CE 8702 Railways, Airports and Harbor Engineering

Course Objective

TO INTRODUCE THE STUDENTS ABOUT RAILWAYS PLANNING, DESIGN, CONSTRUCTION AND MAINTENANCE AND PLANNING DESIGN PRINCIPLES OF AIRPORT AND HARBOUR

UNIT I RAILWAY PLANNING & CONSTRUCTION

- Elements of permanent way – Rails, Sleepers, Ballast, rail fixtures and fastenings,
- Selection of gauges - Track Stress, coning of wheels, creep in rails, defects in rails
- Route alignment surveys, conventional and modern methods—
- Geometric design of railway, gradient, super elevation, widening of gauge on curves- Level Crossings.

UNIT II RAILWAY CONSTRUCTION AND MAINTENANCE

- Earthwork – Stabilization of track on poor soil –
- Track drainage – Calculation of Materials required for track laying –
- Construction and maintenance of tracks
- Railway Station and yards and passenger amenities
- Signalling

UNIT III AIRPORT PLANNING

- Air transport characteristics
- Airport classification – ICAO
- Airport planning: Site selection typical Airport Layouts,
- Case Studies, parking and Circulation Area

UNIT IV AIRPORT DESIGN

- Runway Design: Orientation, Wind Rose Diagram,
- Problems on basic and Actual Length,
- Geometric Design – Elements of Taxiway Design
- Airport Zones – Passenger Facilities and Services –
- Runway and Taxiway Markings.

UNIT V HARBOUR ENGINEERING

- Definition of Basic Terms: Harbour, Port, Satellite Port, Docks, Waves and Tides
- Planning and Design of Harbours: Harbour Layout and Terminal Facilities
- Coastal Structures: Piers, Break waters, Wharves, Jetties, Quays, Spring Fenders, Dolphins and Floating Landing Stage
- Inland Water Transport – Wave action on Coastal Structures and Coastal Protection Works
- Coastal Regulation Zone, 2011

UNIT I RAILWAY PLANNING & CONSTRUCTION

MODES OF TRANSPORTATION

MODES OF TRANSPORTATION

- **Highways**

  Car, Bus, Truck, non- motorized ..etc

- **Railways**

  Passenger and Goods

- **Airways**

  Aircraft and Helicopters

- **Waterways**

  Ships, boats…

- **Continuous Flow systems**

  Pipelines,belts,elevetor,ropeway…etc.

- Merits and Demerits: Based on accessibility, mobility, cost, tonnage..

Highways

- maximum service
- maximum flexibility for travel with reference to route, direction, time and speed of travel
- It provide door to door service
- It requires small investment for the government
- Motor vehicles are cheaper than other carriers
- It saves the time for short distance
- High degree of accident due to flexibility of movement

Railways

- It could be advantageous by railways between the stations both for the passengers and goods, particularly for long distance.
- It depends upon the road transport i.e. road could serve as a feeder system.
- Energy require to haul a unit load through unit distance is less
- Safety

Airways

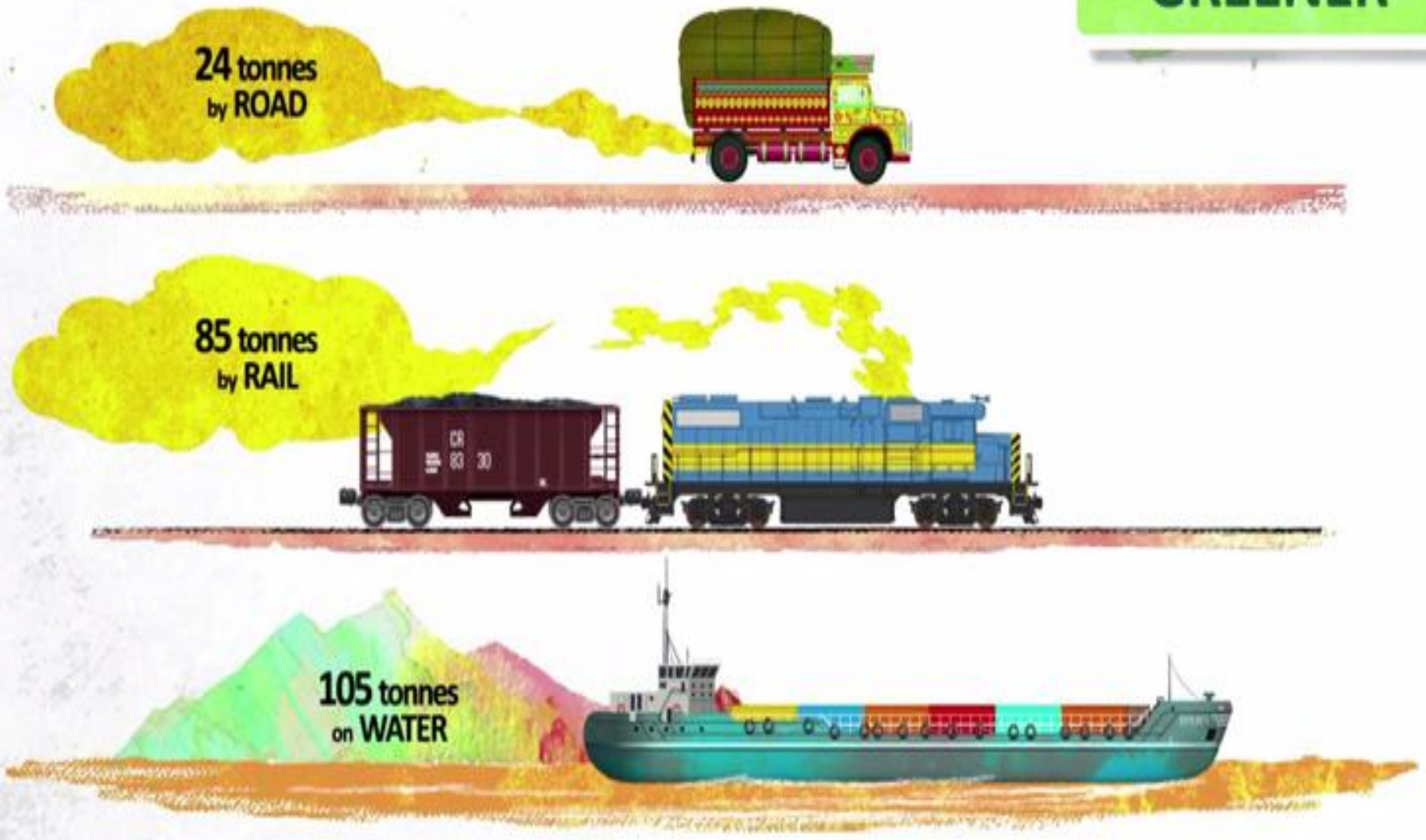
- Fastest among all other modes
- More comfortable
- Time saving
- Uneconomical

Waterways

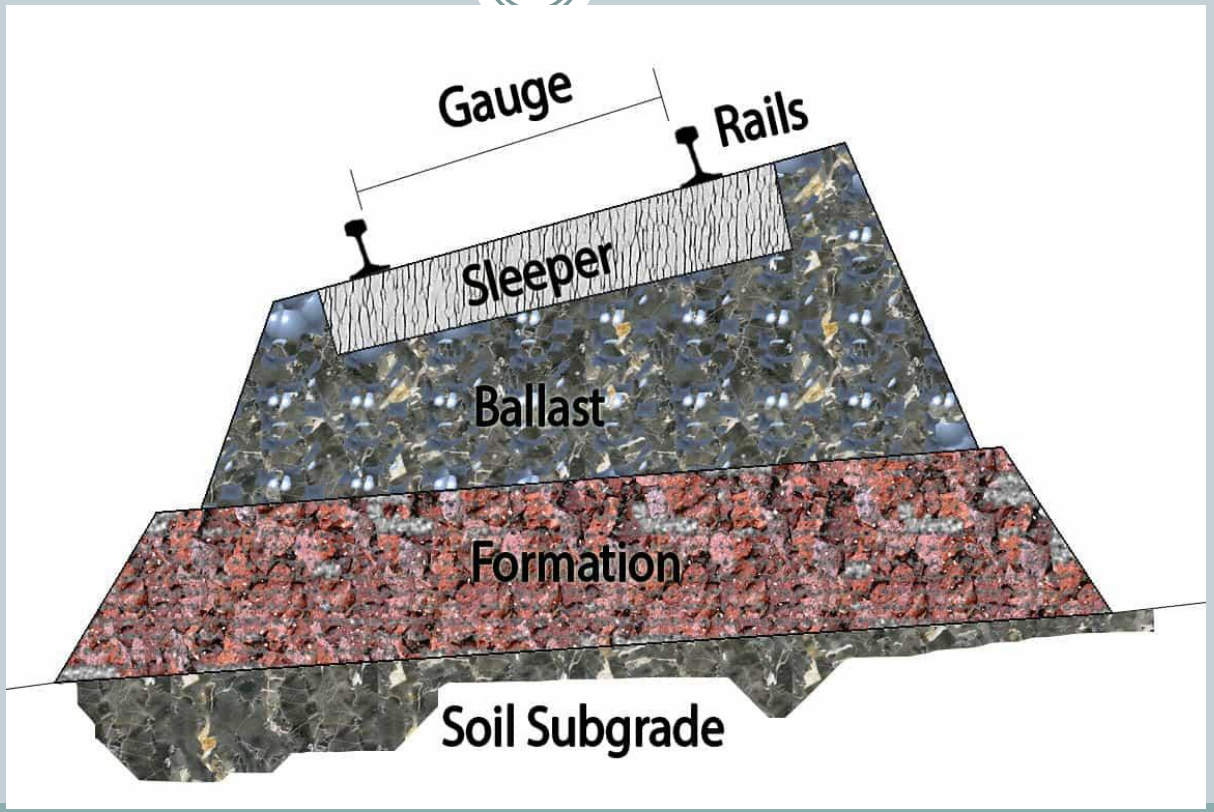
- slowest among all other modes
- It needs minimum energy to haul unit load through unit distance.
- This can be possible between ports on the sea routes or along the river
- economical

1 litre of fuel can move

GREENER

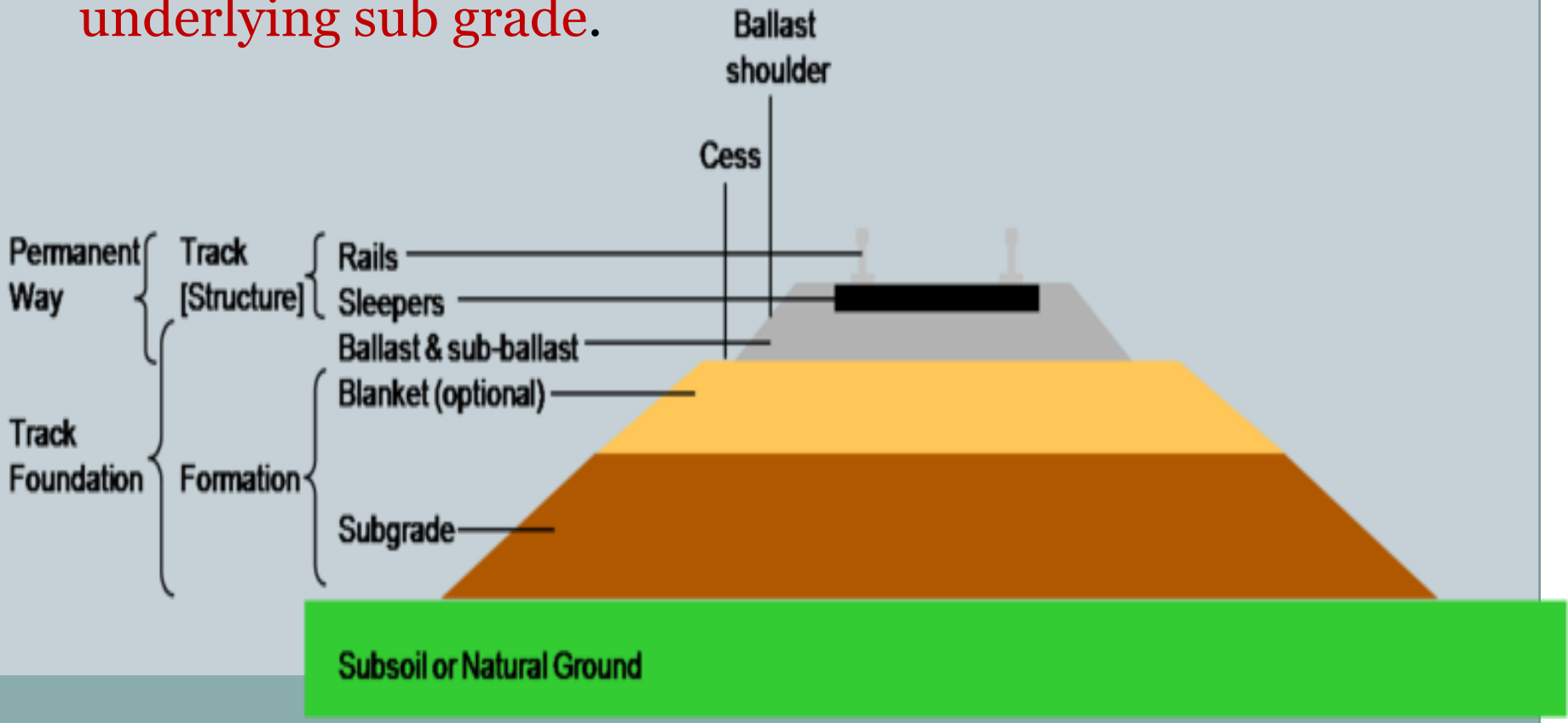


ELEMENTS OF RAILWAY TRACKS



Elements of Railway tracks

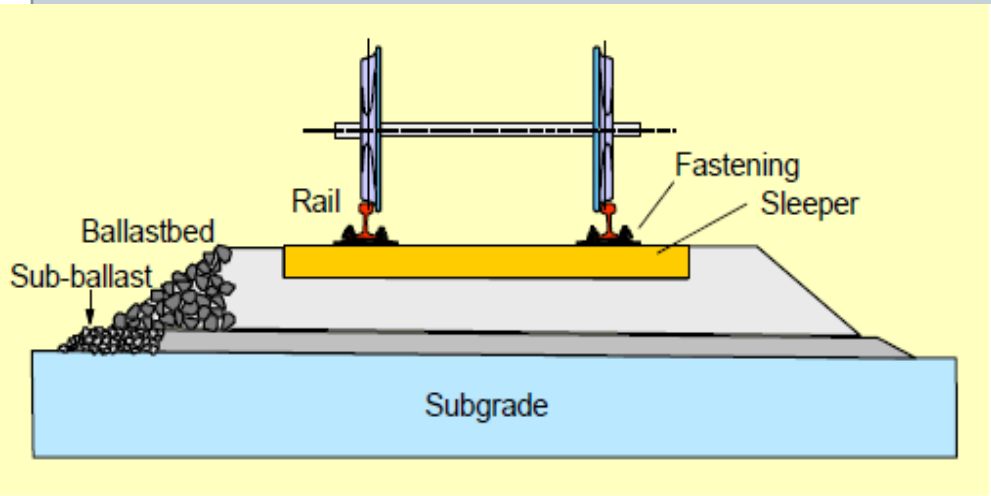
The track on a railway or railroad, also known as the permanent way, is the structure consisting of the rails, fasteners, sleepers and ballast (or slab track), plus the underlying sub grade.

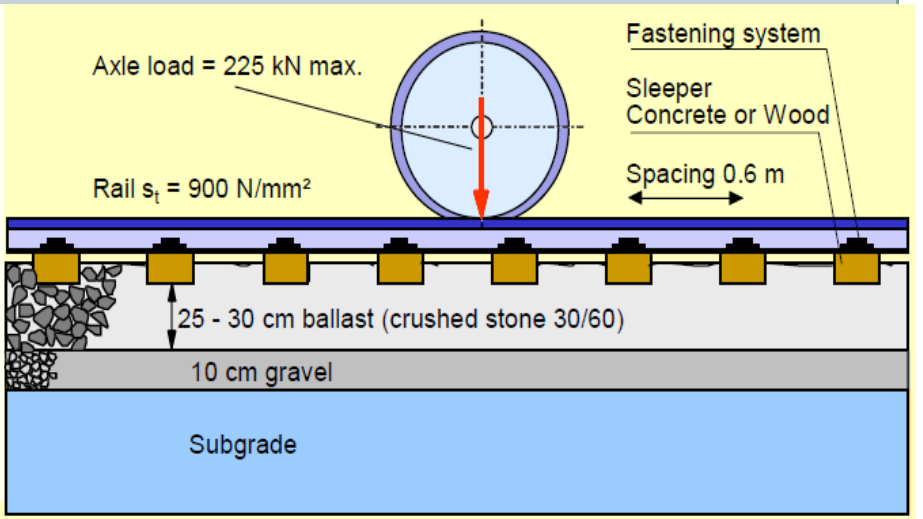


Track Formation

Requirements for Choosing a Track System:

1. Trains running on the track should not cause excessive environmental pollution in the form of noise and ground vibration.
2. Costs of the total service life of the track must be as low as possible.
3. Maintenance should be low and as inexpensive as possible





Requirements of an Ideal Permanent Way

- The gauge Should be correct and uniform
- The alignment Should be correct and it Should be free from kinks and irregularities
- The radii and super elevation and curves Should be properly designed and maintained
- Drainage System must be performed for enhancing Safety and durability of the track
- There Should be adequate provision for easy renewals and replacement
- The track Structure Should be Strong, low initial cost as well as maintenance cost

Permanent Way Materials

1. Rails
2. Concrete Sleepers
3. Fastenings
4. Switches & Crossings (Turnouts)

RAILS

RAILS

The rolled steel sections laid end to end in two parallel lines over sleepers to form a railway track are known as **RAILS.**

Functions of rails :

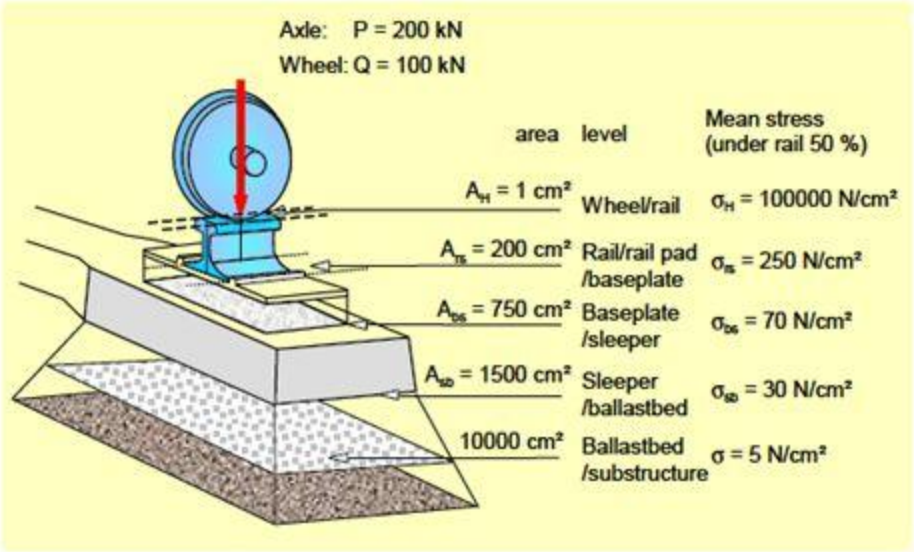
1)Basically it is to provide a continuous and smooth surface with an acceptable gradient for the movement of trains.

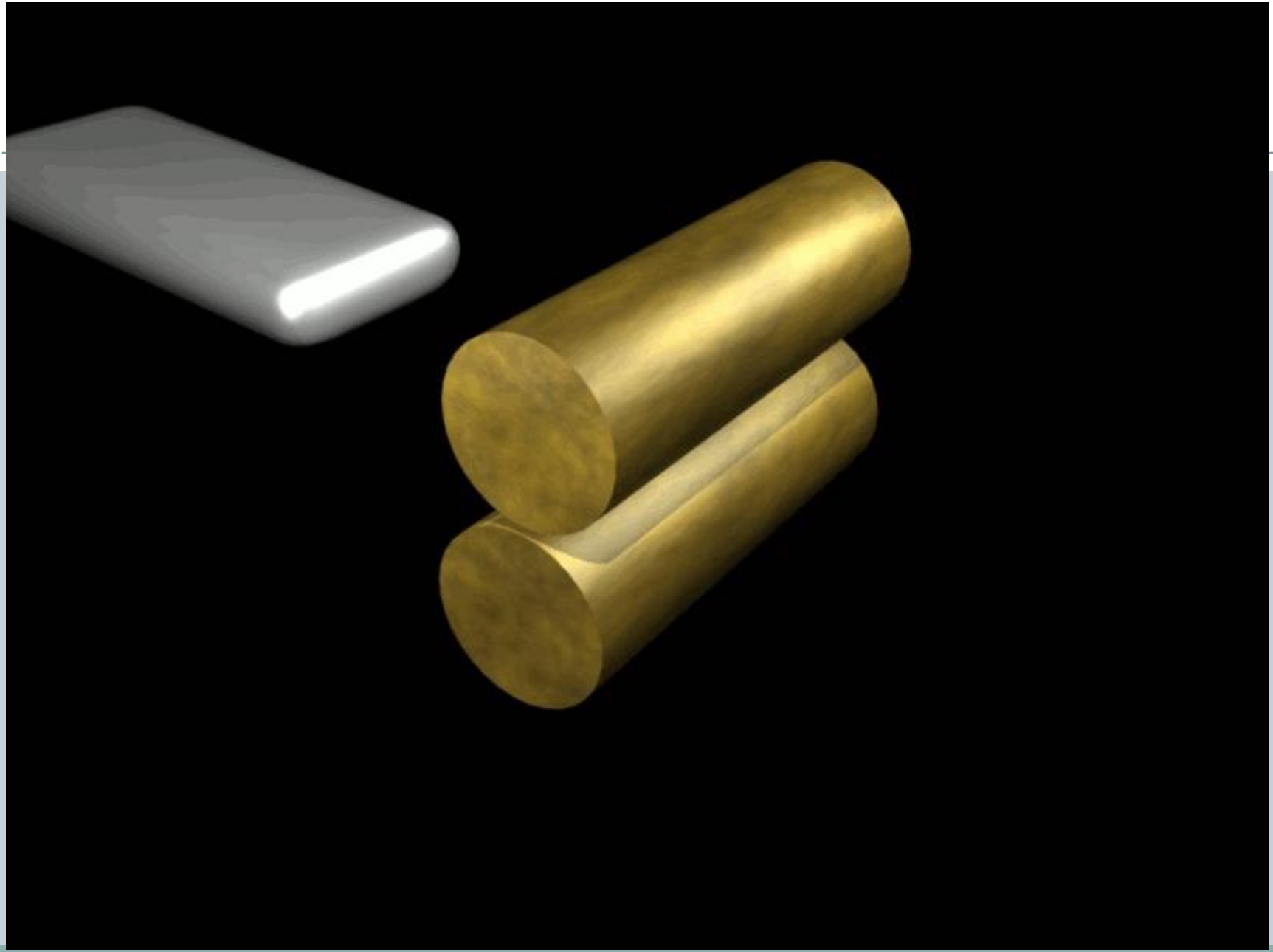
2) Rails to bear the stresses developed due to heavy vertical loads, stresses due to lateral thrust, breaking stresses and thermal stresses.

Load Bearing Function of the Track

The load transfer works on the principle of stress reduction - layer by layer.

1. The greatest stress occurs between wheel and rail and is in the order of 30 kN/cm2 (= 300 MPa).
2. Between rail and sleeper the stress is two orders smaller and diminishes between sleeper and ballast bed down to about 30 N/cm2.
3. Finally the stress on the formation is only about 5 N/cm2.





Types of Rails :-

The rails used in the construction of railway track can be divided into the following three types :

(1) Double Headed Rails (D.H. Rail)

(2) Flat Footed Rails (F.F. Rail)

(3) Bull Headed Rails (B.H. Rail)

1. Double Headed Rail :-

- The rails having their head and foot of same dimensions are known as **double headed rail (D.H.).**

- However it was found that due to the impact of the wheels lower surface in contact with the chairs got dented. This lead to the development of bull headed rail which had one head larger than the other.

2. Flat Footed Rails :-

- The rail section having their foot rolled to a flat are known as **flat footed rails.** Thus a flat-footed (FF) rail with an inverted T-type was developed.

- This type could be fixed directly to the sleepers with the help of spikes. This type of rail is adopted all over the world.

Compared to BH-type, the flat footed rails have the following advantages:

- 1)provides better rigidity and stiffness to resist vertical and lateral forces.
- 2) points and crossings are simpler.

Flat footed rail

3. Bull Headed Rail :

The rails sections having their head of more dimension then that of their foot are known as **bull headed rails (B.H.).**

Rails section and length:

Section

It is designated by weight per unit length.

1) Maximum axial load
2) Maximum permissible speed
3) Depth of ballast cushion
4) Type and spacing of sleepers
5) Gauge of the track

- Two heavier rails sections 60 kg and 52 kg are recently introduced and are designated in metric units. Thus 60kg/m rail denotes that it has a weight of 60kg per meter length.

Rail Length:

- In general longer the rail, lesser the number of joints and fittings, lesser the cost of construction and maintenance.
- However the length of a rail is restricted due to the following factors:

    1) Longer rails are difficult to transport

    2) Manufacture is difficult

    3) Difficulties in handling wide expansion joints

    4) Large internal stresses

GAUGE

The clear horizontal distance between the inner (running) faces of the two rails forming a track is known as Gauge. (see in fig given below)

TYPES OF GAUGES PREVALENT IN INDIA

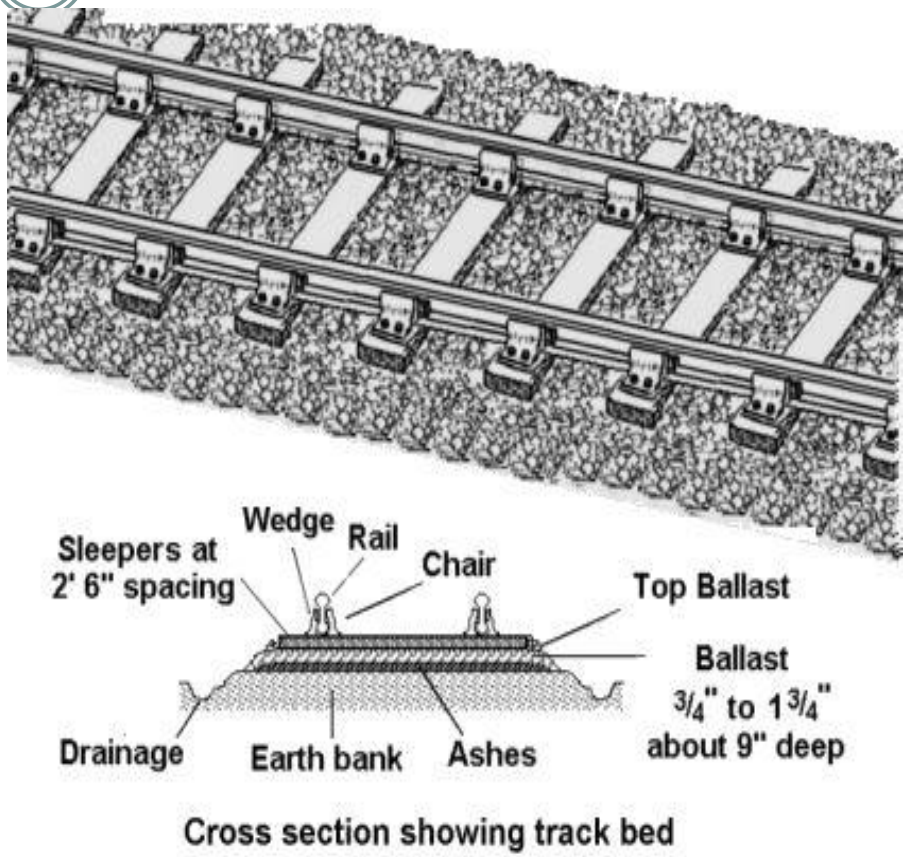
The different gauges prevalent in ***India*** are of the following these types :-

1. ***Broad gauge (1676),***
2. ***Metre gauge (1000),***
3. ***Narrow gauge (762 mm & 610 mm).***

ELEMENTS OF RAILWAY TRACKS

A railway track is a combination of

1. Formation
2. Ballast
3. Sleepers
4. Rails
5. Fastenings



Cross section showing track bed

1. FORMATION

- The surface prepared to receive the ballast, sleepers, rails, etc.. for constructing the railway track is called formation or sub grade.

Function of formation

The formation has the following functions

- It provides a smooth and uniform bed on which the track is laid.
- It bears the entire load transmitted from the moving loads to it through the ballast.
- It provides drainage facilities.
- It provides stability to the track.

Design aspects

WIDTH

The width of the formation depends upon

- Numbers of tracks to be laid over it.
- Gauge of the track.
- Width of ballast layer.
- Width of drains provided.

HEIGHT

The height of the formation depends upon the topography of the alignment and the gradients adopted.

SLIDE SLOPES

The slide slopes of the formation depends upon the characteristics of the soil, as shear strength, angle of repose etc.

3. SLEEPERS

Sleeper is transverse support for a railway to give stiffness to it.

Functions of sleepers

- Holds the rails to correct gauge.
- Give a firm and even support to the rails.
- Distributes the axle load over a sufficiently large area of ballast.
- To act as elastic medium between the rails and ballast to absorb vibration.
- To maintain the alignment of the track.
- To provide insulation for electrified track.

Classification of sleepers

Depending on the material used for their manufacture, the sleepers can be divided into the following categories

- Wooden sleepers.
- Steel sleepers.
- Cast iron sleepers.
- Concrete sleepers

WOODEN SLEEPERS

- Wooden sleepers are the ideal type of sleeper. Hence they are universally used. The utility of timber sleepers has not diminished due to the passage of time.

ADVANTAGES

Wooden sleepers have the following advantages:

- They are easy to manufacture
- They are more useful for heavy loads and high speeds
- They are easy to handle without damage
- They are more suitable for soft formations
- They absorb shocks and vibrations better than other types of sleepers.

DISADVANTAGES

- They are easily liable to attack by vermin and weather. Hence their life is lesser than other type of sleepers
- They are susceptible to fire.
- Their maintenance cost is highest in comparison to other type of sleepers
- Their useful life is short about 12 to 15 years.

STEEL SLEEPERS

- Due to the increasing shortage of timber in the country and other economical factors have led to the use of steel and concrete sleepers on railways.

ADVANTAGES

- It is more durable. Its life is about 35 years
- Lesser damage during handling and transport
- Easy to manufacture
- It is not susceptible to vermin attack
- It is not susceptible to fire
- Its scrap value is very good

DISADVANTAGES

- It is liable to corrosion.
- Cracks at rail seats develop during the service.
- Fittings required are greater in number.

CONCRETE SLEEPERS

- Concrete ties have become more common mainly due to greater economy and Shortage of timber.

ADVANTAGES

- It is more durable having greater life.
- It is economical as compare to wood and Steel.
- Easy to manufacture.
- It is not susceptible to vermin attack
- It is not susceptible to fire

DISADVANTAGES

- It is brittle and cracks without warning.
- It cannot be repaired, and required replacement.
- Fittings required are greater in number.

SLEEPER DENSITY

- Number of sleepers per rail length is called sleeper density. Sleeper density is indicated by (n + x)
- Where, n = the length of rail in meters
- X is number of sleepers.
- (Eg) For a standard 13m B.G rail , m+ 7 density would mean 20 sleepers per rail length.

Joints and fastenings

- **Types of joints**
  1. Supported rail joint
  2. Suspended rail joint
  3. Bridge joint
  4. Welded rail joint
  5. Staggered or Broken rail joint
  6. Square or Even joint

Square joint

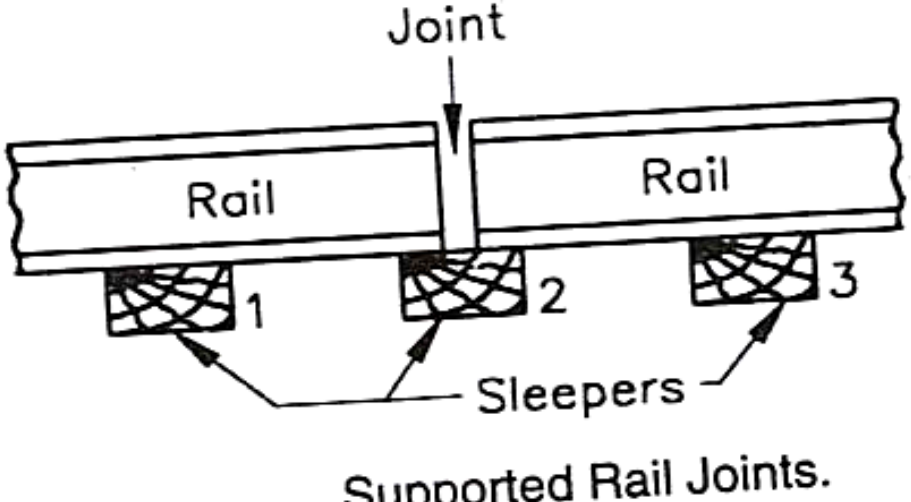
- When a joint in one rail just opposite to the joint is called square joint.

STAGGERED JOINTS

- If the joints are exactly opposite to the centre of the parallel rail then it is called staggered joints.

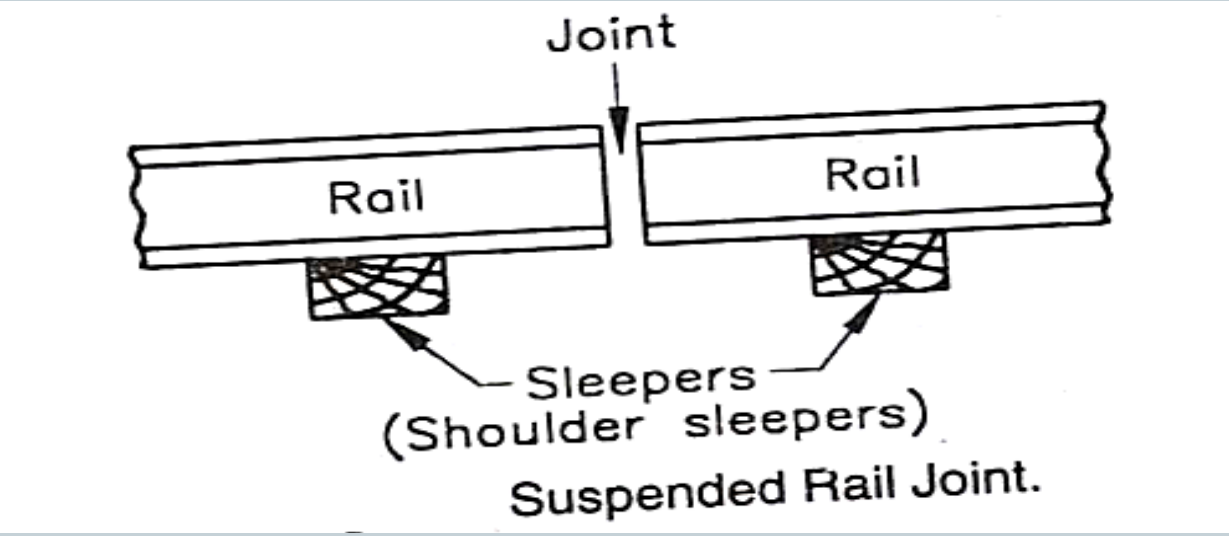
1.Supported rail joint

- The rail ends rest on the single Sleeper is called joint Sleeper and it is also called Supported joint. these Sleepers are Supported with a long fish plate. i.e. combined and Suspended joint is most commonly objectionable



Supported Rail Joints.

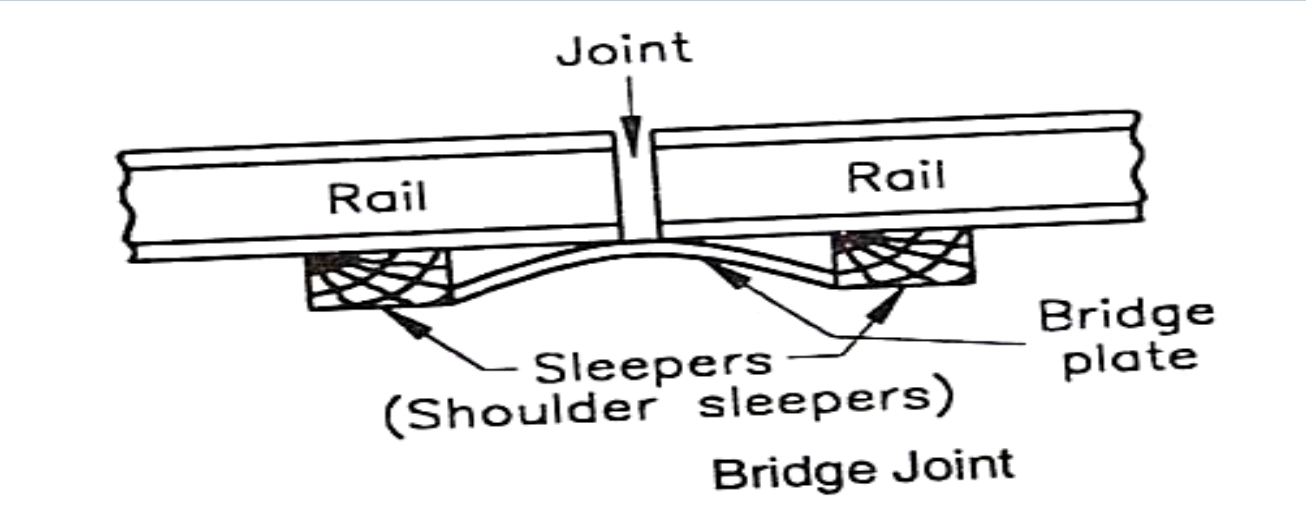
- **2.Suspended rail joint**
- When rail ends are projected beyond Sleepers may be called Should Sleepers. It is termed as suspended. The type of joint is generally used timber and Steel rough Sleeper on Indian and foreign railways



Suspended Rail Joint.

3.Bridge joint

When a rail ends are projected beyond as in case Suspended joint and they are connected by a flat or corrugated plate is called “bridge joint”



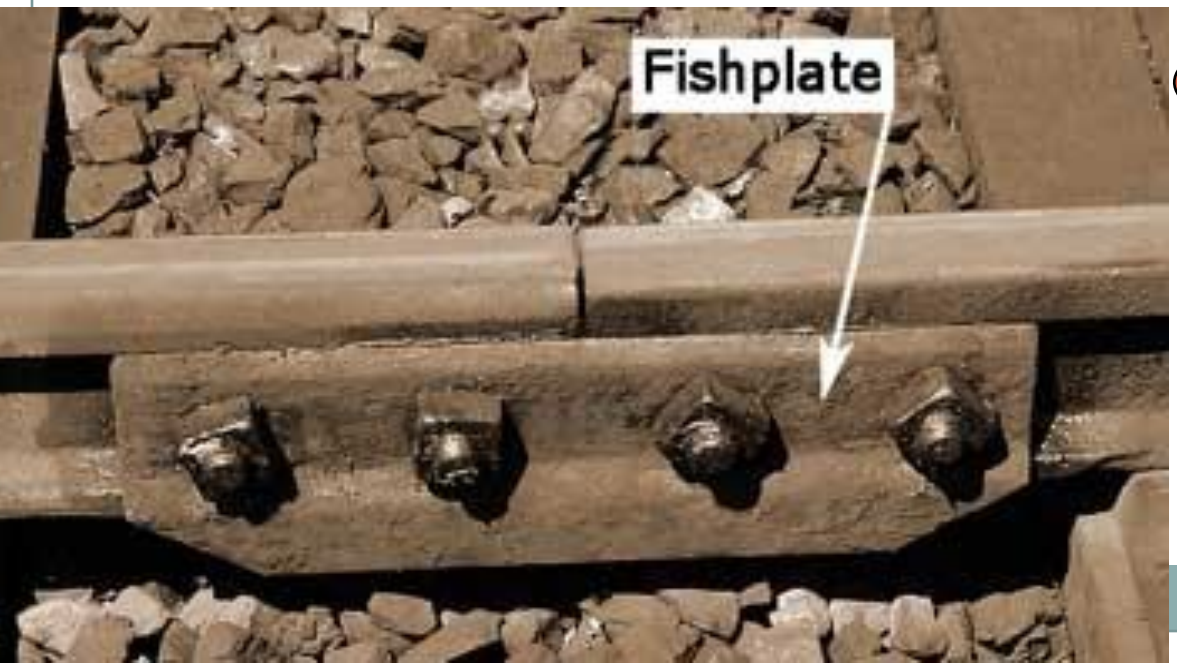
Fastenings

The devices used to connect rails and sleepers together to form the track are known as fastenings. These includes:

- Fish plates
- Bolts
- Chairs
- Keys
- Bearing plates

FISH PLATES

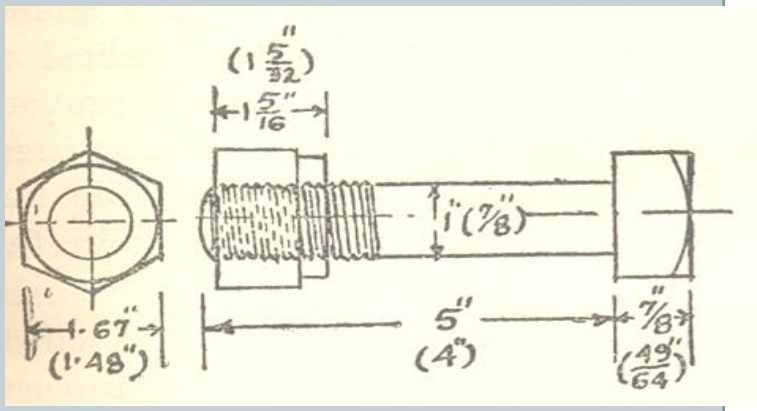
- The function of a fish plate is to hold two rails together.
- At each, joint a pair of fish plates is used.



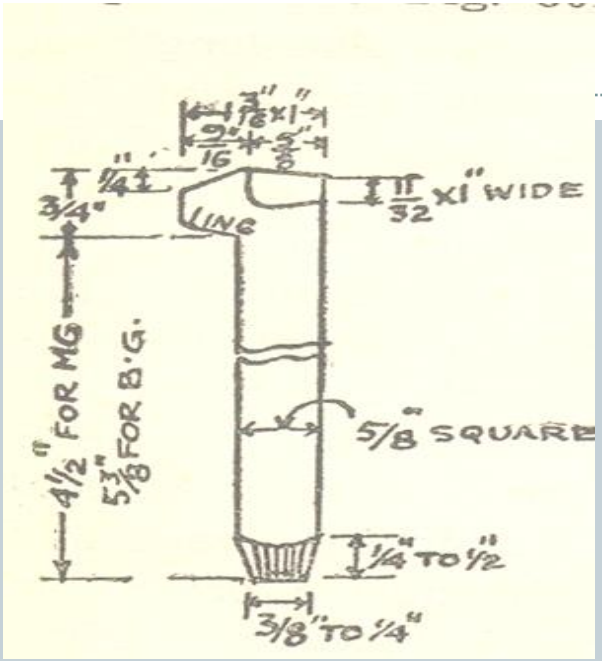
BOLTS

Various types of bolts are used in railroad fitting. Some common types are enumerated below.

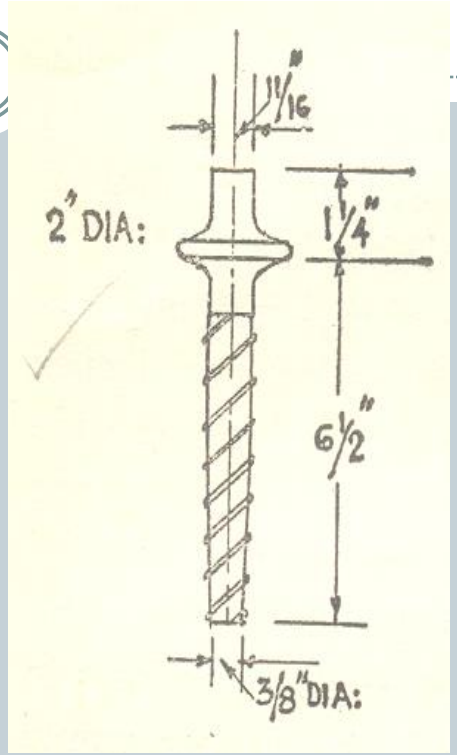
- **Fish bolts:**
  - With each pair of fish plates two, four or six fish bolts are used.
  - The standard practice is to use four bolts.
  - They are made up of high carbon steel to with stand considerable stresses.



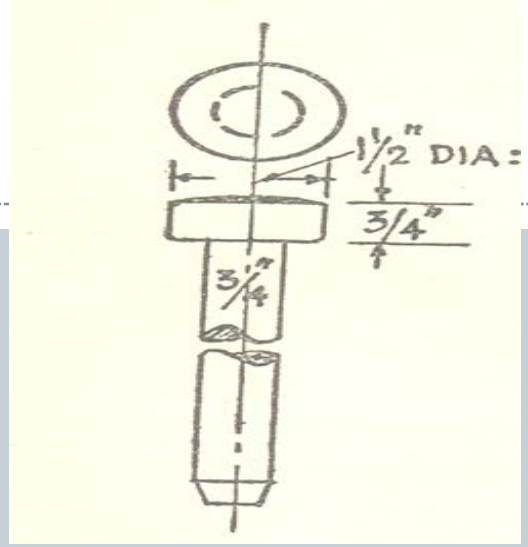
- **Dogspikes:**
  - Dogspikes are used for holding the rail to the wooden sleepers.
  - The spike has smooth sites and depends for its holding power on the friction of wood fiber.

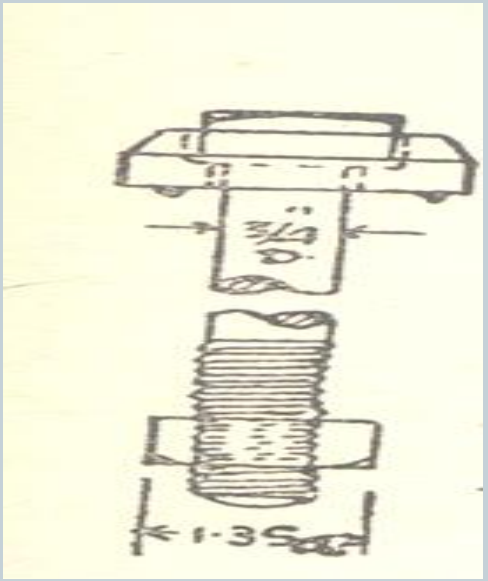


- **Skrewspikes:**
  - Skrewspikes are used for the same purpose as dogspikes
  - But have a much greater holding power than dogspikes approximately double that of dogspikes.



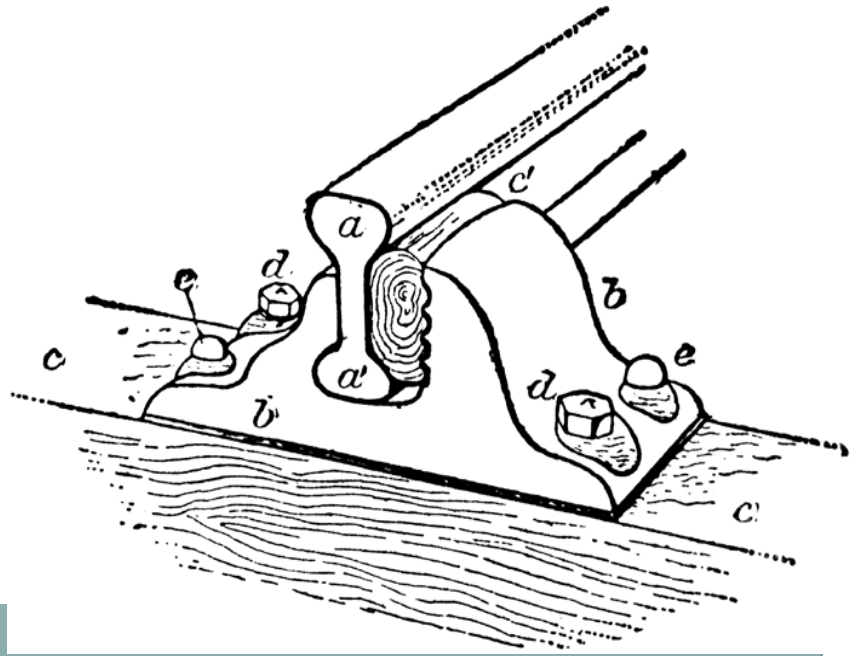
- **Roundspikes:**
  - Roundspikes are used for fixing chairs to the wooden sleepers.
- **Fangbolts:**
  - They have the same purpose as roundspikes.
  - Have greater strength as compared to roundspikes as they have threads and also grip the sleeper from the Bottom





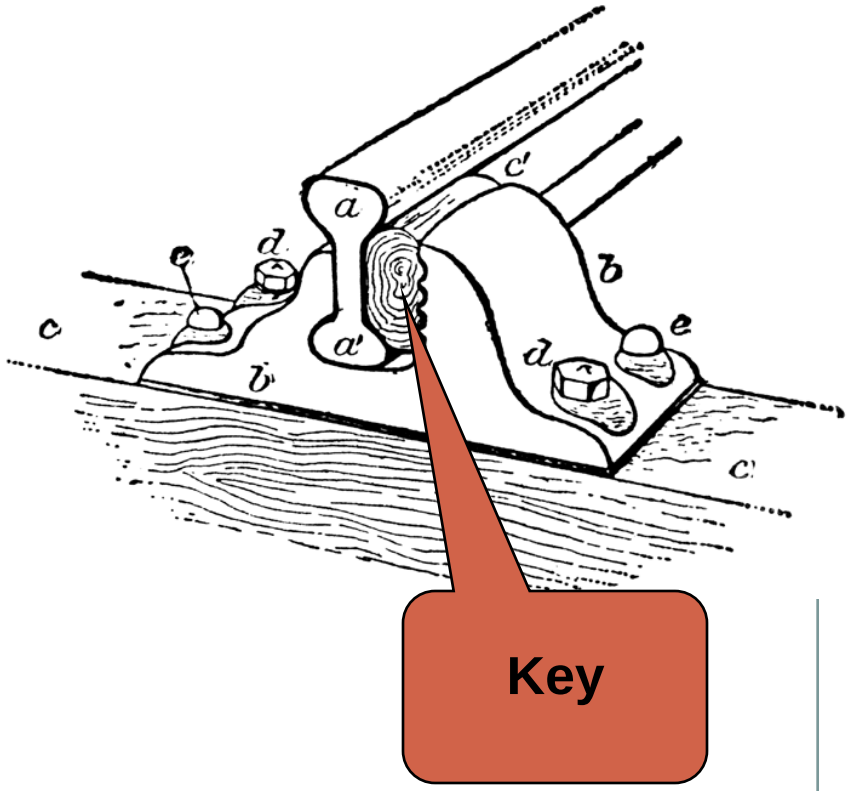
CHAIRS

- Chairs are used to hold the double headed and bull headed rails in position. Invariably chairs are made of cast iron and they help in distributing the load from rails to sleepers.



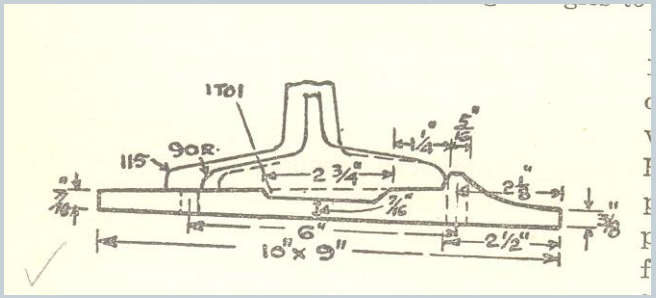
KEYS

- They are generally wedge shaped wooden pieces or metal pieces. They keep the rail in proper position.
- Wooden keys are cheaper, but liable to be attacked by vermin. Hence a number of metal keys have been devised.



BEARING PLATES

- Chair used for flat footed rails are known as bearing plates.
- They increase the bearing area on the sleeper and thus decrease the loading-intensity.



2. BALLAST

Ballast is a layer of broken stone, gravel, or any other suitable material placed under and around the sleepers for distributing the load from the sleepers to the formation

Functions of Ballast

- It provides a suitable foundation for the sleepers.
- It transfer and distributes loads from the sleepers to a larger area of formation.
- it provides effective drainage to the track.
- It helps in protecting the top surface of the formation.

Physical Properties of Good Ballast

- It should be hard and tough.
- It should wear resistant and durable.
- It should be non-porous and non-absorbent of water.
- It should be cheaper and easily available.
- It should not be brittle.
- It should not allow rain water to accumulate

Types of ballast

Following materials can be used as ballast:

1. **Broken stone**
   - It is the best material to be used as ballast.
   - Generally on all important tracks broken stone ballast has been used.
   - Blast of Igneous rocks is the most suitable
2. **Gravel**
   - It stands second in suitability as ballast.
   - Used in large quantities in many countries.
   - It is obtained from river beds.

3. Cinders or Ashes

- The residue obtained from the coal used in locomotives is known as Cinder or Ash.
- They are cheap and easy available
- They are harmful for steel sleepers.

4. Sand

- It stands fourth in merits as ballast material.
- Coarse sand is better than fine sand.
- It has good drainage property but blown off due to light weight.

5. Brick ballast

- Where stone or other suitable ballast is not available, over burnt brick ballast can be used.
- Use in light traffic areas.

6. Kankar

- It is found in the form of particles of varying sizes.
- Where stone is not easily and at reasonable price available, kankar can be used as road metal and ballast for railway tracks.

Track stresses

Stresses on railway tracks are caused due to various reasons

- Wheel loads
- Dynamic effect of wheel loads
- Overbalance of driving wheels of locomotive
- Horizontal thrust
- Pressure exerted by flanges of wheels
- Irregularities in the track
- Additional stresses on curves.

Wheel loads

- This is the static load which is continuously acting on the rail when the wheels are in stationary position .

DYNAMIC AUGMENT OF VERTICAL LOADS

- On account of vertical impact due to speed and rail vibrations, etc., the dynamic load is much more than the static load.
- The dynamic wheel load is obtained by increasing the static wheel load by an incremental amount given by the speed factor.

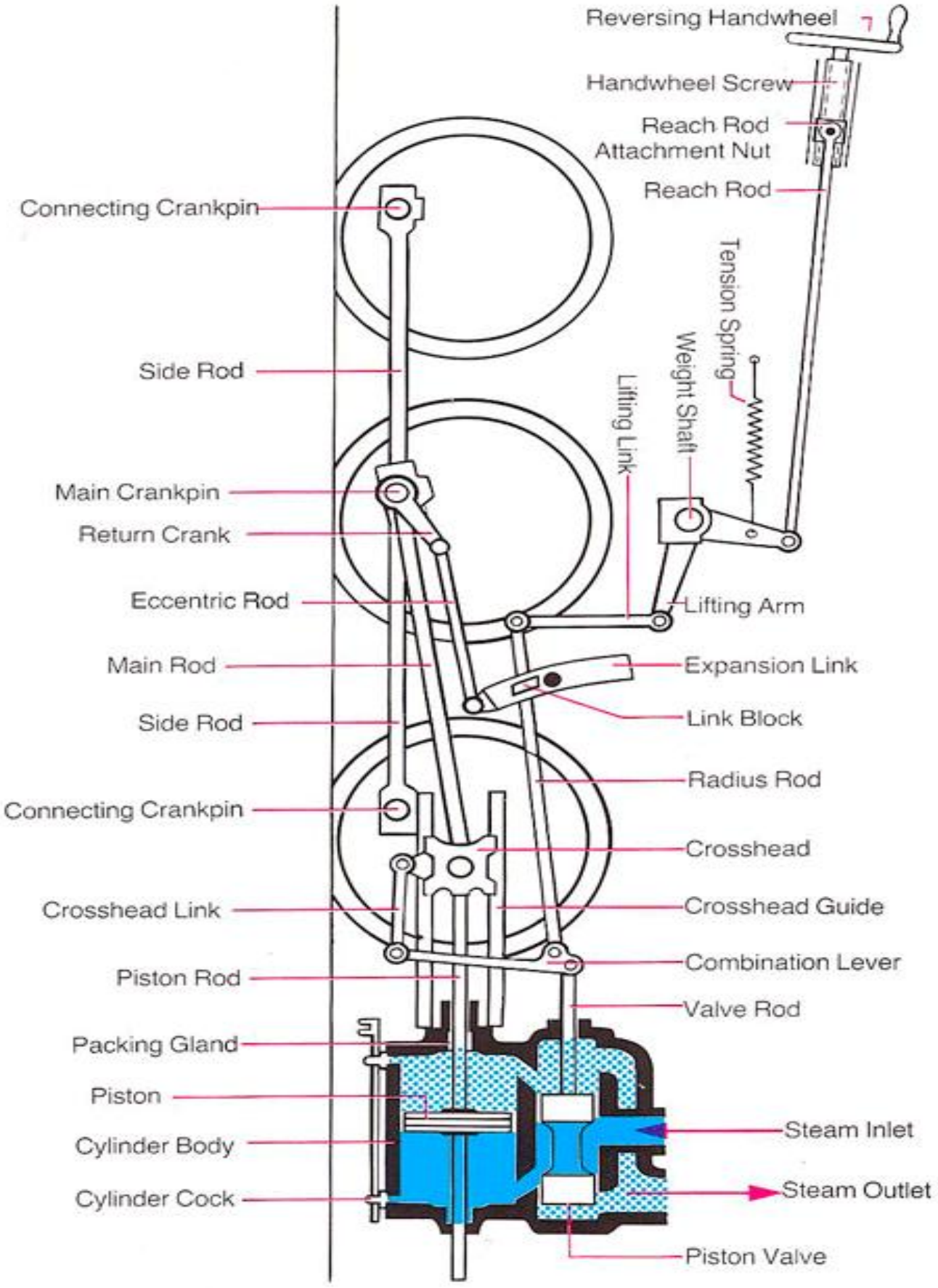
Impact factor = V2/30000(speeds upto 100kmph)

Hammer blow effect:

- The centrifugal forces due to revolving masses in the driving and coupled wheels of a locomotive, such as crank pins, coupling rods, and parts of the connecting rod, are completely balanced by placing counterweights near the rim of the wheel, diametrically opposite to the revolving masses.

- The vertical component of the centrifugal force of the weight introduced to balance the reciprocating masses causes variation in the wheel pressure on the rail, and is called the *hammer blow. The heavier the weight added to balance* the reciprocating masses, the greater the hammer blow.

- This create overbalance of driving wheels.


Reversing Handwheel
Handwheel Screw
Reach Rod Attachment Nut
Reach Rod
Connecting Crankpin
Tension Spring
Weight Shaft
Lifting Link
Side Rod
Main Crankpin
Return Crank
Eccentric Rod
Lifting Arm
Main Rod
Expansion Link
Side Rod
Link Block
Radius Rod
Connecting Crankpin
Crosshead
Crosshead Link
Crosshead Guide
Combination Lever
Piston Rod
Valve Rod
Packing Gland
Piston
Steam Inlet
Cylinder Body
Steam Outlet
Cylinder Cock
Piston Valve

Steam effect

- A steam locomotive works by converting coal energy into steam energy. Steam pressure acts on the piston and is transmitted to the driving wheels through the crank pins and connecting rod. The vertical component of the crank pins and connecting rod is at an angle to the piston rod.
- It creates horizontal thrust on the track.

Pressure by wheel flanges

- Trains not always move in a straight direction. But moves in a zig-zag manner. Because of such movements lateral pressure is exerted by the flanges on the rails. Although coning is provided in the wheels, this pressure cannot be completely avoided.

IRREGULARITIES OF TRACK:

- Non-uniformity gauge may cause hammer blow, lateral thrust

CREEP OF RAILS

CREEP OF RAILS

Definition:

It is a longitudinal or horizontal movement of rails with respect to sleepers in a track. It can be minimized but cannot be stopped.

Causes Of Creep

There are three main causes of Creep

1. Wave motion of trains.

2. Expansion and contraction of rails due to variation in temperature.

3. Due to starting, accelerating, slowing down (decelerating) and stopping of trains.

Wave Motion

- When train passes on a track, the portion of rail length under the wheel of train will under more stresses and little depression will exist.

- As a result, this depression will cause (set) a wave motion in the rail or track

Direction Of Creep

Alignment Of Track:

Creep is more on curve track than on a tangent portion (straight track).

Grades:

In upgrades tracks, creep will be less and in down grades track creep will be more.

Direction of movement of trains:

Creep will be more in the direction to which the loaded train moves more.

Extent Of Creep

- Creep does not vary at some constant rate. (it is not constant)
- Creep does not continue in one direction only.
- Creep for two rails of the track will not be in equal amount.

Result Of Creep

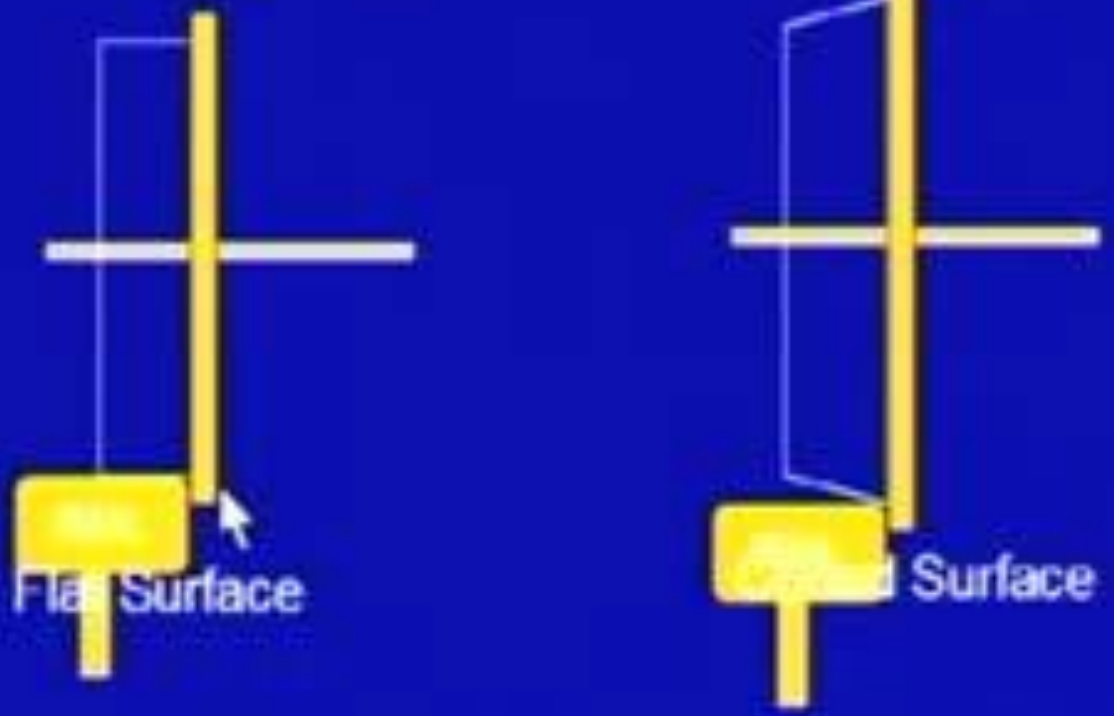
- Expansion gap is reduced, buckling of track take place.
- Sleepers are moved out of a square.
- Crossing points get disturbed.

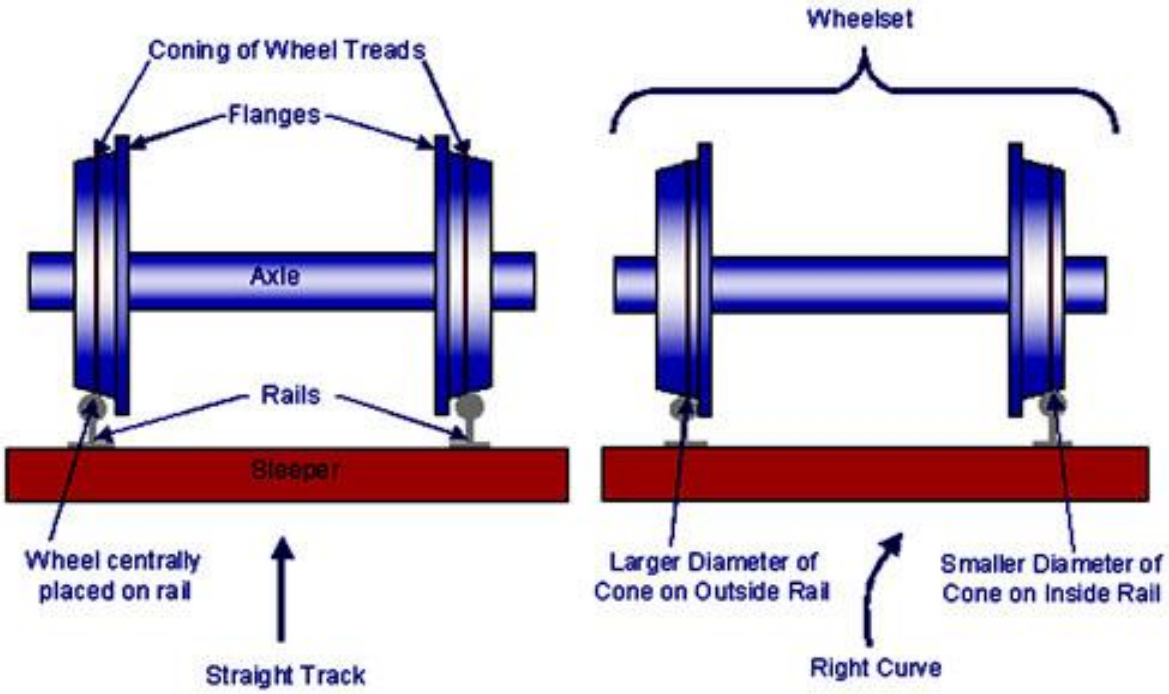
Coning of wheels

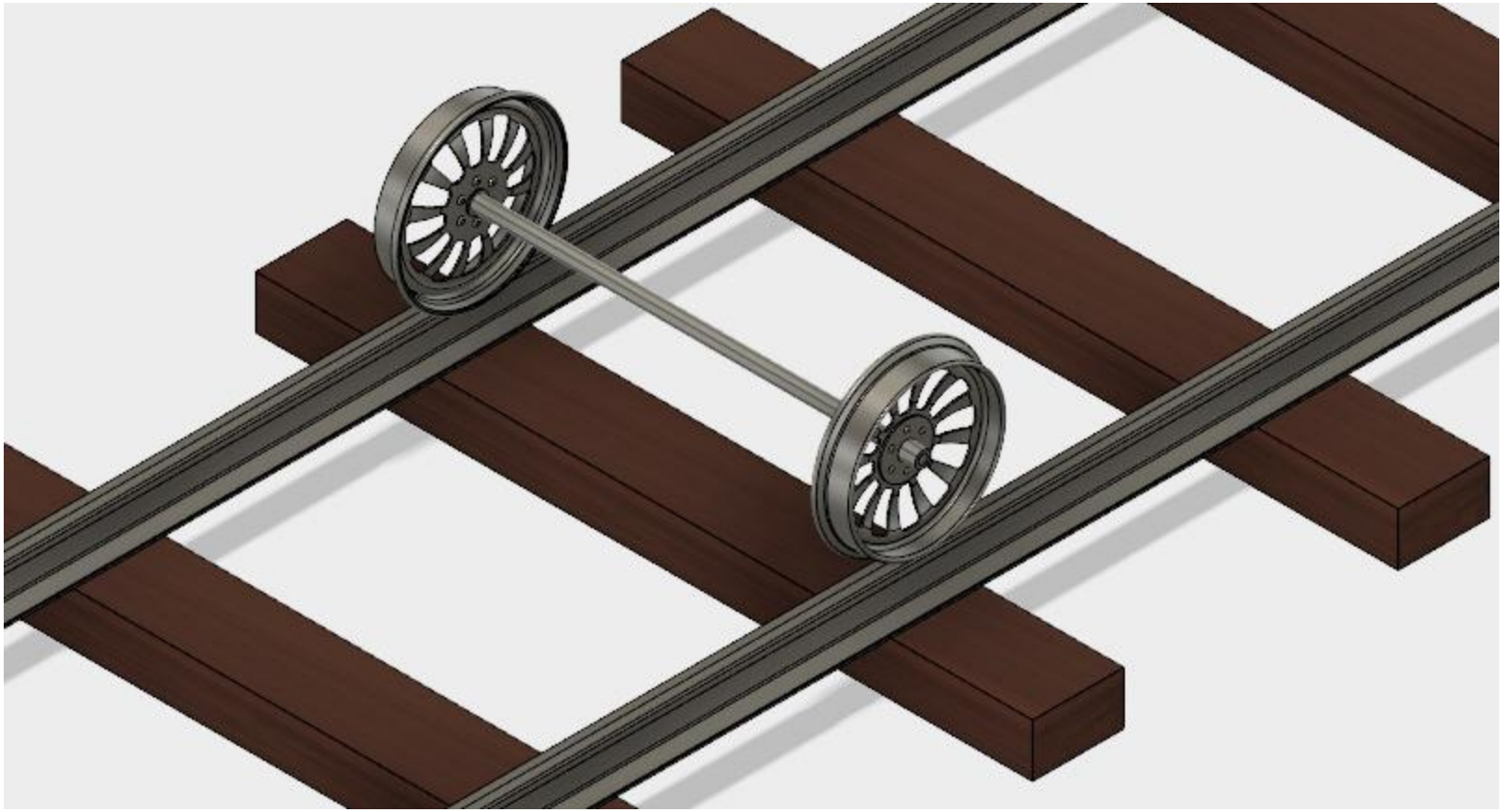
- The tread of the wheels of a railway vehicle is not made flat, but sloped like a cone

- In order to enable the vehicle to move smoothly on curves as well as on straight tracks. The wheels are generally centrally aligned on a straight and level surface with uniform gauge, and the circumference of the treads of the inner and outer wheels are equal

Coning of Wheels




Coning of Wheel Treads
Flanges
Axle
Rails
Sleeper
Wheel centrally placed on rail
Straight Track
Wheelset
Larger Diameter of Cone on Outside Rail
Smaller Diameter of Cone on Inside Rail
Right Curve



It is, however, useful as

- (a) it helps the vehicle to negotiate a curve smoothly,
- (b) it provides a smooth ride, and
- (c) it reduces the wear and tear of the wheel flanges.

OTHER DEFECTS IN RAILS

- **Corrugation of rails**

Corrugation consists of minute depressions on the surface of rails, varying in shape and size and occurring at irregular intervals. The factors which help in the formation of rail corrugation, however, are briefly enumerated here.

(a) Metallurgy and age of rails

(i) High nitrogen content of the rails

(ii) Effect of oscillation at the time of rolling and straightening of rails.

- (b) Physical and environment conditions of track
  - (i) Steep gradients
  - (ii) Yielding formation
  - (iii) Long tunnels
  - (iv) Electrified sections

(c) Train operations

(i) High speeds and high axle loads

(ii) Starting locations of trains

(iii) Locations where brakes are applied to stop the train

(d) Atmospheric effects

(i) High moisture content in the air particularly in coastal areas

(ii) Presence of sand

–Route alignment surveys

The entire survey work to be conducted may be divided into the following parts:

- Traffic survey
- Reconnaissance survey
- Preliminary survey
- Location survey
- Modern methods survey

Traffic survey

❖The main aim of traffic survey is to submit the field data to the authority judge the suitability of the project.

- ❖Particulars of villages and towns within about 20km from the proposed track along with the population.
- ❖Location of existing industries and the potential growth of them.
- ❖Volume of traffic in terms of passengers and goods wagons.
- ❖Availability of export based natural resources like, iron, coal, etc.

Reconnaissance survey

- **Reconnaissance survey should furnish the following details:**
  - Topographical features of the area.
  - Existing water resources along with their discharge details .
  - Natural features like ridges, valley, forest, etc.

  Geographical and soil classification.

- **Preliminary survey:**

- **Steps involved in this survey:**
  - Construction pillar is erected to mark the starting point.
  - A fly leveling is done to connect the starting point and a nearby GTS beach mark.
  - A compass survey is conducted along the alignment to prepare a route survey map covering about 100m on either side of the alignment.
  - A cross sectional leveling is done at regular intervals say 100m.

Location survey

- **The transfer is done by adopting the following steps:**
  - 15cm pegs at 30m intervals are driven
  - Every tenth peg is marked by 60cm pegs
  - Pegs are also driven to demarcate the center line of the track
  - At every km length masonry pillars are constructed which serve as bench marks

Modern surveying instruments and methods:

- Some of these survey aids and techniques are the following:
  - Remote sensing data
  - Aerial photographs
  - Electro - magnetic distance measurement
  - Digital terrain modeling
  - Geographic information system

Remote sensing data

•Remote sensing data or satellite imaginary provides a bird's eye view of large areas. Indian space research organization(ISRO) provides such maps which are up dated once a month.
•Ground conditioned can be well defined with a combination of satellite images and topographical maps.

•**Aerial photographs**
•Aerial photogrammetric is that type of photography wherein the photographs are taken by cameras mounted on an aircraft lying over the area. Stereo photographs are taken is another system which is a recent development.

• In this system photographs are taken in pairs at the ends of a base line of known length and direction.

Electro magnetic distance measurements (EDM)

- Electro magnetic distance measurements is a general term used collectively in the measurements of distance applying electronic methods.
- Depending on the type of carrier wave used, EDM instruments may be classified as
- (1)microwave instruments
- (2)visible light instruments and
- (3)infrared instruments.
- These instruments are very light and compact and can mounted with theodolite. Thus these instruments enable to measure angles and distances simultaneously.

Digital terrain modeling(DTM)

- Digital terrain modeling is a computer aided design. Using such models the most economical alignment may be obtained. After the alignment decision, ground stations are fixed in the form of mutually visible points.

Geographical information system (GIS)

- GIS is new technology which covers a number of fields such as remote sensing, cartography, surveying and photography.

Geometric design of railways

- **Necessity of geometric design of a railway track**
- The need for proper geometric design of a track arises because of the following considerations
- (a) To ensure the smooth and safe running of trains
- (b) To achieve maximum speeds
- (c) To carry heavy axle loads
- (d) To avoid accidents and derailments due to a defective permanent way
- (e) To ensure that the track requires least maintenance.
- (f) For good aesthetics

Design Parameters:

(1) Gradients

(2) Grade compensation

(3) Radius and degree of curve

(4) Super elevation or cant

(5) Safe speeds of trains

(6) Curves: Horizontal and vertical

(7) Widening of gauge on curves

GRADIENT

- Gradient is the rate of rise or fall of the track. It is expressed as the ratio of vertical distance to horizontal distance or as percentage of rise or fall.

- If any track rises 1 m in 100 m horizontal length, its gradient is expressed as 1 in 100 or 1 percent. If another track falls by 1 m in 50 m length, its gradient is 1 in 50 or 2 percent.

- Gradients are provided to the formation of rail track to serve the following purpose:

(i) To reduce the cost of earthwork.

(ii) To provide uniform rise or fall as far as practicable.

(iii) To reach the stations situated at different elevations.

(iv) To drain off rain water.

Types of gradient

(i) Ruling gradient

(ii) Momentum gradient

(iii) Pusher gradient

(iv) Station yard gradient

Ruling Gradient:

- Ruling gradient is the maximum gradient to which the track may be laid in a particular section. It depends on the load of the train and additional power of the locomotive.

- In plains - 1 in 150 to 1 in 200
- In Hilly tracks - 1 in 100 to 1 in 150

(ii) Momentum Gradient :

- Gradient which is steeper than ruling gradient and where the advantage of momentum is utilized, is known as momentum gradient. A train gets momentum when moving in down gradient and this momentum can be utilized for up gradient.

- This rising gradient is called momentum gradient. In such gradients no signals are provided to stop the train.

Pusher Gradient:

- Pusher gradient is the gradient where extra engine is required to push the train. These are steeper gradient than ruling gradient and are provided at certain places of mountains to avoid heavy cutting or to reduce the length of track.
- A pusher gradient of 1 in 37 on western Ghats with B.G.track is provided.
- On Darjeeling Railway with N.G. track, a ruling gradient of 1 in 25 is provided.]

Station Yard Gradient:

- Station yard gradient is the minimum gradient provided in station yard for easy draining of rain water. Gradients are avoided as far as possible in station yard due to following reasons

- (a) In station yard, Bogies standing on gradients may start moving due to heavy wind and may cause accident.
- (b) The locomotives will require extra force of pull the train on gradients at the time of starting the trains.

- In station yards, maximum limit of gradient is fixed as 1 in 400 and minimum gradient recommended is 1 in 1000 for easy drainage of rain water

GRADE COMPENSATION OF CURVES

- Grade compensation on curves is the reduction in gradient on curved portion of a track. On curves extra pull is required to pull the train due to more tractive resistance.

- Therefore, if gradients are to be provided on curves some compensation should be given in ruling gradients to overcome the increased tractive resistance to a certain limit and to pull the trains with same speed.

- It is expressed as percentage per degree of curve.

(i) On B.G. curves – 0.04 percent / degree
(ii) On M.G. curves – 0.03 percent / degree
(iii) On N.G. curves – 0.02 percent / degree

SUPERELEVATION

- Superelevation is the raised elevation of the outer rail above the inner rail at a horizontal curve. It is denoted by ‘e’.

- **Objects of Providing Superelevation**
- (i) To introduce centripetal force to counteract the centrifugal force to avoid derailment and reduce the side wear of rails.
-
- (ii)

- To distribute the wheel loads equally on the two rails. This reduces the top wear of rails and results in saving of maintenance cost.

- (iii) To ensure comfortable ride to passengers and safe movements of goods

The maximum permissible super elevation on Indian Railways are as under:

B.G. track	Metre Gauge	Narrow Gauge
165 mm	102 mm	76 mm

- **Equilibrium cant**

  Value of superelevation derived from the equation using equilibrium speed.

Cant deficiency (Cd)

- Occurs when a train travels around a curve at a speed higher than the equilibrium speed

Difference between cant required at travel speed and actual cant

Maximum permissible Cd: 7.6cm (BG), 5.1cm (MG), 3.8cm (NG)

widening of gauge on curves:

- Due to impounding action of wheels on curves , the gauge of the track gets widened and the rails get tilted outwards. To prevent the tendency of tilting the rail outward, the gauge of the track on curves is suitably widened. The amount of widening of gauges depends on the radius of curve , gauge and rigid wheel base of the vehicles.

The widening

$$d = \frac{13(B+L)^2}{R}$$

Where , d is the extra width of gauge in cm

B is rigid wheel base in metres.

Wheel base is the distance between adjacent axes of a vehicle.

B for B.G = 6.00m

M.G = 4.88m

R is the Radius Of Curve In Metres.

L IS THE Lap of flange in meter

$$L = 0.02\ h^2 + D.h$$ in meters

H = Flange depth in cm

D= Diameter of wheel in cm

However, norms for widening of gauges in practice is as given below

If radius of curvature is more than 350m – upto + 15mm

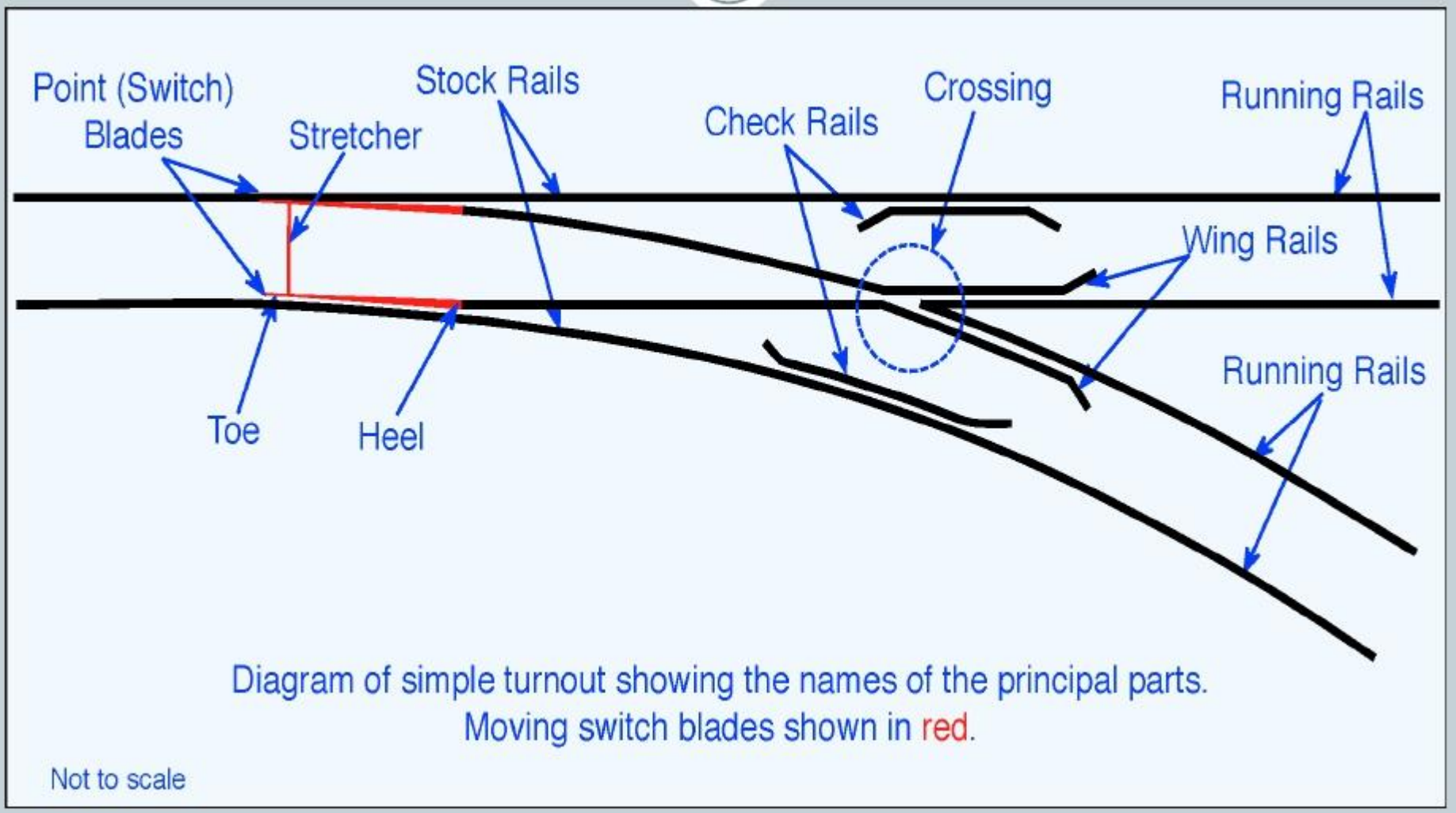
If radius of curvature is less than 350m – upto +20mm

POINTS AND CROSSINGS

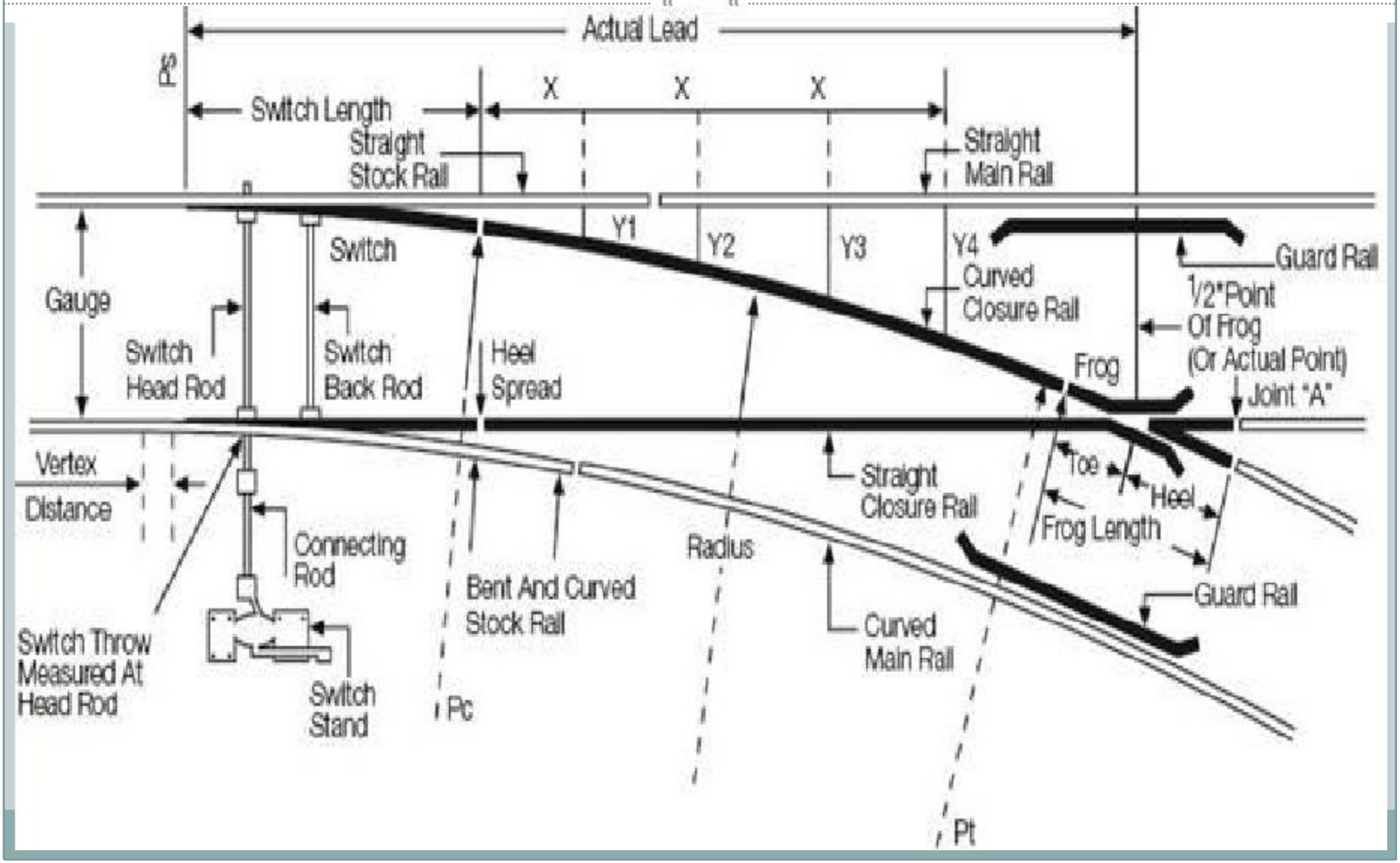
Purpose for providing points and crossings:

- It is the name given to the arrangement which diverts the train from one track to another, either parallel to or diverging from the first track.
- Point and Crossings are peculiar arrangement used in permanent way (railway track) to guide the vehicle for directional change.

POINTS AND CROSSINGS



Turn outs


Actual Lead
PC
Switch Length
X
X
X
Straight Stock Rail
Straight Main Rail
Y1
Y2
Y3
Y4
Curved Closure Rail
Guard Rail
1/2" Point Of Frog (Or Actual Point)
Joint "A"
Switch
Gauge
Switch Head Rod
Switch Back Rod
Heel Spread
Frog
Vertex Distance
Toe
Heel
Frog Length
Straight Closure Rail
Radius
Connecting Rod
Bent And Curved Stock Rail
Guard Rail
Curved Main Rail
Switch Throw Measured At Head Rod
Switch Stand
Pc
Pt

Tongue rail

Throw of Switch

Check rails

Heel block

Nose of crossing

Some definitions:

1.Angle of crossing:

- It is the angle between the running faces of point rail and splice rail

2.Branch Track:

- Track to which train is diverted from main track

3.Check rails:

- To prevent the tendency of wheel to climb over the crossing rail lengths are provided on the opposite side of the crossing

4.Heel block: It is the CI block to which tongue rail and lead rails are both bolted

5. **Lead Rails**: They are the rail which lead the track from heel of the tongue rail to the toe of the crossing
6. **Nose of crossing**: It is the point at which rail, splice rail, or two point rails meet.
7. **Tongue rail:** These are tapered rails
8. **Switch:** It consists of tongue rail and a stock rail
9. **Throw of switch:** Both the tongue rails move through the same distance or gap, this gap is known as throw of switch

10. **Switch angle:** It is the angle formed between the gauge face of the stock rail and the tongue rail
11. **Turn outs:** A complete set of points and crossings along with a lead rail is known as turnout
12. **Facing direction:** If someone stands at toe of switch and looks towards the crossing it is called facing direction
13. **Trailing directions:** If someone stands at the crossing and looks towards the switches, then the direction is called Trailing direction

14. **Facing points or Facing turn outs:** When the train pass over the switches first and then they pass over the crossing
15. **Trailing points or Trailing Turnouts:** The opposite side of facing points in which the trains pass over the crossings first and then over the switches.

Right Hand Turn out and Left Hand Turn out:

- If a train from main track is diverted to the right of the main route in the facing direction, then this diversion is known as Right-hand turnouts.
- If a train from main track is diverted to the left of the main route in the facing direction, then this diversion is known as Left-hand turnouts.

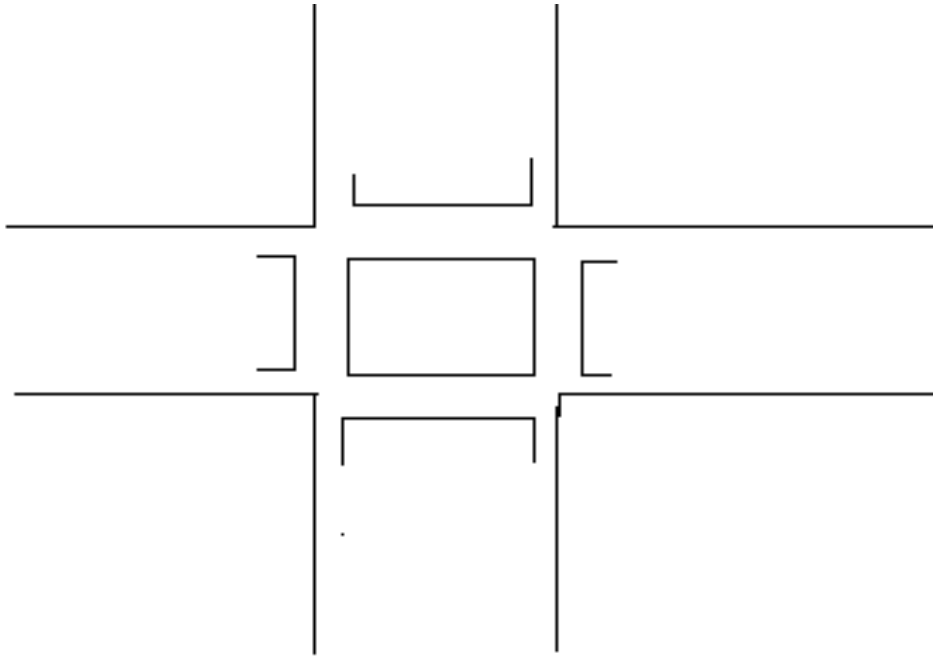
TYPES OF CROSSING

TYPES OF CROSSING

1. Square Crossing
2. Diamond Crossing
3. Cross Over
4. Scissor Crossing
5. Symmetrical Split

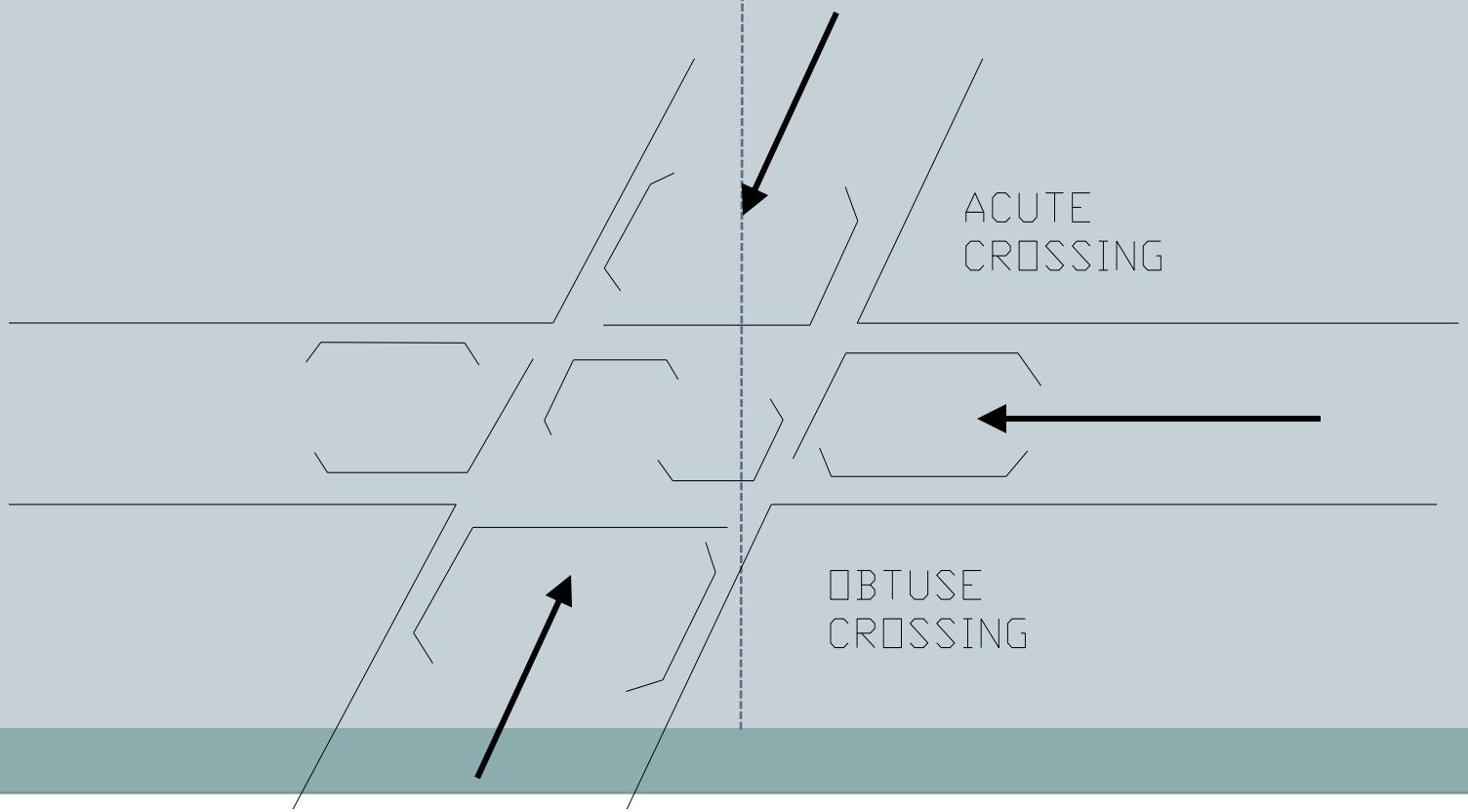
SQUARE CROSSING

- When two railway lines cross each other at 90^0 it is called Square Crossing



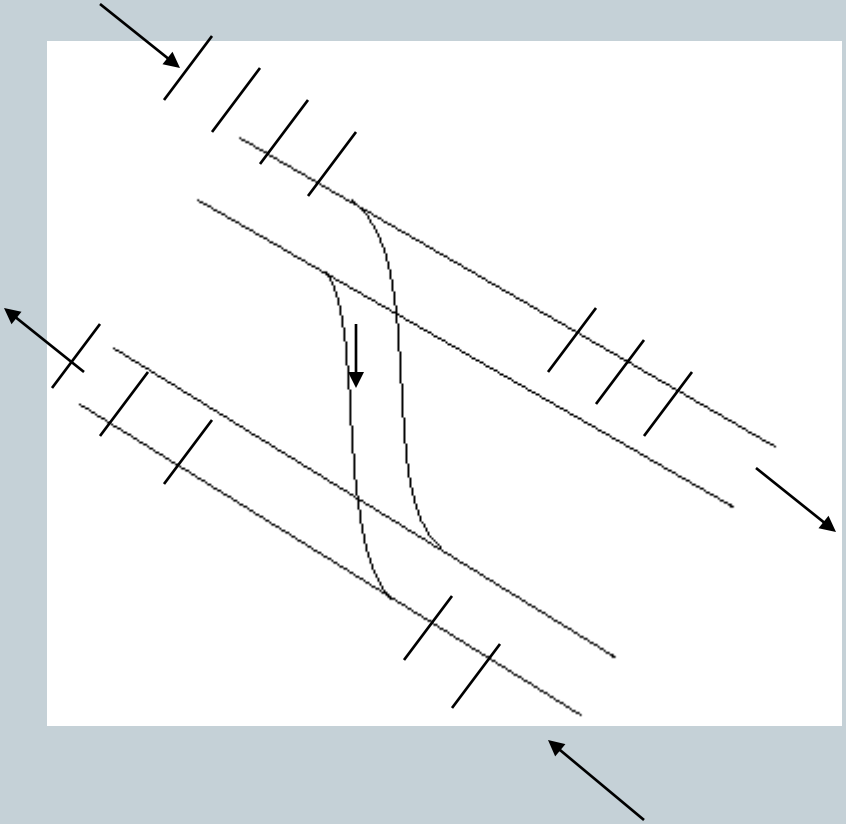
DIAMOND CROSSING

- Angle of intersection (crossing angle) of two tracks is when not 90° , then crossing is called diamond crossing



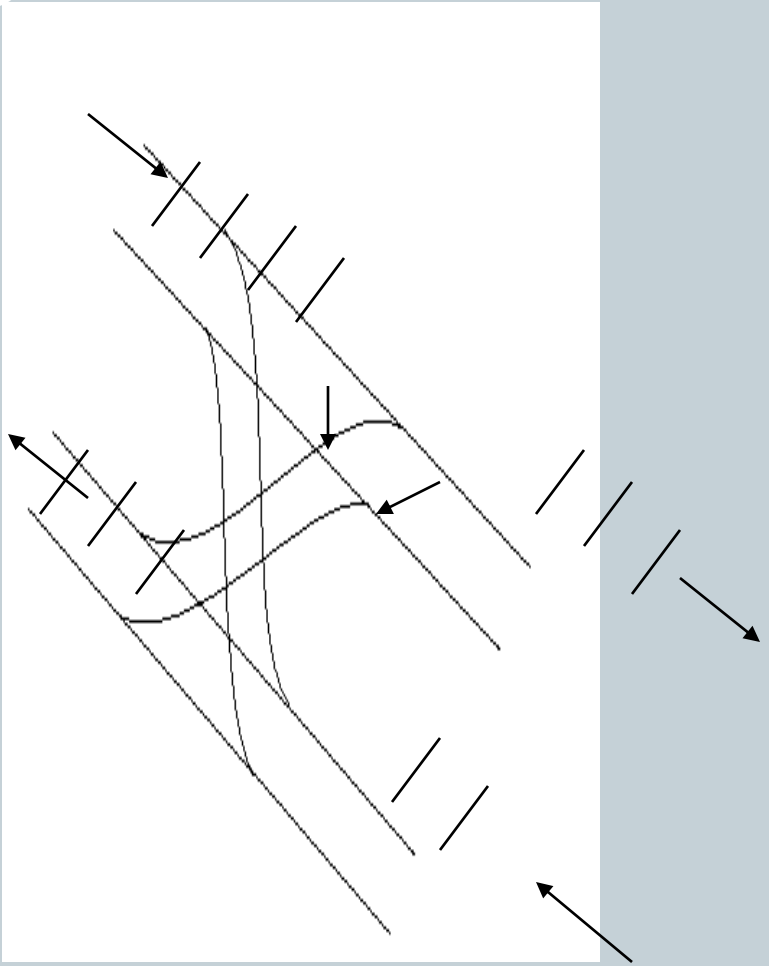
CROSS OVER

- A cross over is introduced to transfer a train from one track to another track which **may or may not be parallel** to each other



SCISSOR CROSSING

- If two cross overs are required between two parallel tracks and there is no sufficient space for crossing to be kept separate, then they are made to over-lap each other and result is a scissor crossing.



SYMMETRICAL SPLIT

- If radius of main track is equal to the radius of turn out curve, then the turn out is known as symmetrical split.