Transportation Engineering

Course Code –CE-422

Contact Hours -3+3

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Rails

- Rails provide a smooth path for the movement of trains at high speed.

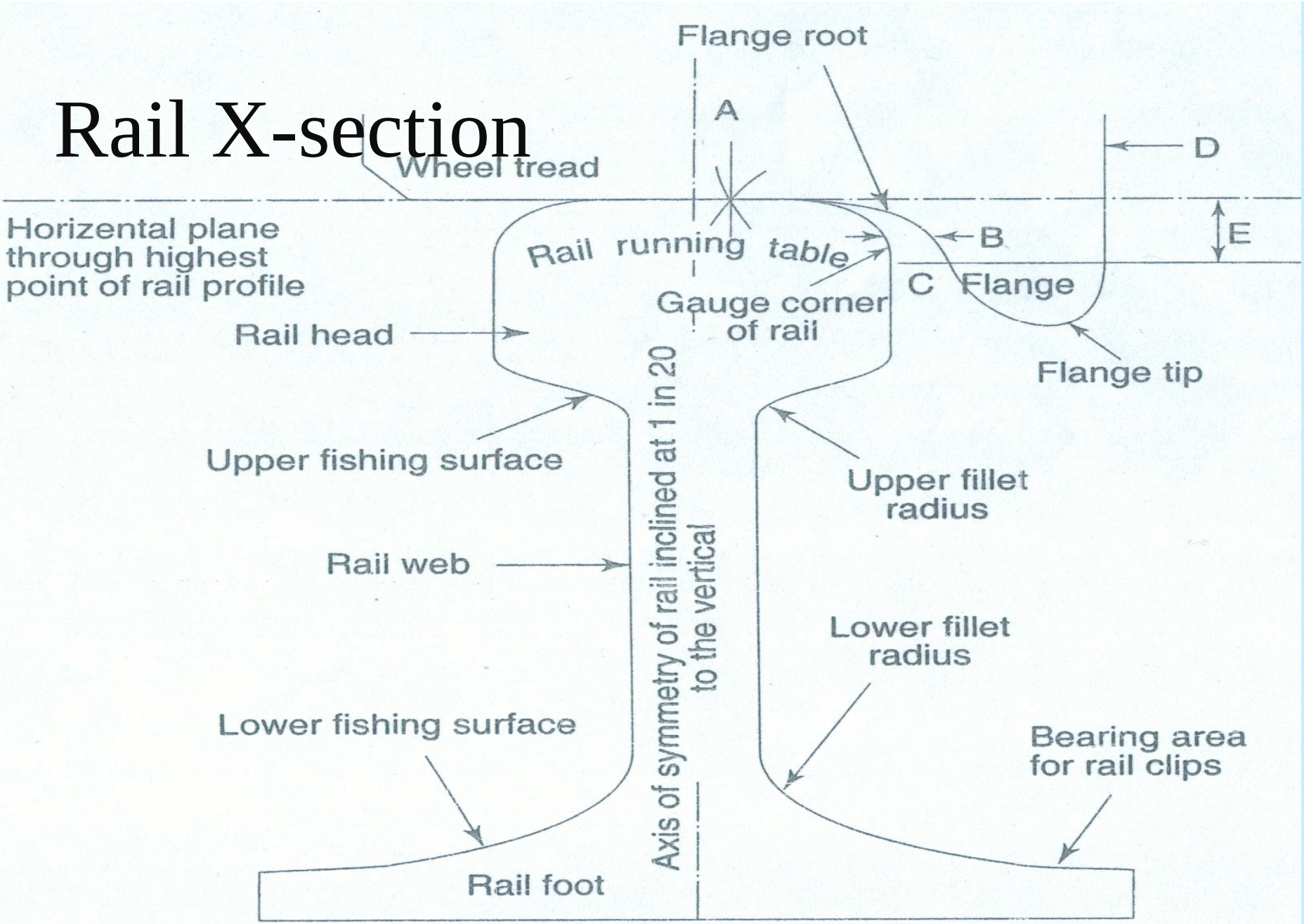
Functions of Rails

- The rails provide a level, smooth and continuous surface for the movement of trains.
- The friction between the wheels of the train and the rail is about 20% of the friction between the pneumatic tyres and the roads.
- The rail serves as a lateral guide for the running of wheels.
- The rail bear the stresses developed due to
  - vertical loads transmitted to it through axles
  - wheels of the rolling stock, due to braking forces and thermal stresses

Functions of Rails

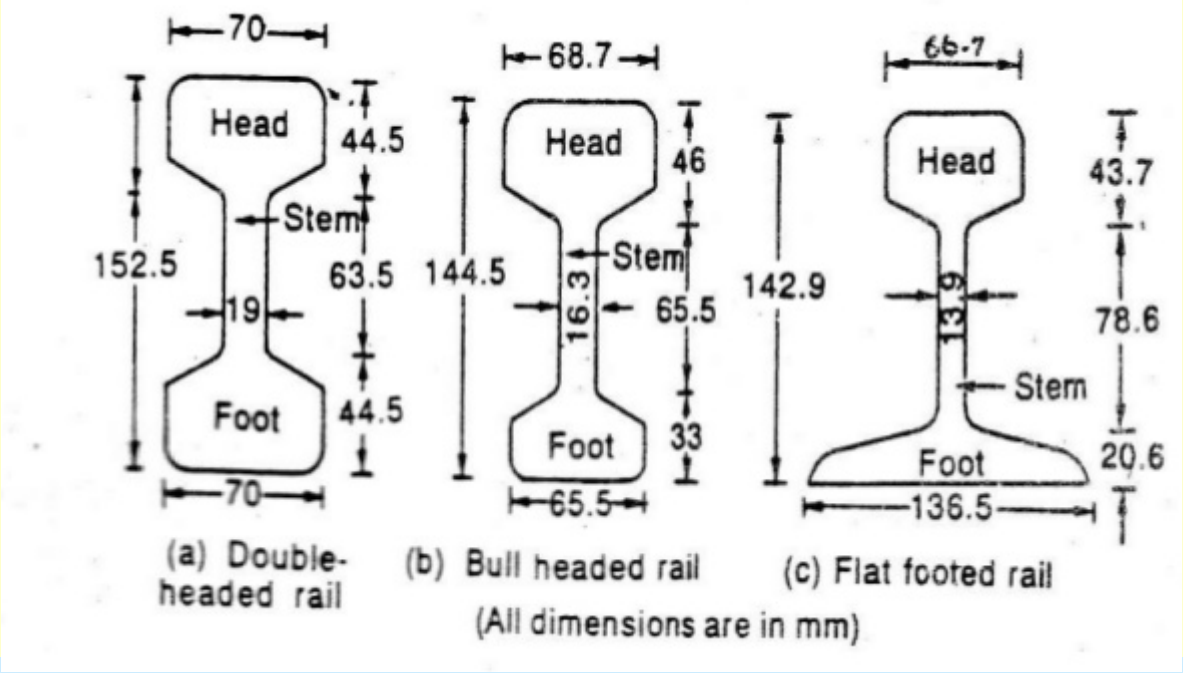
- The rail transmits the heavy load of the rolling stock etc. to the larger area of the formation through sleepers and ballast.
- Distribute the load over wider area of the ballast

Rail X-section



Types of Rail Section

- Double Headed
- Bull Headed
- Flat Footed



Double Head

- The original rails used were double headed made of I section or dumb-bell section.
- The idea being that when the top of the double headed rail was worn, the rail could be inverted and re-used.
- Such rails are supported on chairs, which rest on sleepers.
- It was found that the lower head was dented by the chairs and could not be re-used

Double Headed

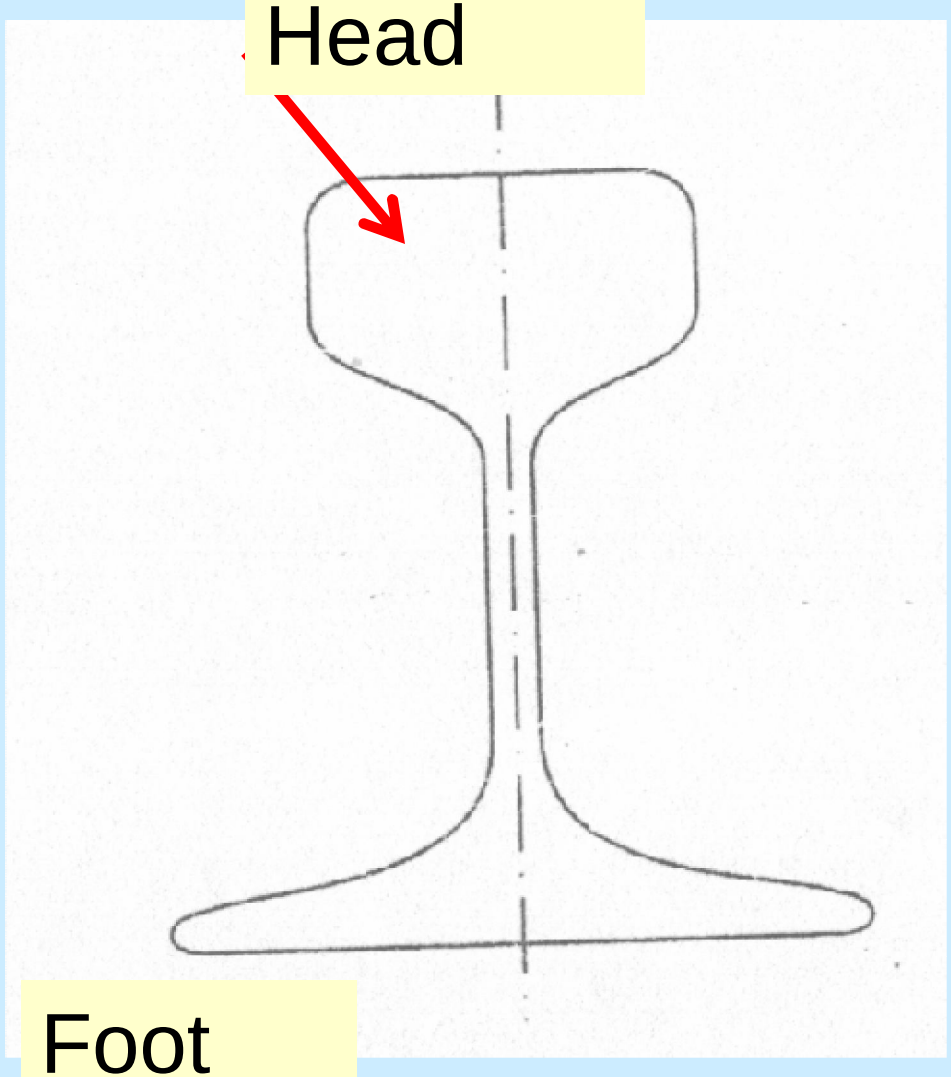
Bull Headed

- The bull headed rails has more metal added to the head, which permit more resistance to wear.
- The lower face was of sufficient size to be able to bear the stresses, which are induced in it by the moving load.

Bull Headed

Flat Footed Rail

- A flat footed rail is of an inverted T shape.
- The advantage of these rails lies in the fact that they are stronger than the bull headed rails and no chairs are necessary and the foot of the rail is spiked direct to sleeper.



Flat Footed Rail

Comparison of Flat footed and Bull headed Rail Sections

- Alignment- the B.H rail keeps better alignment of the track than the F.F rail.
- Lateral Stability – the F.F rails provide more lateral stability than the B.H rail.
- Cost- F.F rails are less costly.
- Flat footed rails are easier to lay and require less no of fastening.

Comparison of Flat footed and Bull headed Rail Sections

- Maintenance of F.F rail is easier.
- The fastenings attached with the F.F rail have a greater tendency than the B.H rails to get loose, particularly if they are laid on wooden sleepers.

Weight of the Rail Sections

- A rail is designated by its weight per yard. Thus, a 90 lbs rail is a rail weighing 90 lbs per yard of its length.

Weight of the rail is governed by

- Axle loads
- Gauge of the track
- Maximum speed which is permitted
- Sleeper Density

Weight of the Rail Sections

- As a rule on a BG track, a rail may be expected to carry an axle load 560 times the weight of the rail per yard.
- Heavier sections proved to be economical in the long run as it has longer life and less maintenance.
- Stability of heavier sections will be more and chances of buckling of the track are less.

Weight of the Rail Sections

- It results is smooth riding.
- Also, when a loaded wheel moves over the rail it depresses the rail and if the rail is light as compared with the load, it has to bear the greater is the depression. The wheel has to be dragged out continuously of such depression and as a result power of locomotive is wasted.

Length of the Rail Sections

- As the rail joint is the weakest part of the track structure, its strength being about one half that of rails, so it is desirable to use as long rails as possible.
- Wear and tear of vehicles is decreased and comfort of the passengers in increased by the longer rails, as the number of blows experienced at the joints by a moving vehicle are diminished.

Length of the Rail Sections

The length of the rail is however governed by

- Lengths, which can be produced at reasonable cost by the manufacturer.
- Handling
- Transportation
- If a defect is found in a rail, a much longer length has to be wasted in renewal than in case of short rails.

Length of the Rail Sections

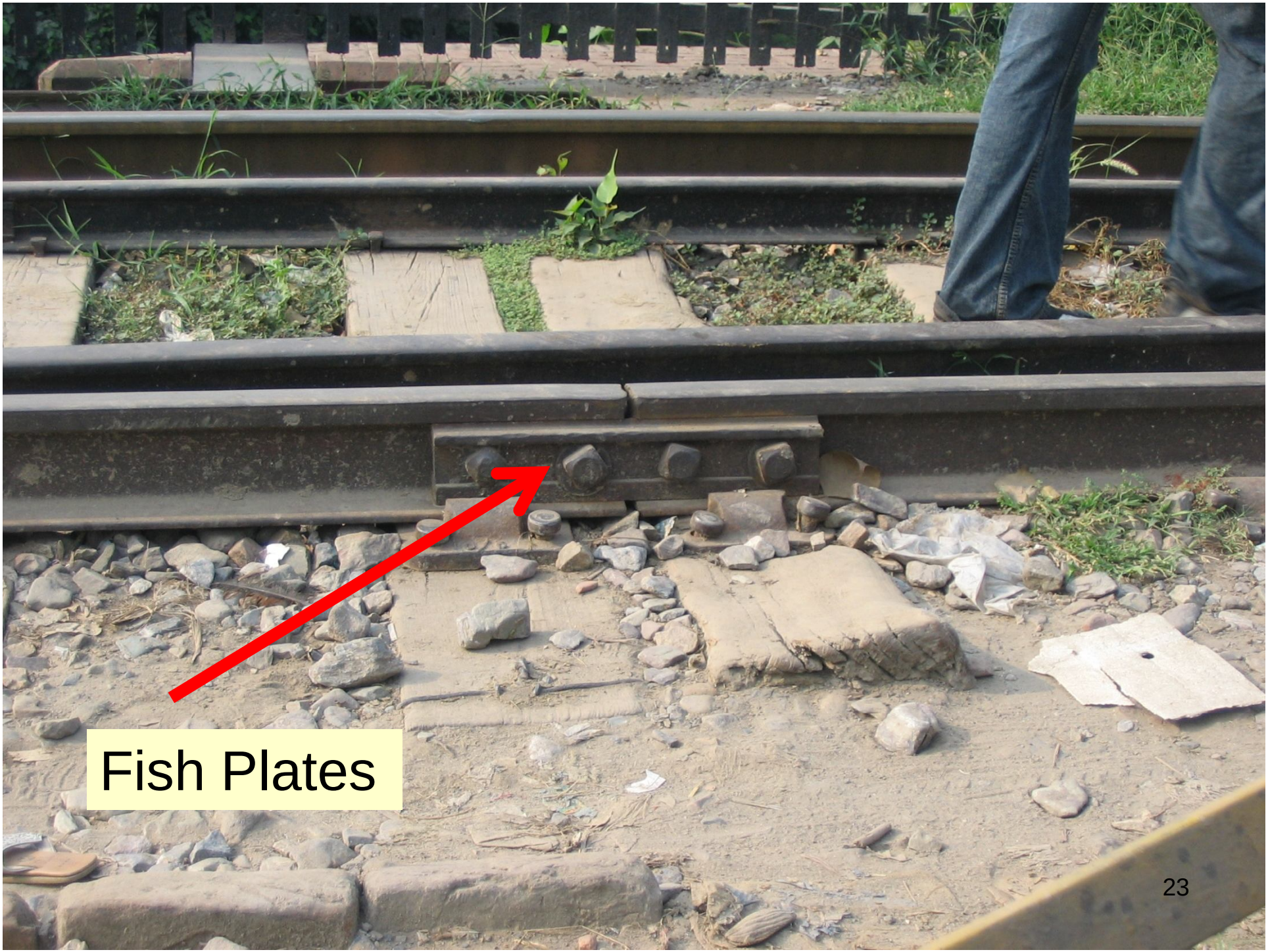
- In Pakistan, the length of the rail used is 20’ – 42’.
- The standard lengths of rails are 42’ for BG and 39’ for MG track.
- The shortest length of the rail, which may be used in the track, is that, which is not shorter than the longest wheel base of the wagon. i.e the distance between two adjacent axles which is 12 ft.

Fish Plates

- The function of a fish plate is to hold two rails together accurately, evenly and firmly in place with reference to surface and alignment.
- It absorbs the blows which the ends of rails receive when the wheel negotiate the gap at the joints.
- The material used for making the fish plates is same as that of rails.

Fish Plates

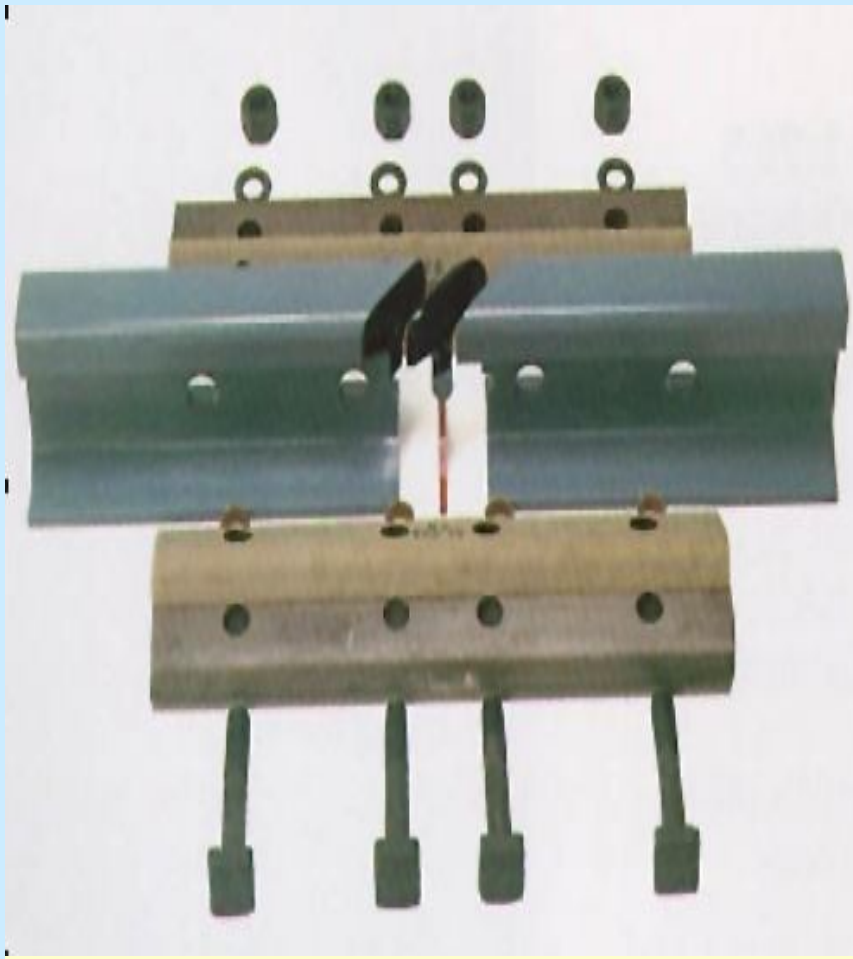
- The shape of the fish plate is such that they fit under the side of rail head and on top of rail foot.
- Fish plates are designed such that it gives maximum support to the rail ends and also allow the free expansion and contraction of the rails.
- For this reason the contact surface of the fish plate and the rails are cleaned and lubricated.

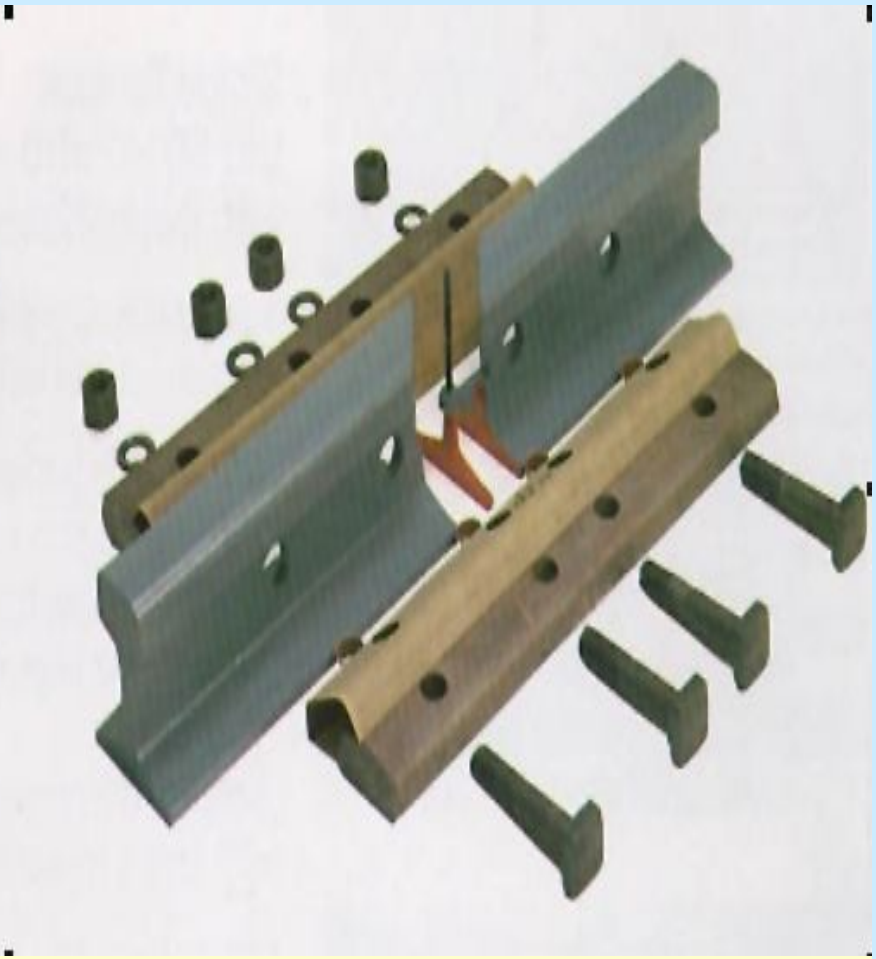

Fish Plates

Fish Plates

- The length of the fish plate is 18”.
- Two fish plates are used at each joint, one on each side of the rail
- Fish plates are usually provided with 4 holes.
- Spring washers are used to prevent the bolts from getting loose.
- Diameter of 1 bolt, ϕ = 1”
  Diameter of hole in fish plate, ϕf = 1” + 1/16”
- Diameter of hole in rail, ϕr = 1” + ¼ ”

Fish Plates





Requirements of Fish Plate

- It should hold the two rails at the same level and in the same straight line
- It should permit easy change of rail whenever this may be necessary.
- It should as far as possible has same strength and same stiffness as that of rail.
- Their shape should be such that free movement of rail for expansion or contraction should not be checked.

Types of Joints

- Joints w.r.t position of joints on track
- Joints w.r.t position of sleepers

Types of joints w.r.t position of joints on track

- Square Joints
- Staggered Joints

Square Joint

- When the joint in one rail is exactly opposite to the joint in the other parallel rail, it is called square joint.
- It is common in straight tracks.
- On curves, the centrifugal force, tend to push the track out and at the joint effect is more, resulting in the formation of kinks.

Staggered Joint

- When joint in one rail is not exactly opposite to the joints of the other parallel rail, then it is called staggered joint. The joint of one rail is kept facing the center of the opposite rail.
- With staggered joints, the number of hammer blows at the joints are doubled but the intensity is halved.
- On curves, staggered joints are preferred since it not only reduces the possibility of kink formation but also reduces the vertical movement of wheels at the joints.
- The number of sleepers is also increased by one in case of staggered joints.

Staggered Joint

Types of joints w.r.t position of Sleepers

- Supported Joints
- Suspended Joints
- Bridge Joints

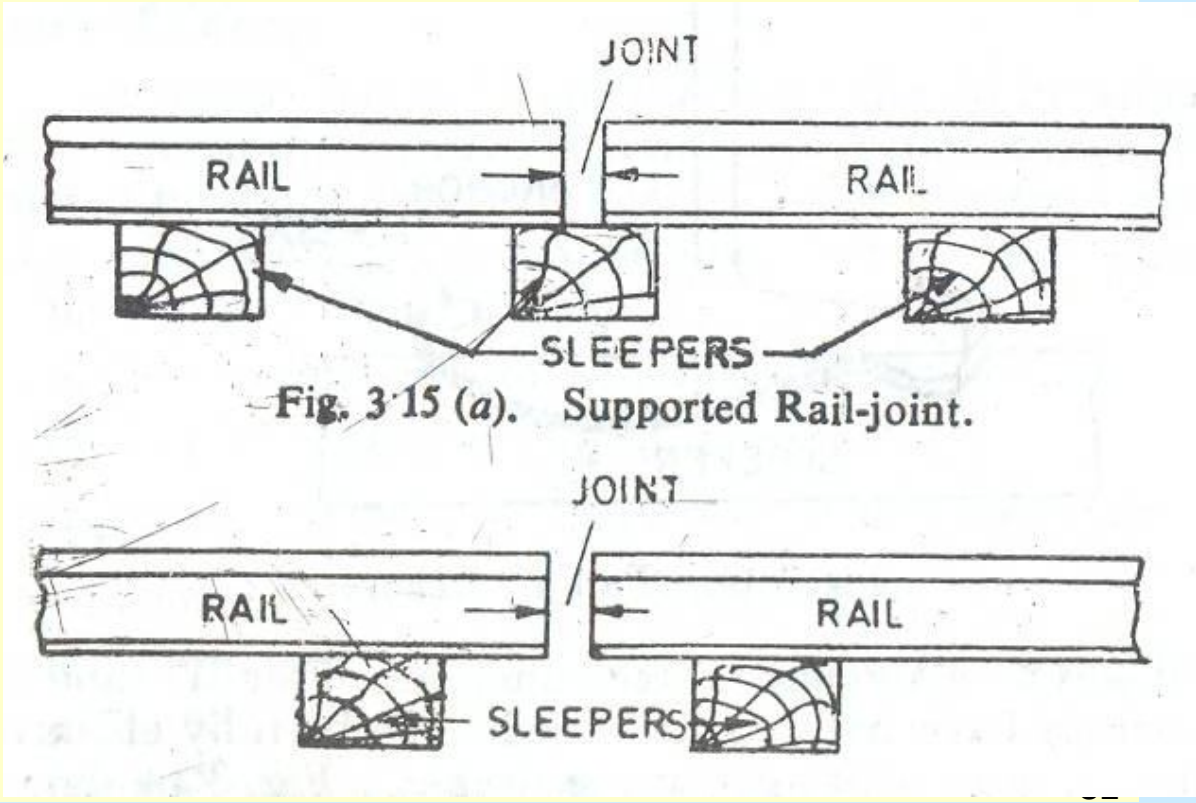


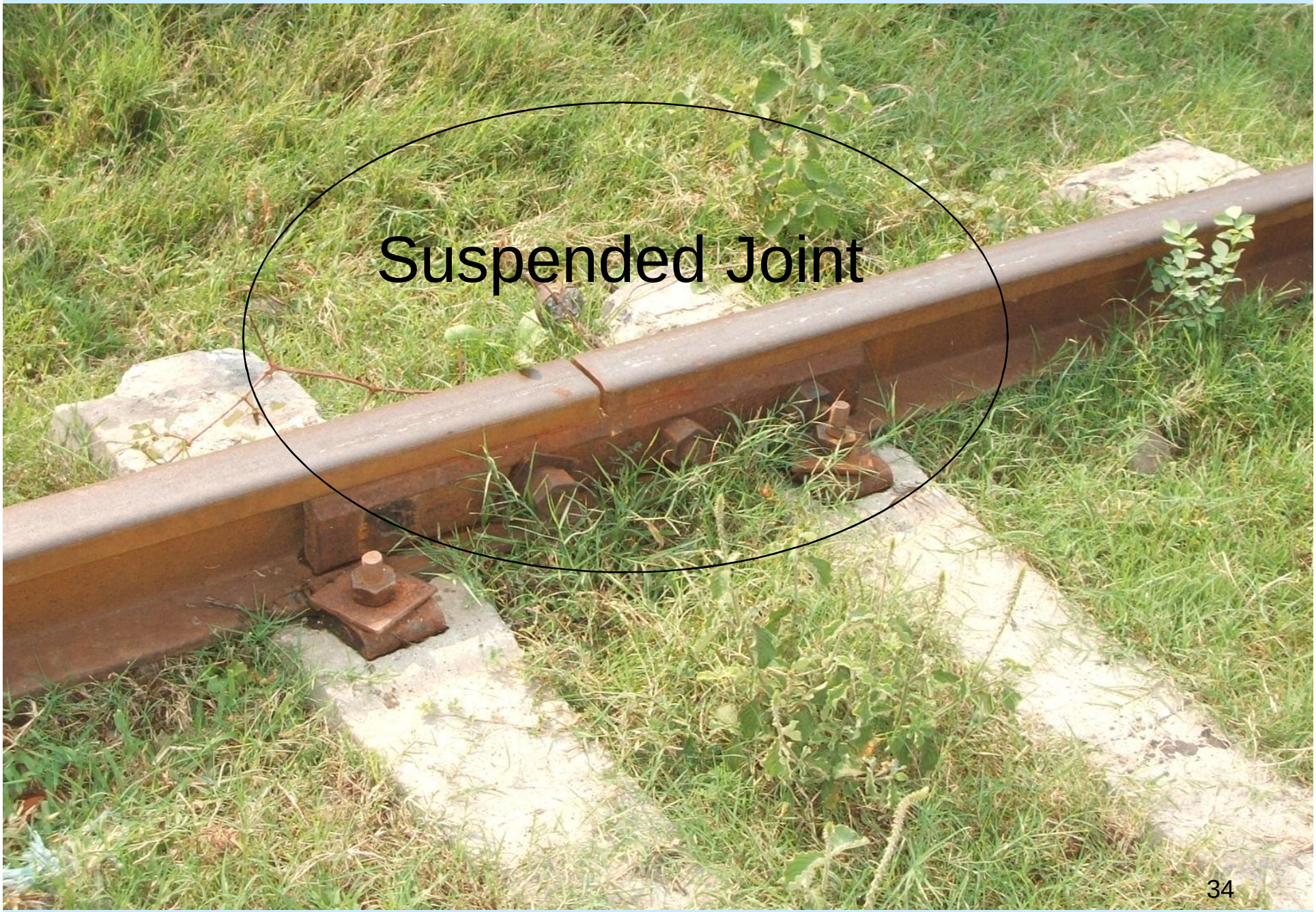
Fig. 3·15 (*a*). Supported Rail-joint.

Supported Joint

- When the joint is directly supported over the sleeper, it is called supported joint. Only one sleeper is supporting the joint.
- Sometimes, an elastic pad is fixed between the rails and sleepers to absorb the shocks.
- If a long bearing plate 3’6” or 4’ is used, then three sleepers may be used to support the joint. The objection to this is, if any of outer sleeper get loose undue load will be on the central sleeper and if central sleeper get loose it will be converted into a very weak suspended joint.

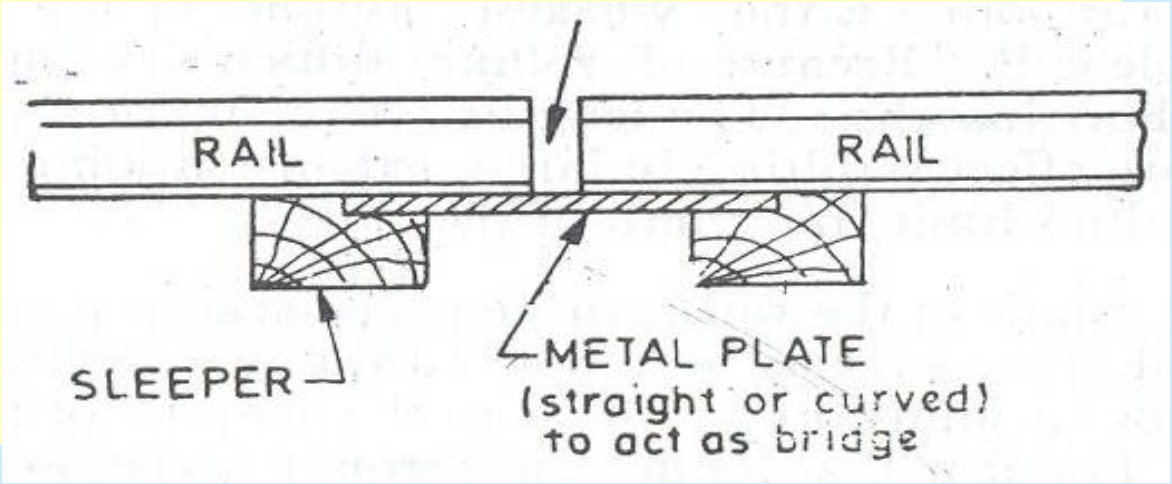
Suspended Joint

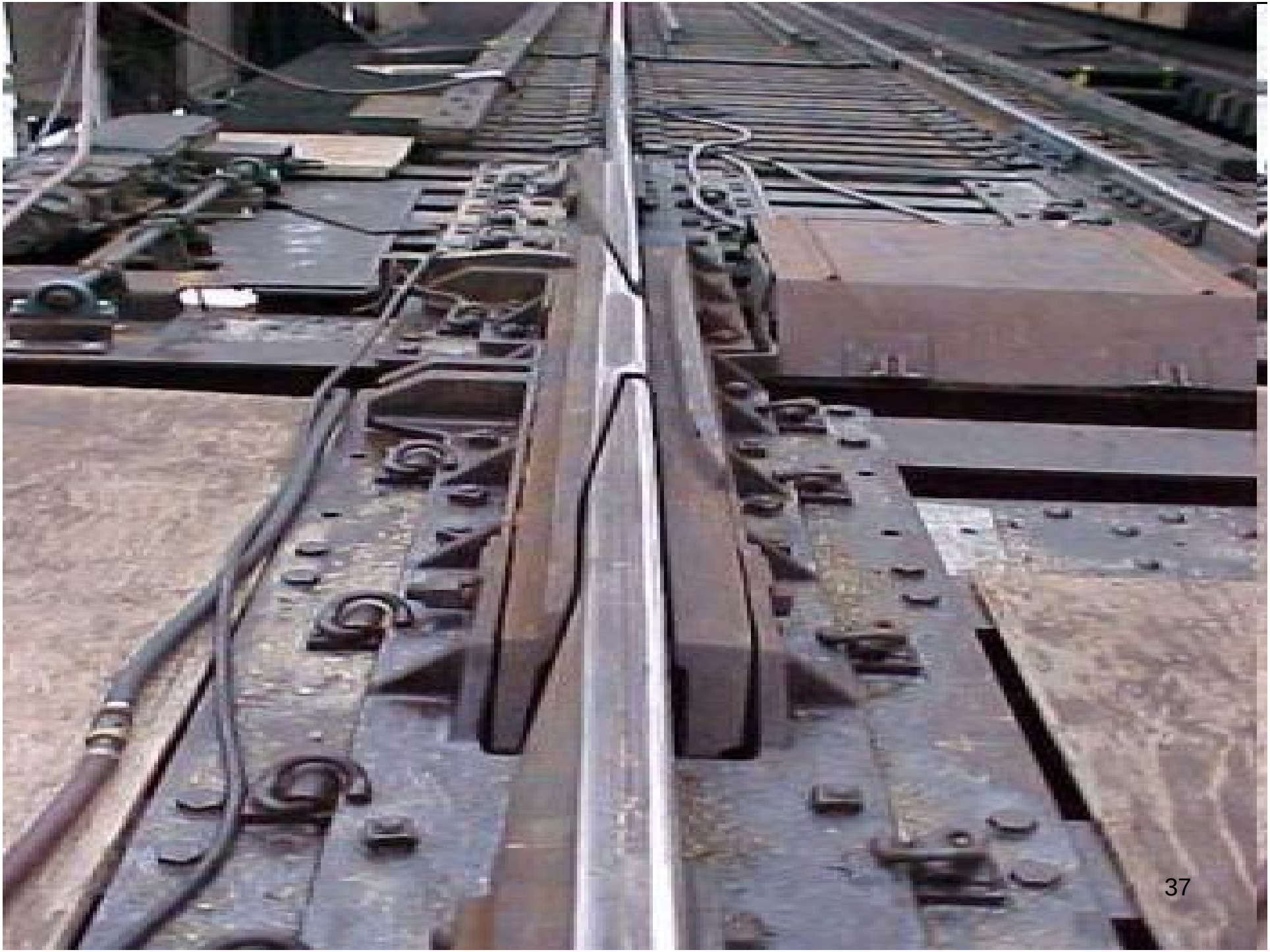
- In suspended joints, the ends of the rails are suspended between the two sleepers.
- The load is distributed equally between the two sleepers.


Suspended Joint

Bridge Joint

- Bridge joint is similar to the suspended joint, but the sleeper at the joint have to be notched so that foot of the rails at the end is supported on a bridge or length of metal, which rest on the two sleepers.
- With bridge allow the bridge to be fitted or the joint sleeper have to be laid at a lower level than the remaining sleeper.





Wear of the Rails

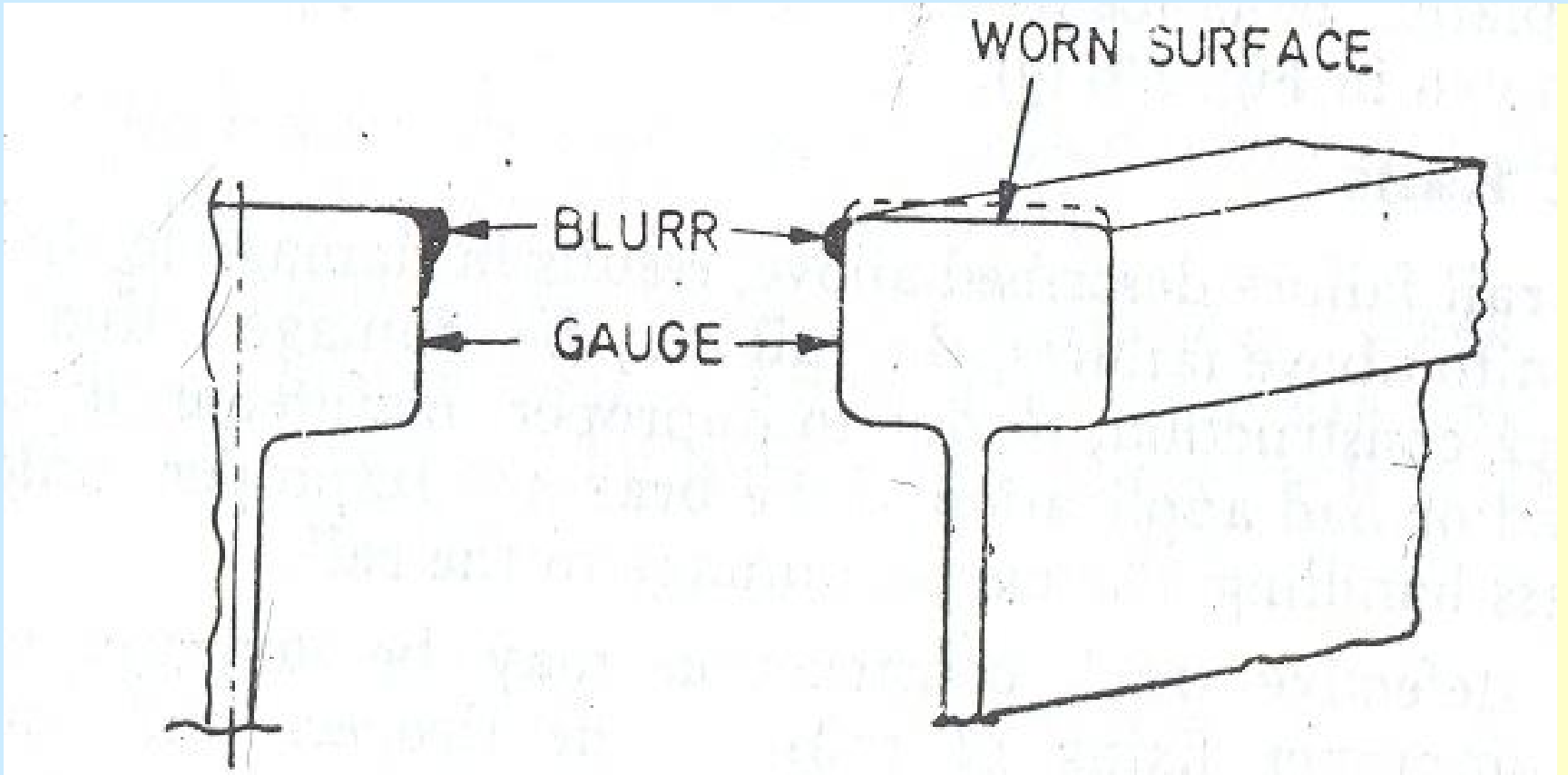
Wear of the rails may be divided into three categories

- Wear on top or head of rail
- Wear at the ends of rail
- Wear on the sides of head

Wear on top or Head of Rail

- The top surface of rails gets direct impact of the load from the wheels and hence abrasion, grounding and corrosion add to the wearing of surface.
- Sometimes the metal from the top flow towards the sides and if it projects towards the gauge end it disturb the gauge.
- A rail head becomes worn due to abrasive action of the moving wheel.

Wear on top or Head of Rail



Wear on top or Head of Rail

- Impact of the moving load due to which head of rail gets battered and chipped.
- Grinding action of sand or dust particles between the wheels and the rails.
- During starting or stopping of train. At time if starting wheel are just slipping, the metal in the rail head is burnt due to much heat or when brakes are applied and sliding takes place wear occurs.
- Wear is also increased by any looseness between rails and sleeper and also due to loose packing of ballast.

Wear on top or Head of Rail

- Gradient especially with curves the resistance is very much increased.
- Corrosion of rails on tracks adjoining to sea and corrosion due to the action of the acids contained in the refuse falling from the trains, reduce the section of the rail.

Remedy

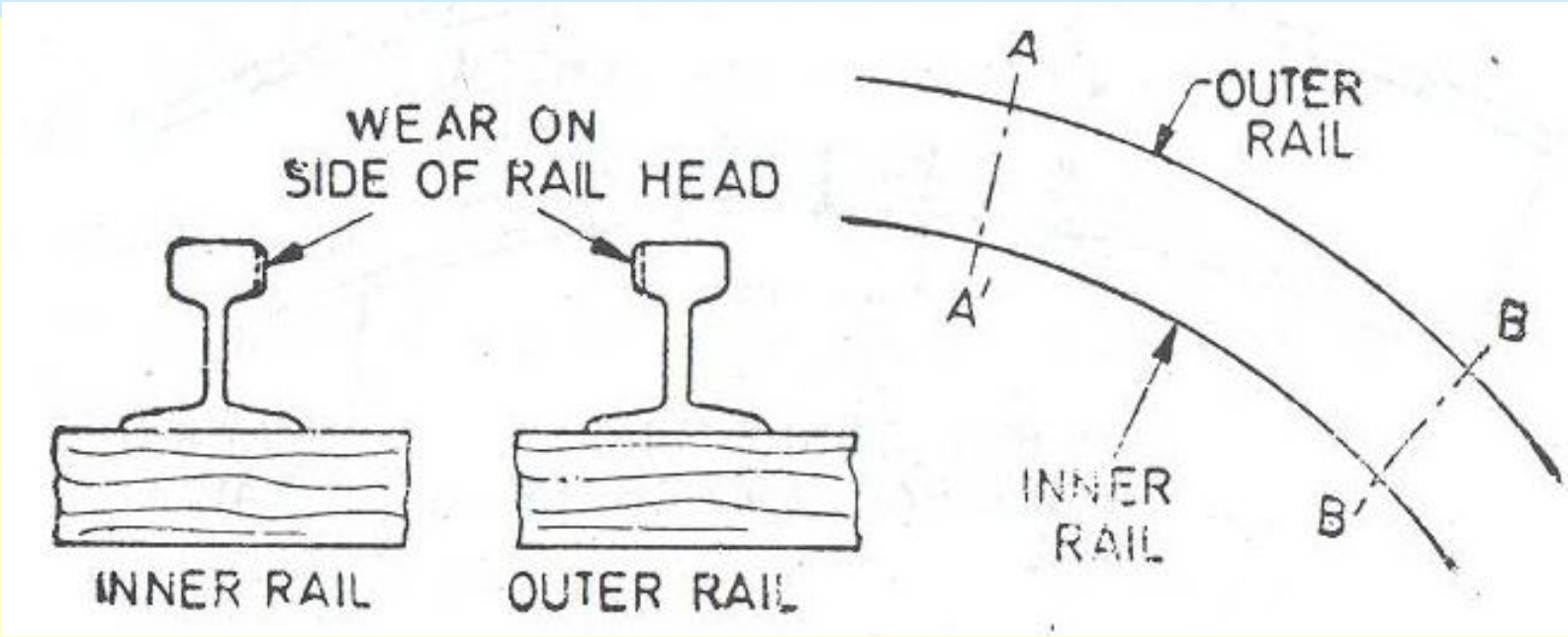
- Use special alloy steel.

Wear on the sides of Head

This type of wear occurs along curved tracks.

- On curves, due to centrifugal force the gauge end face of the outer rails is rubbed by the flanges.
- Also the vehicle on the curve, do not bend to the shape of curvature. The head of the outer rail bends towards the gauge face therefore is hit by the flanges of the wheels
- On curve, the outer wheel has to cover more distance but since wheel are rigidly fixed so inner wheel slides over the rail causing the wear of the rail.

Wear on the Side of Head

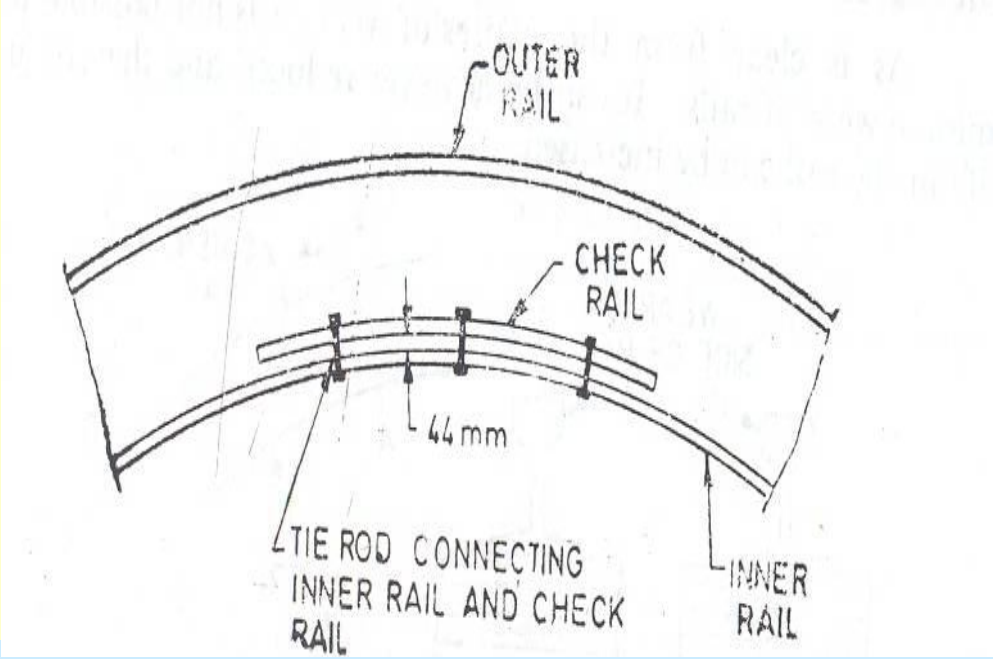


Remedies

- Use curves with larger radii if possible.
- Lubricating the side of the rail head
- Exchange of inner and outer rails on the curves

Remedies

- If the curves are sharper than 8 degrees in BG Use check rails and for MG 14 degrees or above. The flange of the wheel is between the main rail and check rail so check rail will be worn out.



Wear at the end of Rails

- This type of wear will be at the joints due to hammer blows which the end of the rail receives when the wheel jumps the gap between the two rails.
- Also the ends of the rails are battered.
- The surface of contact between rails and sleepers are worn and the effect of blow is increased.

Remedy

- Proper maintenance of joints
- Make the fitting tight
- Minimize the joints

Measuring wear of Rails

Rail wear is determine by

- By measuring the actual weight and comparing it with the standard weight.
- Profile of worn out rail is compared with the standard profile. The reduction in the cross-sectional area compared to the original x-sectional area to obtain % loss of weight.

Rail Corrugations

- Sometimes due to defects in laying of the track or due to poor maintenance of the track, or due to steep gradient resulting in sudden application of brakes, the head of the rails develop a wavy surface. Rails which develop this defect are called corrugated rails.
- When train passes over such rails a roaring noise is created and for this reason these rails are known as roaring rails.

Location of Rail Corrugations

These defect generally develop in the following rails locations

- At starting and termination point of the track due to braking action.
- In long tunnels due to presence of humidity
- On yielding formations or rails laid on soft material like brick ballast.
- The only remedy for rail corrugation is to grind the corrugation with special machines.

Hogging of Rail

- The battering action of the wheel over the ends of the rails results in the rails getting bent and deflected at the ends.
- The loose packing under the joint or the loose fish plates are primarily responsible for the development of this defect.

Hogging of Rail

To rectify this defect any of the following may be adopted

- Cutting of the end of the rail by power saw.
- Replacing the hogged rail by the new one. (Uneconomical)
- The worn out ends of the rails may be improved by welding.
- By use of dehogging machine.

Buckling of Rail

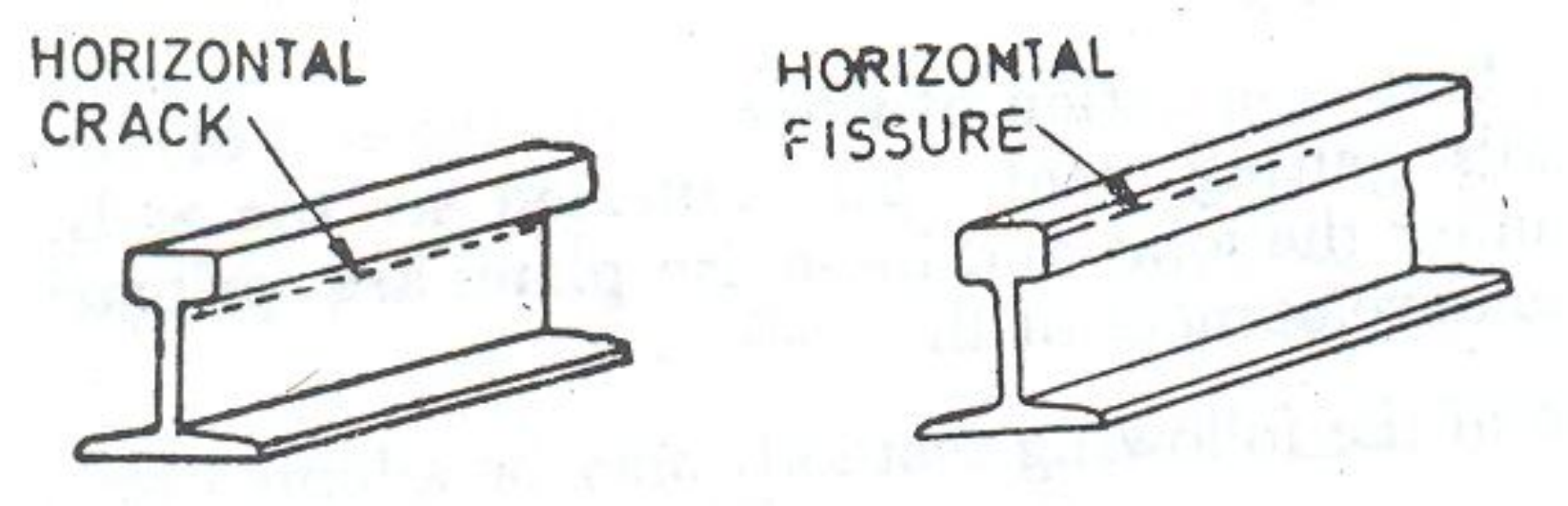
- When the expansion joint is inadequate or the joint is very tight, free movement of the rails due to temperature changes is prevented. This result in the rails gets buckled.

Remedial measures to prevent buckling

- Joint should not prevent expansion and contraction of rails
- The surface of contact between fish plates and rails should be lubricated.
- If rails are welded either steel sleepers should be provided or rails should be properly anchored.

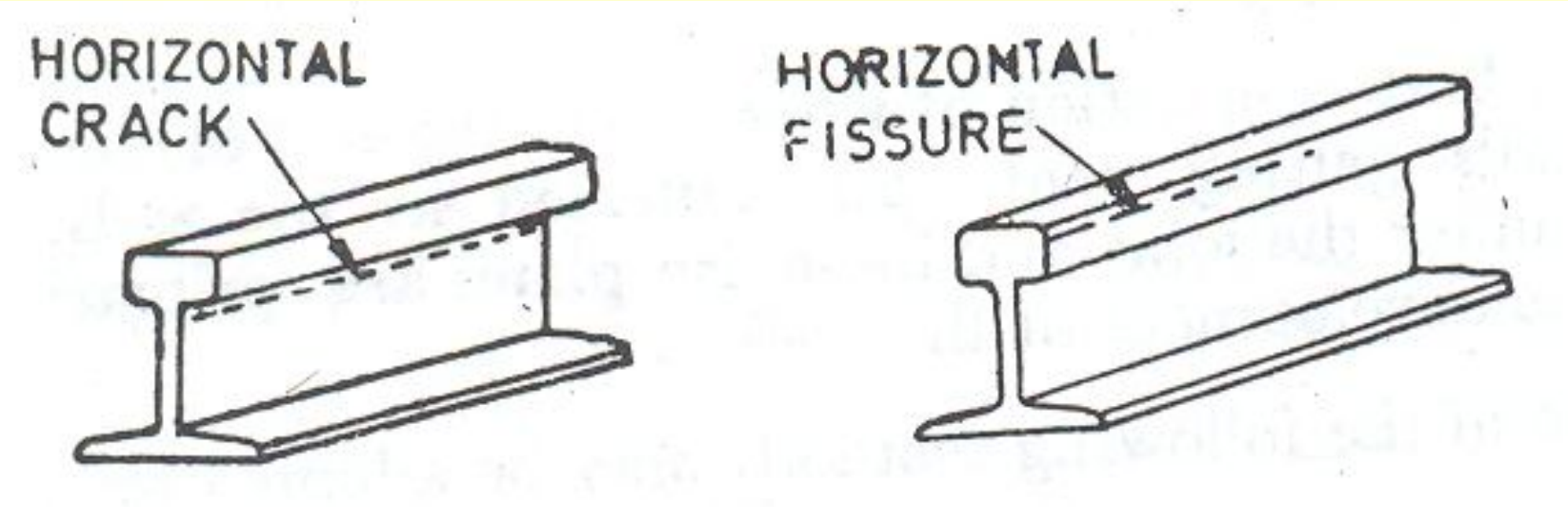
Rail Failures

- Horizontal cracks- this defect occurs at the rail ends where worn out fish plates are used for joining or the ballast is not properly packed. The crack develops due to shearing stresses at the critical section. i.e the junction between rail head and web.



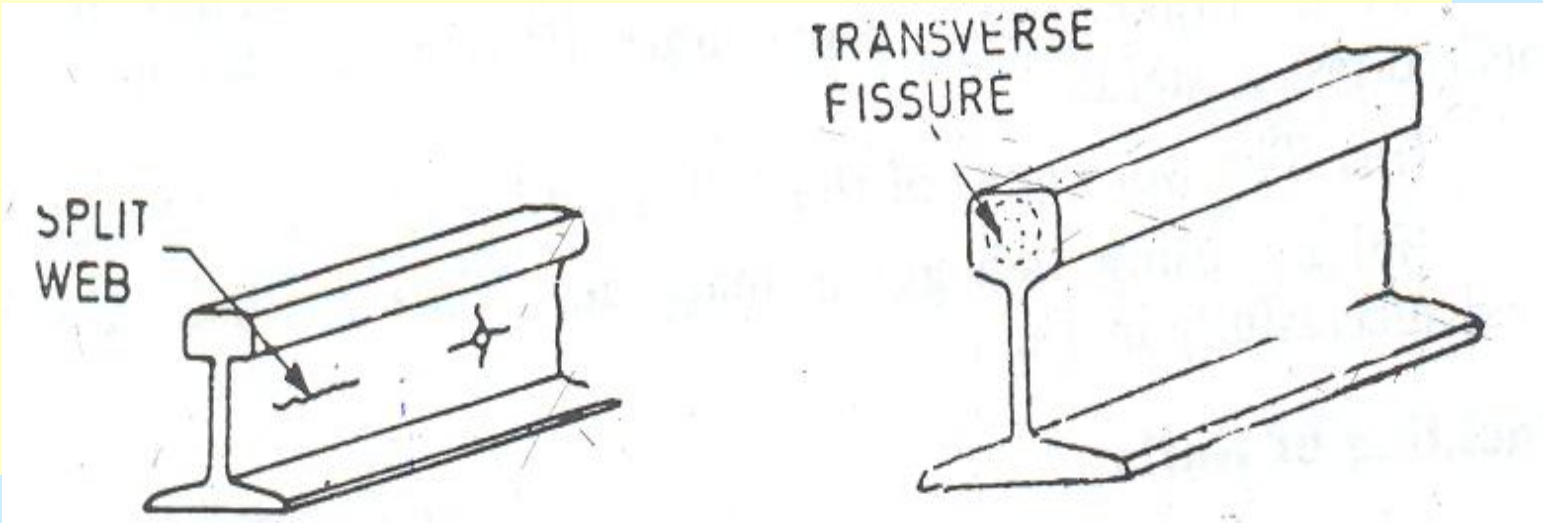
Rail Failures

- Horizontal Fissures- it is caused due to defective rail head. The rail develop horizontal crack.



Rail Failures

- Split Web- this is horizontal crack between the bolt holes in the web. It may propagated from the strained bolt hole. The crack may be horizontal or vertical radiating from the bolt hole.
- Transverse Fissures- this is a manufacturing defect. It starts from the centre of head and spread round the head.

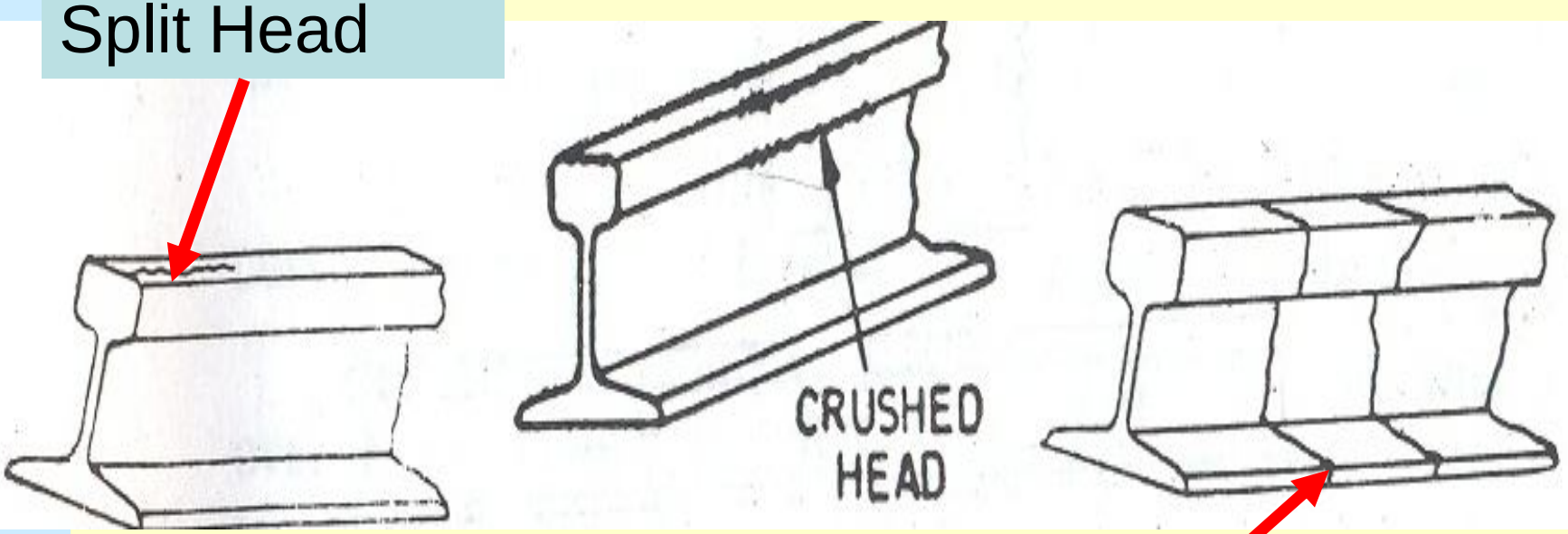


Rail Failures

- Flow Metals in head- rail head get widened as the metal is forced out.
- Split Head- this is also a manufacturing defect indicated by a crack on the top.
- Crushed Head- head get sagged or flattened. This is due to skidding, slipping or due to weak end support.
- Square or angular crack- when rail breaks through a vertical plane, the crack formed is known as square or angular.

Rail Failures

Split Head



Square or Angular Crack

Creep of Rails

- Creep is the longitudinal movement of rails in the track

Causes of Creep

- Wave motion set up in the track by a moving train.
- Expansion and contraction of the rails due to temperature.
- Starting, accelerating and slowing down or stopping of a train. Rails of a track tend to creep backward, when the train starts. Rails creep in the forward direction when brakes are applied.

Creep due to Wave Motion

- Wave motion set up in the track by a moving train. Portions of the rail immediately under the wheels of the train are depressed slightly due to load on the wheels.

- As the wheels move, the depression move with them, the previous depressed portion springing back to their original level. This wave motion tends to move the rail forward with the train.

Creep due to Wave Motion

- The pitch and depth of the waves is governed by the condition of the formation, the stiffness of the track, the weight of the rails, the spacing of the sleepers, the quality and quantity of the ballast, the condition of drainage and the standard of maintenance.

- Creep is reduced by increased stiffness of the track, stability of soil in formation and angular ballast, which interlocks well and reduce wave motion.

Factors governing the Magnitude and Direction of Creep

- Alignment of Track - Creep is found to be greater on the curves than on straights.
- Grade of Track – Creep is found to be more on the down grade.
- Direction of the heaviest traffic- For places connected to seaport, wagons are carrying more load. Creep is found to be more in the direction heavier wagons are moving.
- Condition of Formation – Creep is more in the newly constructed formation.
- Weight of the rail section – Creep is found more in the lighter section.

Factors governing the Magnitude and Direction of Creep

- Creep is not constant at a point nor it does vary at a uniform rate.
- Nor do the two rails of the track creep by the same magnitude.
- The direction and magnitude of creep cannot be predicted, both rails may creep in one direction or in opposite directions.

Results of Creep

- Widening of gaps- at some places the rail joints open beyond their limits and the intensity of hammer blows increases resulting in greater stresses in the fish plates and bolts. At some places, joints get jammed preventing the expansion, which results in the buckling of the rail.
- The sleepers are moved out of square and out of position and consequently the gauge and alignment of the track is disturbed.
- Points and crossings get distorted and it is very difficult to keep them back to correct gauge or to correct alignment.

Results of Creep

- Widening of gaps- at some places the rail joints open beyond their limits and the intensity of hammer blows increases resulting in greater stresses in the fish plates and bolts. At some places, joints get jammed preventing the expansion, which results in the buckling of the rail.
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Methods to correct Creep

- Pull Back Method
- Creep Anchors

Pull Back Method

- The track to be pulled back is inspected and the extent of pulling back necessary at various places is noted. The point from which to start is also determined; usually the starting point is at widely opened rail joints.
- Pulling back should be regulated in such a way that rail joints are made central over the sleepers. It is not enough only to obtain the necessary expansion gaps but also position of one rail joint relative to the joint on opposite side of the rail must also be maintained.

Pull Back Method

- Fish plates or fish bolts at one end of the rail are removed and at the other end are loosened. Fittings, which hold the rail with sleepers are also made loose. The rail is then pushed backed by using a lever rod.

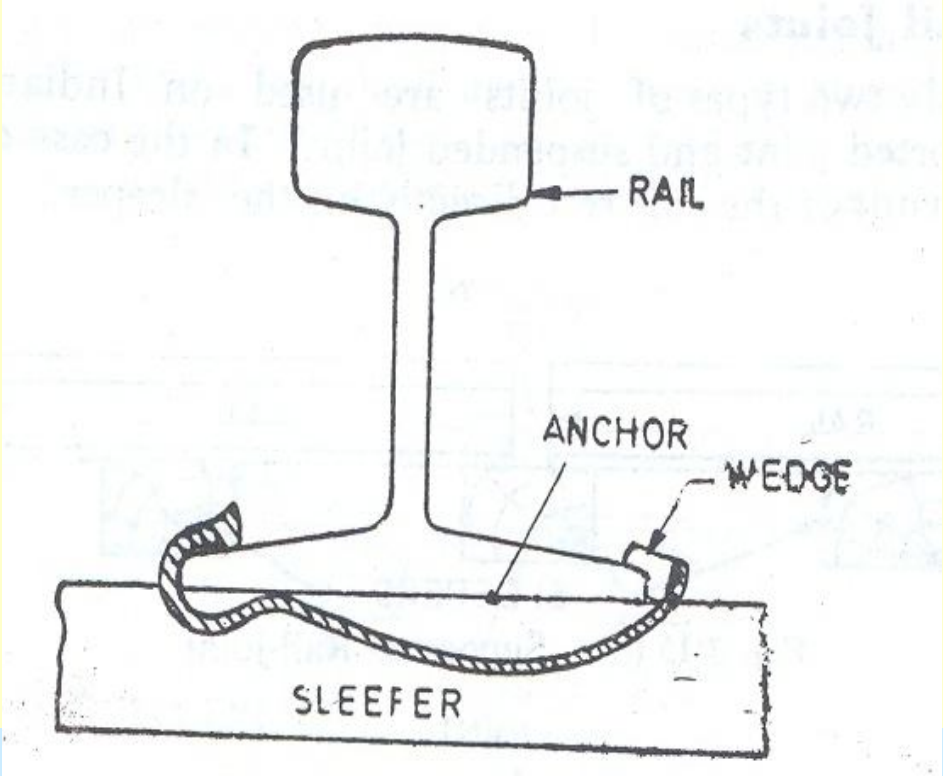
- Mechanical devices are also used for this purpose.

Creep Anchors or Anti Creepers

- After pulling back, there is no guarantee that the rails will not creep again. In fact, they start creeping immediately after pulling back.
- Creep is prevented or reduced by devices known as anchors or anti-creepers. Anchors are fastened to the foot of the rail by means of spring grip and bear against the side of the sleepers. When the rails tend to creep, they have to drag the sleepers also through the ballast and the ballast offer sufficient resistance to prevent the creep of rails.

Number of Creep Anchors

- Minimum no = 2 in one rail panel
- Maximum no = 2 * No of sleepers in one rail panel
- Creep anchors should resist the stresses due to the creep of the rails.



Bearing Plates

- They are simply the metallic plates. They are placed between the foot of the rail and sleepers, in-order to minimize injury to the wooden sleeper.

Functions of Bearing Plates

- Protect the wooden sleeper
- Distribute the load over wider area of the wooden sleeper
- Reduce the maintenance

Bearing Plates

- The shape of the bearing plate is rectangular, made of mild steel, cast iron or wrought iron.
- The size of the bearing plate is 9” * 10 ” * 3/8”.
- It has 4 holes for a spike