CE3830: Railway Engineering

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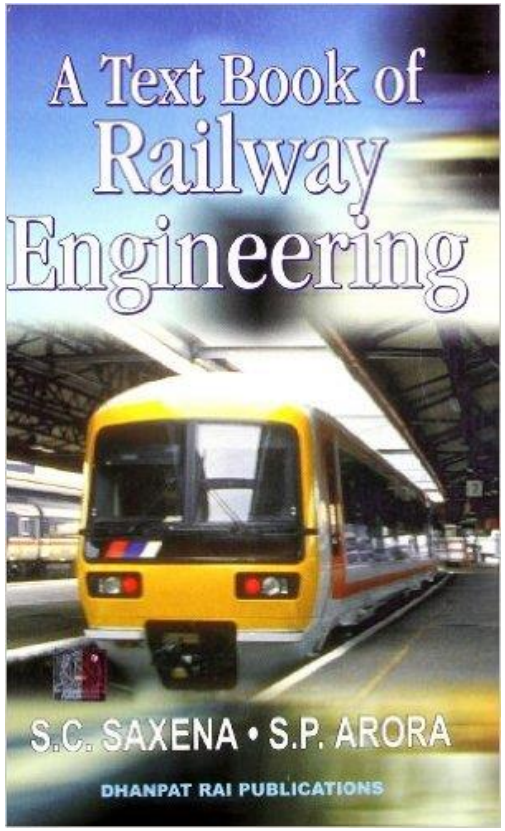
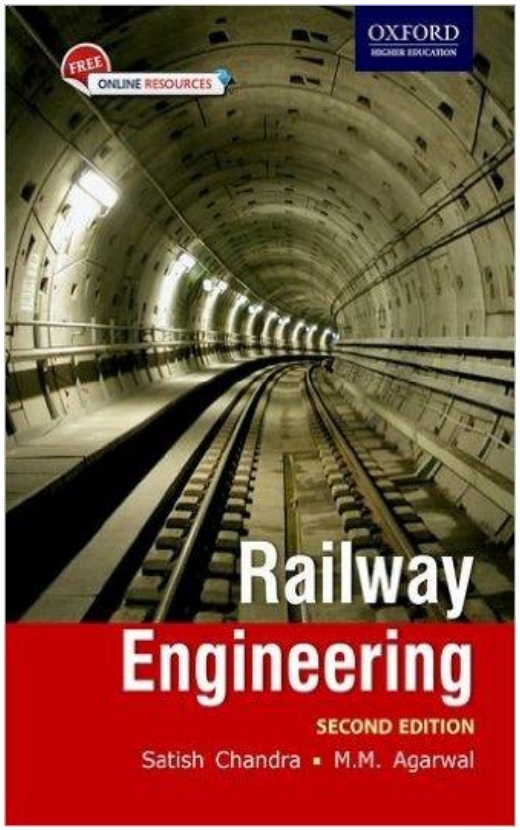
Books





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Urban Rail Transit

Urban Rail Transit: Urban rail transit is an all-encompassing term for various types of local rail systems providing passenger service within and around urban or older suburban areas.

- Urban rail systems can be roughly subdivided into the following categories
  - **Tram**
  - **Light rail**
  - **Rapid transit**
  - **Monorail**
  - **Commuter rail**
  - **Funicular**
  - **Cable car**

Tram

- A **tram**, **streetcar** or **trolley** system is a rail-based transit system that runs mainly or completely along streets
- Has relatively low capacity and frequent stops
- Passengers usually board at street- or curb-level

Light rail

- A **light rail** system is a rail-based transit system that has higher capacity and speed than a tram
- Operates in an exclusive right-of-way separated from automobile traffic
- Not fully grade-separated from other traffic like rapid transit

Rapid transit

- Rail system usually in an urban area with high passenger capacities and frequency of service, and (usually) full grade separation from other traffic (including other rail traffic).
- In most parts of the world these systems are known as a “metro”
- **Underground**, **tube** (termed in UK)
- **Subway** (American System)

Maglev and Bullet Train video

Magnetic levitation train, or *maglev*

Monorail

- A **monorail** is a railway in which the track consists of a single rail, as opposed to the traditional track with two parallel rails
- Mumbai monorail: Each monorail train consists of 4 coaches having a combined passenger capacity of 568

Commuter rail

- A **commuter rail**, **regional rail**, **suburban rail** or **local rail** system operates on mainline trackage which may be shared with intercity rail and freight trains.
- Systems tend to operate at lower frequencies than rapid transit or light rail systems.
- Travel at higher speeds and cover longer distances.

Funicular

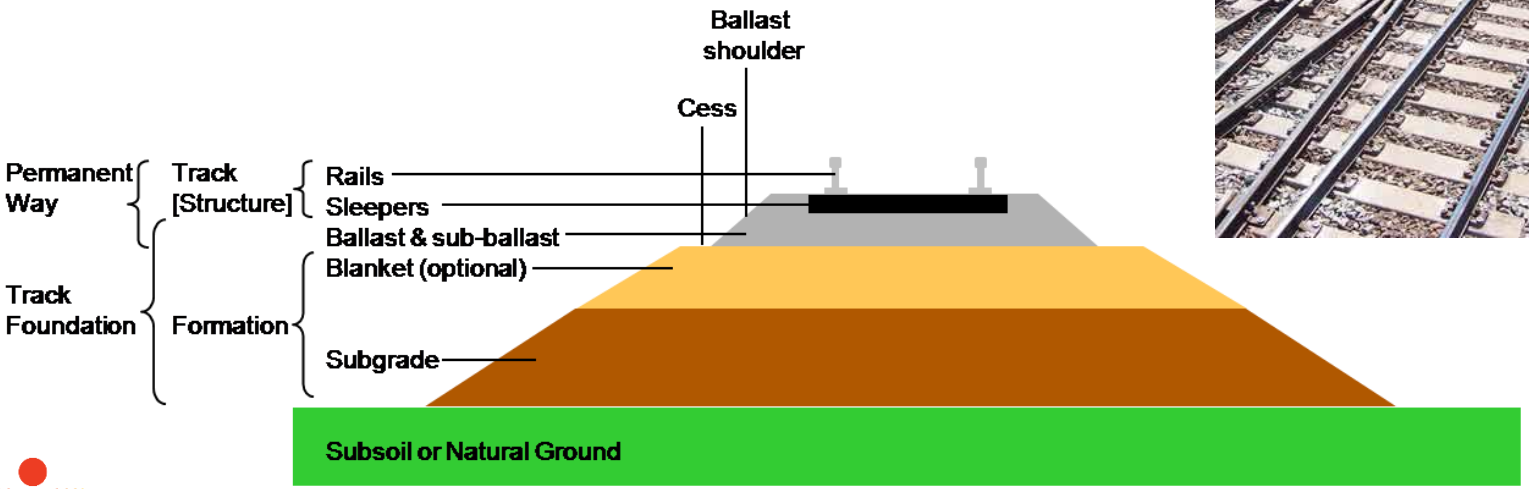
- A **funicular** is a cable-driven inclined railway that uses the weight of descending cars to help pull the ascending cars up the slope.

Cable car

- A **cable car** in the context of mass transit is a system using rail cars that are hauled by a continuously moving cable running at a constant speed.

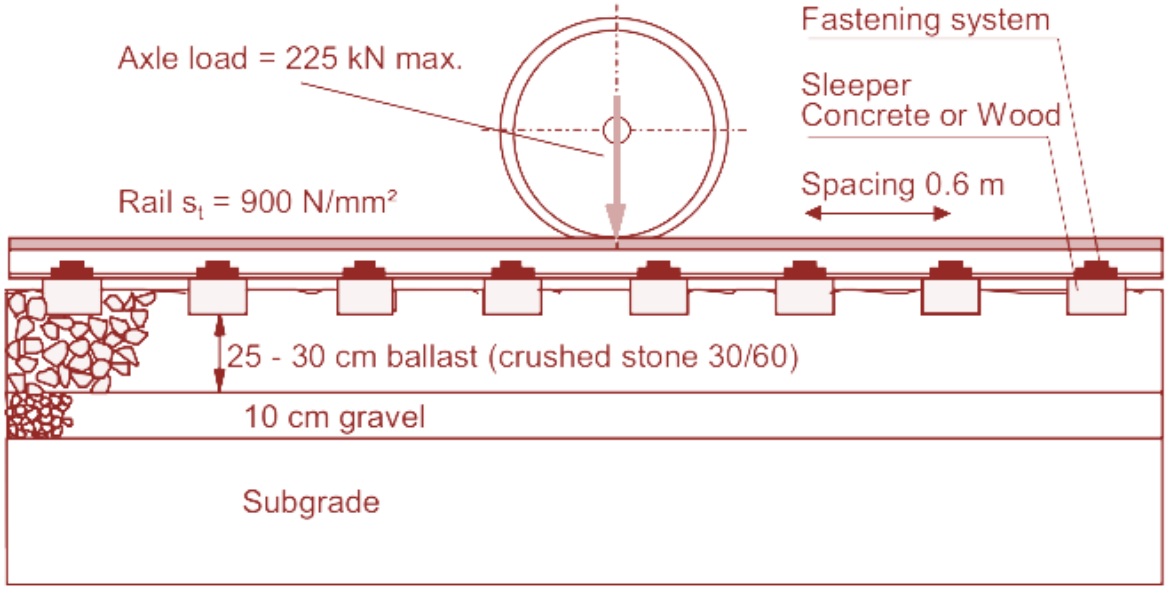
Elements of Railway Track

- A combination of rails, fitted on sleepers and resting on ballast and subgrade is called as railway track or permanent way



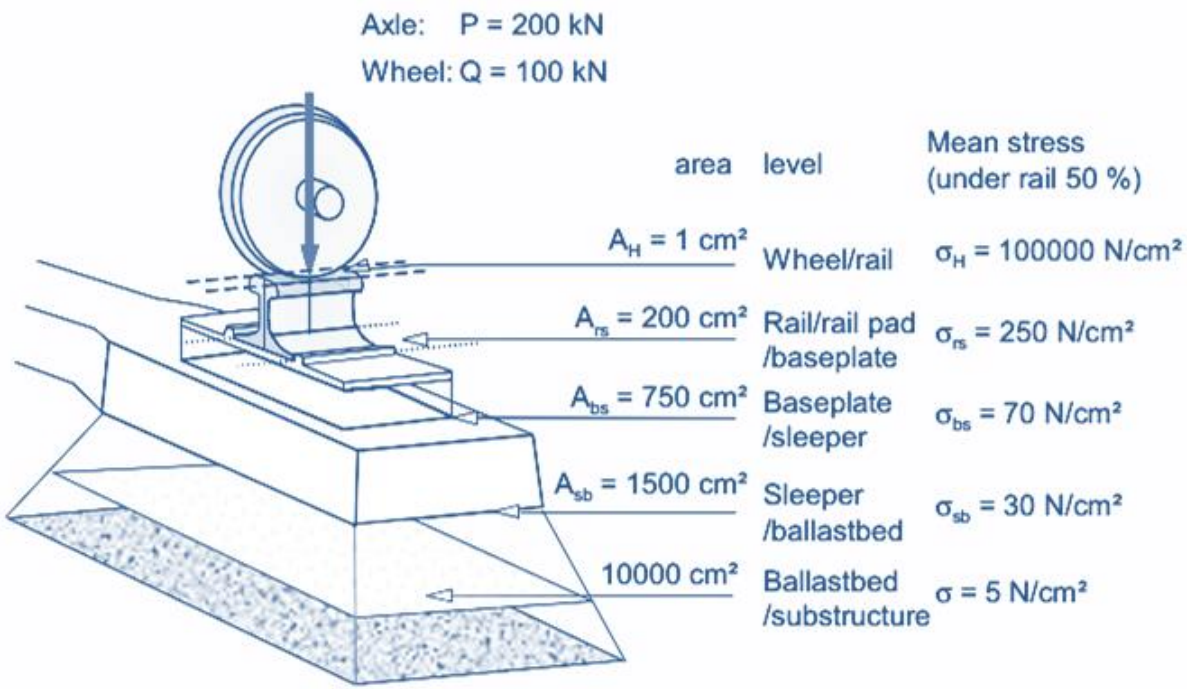
Conventional track structure

- Construction should be such that less noise and ground vibrations
- Total service life cost of the track should be low
- Low maintenance



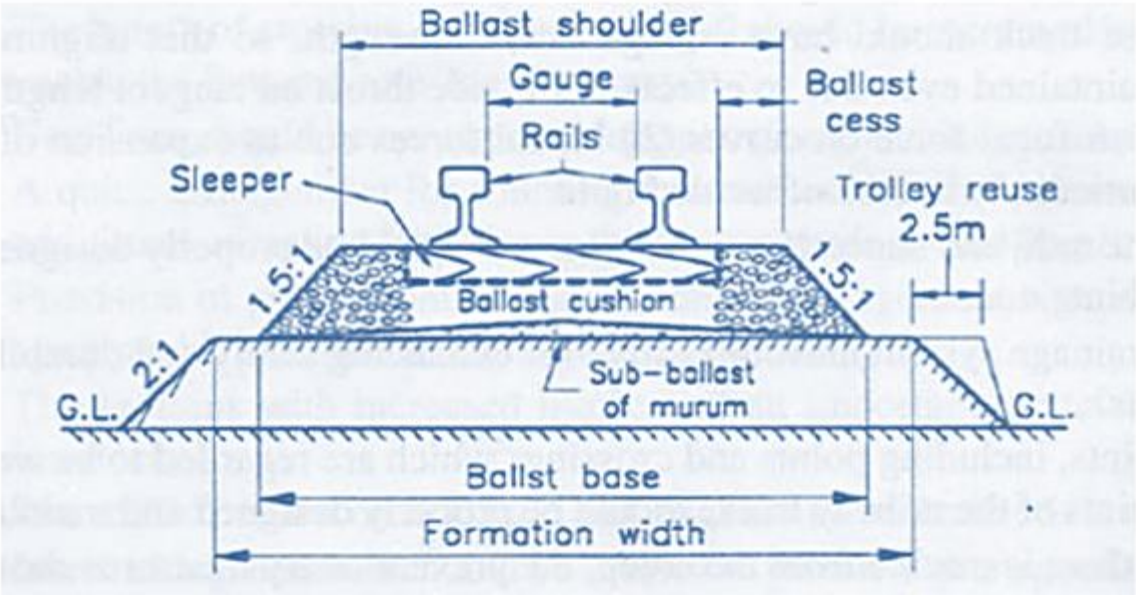
Principle of load transfer

- Load transfer works on the principle of stress reduction
- Stress is high between wheel and rail
- Stress between rail and sleeper is two orders smaller
- Stresses diminishes between sleeper and ballast
- Stress on the formation is very less

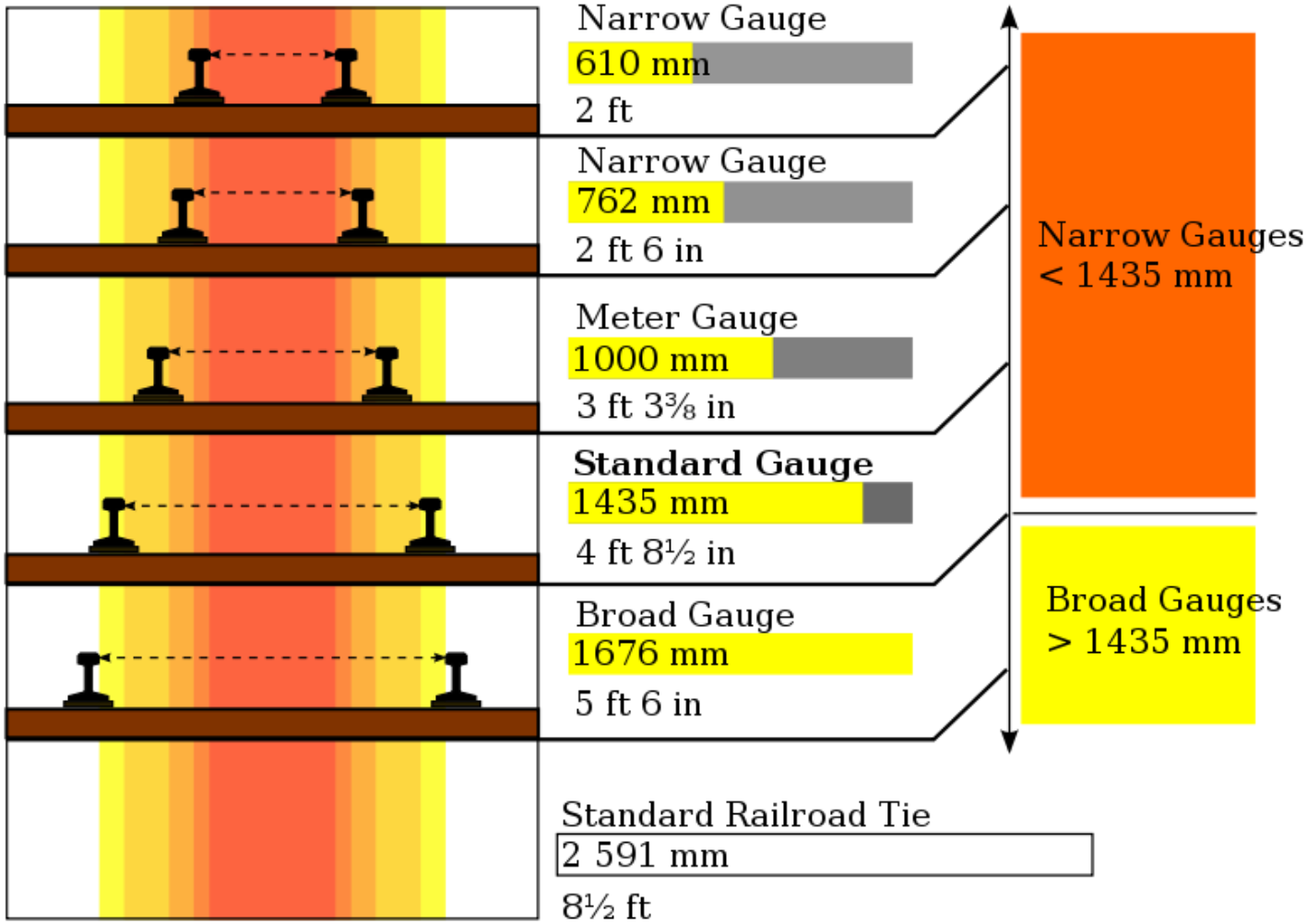


Gauge

- Gauge of a railway track is clear distance between the inner (running) face of the two track rails



Types Gauges

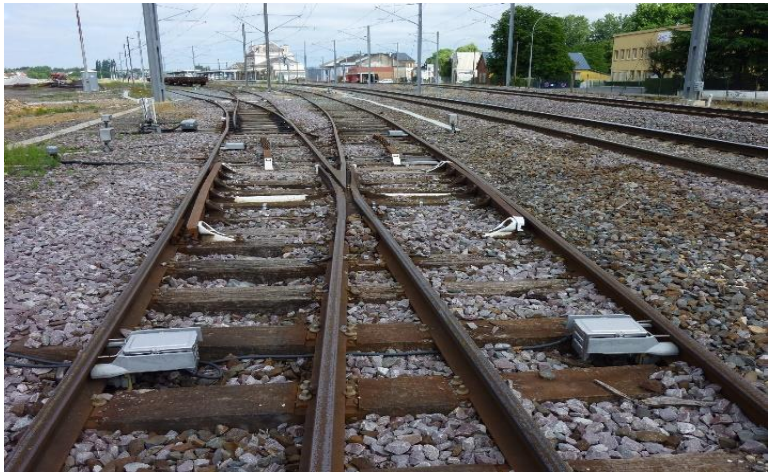


https://en.wikipedia.org/wiki/Track_gauge_in_India

NG rail

- **Neral to Matheran:** This hill railway track is a 2 ft NG line covering 21 km

Points and Crossings

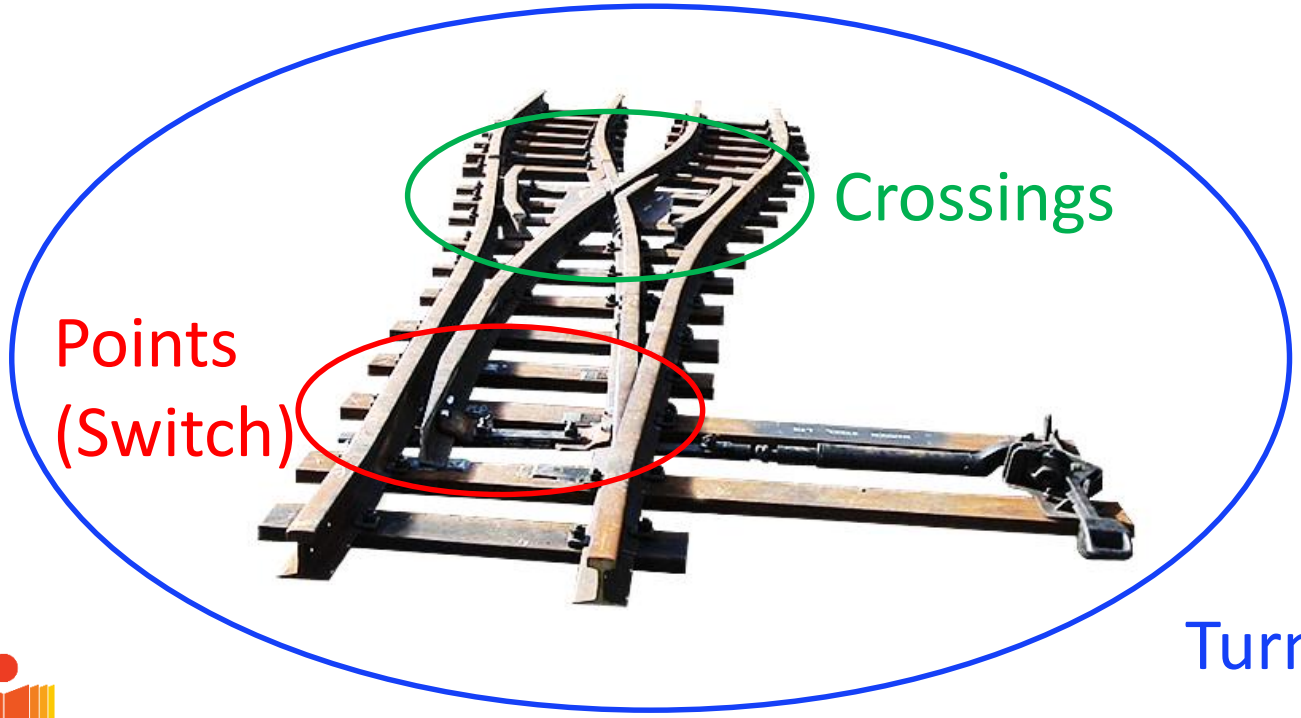


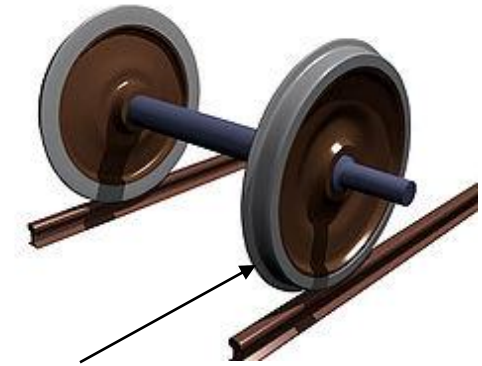
Necessity of Points and Crossings

- On roads vehicle can easily change paths, doesn't require any special arrangements as wheels doesn't have flanges, direction of movement of vehicle will be controlled by driver
- In railways wheels are provided with flanges, so direction of movement and diversion from one path to another are automatically controlled by wheel flanges rather than driver
- The diversion from one path to other in tracks is solved by special arrangements known as points and crossings

Points and Crossings

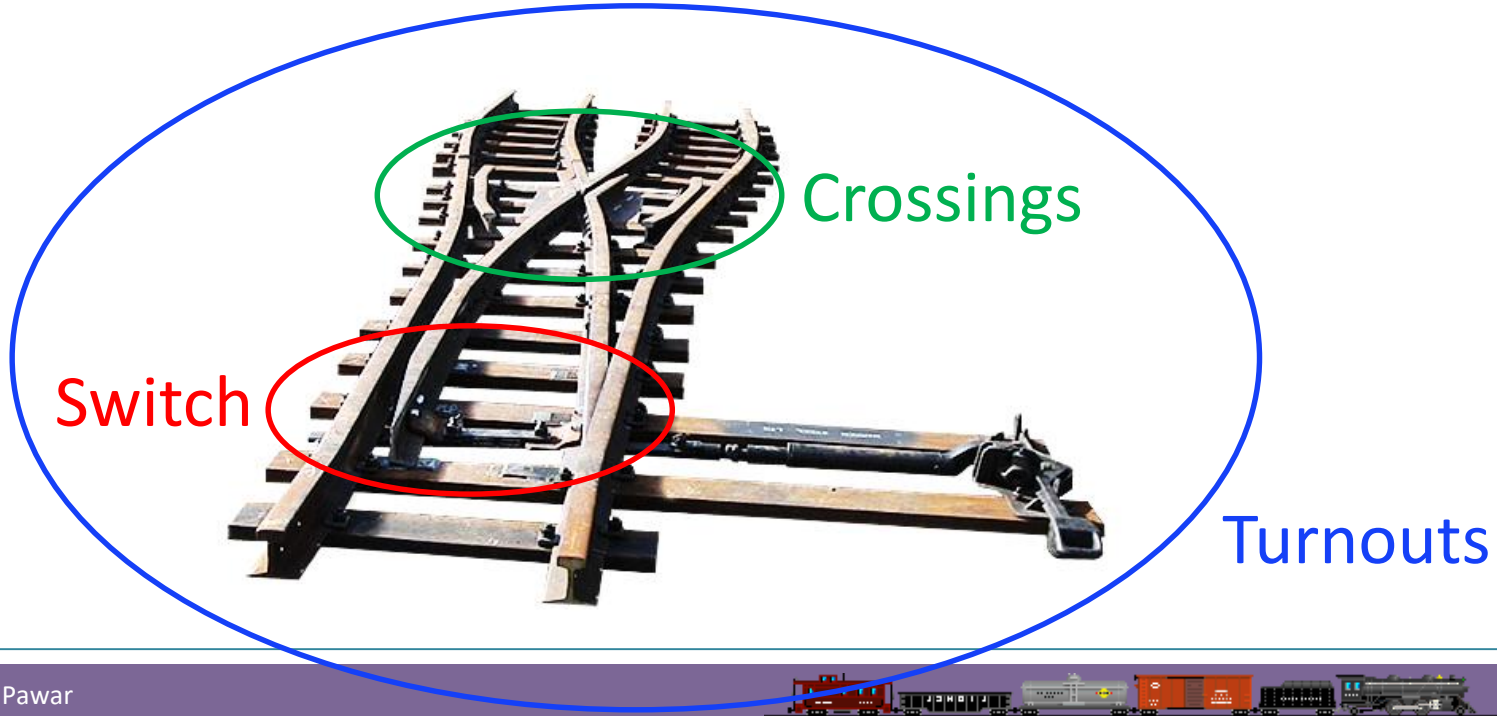
- Arrangements by which different routes either parallel or diverging or merging are connected and provide means for trains to move from one track to another
- **Points** are referred to as switches and are mechanical devices to change the path that trains may take through a junction





Crossings

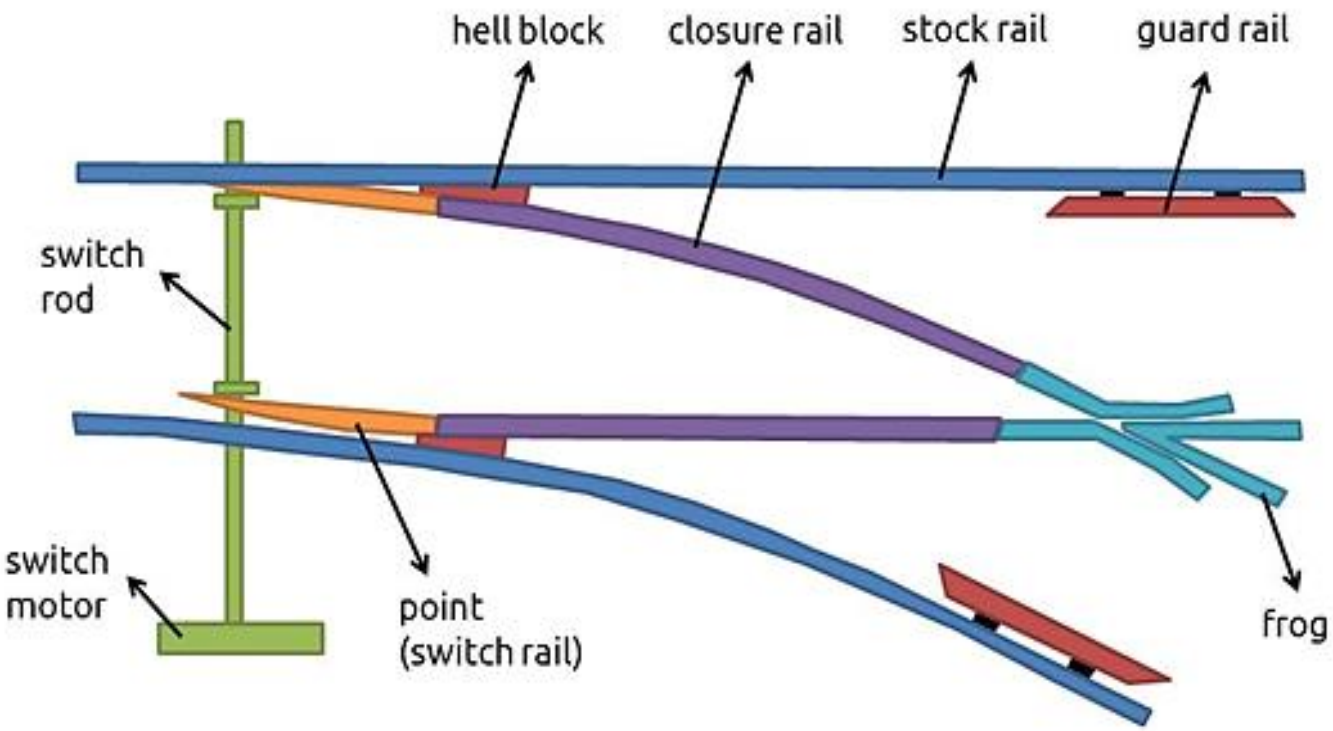
- **Crossing** is a device in the form of V-piece introduced in the track to permit movement of wheel flange at the intersection of two running lines
- It has gap over which the wheel tread jumps
- **Turnouts** is the simplest combination of Points and Crossings



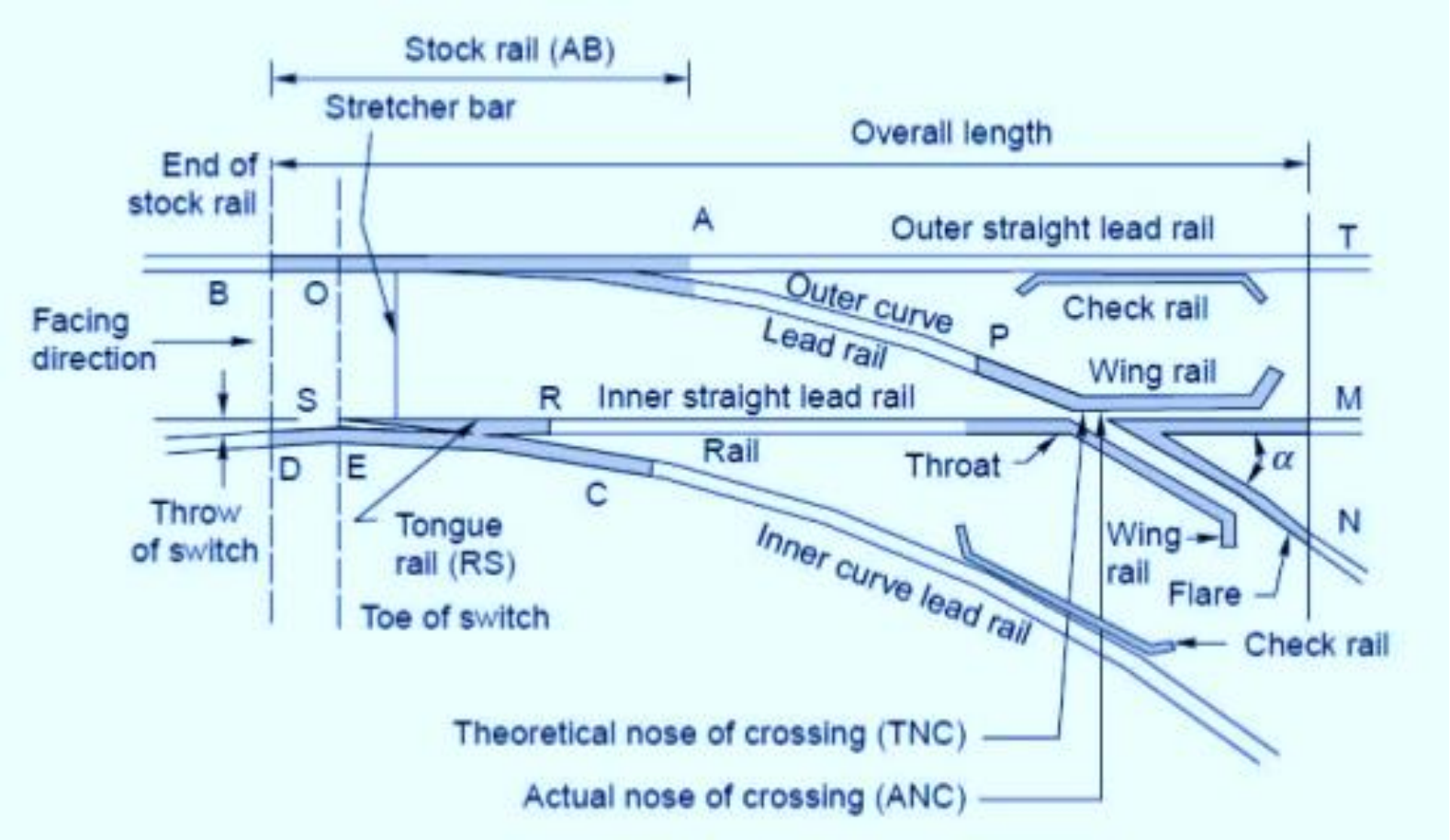
Points and Crossings: Video

Turnouts

- **Turnout** is the simplest combination of points and crossings which enables one track either a branch line or a sliding to take off another track.



Constituents of a Turnout



Component parts of a Turnout

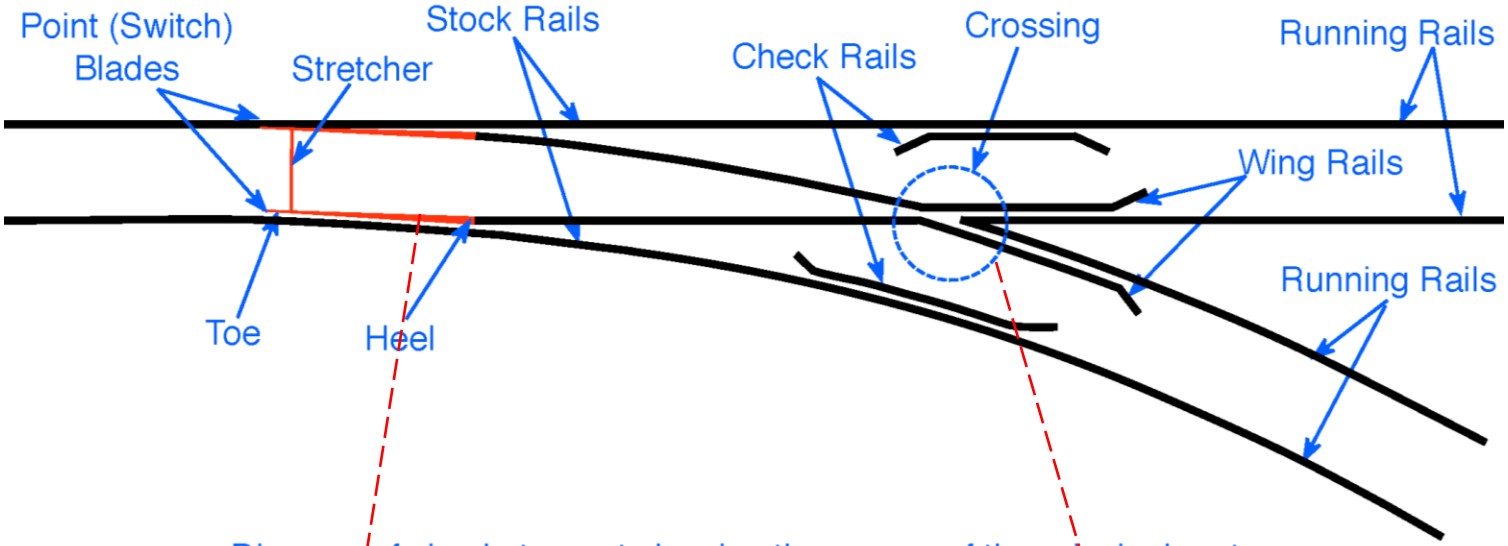
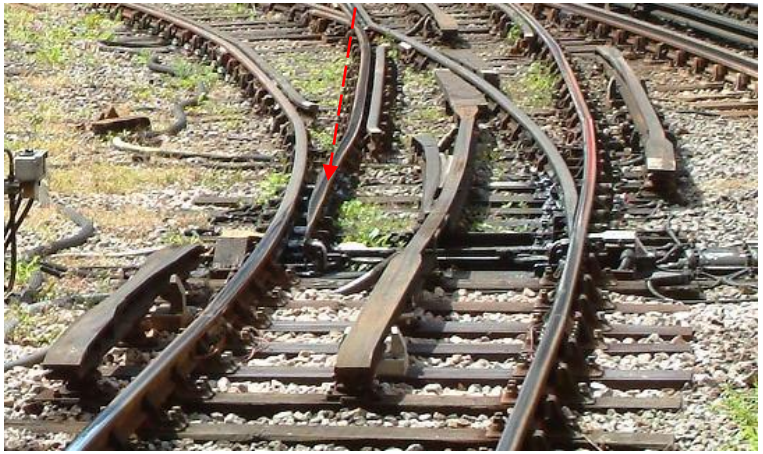


Diagram of simple turnout showing the names of the principal parts.
Moving switch blades shown in red.



Check Rail

- Flared rails provided opposite to crossing and running parallel to the lead rails with a purpose of
  - Guiding the wheel flange
  - Preventing wear and rocking of wheels
  - Preventing derailment at level crossings

Tongue rail

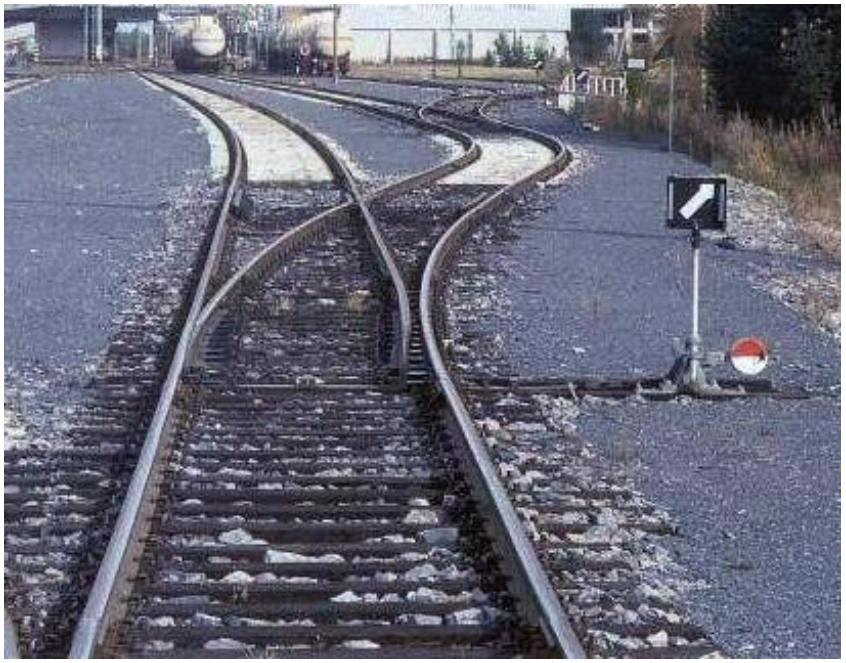
- Tapered section having thickness at the top same as lead rail at the heel of switch and 0.64 cm to 0.95 cm at the toe of switch
- Does not bear any load
- Half thickness of the rail should closely fit within the stock rail at the toe
- Tongue rail should be about 6 mm higher that stock rail at the center

Important terminology

- ***Facing direction**:* Standing at toe of switch and looking towards crossing
- ***Trailing direction**:* Standing at crossing and looking towards switch
- ***Facing points of turnouts**:* If trains first pass over switches
- ***Trailing points of turnouts**:* If trains first pass over crossing
- ***Right hand and Left hand turnouts**:* If train from main track is diverted to the right or left of main track
- ***Right hand and left hand switches**:* Depends upon left or right when seen from the facing direction

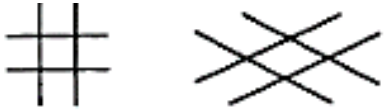
Turnout

- **Left hand turnout**: the turn which diverts the train to the left is called a left hand turnout.
- **Right hand turnout**: the turnout which diverts the train to the right is called a right hand turnout.

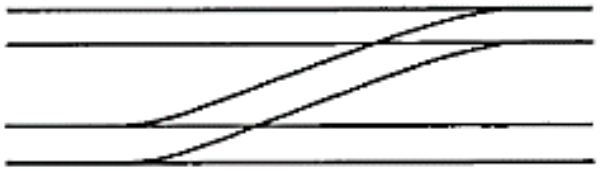


Turnouts

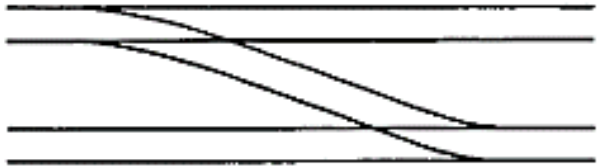
Crossings



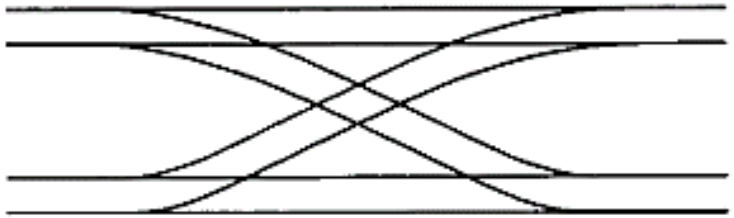
Left hand crossover



Right hand crossover



Double crossover



Left hand turnout

Right hand turnout

Equilateral turnout

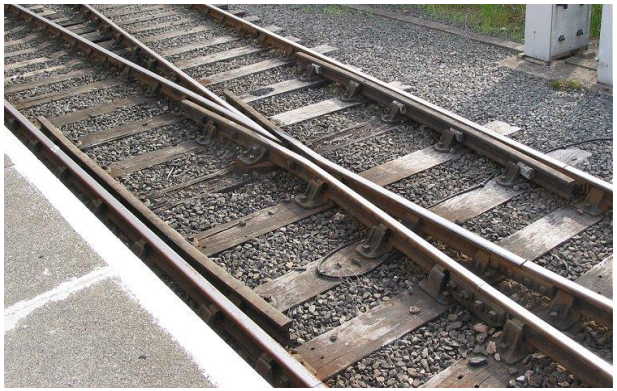
Three-way turnout

Types of Crossings

According to Angle

Acute angle crossing: V crossing or Frog.

- Two gauges faces meet at an acute angle *or*
- When left hand rail of one track crosses right hand rail of other track at acute angle



Obtuse angle crossing: Diamond Crossing

- Two gauges faces meet at an obtuse angle *or*
- When left hand rail of one track crosses right hand rail of other track at obtuse angle

Types of Crossings

Right angle or square crossing:

- Two tracks meet each other at right angle
- Rarely used

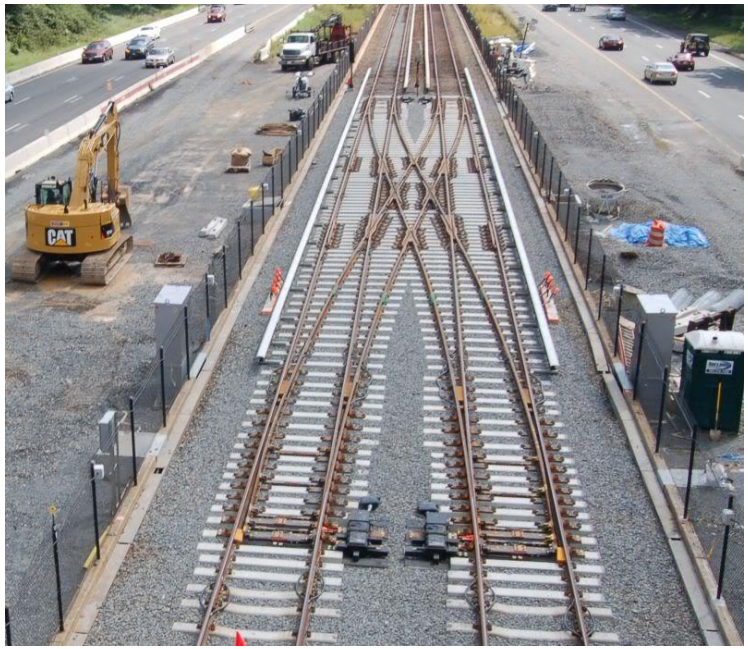
Classification according to Diversion

Spring Crossing:

- In this crossing one wing rail is strongly held against the V part by helical spring so that's why called as spring crossing
- Used in USA but not in India

Crossover crossing:

- Function of this crossing is to connect two parallel or diverging tracks.



Scissor Crossing:

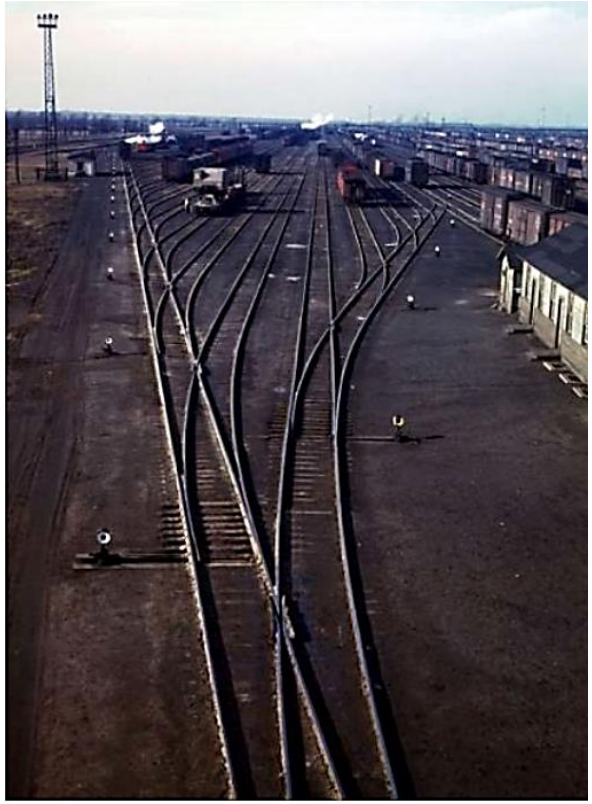
Consist of

- 4 pairs of switch
- 6 acute crossings
- 2 obtuse crossing
- Check rails
- Commonly used at good yards

Diamond Crossing

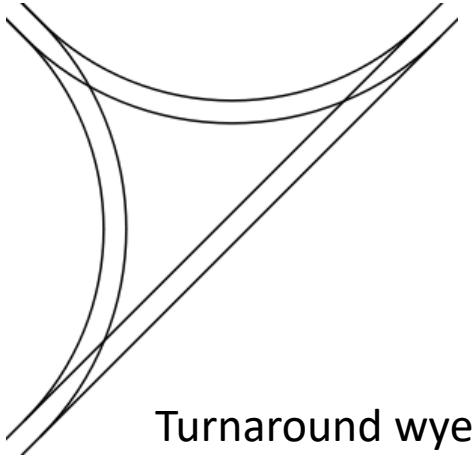
Gathering Lines:

When there are more than two tracks diverting from one line then it is called as gathering lines.



Turn Table

- **Railway turntable** or **wheelhouse** is a device for turning locomotives
- usually locomotives, so that they can be moved back in the direction from which they came
- This is especially true in areas where economic considerations or a lack of sufficient space have served to weigh against the construction of a turnaround wye

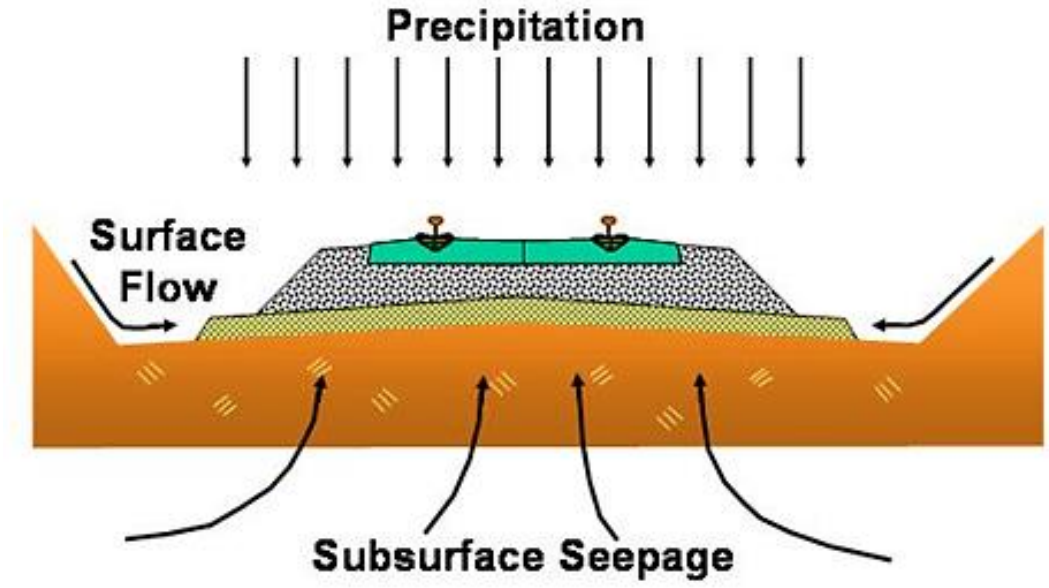


Turn Table: Video

Track Drainage

Drainage systems have two main functions

- To reduce the amount of water entering the track substructure.
- To remove water from the substructure.



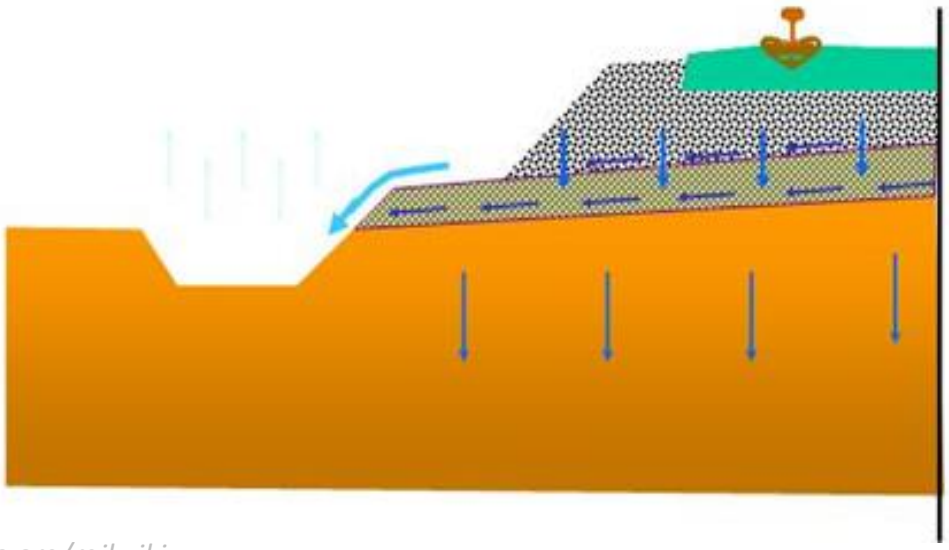
Significance of track drainage

- Track embankment settles due to presence of excess moisture
- Presence of excess moisture reduces track stability
- Presence of surface and ground water results in soft spots, unstable banks, bank slips and land slides
- Moisture in contact with soil causes heaving up due to swelling and shrinkage of soil on drying
- Bad soil on drying shrinks resulting in cracks which allows ballast to move into cracks
- Due to dynamic loading soil slush is formed and is pushed into ballast
- Derailment

Surface Flow

Sources of moisture in a railway track

- **Surface water due to rain, dew or snow**
  - Water which is free to move under gravity
  - Removed and diverted from track by side drains termed as surface drainage

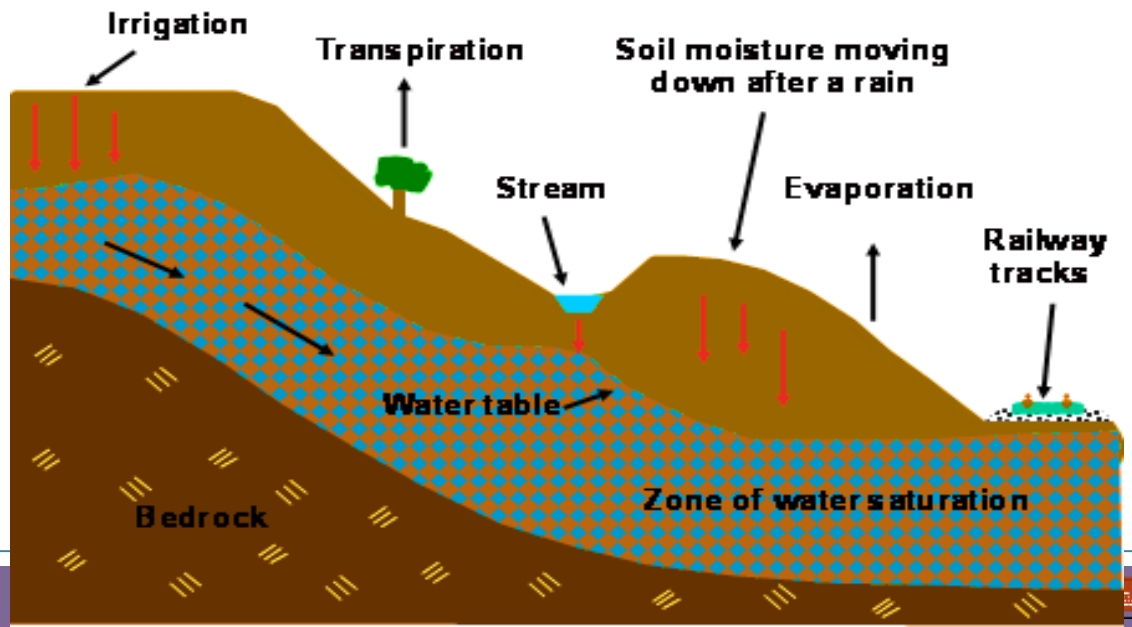


Source: railwaysubstructure.org/railwiki

Sources of moisture in a railway track

- **Moisture due to capillary action**
  - Removed by lowering water table using subsurface drainage system
- **Seepage water from adjacent area**
  - Removed by lowering water table using subsurface drainage system
- **Hydroscopic water or held water**
  - Retained in pores of soil mass
  - Cannot be removed by normal gravitational methods

Sources of groundwater



Surface Drainage

- **Drainage ditch blocked by excess ballast.**

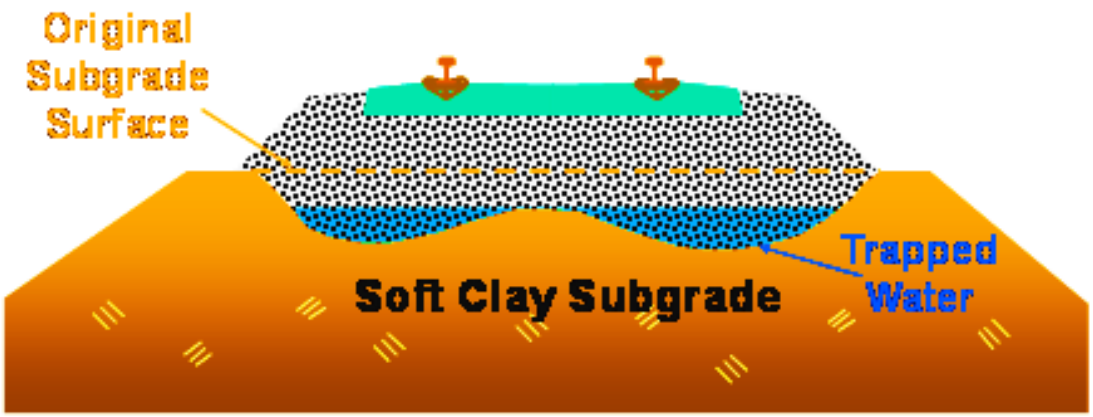
- **Old ties left along track after being removed block the flow of water in drainage ditches.**

- **A pile of ballast blocks drainage of a side ditch.**

Source: railwaysubstructure.org/railwiki

Drainage problems

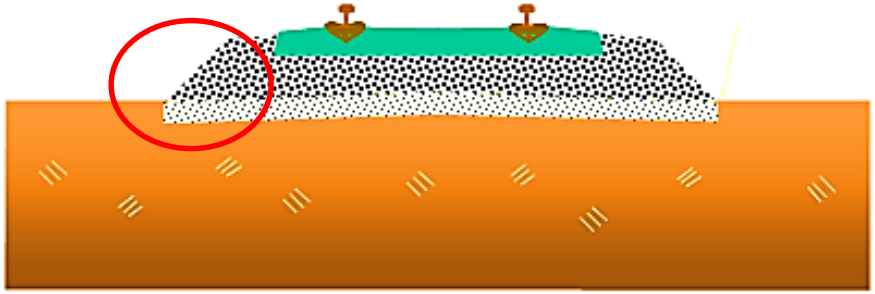
- Soft subgrade deforming under repeated train loading traps water because the clay subgrade is not permeable.
- This depression becomes filled with sub-ballast and ballast forming a "ballast pocket"
- This is also sometimes called a "bathtub effect".

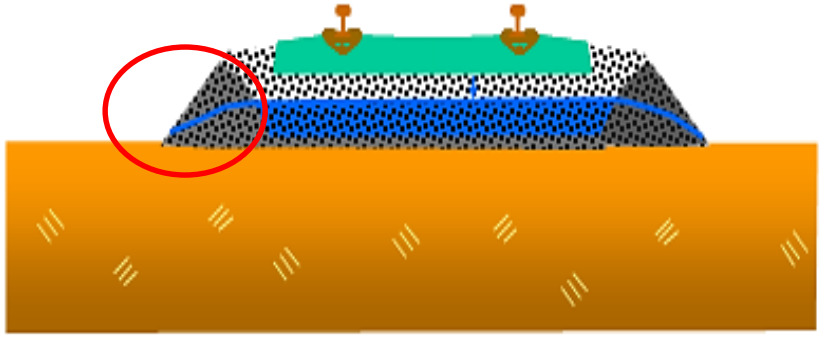


Source: railwaysubstructure.org/railwiki

Drainage problems

- Edges of the sub-ballast and even the toe of the ballast is below the surface of the subgrade.
- This keying in effect confines the edges of the granular material but also blocks drainage from the lower part of the ballast and the sub-ballast.
- Shoulder ballast contamination inhibit drainage of the ballast and subballast.

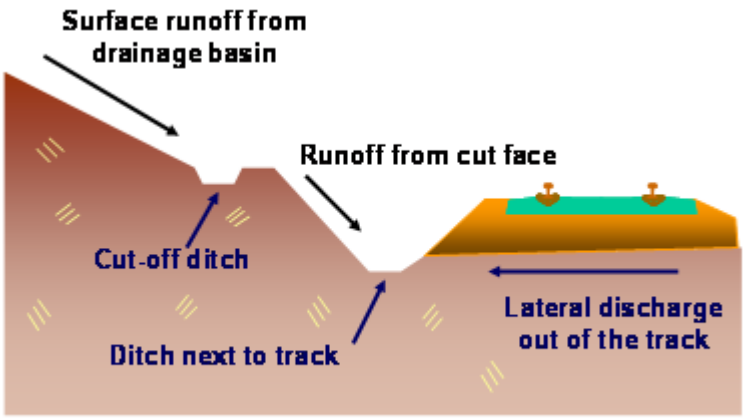




Source: railwaysubstructure.org/railwiki

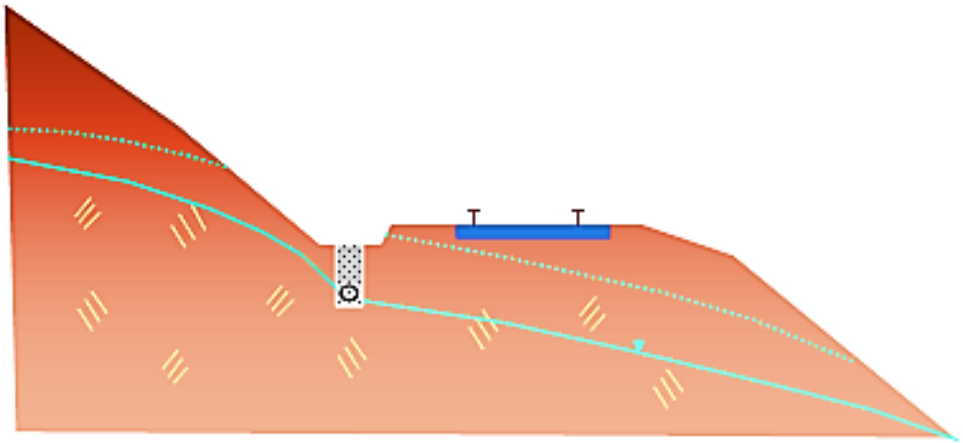
Surface water control

- Construct a cut off ditch to intercept the water flowing down from the area away from the track
- Water will not enter either the track drainage system or the track substructure

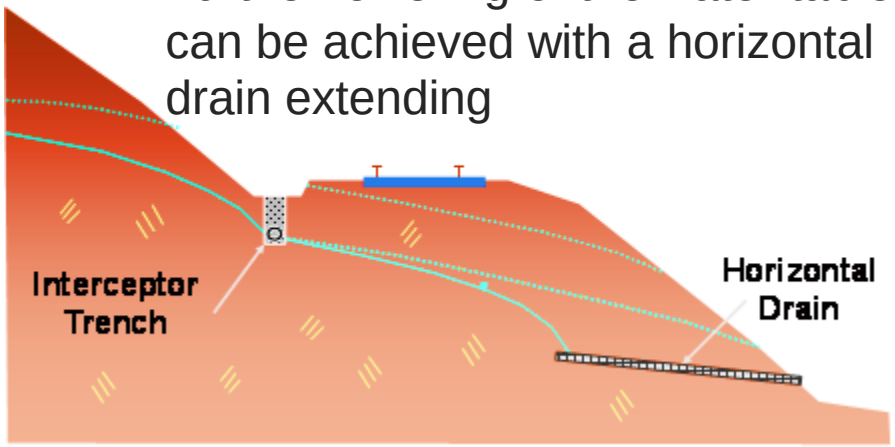


Subsurface drains

- Subsurface drains are drains installed below the surface to collect water from the track substructure or intercept ground water moving towards the substructure.
- In special cases the subsurface drains may be designed to capture both surface and subsurface water.
- Subsurface drain placed beneath a surface drainage ditch will lower the water table. This will improve the performance of the track substructure.

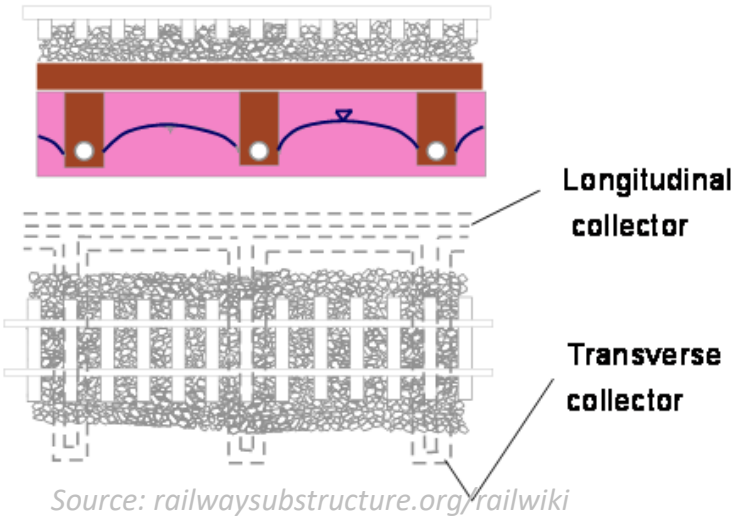


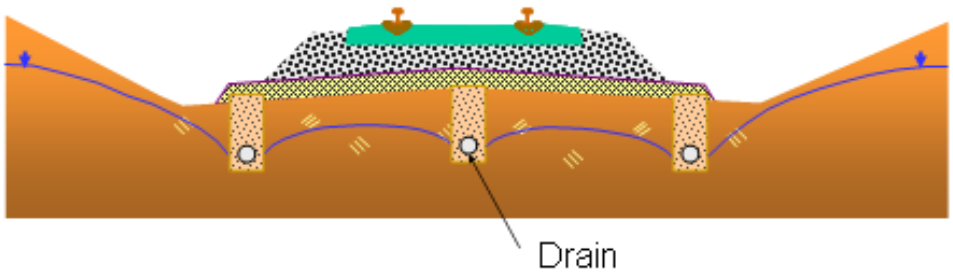
Further lowering of the water table can be achieved with a horizontal drain extending



Subsurface drains

- For high ground water table, relatively closely spaced subsurface drains transverse to the track may be required.
- Same effect may be achieved by subsurface drains running parallel to the track.

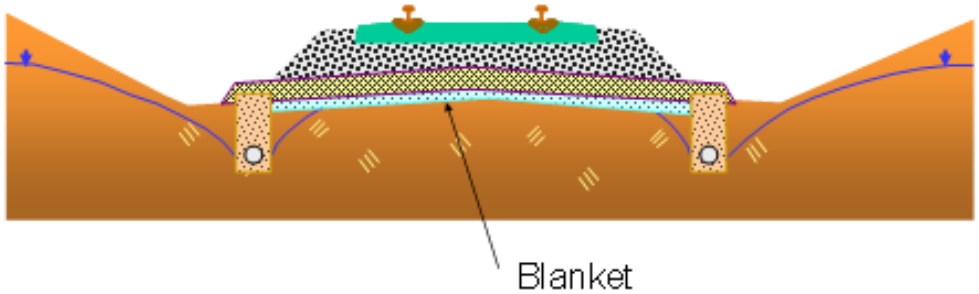


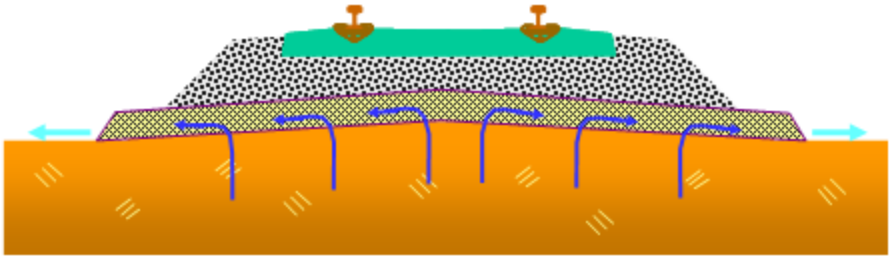


Source: railwaysubstructure.org/railwiki

Subsurface drains

- Instead of a center longitudinal drain a permeable layer may be placed on top of the subgrade
- Intercept the ground water and prevent it from entering the subballast and ballast
- Permeable layer is known as a “drainage blanket.”
- If the subballast is permeable enough, it may serve as a drainage layer

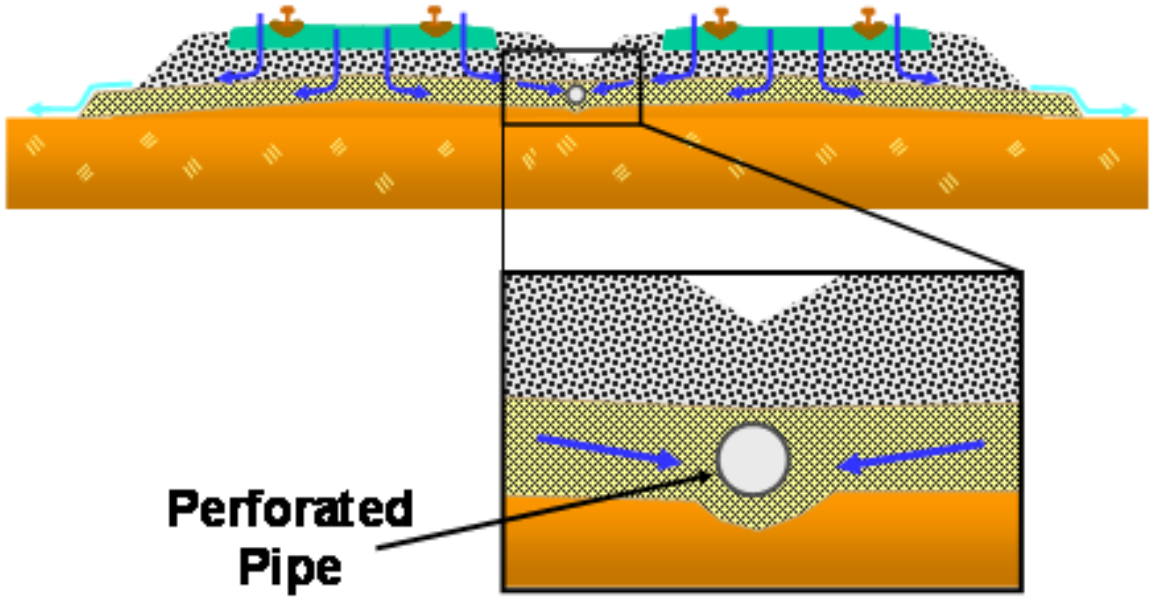




Source: railwaysubstructure.org/railwiki

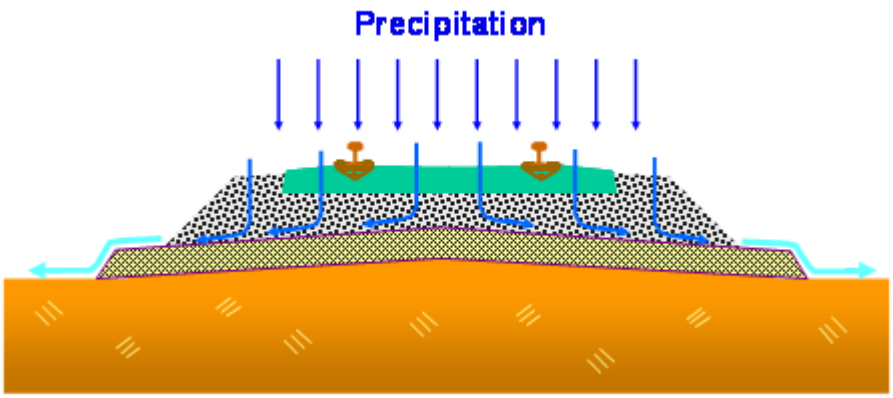
Subsurface drains

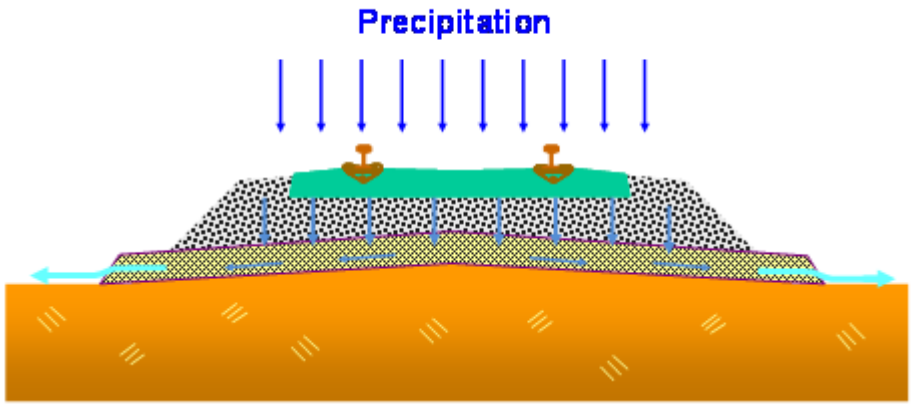
- Parallel tracks are commonly placed too close together to provide a longitudinal ditch drain between them.

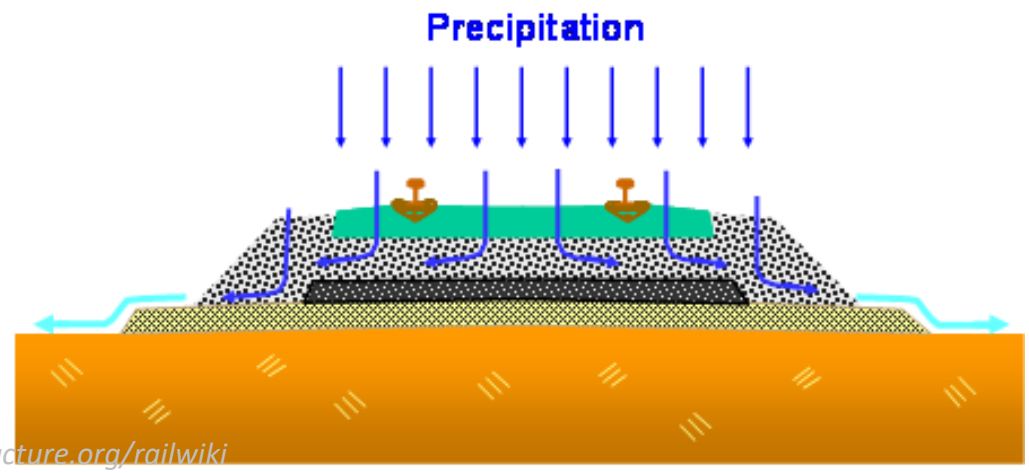


Source: railwaysubstructure.org/railwiki

Draining the ballast and subballast







Source: railwaysubstructure.org/railwiki

Ballast

- A layer of broken stones or gravel, laid and packed below and around sleepers

Functions of ballast

- Transfer the load from sleeper to subgrade
- Provide good drainage for the track structure
- Hold the track structure to line and grade
- Provide elasticity and resilience to track for getting proper riding comfort
- Reduce dust
- Prevent growth of bushes and weeds

Requirements of Good Ballast

- Should withstand hard-packing without disintegration
- Should be tough and should not crumble under heavy loads
- Should not make the track dusty or muddy under dynamic loading
- Should allow easy drainage with minimum soaking
- Should offer resistance to abrasion and weathering
- Should not produce any chemical reaction with rails and sleepers
- Materials should be easily workable
- Should retain its position and should not get distributed
- Large voids to prevent capillary action
- Available at nearby quarries

Sleepers

- Sleepers are members generally laid transverse to the rails on which the rails are supported and fixed
- Used to transfer loads from rail to the ballast and subgrade, and to hold the rails to the correct gauge

Function of Sleepers

- Hold rails firmly and evenly
- To act as elastic medium between ballast and rails
- To distribute the load from rails to ballast or girders in case of bridges
- To support rails at proper level and at proper SE on curves
- Provide longitudinal and lateral support
- Maintain proper alignment of the railway track

Classification of Sleepers

Wooden Sleepers

Advantages

- Available in all parts of India
- Fitting is simple
- Suitable for all types of ballast
- Able to resist shocks and vibrations
- Easy to lay and relay

Disadvantages

- Subjected to wear, decay, attack by white ants, warping, cracking
- Minimum service life compared to other types
- Difficult to maintain gauge
- Track easily disturbed

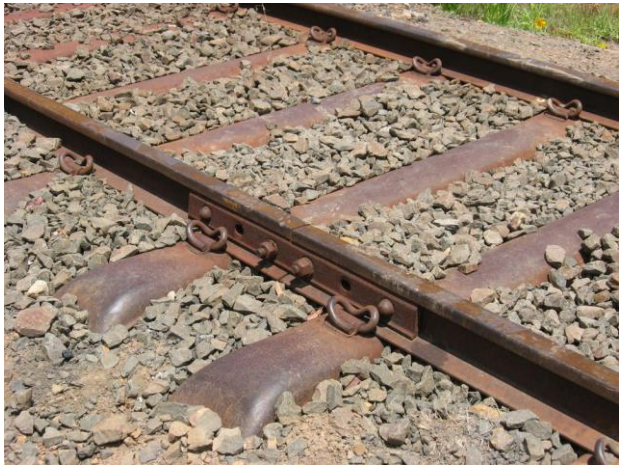
Metal Sleeper

Advantages

- Uniform in strength and durability
- Performance of fitting is better
- Economical : since long life and less maintenance
- Gauge can be easily adjusted
- Good scrap value and no fire hazard

Disadvantage

- More ballast is required
- More number of fittings required
- Liable to rusting/corrosion
- Interferes with track circuiting
- Unsuitable for bridges, level crossings, and at points and crossing



Concrete Sleepers

Reinforced concrete sleepers and Pre-stressed concrete sleepers

Advantages

- Free from natural decay
- Not affected by moisture and chemical action of ballast
- Maximum life period
- Highest elastic modulus
- Greater stability & withstand higher stresses

Disadvantages

- Handling difficult due to more weight
- No scrap value
- Requires pads and plugs for spikes

Sleeper Density

- In case of railway track the spacing of sleepers is specified by "Sleeper Density"
- Sleeper Density represents the no. of sleepers per rail length. It is specified as $n+x$

$$n = length\ of\ rail\ in\ m$$

$$x = a\ number \quad (4 \text{ or } 5 \text{ or } 6 \text{ or } 7)$$

e.g., sleeper density : (n+4), here $x = 4 = no.\ of\ sleepers$

- Length of Rail (n): for B.G : 12.8 m

  for M.G : 11.89 m

Problem

Q) In case of B.G track, what is the total no. of sleepers per unit length, if sleeper density is (n+5)

Q) For a B.G track the sleeper density adopted is (n+4). Determine the total no. of sleepers required for 1 km length of the track.

Stresses in the Railway Track

- Railway track is a composite structure consisting of rails, sleepers, sleeper fastenings and ballast resting on subgrade
- Railway track is not firmly embedded in the ground
- Railway track floating on ground
- Analysis of stresses for railway track is based on theory of elasticity

Elastic Theory

- Assumes superstructure and its support will deflect slightly under the load but return to their initial position.
- The effect of various stresses is calculated by considering the track as an elastic member as a whole.

Stresses in the Railway Track

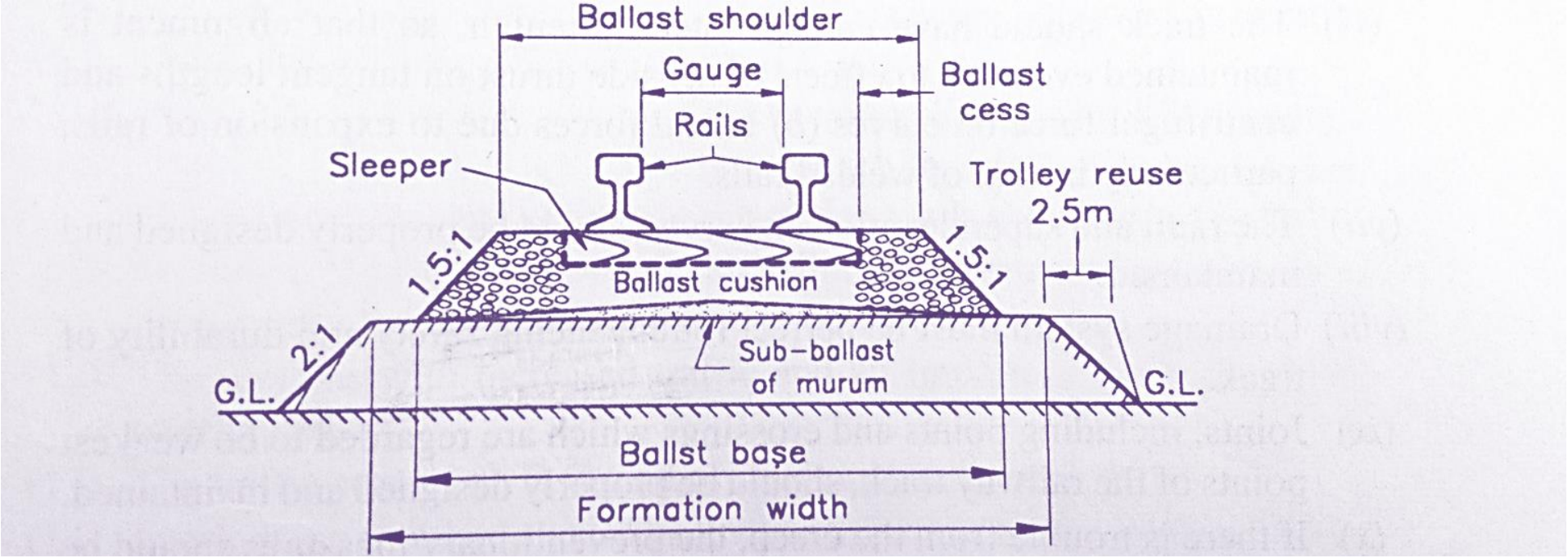
- The elastic property of track is represented by Track Modulus
- **Track Modulus** if defined as load per unit length of the rail required to produce a unit depression in the track.
- Track modulus depends on
  - Gauge
  - Type of rails
  - Type and density of sleepers
  - Type and section of ballast
  - subgrade

Geometric Design of Railway Tracks

- Gradient
- Curves
- Transition curves
- Superelevation
- Negative superelevation
- Speeds (Safe speed, maximum speed)

Railway Track (Permanent way)

- The railway track is considered to be semi-elastic. The ballast provides a semi-elastic behaviour to take vibrations.

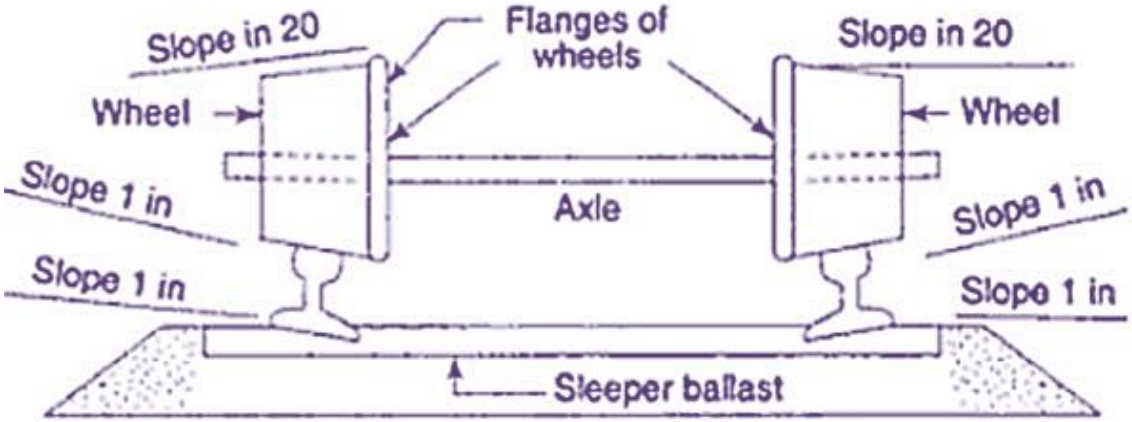


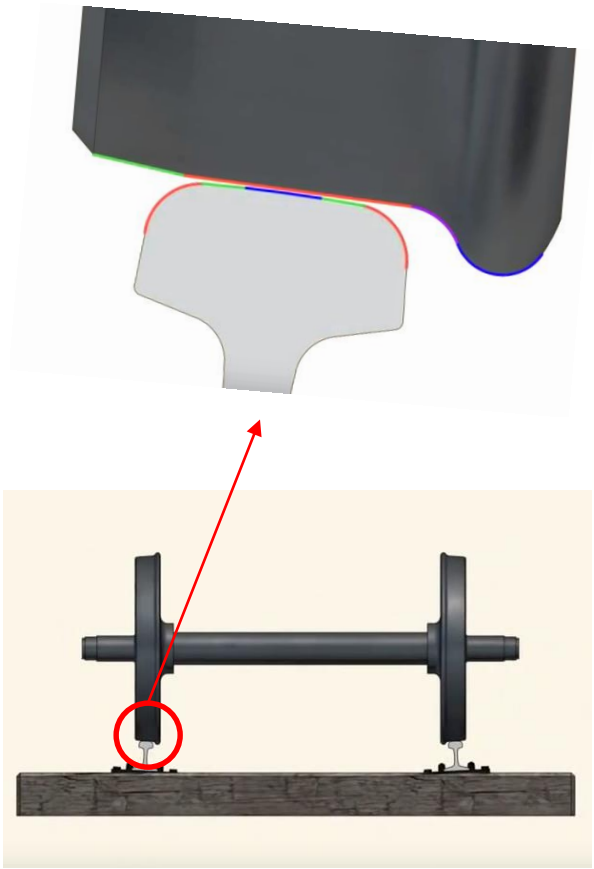
Track capacity

- **Track capacity:** Track capacity is the number of trains that can run safely on a track per hour.
- **Types of gauges**: Clear distance between inner faces of two track rails is called as Gauge of railway track.
  - Broad gauge (BG): 1.676 m
  - Meter gauge (MG): 1.0 m
  - Narrow gauge (NG): 0.762 m
  - Light gauge (LG): 0.610 m (feeder track gauge)

Coning of Wheels and Tilting of Rails

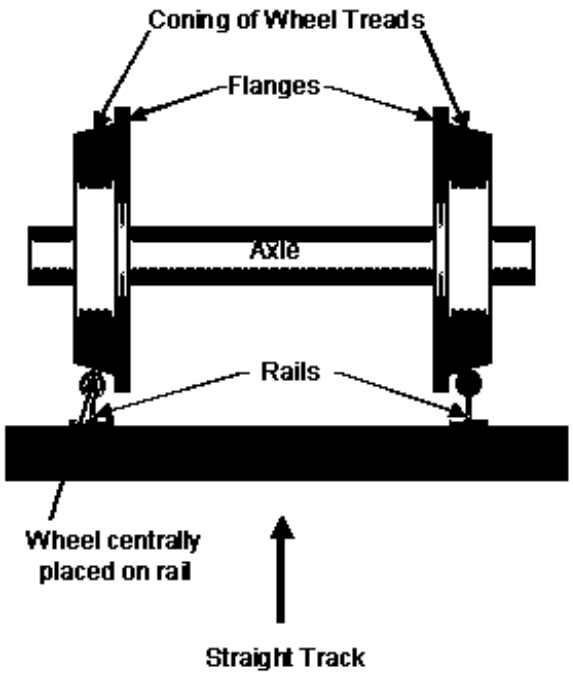
- This reduces the wear and tear between wheels of railway and rail
- It allows the wheels to move laterally on a curve to reduce wear and tear

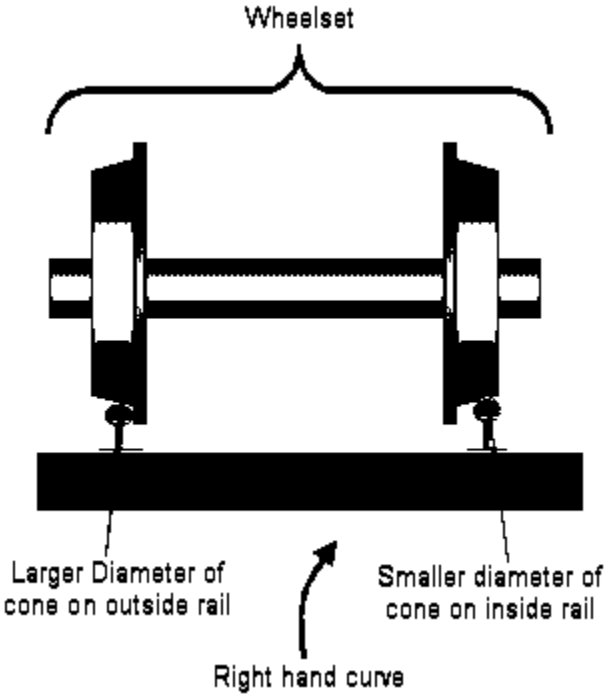




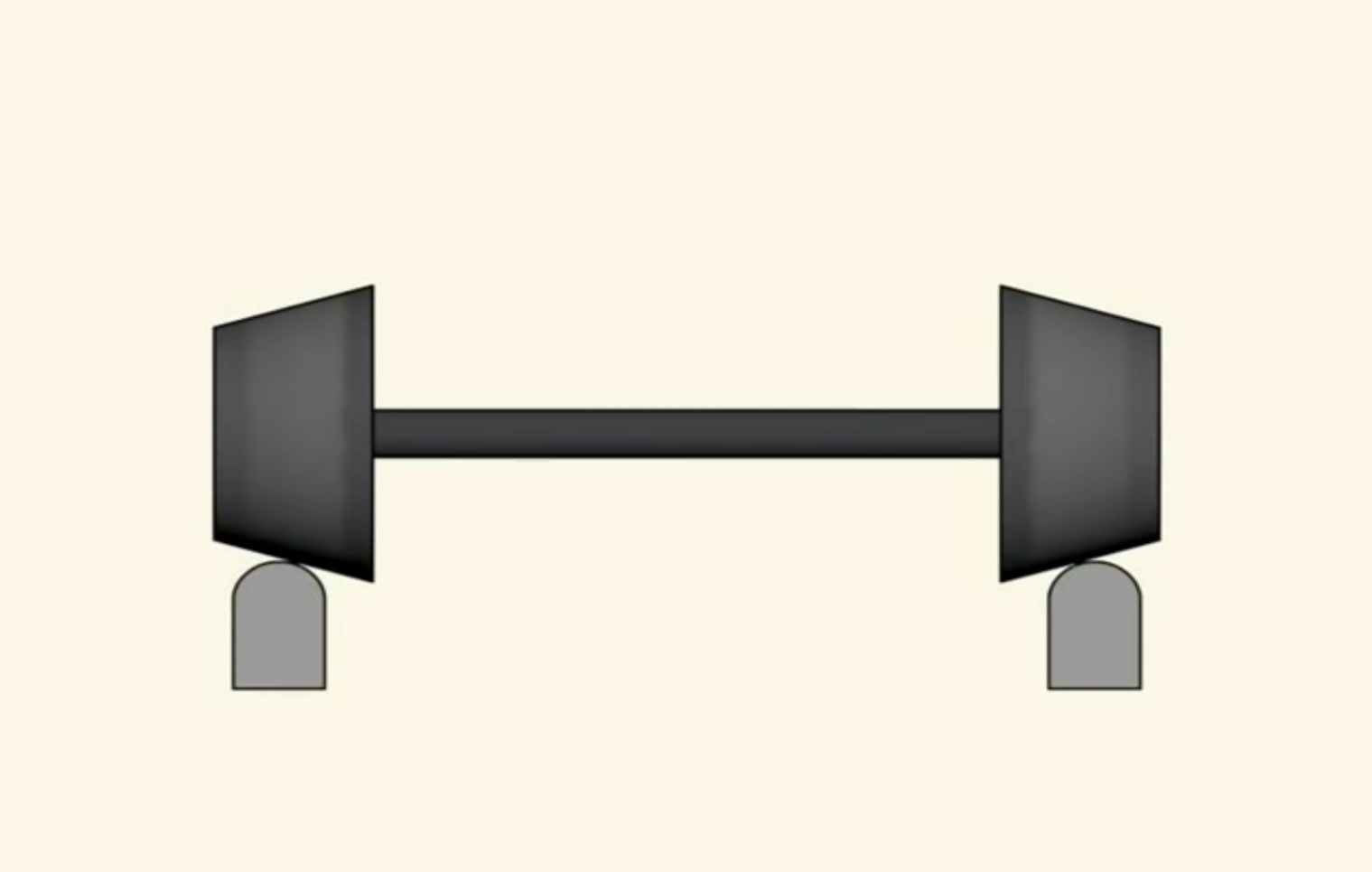
Coning of Wheels and Tilting of Rails

- On curved track, the outer wheel has a greater distance to travel than the inner wheel. To compensate for this, the wheel-set moves sideways in relation to the track so that the larger tyre radius on the inner edge of the wheel is used on the outer rail of the curve





Coning of Wheels and Tilting of Rails: Video



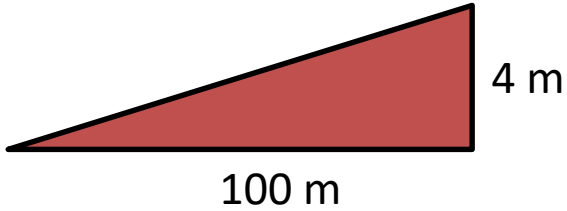
Gradient

- Any departure of track from the level is known as grade or gradient.

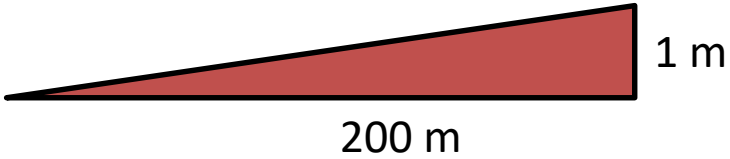
- **Designation**

1) In % for e.g., 4% or 3% gradient
2) 1 in x for e.g., 1 in 200 or 1 in 150

4% = 4/100 =



1 in 200 =



Gradient

Purpose of providing gradient

- To provide uniform rate of rise or fall
- To reduce cost of earth work
- To reach different stations at different level

Types of gradient

1) Ruling gradient
2) Momentum Gradient
3) Pusher gradient
4) Gradient at stations

Ruling Gradient

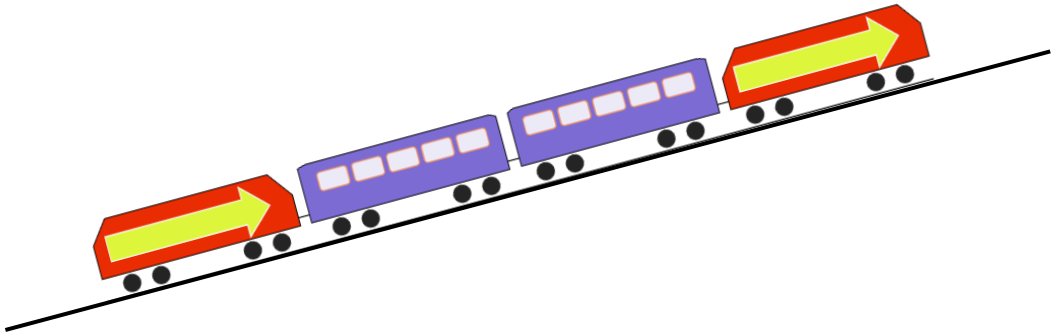
- The steepest gradient allowed on the track section
- It determines the max load that the locomotive can haul that section
- The steep gradient needs more powerful locomotives, smaller train loads, lower speed, resulting in costly hauling
  - In plains: 1 in 150 to 1 in 200
  - In hilly regions: 1 in 100 to 1 in 150

Momentum Gradient

- The gradient on a section which are steeper than the ruling gradient acquire sufficient momentum to negotiate them are known as momentum gradient.
- In Valleys, falling gradient is followed by a rising gradient so as to acquire good speed and momentum and therefore to negotiate the steeper gradient with ease
- In sections with momentum gradient obstacles in the form of signals and crossings are generally avoided.

Pusher or helper gradient

- If the ruling gradient is so severe on a section that it needs the help of additional engine to push/pull the same load, then this gradient is known as pusher of helper gradient.
- Generally required in Hilly areas



Gradient at station yards

- These gradients are provided at station yards for drainage purpose only
- Stations gradient are provided sufficient low due to following reason:
  - To prevent movement of standing vehicle
  - To prevent additional resistance due to grade
- The permissible gradient at station yards: 1 in 1000 to 1 in 400

Grade compensation on curves

- To avoid resistance beyond the allowable limit, the gradients are reduced on the curves. This reduction in gradient at the curves is known as grade compensation for curves.
  - B.G track: 0.04 % per degree of curve
  - M.G track: 0.03 % per degree of curve
  - N.G track: 0.02 % per degree of curve

Problem

Q) In a broad gauge railway track the specified ruling gradient is 1:150. If a horizontal curve of 4^0 is present, what is the permissible compensated gradient.

→ 0.51% or 1 in 196

Curves

- Generally circular curve is provided
- Designation: a) Degree of curve
  b) Radius of the curve

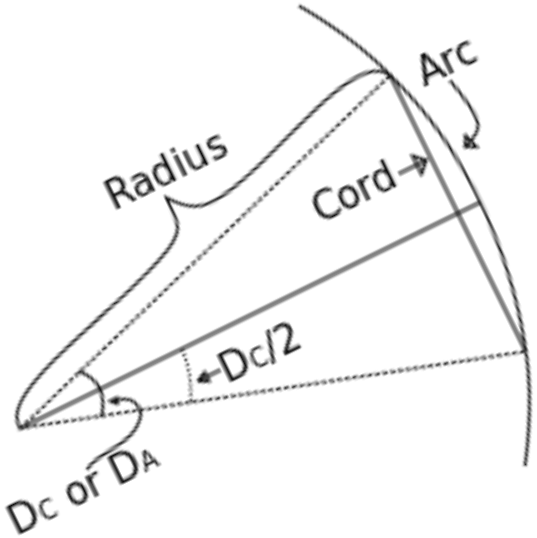
Degree of the curve: Angle subtended by the arc of 30 m length.

Arc = R x D^0

$$30 = R \times D \times \frac{\Pi}{180} \text{ (Radians)}$$

$$D = \frac{1718.9}{R} \approx \frac{1720}{R} \quad \text{(R in meters)}$$

Therefore for 1^0 curve, R = 1720 m



Degree of the curve

Maximum degree of curve permitted

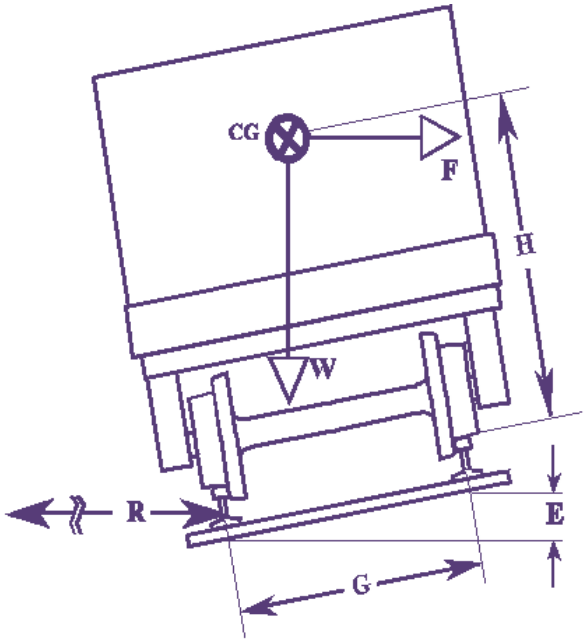
- For B.G = 10^0 (R = 175 m)
- For M.G = 16^0 (R = 109 m)
- For N.G = 40^0 (R = 44 m)

Superelevation or Cant (e)

- It is the raised elevation of outer rail over the inner rail ***or***
- Difference in height between the inner and outer rails on the curve
- It is provided by gradually raising the outer rail above the inner rail level
- The inner rail is considered as the reference rail and normally is maintained at its original level
- The inner rail is known as the gradient rail

Function of superelevation:

- Neutralizes the effect of lateral force
- It provides better load distribution on the two rails
- It reduces wear and tear of rails and rolling stock
- It provides smooth running of trains and comforts to the passengers



Equilibrium cant

- It is the cant at which the loads on the two rails are equal
- It is calculated based on the average speed
- Equilibrium Cant $e = G\frac{V^2}{gR}$

where,

e= meter

G = gauge in meter

V = speed in m/s

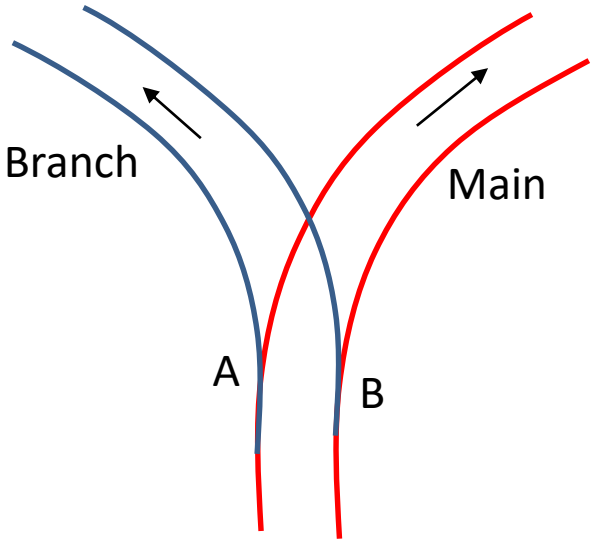
g = 9.81 m/s^2

R = meter

$e = G\frac{V^2}{127R}$, V = in km/hr and e, G, R in meter

Negative Superelevation

- When a track is diverging into two curved tracks in opposite direction as shown in figure.
- The superelevation cannot be provided simultaneously on both the tracks
- In such case preference is given to the main track and S.E is provided for the main track only.
- In this case the branch track is said to to have negative S.E.
- For safety purpose the speed on the branch track is to be restricted



Cant Deficiency

- It is the difference between the equilibrium cant (theoretical) necessary for the maximum permissible speed on a curve and the actual cant provided

Cant Deficiency = Equilibrium Cant – Actual Cant

Maximum cant deficiency permitted

Gauge	For speeds upto-100km/hr	For speeds > 100 km/hr
B.G	76 mm	100 mm
M.G	51 mm	-
N.G	38 mm	-

Cant Excess

- When a train travels on a curved rack at a speed lower than the equilibrium speed, then the cant excess occurs
- It is the difference between the actual cant provided and the theoretical cant required for such lower speeds
- Maximum value for cant excess is
  - BG track: 75 mm
  - MG Track: 65 mm

Video

Problem

Q) If a 5^0 curved track diverges from a main curve of 8^0 in opposite direction in the layout of broad gauge yard, calculate the superelevation and the speed on the branch line if the maximum speed permitted on main line is 45 km/hr.

Q) A 5^0 curve diverges from a 3^0 main line in reverse direction in BG layout. If the speed on the branch line is restricted to 35 km/hr, determine the restricted speed on the main line.

Transition curve

The curve introduced between a straight and circular curve or between two branches of compound curve

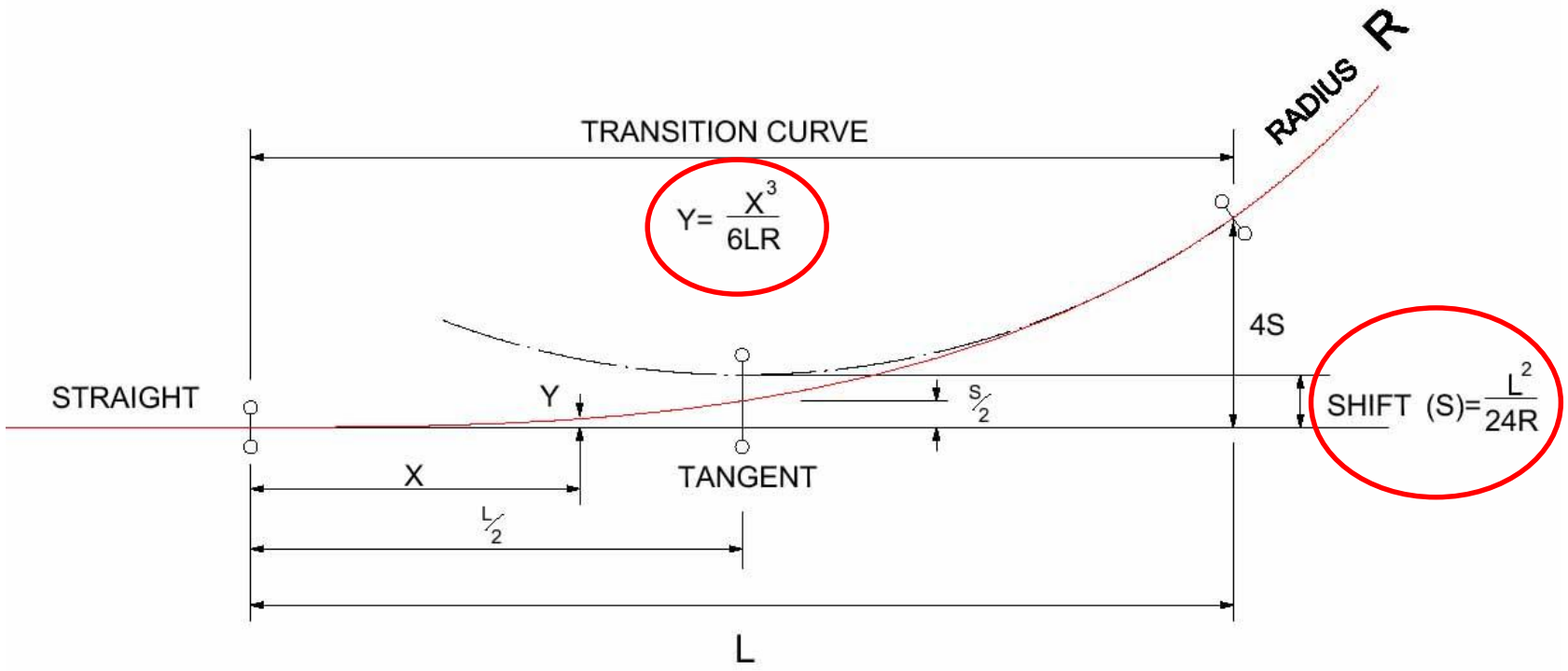
Purpose:

- To reduce radius of curve gradually from infinite value at the straight to that of circular curve
- To attain gradually the required super elevation
- To have a smooth and comfort running of vehicles

Shape of transition curve

Cubic parabola commonly used in Indian Railways

Transition curve and Shift of Curve



Hauling capacity of Locomotive

Hauling Capacity $= \mu . W_d$

μ = coefficient of friction between the rail and wheel = $\frac{1}{6}$ (usually)

W_d = total weight on the driving wheels of the engine

Wheel configuration

2 – 6 – 2

4 – 8 – 4

driving wheels

The middle number indicates no. of total driving wheels and remaining no's indicate idle wheels

Q) What is the hauling capacity of railway locomotive carrying an axle load of 24 tons. The engine has wheel configuration as 2 – 8 – 2.

Thank You