CIVIL ENGINEERING

Railway, Airport, Dock, Harbour and Tunnelling Engineering

Comprehensive Theory
with Solved Examples *and* Practice Questions

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CHAPTER

1

Railway Track

Section - A

1.1 INTRODUCTION

- Railway engineering is a branch of civil engineering that deals with the design, construction and maintenance of the railway track for safe and efficient movements of the rail transport system (trains).
- The railway is a rapid, reliable and very huge transportation system.

1.1.1 Advantages of Railways

- Due to railways, industrial development is possible, increasing the land values & standard of living of the people.
- During famines, railways have played a vital role in transporting food & clothing to the affected areas.
- Commercial farming is very much helped by the railway network throughout the country.
- Speed movement of commodities is possible through railways.
- Railway provides a convenient & safe mode of transport throughout the country.
- Railways have helped in the mass migration of the population.
- With an adequate network of railways, the central administration has become easy & effective.

1.2 RAILWAY TRACK

- Railway track is a combination of rails, fitted on sleepers and resting on ballast and subgrade.
- Essential function of railway track is to support and guide the vehicles that run over it.
- The conventional railway track consists of two rails located at fixed distance apart. The pressure exerted over by the rails is in turn transmitted to the formation with the help of sleepers and ballast.
- Railway track is also known as permanent way.
- The name permanent way is given to distinguish the final layout of the track from temporary tracks. Temporary tracks are laid for conveyance of earth and materials during construction works.
- In a permanent way, rails are joined in series by fish plates and bolts and then they are fixed to sleepers by different types of fastenings.

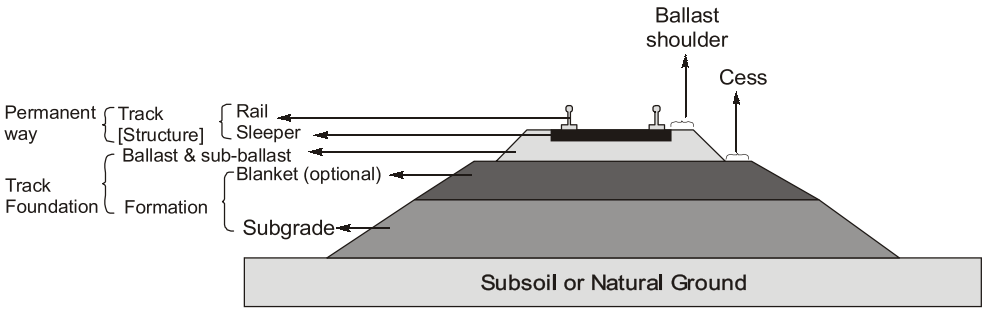


Fig. Typical cross-section of a permanent way on embankment

- The sleepers properly spaced, resting on ballast, are suitably packed and fixed with ballast.
- This layer of ballast rests on the prepared subgrade called the formation.

1.3 REQUIREMENTS OF AN IDEAL PERMANENT WAY

Following are the basic requirements of an ideal permanent way

(i) The gauge should be uniform and correct.
(ii) Both the rails should be at the same level in a straight track.
(iii) On curves, proper superelevation should be provided to the outer rail.
(iv) Track should have enough lateral strength.
(v) Track must have certain amount of elasticity.
(vi) Radii and superelevation, provided on curves, should be properly designed.
(vii) All joints, points and crossings should be properly designed.
(viii) Drainage system should be perfect.
(ix) It should have adequate provision of easy renewals and repairs.
(x) The components of track i.e., rail, fittings, sleepers, ballast must fully satisfy requirement for which they are provided.

1.4 LOAD TRANSFER ON A RAILWAY TRACK

- All the components of a Permanentway are required to transfer the rolling load of the train to the subgrade while maintaining the proper position.
- Rail acts as girders to transmit wheel load to sleeper.
- Sleeper holds the rail in correct alignment and transmit the load to ballast.
- Ballast distributes load over formation known as subgrade and finally to natural soil on ground.

NOTE

Survey required before laying railway track:
- Traffic survey- Types of train, type of gauge required, future and present traffic.
- Reconnissance survey- Rough survey (Topography, waterbodies, road network).
- Preliminary survey- Instrumental analysis of recase survey and a rough estimate.
- Final location survey- Final work allocation, final estimate, centre line of track.

1.5 GAUGE OF RAILWAY TRACK

The gauge of a railway track is the clear distance between the running or gauge faces of the two rails.

NOTE: These running faces are the inner faces of the rails in India.

Some of the common types of gauges are as follows:

(i) Broad Gauge (BG) → 1676 mm (5 ft. 6 inches)

(ii) Metre Gauge (MG) → 1000 mm (3 ft. 3.375 inches)

(iii) Narrow Gauge (NG) → 762 mm (2 ft. 6 inch) 610 mm (2 ft.)

(iv) Feedergauge → 692 mm

(v) Standard gauge → 1435 mm

(vi) Cape gauge → 1067 mm

A larger gauge has the advantage of greater traffic capacity, speed and safety. However, it requires flatter gradients and curves.

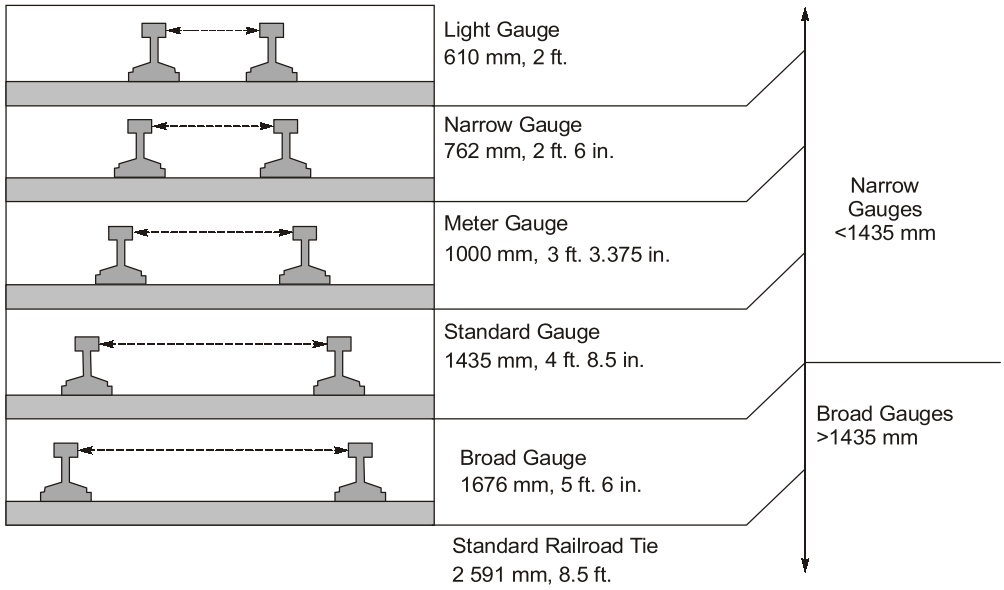


Fig. Gauges of Railway Track

NOTE

Small lengths of standard gauge (1435 mm) are used in India for individual projects and short line lengths.

For example: Delhi Metro Rail Corporation.

- On important section in India, Broad Gauge is preferred.
- Gauge should be uniform throughout as far as possible in a country.
- Because transshipping passengers and goods from vehicles of one gauge to another is a cumbersome task.

Factors responsible for selection of gauge are as follows:

(i) Cost of construction
(ii) Volume and nature of traffic
(iii) Development of under developed area
(iv) Physical features of the country
(v) Speed of vehicle movement

1.6 CONING OF WHEELS AND CANTING OF RAILS

1.6.1 Coning of Wheels

- The tread or rim of railway vehicles are not made flat but are sloped and this sloping surface along the circumference forms part of a cone (with a slope of about 1 in 20). This is known as coning of wheels.
- On straight and level track, the wheel remains central and circumference of treads of both wheels are equal.
- On the level track as the axle moves towards one rail, the diameter of wheel tread over the rail increase while it decreases over the other rail. This prevents the further movement of axle and it retreat back to original position with equal diameters and equal pressure on both rails.

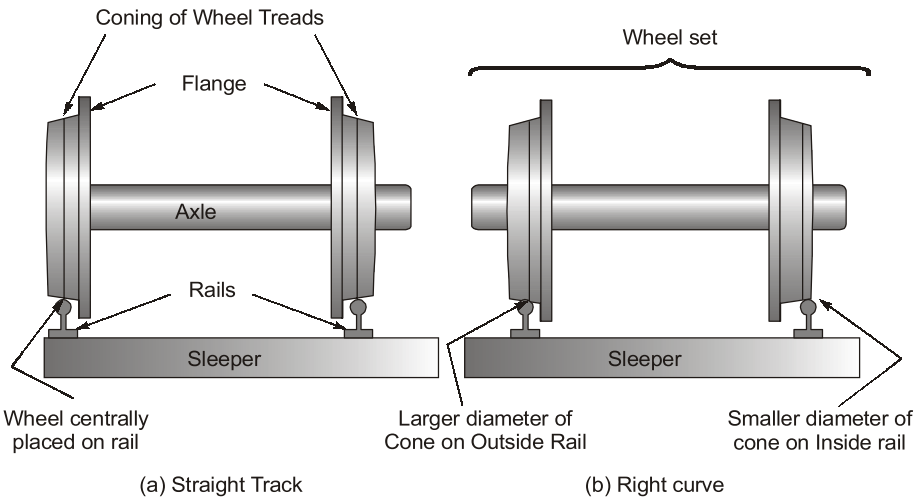


Fig. Coning of Wheels

- On curved track, outer wheel has to travel greater length than the inner wheel. Vehicle on a curve has the tendency to move sideways towards the outer rail, so the circumference of the tread on the outer rail towards inner edge of the wheel becomes greater than that on the inner rail. This helps outer rail to cover a greater distance than the inner rail.
- Conicity of wheel is the angle between wheel tread and horizontal axis of axle.

1.6.2 Advantages of Coning of Wheel

- It helps vehicle to negotiate curves smoothly.
- It keep the train just in central position in a level track.
- It provide for possibility of lateral movement of axle with its wheels.
- It prevent wheels from slipping to some extent.
- It reduces wear and tear of the wheel flanges.

1.6.3 Disadvantages of Coning of Wheel

- The pressure of the horizontal component of the force near the inner edge of the rail has a tendency to wear the rail quickly.
- The horizontal component of the force tends to turn the rail outwards and hence the gauge is widened sometimes.
- If no base plates are provided, sleepers under the outer edge of the rail may get damaged.

1.6.4 Canting of Rails

- In order to minimize the disadvantages due to coning of wheels, canting of rails is done which means that rails are not laid flat but are tilted inwards.
- This reduces wear of the rail as well as of the tread of the wheel.
- The slope of the base plate is 1 in 20 which is also the slope of the wheel flange.
- Tilting of rails can be achieved by
  (i) Adzing of sleepers
  (ii) Use of canted base plate

1.6.5 Adzing of Sleepers

- A groove (having angle of 1 in 20) is being cut on the top of the sleepers. The rail is being seated into this groove in such a manner that it remains fixed in this location.
- This sort of angle making in sleepers so as to seat the rail is known as adzing of sleepers.

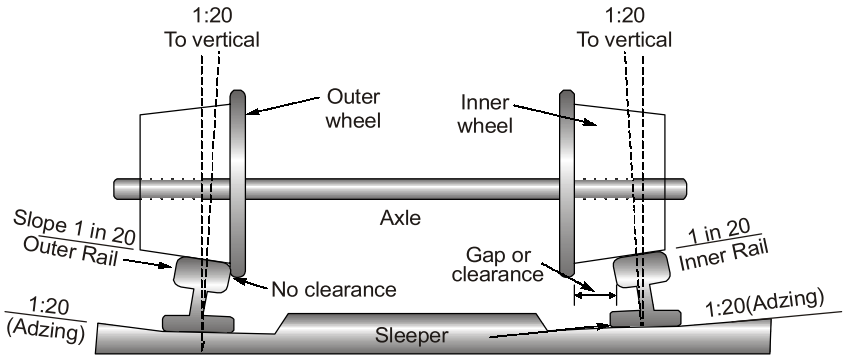


Fig. Adzing of sleepers

OBJECTIVE BRAIN TEASERS

Q.1 Which of the following factors govern the choice of the gauge?
(i) volume and nature of traffic
(ii) speed of train
(iii) physical features of the country
(a) only (i) (b) both (i) and (ii)
(c) both (ii) and (iii) (d) (i), (ii) and (iii)

Q.2 For developing thinly populated areas, the correct choice of gauge is
(a) Broad Gauge (b) Metre Gauge
(c) Narrow Gauge (d) any of the above

Q.3 The formation width for a single line metre gauge track in embankment as adopted on Indian Railways is
(a) 4.27 m (b) 4.88 m
(c) 5.49 m (d) 6.10 m

Q.4 The side slope of embankments for a railway track is generally taken as
(a) 1 : 1 (b) 1.5 : 1
(c) 2 : 1 (d) 1 : 2

Q.5 The formation width for a double line Broad Gauge track in cutting (excluding drains) as adopted on Indian Railways is
(a) 6.10 m (b) 8.84 m
(c) 10.21 m (d) 10.82 m

Q.6 The tread of wheels is provided an outward slope of
(a) 1 in 10 (b) 1 in 15
(c) 1 in 20 (d) 1 in 25

Q.7 Wheels of rolling stock are provided flanges on
(a) outer side (b) inner side
(c) both sides (d) neither side

Q.8 Coning of wheels is provided
(a) to check lateral movement of wheels
(b) to avoid damage to inner faces of rails
(c) to avoid discomfort to passengers
(d) All the above

Q.9 For providing the required tilt of rails, adzing of wooden sleepers, is done for
(a) bull headed rails
(b) double headed rails
(c) flat footed rails
(d) any type of rails

Q.10 Check rails are provided on inner side of inner rails if sharpness of a B.G. curve, is more than
(a) 3^o (b) 5^o
(c) 6^o (d) 8^o

Q.11 The rail section which is not used on Indian Broad Gauge tracks, is
(a) 35 R (b) 40 R
(c) 45 R (d) 55 R

Q.12 The rail section which is not used on Indian metre gauge tracks, is
(a) 25 R (b) 30 R
(c) 35 R (d) 40 R

Q.13 In India the rails are manufactured by
(a) open hearth process
(b) duplex process
(c) both (a) and (b)
(d) neither (a) nor (b)

Q.14 In Indian railways, the ratio of axle load and weight of rail, is
(a) 312 (b) 412
(c) 512 (d) 600

Q.15 Match **List-I** (Railway zone) with **List-II** (Headquarters) and select the correct answer by using codes given below the lists:

List-I	List-II
A. N.E.R.	1. Calcutta
B. E.R	2. Gorakhpur
C. S.C.R	3. Maligaon (Guwahati)
D. N.E.F.R	4. Secunderabad

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	2	1	4	3
(c)	3	2	1	4
(d)	4	3	2	1

ANSWER KEY

1. (d)	2. (c)	3. (b)	4. (c)	5. (c)
6. (c)	7. (b)	8. (d)	9. (c)	10. (d)
11. (b)	12. (d)	13. (c)	14. (c)	15. (b)

■■■■

CHAPTER

2

Rails

2.1 INTRODUCTION

- Rails on the track can be considered as steel girders for the purpose of carrying axle load.
- Rails are made of high carbon steel to withstand wear and tear.
- Rails are member of a railway track laid in two parallel lines.
- Rail converts the rolling (moving wheel) loads of Train into point load, which acts on the sleepers.
- Sleepers convert this point load into distributed load.

2.1.1 Functions of Rails

Rails serves the following purpose

(i) Provides a continuous and levelled surface (for movement of heavy axle loads, in order to avoid hazardous condition due to induction of stresses or moments).

(ii) Provides a smooth surface (to keep friction between the rails and wheels to a minimum).

(iii) Bears the stresses due to heavy vertical loads, lateral forces, breaking forces and thermal effect (rails should be able to bear the stresses without failure).

(iv) Should transmit load to a greater area below (load is transmitted from rail to sleeper and consequently reduces pressure on ballast and formation below).

(v) Provides a material which resist wearing out and failure.

2.1.2 Composition of Rail Steel

- In India, Rails are generally made by open hearth process or duplex process.
- Rail steel is composed of Carbon, Manganese, Silicon, Sulphur and Phosphorus.
- For ordinary rail, high carbon steel is used.
- For rails on points and crossings, medium carbon steel and high manganese steel is used.

2.1.3 Requirements of Rails

Rail should meet the following requirements:

(i) Proper composition of steel

(ii) Sufficient vertical and lateral stiffness.

(iii) Deep and hard wearing surface of head.

(iv) Sufficient web thickness.

(v) Sufficient foot thickness and foot width.

(vi) Balanced distribution of material of rail in head, web and foot.

(vii) Centre of gravity of rail section should be approximately at mid-height.

(viii) Sufficient fillet radii.

(ix) Tensile strength of rail piece > 72 kg/m^2

(x) Rail specimen should satisfy "Falling Weight Test" or "Tup Test".

2.2 RAIL SECTIONS

2.2.1 Types of Rail Sections

The types of rail section which have been tried so far for constructing railway tracks are as follows:

(i) Double headed rails (D. H. Rails)

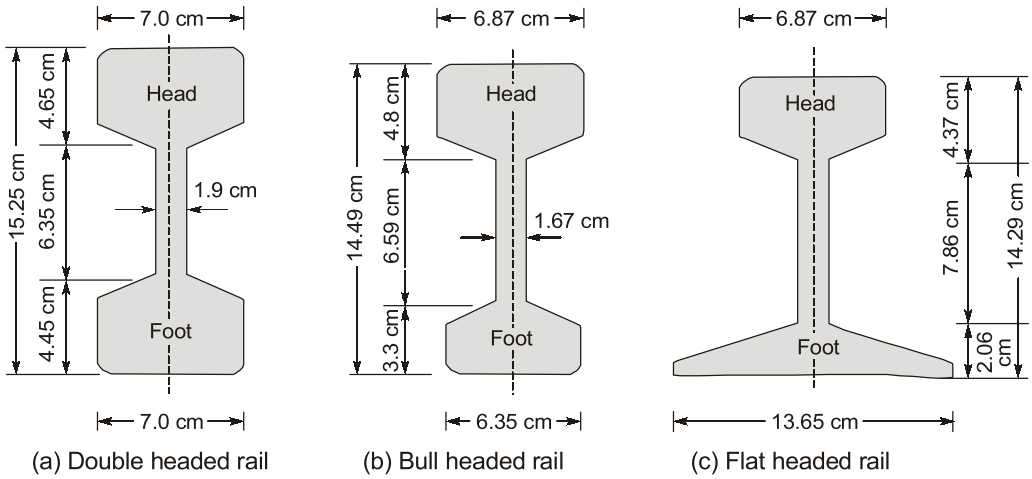
- These rails indicate the early stage of development.
- It mainly consists of three parts (a) Upper table (b) Web (c) Lower table
- Both upper tables and lower tables were identical
- When upper table gets worn out, then the rails can be inverted and reused.
- This type of rail is practically out of use in Indian Railways.

(ii) Bull headed rails (B. H. Rails)

- The next evolution was that of bull– headed rails.
- It mainly consists of three parts (a) Head (b) Web (c) Foot
- Head has larger size than foot. So that even after wear, it can withstand stresses.
- Foot is designed only to furnish necessary strength and stiffness to rails.
- Bull headed rails are especially used for making points and crossing.

(iii) Flat footed rail (F. F. Rails)

- These rails are also called Vignole's rails after the name of inventor.
- It consists of three parts (a) Head (b) Web (c) Foot
- The foot is spread out to form a base (as the name "Flat Footed" suggests)
- About 90% of the railway tracks in the world are laid with this form of rails.
- In India, flat footed rails are most commonly used.



(a) Double headed rail (b) Bull headed rail (c) Flat headed rail

Fig. Types of Rail Sections

Advantages of Flat Footed Rails:

- No requirement of chairs or keys (as the foot of the rail is directly spiked to the sleepers)

- This form of rail is stiffer both vertically and laterally then the full headed rail of equal weight.
- Less liable to develop kinks (maintain a more regular top surface than the full headed rails)
- More cheaper than the B.H. Rails
- Distributes the train load over a large number of sleepers (this results in greater track stability)

Disadvantage of Flat Footed Rails:

- Due to impact of rolling wheel loads, fitting get loosened more frequently.

2.2.2 Details of Standard Rail Section

Types of sections in use

(i) British Railways (RBS sections–Revised British Standard specification)
  (a) 75R (75 lbs/yd) (b) 90R (90 lbs/yd)
  (c) 115R (115 lbs/yd)

(ii) Indian Railways
  (a) 60 kg/m (UIC section–Union International des Chemins de fer or International Union of Railways) — suitable for speed upto 160 kmph.
  (b) 52 kg/m (IRS section–Indian Railway Standard) — suitable for speed upto 130 kmph.

NOTE

- In India, standard length of rails are 12.80 m for B.G. and 11.89 m for meter gauge.

	Area	UTS	GMT	Speed
52 kg/m	6615mm^2	710 MPa	20-25	130kmph
60kg/m	7686mm^2	880 MPa	35	160kmph

GMT → Gross million tonne/year/km.

IRS	52	720	SAIL	XI	19	OB
Indian Rail section	Section	UTS	Brand	Month	Year of manufacture	Manufacturing process

Types of sections in use in India

(i) Rail section in use on BG
  (a) 60 kg/m [UIC] (b) 52 kg/m [IRS]
  (c) 90R (90 lb/yd ~ 45 kg/m) [RBS]

(ii) Rail section in use on MG
  (a) 90R (90 lb/yd) (b) 75R (75 lb/yd)
  (c) 60R (60 lb/yd)

(iii) Rail Section in use on NG
  (a) 50R (50 lb/yd) (b) Length-12 m

NOTE

- Rails of larger length are preferred to smaller length of rails as it gives more strength economy and lesser number of joints between two rails.
- **Thumb Rule:** The relationship between weight of rail and heaviest axle load, which rails have to carry follows: [Maximum axle load = 560 x sectional weight of rail (in lbs/yd or kg/m)]

2.2.3 Selection of Rails

Various considerations in selection of a rail section

(a) Gauge of track
(b) Heaviest axle load
(c) Maximum permissible speed
(d) Type and spacing of sleepers
(e) Depth of ballast cushion
(f) Maximum permissible wear on top of rails (5% of weight of rails is allowed)

2.3 WEAR IN RAILS

- Wear is one of the prominent defects of the rail.
- Wear of the surface of the rail means either the top of the rail head or side of the rail head or end of the rail head gets removed.

2.3.1 Major Reasons of the Wear

- Extraordinarily large load
- High speed trains
- Concentrated load which are exceeding the elastic limits of the rail section.
- Gap at the rail joints.
- Slipping, skidding or striking of flanges on curves.

2.3.2 Classification of Wear

Classification of wear can be done on the following basis:

(i) Based on location through which rail passes

Following are certain specific location along the track which may induce the wearing of the rail section:

(a) Sharp curves (due to application of centrifugal force in the outward direction)
(b) Steep gradients (when train is going up, extra effort is required in pulling while in going down, extra effort is required in pushing)
(c) Approaches to station (due to braking or acceleration)
(d) In tunnels and coastal areas (due to humidity and weather effect)
(e) Weak foundations (deformations of rails due to heavy load)

(ii) Based on position of wear

On the basis of position, wear can be at the top of the rail head, or side of the rail head or end of the rail head.

(a) Wear at the top of the rail head

- Flow of metal (concentrated stress exceeds the elastic limit and hence the plastic flow of metal)
- Rubbing action on the top of the rail head (because of movement of rolling stock at that section)

- Abrasive action/corrosive action
  (Abrasive → due to rubbing action of different types of material)
  (Corrosion→ due to the effect of weather or chemicals)
- Improper superelevation/centrifugal force (due to unbalanced forces on the inner and the outer rail section, there will be more stress at one location compared to another location, leading to wearing)
- Slipping of wheels on curves.
- Fluctuations in tracks (creates surface irregularities leading to discontinuity in the contact between wheel and rail and hence wearing occurs)
- Lack of provisions of adzing of sleepers
  (leads to striking behaviour at the point of contact between wheel and the rail section)

(b) Wear at the side of the rail head

- Rigidity of wheel base (due to striking of the wheel flange on the inner side of the outer rail and inner side of the inner rail at the leading section or the trailing section leading to wear)
- Slipping/skidding of wheel on curves (wheel tries to slip to the equilibrium condition towards average diameter of the wheel leading to wear)
- Greater thrust on inner rail (due to speed lesser than the equilibrium speed)

(c) Wear at the end of the rail head

- Loose fish plates, fish bolts (due to relative movement of the rail sections, there is a striking behaviour of wheel on rail head)
- Heavy load at high speed (impact transferred at the end of the rail head will be high)
- Effect of wide joints and openings (there is more contact between the wheel and the forward rail leading to wearing)
- Difference in rail heights at joints (hogging effect when wheel moves from higher level to lower level; while from lower level to higher level, movement of the rail section is in forward direction due to horizontal component of the force)

2.3.3 Permissible Limits of Vertical Wear

Section	Gauge	Category of track	Lateral wear (mm)
Curves	BG	Group A & B	8
	BG	Group C & D	10
	MG	Q & R	9
Straight	BG	Group A & B	6
	BG	Group C & D	8
	MG	Q	6
	MG	R	8

Measured at a distance of 13-15 mm below the rail top table. Profile of worn-out rail is recorded and superimposed over a new profile to determine lateral wear

2.3.4 Prevention of Wear

Following are the ways of preventing wear:

- Better maintenance of track
- Use of heavier and higher UTS rail sections
- Reducing number of joints
- Use of bearing plates (adzing of sleepers)

- Lubricating gauge face
- Track renewal
- Welding or dehogging of battered ends
- Using check rails on sharp curves
- Interchanging inner and outer rails
- Maintenance of correct gauge

2.4 DEFECTS IN RAILS

2.4.1 Corrugation in Rail (Roaring Rails)

- The minute depression on the rail surface due to application of break or during the start or due to abnormal load is known as corrugation.
- It induces high roaring sounds.
- The corrugated rails should be replaced as soon as possible because minute depressions are spreading in nature.

2.4.2 Hogged Rails

- Due to battering action of wheels over the end of the rails, the rails bent down and get deflected at the ends.
- This hogging at ends is due to loose packing under the joints and/or loose fish plate.

Remedial Measures

- Hogged ends are cut-off and fresh holes for fixing fish plates are provided — cropping.

  Hogged rails are entirely replaced.
- Deflected ends are brought to level by welding

2.4.3 Buckling of Rails

- It means track has gone out of its original alignment.
- It happens when expansion of rails due to temperature variations is prevented due to insufficient gap at joint so the rails do not get enough space for expansion. This results in widening of the gauges.

Remedial Measures

- Ballast, sleeper and rail sections must be checked for design.
- Providing steel sleeper
- Provision of expansion gap
- Not very strong tightening of fish bolts.

2.4.4 Kinking in Rails

- Due to loose packing of ballast and loose joint, the misalignment of the rail can take place at the joint known as kinking of rail. (In the joint portion)

2.5 WELDING OF RAILS

The welding of rails is carried out in a depot by the “Flash butt welding” process and at site by the “Thermit Welding” process.

In general, there are four welding method:

(i) Gas pressure welding
(ii) Electric arc welding (or metal arc welding)
(iii) Flash butt welding
(iv) Thermit welding

2.5.1 Types of Welded Track

Welded tracks can be classified as short welded rails, long welded rails and continuous welded rails.

(i) Short Welded Rails (SWR)

- It is a welded rail that contracts and expands throughout its length; thus producing excessive thermal stresses.
- Normally 3, 5 or 10 rail lengths are welded together.
- Short welded rails of more than 3 rail lengths produces higher thermal stresses, so these have been limited to 3 rail lengths.
- It has a length upto 130 metres.

(ii) Long Welded Rail (LWR)

- It is a welded rail the central part of which does not undergo any longitudinal movement due to temperature changes.
- A long welded rail continues to expand at its end for a particular length till adequate resisting forces gets developed towards the centre.
- A stage is reached when at a particular length of the rail from its ends, the resistance offered by track structure becomes equal to thermal changes.
- There is no movement of rail beyond this point.
- A length greater than 250 m on B.G. and 500 m on M.G. will normally function as LWR.
- The maximum length of LWR under Indian conditions shall normally be restricted to one block section.
- The length at each end of the LWR (or CWR) which is subjected to expansion/contraction on account of temperature changes is called breathing length.
- An expansion joint installed at each end of LWR (or CWR) to permit expansion/contraction of the adjoining breathing lengths due to temperature changes is called switch expansion joint (SEJ).
- Buffer rails are sometimes provided in place of SEJ at the end of LWR (or CWR).
- It has a length upto 1000 metre.

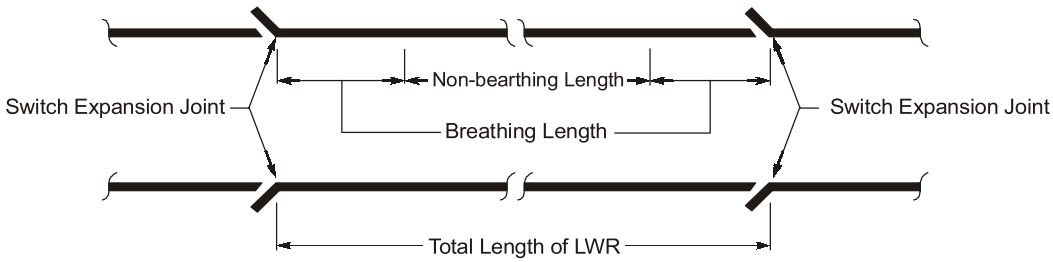


Fig. Long Welded Rail

(iii) Continuously Welded Rails (CWR)

- It is a higher category of LWR.
- It may be of a length greater than 1000 m.