

# **Study Material**

## **On**

### **Railway and Bridge Engineering**

**Department of Civil Engineering**



**CAPITAL ENGINEERING COLLEGE**

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(Affiliated to Biju Patnaik University of Technology, Odisha and SCTE & VT,  
Odisha, Approved by AICTE, New Delhi and Recognised by Govt. of Odisha)

# Railway Engineering

## Rails

### Introduction :

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 & 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 & unchanging surface for passage of heavy moving loads with a min friction bet the steel rail & steel wheels.
- (ii) Rails bear the stresses developed due to heavy vertical loads, lateral & braking force & thermal stresses.
- (iii) The rail material used is such that it gives min wear to avoid replacement charges & failures of rails due to wear.
- (iv) Rails transmit the loads to sleepers & consequently reduce pressure on ballast & formation below.

### Requirements of rails :

- (i) They should be of proper composition of steel as given above & 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 & 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 & 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 & top of the foot of rail 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 & 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 max<sup>n</sup> tensile & compressive stresses are equal.
- (x) The fillet radii must be large to reduce the concentration of stresses.
- (xi) The tensile strength of the rail piece should not be less than  $72 \text{ kg/cm}^2$ .
- (xii) The rail specimen should withstand the blow of "falling weight" Test or "Tup Test" as specified by Indian Railway Standards without fracture.

### Types of Rail sections:

The 3 types of rail sections which have been true so far for the construction of railway track are

(1) Double headed Rail.

(2) Bull headed Rail.

(3) Flat footed Rail.

## Length of Rails

The rails of larger length are preferred to smaller length of rails, because they give more strength & economy for a railway track. The weakest point of a track is the joint bet<sup>n</sup> two rails. Lesser the no. of joints, lesser would be the no. of fish plates & this would lead to lesser maintenance cost, smoother running of trains & more comfort to the passengers. Moreover, the more no. of joints would increase wear & tear of the vehicle components, including wheels.

Though the long length of the rails is desired however, the length is governed by the following factors

- (1) The length of the rails is so chosen that the manufacture cost is most reasonable.
- (2) It depends upon the transportation facilities, so only those lengths of rails are possible which can be transported by longest wagons available on the railways.
- (3) To some extent, the length is also limited by the facilities of lifting & handling, during the loading & unloading of wagons.
- (4) More the length of the rail, more will be the gap required for expansion of rail due to temperature but, however, the expansion is not proportional to gap because fastenings check the movement of rails, so expansion gap is not limiting factor for length of rails though it affects to some extent.

On Indian Railways the standard lengths are the following

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

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

It is proposed to increase the lengths economically to 25.6 m or 19.2 m for B.G tracks. In countries like U.S.A & U.K etc a length of 30 m.

# Rail Joints

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

## Requirements of an Ideal joint,

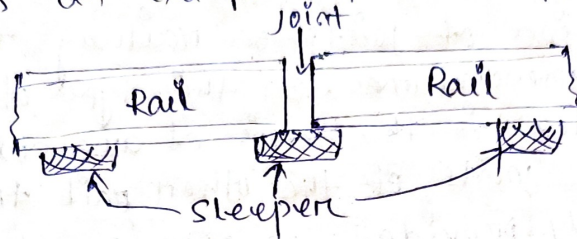
An ideal or perfect rail joint is one which provides the same strength & stiffness as the other rail section of the track. The following requirements should be met by an ideal joint.

- (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 connect path of movements.
- (ii) The rail joint should be as strong & stiff as the rail itself & should be elastic both laterally & horizontal.
- (iii) The rail joint should provide enough space for free expansion & 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 purpose of changing rail or a fish plate & lubricating the contact faces.
- (v) It should not allow the rail ends to get bettered in any case.
- (vi) The joint should fulfill the above requirements with the minimum of initial & maintenance cost.

### 3(a) Types of Rail joints

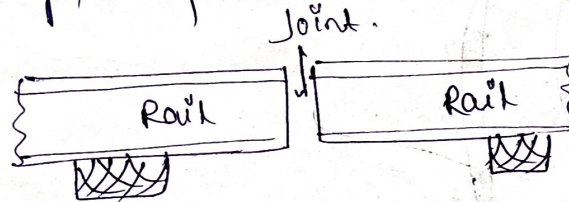
#### (1) Supported Rail joints

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.



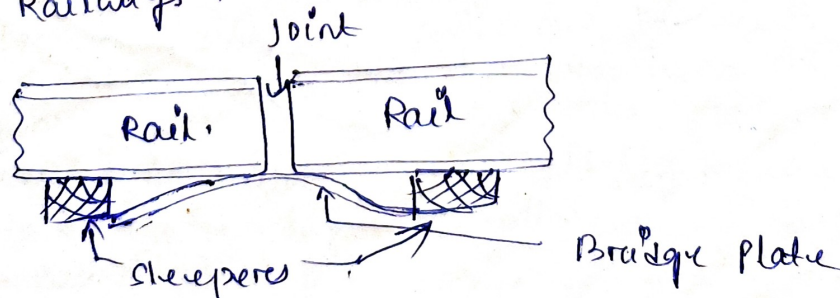
#### (2) Suspended Rail joint

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 through sleepers on Indian & foreign railways.



#### (3) Bridge joint

When the rail ends are projected beyond sleepers as in case of suspended joint & 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.



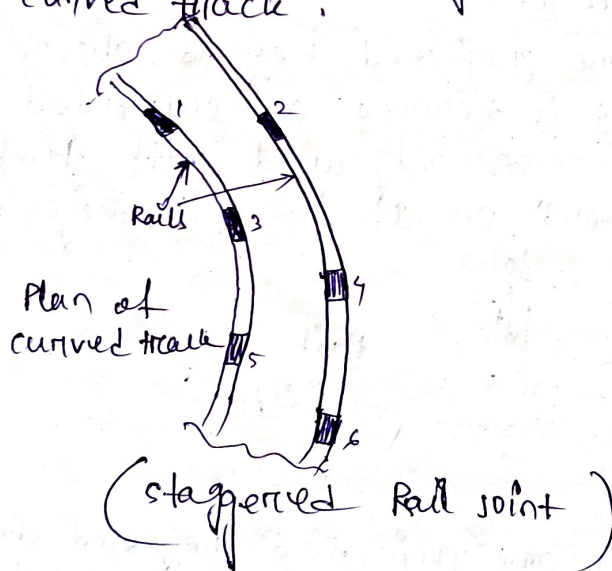
(4) Base joint: This is similar to the bridge joint, with the difference that the inner fish plates are of bar type & outer fish plates are of the special angle type, in which the horizontal leg is further extended over the sleepers to be bolted to both bridge plate & sleeper. Due to complicated design, it 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 & will be discussed in next article.

### (6) Staggered or Broken joint :

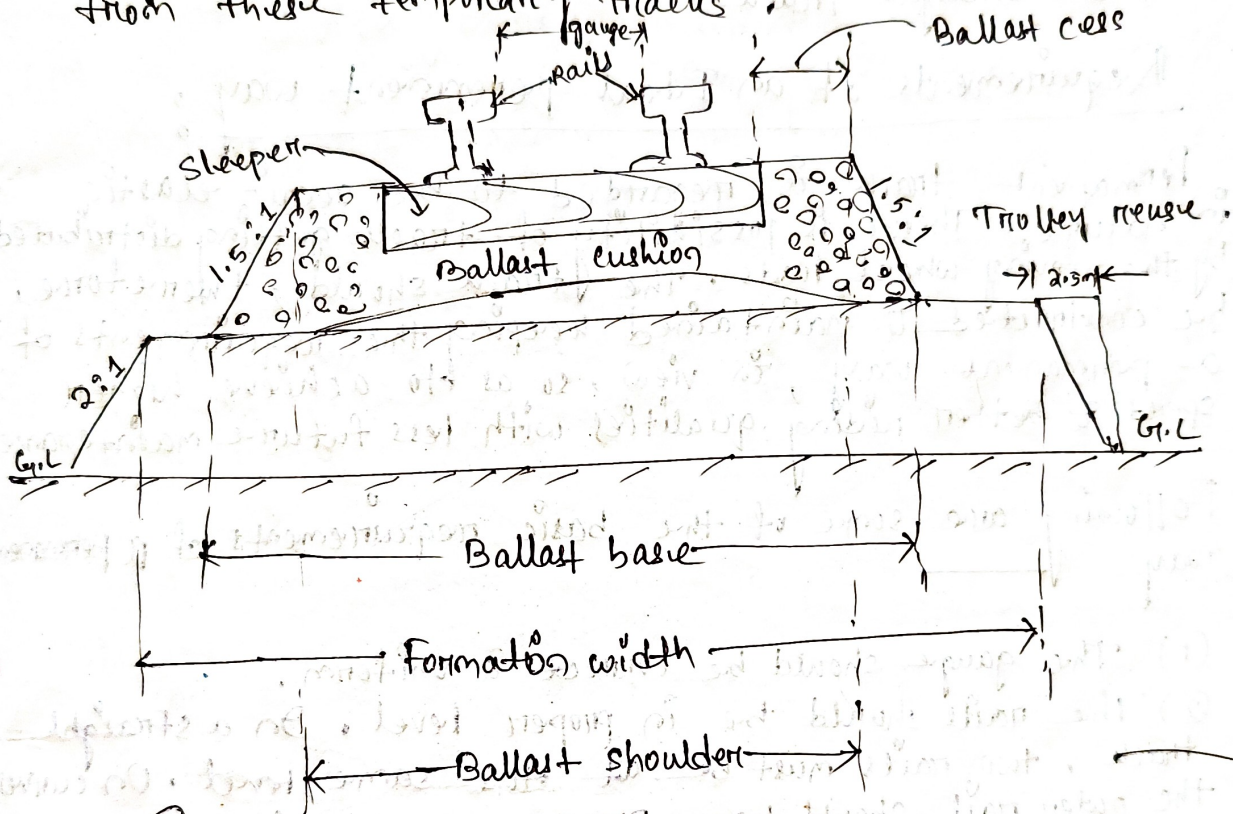
In this position of joints on railway track & the basis of its nomenclature, in this type of joint, the joints on railway track ~~is the basis of~~ are not directly opposite to the joints of the other rail track. These joints are generally provided on curves, where the length of outer curved track is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



2C)

## Permanent Way

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



Typical cross-section of a Permanent way on Embankment

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

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

On curved tracks, super-elevation is maintained by ballast & the formation is levelled.

Minimum ballast cushion is maintained by ballast and the formation is levelled.

at the inner rail, while the outer rail gets kept more ballast cushion. Additional quantity of ballast is provided on the outer side of each track for which the base width of the ballast is kept more than for a straight track.

### Requirements of an Ideal permanent way,

Permanent track is regarded to be semi-elastic in nature. There is possibility of track getting disturbed by the moving wheel loads. The track should, therefore, be constructed & maintained keeping the requirements of a permanent way, in view, so as to achieve higher speed & better riding qualities with less future maintenance.

Following are some of the basic requirements of a permanent way.

- (1) The gauge should be correct & uniform.
- (2) The rail should be in proper level. In a straight track, two rails must be at the same level. On curve the outer rail should have proper super-elevation & there should be proper transition at the junction of a straight & a curve.
- (3) The alignment should be correct i.e. it should be free from kinks or irregularities.
- (4) The <sup>track</sup> gradient should be resilient & elastic in order to absorb shock & vibrations of running track.
- (5) The gradient should be uniform & as gentle as possible. Any change of gradient should be followed by a smooth vertical curve, to give smooth riding quality.
- (6) The track should have enough lateral strength so that alignment is maintained even due to effects of
  - (a) side thrust on tangent lengths & centrifugal force on curves.

(b) lateral forces due to expansion of rails, particularly in case of welded rails.

- (7) The radii & super-elevation on curves should be properly designed & maintained.
- (8) Drainage system must be perfect for enhancing safety & durability of track.
- (9) Joints, including points & crossings which are regarded to be weakest points of the railway track, should be properly designed & maintained.
- (10) If there is trouble from the creep, the precautionary measures should be to prevent it.
- (11) The various components of the track, i.e. the rails, fittings, sleepers, ballast & formation must fully satisfy the requirements for which they have been provided. If any component is lacking or fulfilling its requirements then either it should be improved or replaced.
- (12) There should be adequate provision for easy repairs and replacements.
- (13) The track structure should be strong, low in initial cost as well as maintenance cost.

### Gauges in railway track:

Definition: The gauge of a railway track is defined as the clear distance between inner or running faces of two track rails. The distance between the inner faces of a pair of wheels is called the wheel gauge.

### Different gauges in India & Abroad:

In 18th century, the British railways were using the flanges on the outside of rails & the gauge was defined as the distance between the outer faces of the rails. The gauge then maintained was 5'. Subsequently the adoption of flanges inside the wheel on rails changed the definition of gauge. The position of rails of track was not changed in view of economy & clear distance between inner faces was defined by gauge.

$$\begin{aligned}\text{So present gauge} &= \text{Past gauge} - 2 \times \text{rail width at top} \\ &= 5' - 2 \times 1\frac{3}{4}' \\ &= 4' - 2\frac{1}{2}' \text{ or } 1.435\text{m}\end{aligned}$$

A gauge of 1.435m is the standard gauge in most of the countries even today.

Thus, in India the following gauges are used

<u>Type of gauge</u>	<u>Gauge width</u>
(i) Standard gauge (S.G.)	1.67m
(ii) Metre gauge (M.G.)	1.0m
(iii) Narrow gauge (N.G.)	0.762m
(iv) Broad gauge (B.G.)	0.610m

# Sleepers

## Introduction:

Sleepers are the transverse ties that are laid to support the rails. They have an important role in the track as they transmit the wheel load from the rails to the ballast. Several types of sleepers are used on Indian railways. The characteristics of these sleepers & their suitability with respect to load conditions are described in this chapter.

## 2a) Functions of sleepers:

The main functions of sleepers are as follows

- 1) Holding the rails in their correct gauge & alignment.
- 2) Giving a firm and even support to the rails.
- 3) Transferring the load evenly from the rails to a wider area of the ballast.
- 4) Acting as an elastic medium bet<sup>n</sup> the rails & the ballast to absorb the blows & vibrations caused by moving loads.
- 5) Providing longitudinal and lateral stability to the permanent way.
- 6) Providing the means to rectify the track geometry during their service life.

## Requirements of sleepers:

- 1) The initial as well as maintenance cost should be minimum.
- 2) The design of the sleeper & the fastenings should be such that it is possible to fix & remove the rails easily.
- 3) The sleeper should be such that it is possible to maintain and adjust the gauge properly.
- 4) The material of the sleeper & its design should be such that it does not break or get damaged during packing.

- 5) The material of the sleeper & its design should be such that it does not break or get damaged during packing.
- 6) The design of the sleeper should be such that it is possible to have track circuiting.
- 7) The sleeper should be capable of resisting vibrations and shocks caused by the passage of fast moving trains.
- 8) The sleeper should have anti-sabotage & anti-theft features.

### Types of sleepers:

The sleepers mostly used in Indian Railways are-

- (1) Wooden sleepers.
- (2) Cast iron sleepers.
- (3) Steel sleepers
- (4) Concrete sleepers.

#### (1) Wooden Sleepers:

The wooden sleeper is the most ideal type of sleepers and its utility has not decreased with the passage of time. However, due to the overgrowing need to preserve forests & also the need to use timber for domestic use and for architectural purposes, it was felt that alternative materials should be explored for sleepers. Accordingly steel, cast iron and cement concrete have been extensively used for manufacture of sleepers. The different types of sleepers for Indian Railways is presented in table

Type of sleeper	Percentage use
Concrete sleepers	94.2
Cast iron sleepers	4.0
Steel sleepers	1.5
Wooden sleepers	0.3
All sleepers	100.0

Due to economical, technical and environmental reasons the use of new wooden sleepers on Indian railways has been prohibited.

## Advantages & Disadvantages of wooden sleepers,

### Advantages :

- 1) Cheap & easy to manufacture.
- 2) Absorb shock & bears a good capacity to dampen vibrations, therefore retains the paving well.
- 3) Easy handling without damage.
- 4) Suitable for track-circuited sections.
- 5) Suitable for areas with yielding formations.
- 6) Alignment can be easily corrected.
- 7) More suitable for modern methods of maintenance.
- 8) Can be used with or without stone ballast.
- 9) Can be used on bridges and ashpits also.
- 10) Can be used for gauged track.

### Disadvantages :

- 1) Lesser life due to wear, decay & attack by vermin.
- 2) Liable to mechanical wear due to beaten packing.
- 3) Difficult to maintain the gauge.
- 4) Susceptible to fire hazards.
- 5) Negligible scrap value.

## (2) Cast iron sleepers

Cast iron (CI) sleepers are also used on Indian railways and currently about 8.5% of the track consists of CI sleepers, which may be either pot type or plate type.

### Advantages of cast-iron sleepers

- 1) They undergo less corrosion.
- 2) There is less probability of cracking at rail seat.
- 3) They are easy to manufacture.
- 4) They have high scrap value.

## Disadvantages

- 1) Gauge maintenance is difficult as the bars get bent
- 2) Provides less lateral stability
- 3) Unsuitable for track-circuited lines.
- 4) Not very suitable for mechanical maintenance and MSP because of rounded bottom.
- 5) Susceptible to breakage.

## (3) Steel Channel Sleepers

In view of the great shortage of wooden sleepers, steel channel sleepers have been developed by Indian Railways particularly for use on girder bridges. Steel channel sleepers can be used for welded plates, riveted plates, as well as open web girders.

Composite sleepers have been developed in India as a replacement for wooden sleepers. These are made from waste products such as used rubber tyres and the manufactures claim a lifespan of about 40 years for these sleepers. The Patel group of Industries is one such firm that has developed these composite sleepers.

Composite sleepers are similar to wooden sleepers and use similar fittings. These sleepers are under trial and the results so far have been quite encouraging.

## Steel trough sleepers

About 4% of the track on Indian Railways is laid on steel trough sleepers. The increasing shortage of timber in the country and other economical factors are mainly responsible for the use of steel sleepers in India.

## Advantages

- 1) Long life
- 2) Easy to maintain gauge & less maintenance problems.
- 3) Good lateral rigidity
- 4) Less damage during handling & transport.
- 5) Simple manufacturing process.
- 6) Very good scrap value.
- 7) No risk of fire.
- 8) No risk of attack by vermin as not susceptible to fire.

## Disadvantages:

- 1) <sup>unsuitable</sup> liable to corrude.
- 2) Unsuitable for track-circuited areas.
- 3) liable to become centre-bound because of slopes at the two ends.
- 4) Develops cracks on rail seats during service.
- 5) Design is ~~too~~ rail specific.

## (4) Concrete sleepers

The evolution of concrete sleepers has been mainly due to economic considerations coupled with the elements of changing traffic pattern.

### Development of concrete sleepers

The development of concrete sleepers that took place on various railway systems was mainly based on the following concepts of design.

- (a) RCC or prestressed sleepers similar in shape & size to wooden sleepers.
- (b) Block-type RCC sleepers connected by a steel tie bar.
- (c) Prestressed concrete blocks & a steel or an articulated concrete tie bar.
- (d) Prestressed type of concrete sleepers.

### Advantages of concrete sleepers

- 1) Concrete sleepers, being heavy, lend more strength and stability to the track & are specially suited to LWR due to their great resistance to buckling of the track.
- 2) Concrete sleepers with elastic fastenings allow a track to maintain better gauge, cross-level, & alignment.

# Ballast

Ballast is a layer of broken stones, gravel, mortar, or any other granular material placed & packed below or around sleepers for distributing load from the sleepers to the formation. It provides drainage as well as longitudinal & lateral stability to the track.

## Functions of ballast

The ballast serves the following functions in a railway track,

- 1) It provides a level and hard bed for the sleepers to rest on.
- 2) It holds the sleepers in position during the passage of trains.
- 3) It transfers & distributes load from the sleepers to a large area of the formation.
- 4) It provides elasticity and resilience to the track for proper riding comfort.
- 5) It provides the necessary resistance to the track for longitudinal & lateral stability.
- 6) It provides effective drainage to the track.
- 7) It provides an effective means of maintaining the level & alignment of the track.

## Requirements of a good ballast

- 1) It should be tough & wear resistant.
- 2) It should be hard so that it does not get crushed under the moving loads.
- 3) It should be generally cubical with sharp edges.
- 4) It should be non-porous & should not absorb water.
- 5) It should resist both attrition & abrasion.
- 6) It should be durable & should not get pulverized or disintegrated under adverse weather conditions.

## Types of ballast ; The diff types of ballast used

### (1) Sand ballast ;

It is used primarily for east iron pths. It is also used with wooden & steel through sleepers in areas where traffic density is very low. Coarse sand is preferred in comparison to fine sand. It has good drainage properties, but has the drawback of blowing off because of being light. It also causes excessive wear of the rail top and the moving parts of the rolling stock.

### Morton ballast ;

The decomposition of laterite results in the formation of Morton. It is red and yellow in colour. The Morton ballast is normally used as the initial ballast in new constructions and also sub-ballast. As it prevents water from percolating into the formation, it is also used as a blanketing material for black cotton soil.

### Coal ash or cinder ;

This type of ballast is normally used in yards and sidings or as the initial ballast in new constructions since it is very cheap & easily available. It is harmful for steel sleepers & fittings because of its corrosive action.

### Broken stone ballast ;

This type of ballast is used the most on Indian railways. A good stone ballast is generally procured from hard stones such as granite, quartzite and hard trap. The quality of stone should be such that neither is it porous nor does it flake off due to the vagaries of weather. Good quality hard stone is normally used for high-speed tracks. This type of ballast works out to be economical in the long run.

## Other types of ballast

There are other types of ballast also. Such as the brickbat ballast, gravel ballast, kankar stone ballast and even earth ballast. These types of ballast are used only in special circumstances.

### 1) Sand ballast

#### Advantages of Sand ballast

- Good drainage properties.
- Cheap
- No noise produced on the track.
- Good packing material for C sleepers.

#### Disadvantages of Sand ballast

- Causes excessive wear.
- Blows off easily.
- Poor retentivity of packing.
- Track can not be maintained to high standards.

### 2) Mortum ballast

#### Advantages of Mortum ballast

- Cheap, if locally available.
- Prevents water from percolating.
- Provides good aesthetics.

#### Disadvantages of Mortum ballast

- Very soft and turns into dust.
- Maintenance of track is difficult.
- Quality of track average.

#### 3) Coal ash or cinder

#### Advantages

Disadvantages: Easy availability on railways. Harmful for steel sleepers.

### 3) Advantages of coal ash or cinder

- Easy availability on railways.
- very cheap.
- Good drainage.

### Disadvantages :

- Harmful for steel sleepers.
- Corrodes rail bottom & steel sleepers.
- Soft & easily pulverized.
- Maintenance is difficult.

### 4) Advantages of broken stone ballast

- Hard & durable when procured from hard rocks.
- Good drainage properties.
- Stable & resilient to the track.
- Economical in the long run.

### Disadvantages :

- Initial cost is high.
- Difficulties in procurement.
- Angular shape may injure wooden sleepers.

# Creep

## Definition

Creep is defined as the <sup>transverse dir.</sup> longitudinal movement of rails with respect to sleepers in a track. Creep is common to all railway tracks, but varies in magnitude considerably, the rail, in some places, moves by several centimeters in a month while in other locations the movement of rails may be negligible. It is observed that the rails have tendency to move gradually in the direction of dominant traffic. <sup>(slowly or distance)</sup> (until a break in traffic)

## Indication of creep

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

→ Marks on flanges & webs of rails made by spikes (a large nail with an offset head) by scraping or scratching as the rails slide. <sup>(indicating)</sup> <sup>(is sometimes placed to rail road ties)</sup> (ex - green spike)

## Effects of creep

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

→ Rail-joints are opened out of their limit in some cases & stretchers are set up in fish-plates & bolts to which the bolts sometimes break. The rails are also battered at ends due to excessive gaps at joints. While at other places, joints are jammed & prevent required expansion due to temp<sup>n</sup> variation.

→ Points & crossings get distorted & it becomes very difficult to keep them to correct gauge & alignment. The movement of switches is made difficult & interlocking is thrown out of gear.

→ If any rail is removed from the track for any purpose, it becomes difficult to fix it again at <sup>not</sup> proper position because by the time gap becomes too short or too long due to creep.

→ Besides these effects, smashing of fish-plates & fish-bolts, bending of bars, ricks at joints of rails & forging of ballast ahead are common effects of creep.

## Prevention of creep

<sup>any action taken to keep people healthy & well</sup>

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 to pull back the rails to their original position. For doing this, first inspect the track, note the extent of pulling back distance & determine the point from which to begin. Now start pulling the rails back to their

original positions by means of crow bars & 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 position.

Pulling back the rails is a very slow & tedious process & is only possible when a small length is to be dealt. It has more over, been noticed that rails st

## (2) Provision of Anchors on Anticreeps:

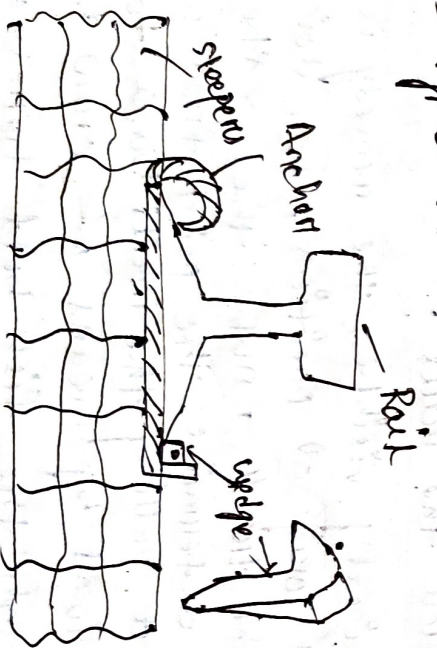
The creep of the track can be prevented by use of Anchors & sufficient cu's ballast - for creep of 7.5cm to 15cm in a month 4-anchors per rail & for creep of 22.5cm to 35cm - 6-anchors per rail are used in the Indian practice.

Anchors are fastened to the foot of rail & 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, anticreeps are provided on both the sides of sleepers, starting from the centre of the rail & should never be fixed near the joints.

Anchors are fixed to rails either

- (i) By wedging action
- (ii) by clamping or
- (iii) by a spring grip.

There are several varieties of anchors based on these 3 types.



(Anchor placed by wedging Action)

(20)  
The following points should be considered for efficient maintenance of anchors.

- (i) The anchors should but against the sleepers otherwise they do not function effectively.
- (ii) The creep anchors should be strong enough to resist the movement of rails due to creep.
- (iii) The anchors should be uniformly distributed over the entire rail length.
- (iv) Defective anchors must be renewed to prevent accumulation of creep.
- (v) Anchors should be fixed to good sound sleepers only.
- (vi) Anchors, which depend on spring effect for their grip, must not be driven along a rail as this will destroy the spring.
- (vii) As far as possible, creep anchors should not be provided on the railway bridges.
- (viii) It is a good practice to use number of anchors ~~should~~ at approaches to the yards, in yards, at level crossings or at places where heavy brake applications are made, since the creep adversely affects the alignment, gauge & position of points & crossings at these location.

### (3) Use of steel sleepers.

Sleepers should be of such a type & with such fittings that they effectively prevent the rails 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.

## Geometric Design of the track

### Necessity of Geometric design of a Railway

Most of the train derailments are due to the following reasons: -

- (i) Train defects.
- (ii) Vehicular defects.
- (iii) Operational defects.

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

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

- (i) Defective cross-levels.
- (ii) Defective alignment.
- (iii) Defective gauge
- (iv) Low joints.

In addition to this, on curved tracks, the derailment may occur due to additional following causes.

- (1) Improper super-elevation.
- (2) Improper speed.
- (3) Improper radius of the curve.
- (4) Unequal distribution of loads on two-rails.

The derailments over the turn-outs & crossings may occur due to the following reasons.

- (1) Grasping points
- (2) Lifting of toe of switch due to inadequate fitting
- (3) Improper assembly of crossing, loose crossing bolts or wing rail has the crossing nose.

- (iv) Excessive wear in switches.
- (v) Tight gauge & defective clearances at the nose of crossing.

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

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

- (1) Gradients & grade compensation
- (2) Speed of train
- (3) Radius or degree of the curve.
- (4) Cant or super elevation.
- (5) Curves.  $\frac{50}{\text{km}}$
- (6) Widening of gauge on curve.

### (1) Gradients and grade compensation.

Any departure of the track from the level is known as grade or gradient. An up or rising gradient is one when the track rises in the direction of movement & a down or falling gradient is one when the track falls in the direction of movement.

Gradient is measured either (i) by the extent of rise/fall in 100 units horizontal distance or (ii) the horizontal distance travelled for a rise/fall in 1 unit. An alignment which rises on a horizontal distance travelled of 500 would be shown either as 1 in 100 or 4/100 or 1 in 25.

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.
- (iii) To reduce the cost of earth work.

Various