Transportation Engineering

Course Code –CE-422

Contact Hours -3+3

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Ballast

- Ballast is an important constituent of the conventional track system.
- It importance has grown with increasing axle loads and train speeds.
- Ballast is a layer of crushed stone or other material, which is placed between/ under the sleepers and the formation for holding a track to line and surface.

Ballast

- Ballast has a strong influence on the relative smoothness of riding.
- Experience has shown that the railways constructed with the track laid directly on the earth surface, indicated that some selective materials should be placed between sleepers and formation for economical maintenance.
- If the ballast is not provided the weight of the traffic pushes the track into the yielding soil.

Functions of Ballast

- It distributes the load over wider area of formation
- It protects the top surface of the formation from erosion
- Its characteristics facilitates drainage
- It impedes the growth of vegetation
- It act as an elastic bed to absorb the load and shock of the moving train

Functions of Ballast (cont'd)

- It provides a suitable foundation to the sleepers
- It holds the sleepers in their correct position
- It provides an easy means such that sleepers may be corrected to true grade line. (level of track)
- Provides longitudinal and lateral stability to track

Requirements of a good Ballast

- It should be hard, strong and durable.
- It should be angular
- It should have good drainage properties
- It should be non porous
- It should be stable under traffic loads
- It should provide high frictional resistance to the movement of sleepers
- It should be suitable for packing
- It should be economical in cost.

Size of Ballast

- The size of the ballast used varies from ¾” to 2-1/2”.
- Stones of larger sizes are not desirable and 2” as the maximum size is preferred as interlocking of stones of this size is better than the other.
- The best proportion is that varies from ¾” to 2” with reasonable proportion of intermediate sizes.

Size of Ballast

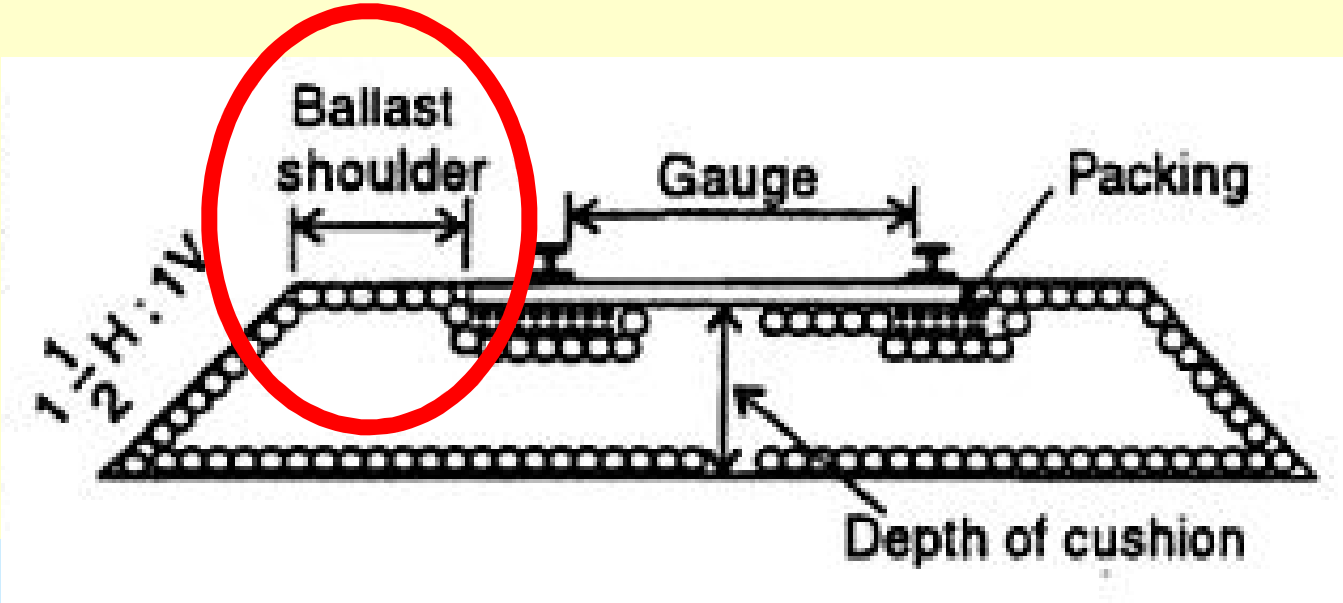
- For BG Track with wooden sleepers = 2”
- For BG Track with cast iron sleepers = 1-1/2”
- Ballast under switches and crossing = 1”

Factor Influencing Selection of Ballast

- Wheel loads
- Traffic density
- Speed of train
- Durability under impact with least possible disintegration both from exposure to weather and mechanical wear of packing tool
- Stability of material

Width of Ballast

- The width of the ballast layer is also important, as the lateral strength of the track depend partly on the quantity of ballast at the ends of sleepers.
- The lateral strength increases with increase in the width of ballast layer but there is a limit beyond which the ballast layer does not serve any useful purpose.



Width of Ballast

- The limit is from 15” to 17” from the end of the sleeper.
- The distance from shoulder to shoulder is

  BG ----- 11’-0”, MG --- 7’-6”, NG ---------- 6’-0”

- Experiments have shown that lateral strength of track chiefly depends upon the sleeper spacing and the value of grip they have in the ballast.

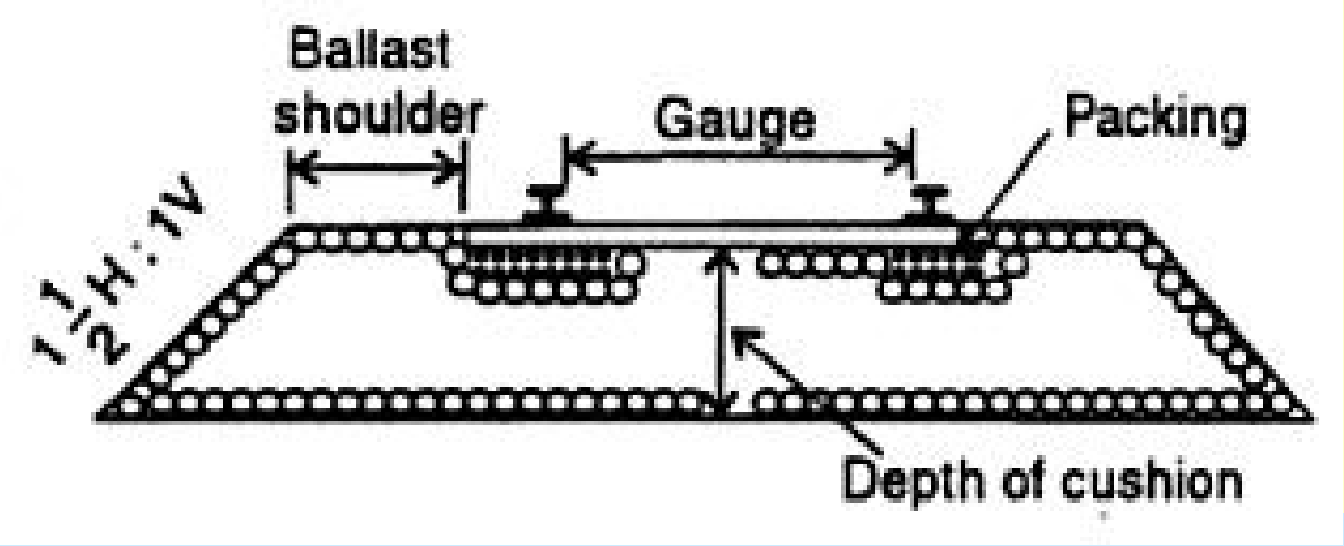
Depth of Ballast

- The depth of the ballast under the sleepers is an important factor in the load bearing capacity of the track.
- The thickness of the ballast under the sleeper bottom depends upon the traffic density, quality of ballast and the formation soil.
- On new tracks ballast is usually laid in two layers
  - The bottom ballast or the sub ballast
  - Top ballast

Depth of Ballast

- Experiment has shown that the load carrying capacity of the track with 9” depth of ballast under the sleeper is 30% more than a track with 6” depth.

- In Pakistan, the minimum depth of ballast required below sleeper is
  - For Main Line 12”-13”, Branch Line 8”-10”



Quantity of Ballast

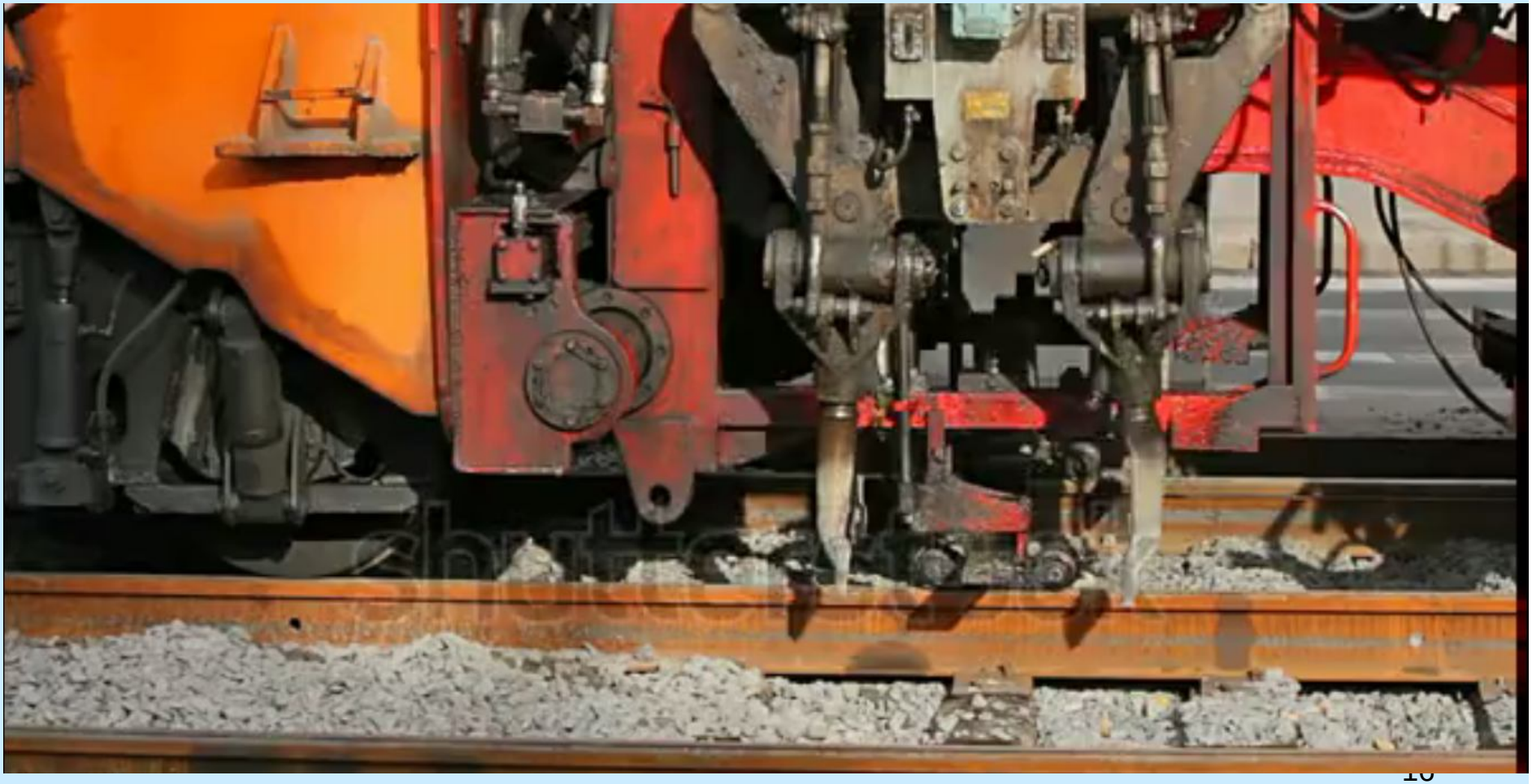
- Quantity of Ballast required for every foot length of BG track is 12 c.ft

- Quantity of Ballast required for every foot length of MG track is 8.25 c.ft

Packing of Ballast

- Ballast is not packed throughout the length of the sleeper because load is concentrated under the rails.
- The sleeper is packed from each rail seat to the end of the sleeper and an equal distance in the inter-rail space.
- The packing under the rail seats should be done first and care should be taken not to strike the sleeper with the beater, while packing.
- The sleepers should be sufficiently far apart so that the sweep of beater is not hindered by the adjoining sleeper.
- On curves, the inner or lower rail should be leveled first and then the outer rail gives the correct super-elevation.

Mechanical Packing of Ballast



Mechanical Packing of Ballast

Packing of Ballast

- The ballast round the sleepers is pulled aside with ballast forks or shovels; ballast is then removed to a depth little below the bottom of sleeper. Ballast is then packed under the sleepers with picked axes/ beater, until the level of the rail is raised to the required height.

- One man can pack a sleeper but when this is done, the sleeper is likely to have an uneven bearing. A better method is to position two men, back to back on the same sleeper, one man in the inter rail space and the other on the shoulder, and to make them pack diagonally under the rail seat. This is known as **Scissors Packing.**

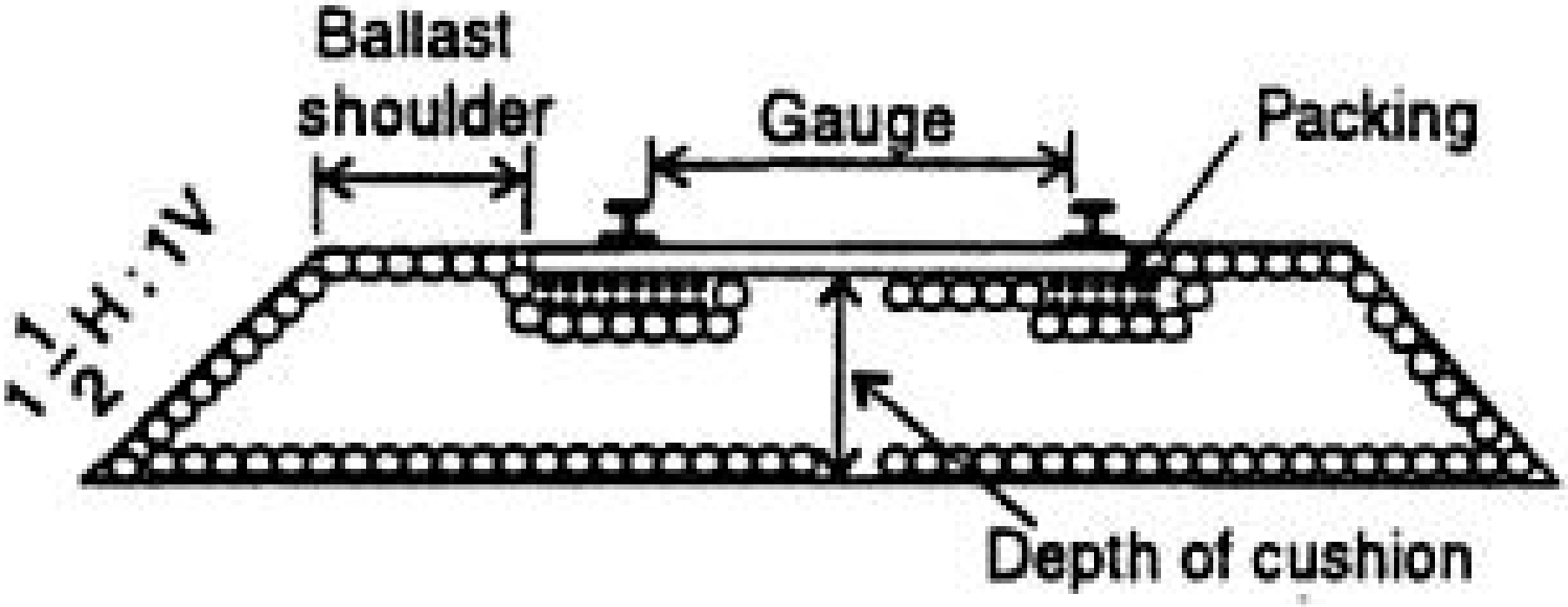
Boxing of Ballast

- Process of filling the ballast between the two rails and forming the shoulders at each end of the sleeper is called boxing of the ballast.
- On completion of packing, the ballast which is scattered during packing, is gathered and put back in order to restore the profile of the ballast layer.
- It is done by means of ballast forks not with shovels which result in earth and weeds from the formation being pulled up with the ballast and fouling the ballast.

Centre Bound Sleepers

- Under the rolling load, the ballast is pressed down under the rail seats more than at the centre of the sleepers due to the loads being greater under the rail seats.
- If slight lifts are not given under the rail seat periodically to make up for the depressions, the sleeper instead of being supported firmly at the rail seats are found to be better supported at the centre.
- This causes rocking of the train and the sleeper is said to be centre bound.
- Centre binding can be easily removed by loosening the consolidated ballast at the centre of the sleeper. Centre binding does not occur where a shallow central depression is left in the ballast section.

Centre Bound Sleepers



Renewal of Ballast

- The frequency of ballasting depend mainly on the condition of the ballast but other factors such as the riding quality of the track, traffic density, prevailing train speed, sleeper and rail renewal, and the condition of sub grade also influence the selection of operation to be followed.
- The quantity of the ballast get decreased due to
  - By crushing of ballast due to abrasion action of the moving loads
  - By sinking of the ballast in the formation

Renewal of Ballast

- Fresh ballast has therefore to be added periodically so that the layer of ballast retains the correct depth and width.

Renewal of ballast follows the following procedure

- Take out ballast from the track using the ballast fork
- Screening of the existing ballast
- Estimate the additional amount of ballast to be added
- Additional is brought to the site through the material trains
- Addition of the new ballast
- Packing and Boxing of ballast again

Physical properties of Ballast

Ballast material should satisfy the following physical properties

- Aggregate Abrasion value 30% max for BG and MG ; 35% max for NG.
- Aggregate impact value 20% max for BG and MG; 30% max for NG.
- The water absorption should not be more than 5%.

Size and Gradation of Ballast

Ballast should conform to following size and gradation.

- Retained on 65 mm (2.5 in) sieve ---------NIL
- Retained on 40 mm (1.5 in) sieve ---------40-60%
- Retained on 20 mm (0.75 in) sieve ----------Not less than 98% for machine crushed and not less than 95% for hand broken.

- Oversize and undersize ballast should only be used after careful study of all the characteristics of the quality of ballast

Test for Ballast

- LOS Angles Abrasion Test
- Impact test
- Angularity Test
- Flakiness and Elongation Index test.

Blanket/ Sub-Ballast

- It is a layer of specified coarse grained material interposed between the ballast and the formation. It serves the following objectives:
  - To distribute the load on formation reducing the subgrade stresses within the subgrade strength.
  - To eliminate mud pumping
  - To control the seasonal moisture content variation in the subgrade.

Cost of Ballast

Cost of ballast depends upon the following factors

- Initial cost as it comes to the road
- The distance from the source of supply to place where it is to be used.
- The method of handling

Types of Ballast

Mud Ballast

- No ballast except the natural soil.

- Some times, the natural soil is sandy and gravelly and it makes fairly good ballast .

- It is used for temporary track where cost consideration necessitates its use.

Types of Ballast

Mud Ballast

- It is used in initial stages of a new line till the settling of the formation due to heavy loads is stabilized.

- Stone ballast is subsequently placed over consolidated and hardened earth.

MUD BALLAST

Cinder/ Coal Ash

- It is the residue of the burnt coal.
- These are available in large quantities where coal is used in locomotives.
- It has good drainage properties as it is very porous.
- Due to its low cost, it is largely used in yards.
- It cannot be used for main lines as it is very soft, get easily reduced to powder by packing and vibration.

Cinder/ Coal Ash

- It is excellent for yards where it is used as ballast under the track and it forms excellent path between tracks for shunting staff particularly in the rainy weather as it does not retain water and is not slippery.
- It is also used for blanketing the formation for improving poor soil conditions
- It also provides invaluable help in repairing formation or as ballast for packing track in an emergency such as caused by heavy floods.
- Its greatest disadvantage is its corrosive quality and it must not be used with steel sleepers.

Sand

- It is good material for the ballast as it is free draining provided it is free of earth and vegetation.
- It is also comparatively cheap. Coarse sand should be preferred instead of fine sand.
- It is suitable for C.I pot sleepers or where intensity of traffic is low. It is used on branch line or for feeder railways.
- Sand ballast is sometimes covered with stones to prevent it blowing. The best sand for ballast is that which contain a quantity of fine gravel varying in size from 1/8” upwards

Sand

- A covering of sand ballast is sometimes given on the tracks in yards as it soaks up water and makes easier walking for men working in the yards.

The major disadvantages of using sand as ballast are

- It can be easily blown or washed away
- It is easily disturbed by vibration making the maintenance rather difficult.
- It causes heavy wear in vehicles as the sand gets into the moving part and causes friction.

Gravels

- It is easily handled, provides almost perfect drainage and is available from rivers beds.
- It disadvantage is the smoothness of gravel, which rolls down easily due to vibration and the packing under the sleeper get loose.
- If the gravel contains very fine stones, it must be screened to ensure proper drainage of track.
- Larger pieces are broken to smaller sizes.
- To increase interlocking of stones rounded pieces are broken. On soft formation gravel ballast give better results.

Brick Ballast

- When no stone or substitute is available for use as ballast, over-burnt bricks are broken to small pieces and used as ballast.
- It powders easily and produces a dusty track.
- It is very porous and has good drainage.
- It is economical in cost.

Stone Ballast

- This is the best type of ballast available and is almost provided in all the important tracks.
- The best stone for ballast is a non-porous, hard, angular stone, which does not flake when broken.
- It is easily shovelled with forks with the advantage that fine chips and dirt are screened out and provides excellent drainage.
- It can withstand vibrations well and hold the sleepers more firmly.
- Igneous rock such as quartz and granite make excellent ballast. Sandstone and limestone, which are soft, but make fairly good ballast.


Stone Ballast

Blast Furnace Ballast

- Blast furnace slag is the by-product of the steel industry.
- It can be used as a ballast material if available easily.

Sleepers

- Rails in a railway track need support and the greater the support, the lower are the stresses induced in the rail.
- Sleepers are responsible for keeping the two rails forming a track at an exact distance apart.

Functions of Sleepers

- Distribute the load over wider area of the ballast
- Keeps the two rail of the railway track to correct gauge
- Sleepers are support to rails
- To act as an elastic medium between the ballast and the rails to absorb the blows and vibrations of the train.
- To help in the stability of the track as a whole

Requirements of Sleepers

- It should last as long as possible in the ground
- Have sufficient compressive strength to resist rail pressure
- Have sufficient transverse strength to resist breakage by centre binding
- Have hardness to resist rail abrasion
- Have the spike holding property to resist the tendency of the spikes to loosen owing to vibrations (wooden)
- Resist attack by white ants or vermin (wooden)
- Sleepers should be cheap

Types of Sleepers

- Longitudinal Sleeper
- Cross Sleeper / Transverse Sleepers

Longitudinal Sleepers

- Sleepers originally consisted of slabs of stone or pieces of timber laid under the rails longitudinally.
- The cross pieces were provided at intervals to maintain correct gauge of the track.

Why Longitudinal Sleepers are discarded

- Running is rough
- Noise produced by the track is great
- Uneconomical i.e large section is required to be placed under the rail to support, so cost increase.
- Secondly, as additional timber is required to hold the two longitudinal timber to correct gauge.

Transverse Sleepers / Cross Sleepers

- were first introduced in 1835
- Now used universally.
- They remove all the defect of longitudinal sleepers
- They are placed at right angles to the rails.

Types of Transverse Sleepers / Cross Sleepers

Depending upon the construction material

- Wooden Sleeper
- Steel Sleeper
- Cast Iron Sleeper
- Concrete Sleeper
- Composite Sleepers

Wooden Sleepers

- Timber is an ideal material, which fulfills all requirements for making the sleepers.
- Soft wood sleepers have less life as compare to hard wood sleepers.
- In case using soft wood for sleepers, give treatment to it.
- Soft wood sleepers become unserviceable earlier than hard wood, as the foot of flat footed rail cuts into the soft wood easily.
- This defect is reduced, by using a steel or cast iron bearing plate between the rail and the sleeper.

Wooden Sleepers

Laying of Wooden Sleepers

- As far as possible, only treated sleepers should be used in the track.
- For treated sleepers, sap wood absorbs more creosote and is therefore more resistant to vermin and fungus attack and is therefore placed downward and the heart wood side is kept upwards.
- For untreated sleepers, they should be laid with the sap wood laid upwards and heart wood downwards side as it is more resistant to the attack of fungus.

Seasoning of wooden sleepers

- A living tree contains juices known as sap, and after the tree is cut the sap has to be dried before using the timber. This is known as seasoning. Unless sap is removed, the sleeper tends to twist, bend, warp and decay. Seasoning of timber is done by
- Natural seasoning
- Artificial or kiln Seasoning

Care of Wooden Sleepers

- Splitting of sleeper at the ends can be avoided if the sleepers are bolted, clamped or tied with wire.

- Wooden sleepers should be stacked on a well drained plot of ground which should be clear of all the vegetation for at least one foot all around the stack and in such a manner that a free circulation of air all around. The top of the stack should be covered with a thin layer of soil is put at the top to protect the sleeper from direct rays of sun on the sleeper and to mitigate the fire from the sparks of locomotives.

Care of Wooden Sleepers

- Care is to be exercised in driving spikes for holding the rail to the sleeper.
- The spike must be held and driven vertically, otherwise the gauge will be affected.
- The spikes are driven into the bored holes.
- The boring of the holes should also be done accurately otherwise spike will not be in correct position.

Care of Wooden Sleepers

- The rail gradually cuts into the sleeper, particularly where heavy axle loads are used and the sleeper becomes unserviceable through such wear.
- Bearing plates if used between rail and sleepers, distribute the load from the rails to the sleeper and prevent crushing of sleeper.
- Bearing plates extend the life of the sleeper by as much as 30 %.

Mechanical Preparation

- In order to obtain the cant of 1 in 20 for the rails, wooden sleepers are adzed.
- Accurate adzing is essential otherwise the track will ride rough due to cant varying from sleeper to sleeper.
- Where canted bearing plates are used, sleepers do not have to be adzed

Standard Size Of Wooden Sleepers

- For Broad Gauge 9’ * 10” * 5”
- For Meter Gauge 6’ * 8” * 4.5”
- For Narrow Gauge 5’ * 7” * 4.5”

Life of Wooden Sleeper

Factors that affect the service life of the sleepers are

- Type of wood used
- Seasoning
- Treatment
- Climatic condition
- Axle loads
- Handling Conditions
- Location of sleeper on track

Merits and Demerits Of Wooden Sleepers

- Connection of foot of the rail with the sleeper is simple.
- Easy to handle
- Can be obtained in any size
- Wooden sleepers have good vibration absorbing capacity
- In case of derailment the damage to wooden sleeper is less

Merits and Demerits Of Wooden Sleepers

- Scrap value is negligible.
- They are easily liable to attack by weather and vermin, hence there life is less.
- Susceptible to fire.

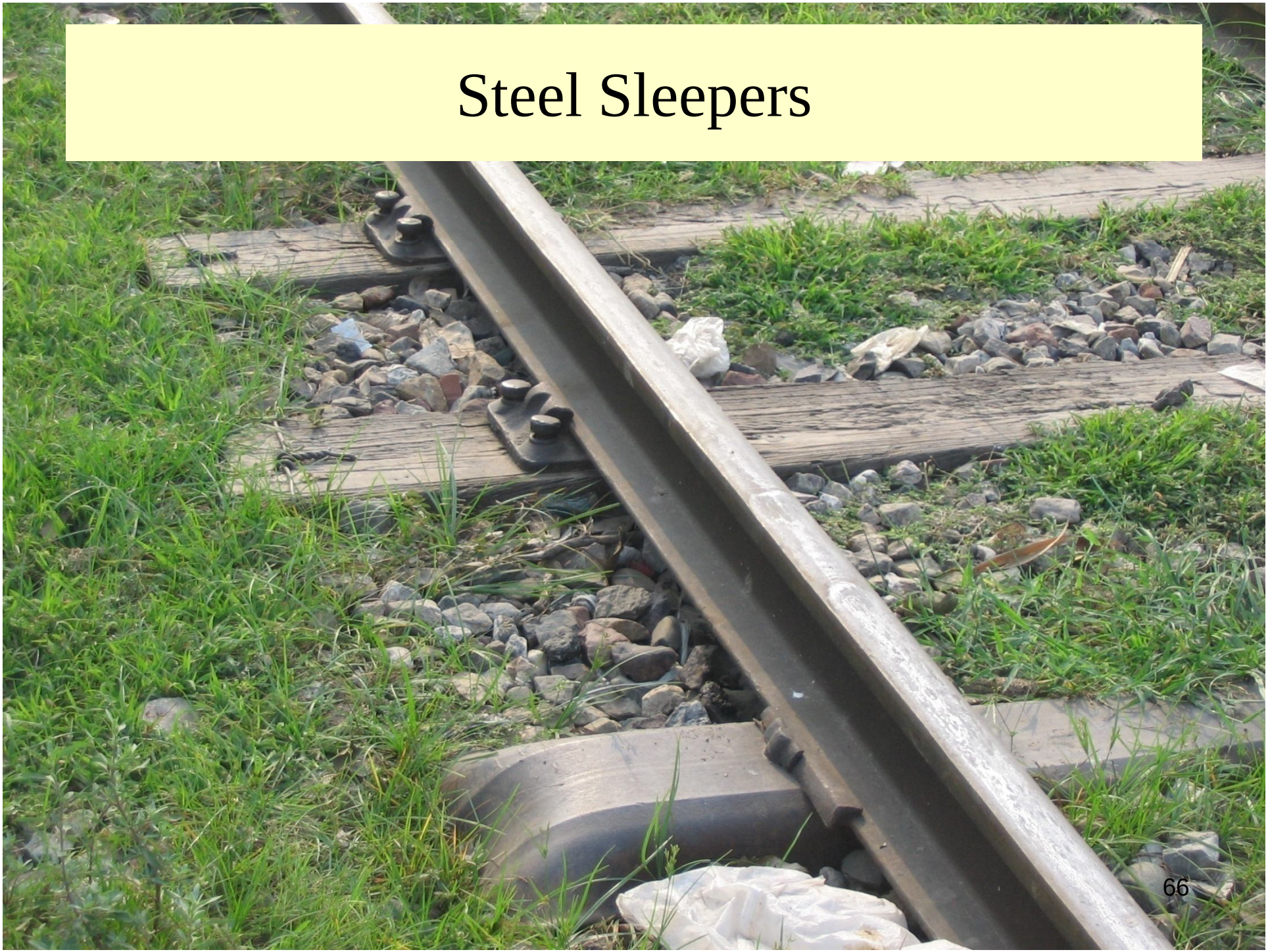
Steel Sleepers

- Steel sleepers are in the form of shallow inverted trough/ channel with special fittings to hold the foot of the rail with sleepers.
- The ends of the sleepers are bent down to prevent / stop the ballast from running out.
- Pressed up lugs/ jaws are provided to hold the rail in position.

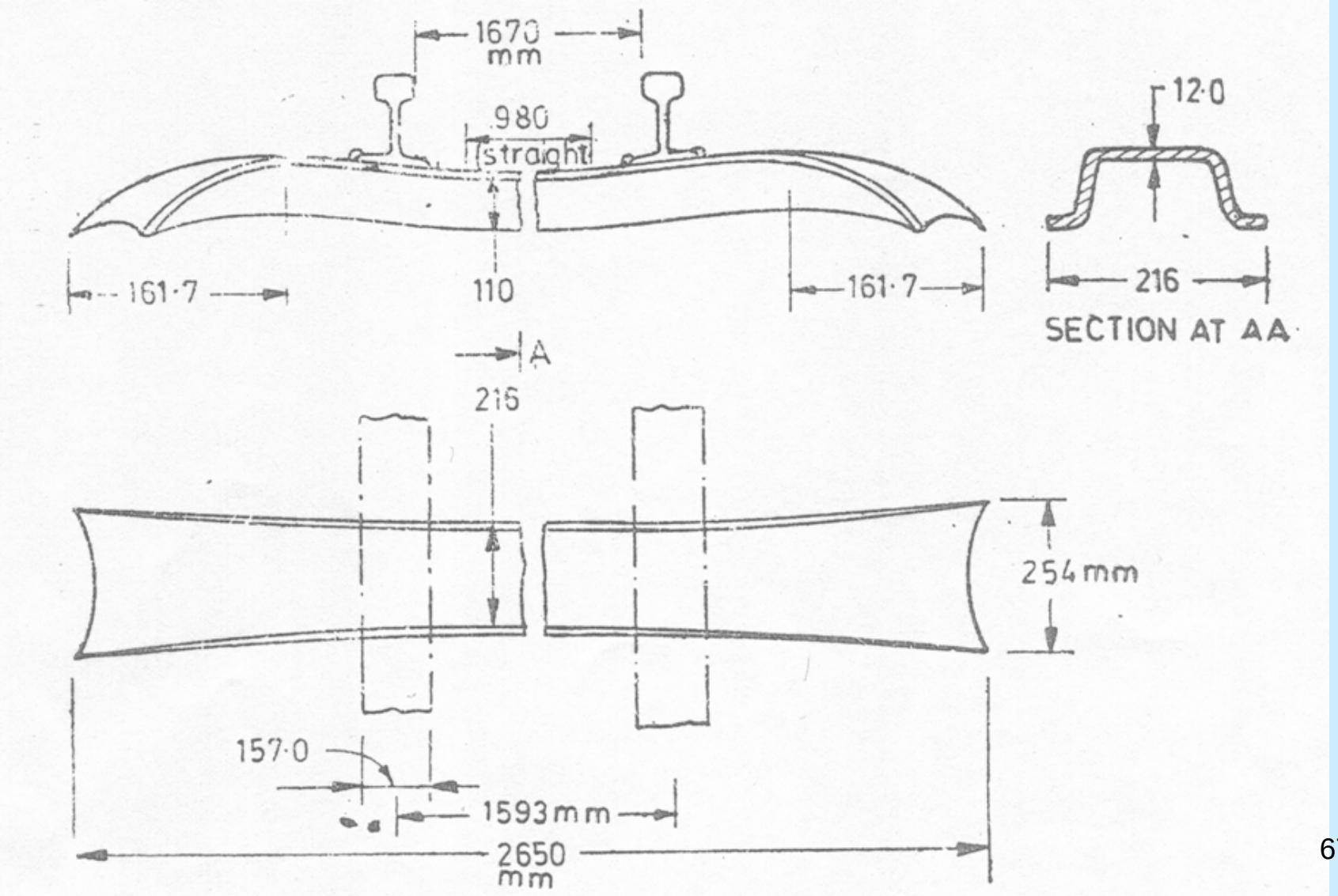
There are two distinct types of steel sleepers

- Wedges/ keys
- Clips and bolts

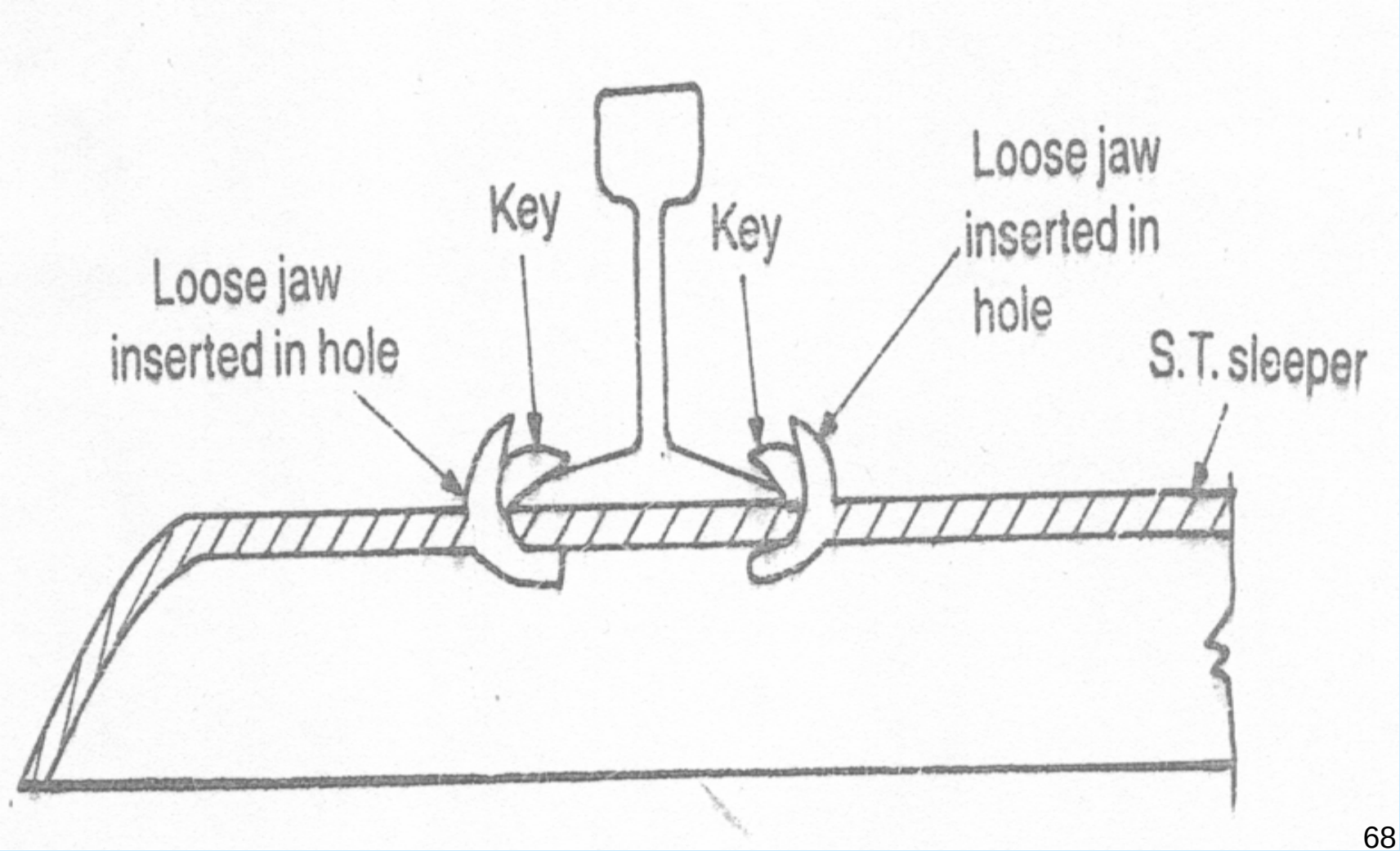
Steel Sleepers



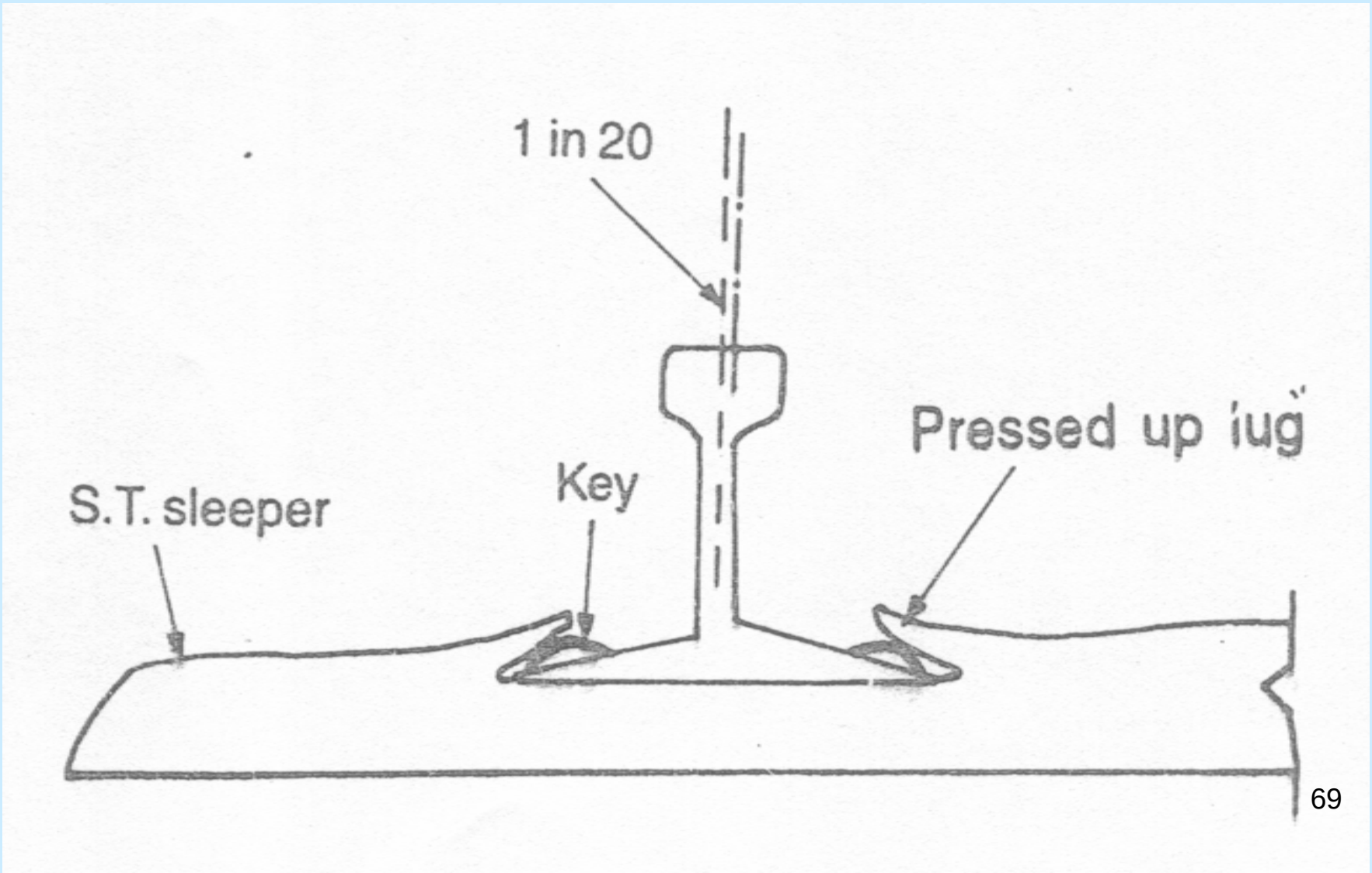
Steel Trough Sleepers



Steel Sleepers with Loose Jaws



Steel Sleepers with Pressed up Lugs and Keys



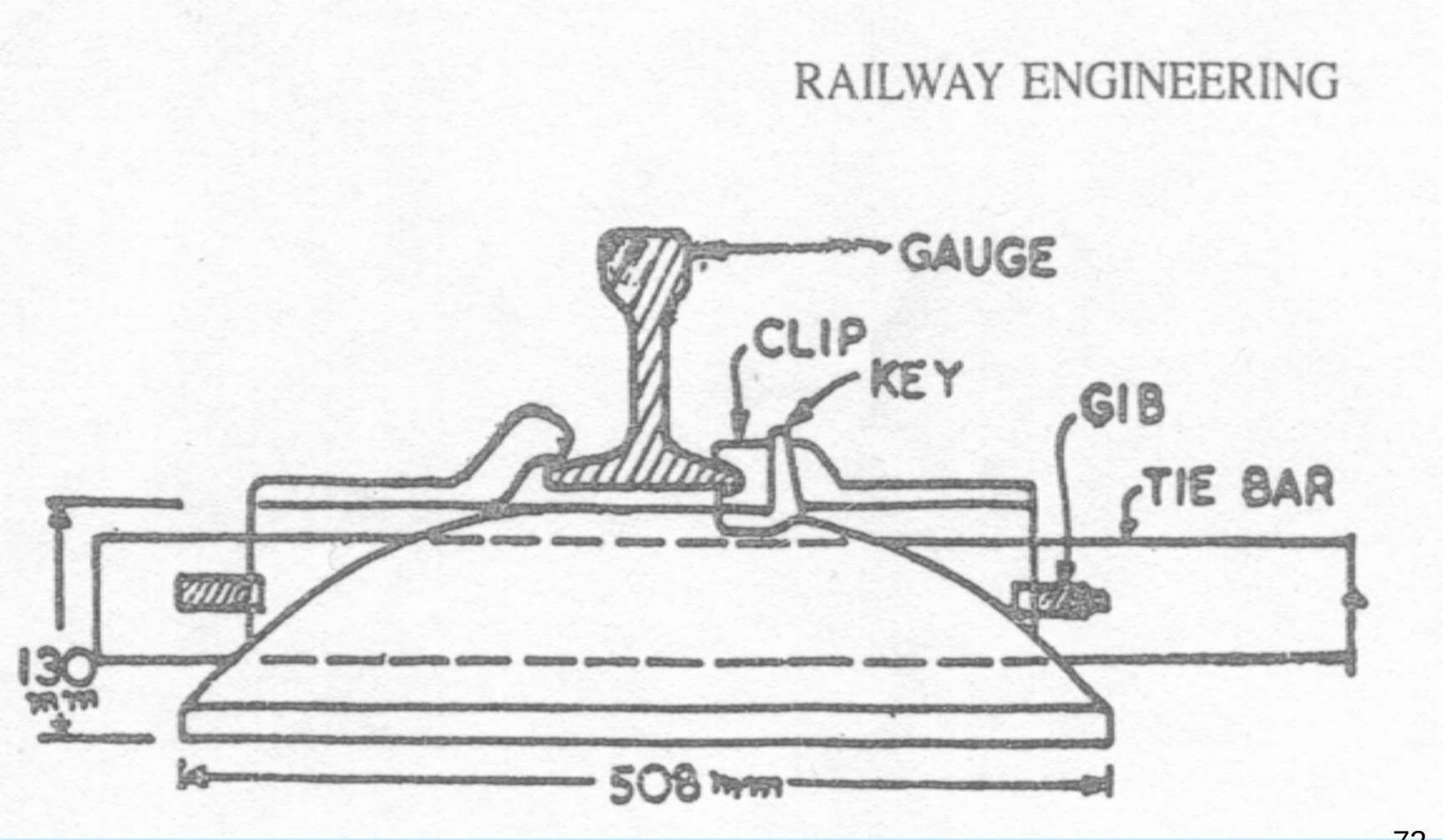
Advantages and disadvantages Of Steel Sleepers

- Connection of the foot of the rail with the sleeper is more stronger
- Steel sleeper keep better alignment of the track
- Maintenance is less
- It gives better lateral rigidity
- Life is longer. Service life is about 50 years.
- It gets easily corroded so it should not be used in moist climates.

Cast Iron Sleepers

- Cast iron sleepers are in the form of pots / plates connected by means of tie bars.
- The pots or bowls and the plates are fixed, one under each rail and they are held together with the tie bar.
- The pots are either circular or oval shaped, the larger diameter being 2’ and smaller diameter being 1’-8”.
- The oval shape is better than the round shape particularly at rail joints where closer spacing is required.

Cast Iron Pot Sleepers



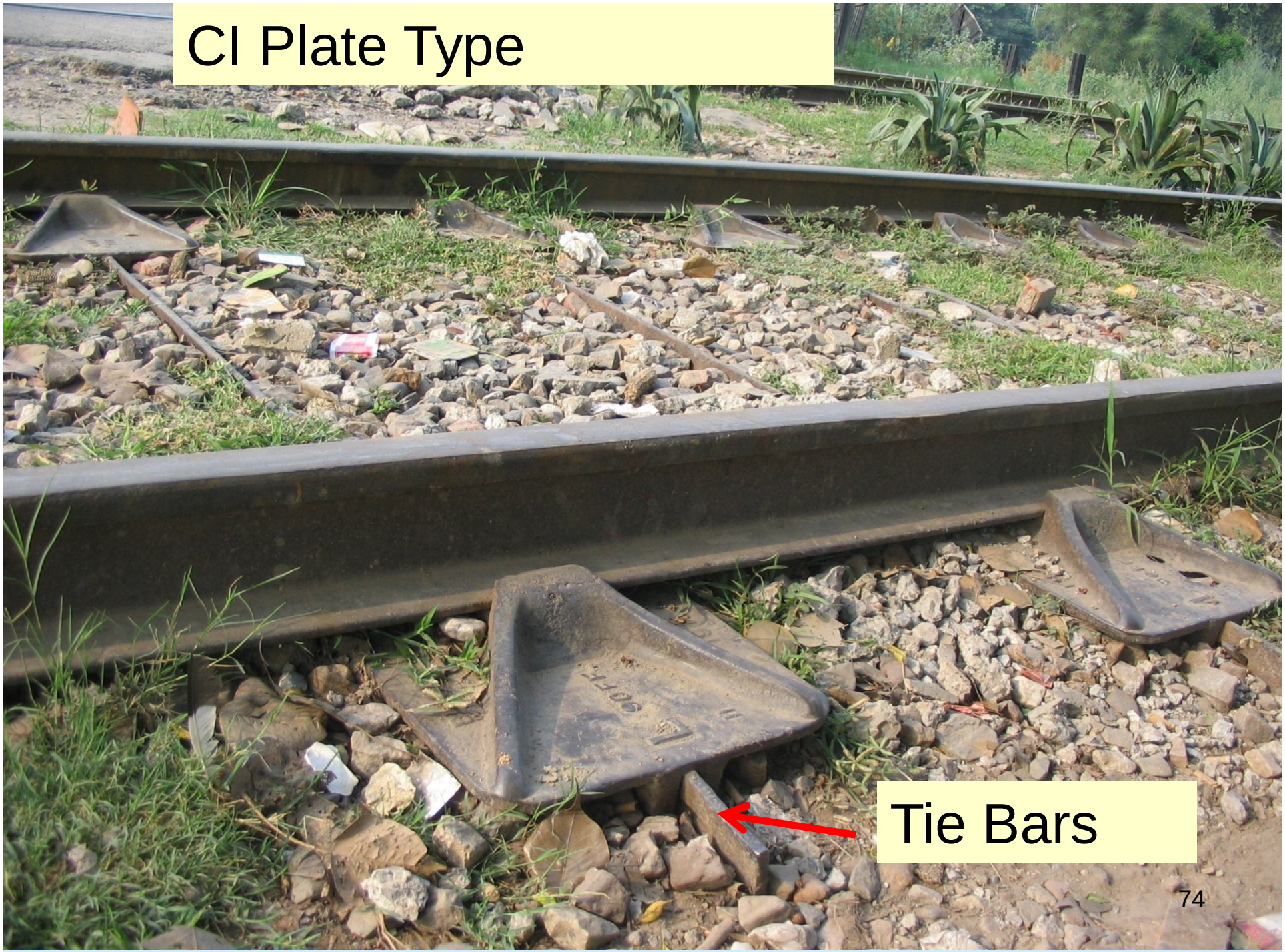
Cast Iron Sleepers

- Tie bars either extend to the outer edges of the pots or plates or end a little beyond the rail seat.

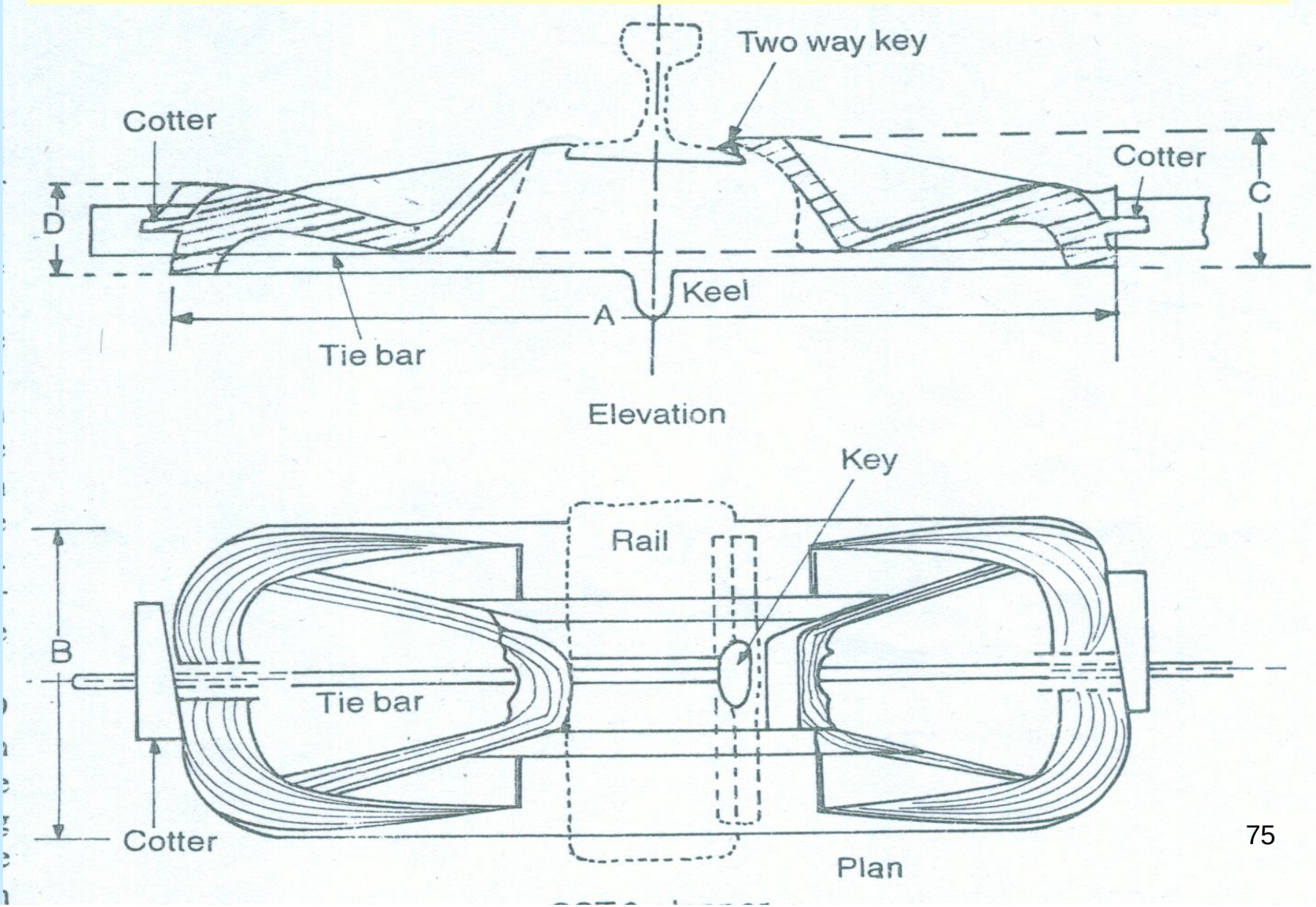
- Long tie bars are preferable as they counteract the tendency of the pot to tilt inward under load.
- Tie bars are fixed to the pots with various fittings.

- Plate sleepers consist of rectangular plates with projecting ribs under the plates for lateral stability.
- The plates are held in position with tie bars.

CI Plate Type



Cast Iron Sleepers



Advantages and Disadvantages

- Cast iron sleepers possess considerable scrap value.
- Cast iron sleeper requires a number of fitting than any other type of sleeper and these are liable to break if not handled carefully.
- Since CI is brittle material, damage is substantial in case of derailment

Concrete Sleeper

- Through Reinforced Concrete Sleeper
- Composite Block and Tie Sleeper
- Prestressed Concrete Sleepers

Concrete Sleeper

Advantages of Concrete Sleepers

- They have longer life, useful life is 40-50 years
- Weight about 3 times heavier than wooden sleeper
- Concrete sleeper provide more stability to track
- No corrosion no decay
- Concrete sleeper are better for the alignment of track
- Maintenance is less and easy to manufacture

Sleeper Density

- Sleeper density is a number indicating number of sleepers per rail length
- It is expressed as m+x
- For Metric system
  - m = length of rail in meter
  - x – additional number of sleepers
- For FPS system n + x
  - n – no of yards per rail length
  - x – additional number of sleepers
- Length of one rail is 36 ft or 42 ft

Sleeper Density

- Additional number of sleepers depends upon
  - Axle load and speed
  - Type of rail section
  - Nature of ballast
  - Type and length of sleepers
  - Nature of formation
- Number of sleepers cannot be increased indefinitely as space between sleepers is required for packing of ballast

Spacing between Sleepers

Note:

Sleepers closely spaced near the joints as high stresses are induced at joints.

Sleeper Density

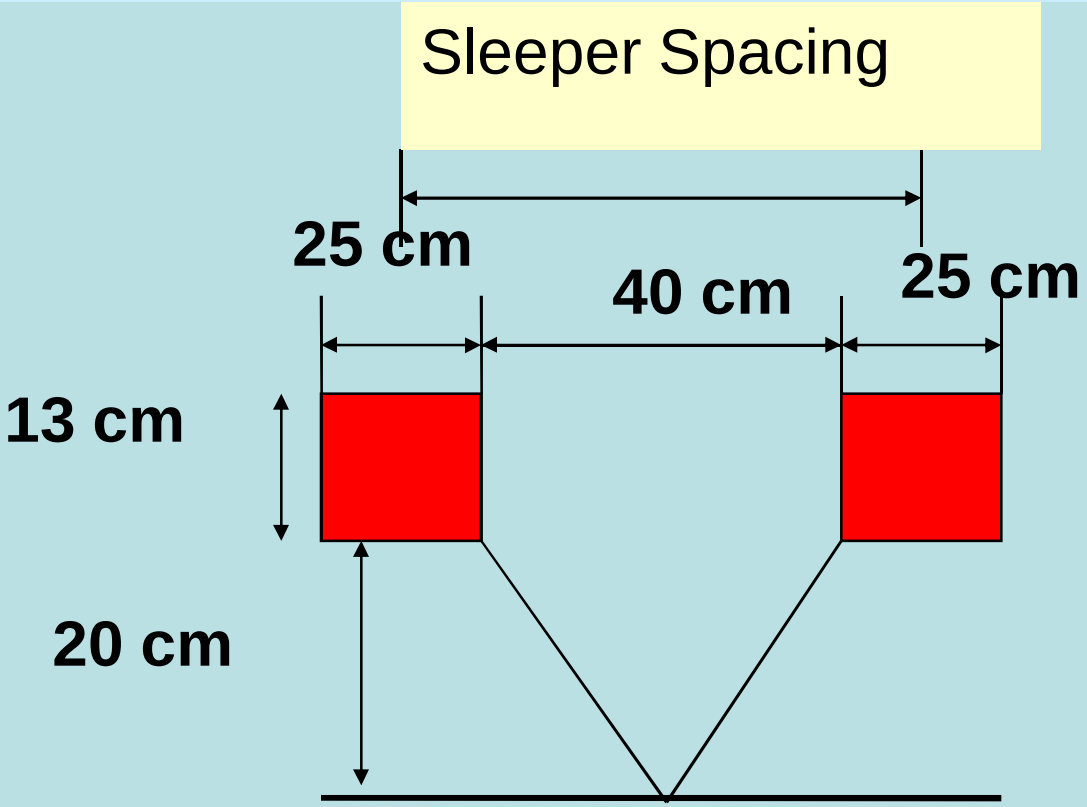
- First two to three sleepers close to the joints are placed at closer spacing and afterwards they are equally spaced.
- The stiffness of track increases
  - By increasing the weight of rail
  - By increasing sleeper per rail
- In Pakistan, sleeper density varies from *n+3 to n + 6*
- In Pakistan, sleeper spacing is 2 ft to 14 in except at joints

Depth of Ballast Section

- For sake of simplicity the load dispersal may be assumed as 45º to the vertical.
- The depth of the ballast should be such that the dispersion line do not over lap.
- For even distribution the following formula is used

Sleeper spacing = width of sleeper + 2 x depth of ballast

Depth of Ballast Section



Size of Sleeper

270 x 25 x 13 cm

Sleeper spacing = width of sleeper + 2 x depth of ballast

Material Train