Lecture 3

University of Anbar
Civil Engineering Department
MSc- Highway Engineering
Railway and Airport Engineering

Railway Track: Components of Superstructure
- Rail
- Sleeper (Tie)

Instructor : Dr. Hameed Aswad Mohammed

Rails

- The rails are produced in the factory by hot-rolling the steel, and then cooled and straightened to form finished lengths of 80 feet (24 meters).
- Fixed welding plants, where the customer can send rail to be welded, while mobile welding plants will come to a railroad, and intrack-flash butt welding machines will go on their track and weld jointed rails together.
- These lengths can be electric flash-butt-welded (EFW) to form longer lengths, typically 1,440 feet (439 meters), that can be transported to the field for installation.
- The rail may be heat-treated at the mill for increased hardness to increase the wearing resistance.
- Varying the steel composition can also give increased hardness with a slight loss of ductility.

Chemical Composition

- Rails are made of steel, and the basic element in steel is iron.
- With the iron are combined small quantities of carbon, manganese, silicon and less desirable elements, sulfur and phosphorus.
- Each of these contributes certain characteristics to the steel
  - ✓ Carbon: adds hardness.
  - ✓ Manganese: gives strength and toughness.
  - ✓ Silicon: its high affinity for oxygen aids in removing during the pouring and rolling process.
  - ✓ Phosphorus: makes steel brittle and likely to break under impact.
  - ✓ Sulfur: causes breaks during the rolling process.
- Rail steel must resist wear, fatigue and plastic flow; it must be weldable. According to the specifications of Iraqi Railways (which follows the international union of Railways specification (UIC)), the percentage of chemical composition is following

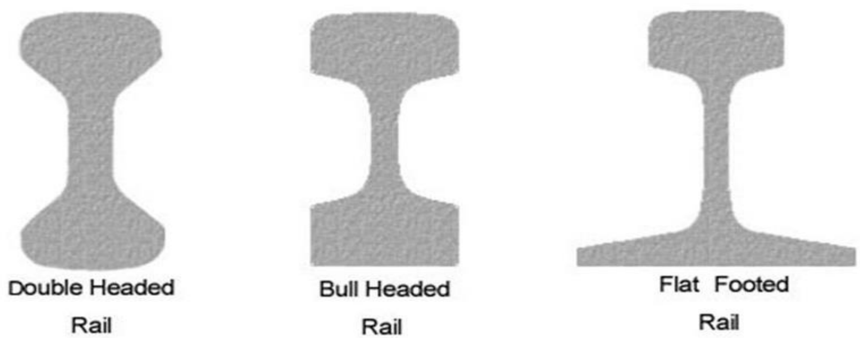
Element	Percentage
Carbon (C)	0.60-0.75
Manganese (Mn)	0.80-1.30
Silicon (Si)	0.50
Sulfur (S)	0.05 (max.)
Phosphorus (P)	0.05 (max.)

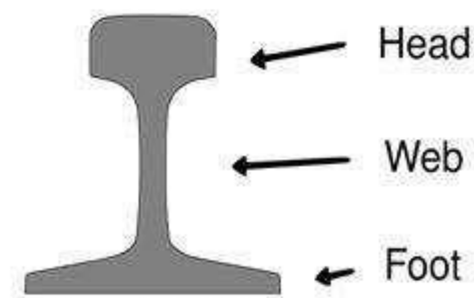
Requirements of Rails

- The section of the rail should be so designed that it should safely transfer the load of the train through their wheels to the sleepers under them.
- Rail should be capable of withstanding lateral forces. The large width of the head and foot gives the rail with high rail stiffness.
- The center of gravity of the rail section must lie approximately at mid-height so that maximum tensile and compressive stresses are equal.
- The head must be sufficiently deep to allow for an adequate margin of vertical wear. The wearing surface should be hard.
- The web should be sufficiently thick to bear the load coming on it and should provide adequate flexural rigidity in the horizontal plane.
- The bottom of the head and top of the rails foot should be so shaped as to enable the fish plates to transmit efficiently the vertical load from the head to the foot at rail joints.
- The foot should be wide enough so that rails are stable against overturning.
- The area of contact between the rail and the wheel should be large so that the contact stresses are low.
- The height of the rail should be adequate so as to have sufficient vertical stiffness and strength as a beam.

Types of Rail Sections

- Double headed rails (D.H. Rails).
- Bull headed rails (B.H. Rails).
- Flat footed rails (F.F. Rails).





Standard Rail Section

- The rail is designated by its weight per unit length. In F.P.S unit, it is weight in Ibs per yard and in metric units it is kg. per meter.
- The section of rail is decided on various considerations such as:
  - ✓ Heaviest axle load.
  - ✓ Maximum permissible speed.
  - ✓ Depth of ballast cushion.
  - ✓ Type and spacing of sleepers.
- The standard section in use on Iraqi Railways are R 43 (43 kg/m) for Baghdad-Basrah main line, BS 90 A (44 kg/m) for Baghdad-Mosul main line, and UIC 60 (60 kg/m) for Baghdad-Al-Qaim-Akashat and all new projects.

Criteria for Determining Length of Rails

- Theoretically longer the rail, lesser are the number of joints and fittings and lesser should be the cost of construction and its maintenance.
- Longer rails are not only economical but give smother and comfortable riding of trains.
- The length of rail is, however, restricted due to the following factors:
  - ✓ Lack of facilities for transport of longer rails particularly on curves.
  - ✓ Difficulties in handling of long rails.
  - ✓ Uneconomical in manufacturing very long rails.
  - ✓ Difficulties in having a bigger expansion joint for long rails.
  - ✓ Heavy internal thermal stresses in long rails.
- In Iraq and other countries, the following rail lengths have been adopted as given in the following Table:

Name of country	Length of rail (m)
Iraq	12.5 and 18
France	24
Germany	30
U.S. A	12
U. K	18
India	13

Rail Connection

- The rail sections are connected in the field by either bolted joints or welding.
- The locations of the bolted joints are high-maintenance areas because of the impact of the wheels passing the rail end gap at the center of the joints.
- The combination of the impact load and reduced rail stiffness of the supporting joint bars causes greater stress on the fasteners, ties, ballast, and subgrade.
- This in turn causes fastener looseness, plate cutting (wood ties), pad deterioration and concrete tie seat abrasion (concrete ties) and more rapid track settlement and geometry deterioration.
- This problem can be reduced by eliminating the joints by field welding.
- This approach is preferred on high-speed and heavy axle load lines.

Jointed Rails

- Jointed track is made using lengths of rail, usually around 20 m long (in the UK) and (12 or 24 m) long (in North America), bolted together using perforated steel plates known as *fishplates* (UK) or *joint bars* (North America).
- Fishplates are usually 600 mm long, used in pairs either side of the rail ends and bolted together (usually 4, but sometimes 6 per joint).
- The bolts may be oppositely-oriented so that in bolts the event of a derailment and a wheel flange striking the joint, only some of the bolts will be sheared, reducing the likelihood of the rails misaligning with each other and exacerbating the seriousness of the derailment.
- Because of the small gaps left between the rails, when trains pass over jointed tracks, they make a "clickety-clack" sound. Unless it is well-maintained, jointed track does not have the ride quality of welded rail and is less desirable for high-speed trains.
- However, jointed track is still used in many countries on lower speed lines and is used extensively in poorer countries due to the lower construction cost and the simpler equipment required for its installation and maintenance.

Continuous Welded Rail

- Most modern railways use **continuous welded rail** (CWR), sometimes referred to as **ribbon rails**.
- In this form of track, the rails are welded together by utilizing flash butt welding to form one continuous rail that may be several kilometers long.
- Because there are few joints,
  - ✓ this form of track is very strong,
  - ✓ gives a smooth ride, and needs less maintenance
  - ✓ trains can travel on it at higher speeds and with less friction.
  - ✓ welded rails are more expensive to lay than jointed tracks but have much lower maintenance costs.

Rail Gauge

- The spacing of the rails is standardized at a value termed *gauge*.
- The gauge is the distance between the inside faces of the rail at (14 mm) below the top of the railhead.
- Gauge limitations and excesses are defined by the U.S. Federal Railroad Administration (FRA) Track Safety Standards (FRA 1998) based on the class of track.
- For example, in North America the gage is (1435 mm) with various tolerances as defined by the FRA.
- The gauge used by different systems. Today, 54.8%of the world's railways use a gauge of 1435 mm.
- Gauge can safely vary over a range. For example, U.S. federal safety standards allow standard gauge to vary from (1420 mm) to (1460 mm) for operation up to 60 mph (97 km/h).

Different Gauge Used

- Broadly railway gauges can be divided into the following:
  - ✓ Broad gauge;
  - ✓ Standard gauge;
  - ✓ Meter gauge;
  - ✓ Narrow gauge.

No.	Name of Gauge	Gauge (mm)	% of total length
1	Standard Gauge (S.G)	1435	62%
2	(a) Broad Gauge (B.G)	1676	6%
	(b) Broad Gauge (B.G)	1524	9%
3	(a) Meter Gauge (M.G)	1067	8%
	(b) Meter Gauge (M.G)	1000	9%
4	Narrow and other gauges	672 to 610	6%

Uniformity of Gauges

- Gauge to be used in a particular country should be uniform throughout as far as possible, because it will avoid many difficulties experienced in a non-uniform system and will result in the following advantages:
- The delay, cost and hardship in transshipping passengers and goods from the vehicles of one gauge to another are avoided.
- Difficulties in loading and unloading are avoided and labour expenses are saved.
- At every change of gauge, the passengers have to change the train, which causes much inconvenience to passengers. This is avoided if gauge is uniform.
- Possibility of thefts and misplacement, while changing from one vehicle to another, is eliminated.
- Surplus wagons of one gauge can not be used on another gauge. This problem will not arise if gauge is uniform.
- Locomotives can be used on all the tracks if a uniform type of gauge is adopted.

Sleepers (Ties)

Sleepers are members generally laid transverse to the rails, on which the rails are supported and fixed, to transfer the loads from rails to the ballast and sub-grade below.

Requirement of Sleepers

- The sleepers should be capable of resisting shocks and vibrations due to heavy loads of high-speed trains.
- The weight of sleepers should not be too heavy or excessively light, they should have moderate weight.
- The sleepers should be sufficiently strong to act as a beam under loads.
- The design of sleepers should be such that the gauge, alignment of track and levels of the rails can be easily adjusted and maintained.
- The sleeper design and spacing should be such as to facilitate easy removal and replacement of ballast.
- The sleepers should be able to bear the stresses, which will come over them.
- The sleepers should not be pushed out easily of their position in any direction even under maximum forces of the moving trains.
- The fittings of the sleepers should be such that they can be easily adjusted during maintenance operation such as easy lifting, packing, removal and replacement

Classification of Sleepers

Sleepers can be classified according to the materials used in their construction, in the following categories:

- Wooden sleepers.
- Metal sleepers.
- Concrete sleepers.

1. Wooden Sleepers

Wooden sleeper is the most ideal type of sleeper, and its utility has not decreased with the passage of time. The life of wooden sleepers depends upon their ability to resist wear, decay, attack by vermin, atmospheric actions and quality of wood used. Following are the advantages and disadvantages of using wooden sleepers:

(A) Advantages:

- These sleepers are able to resist the shocks and vibrations due to heavy moving loads and hence give less noisy track.
- These wooden sleepers are suitable for all types of ballast.
- Fittings for wooden sleepers are few and simple in design.
- Wooden sleepers are easy to lay, relay, pack, lift and maintain.
- Suitable for areas having yielding formations.
- Alignment can be easily corrected.

Classification of Sleepers

(B) Disadvantages:

- The sleepers are subjected to wear, decay, attack by vermin, cracking and rail cutting.
- Wooden sleepers have got minimum life (12 to 15 years) as compared to other types of sleepers.
- It is difficult to maintain the gauge in case of wooden sleepers.
- Track is easily disturbed; alignment maintenance is difficult.
- They are susceptible to fire hazards.

2. Metal Sleepers

Due to the growing scarcity of wooden sleepers, their high cost and short life, metal sleepers are now being widely adopted in some countries of world. Metal sleepers are either of steel or cast iron. Cast iron is in greater use than steel for sleepers because it is less prone to corrosion. Cast iron is not used on Iraqi railways, but steel sleepers are used on some places such as Mosul-Rebia section (112km.) and also on a small stretch of Baghdad-Mosul line.

Classification of Sleepers

Requirements of Metal Sleepers

- Metal sleepers should bear the tensile and compressive stresses, which come on them.
- They should provide sufficient area for rails, area on ballast should be at least equal to that of wooden sleepers.
- Tamping and packing of ballast should not disturb the sleeper.
- Metal sleepers should provide sufficient grip on the rails and ballast to prevent the dislocation of track due to shocks and vibrations.
- The design of metal sleepers should be such that they give easy fixation and removal of rails without disturbing the sleepers.
- They should be sufficiently heavy for stability and should not be pushed out easily from their position.

(A) Advantages:

- Metal sleepers are uniform in strength and durability.
- Gauge can be easily adjusted and maintained in case of metal sleepers.
- In metal sleepers, the performance of fitting is better and hence lesser creep occurs.

Classification of Sleepers

- Metal sleepers are economical, as life is longer, and maintenance is easier.
- Metal sleepers give better lateral rigidity.
- They are not susceptible to vermin attack and to fire hazards.

(B) Disadvantages:

- More ballast is required than other type of sleepers.
- Metal, cast-iron (C.I) or steel are liable to rust.
- Metal sleepers are unsuitable for bridges, level crossings and in case of points and crossings.
- In steel sleepers, generally, cracks develop at rail seat, which require the use of saddle plate.
- The sleepers, being of metal, are liable to corrosion.
- Fitting are greater in number.
- These sleepers are only suitable for stone ballast.

Classification of Sleepers

3. Concrete Sleepers

The concrete sleeper appears to have originated from attempts aimed at producing a more economical and technically superior alternative to the metal and timber sleepers then in use [. Actually Mr. Monnier a French gardener is the inventor of cement concrete sleepers in 1877. Concrete sleepers are widely used in Iraqi Railways. They have good characteristics for the following reasons : (They are made of a strong homogenous material; impervious to effect of moisture and is unaffected by the chemical attack of atmospheric gases or sub-soil salts. It is molded easily to size and shape required by scientific investigation to withstand the stresses introduced by fast and heavy traffic).

(A) .Advantages:

- Concrete sleepers are free from natural decay and attacks by insects.
- They have maximum life when compared to other sleepers, the life under normal conditions is 40 to 60 years.
- The high weight of sleepers help in minimizing joint maintenance by providing longer welded lengths, greater stability of the track and resistance against temperature rise.
- This is not affected by moisture, chemical action of ballast and sub-soil salt.

Classification of Sleepers

- The concrete sleepers can generally be mass produced from local resources.
- Concrete sleepers maintain better gauge, cross level and alignment.
- The sleeper has higher elastic modulus and hence can withstand the stresses induced by fast and heavy traffic.

(B) Disadvantages:

- The weight of concrete sleeper is as high as 2.5 to 3 times of wooden sleeper, requiring the mechanical appliance for handling.
- They damage the bottom edge during the packing.
- Concrete sleepers require pads and plugs for spikes.
- Heavy damage to sleepers at the time of derailment.

Types of concrete sleepers

There are two types of concrete sleepers :

- Reinforced concrete sleepers.
- Pre-stressed concrete sleepers

Classification of Sleepers

Design Considerations

The factors considered in design of concrete sleepers may be enumerated as follows:

- Forces acting on a sleeper.
- Effects of the geometrical form including, size and weight.
- Effect of the characteristics of fastenings used.
- Provision of failure against derailments.

Laying of Concrete Sleepers

At the time of laying concrete sleepers due to care should be taken. Following points should be attended to very carefully:

- Provide complete complement of fittings at the time of laying.
- Ensure adequate clean ballast cushion.

Sleeper Density and Spacing of Sleepers

- The number of sleepers used per rail length is known as the density of sleepers. Generally, one sleeper is used for every one-meter length of the rail. If the spacing is kept less and more number of sleepers are used, then it is specified as ($\boldsymbol{n}$ + $\boldsymbol{x}$), where ($\boldsymbol{n}$) is length of rail in meters and ($\boldsymbol{x}$) is a mathematical number which varies according to the following factors:

  (*i*) Axle load and speed, (*ii*) type and section of the rails, (*iii*) type of ballast and depth of ballast cushion, (*iv*) type and strength of sleepers and (*v*) nature of formation.

- On Iraqi Railways, the sleeper density on (S.G) is varied from ($\boldsymbol{n}$ + 7) to ($\boldsymbol{n}$ + 8) for main tracks. In Britain, ($\boldsymbol{n}$ + 4) sleepers are used, while in America, ($\boldsymbol{n}$ + 9) to ($\boldsymbol{n}$ + 11) sleepers are common in through tracks.
- The spacing of the sleepers depends upon the sleeper density. Generally, the spacing is kept uniform throughout the length of the rail. The allowable number of cycles that may be imposed on a sleeper is inversely proportional to sleeper spacing. As sleeper spacing increases, the allowable number of cycles imposed on that sleeper decreases .The number of sleepers in a track is indicated by the number per rail length, since sleeper provides lateral stability. The number of sleepers, however, can not be increased indefinitely, as a certain minimum space between sleepers is required for packing of ballast

Sleeper Density and Spacing of Sleepers

- The spacing between sleepers is not uniform. Three or four sleepers on either side of the joint are kept close together. The joint sleepers are very close to avoid loosening of ballast due to impact. Table below gives the spacing of sleepers adopted in various railway are as follows:

Country	Straight	Curve
Iraq	60 cm	60 cm
Britain	66 cm	66 cm
Germany	63 cm	63cm up to 500m radius 60cm below 500m radius
France	58/60 cm	58/60 cm
U.S.A	76.2 cm	76.2 cm
Japan	60 cm	60 cm
Hungary	65 cm	65 cm
India	68 cm	68 cm