TRACK STRUCTURE

CHAPTER 1

RAILS

1.0 RAILS AND ITS OBJECTIVE

They are steel sections laid in two parallel lines on sleepers to form a track on which trains can run. These provide:

(i) Firmly held smooth passage for heavy wheels to roll upon, with a minimum amount of friction between the steel wheels and the smooth steel rails.

(ii) The section of the rail should be able to bear the stresses caused by the heavy moving loads economically.

(iii) The material of the rail should be such as to provide minimum possible wear to reduce replacement costs.

Note : Ideal steels for rails and wheels are the ones that achieve even rate of wear both on rail and wheels. Too large a differential in hardness between rails and wheels lead to a very large rate of wear on the less hard component.

1.1 Gauge

Distance between inner faces of the two parallel rail heads is called "gauge". Following gauges exist on Indian Railways:

Broad Gauge (BG)	:	1676 mm
Meter Gauge (MG)	:	1000 mm
Narrow Gauge (NG)	:	760 mm & 610 mm.

2.0 RAIL SECTION

The original rails were made of dumb-bell or double headed section (See Fig. 1.1), both the heads having the same cross-section. The object of this type of rails was that when the top head wears off due to rubbing action of wheels, the rails could be inverted and the lower head used. These rails had to be held in vertical position by means of chairs having support on either side. It was found that due to impact, the lower head got dented and hence could not be used as top head by inverting. It was, therefore, found unnecessary to provide the bottom head of the same section as the top head.

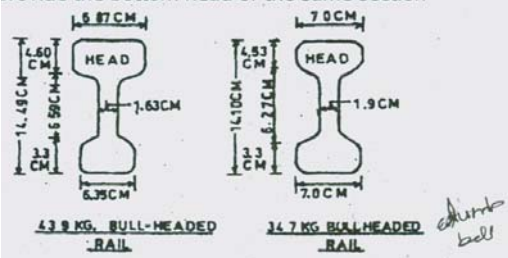

Fig. 1.1 BULL HEADED RAILS

Later, rails were provided with less metal in the bottom head and more in the top head. These were termed as bull-headed rails. The metal in the bottom flange is just enough to bear the stresses caused by moving wheels. This rails also held in position by means of chairs.

Along with the bull-headed rails, a flat-footed rail was developed. This rail could remain in position without the help of chairs by providing direct bearing on sleepers.

Flat-footed sections with the following weights are used Indian Railways:-

	Gauge	Section of Rail (Nomenclature)
Broad Gauge	BG	60 kg
Broad Gauge	B.G	52 kg
Broad Gauge	B.G	90 lbs
Meter Gauge	M.G	90 lbs
Meter Gauge	M.G	75 lbs
Meter Gauge	M.G	60 lbs
Narrow Gauge	N.G	60 lbs

Nomenclature suggests approximate weight (rounded off) in kg/m or lbs/yd.

2.1 Requirements for an ideal rail section

The rail section should be such as to utilize every bit of the material in the section to its maximum use. The requirements of the section are:-

1. The rail should have most economical section consistent with strength stiffness and durability.
2. The Centre of gravity of rail section should preferably be very near to the centre of height of rail so that maximum tensile and compressive stresses are equal.
3. A rail primarily consists of a head, web and foot and there should be an economical and balanced distribution of metal in its various components so that each of them can fulfil its requirements properly. The requirements as well as the main considerations for design of these rail components are given below:

(a) Head

The Head of the rail should have adequate depth to allow for vertical wear. The rail head should also be sufficiently wide so that not only wider running surface is available but the rail has the desired lateral stiffness also.

(b) Web

The web should be sufficiently thick so as to withstand the stresses due to the loads coming on it after allowing for normal corrosion.

(c) Foot

The foot should be of sufficient thickness so as to with-stand vertical and horizontal forces after allowing for loss due to corrosion. The foot should be wide enough so as to be stable against overturning. The design of foot should be such that it can be economically and efficiently rolled.

(d) Fishing Angles

The fishing angles must ensure proper transmission of the loads from the rail to the fish plates. The inclination of the fishing angles should be such that the tightening of the fish plate does not produce any excessive stress in the web of the rail.

(e) Height of the rail

The height of the rail should be adequate so as to have sufficient vertical stiffness and strength as a beam.

3.0 STANDARD RAIL SECTION

The rail is designated by its weight per unit length. In F P. S. unit, it is the weight of rail in lbs per yard and in metric units it is weight in kg per metre. A 52 kg rail denotes that it has a weight of 52 kg per metre.

The weight of a rail and its section is decided on various considerations such as:

(i) Heaviest axle load.
(ii) Maximum permissible speed.
(iii) Depth of ballast cushion.

(iv) Type and spacing of sleepers.
(v) Other miscellaneous factors.

The standard rail sections in use on Indian Railways are 60 kg, 52 kg, 90 R, 75R, 60 R and 50 R.In the nomenclature 90R and 75R etc., R stands for Revised British Specifications.

Branding of Rail

Every rail rolled has a brand on its web, which is repeated at interval such as:

IR - 90R - TISCO - II 1985 - Basic BASSEMER

The abbreviations used indicates

(i) IR : Indian Railways
(ii) 90 R : Weight and type of section; 90 Ibs/yard rails as per Revised British Specifications
(iii) TISCO : Tata Iron and Steel Company
(iv) II 1995 : Month and year of manufacture; Feb. 1995
(v) Basic Bessemer Process of manufacture

As per IRS/T-13-2009, the brand marks are being revised and these will be as follows:

52 kg-880-SAIL-II 1991 - OB

The explanation for various new abbreviations is as given below:

(i) 52 Kg : Weight of Rail section i.e. 52kg/m or any other section.
(ii) 880 : Grade of rail section i.e. 880 or 1080.
(iii) SAIL : Manufacturer's name i.e. Steel Authority of India Ltd.
(iv) II 1991 : Month & year of manufacture.
(v) ➔: An arrow showing direction of top of ingot.
(vi) OB : Process of steel making i.e. Basic Oxygen (o) or any other Process.

The brand marks on the rails shall be rolled in letters at least 20 mm in size and 1.5 mm in height at intervals of 3.0 meters.

3.1 Length of Rail

The weakest part of a track is the joint between the two rails. Lesser the number of joints, lesser would be the cost of maintenance and fishplates. Also increased number of joints increase wear and tear of the vehicle and produce uncomfortable riding. The length of rail should be as long as possible, but is limited by the following two factors:-

(i) Facilities for the manufacture of the rails at reasonable cost, and
(ii) Transportation facilities, which depend upon the longest, wagon available on the railways. This can be overcome by specialized loading arrangements at restricted speed of movement. Length of rail commonly procured by Indian Railways is 13m, 26m,130m and 260m.

3.2 Types of Rail joint

Rail joint can be divided into 7 types as given and discussed below:-

(i) Supported rail joints.
(ii) Suspended rail joints.
(iii) Bridge rail joints.
(iv) Welded rail joints.
(v) Rail free joint.
(vi) Staggered or broken joints.
(vii) Square or even joints.

Supported rail joints are those where the ends of two adjacent rails are supported on a single sleeper directly under the joints these were first obtained by keeping 3 wooden sleepers butting against each other, under the two opposite joints of the parallel rails. The trouble was the difficulty of packing under these sleepers.

The other type of supported joint is, where space is provided between these three sleepers as shown in fig.1.2(A). In this case also when the packing under the outer sleeper gets loose, undue load is brought on the central sleeper and the loose central sleeper converts the joint into a week supported joint. This practice has, therefore, been stopped. The present Duplex joint rail sleepers is an improvement, on this type of rail joint.

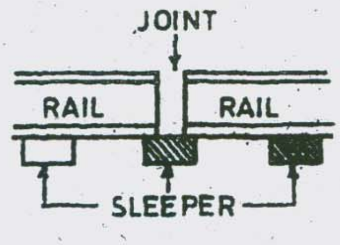

Fig. 1.2 (A) SUPPORTED RAIL JOINT

Suspended rail joints are those at which the sleepers are placed at a distance from the ends of the rails as shown in fig.1.2(B). The ends of each rail therefore, hangs or are suspended between the two sleepers. The suspended joint is commonly used on Indian and Foreign railways.

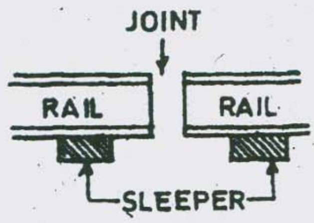

Fig. 1.2 (B) SUSPENDED RAIL JOINT

Bridge joint is similar to suspended joint, but in addition, the foot of the rails at the end is supported on a piece of metal bridging between and resting on the two end sleepers (flg.1.2C). This type of joint is not used on Indian Railways.

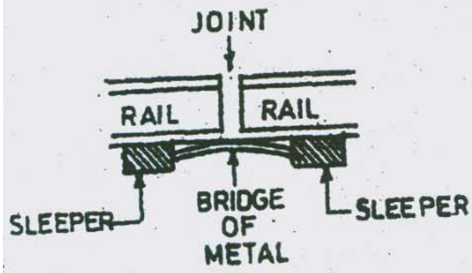

Fig. 1.2 (C) BRIDGE RAIL JOINT

Welded rail joint are the best and have been discussed in a separate chapter.

Rail free joints are those in which the sleeper is free of the rail, i.e the rail is not linked with the sleeper. This is found in case of duplex sleepers which causes a play between the rail and the sleeper. This type of joint is dangerous.

Staggered or broken joint is one in which the joint of one rail of the track is not directly opposite to the joint of the other rail. This is found on curves, where the length of outer curve is greater than the length of inner curve.

Square or even joints is one in which the joint of one rail of the track is directly opposite to the joint of the other rail. This is obtained on straight length of track.

Experiments carried out on Indian Railways have indicated that on comparison of stress produced in rails and fish plates, wooden sleepers could be considered as the best type of sleepers for joints, as they produce comparatively low stresses in rails and fish plates and also put up a good performance from the point of view of deflection, maintenance of gauge and cross-levels. The next in order comes C.S.T 9, steel and duplex sleepers. From the point of view of good track maintenance, duplex sleepers are very good but they are hard on rails. If some suitable elastic pad is evolved, it is possible that duplex sleepers may also be provided a suitable joint support. Duplex sleepers no doubt produce minimum deflection.

Joints should be avoided as far as possible in the following cases-

(i) On level crossings.

(ii) On bridge approaches, within 3m of bridge abutment.

(iii) On short bridge spans of any type.

(iv) Near the Centre or near the ends of long bridge span. The best position for a joint, if provided, is at a point located at one third of the span length.

4.0 RAIL STEEL

4.1 Effect of different elements in medium manganese & 880 grade rails.

4.1.1 Carbon

Carbon, from carbide Fe_3 C is called (cementite). Steel is fully pearlitic, carbon contents are 0.8%. It may be noted that above 0.8% carbon increases hardness, yield point and ultimate tensile strength. Beyond this percentage, it also tends to make steel brittle.

4.1.2 Manganese:

It is used for deoxidizing the molten steel. It has greater affinity for oxygen than Iron. Above 0.8% manganese enables higher tensile strength and better harden ability.

4.1.3 Silicon:

Its presence is used as deoxidizing agent in the production of steel. Presence less than 0.1% in rimmed steels and 0.1% to 0.5% in killed steel does not affect the physical properties of steel to any useful degree.

4.1.4 Phosphorous:

Phosphorous is a harmful element in steel. It makes steel brittle and liable to crack when cold worked. Phosphorous is usually restricted to 0.03%, to increase tensile strength, hardness and yield point.

4.1.5 Sulphur:

It is also deleterious element, it makes steel liable to crack when hot. Sulphur content up to about 0.03% is generally allowed in steels.

The approximate proportion of various elements in different type of steels is as given in the Table.

Elements	**% in 880 Grade Rails.**	**%in Medium manganese (710 Grade Rails)**
Carbon	0.40 to 0.60	0.60 to 0.80
Manganese	0.90 to 1.45	0.60 to 1.30
Silicon	0.03 to 0.30	0.10 to 0.50
Phosphorus (Max)	0.06	0.030
Sulphur (Max)	0.06	0.030
Aluminum (max)	**-**	**0.015**
Hydraogen Contents in liquid steel (max)	3 ppm	1.6 ppm
Hardness (min)	260 BHN	260 BHN

5.0 SIGNIFICANCE OF SOME STIPULATIONS IN INDIAN RAILWAY STANDARD SPECIFICATION IRS-T-12 FOR MANUFACTURING OF FLAT BOTTOM RAILS:

5.1 Steel making process

Rails are to be made out of steel processed in open hearth (acid or basic or duplex process. Duplex process is a combination of two processes and in India is acid Bessemer and Basic open hearth),basic oxygen or electric arc furnace process and continuously cast. Any other method of casting should have prior approval of the purchaser.

In case of steel made by electric arc furnace process, secondary ladle refining is mandatory. The manufacturer should be asked to furnish details of the steel making process including refining, vacuum degassing control cooling of blooms/rails, etc.

Any national specification should reflect the practice prevalent in that country. In India, the processes mentioned above are the ones, which are used for making steels for rails. The specification therefore, mentions these processes. Provisions have also been made to approve other suitable processes, which come up in the country in future.

5.2 Chemical Composition

IRS.T.12 stipulates 4 grades of rail, viz.880, 1000, 1080(Cr) and 1080 (H.H) rails. The grade being its minimum UTS in Mpa. The percentage elongation prescribed is 10% (Minimum) for all the three grades. The steel for rail should be of fully killed quality.

5.3 Freedom from defects

The specification requires that rails shall be free from harmful internal and external defects. Pipe, heavy segregation and inclusions are internal defects and have their origin in the steel making process. External defects are seems, laps, shatter cracks, deep guide marks, pits, etc. and these originate in the rolling process.

5.4 Falling weight test

This test is carried out on the rail rolled from that portion of the ingot nearest the pipe. The rail is held between two supports at specified distance. A tub of specified weight is allowed to drop from a specified height. The blow should not result in cracking or fracturing of the rail piece.

The test is primarily intended to ensure that the rail is not in any way brittle and is sufficiently tough.

5.5 Tensile Test

The tensile test included in the specification is to determine the tensile properties of the steel in accordance with the requirements of IS:1608-1972. The test is carried out to ensure that the rail steel is having the tensile strength and the percentage elongation depending upon the grade of steel.

5.6 Controlled Cooling

This is for ensuring against shatter cracks in rails, since shatter cracks are primarily responsible for transverse fissure type of defects in service. Transverse fissures are dangerous because these commence from the inside of the head and failure invariably occurs before their traces appear on the outside surface of the rails.

Also the same rail may develop transverse fissure at a number of places and all the rails made from the same heat may develop this defect.

6.0 DEFINITION OF WELDING OF RAILS

According to American Society of welding, welding is a localized coalescence of metal which is produced by heating to suitable temperature, with or without the use of filler metal. The filler metal either has a melting point approximately the same as the base metal or below that of the metal. Heating to suitable temperature is compulsory but either pressure or filler metal only is required.

On Indian Railways, welding of rails is carried out extensively by two processes, viz. Thermit welding and Flash Butt Welding (these are proposed to be discussed in separate chapter subsequently).

7.0 CREEP OF RAIL

It is a longitudinal movement of rails in the track. Creep takes place on every track but is considerable in some localities (moving several inches in one month) and negligible in other place:

The causes of creep are not yet well defined. Three theories are put forward to account for creep. They are discussed below:

(i) Wave action or wave theory: Due to the moving loads, waves are formed in the rail along with the depression of the rail. As the wheel moves, the lift in front of the moving wheel is carried forward while the lift at the rear of the wheel gets back to its normal position. The rail thus moves forward with the train.

The pitch and depth of the wave depends upon the track modulus, increased stiffness of track and stability of formation. Angular ballast which develops goods interlock when provided in enough quantity reduces wave action. Wave action is further reduced with lesser sleeper spacing and bigger section of rail. Its is further argued that the wave action is partly or fully arrested at the joint.

(ii) Percussion theory: This theory attributes creep to the shock of the wheel at the joints. As the wheel leaves the trailing rail and strike the facing rail-end at each joint, it pushes the rail forward. This action increases when fish bolts are loose and weak, or fish plates are worn out or there is loose packing at the joint or there is too much of expansion gap.

(iii) Drag theory: It states that the backward thrust on driving wheel of the locomotive of train tends to push the rail of the track backward; the other wheels of the locomotive and the vehicles push the rail in the direction of travel as explained in wave theory above and they have a greater effect. This results into creep of rails in the direction of motion.

(iv) Accelerating, decelerating, starting and stopping: When a train is accelerating or starting, the backward thrust on the driving wheels of the locomotive pushes the rails backwards. When the train is slowing down or coming to a stop, the braking effect pushes the rails forward.

(v) Expansion and contraction of rails: This is caused by temperature variation and is found to encourage creep. It has been noticed that creep is:-

(a) Greater on curves than on tangent lengths,

(b) Normally in the direction of downward grade,

(c) Normally in the direction of heaviest traffic, e.g. from the production centers to the markets.

(d) Varying in amount and direction from time to time on the same track. Also both the rails do not creep by the same amount sometimes they creep in opposite directions. Such variations are daily or seasonal.

7.1 Effect of creep

Creep affects the track in the following manner:-

(i) The sleepers move out of square and out of position affecting the gauge and alignment of track

(ii) Due to sleepers moving out of position, bad riding results. Also there is disturbance in sleeper spacing.

(iii) Rail joints open and produce heavy stresses in fish plates and bolts. The bolts sometimes break. Also the rail joints become supported instead of suspended.

(iv) Due to rail joints opening out, expansion gap become irregular with excessive gaps in expansion, joints at some places while joints in other places get jammed, preventing expansion.

(v) Points and crossing get distorted and they go out of gauge and alignment. The movement of switches is made difficult and interlocking is thrown out of gear. Proper precautions are especially necessary at points and crossings.

7.2 Prevention of Creep

If creep is not prevented, it may cause derailment, following are the methods adopted to prevent creep:-

(i) Pulling back: When creep has set in, the rails are pulled back to their original positions by means of crow bars and hooks provided through the fish bolt holes of the rail. It has been noticed that rails start creep immediately after pulling back.

(ii) Providing steel sleeper: Sleeper should be of such a type and with the fittings that they prevent the rails from creeping of them. Secondly the sleepers must have a good grip in the ballast. Steel trough sleepers are the best of this purpose. Increase in the number of sleepers will also therefore, help in the prevention of creep.

(iii) Providing anchors or anti-creepers: They are fastened to the foot of the rails and are in absolute contact with the side of the sleeper on the side opposite to the direction of creep. If creep is taking place in both directions, anti-creepers are provided on both the sides of the sleeper. The number of anti creepers depends upon the amount of creep and varies from two to twice the number of sleepers for each rail. There are various types of anchors in use on the railways. They are fixed either by wedge action or by clamping or by spring clip (see fig. 1.3)

(iv) Providing efficient maintenance, clean & more ballast: In station yard and approaches to station yards, provision of anchors is to be seriously considered. This is because there are number of points and crossing, and also there is acceleration and deceleration of speed in station yards and approaches to station yards.

7.3 Rail Joints

Rail joints form the weakest part of the track. The strength of a rail joint is about half the strength of a rail. A perfect rail joint is one which provides the same strength and stiffness as any other section on the track. As far as possible the rail joint should satisfy the requirements given in para 7.4 below.

7.4 Requirements of rail joints

(i) They should remain true in line both laterally and vertically, when load is applied. This will prevent the wheel jumping or changing its direction of motion.

(ii) It should be as strong as the rail.

(iii) It should be elastic as other portion of the track; because any change in elasticity will affect the transmission of wave in the rail, resulting into an impact on the joint.