagram of Fixed Heel Typ

CROSSINGS

A crossing' or a '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.

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;

(1) Acute angle crossing or "V" crossing or Frog.

(2) Obtuse angle crossing or Diamond crossing.

(3) Square crossing.

(4) Spring or movable wing crossing.

(1) Acute angle crossing.

- 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 (Fig. 16.13).

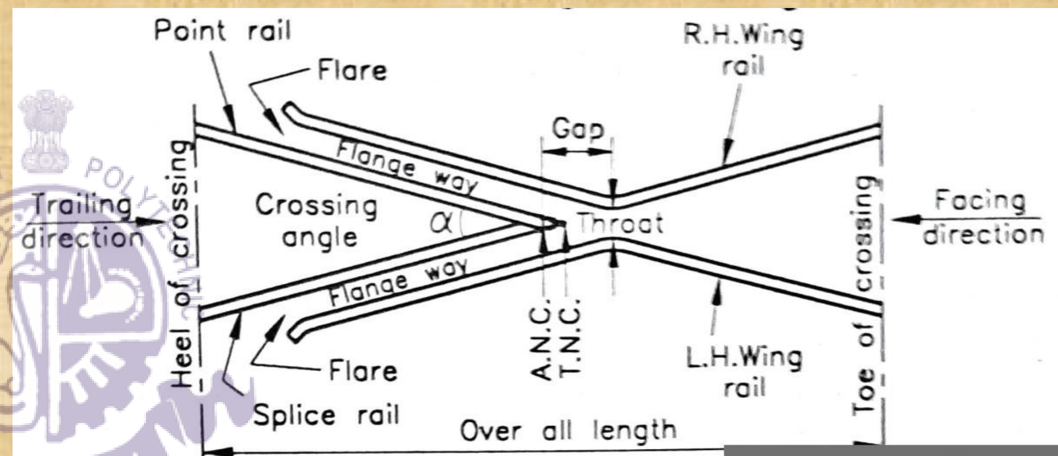


Fig. 16.13. Acute Angle Crossin

(2) Obtuse angle crossing.

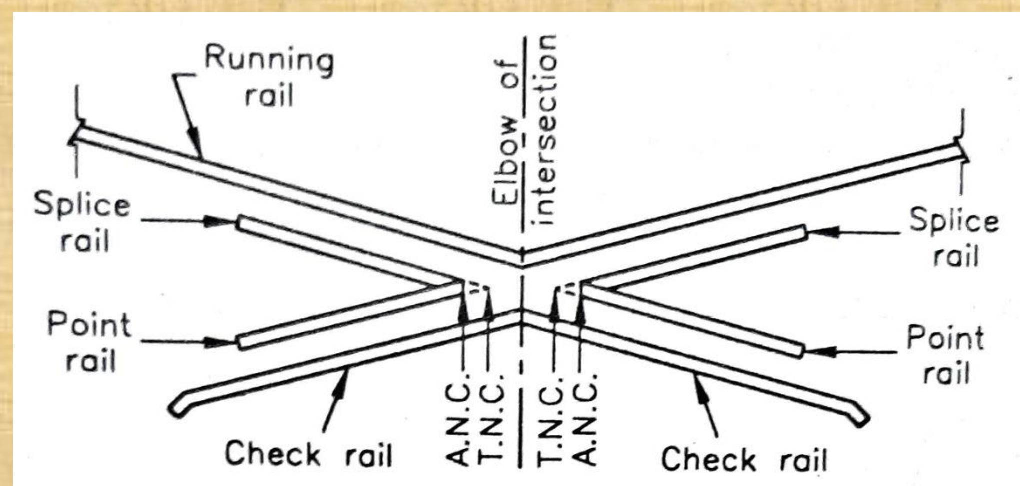


Fig. 16.16. Obtuse Angle Cr

- 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 (Fig. 16.16).

(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).

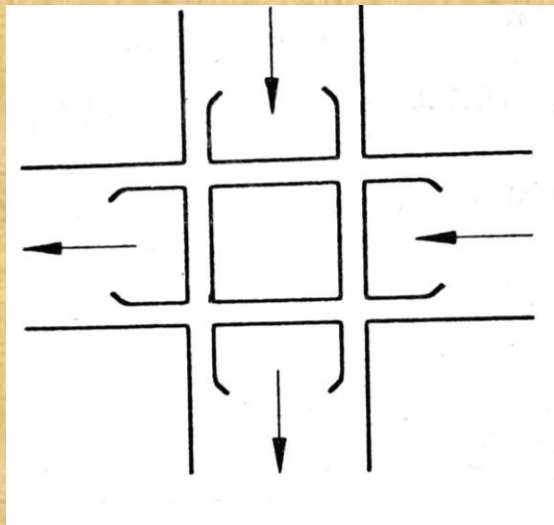


Fig. 16.17. Square Crossing

(4) Spring or movable crossing.

- In such a crossing, one wing rail is movable and is held against the Vee of the crossing 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 (Fig. 16.18).

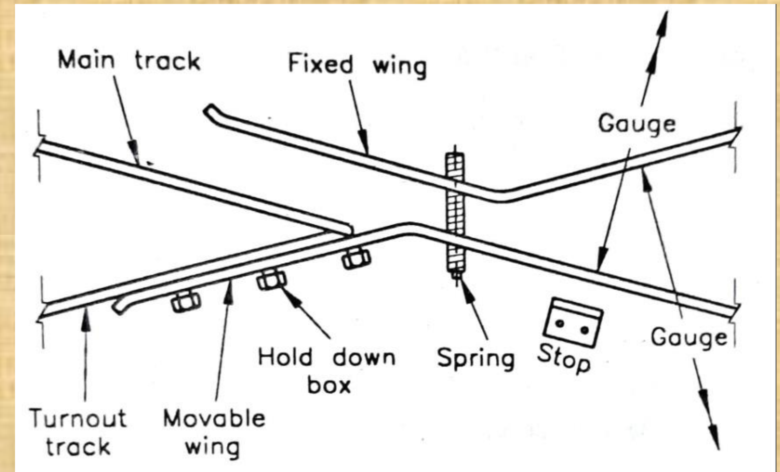


Fig. 16.18. Spring Crossing

end

RAILWAY ENGINEERING

CHAPTER:-06 [Laying & 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 tack drainage should be good and 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 calendar year (12-months) are as follows for achieving the above mentioned standards:-

1) Through Packing
2) Systematic Overhauling
3) Picking up slacks

1) 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 of NG.

- **Examination of rails, sleepers and fastening:-**

  The rails, sleepers and fastening to be used are thoroughly examined. Defective sleepers are removed and loose fastening are tightened. Any kinks in rails are removed.

- **Squaring of sleepers:-**

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

(b) The position of the sleeper 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.

- **Aligning the track:-**

(a) The alignment of the track is normally checked visually, where in the rail is visually assessed form a distance of about four rail lengths 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 deep into the ballast at an angle not more than 30 form the vertical.

Advantages of Track Maintenance:-

1. 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.

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

3. Small maintenance jobs done at the appropriate time, such as tightening a bolt or key, hammering the dog spike, etc., help in avoiding loss of concerned fitting and thus saving on the associated expenditure.

4. 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 operations 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 stacks:-

Stacks are those points in the track where the running of trains is faculty.

Slacks generally occur in the following cases:-

(a) Stretches of yielding formation.

(b) Improperly aligned curves.

(c) Portions of track with poor drainage.

(d) Approaches to level crossing, girder bridges etc.

(e) Section with an inadequate or unclean ballast cushion.

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.

Duties of a permanent way Inspector (PWI)

The PWI is generally responsible for the following:-

(a) Maintenance and inspection of the track to ensure satisfactory and safe performance.

(b) Efficient execution of all works incidental to track maintenance, including track relaying work.

(c) Accounts and periodical verification of the stores and tools in his or her charge.

(d) Maintenance of land boundaries 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 night patrolling at last once a month by train as well as by trolley.

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

(d) Periodically inspects and respective LWR tacks to ensure their safety.

(e) Ensures the cleanliness of station yards.

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

(g) Looks after all establishment work, including the welfare of the staff working under his charge and maintenance their service records.

(h) Ensures the safety of the track during the execution of work that affects the track.

*****END*****

BRIDGE ENGINEERING

CHAPTER:-01 [Introduction to bridges]

INTRODUCTION:

- A bridge is a structure that facilitates the crossing over the deep valleys full of water or other obstructions etc.
- They can be classified according to their functions, materials used, nature of permanency as permanent or temporary etc.

REQUIREMENTS OF AN IDEAL BRIDGE

An ideal bridge must meet the following requirements.

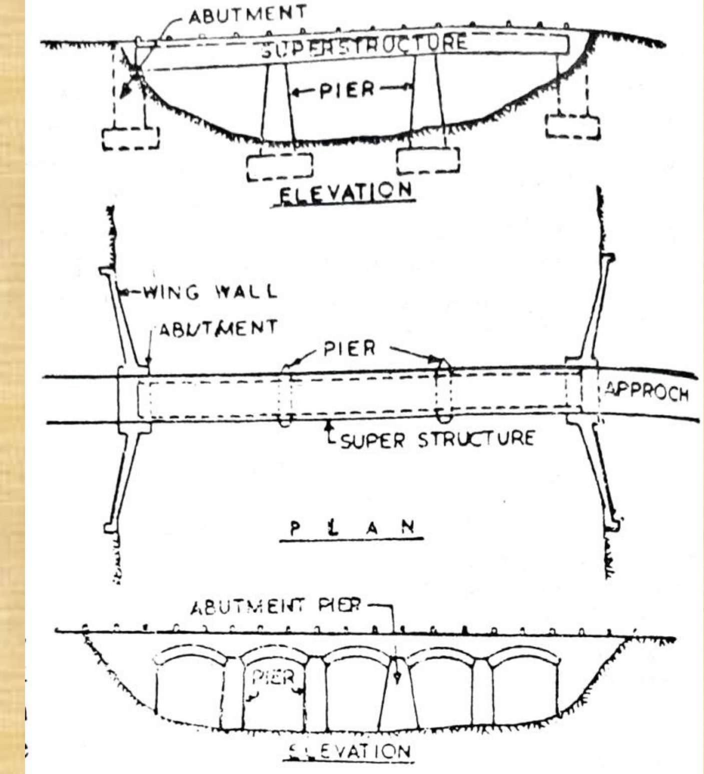
(a) It should be economical.

(b) It should serve the intended functions with safety and convenience.

(c) It should give aesthetic elegant look.

DEFINITIONS

Valley: A depression in between two banks or sides with water is known as a valley



ELEVATION
Fig. 4.1.

Viaduct: A deep valley without perennial water is known as a viaduct.

Span: The centre to centre distance between two piers or supports is known as span. The clear distance between the two supports is known as clear span.

Abutments: The end supports of the super structure of a bridge are called abutments. They may be either arched shaped or flat.

Piers: The intermediate support of the super structure are called piers. They transfer the load from the super-structure to the sub-soil through the foundation.

Abutment piers: In arch bridges, sometimes, some of the intermediate supports or piers are made of a stronger section than others. They are designed to function as a abutment, except retaining and protecting the earth fill.

Wing walls: The walls constructed on both sides of the abutments are called wing walls. They support the soil behind them or embankments of approach roads and also protect the embankments etc., from the wave action of the running water.

Approaches: The structures that carry the road or railway track upto the bridge are known as approaches.

Foundations: The structures used for transferring and distributing the dead load of super-structures, piers and abutments etc. along with live loads likely to come on the bridge to soil underneath are known as foundations.

High flood level: The highest water level ever recorded during a flood in a river or stream is known as high flood level.

Free board: The difference between the high flood level and the level of the crown of the road at its lowest point is called free board.

Low water level: The lowest or minimum water level in the stream or river during dry weather is known as low water level.

Scour: The vertical cutting of river bed is called scour.

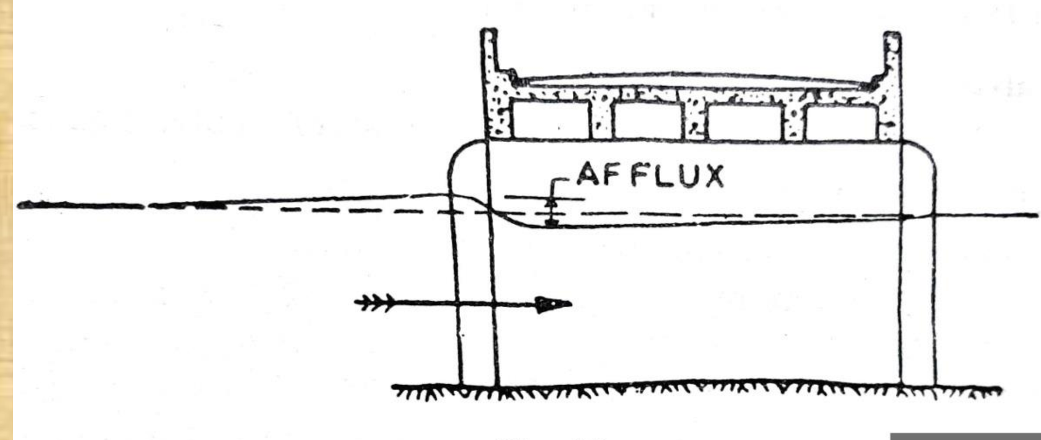


Fig. 4.2.

Afflux: The rise in water level of the river near bridge due to the obstruction created by the construction of piers is called afflux.

Water way: The area of opening sufficient to pass the maximum flood discharge expected in the river without increasing velocity of flow beyond safe limits is called the water way.

Economic span: The length of the span for which the cost of construction of the bridge will be least is known as economic span.

Head room: The distance between the highest point of the vehicle and road using that bridge is called head room. It is a very important factor to be considered in through bridges.

Clearance: The least or minimum distance between the specified positions of a bridge is called clearance. It may be horizontal as well as vertical. The vertical clearance is the clear height from the H.FL, to the lowest point of the bridge structure.

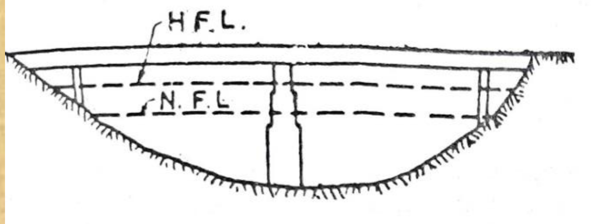


Fig. 4.3. High level Bridge

High level or non-submersible bridge: In this type of bridges flood water in all conditions is allowed to pass below it. Generally all railways and road bridges come under this category.

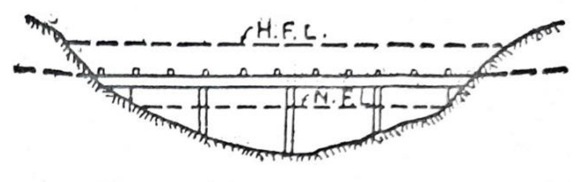


Fig. 4.4. Submersible Bridge

Cause way: It is a submersible bridge having no span for passing water below it. Thus the flood water passes over the communication route.

Culvert: It is a small bridge. The maximum span of a culvert generally is 6 metres. It may have 3 to 4 spans.

COMPONENT PARTS OF A BRIDGE

The bridge structure can be divided into two parts as follows:

1. Super-structure   2. Sub-structure

1. Super-structure:- It is that part of the bridge over which the traffic moves safely. It consists of parapet, road way, girders, arches, or trusses over which the road is supported.

2. Sub-structure:- The sub-structure consists of foundation, piers, abutments, wing walls and approaches. They all support the super-structure of the bridge.

CLASSIFICATION OF BRIDGES

The bridges may be classified as follows according to:

1. Their functions or purpose as railway, highway, foot bridge, aqueduct etc.

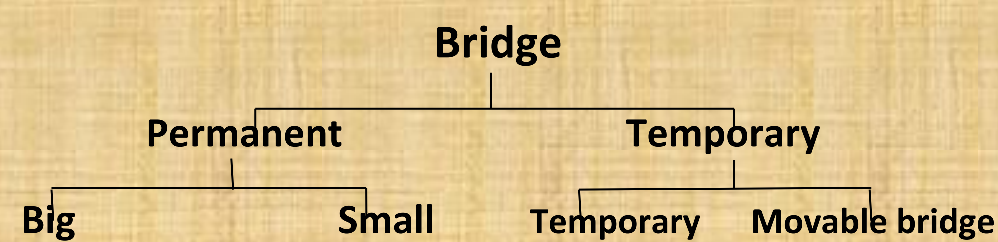
2. Their material of construction used as timber, masonry, R.C.C. steel, prestressed concrete etc.

3. Nature or life span such as temporary, permanent bridge etc.

4. Their relative position of floor such as deep bridge, through brides, etc.

5. Type of super-structure such as arched, girder, truss, suspension bridge, etc.

Classification of bridges may also be done as follows:



According to the material of Construction;

1. **Timber bridges**
2. **Masonry bridges**
3. **Steel bridges**
4. **R.C.C. bridges**

BRIDGE ENGINEERING

CHAPTER:-02 [Bridge site investigation, hydrology & planning]

SELECTION OF SITE OF CONSTRUCTION

The first step in constructing a bridge, the selection of site is very important from the point *of view of economy and safety too.*

Following are the characteristics of an ideal site for a bridge:

1. **Straight reach of the stream.** In order to avoid formation of eddies and to give smooth flow under the entire length of the bridge the river on both sides of the bridge.
2. **Good foundation.** For abutments and piers foundations, good rock or strata should be available at reasonable depth.
3. **Well defined firm banks.** On both sides of the bridge site, there should be high and permanent banks as they will avoid the river training works and also provide good foundation for the towers of suspension bridge.

Alignment.

After selecting the site, the exact alignment is located. At the time of locating exact alignment of the bridge, following points should be kept in mind:

1. As far as possible the alignment should be *square* i.e., the axis of the bridge should cross the river at right angle.
2. As far as possible skew alignment of the bridge should be avoided. A skew bridge has the following disadvantages:
   (a) The construction and maintenance of skew bridges is very difficult. Specially the construction of skew piers is very difficult.
   (b) The piers have to resist excessive water pressure.
   (c) The passage of water under the super-structure is not smooth and eddies are produced.
   (d) The foundations are more likely to be scoured.
3. As far as possible the alignment should be such so that smooth entry and exit may be obtained.
4. As far as possible the alignment should not be curved.

ESTIMATION OF DISCHARGE

For the safe and stable design of a bridge, the correct estimation of the discharge to be passed through the bridge is very essential.

Generally two methods may be adopted for calculating the maximum flood discharge of a river.

1. Direct method 2. Indirect method

1. Direct method. **In this method the area is obtained by direct measurement and the velocity can be obtained by any of the following formula:**

1. By Chazy's formula, $v = c\sqrt{mi}$

2. By Manning's formula, $v = \frac{1}{N} m^{2/3} i^{1/2}$

where, c = a constant which can be found out by Kulter, or Bazin's formula

Empirical Methods for Estimation of Flood Discharge:-

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

(a) Dicken's formula $Q = CA^{3/4}$

(b) Ryve's formula $Q = CA^{2/3}$

(c) Inglis formula $Q = \frac{123.2\,A}{\sqrt{A+10.40}}$

where,

Q = Max. flood discharge in cubic metre per sec.

A = Area of catchment in square kilometer.

C = A constant which is different for Dicken and Ryve's formulae.

WATER WAY.

Water way may be defined as the area of opening, under the bridge which should be sufficient to pass the maximum flood discharge that would ever pass under the bridge without increasing the velocity of flow beyond permissible limit.

For determining the water way followings should be known:

1. Maximum expected flood discharge which will pass under the bridge.
2. Maximum permissible velocity. Generally maximum velocity should not be allowed more than 3 m/sec.

Economical span.

It may be defined as ,the economic span is that span for which the cost of super structure for one span is equal to the cost of sub structure of that span.

Actually the cost of a bridge is affected by the following factors;

1. The length of span
2. Nature of water way or river to be bridged or crossed.
3. The conditions under which the structure is to be constructed.
4. Nature of the available construction materials for the bridge.
5. Availability of the skilled labour in the locality.

Afflux.

It is the rise in water level near the bridge or difference in water level immediately above and below the bridge due to the obstruction caused by the construction of the bridge. Water level piles up on the up stream side of the bridge.

It can be calculated by the following two formulae:

1. Merriman's formula,

$$h = \frac{V^2}{2g}\left[\left(\frac{A}{c.a}\right)^2 - \left(\frac{A}{A_1}\right)\right]$$

where,

V = Velocity of approach in m/sec.

A = Natural water way at site (L x d)

a = Artificial water way

c = Coefficient of discharge

A_1 = The enlarged area up stream of the bridge

h = Height of afflux in metres.

2. Molesworth's formula

$$h = \left[\frac{V^2}{17.87} + 0.0125\right]\left[\left(\frac{A}{a}\right)^2 - 1\right]$$

where all terms convey the same meaning as above in Merriman's formula.

Clearance.

- **To avoid any possibility of striking normal traffic against any part of the super structure, clearances are provided.**
- **The super structure should be laid in such a manner that no part of the super structure is constructed within the clearance diagram.**
- **This clearance diagram determines the minimum values of widths for deck bridge etc. and depth of structure and widths for through bridges.**

FREE BOARD.

It is the vertical distance between the H.F.L. of the river and the bottom level of the girder or springing level in case of arch bridges.

It is provided for the following reasons:

(a) Free board is provided to pass the fallen tree trunks and other similar debris at the time of high floods in the river under the bridge and also to accommodate the height of waves under the bridge above the highest flood level.

(b) To accommodate the afflux due to contraction of water way during maximum flood discharge. Otherwise the water will strike the structure of the bridge and there may be chances of its damage.

*****end*****

BRIDGE ENGINEERING

CHAPTER:-03 [Bridge foundation]

INTRODUCTION

Foundation is that part of the structure, which is in direct contact with the loads and transmits them to the ground below. It is very important part of every structure. Specially for massive structures. Its design is very important and difficult.

FUNCTIONS OF FOUNDATION

Following are the functions of the foundation:

1. To keep the intensity of pressure within safe limits of the bearing capacity of soil, the foundations are used to distribute the load of the structure over a larger area of the sub-soil.

2. To provide a levelled base for the construction of piers and abutments.

3. To prevent the tilt and over turning of the piers and abutments.

4. To prevent the lateral escape of the supporting material of the river bed. This will prevent piers from sinking. Thus the damage caused due to the failure of bridge will be averted.

5. To avoid unequal settlement of the sub-soil and supper structure etc.

TYPES OF FOUNDATION

Generally following types of foundations are adopted for bridges:

1. Spread foundation
2. Raft foundation
3. Pile foundation
4. Caisson foundation

1. Spread foundation.

- This type of foundation in shape is similar as provided for walls.

- **It is best suited in such situations where the scouring of the river bed is minimum and good and hard soil is available within 2 to 3 metres below the river bed level.**
- **This type of foundation can also be provided even if the bed contain erodable material as sand, but the scouring is prevented by driving sheet-piles on upstream and down stream side and floor pitching.**

The minimum depth of this foundation is determined by the following formula.

$$D = \frac{P}{d}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)^2$$

where,

D = depth of foundation

P = bearing capacity of sub soil in kg/m²

d = density of sub soil in kg/m³

ϕ = angle of repose of soil.

Raft or Mat Foundation

2. Raft foundation or floating foundation.

- **This type of foundation is best suited for situations where the bearing capacity of soil is very poor and the river bed contains soft clay and good soil is not available** within a reasonable depth. This foundation is also known as floating or mat foundation.

- In this case a thick slab of reinforced cement concrete is laid over a layer of well compacted lime concrete.
- Over this reinforced cement concrete piers may be constructed at specified intervals.
- From economical considerations the provision of inverted tee) beam has been found useful. Inverted *T-beam* raft foundation is shown in Fig.7.1.

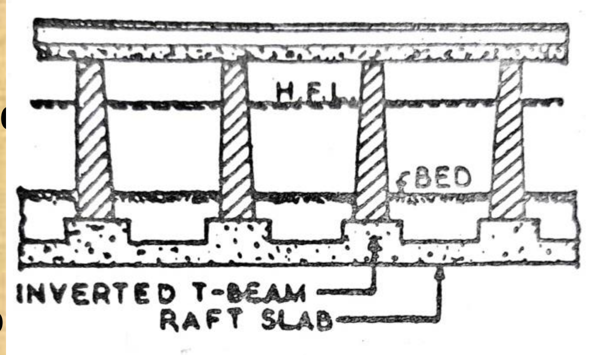


Fig. 7.1. Raft Foundation

3. Pile foundation.

Under following circumstance pile foundations are used:

(a) When the hard soil is encountered at great depths and the provision of spread foundation is not economical.

(b) When the provision of raft and grillage foundation is expensive.

(c) When concentrated heavy loads are to be taken by the foundation.

(d) When the scouring depth in the river bed is very much deep.

(e) When the top soil is compressible.

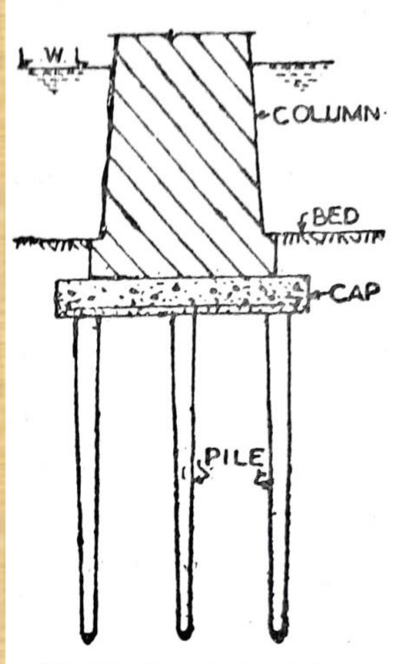


Fig. 7.2. Pier pile foundation

TYPES OF PILES

Piles may be of following types:

(a) Wooden (b) Precast concrete piles

(c) Cast in situ piles (d) Structural steel piles

(e) Composite piles etc.

WELL FOUNDATION

In situations where due to scouring or bearing capacity considerations, foundations are to be taken to greater depths than 5 to 7 metres, open excavation becomes costly and uneconomical due to following reasons:

1. To retain the sides, heavy timbering is required.

2. Due to greater earthwork involved due to side slopes, progress in open excavation will be very slow.

3. The excavated material refilled in the open excavated foundation leads to loose soil which can be easily scoured.

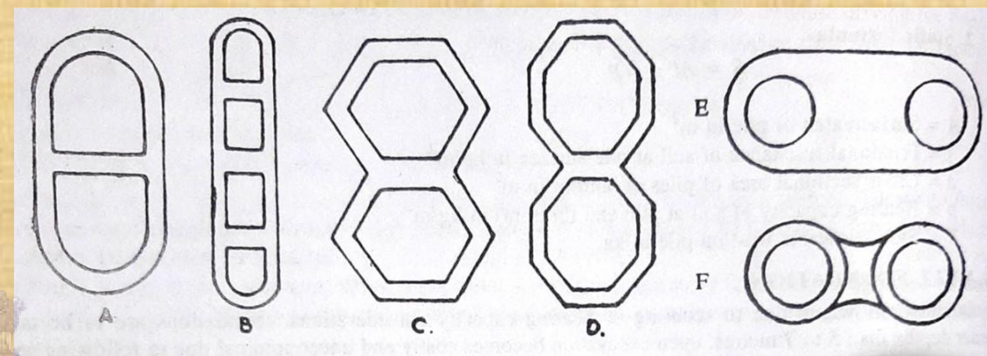


Fig. 7.3.

SHAPE OF WELL

Following are the common shapes of the well which can be adopted:

1. Single circular
2. Twin circular
3. Dumb well
4. Double D
5. Twin hexagonal
6. Twin octagonal
7. Rectangular etc.

COMPONENTS OF A WELL FOUNDATION AND THEIR

Following are the components of a well foundation:

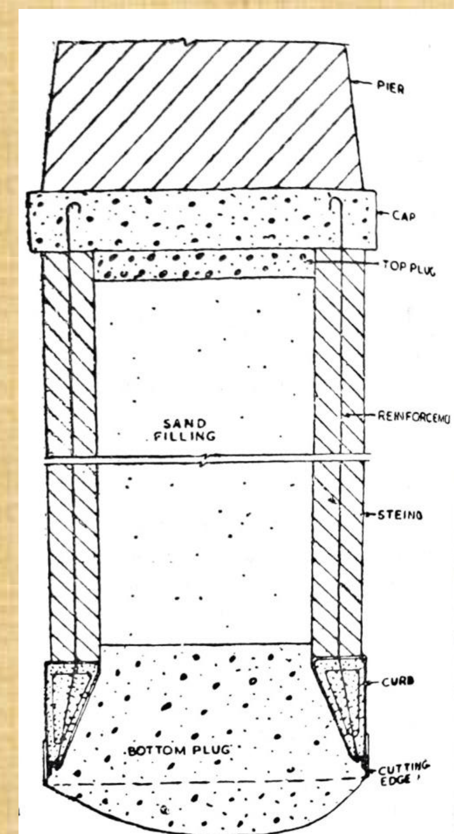


Fig. 7.4. Components of well foundation

(a) Well curb and cutting edge.

(b) Staining

(c) Bottom plug

(d) Well cap

(a) Well curb. It is circular in plan having a wedge shaped support at the bottom as shown in Fig. 7.5. It can be made of timber or R.C.C. It is designed to support the weight of the well with partial support at the bottom of the cutting edge.

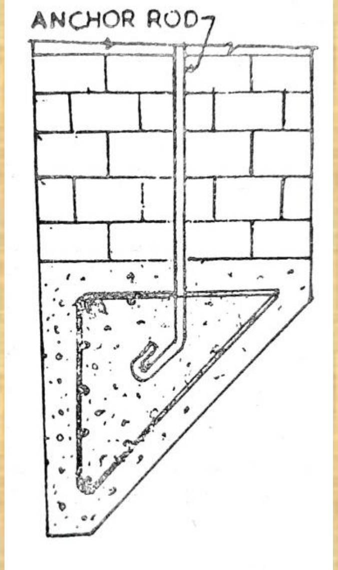


Fig. 7.5. Well curb

(b) Cutting edge. The cutting edge should have as sharp an edge as practicable to cut the soil but it should be sufficiently strong to withstand the various stresses induced by boulders, blows, blasting etc.

(c) Staining thickness. The staining may be of brick, stone masonry or R.C.C. Its thickness should be designed in such a way that at all stages, the well could be sunk under its own weight.

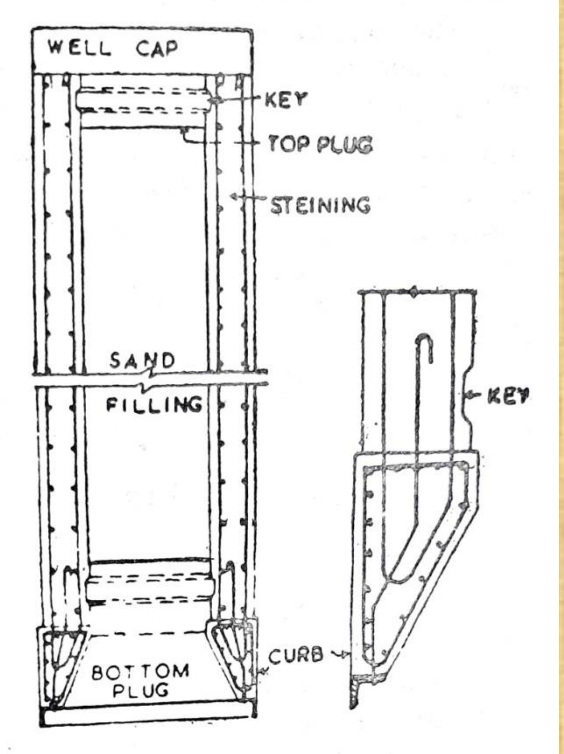


Fig. 7.6.

Theoretically the staining thickness may be obtained by the following equation:

$$t = W(0.01\,H + 0.1\,D)$$

where,

t **= Minimum thickness of concrete staining.**

H **= Depth of well below bed level.**

D **= External diameter of well.**

K **= A constant whose value varies with the type of soil.**

4. Caisson foundation

The term caisson has been derived from the French word caisse, meaning box. It can be round or rectangular, which is sunk from the surface of either land or water to the desired depth.

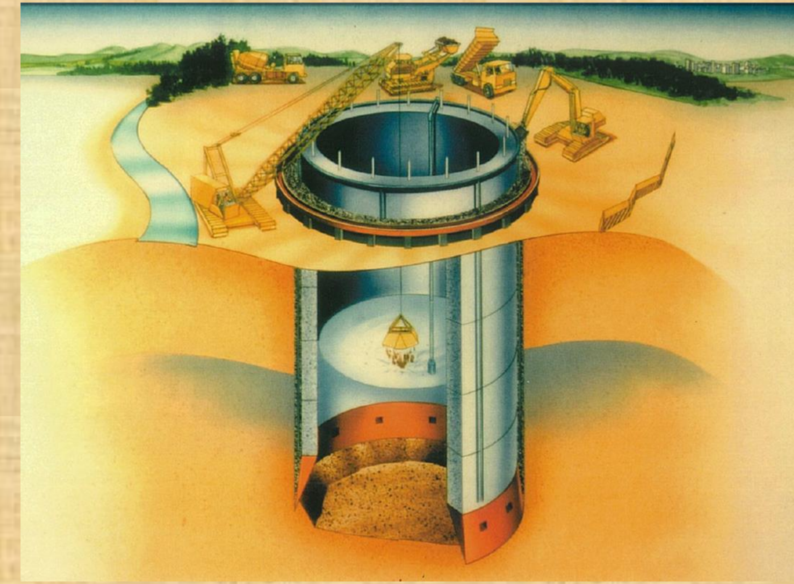
Classifications

Caissons may be classified into the following three categories:

1. Box caissons 2. Open caissons 3. Pneumatic caissons.

1. Box caissons.

- Box caissons are open at top and closed at the bottom. They can he made of steel. R.C.C. or timber. This type of caissons are built on land, then launched and brought to the site of pier where they have to be sunk to the position.
- Box caissons can be used where (1) bearing stratum is available at shallow depth, (ii) Loads are not heavy, (i) For sea wells and break waters.

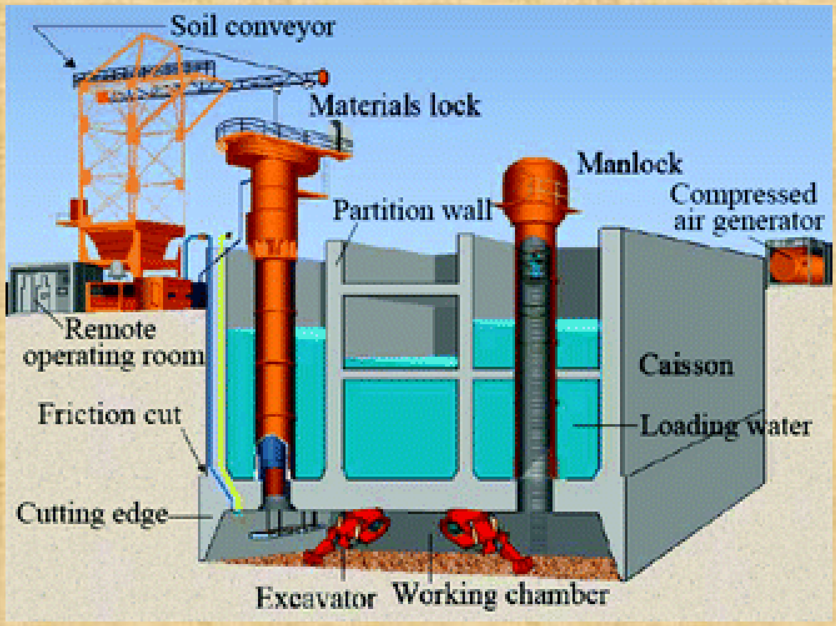


2. Open caissons.

- It is a box of timber, steel or R.C.C. or masonry with both ends open. It is used for building well as well as bridge foundations. Open caissons are called wells. Small caissons consist of one opening or well while large caissons contain a series of wells.

3. Pneumatic caissons.

- A pneumatic caisson is one which has a permanent or temporary roof near the bottom and its lower end is designed as a working chamber in which compressed air is forced to prevent the entry of water and thus permits excavation in dry condition.



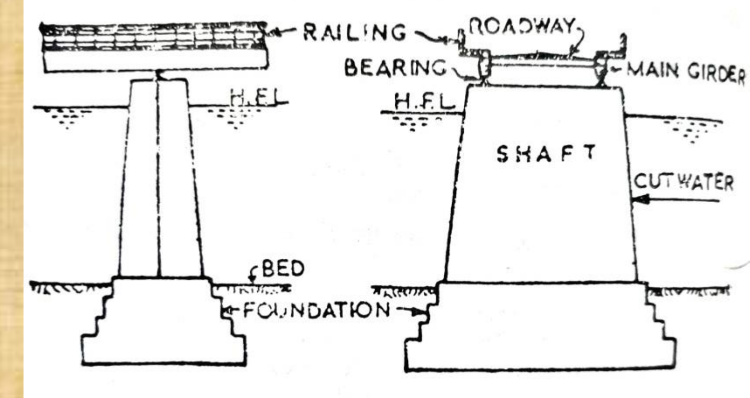
- The essential parts of a pneumatic caissons are (i) Working chamber, (ii) Shaft and air locks. The working chamber may be made of timber, steel or R.C.C. but the shaft is usually made of steel.

end

BRIDGE ENGINEERING

CHAPTER:-03 [Bridge substructure and approaches]

PIERS



Side view of pier
Longitudinal view of pier
Fig. 6.7.

Pier is an intermediate support of a multi-span bridge. Its height generally is kept equal to the height of the abutments.

Functions of piers

1. To transmit loads from the bridge superstructure to the foundation with minimum obstruction to the flow of river.

2. To divide the total length of bridge into suitable spans.

Types of piers

Piers may be *solid or open type*. Open type piers are composed of beams, columns and bracings. Solid piers have a solid section in elevation plan etc.

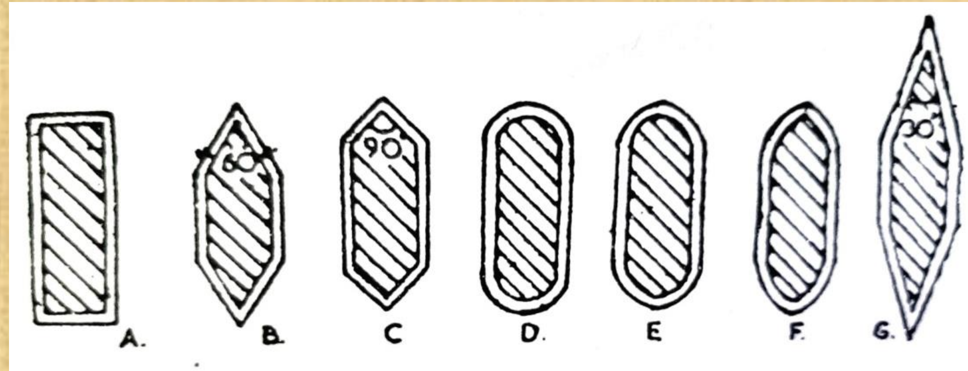


Fig. 6.8. Shape of bridge piers.

1. Masonry piers.

- **Masonry piers may be constructed of stone, brick or plain cement concrete.**
- **The cast in situ cement concrete piers need form work either of timber or steel plates.**
- **The top of masonry piers is level and a cement concrete block of richer mix is provided at the top. This block is called *bed block.***
- **The end on the up-stream side is known as the *cut water* and cut waters are usually triangular in shape, making an angle of 30° to 60° with side.**
- **The end on the down-stream side is known as *ease water* and are generally of semi-circular in shape.**
- ***Now a days* the practice is to provide *cut and ease* of semi-circular shape.**

2. R.C.C. piers: **R.C.C. piers are generally rectangular in cross-section and do not need bed blocks. They also have cut waters and ease waters. The main reinforcement is provided vertical and the secondary reinforcement as horizontal.**

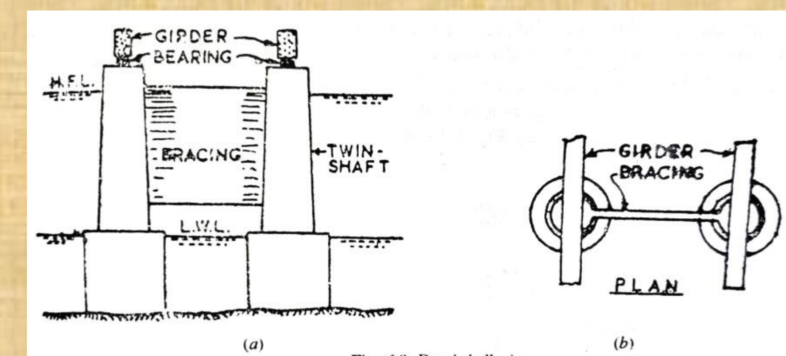


Fig. 6.9. Dumb bell pier

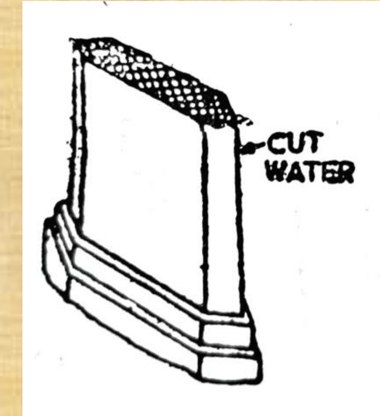


Fig. 6.11. Solid pier

3. Dumb bell pier: It is a special type of R.C.C. pier. It consists of R.C.C. columns connected by reinforced wall, to the full height parallel to the flow of water.

4. Solid piers:

- In masonry brides generally solid piers are provided as shown in Fig. 6.11.
- They provide excellent resistance against floating debris and can be used for any type of super structure of the bridge.
- For these piers the minimum top width should not be less than 120 cm.

5. Open piers.

Open piers may be classified as:

(a) Cylindrical piers — (c) Pile bents

(b) Column bents — (d) Trestle bents

(a) Cylindrical piers. In this case mild steel cylinders filled with concrete are used to support the main girders. They are connected by steel frame work as shown in Fig. 6.12.

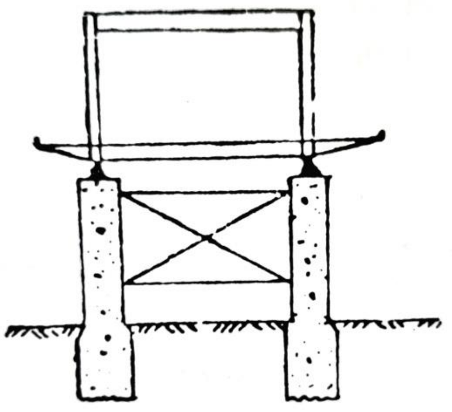


Fig. 6.12. Cylindrcal pier

(b) *Column bents.* **In this case two or more columns are constructed to support the main girders and are connected laterally by beams, braces or short diaphragms. The column may be of a any cross section such as uniform or varying. Fig. 6.13 shows a column bent.**

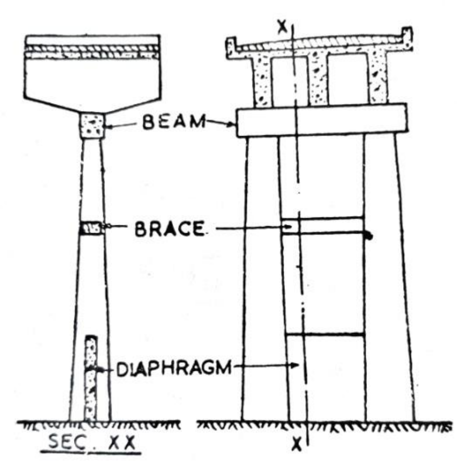


Fig. 6.13. Column bent

(c) *Pile bents.* **In this case piles may be used to support the main girders over their caps as shown in Fig. 6.14. They are laterally connected by frames of R.C.C. or steel. In this case piles of any material except timber piles may be used.**

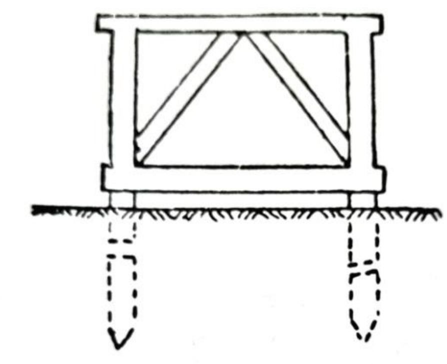


Fig. 6.14. Pile bent

(d) *Trestle bents.* **All members of the trestle are rectangular or square in sections. Fig. 6.15 and 6.16 show steel and R.C.C. trestles bent respectively.**

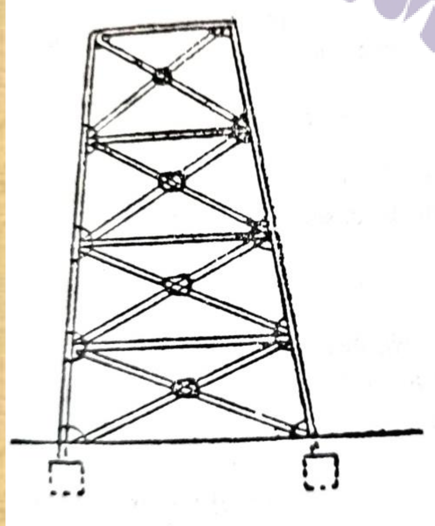


Fig. 6.15. Steel trestle bent

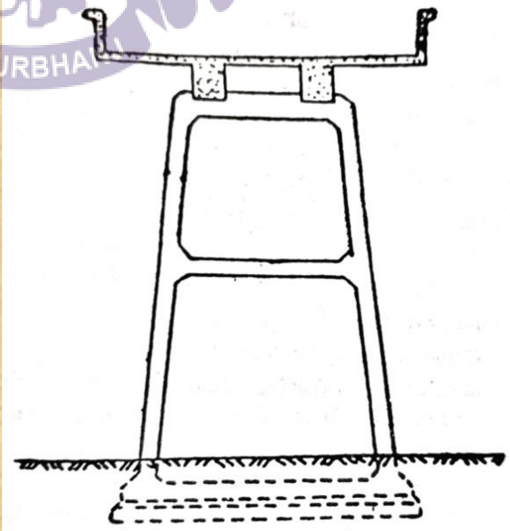


Fig. 6.16. R.C.C. Trestle bent

6. Piers for arch bridges.

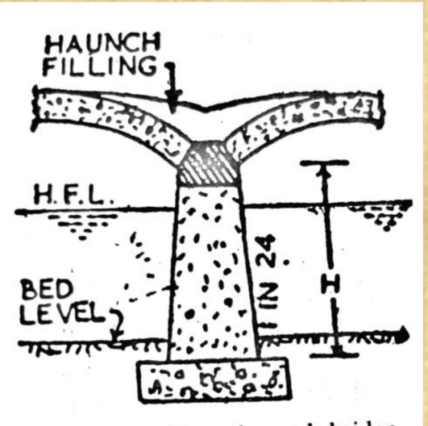


Fig. 6.17. Piers for arch bridge

For an arch bridge all piers or abutment piers are always solid. As shown in Fig. 6.17 at the top their sides are splayed to receive the arch ring or their bearings normally.

7. Abutment piers.

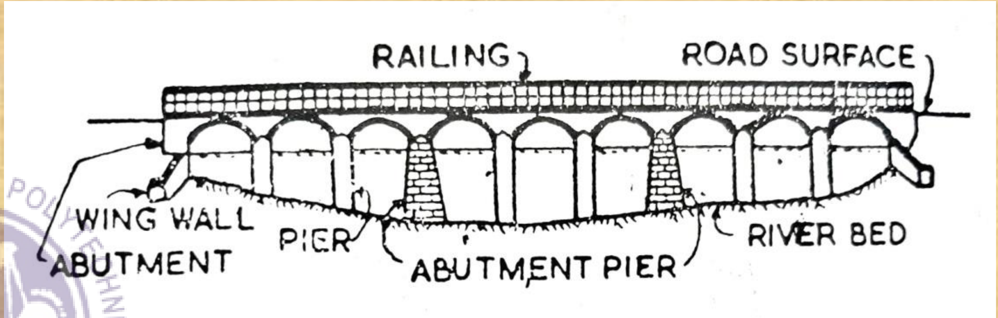


Fig. 6.18. Abutment pier

- **In a multi span arch bridge every fourth or fifth pier is known as abutment pier.**
- **It is so called because it is made thicker in cross-section than other piers, so that it should be strong enough to resist the horizontal thrust of the arch on each side.**
- **This arrangement reduces the cost of centering as the arches may be constructed in sets between abutment piers.**
- **The damage caused by failure of an arch under adverse conditions is also localised by providing abutment piers (Fig. 6.18).**

ABUTMENTS

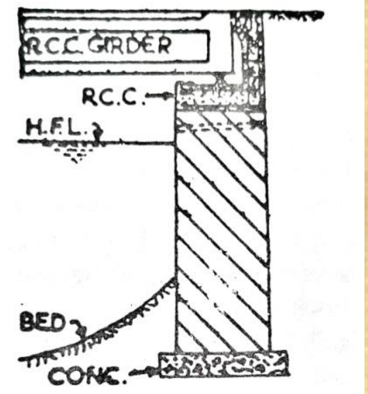


Fig. 6.3. Abutment for R.C.C. beam bridge

The end supports for the super structure are called abutments. Generally all types of bridges have abutments except cause way without vent or a pipe drain.

Functions of abutments

Following are the functions of abutments:

(a) They transmit the load from the super structure of the bridge to the foundation.

(b) They give final formation to the bridge.

(c) They give support and retain the earthwork of the embankments of the approaches.

(d) They serve as pier and retaining wall both.

TYPES OF ABUTMENTS

Abutments can be classified as follows:

(a) Straight abutments without wing walls (b) Abutments with straight wing walls

(c) Abutments with splayed wing walls (d) Tee abutments

(e) Abutments with wing walls at right angles (f)Pulpit abutment

(g) Hollow abutments

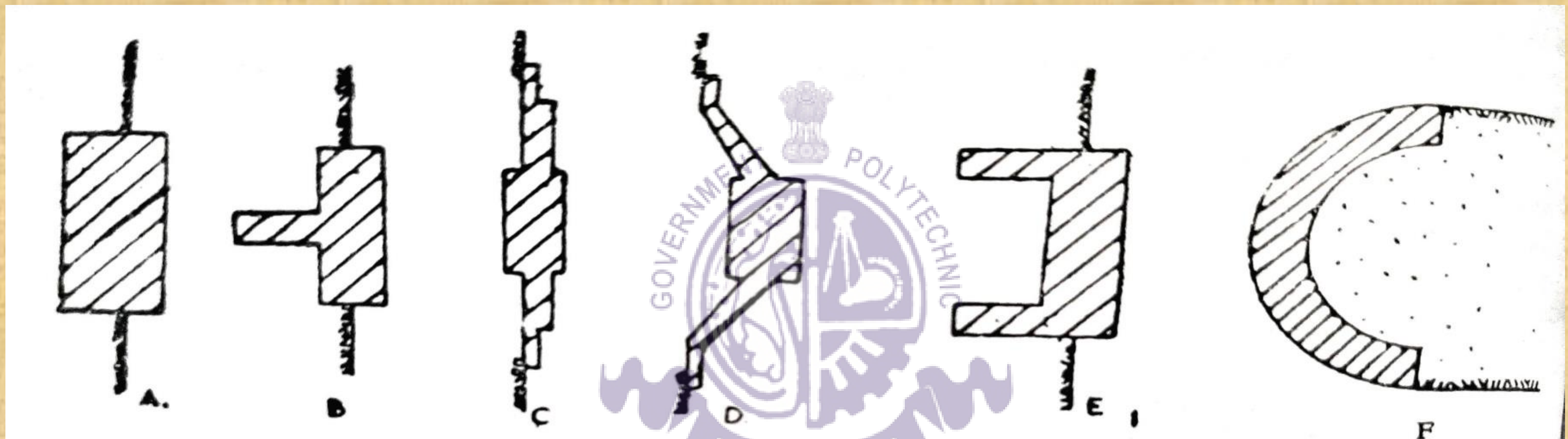


Fig. 6.4. Different types of abutments

(a) Straight abutments without wing walls. This type of abutments are not generally adopted on water ways as the flood water will penetrate through the joint of masonry with the earthwork into the embankment. This will reduce the bearing power of the soil and damage it. Thus this type of abutment is not suitable for water ways [Fig. 6.4 (A)].

(b) Abutments with straight wing walls. This type of abutments are also not suitable for water ways as water may flow immediately behind the wing walls and damage the embankments. However they are suitable in situations where a street crosses another street at low level or a railway bridge passes over a roadway at the lower level [Fig. 6.4 (C)].

(c) Abutments with splayed wing walls. As shown in Fig. 6.4 (D) the wing walls are made straight, but they are splayed at angle of 45° or 30° with the face of abutment as the design permits.

(d) T-Shaped abutments. This type of abutments were used in early rail-road construction. The head of supported the bridge and the stem carried the railway track. The width of the stem was kept wide enough to carry the railway track. Therefore, the quantity of masonry in its construction is larger than other types of abutments [Fig. 6.4 (B)].

(e) Abutments with wing walls at right angles or U abutments. As shown in Fig. 6.4 (E) the wing walls run back into the fill, which flows down in front of the wings. The wings are parallel to the roadway. The wing walls are tied together with the help of old rails. This type of abutments are suitable where rock slopes make it possible to step up the wing walls footing.

(f) Pulpit abutments. It is a modified (U) abutment, where the arms of (U) wings at right angles are made shorter. The return wing walls should be of sufficient length to prevent the retaining material from flowing on bridge seat.

(g) Hollow abutments. As shown in Fig. 6.4 (F), they are adopted where a rail track crosses a highway having side walls.

WING WALLS

Actually they are retaining walls constructed to retain the earth work of the approach embankments behind the abutments. They can be classified according to their positions in plan with respect to the banks and abutments.

Functions

1. To provide a smooth entry of water into the bridge site.

2. To support and protect the embankment.

TYPES OF WING WALLS

They may be classified as follows:

1. Straight wing walls   2. Splayed wing walls   3. Return wing walls

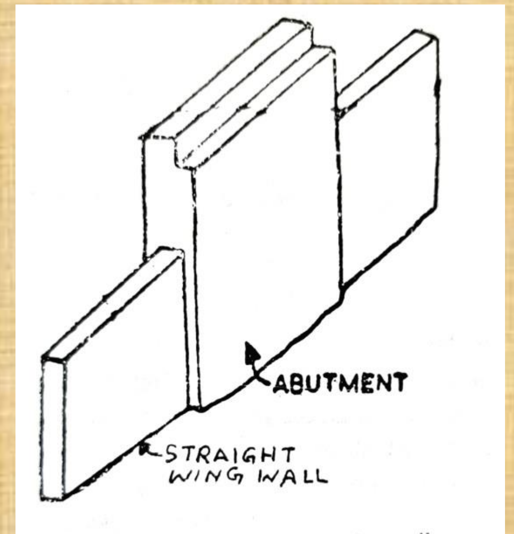


Fig. 6.19. Straight wing wall

1. Straight wing walls. This class of wing walls specially suited where the cost of land is very high such as for railway bridges in cities. The plan of this type of wing wall is shown in Fig. 6.19.

2. Splayed wing walls. As shown in Fig. 6.20, this type of wing walls make an angle of 45˚ with the abutment. It is best suited in the following situations:

(a) When two or more roads meet at the approach.

(b) When the road has to be narrowed on crossing the bridge.

(c) Crossing of a river, as it affects the smooth entry and exit of the current.

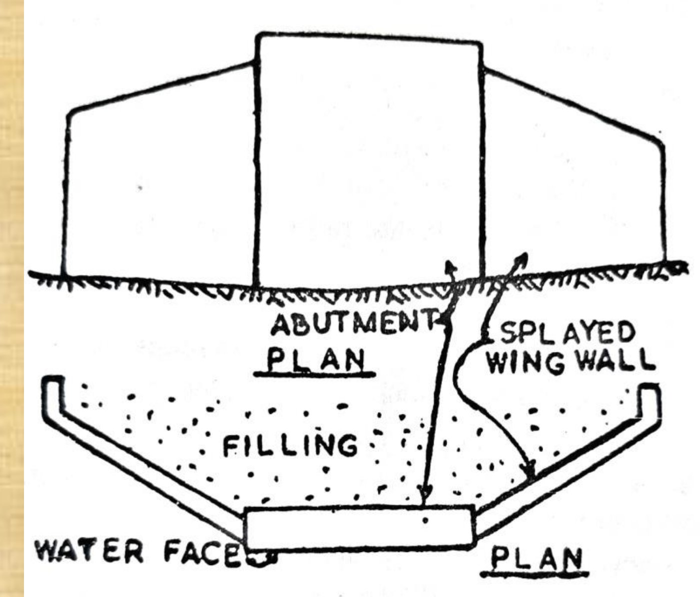
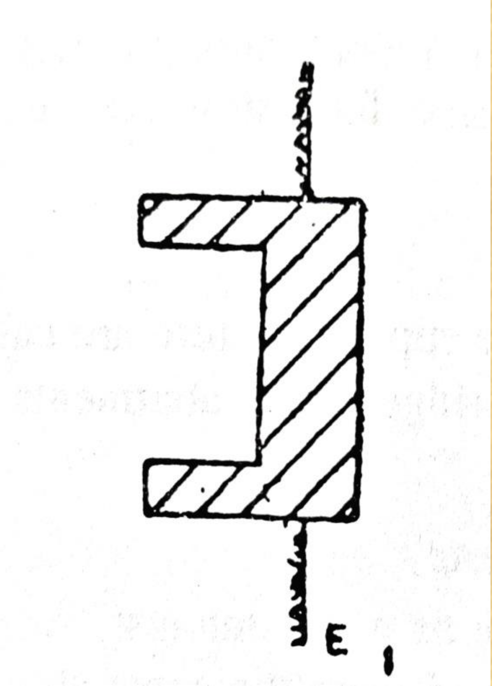


Fig. 6.20. Splayed wing wall

3. Return wing walls. In this class of wing walls, wings are constructed at right angle to the abutment .They are most suited to the situations where the banks are high on both flanks and rocky. They are most useful where the cost of land is very high.



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BRIDGE ENGINEERING

CHAPTER:-05 [CULVERTS AND CAUSE WAYS]

CULVERTS:- **A culvert is defined as a small bridge constructed 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.**

CLASSIFICATION OF CULVERTS

Culverts may be classified as follows:

1. Pipe culverts **2. Box culverts**

3. Arch culverts **4. Slab culverts**

1. Pipe culverts.

- **For a very small drainage, pipe culverts may be used.**
- **It may have one pipe or more than one pipe placed side by side below the embankment of the road or railway.**

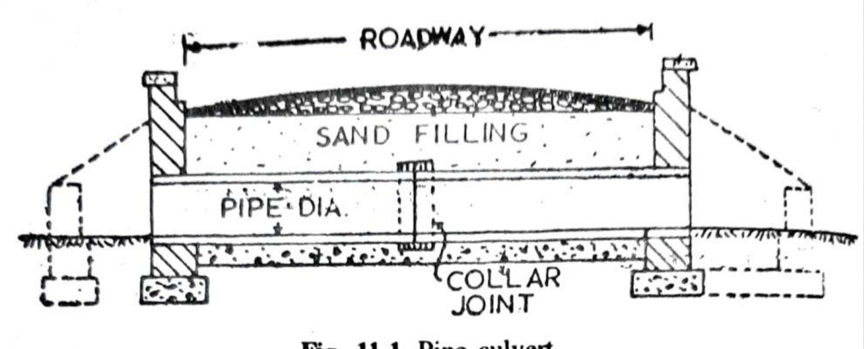


Fig. 11.1. Pipe culvert

- The pipes may be wooden, steel, R.C.C., cast iron etc.
- To retain the embankment in its proper position and protect the pipe from the action of spring water etc., the pipe is surrounded at both ends with masonry work in the form of arches or by stone pitching.
- When the height of embankment over the pipe is about 6 m, it should be given a proper all-round cushion.
- As a rule the cushion should not be less than half the diameter of the pipe with a minimum of 45 cm at the top.
- It should also be provided with a suitable concrete bedding at the bottom.

2. Box culverts.

- For larger spans and in loose soils box culverts may be preferred.
- They can be used for a single span of 3 m or for a double span of 6 m. They cause least interference to traffic during construction operations.
- Actually box culverts provide one or more number of rectangular or square openings.

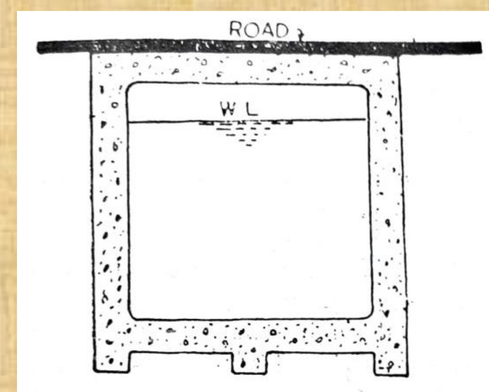
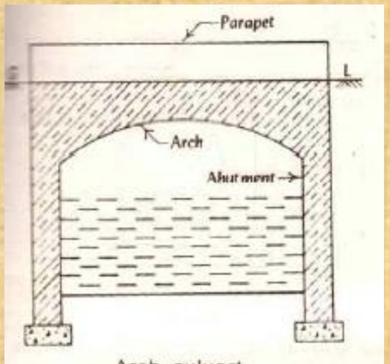


Fig. 11.2. Box culvert

- They are usually made of precast R.C.C. units. They are designed on the principle of continuous beam theory.
- For the construction of box culverts, good foundation is an essential requirement. The thickness of R.C.C. slab may vary from 12.5 to 22.5 cm.
- If sinking of any portion is allowed, it will cause considerable changes in the B.M. and S.F. of the sections.
- Box culverts have not been found economical for spans greater than 6 m.

3. Arch culverts.

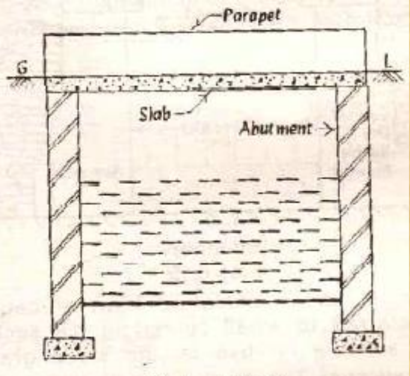


Arch culvert
FIG. 6–1

- In this case the superstructure is consisted of arches. Actually it is similar to masonry bridges.
- In arch culverts piers and varying batters to the sides of abutments are not provided.

4. Slab culverts.

- Slab culverts generally are adopted for maximum spans upto 2.5 m.



Slab culvert
FIG. 6-4

- **In this case a stone slab or R.C.C. slab is directly placed as simply supported beams on piers or abutments.**
- **The slabs form the superstructure. Parapet and wing walls may also be provided as in the case of permanent bridges.**

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.*

Causeways may be provided under the following conditions:

(a) When the depth of water in the stream is very low.

(b) The seasonal flow is less.

(c) When sufficient funds are not available for the construction of high level bridge.

(d) The average flood discharge should not be more than 40% of the highest flood discharge.

(e) The highest flood discharge should not flow in the stream for more than 8 to 10 days in a year. The flood discharge should not flow for 4 to 5 hours in the days of highest flood discharge.

(f) In hill roads, at concave curves where a large number of small tributaries flow over a wide area.

(g) In hill roads if streams carry rubbish or shingle which may choke the road culverts.

DIFFERENCE BETWEEN A CAUSEWAY AND A BRIDGE

Generally following differences are there between a causeway and a bridge:

(a) Causeway does not have foundation, pier or abutment.

(b) Usually water flows over the top surface of the causeway.

(c) These are cheap as they are constructed of a R.C.C. slab over foundation with approaches on both sides.

CLASSIFICATION OF CAUSEWAYS

Causeways may be classified as follows:

1. Flush causeway 2. Low level cause way 3. High level cause way

1. Flush causeway.

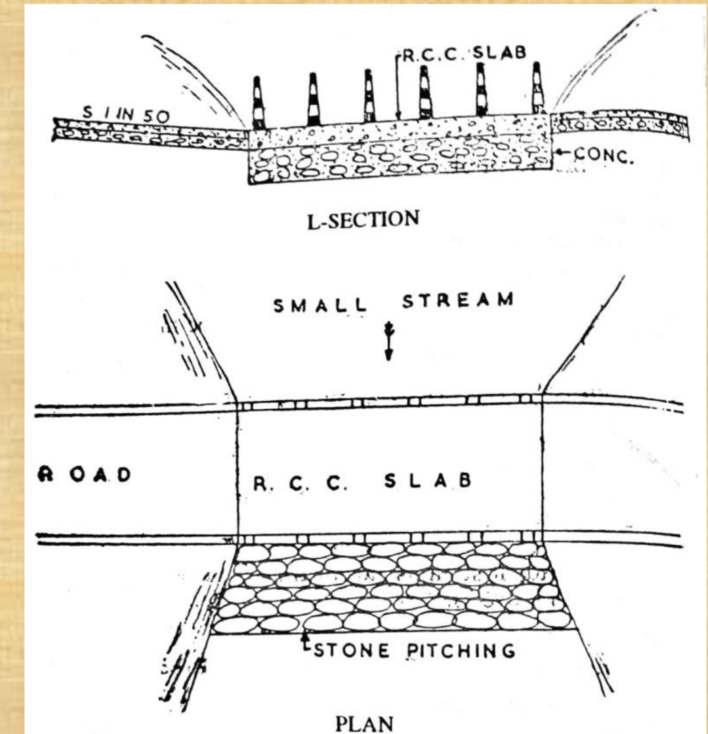


Fig. 11.3. Flush causeway

- **Flush causeways usually are provided in hilly roads if the maximum depth of flood water does not exceed about 1.75 m and the road does not remain interrupted for more than 10 to 15 days in a year.**
- **In this type of causeway, the road or pavement is laid at the bed level of the stream without any vents.**
- **The water of the stream flows continuously over the firmly paved bed throughout the year.**
- **Usually R.C.C. slab is provided in the bed for smooth surface.**
- **To protect the floor, a curtain wall is provided on the downstream side and apron wall on the up-stream side.**

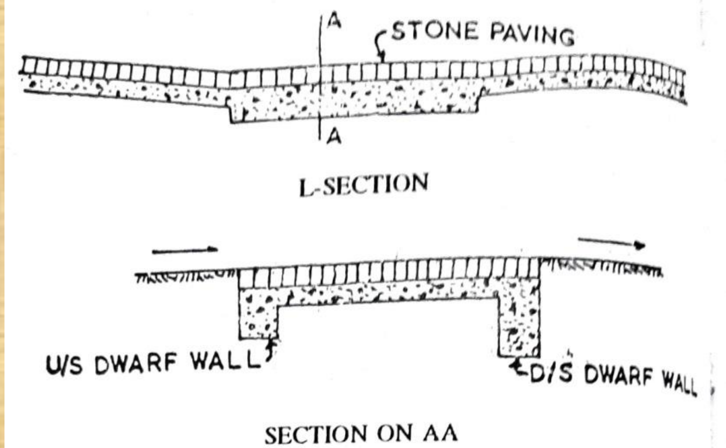


Fig. 11.4. Low level causeway

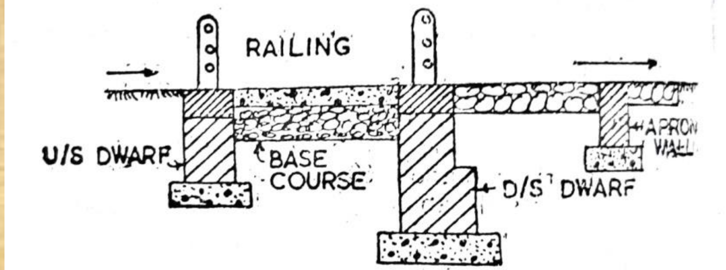


Fig. 11.5. Low level paved causeway

2. Low level causeway.

- **When the streams or water courses remain dry for the major part of the year or the depth of water is very small then low level causeway may be provided with vents, so that fair weather discharge may pass through vents without interfering with the traffic.**
- **In sandy formations to prevent scour or undermining, stone or brick pitching flush with bed level of the stream should be provided in the bed on both sides.**
- **The stone paving must have a concrete bedding laid over filling of sand and shingle between the apron and the curtain walls.**

3. High level causeway.

- **It is also known as *submersible bridge*. According to Indian Road Congress, the submersible bridge should not remain submerged under water for a maximum period of 72 hours at a time and such occurrences should not occur more than 10-12 times a year.**

- The aim of providing high level causeway is to reduce the cost of construction.
- On a high level causeway during high flood vehicles may be allowed through 25-30 cm deep water on the causeway.
- Previously submersible bridges or high level causeways were built on firm rocky foundations, but nowadays they are also built on loose soil beds.

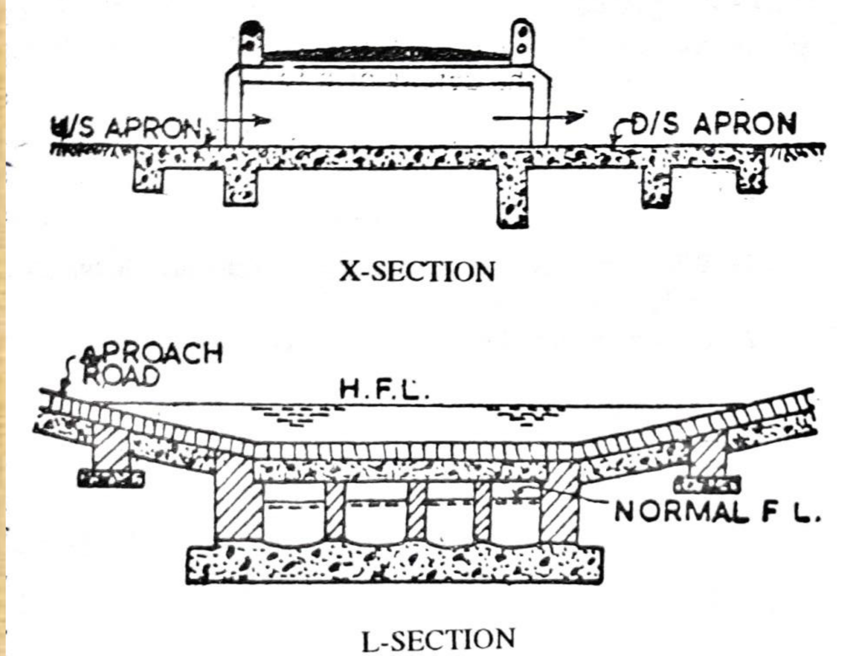


Fig. 11.6. High level causeway

- First of all thick cement concrete layer is laid on bed and over this concrete flood vents of requisite cross-sections are constructed.

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