Lecture Notes on
Railway Engineering
5^{th} Semester Civil Engineering

Compiled by
Er. Rakesh Kumar Panda
(Guest Faculty in Civil engineering department)

Uma Charana Patnaik Engineering School, Brahmapur-10
Based on the SCTE & VT Syllabus

Chapter 1

Introduction

1.1. History Of Indian Railway:

The first steam-powered railway in England started operating in 1832. Following that, the Great Indian Peninsular Railways Company was founded in India on August 1st, 1849. A contract was signed on August 17, 1849, by the East India Company and the Great Indian Peninsular Railways Company. A railway track was laid between Thane and Bombay (56 km) as an experiment as a result of the contract.

1. On 16th April, 1853, the first train service was started from Bombay to Thane.
2. On 15th August, 1854, the 2nd train service commenced between Howrah and Hubli.
3. On the 1st July, 1856, the 3rd train service in India and first in South India commenced between Vyasarpadi and Walajah Road and on the same day the section between Vyasarpadi and Royapuram by Madras Railway Company was also opened.

Early railway rolling stock was created from carriages and waggons that were used on motorways to transport both passengers and large loads.

The rolling stock design changed along with the experience gained in the railway industry. When travelling at a slower pace on rough roads versus much quicker speeds on trains, which offer a relatively smoother ride, different loads and pressures are placed on the springs, body structure, wheels, and axles.

Hard wheels are typically used on hard rails by railway rolling stock. The rails not only provide support for the wheels, but they also act as guides. This only doesn't apply to a select few metros when rubber tyres have been installed. In this instance, the rail's directing and supporting functions may be distinguished.

In all cases railway rolling stock will transmit vertical, horizontal and longitudinal forces to the track and its supports. Most railways have adopted twin rails and flanged wheels. Forces are transmitted to the rail structure either by direct bearing on the rail top from the wheel tyre, or by bearing laterally through the flange, or by longitudinal friction. Potential ‘overturning’ forces, caused by centrifugal force on curves, coupled with wind forces on exposed locations are resisted by vertical dead weight and super-elevation or ‘cant’ on curves.

1.2. Advantages of Railways:

The railways offer various advantages and for the purpose of convenience, they can be described in following three categories

1.2.1. Political Advantages

- **a.** Railway have united the people of different caste, religions, customs and tradition.
- **b.** With adequate network of railway, the central administration has become easier & more effective.
- **c.** Railways have contributed towards development of national mentality in the minds of peoples.

d. the role of railways during emergencies in mobilising troops & war equipment's has been very significant.
e. Railway have helped in the mass migration of the population.

1.2.2. Social Advantages

a. The felling of isolation has been removed from the inhabitants of the Indian villages
b. By travelling together into the compartment without any restriction of caste, the felling of caste difference has disappeared considerably.
c. The social outlook of the masses has been broadened through railway journeys.
d. Railway has made it easier to reach the places of religious importance.
e. Railways provide a convenient and safe mode of transport for the country.

1.2.3 Economic Advantages

a. Mobility of labour has contributed to industrial developments.
b. During famines, railways have played the vital role in transporting food and clothing to the affected area.
c. Growth of industries has been promoted due to transportation of raw materials through railways.
d. Speedy distribution of finished products is achieved through railways.
e. Trade developed due to railways thereby has increased the earnings & standard of livings of Indian people.
f. Commercial framing is very much helped by the railway network
g. Due to mobility of products through railways the price stabilisation of commodities could be possible.

1.2.4 Techno – Economic Advantages

a. Cost saving in transportation of long-haul bulk traffic.
b. Energy – Efficient
c. Environment friendliness.
d. Higher safety.
e. Efficient land use & ease in capacity expansion.

1.3. Organizational structure

1.3.1. Railway zones

Indian Railways is divided into several zones, which are further sub-divided into divisions. The number of zones in Indian Railways increased from six to eight in 1951, nine in 1952 and sixteen in 2003. Each zonal railway is made up of a certain number of divisions, each having a divisional headquarters. There are a total of sixty-eight divisions. Each of the sixteen zones is headed by a general manager who reports directly to the Railway Board. The zones are further divided into divisions under the control of divisional railway managers (DRM). The production units of the railways are given below

Zones Of Railway in India

Sl.no	Name of the zone	Headquarters
1	Central Railway	Mumbai
2	Eastern Railway	Kolkata
3	East Central Railway	Hajipur

4	East Coast Railway	Bhubaneswar
5	Northern Railway	New Delhi
6	North Central Railway	Allahabad
7	North Eastern Railway	Gorakhpur
8	Northeast Frontier Railway	Guwahati
9	North Western Railway	Jaipur
10	Southern Railway	Chennai
11	South Central Railway	Secunderabad
12	South Eastern Railway	Garden Reach, Kolkata
13	South East Central Railway	Bilaspur
14	South Western Railway	Hubli
15	Western Railway	Churchgate
16	West Central Railway	Jabalpur
17	Metro Railway	Kolkata

Production Units

Sl no.	Manufacturing Units	Headquarters	Function
1	Chittaranjan Locomotive Works	Chittranjan	Manufacturing of Electric locomotives
2	Diesel Locomotive Works	Varanasi	Manufacturing of Diesel locomotives
3	Integral coach Factory	Chennai	Manufacturing of Coaches
4	Diesel components Works	Patiala	Manufacturing of Diesel components
5	Rail Coach Factory	Kapurthala	Manufacturing of Coaches
6	Wheel & Axle Plant (W & AP	Bangalore	Manufacturing of wheels & Axles

1.4. **Railway Terminology:** The commonly used terms in Railway Engineering includes: -

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

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

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

Gauge: The gauge of a track is the minimum distance between the inner running faces of the two rails.

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

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

Narrow Gauge: The gauge of track in which the distance between the running faces of two rails is 0.762 metre is known as Narrow Gauge.

Railway Track: Railway track is the structure provided by rails fitted on sleepers, resting on ballast and subgrade for passage of wheels.
Bearing Plates: To reduce the intensity of pressure, particularly on soft variety of sleepers, a rectangular plate of mild steel or cast iron is introduced between the rails and sleepers. This plate is known as Bearing Plate. This plate distributes the loads on large area.

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.

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

Creep of rails: Creep is the longitudinal movement of rails in a track. The effect of creep tends to drag the track if the ballast is insufficient to hold the rails.

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

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

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

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

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.

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

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

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

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

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

Ruling Gradient: It is the maximum rising gradient which is provided keeping in view the power of the locomotives.

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

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

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

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

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 of property damages.

Super elevation or cant: On curves, to counter act 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 super elevation or cant.

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

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

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

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

Boxing: The process of filling the ballast around the sleepers is called boxing of the ballast.

Chapter 2

Permanent Way

2.1. The 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. Fig. 2.1 throws a typical cross section of a permanent way on an embankment.

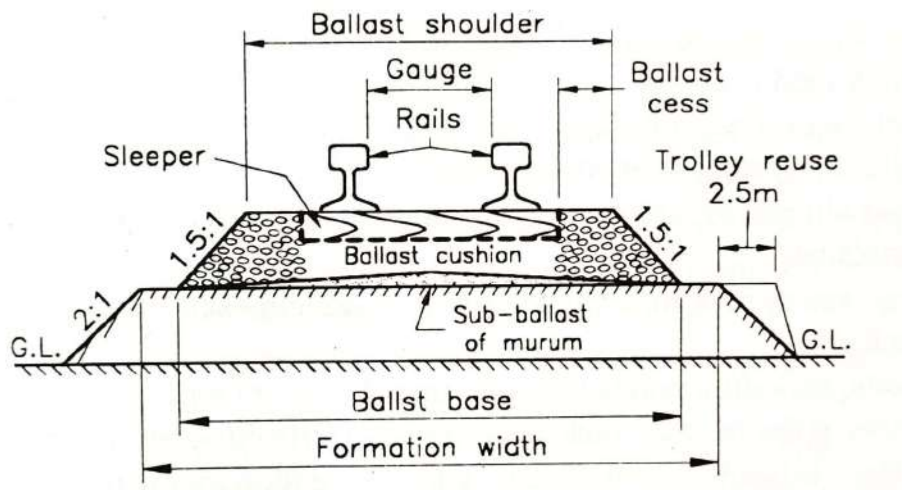


Fig- 2.1

In a permanent way, the rails are joined in series by fish plates and bolts and then they are fixed to sleepers by different types of fastenings. The sleepers properly spaced, resting on ballast, are suitably packed and boxed with ballast. The layer of ballast rests on the prepared subgrade called the formation. The rails act as girders to transmit the wheel load to the sleepers. The sleepers hold the rails in proper position with respect to the proper tilt, gauge and level, and transmit the load from rails to the ballast. The ballast distributes the load over the formation and holds the sleepers in position. On curved tracks, super-elevation is maintained by ballast and the formation is levelled. Minimum ballast cushion is maintained at the inner rail, while the outer rail gets kept more ballast cushion. Additional quantity of ballast is provided on the outer cess of each track for which the base width of the ballast is kept more than for a straight track.

2.2. Requirements of an Ideal Permanent Way:

i. The gauge should be correct and uniform.
ii. The rails should be in proper level. In a straight track, two rails must be at the same level. On curves, the outer rail should have proper superelevation and there should be proper transition at the junction of a straight and a curve.
iii. The alignment should be correct, i.e., it should be free from kinks or irregularities.
iv. The gradient should be uniform and as gentle as possible. Any change of gradient should be followed by a smooth vertical curve, to give smooth riding quality.
v. The track should be resilient and elastic in order to absorb shocks and Vibrations of running track.

vi. The track should have enough lateral strength, so that alignment is maintained even due to effects of (a) side thrust on tangent lengths and centrifugal force on curves (b) lateral forces due to expansion of rails, particularly in case of welded rails.
vii. The radii and superelevation on curves should be properly designed and maintained.
viii. Drainage system must be perfect for enhancing safety and durability of track.
ix. Joints, including points and crossings which are regarded to be weakest points of the railway track, should be properly designed and maintained.
x. If there is trouble from the creep, the preventionary measures should be to prevent it.
xi. The various components of the track, i.e., the rails, fittings, sleepers, ballast and formation must fully satisfy the requirements for which they have been provided. If any component is lacking in fulfilling its requirements, then either it should be improved or replaced.
xii. There should be adequate provision for easy renewals and replacements.
xiii. The track structure should be strong, low in initial cost as well as maintenance cost.

2.3. 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 (Fig. 2.1). The distance between the inner faces of a pair of wheels is called the "wheel gauge".

Types Of Gauges	Gauge Width (m)
Broad Gauge (B.G)	1.676
Meter Gauge (M.G)	1
Narrow Gauge (N.G)	0.762
Light Gauge (L.G)	0.61

2.4. Selection Of Gauges:

2.4.1. **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:

i. The cost of bridges, tunnels, station buildings, staff quarters, signals, cabins and level crossings are the same for all the gauges.
ii. The cost of earth work, (in making embankments and cuttings) ballast, sleepers, rails, etc. would proportionally increase with in- crease in gauge width.
iii. There is little proportional increase in the acquisition of land for permanent track with increase in gauge.
iv. 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.

2.4.2. **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 locomotives. For heavier loads and high speed, the wider gauges are required because subsequently the operating cost per ton-km is less for higher carrying capacity.

2.4.3. **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.

2.4.4. **Physical Features of the Country:** Use of Narrow gauge is warranted in hilly regions where broad and meter gauges are 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.

2.4.5. **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.

2.5. Uniformity Of Gauge

Gauge to be used in a particular country should be uniform throughout as far as possible, because it will avoid many difficulties experienced in a non-uniform system. The Uniformity of gauges results in the following advantages:

i. The delay, cost and hardship in transshipping passengers and goods from the vehicles of one gauge to another is avoided.
ii. As the transshipping is not required, there is no breakage of goods.
iii. Difficulties in loading and unloading are avoided and labor expenses are saved.
iv. Possibility of thefts and misplacement, while changing from one vehicle to another, is eliminated.
v. Large sheds to store goods are not required.
vi. Labor strikes, etc., do not affect the service and operation of trains.
vii. Surplus wagons of one gauge cannot be used on another gauge. This problem will not arise if gauge is uniform.
viii. Locomotives can be effectively used on all the tracks if a uniform type of gauge is adopted.
ix. Duplication of equipment such as platforms, sanitary arrangements, Clocks, etc. is avoided. This saves a lot of extra expenditure.
x. During military movement, no time is wasted in changing personnel and equipment from one vehicle to another if gauge is uniform.
xi. It is quite expensive to convert one gauge into another at a later stage as it may require new rolling stock, fresh construction and widening bridges and tunnels.
xii. Due to late arrival of the trains at the junction, where change of gauge is trains an involved, the missing links result in number of difficulties. Passengers have to pass times on platforms. In uniform gauge, this problem doesn't arise.
xiii. Porter charges are increased when passengers have to change compartment due to a different gauge. This is avoided if gauge is uniform.

2.6. Conning Of Wheels:

The distance between the inside edges of wheel flanges is generally kept less than the gauge of the track. So, there is a gap between the wheel flanges and running edges of the rails, nearly equal to 1 cm on either side. Normally, the tread of wheels is absolutely dead center of the head of the rail, as the wheel is coned to keep it in this central position automatically. These wheels are conned at a slope of 1 in 20 as show in fig 2.2.

The advantages of conning of wheels are,

- To reduce the wear and tear of the wheel flanges and rails, which is due to rubbing action of flanges with inside faces of the rail head.
- To provide a possibility of lateral movement of the axle with its wheels.
- To prevent the wheels from slipping to some extent.

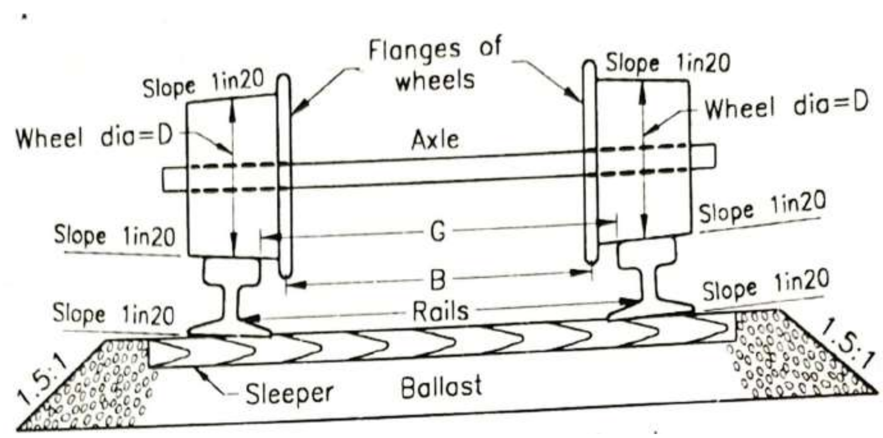


Fig 2.2

2.6.1. Theory of conning: On a level track, as soon as the axle moves towards one rail, the diameter of the wheel thread over the rail increases, while it decreases over the other rail. This prevents the further movement & axle retreats back to its original position (i.e. with equal diameter in both rails & equal pressure on both rails).

On a curved path, (the behavior of wheels on rails is explained under the article on resistance due to curves), it is seen that due to rigidity of the wheel base either of the wheel must slip by an amount equal to the difference of length or the axle must slightly move outwards to provide a tread of longer diameter over the outer rail and smaller diameter over the inner rail as shown in figure 2.3

Slip = $\Theta (R_2 - R_1)$,

Outer Radius = $R_2 = R + G/2$

Inner Radius = $R_1 = R - G/2$

Were,

Θ = Angle at center in radians.

G = Gauge of track in m

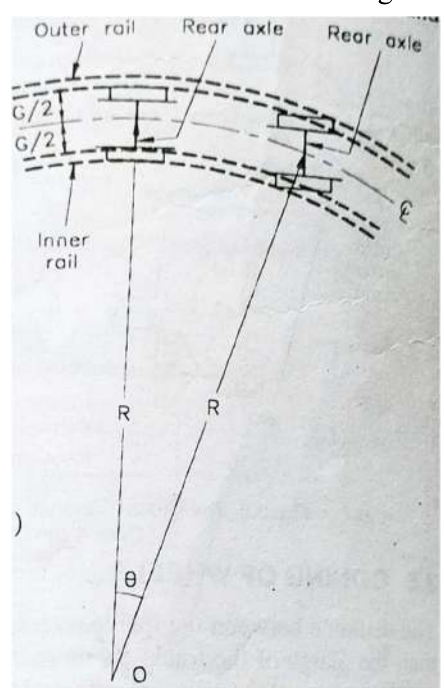


Fig – 2.3.

Coning of wheels on curves is not of much use as the leading axle if due to centrifugal force moves towards the outer rail the rear axle (or trailing axle) will move towards the inner rail and the full advantage of coning wheels cannot be availed. In other words, there is no free lateral movement of wheels and this leads to following disadvantages:

- Pressure on outer rail is more while on inner rail it is less. This results in wear of outer rail.
- Due to the centrifugal force, the horizontal components tend to turn the rail out and gauge has widening tendency.
- If no base plate is used under the void's sleepers under the edge of the rail are damaged.

In order to eliminate or minimize the above demerits "tilting of rails" is done. In tilting of rails, the base plate or sleeper is not laid horizontal but at a slope of 1 in 20 inwards. This is known as "adzing of sleepers" as shown in Fig. 2.4.

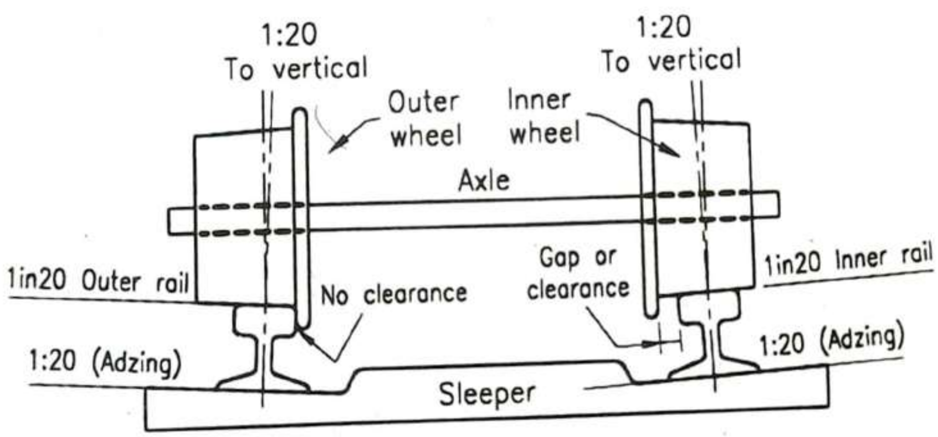


Fig – 2.4

Chapter 3

Rails

3.1. Introduction

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

3.2. Functions Of Rails:

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.

3.3. Composition Of Rail Steel:

Elements	For Ordinary Rails	For Rails on Point & crossing
Carbon (C)	0.55% - 0.68%	0.5% - 0.6%
Manganese (Mn)	0.65 % - 0.9%	0.95% - 1.25%
Silicon (Si)	0.05% - 0.3%	0.05% - 0.2 %
Sulphur (S)	0.05% or below	0.06% or below
Phosphorus (P)	0.06% or below	0.06% or below

3.4. Requirements of Rails:

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 center of gravity of the rail section must lie approximately at mid-height so that maximum tensile and 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 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.

3.5. Types of Rail Section:

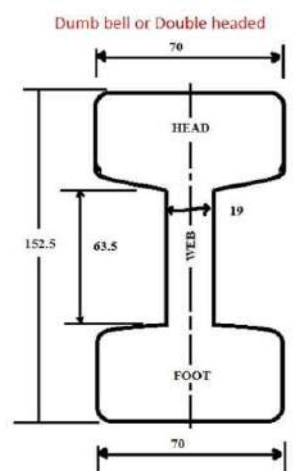


Fig – 3.1

i. **Double Headed Rails (D.H. Rail):** In the beginning, the rails used were double-headed (D.H.) of a dumb-bell section. The idea behind using of these rails was that when the head has won out in course of time, the rail can be inverted and reused. But experience showed that such indentations are formed in lower table due to which smooth running over that surface at the top was impossible. (Fig – 3.1)

ii. **Bull Head Rails (B.H. Rails):** The next evolution was that of a bull-headed (B.H.) rails, in which the head was made a little thicker and stronger (i.e. Bull size) than the lower part, by adding more metal to it, so that even after wear, it can withstand stresses. (Fig – 3.2)

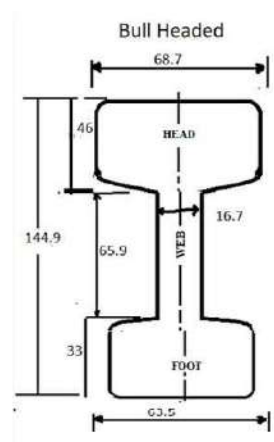


Fig- 3.2

iii. **Flat Footed Rails (F.F. Rails):** Side by side with the B.H. rails, flat-footed rails also called Vignola's rails after the name of the inventor, were developed. It was originally thought that the flat-footed rails could be fixed to sleepers directly and would eliminate the need for chairs and keys required for the B.H. rails. However, it was observed that heavy train loads caused the foot of the rail to sink into the wooden sleeper, making the spikes work loose. To remedy this, steel bearing plates were introduced, between the sleeper and the rail, at rail joints and other important places. In India, flat-footed rails are most commonly used. Fig – 3.3

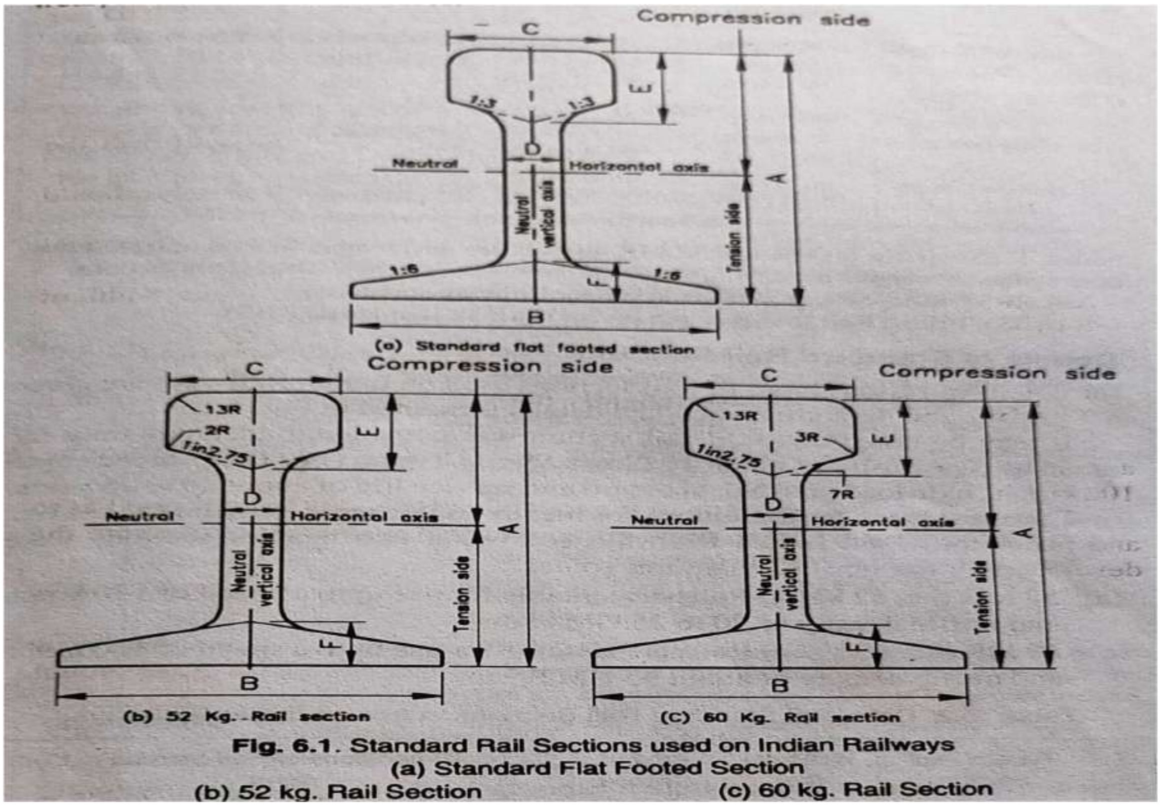


Fig – 3.3

3.6. Selection Of Rails:

i. Speed of the train.
ii. The gauge of the track
iii. The axle load & nature of traffic.
iv. Type of rails.
v. Spacing of sleepers.
vi. Minimum permissible wear on the top of rails.

3.7. Length of rails:

For B.G. Length = **12.8 m (Say 13 m)**
For M.G. Length = **11.89 m (Say 12 m)**

3.8. Comparison of rail types:

SL. No.	Point of Comparison	Flat-footed Rails	Bull-headed Rails and Double-headed Rails
1	Strength and Stiffness	These have more strength and stiffness for the same weight, both laterally and vertically.	These have less strength and stiffness.
2	Laying and Relaying	Fitting of these rails is simpler and so can be easily laid and re-laid. No chairs are required.	The fitting of these rails is difficult and time consuming as they are supported on chairs.
3	Arrangements at points, crossings and at sharp curves	The arrangements are simpler and easy.	The arrangements are complicated and difficult.

4	Alignment and stability of track	In this, impact of Rolling wheels affects the fittings and the loosening of fit- tings disturbs the alignment and gives less stability	These rails when fitted on chairs, provide a more solid, smooth track and better stable alignment.
5	Initial cost	These rails require lesser and cheaper fastenings, so the initial cost is less.	These require more and costly fastenings and hence initial cost is more.
6	Rigidity	These rails can be used, without bearing plates on sleepers as these rails are strong to withstand vertical loads. Hence, they are more rigid.	These rails without hairs cannot be used on inferior type of sleepers, being less strong against vertical loads. Hence, they are less rigid.
7	Inspection	Daily inspection is not necessary as no special risk is involved.	in case of B.H. or D.H. rails, daily inspection of wooden keys is necessary.
8	Replacement of rails	In F.F. rails, the dog spikes have to be taken out in addition to fish bolts and fish plates to change the rail. So, replacement is difficult.	These rails can be changed easily by driving out the keys and taking out fish bolts and fish plates, without disturbing sleepers.
9	Maintenance cost	The maintenance cost is less.	It requires heavy maintenance cost.
10	Suitability	These are more suitable due to better stability, economy, strength and stiffness	These are more suitable when lateral loads are economy, strength and more important rather than vertical loads.

3.9. Hogged Rails:

Due to battering action of wheels over the end of the rails, the rails get bent down and get deflected at the ends. These rails are called "Hogged Rails". This hogging of the rails at the ends is due to lose packing under the joints and/or loose fish plates. This defect causes rough riding and the following measures are taken to rectify the hogged rails.

- **Cropping:** In this the hogged ends of the rails are cut off and fresh holes for fixing the fish plates are provided. This cutting of rails either is done in workshop or at site. This former method of cutting the rails at workshop is both tedious and uneconomical. So, the hogged portion is desired to be cut at the site by use of portable drilling machine and power saws. After cutting the defective ends, the rails are pulled back equal to the length of the cut off. This method is very common in advanced countries.
- **Replacing:** In this, the hogged rails are completely removed and replaced by new rails. However, this method is very uneconomical.
- **Welding:** Hogged rails are brought to the level by welding over the worn out or bent portions at the ends.
- **Dehogging:** This is the method of straightening the end by means of Jim crow or by using a dehogging machine. But it is seen that Jim crow cannot straighten it satisfactorily. So, cropping of rails becomes the only satisfactory method to remove this defect.

3.10.Kinks in Rails:

When the ends of adjoining rails move slightly out of position, "shoulders" or "kinks" are formed. The causes of formation of kinks may be the following:

i. Loose packing at joints.
ii. Defect in gauge, and alignment
iii. Defect in cross level at joints.
iv. Uneven wear of rail head, where kinks are formed at joints.

The kinks produce the following undesirable effects:

- These kinks cause unpleasant jerks in vehicles passing over them.
- Due to uneven wear of rail heads, these kinks appear at places other than the joints and obstruct the smooth running of trains.
- A series of kinks are seen at curves due to which defect in gauge, alignment and camber may occur. This involves, sometimes, a serious risk in turning operations of trains.

The following measures are generally taken to remove this defect:

- By correcting alignment at joints and at curved locations.
- Proper packing at joints.
- Proper maintenance of the track periodically in respect of cross levels, gauge, alignment, welding of worn-out portions, etc.

3.11.BUCKLING OF RAILS

Buckling means the track has gone out of its original position or alignment due to prevention of expansion of rails in hot weather on account of temperature variations. This buckling may take place on tangent lengths and at curves.

The causes of buckling are summarized below:

- When expansion gap is not sufficient, the force of expansion throws the track out of position, resulting in bending of rails known as buckling, or
- The fish plates being bolted so tight that the rails are not allowed to slip or expand, or
- Due to presence of longer welded rails on weak tracks which result in excessive expansion.

Buckling in tracks has caused many times in serious derailments. Various **precautions or measures** to be taken to prevent buckling are:

- The ballast section, sleeper density and the rail sections must be checked for design and redesigned for safety under various stresses.
- Number of welded rails should not be very large.
- Provision of steel sleepers or anchoring of welded rails should be done.
- Proper lubrication of contact surfaces of fish plates and rails should be done at regular intervals (once in a year or two).
- Expansion gap should be provided by taking into account the expansion of rails due to rise in temperature in that region.
- The fish bolts should not be tightened too hard as to prevent the expansion or contraction of rails.

3.12.Damaged Rails:

These are the rails which should be removed on account of their becoming unsafe for a railway track due to any of the following causes:

i. The wear of rails.
ii. The defect, due to manufacture of rails.
iii. Defect of hogging in excess.
iv. Due to damage caused to the rails.

The defect of wear will be dealt in subsequent articles. The defects due to manufacture in India are comparatively few. The hogging of rails is discussed in preceding articles. Damage to the rails may also be caused by one or more of the following reasons:

- Careless unloading or handling of rails.
- Bending of rails to sharp curves.
- Improper striking of rails while fixing to the sleepers.
- Poor maintenance of track, such as loose sleepers at joints, loose fish bolts, incorrect superelevation at curves, etc.
- Slipping or skidding of wheels due to overloading or sudden application of breaks.

3.13.Rail Failures:

The sudden failure of a rail is generally due to defects in its manufacture, although the other causes may also exist. Two such other common causes,

i. Abrupt change of section of rail
ii. Notches with corners in the foot of the rails.

Such failures, though rare on Indian Railways, may occur in one or more of the following forms (Fig. 3.4)

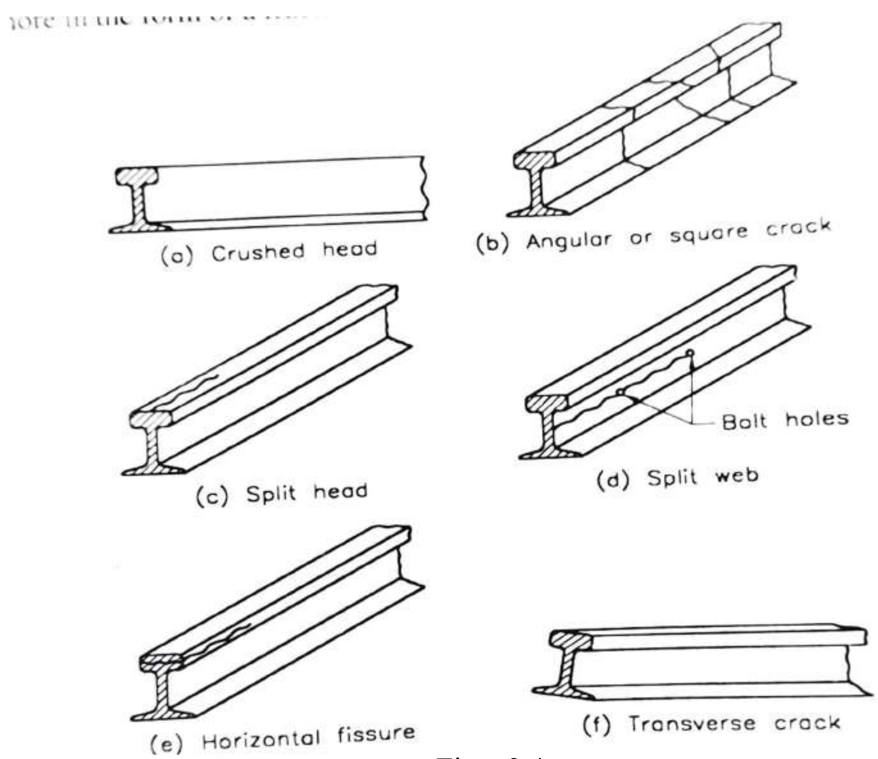


Fig – 3.4

1. **Crushed Heads:** Crushed heads are those which have either sagged or flattened. Besides the defect of manufacture, crushed heads are due to,
   a) Slipping of wheels
   b) Flat spots on wheels which are developed due to skidding of wheels
   c) Weak support at the rail end.

   This weak end support may be due loose fish bolt.

2. **Square or Angular Break:** The rail may be completely broken either in a vertical plane or in an inclined plane.
3. **Split Heads:** In this, cracks occur in the middle of the head or pieces are split from the side to the end of the head. If the surfaces of the crack, when opened, appear smooth and dark, the defective rail is known as "piped rail". This happens either due to cavity formed during manufacture or shrinkage of metal when the metal not having been closely welded together.
4. **Split Web:** This is the through crack in the web, though not necessarily, runs through the bolt holes.
5. **Horizontal Fissures:** These are developed in the rail head. They are more in the form of a fracture and develop gradually.
6. **Transverse Fissures:** This is the most common cause of rail failures in America. It is a cross wire crack which starts from a point inside the head and spreads like contours shape gradually. The broken surface has a smooth oval or round bright spot. This defect is either a manufacturing defect or may occur due to overstraining of metal in service.
7. **Flowing Metal in Heads**: The metal in the rail head is forced to flow on the sides due to which, the rail head gets widened and depressed.
8. **Horizontal Cracks:** These occur at rail ends between head and web. Such cracks are believed to be due to worn fish plates or insufficient ballast packing under joint sleepers, resulting in pumping of joints and consequent fatigue failure of steel. This defect is very common in rails in America and is increasing day by day. This defect is either due to fatigue caused by shearing stresses or due to reversal of stresses (from high compressive to low tensile stresses) in the rail between supports.

Chapter 4

Rail Joints

4.1. Introduction:

Rail joints are necessary to hold together the adjoining ends of the rails in the correct position, both 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 the rail.

4.2. Requirements Of an Ideal Joint

- 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.
- The rail joint should be as strong and stiff as the rail itself and should be elastic both laterally and horizontally.
- The rail joint should provide enough space for free expansion and contraction to account for the effect of temperature variations.
- A good joint should be easily disconnected able 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.
- It should not allow the rail ends to get battered in any case.
- The joint should fulfil the above requirements with the minimum of initial and maintenance cost (i.e., it should be economical).

4.3. Types Of Rail Joints:

4.3.1. 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.

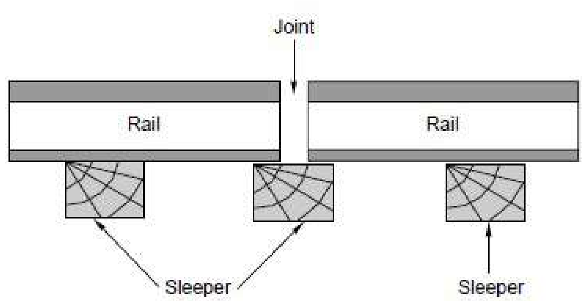
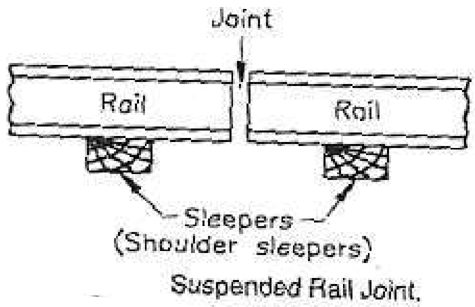


Fig – 4.1

4.3.2. Suspended 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.

4.3.3. 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 net used on Indian Railways.



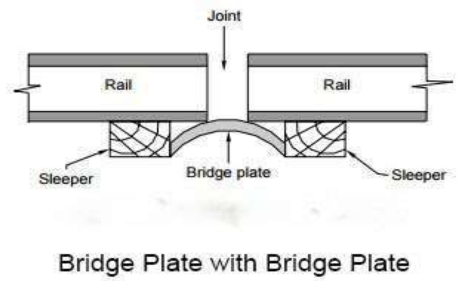


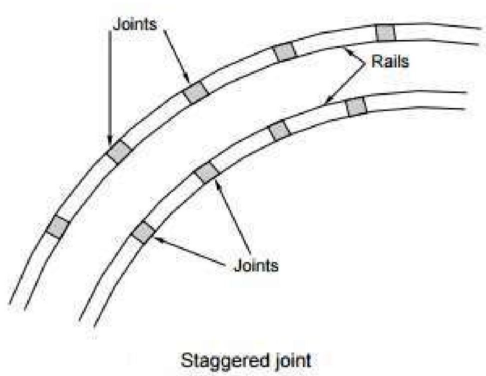
Fig – 4.2

Fig – 4.3

4.3.4. 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.

4.3.5. Welded Rail Joints: These are the best joints as they fulfil nearly all the requirements of an ideal or perfect joint land will be discussed.

4.3.6. 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.



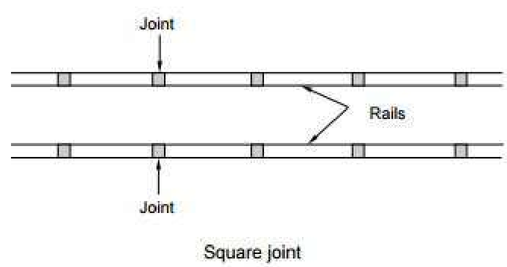


Fig – 4.4

Fig – 4.5

4.3.7. 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 another rail track. This type is generally used on straight tracks.

4.3.8. 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.

4.3.9. 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.

4.3.10. Expansion Joint: In bridges provision for expansion and contraction is kept for girders and rails. The gap is 2.2 cm in case of mitered joints & 7.2 cm in case of Halved joints.

4.4. Welded Joints:

4.4.1. Purpose of Welding:

- 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.
- To repair the worn out or damaged rails and thus increase their life.
- To build up worn out points and rails on the sharp curves.
- To build up the burnt portion of rail head which is caused due to slippage of wheels over the rails or other defects or spots in rail steel.

4.4.2. Advantages Of Welding Rails:

- 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.
- It reduces the creep due to increase in the length of rail and in turn friction as well.
- Expansion effect due to temperature is reduced which in turn also reduces the creep.
- 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.
- Long rail lengths being heavier, dampen the intensity of high frequency vibrations due to moving loads.
- Welding increases the life of rails due to decrease in the wear of rails at joints.
- Welding facilitates track circuiting on electrified tracks.
- Welded rails provide on large bridges for the span length are helpful as they result in better performance.
- Welded rails provision on curves is under investigation. However, maximum curve length may be welded depending upon resistance and lateral displacement of track.
- The cost of track construction by welding of rails decreases due to a smaller number of rail joints

---

Chapter 5

Creep Of Rails

5.1. Definition:

Creep is defined as the 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.

5.2. Indications Of Creep:

Occurrence of creep can be noticed from the following observations,

- Closing of successive expansion spaces at rail joints in the direction of creep and opening out of joints at the point from where the creep starts.
- Marks on flanges and webs of rails made by spike heads, by scraping or scratching as the rails slide.

5.3. Theories Of Creep:

5.3.1. 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.

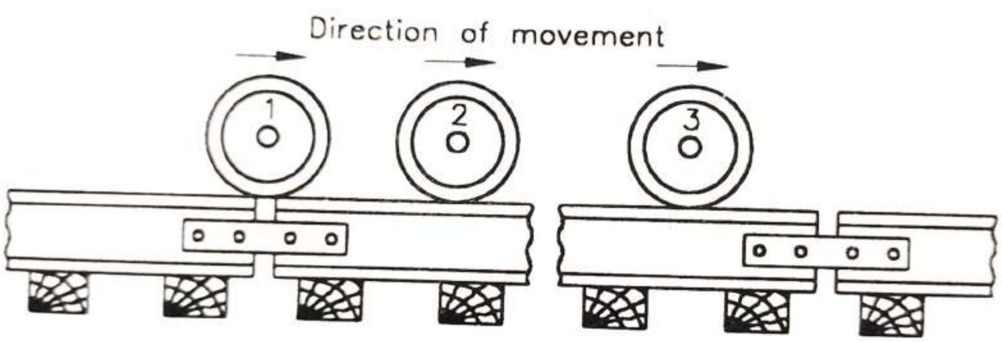


Fig – 5.1

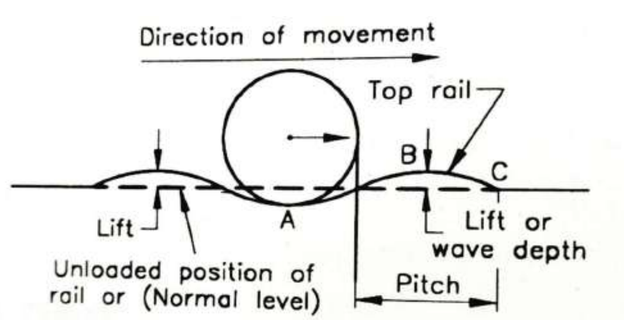


Fig – 5.2

The pitch and depth of wave depend upon the following:

i. Track modulus
ii. Stiffness of track
iii. Stability of formation

The wave action can be reduced (i.e. creep is reduced) by adopting following measures:

i. Angular and heavy ballast-which develops good interlock,
ii. Increased stiffness of track
iii. Lesser sleeper spacing
iv. Bigger section of the rail.

5.3.2. 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. The creep by this theory will increase due to following factors:

i. Due to weak and loose fish bolt.
ii. Due to worn out fish plates.
iii. Due to lose packing at joints.
iv. Due to wide expansion gap.
v. Due to heavy axle loads moving at high speed. thrust on driving.

5.3.3. Drag 'or' Dragging Theory: It states that backward wheels of the locomotive of train have 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.

5.3.4. 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.

5.3.5. 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.

5.3.6. Unbalanced Traffic:

- 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.

- In the double line system, trains on a particular line being unidirectional, creep occurs in both the lines. The above-mentioned causes are main but by no means the only causes of creep. Following factors also govern the magnitude and direction of creep:

i. Alignment of Track - Creep is observed greater on curves than on tangent railway track.
ii. Grade of Track - Creep is more with steep gradient particularly if the trains move downward with heavy loads. Though in the opposite direction, it is not impossible for creep to develop.
iii. Type of Rails - The old rails have more creep than new rails.
iv. Direction of Heaviest Traffic - If the loaded trains run in one direction (such as from production centers to the markets) and empty trains in opposite direction, creep will usually be found in the direction of loaded trains.
v. Poor Maintenance of Track Components and Ill design - of superelevation, curves, joints, etc. will also increase the creep. It is observed that creep is not constant over any given time nor does it vary at uniform rate, nor does it continue in one direction, nor do both the rails creep by an equal amount. In fact, the direction and extent of creep cannot be predicted. Such variations may occur daily or may be seasonal.

5.4. Effects of Creep:

The effects of creep are several and serious too, the most serious effect being buckling of the track. If a buckled track is not attended at proper time, it may easily derail a train and result in serious losses. The common effects of creep, are the following:

- 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.
- 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 gaps at joints. While at other places, joints are jammed and prevent required expansion due to temperature variation.
- 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.
- 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.
- 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.

5.5. Remedies 'or' 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.

- **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 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.

- **Provision of Anchors or Anti creepers:** 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, anti-creepers are provided on both the sides of sleepers, starting from the center of the rail and should never be fixed near the joints. Anchors are fixed to rails either
    i. By wedging action.
    ii. By clamping
    iii. By a spring grip.

  The following points should be considered for efficient maintenance of Anchors:

  i. The creep anchors should be strong enough to resist the movement of rails due to creep.
  ii. The anchors should butt against the sleepers otherwise they do not function effectively.
  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 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 and position of points and crossings at these locations.
- **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.

Chapter 6

Sleepers

6.1. Introduction:

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.

6.2. Function 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 tilts 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.

6.3. 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.

6.4. 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

Different types of sleepers are manufactured with the same material. They are described in the following pages:

6.4.1. Timber or 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 Wear, Decay, Attack by Vermin, (i.e. white ants) and Quality of the timber used. Following are the advantages and disadvantages of using wooden sleepers.

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.

6.4.2. 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. The metal sleepers should satisfy the following requirements:

i. They (metal sleepers) should bear the tensile and compressive stresses which come on to them.
ii. They should provide sufficient area for rails, i.e., area on ballast should be at least equal to that of wooden sleepers.
iii. Tamping and packing of ballast should not disturb the sleeper.
iv. For track circuiting, insulation should be possible.
v. Metal sleepers should be overall economical as compared to wooden sleepers.
vi. The design of metal sleepers should be such that they provide

a) Ease in fixation and removal of rails without disturbing the sleepers.
b) Ease in pushing out the sleepers and replacing them without disturbing the rail and the ballast.

vii. Metal sleepers should provide sufficient grip on the rail and ballast to prevent the dislocation of track due to shocks and vibrations, caused by heavy loads.
viii. Metal sleepers should provide sufficient grip on the rail and ballast to prevent the dislocation of track due to shocks and vibrations, caused by heavy loads.

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.

6.4.3. 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. These sleepers are mainly of two types:

- Reinforced concreate sleepers.
- Pre-stressed concreate sleepers.

Experiments have been conducted in India and abroad on concrete sleepers and it has been proved that concrete is an ideal material for the sleepers for the following reasons:

They are made of a strong homogeneous material, impervious to effects of moisture, and is unaffected by the chemical attack of atmospheric gases or sub-soil salts.

It is moulded easily to size and shape required by scientific investigation, to withstand the stresses produced by fast and heavy traffic.

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.

Disadvantage:

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 are very heavy in case of derailment.

Reinforced Concrete Sleeper: These are of two types: Through type, Composite or Block and tie type.

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

This is the main cause of the failure of these sleepers.) These composite or block and tie type of sleepers are not subjected to same degree of tensile stress and have given excellent results in France where a steel tie of inverted 7-section is used. It is not in use, at present.

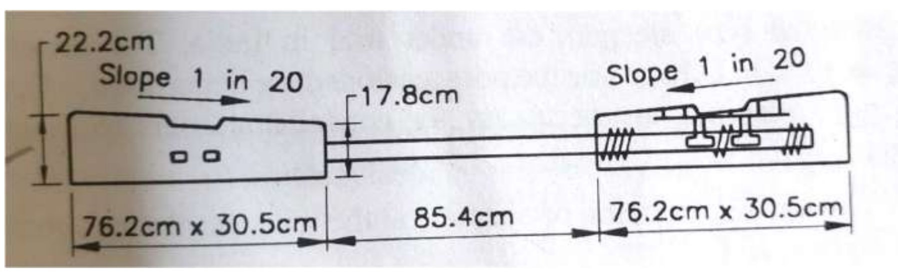


Fig – 6.1

Pre-stressed Concrete Sleepers: All the disadvantages of reinforced concrete sleepers have been eliminated by prestressing technique for sleepers. In pre-stressed concrete sleepers, the concrete is put under a very high initial compression. The design is based on:

- The maximum permissible compressive strength of 211 kg/cm².
- The minimum cube crushing strength of concrete in the sleeper is 422 kg/cm² at 28 days.
- The pre-stressed wires are stressed to an initial stress of 8.82 kg/cm².

Disadvantages of Pre-stressed Concrete Sleepers :

- These are heavily damaged in case of derailments.
- The bed of the ballast is specially prepared.
- These are uneconomical.

- The standard of maintenance for the track, where these sleepers are used, is to be kept very high.
- They are more rigid in nature.
- The design and construction are complicated but even then, the desired strength is not developed at the centre of sleepers.

Chapter 7

Ballast

7.1. Introduction: 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. The lateral stability of a track depends on the ballast.

7.2. Functions of Ballast: Ballast performs the following functions:

a) It transfers the load from the sleeper to the subgrade and then distributes it uniformly over a larger area of the formation.
b) It holds the sleepers in position and prevents the lateral and longitudinal movement, due to dynamic loads and vibrations of moving trains.
c) It imparts some degree of elasticity to the track.
d) 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.
e) 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.

7.3. Requirements of The Good Ballast:

a) It should be able to withstand hard-packing without disintegrating. In other words, it should resist crushing under dynamic loads.
b) 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.
c) It should allow for easy drainage with minimum soakage and the voids should be large enough to prevent capillary action.
d) It should offer resistance to abrasion and weathering. Abrasion means wear due to rubbing action of particles with each other and weathering means cracking and shattering of the material due to variation in temperature, moisture and freezing. Non-porous particles of ballast are usually more durable due to better resistance against abrasion and weathering.
e) 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. The internal friction between particles which provide stability depends upon the size, shape and texture of particles, therefore, angular and cubical aggregates should be used but not the flat-particles.
f) It should not produce any chemical action with rail and metal sleepers.
g) 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.
h) The materials should be easily workable by means of the implements in use.
i) 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.

In short, the ballast should be such which fulfils the characteristics of strength, cleanability, durability, drain-ability, economy and stability and is workable with specific size with no harmful effects on rails and sleepers.

7.4. Types of Ballast:

The different materials used as ballast in India are broken stone, gravel, sand, ashes or cinders, soft aggregates like moorum, kankar, overburnt and broken brickbats, blast furnace slag and sometimes selected earth.

a) **Broken Stone:** This is the best material for the ballast and almost all-important tracks are provided with stone ballast. Broken stone satisfies all the specifications and requirements of a good ballast mentioned above. 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. Where such hard stone is not available, sandstone and limestone which make fairly good ballast are used.
For stability, graded broken stone ballast is better than ungraded one. Graded stone of 5.08 cm to 1.9 cm size is found to provide the maximum stability. On the other hand, workability is better with smaller size ballast say. 1.9 cm size.

b) **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, (because the particles roll down the section due to vibrations and the packing under the sleeper gets loose).
The process of ramming the ballast underneath the sleeper is known as **"packing".** The ballast above this layer which surrounds the sleeper, is loose-filled and is known as **"Boxing".** The loose ballast between the two adjacent sleepers is known as **"Ballast crib".**

c) **Ashes or Cinders:** This material is available in large quantities on railways from coal being used in locomotives. 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. The great drawback of ashes is its corrosive quality and, therefore, it corrodes steel sleepers and foot of the rails. In emergency, such as destruction of track by floods, the ashes or cinders being easily available in large quantities, can be used for repairing formation or packing tracks.

d) **Sand:** It is reasonably good material as ballast as it is cheap and provides good drainage (provided it is free of earth and vegetation). 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. The sand gets into the moving parts and on the track and causes heavy wear. The maintenance of the track is, therefore, difficult. Sand ballast is sometimes covered with a layer of stone or brick or some such material to prevent it from blowing about too much. The coarse sand is preferred to fine sand. The best sand consists of a good quantity of fine gravel and sand which is used on narrow gauge tracks.

e) **Moorum:** It is the soft aggregate and is the result of decomposition of laterite and has a red or sometimes a yellow colour. The best moorum for ballast is that which contains large quantities of small laterite stone. 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.

f) **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.

g) **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.

h) **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. Slag, suitable for use as ballast, is obtained by pouring molten slag collected at the blast furnace into shallow pits of thin layers, allowing it to cool, and then by digging, crushing and screening.

i) **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.

7.5. Size & Section of Ballast:

The size of the ballast used varies from 1.9 cm. to 5.1 cm. gauge. Stones of larger sizes are not desirable and the maximum size as 5.1 cm. is preferable, as interlocking of stones of this size is better than that of stone of larger sizes. The best ballast is that which contains stones varying in size from 1.9 cm to 5.1 cm. with reasonable proportion of intermediate sizes. The exact size of the ballast depends upon the type of sleeper used and location of the track as below:

a) Ballast size for wooden sleepers' tracks = 5.1cm . (gauge)
b) Ballast size for steel sleepers track = 3.8 cm. (gauge)
c) Ballast size for under switches and crossings = 2.54 cm. (gauge)

The section of ballast layer consists of depth of ballast under the sleepers and the width of the ballast layer.

The depth of the ballast under the sleepers is an important factor in the load bearing capacity and uniformity of distribution of load. The more is the depth of ballast more will be the load-bearing capacity. In America, a depth of ballast equivalent to the sleeper spacing is recommended, because of heavier loads and the closer spacing of sleepers being used in that country. In India, this recommendation will give unnecessarily thicker layer of ballast due to large spacing of sleepers, being used.

The width of the ballast layer is also important as the lateral strength of track depends partly upon the quantity of ballast used at the ends of the sleepers. The lateral strength increases with increase in width of the ballast layer but there is a limit beyond which no useful purpose is served by widening. This width limit is at 38 cm. to 43 cm. from the end of the sleeper as computed. The Indian standards have recommended dimensions for, width of ballast section at the level of the foot of the rail and for depth of ballast below the sleepers.

7.6. Minimum Depth of Ballast Section:

Although the lines of equal pressure in ballast through wheel loads are in the shape of a 'bulb' yet for simplicity purpose, the load dispersion can be assumed at 45° to the vertical. For uniform distribution of load on the formation, the depth of ballast should be such that the dispersion lines do not overlap each other. From simple geometry.

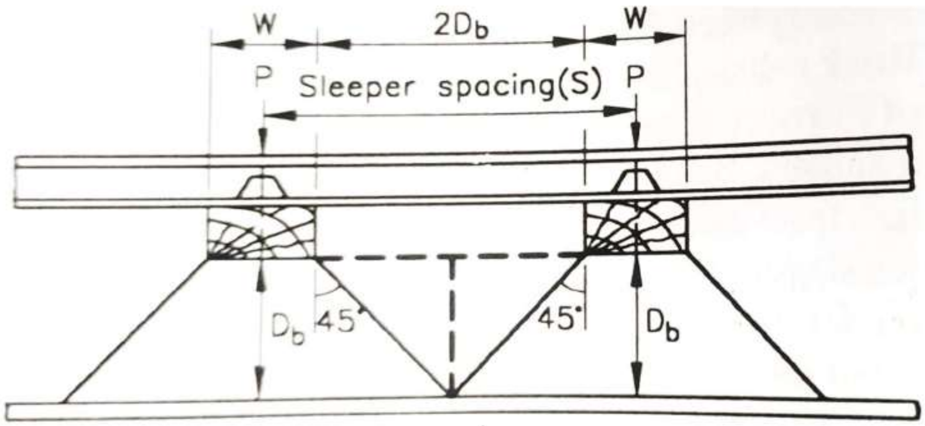


Fig – 7.1

$$Db = \frac{S - w}{2}$$ S = w + 2Db

Were, S = Sleeper spacing

w = Width of sleeper

Db = minimum depth of ballast

Dimensions	B.G.	M.G.	N.G.
Width of ballast	3.35m	2.25 m	1.83 m
Depth of ballast	20 to 25cm	15 to 20 cm	15 cm
Quantity of stone ballast per meter length	1.036 m^2	0.71 m^3	0.53 m^3

Chapter 8

Points and Crossing

8.1. Definition:

Points, crossings, turnouts, cross-overs and such related terms are contrivances or arrangements by which different routes either parallel or diverging are connected and afford the means for trains to move from one route to another. These connections are not only useful for trains to move from one route to another but also help for marshalling and shunting work in station yards.

8.2. Necessity of Points & Crossings:

In case of roads, the facilities for turning of vehicles from one path to another, do not require any special arrangement as the wheels have no flanges. The direction of movement of vehicles is controlled by the driver and the steers according to his own sweet will. But this is not true in case of railways because the wheels are provided with flanges inside, so the direction of movement and the diversion of the vehicles to another track are controlled automatically by the wheel flanges rather than the driver as in case of roads. The problem of diversion of trains from one track to another is solved by special arrangements known as points and crossings. The knowledge of the points and crossings is important in following ways for the operating personnel:

- Points and crossings provide flexibility of movement by connecting one line to another according to requirements.
- They also help for imposing restrictions over turnouts which necessarily retard the movements.
- From safety aspect, it is also important as points and crossings are weak kinks or points in the track and vehicles are susceptible to derailments at these places.

8.3. TURNOUTS

Turnout is the simplest combination of points and crossings which enables one track either a branch line or a siding, to take off from another track. So, the object of turnout is to provide facilities for safe movement of trains in either direction on both the tracks. As shown in below figure, the following are the parts of a turnout:

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

8.3.1. 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".

ii. Trailing Direction. If someone stands at the Overall length Stretcher crossing and looks towards the switches, then the direction is called "Trailing Direction".

iii. **Facing Points of Turnouts:** Are those where trains pass over the switches first and then they Passover 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 & the over the switches. These are important to specify when the direction of movement of trains is reserved for trailing direction only. So, every point may be a facing of trailing point depending upon the direction of the movement

v. **Right Hand & 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. If a train from main track is diverted to the left of the main route in the facing direction, then this diversion is known as Left – Hand Turnout.

vi. **Right – Hand & Left – Hand Switches:** These are termed as left – hand of right-hand switches depending upon left & right seen from the facing direction i.e. stand at points & look towards the crossing.

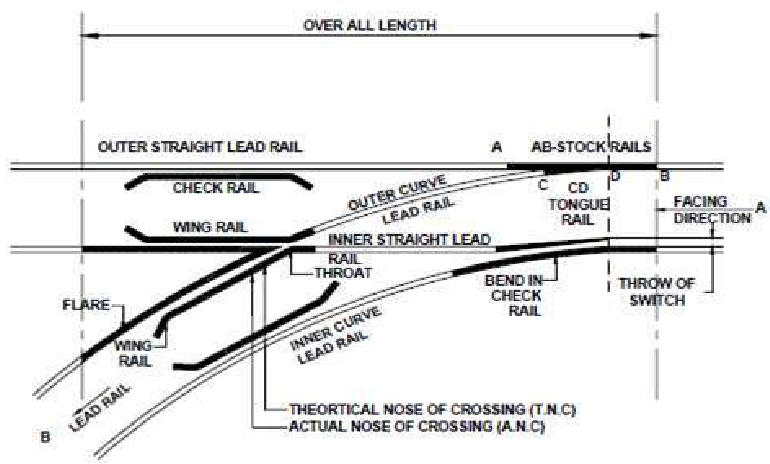
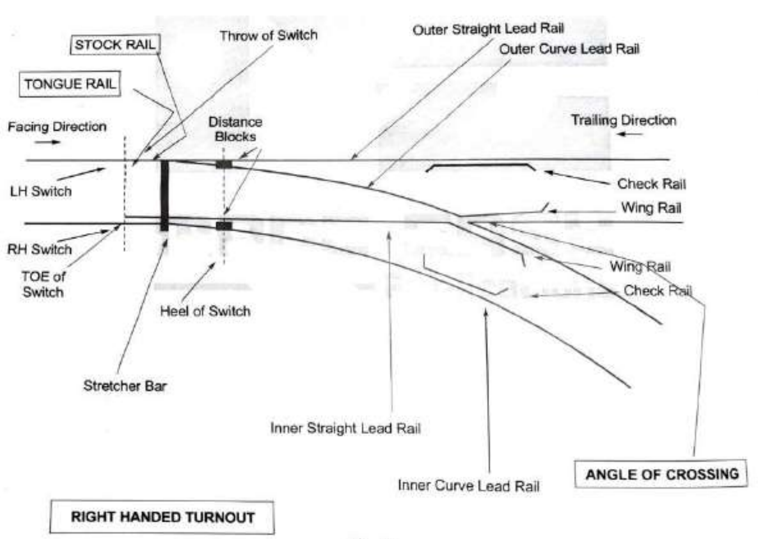


Fig – 8.1 (Left Hand Turnout)

Fig – 8.2 (Right Hand Turnout)



8.3.2. Working Principle of a Turnout: In Fig. 8.1 as already mentioned, a turnout provides facilities for safe turning of vehicles from one track to another. One turnout provides facilities for turning of vehicles from one direction only not from both the directions of the straight path or route as in case of roads.

A turnout works with the combination of points and crossings. (This consists of mainly a pair of points or switches, four lead rails (2-straight and 2-curved lead rails), two check rails and a crossing.

8.3.3. A Pair of Switches: Each of which consists of a tongue rail and stock rail. A tongue rail is tapered having toe at one end & heel at the other end. This is fixed at heel end to regular alignment and can be moved about this point so that in one position (e) it leaves a gap with alignment and permits the trains to go along the straight alignment and in other position it leaves a gap with alignment & permits the trains to go along the straight alignment and in other position the toe fits closely against the straight alignment & track can thus be diverted to some other track (i.e., branch line or a siding). The position of the straight alignment against which the tongue rail fits is known as the stock rail. Two such switches are fixed to either rail, the tongue rails move together so that the route can be set for one line (i.e., main track) or the other (i.e., branch line or a siding).

8.3.4. A crossing (one-piece): It is connected with the ordinary rails (known as lead rails) so as to permit the two rails to cross each other. Check rails are provided on the opposite sides of the crossings for guiding one wheel of the vehicle and thus to check the tendency of the other wheel to climb over the crossing. GO is known as the point rail while 10 is known as the splice rail. The point where these rails meet is known as the 'Nose of Crossing'. Wing rails further help in channelizing the wheels in their proper routes.

8.4. Points of 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. 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:

- A pair of stock rails.
- A pair of tongue rails
- Heel block or Distance block.
- Stretcher bars
- Switch tie plate or gauge tie plate.
- Slide chairs or sliding plates
- Studs of stops.

8.5. Crossing:

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.

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

8.5.1. Component parts of crossing:

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

8.5.2. Requirements and characteristics of a good crossing:

- **i.** The assembly of a crossing has to be rigid to stand against severe vibrations which cause loosening of the components. This can be achieved by the following ways:
  - The use of sole plate at turned bolts for connecting the point and splice rails.
  - The foot-flanges of the wing walls should also be rivetted to the sole plate.
- **ii.** The wear on parts of the wing rails, opposite the nose and also of nose itself must be protected. This can be achieved by use of special steel. Alloy steels are generally used for this purpose. The medium manganese steel (i.e., an alloy steel) is used where traffic is light whereas high manganese steel is used where traffic is heavy.
- **iii.** The crossing body should be as rigid as possible and as long as practicable. A short crossing body has a tendency to rock due to heavy loads at one end and lifting of the other unloaded end. This can be achieved by the following means:
  - Extending the flange of the nose and bolting to nose chair.
  - Ramping the wing rails by 3 mm to 6 mm at the top from throat to nose and flushing it to the normal level of the chair.
  - By use of the distance blocks closely touching the web.
  - Maintaining the perfect gauge from toe to heel.
- **iv.** The nose of crossing should have some thickness, from practical considerations.

This thickness varies from 6 mm to 18 mm. In India, the practice is to make this thickness equal to the thickness of web of the rail. In America, standard thickness of 1.25 cm is adopted. The distance between theoretical nose of crossing (T.N.C.) and Actual Nose of Crossing (A.N.C.) for practical purposes is equal to Nosed Actual x Number of crossing.

8.5.3. Type of Crossings. Crossings can be classified as below:

- **i.** On the basis of shape of crossing.
  - Acute angle crossing or "V" crossing or Frog.
  - Obtuse angle crossing or Diamond crossing.
  - Square crossing.
- **ii.** On the basis of Assembly of crossing:
  - Spring or movable wing crossing.
  - Ramped crossing.
  - ❖ **Acute angle:** This type of crossing is widely used. This crossing is obtained when a left-hand rail of one track crosses a right-hand rail of another track or vice versa (Fig. 16.1) If the angle of intersection of the approaching rails is acute angle, it is termed as Acute angle crossing. It consists mainly of point and splice rails, wing rails and check rails.
    - **Point and splice rails:** An acute angle is formed either by a point rail and a splice rail or by combination of two-point rails. These are made of a special steel (i.e. alloy steel such as carbon steel or manganese steel).

- **A pair of wing rails:** These are bent at the ends. One end of the wing rails is connected to lead rails whereas the other end is flared. This flaring is done to facilitate the entry and exit of flange wheels to the gap.
- **A pair of check rails:** These are subsidiary rails parallel to the running rails. They are flared at end for guiding the wheel flanges. They are provided on the opposite sides of the crossing angle to serve the following purposes:
  - **i.** To guide the wheel flanges.
  - **ii.** To prevent wear and rocking of wheels.
  - **iii.** To prevent derailment at level crossings.

❖ **Obtuse angle crossing:** This crossing is obtained when left-hand rail of one-track crosses right-hand rail of another track or vice versa at an obtuse angle. In diamond crossing, a pair of special crossings is used which is called "Obtuse crossing". In case of obtuse angle crossing the long wing, rails do not carry the wheels as in case of acute angle crossing, rather act as check rails.

❖ **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

❖ **Spring or movable crossing:** 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. This type of crossing is used in U.S.A. but in India spring crossing is not favoured because there is a danger of accident in case of spring failure.

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

8.5.4. Important Terms used in Crossings:

i. Theoretical and Actual nose of crossing (T.N.C. and A.N.C.): The point rail is never manufactured to a well-defined sharp point as it would break off under the dynamic action of moving traffic. So, a blunt nose is provided for the point rail. The thickness of blunt nose is usually equal to the thickness of the web of the rail. The thickness of blunt nose varies from 0.6 cm to 1.9 cm with increasing gauge and section of rails. In U.S.A., the thickness of blunt nose is kept 1.25 cm for all the sections.

The sharp imaginary point where the two gauge faces in case of acute angle crossing, or the gauge face and sloping obtuse angle crossing would meet is known as true or theoretical nose of crossing (T.N.C.). All the calculations are made from theoretical or true nose of crossing. As mentioned earlier the distance between T.N.C. and A.N.C. (either acute or obtuse angle crossing) say d_{ta} is given by

$d_{ta} = N \times t$

where,

N = Number of crossings

t = Thickness of the nose of crossing.

ii. **Number of crossing and angle of crossing:** Acute angle crossings are designated by either the angle that the gauge faces make with each other (i.e., angle of crossing) or generally by the number which is represented by 'N.

The number of crossing (N) is defined as the ratio of

$$\frac{\text{The spread at the leg of crossing}}{\text{The length of crossing T.N.C.}}$$

There are three methods of calculating the number of crossings, and value 'N' depends upon the method adopted.