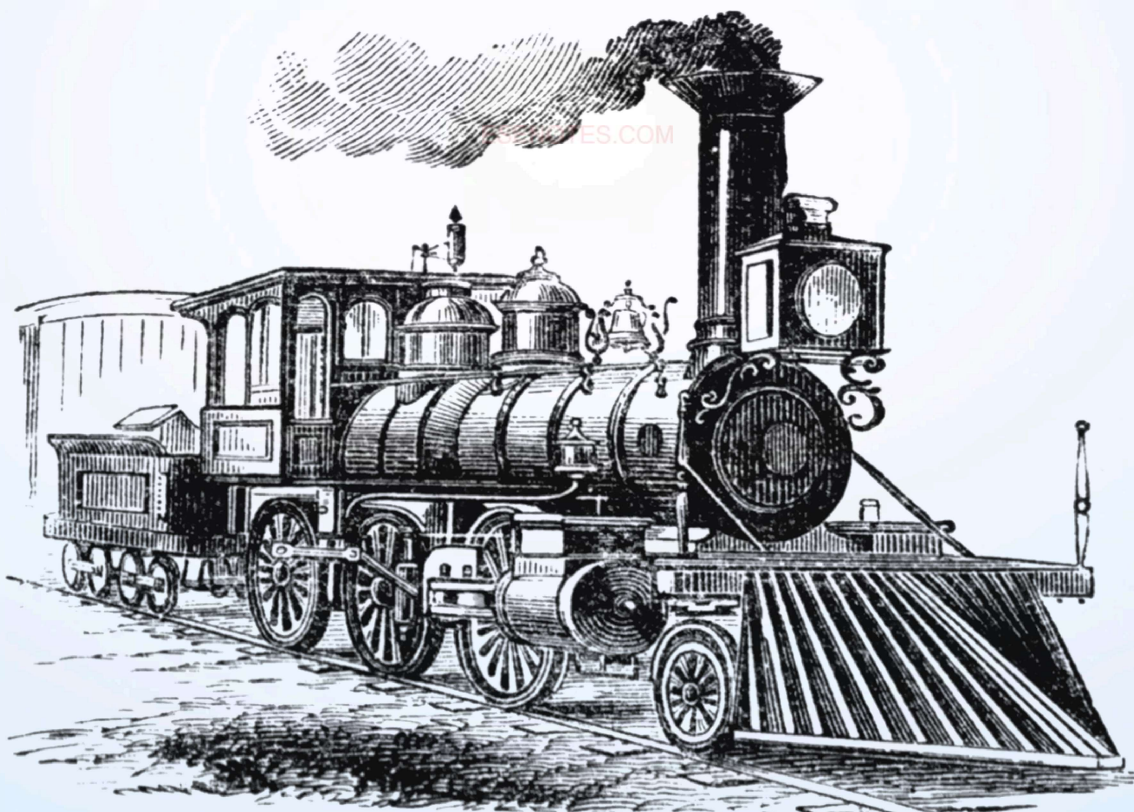


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RAILWAY ENGINEERING



BY JASPAL SIR

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RAILS & RAIL JOINTS

Rails :

- These are steel girders used for carrying the axle load (train load) and transfer it to the subgrade through sleeper and ballast.
- Rail convert the moving wheel load of train into point load, which acts on the sleepers.
- Since it has to resist high wear & tear, it is made of high carbon steel.
- In India, its manufacturing is done by 'open hearth/duplex process'.

NOTE :

- Steel is manufactured by two processes :

(i) Triplex Process :

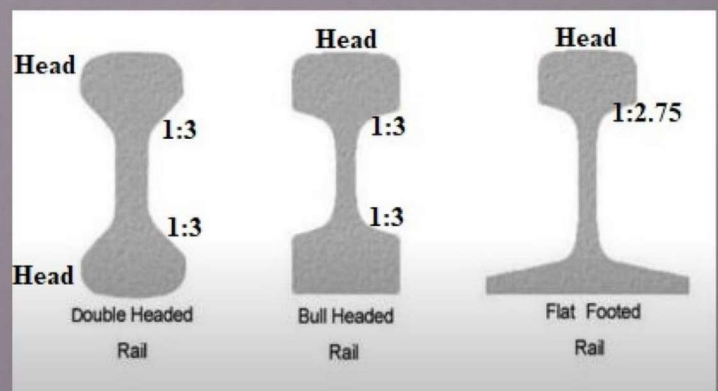
- It has three main production facilities :
 - (a) Acid Bessemer Converter
 - (b) Basic Open Hearth Furnace
 - (c) Acidic Open Hearth Furnace
- It is outdated.
 - ↳ 1950's में बन्द हो गया था।

(ii) Duplex Process : (or, Open Hearth Process)

- It consists of blowing hot metal & scrap in the Acid Bessemer Converter and finally refining them in Basic Open Hearth
- Here, scrap is also utilized.
- Used in today's time

Types of Rails :

- (1) Double Headed Rails (DH Rails)
- (2) Bull Headed Rails (BH Rails)
- (3) Flat Footed Rails (FF Rails)
OR, Vignoles Rails



Lec-1

(1) Double Headed Rails :

- These rails were used in beginning.
- The idea behind providing two heads was, if one head will worn out, the rail can be inverted and re-used.
- But in lower part due to indentations, smooth running surface was not obtained.

(2) Bull Headed Rails :

- In these rails, head was made a little thicker and stronger than lower part.

(3) Flat Footed Rail / Vignole's Rail :

- Here, bearing plate / flat plate is used at bottom.
- These rails are designated by weight of rail per unit length

eg: 52 kg/m or 52 MR
60 kg/m or 60 MR

- 52 MR : $V \leq 130$ kmph

60 MR : $V \leq 160$ kmph



Double Headed Rails



Bull Headed Rails



Flat Footed Rails



Lec-1 (20:35)

- Flat footed rails are more stronger, stiffer, easy to lay, cheaper and easy to maintain in comparison to double head / bull headed rails.

Requirement of Rails :

- These must be capable of withstanding the lateral forces.
(Hence, width of head and foot is increased.)

- To allow for vertical wear of 10 mm on its head.

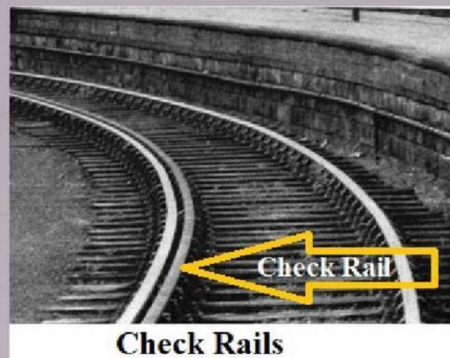
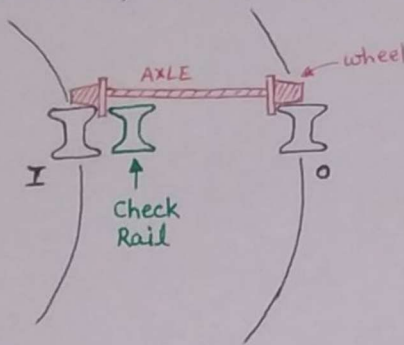
↳ अगर 10 mm से ज्यादा wear & tear हो रही है तो उस rail को change करना पड़ेगा

- Minimum tensile strength is 72 kg/m^2 .

- Must pass weight / tup test.

↳ इसमें 1.5 m की rail लेते हैं और इसके ऊपर 1000 kg (1 tonne) का weight ^{tup} fall कराया जाता है, 7.2 m की height से। ऐसा करने से concerned rail fail नहीं होनी चाहिए।

- Ratio of weight of rails to weight of locomotive (axle load) is 1:510.
 ↳ rails का weight निकाला per unit length, और locomotive का weight निकाला per unit length 1:510 उन weight per unit length का ratio है।
- When wear of head exceeds 5% to total weight, it must be replaced.
- On curves, check rail parallel to inner rails is introduced to control wear & tear of outer rail and to avoid the derailment
- Check rail is used, if curve is more than 8° for BG and more than 14° for MG.
- ↳ जब train, circular path के around चलेगी तो इस पर centrifugal force लगेगा। इस force की वजह से train के wheel, outer rail के inner side के contact में आएंगे और outer rail के inner side की wear & tear start हो जाएगी। इसको रोकने के लिए curve की inner side पर rail लगा दी जिससे train बाहर निकल ही नहीं पाएगी। So, एक फायदा तो ये हुआ कि outer rail की wear & tear बच गई। दूसरा फायदा ये हुआ कि centrifugal force की वजह से train की derailment हो सकती थी, वो बच गई।



lec-2

Length of the Rails :

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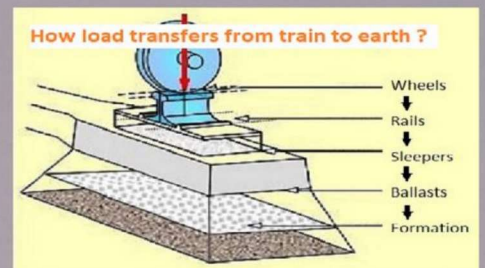
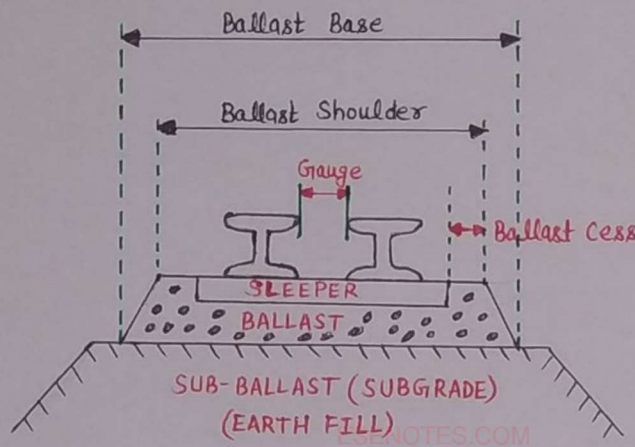
Lec-2

- Since joints are weakest points of railway track and they require fasteners also, so number of joints are required to be reduced.
- Hence, larger rails are preferred to smaller rails, as they would give strong rails and economical rails.
- Rails length is restricted by transportation limitations & due to gap required for expansion joints.
- Rail length for BG tracks is $12.8 \text{ m} \approx 13 \text{ m}$
 for MG tracks is $11.89 \text{ m} \approx 12 \text{ m}$

→ Rails की बड़ी length prefer की जाती है, in comparison to smaller length, bcoz joints पूरे railway track में weakest point होते हैं, तो अगर rail length छोटी होगी तो number of joints ज्यादा लगेंगे जिससे पूरे track की strength कम निकल कर आएगी। Moreover, joints ज्यादा होंगे तो fasteners ज्यादा लगेंगे जिससे cost ज्यादा आएगी इसलिए long rail prefer की जाती है। पर ये भी possible नहीं है कि 100 km की एक ही rail बनाकर use कर लें, due to transportation limitations. Also, long rails होंगी तो expansion joints में भी gap ज्यादा चाहिए (due to temp. deformation $L \propto \Delta T$), मतलब लम्बी rails हो गई तो gap ज्यादा आएगा जिसमें wheel ही फंस जाएगा। So, length of rail is restricted. [Joint की strength $\approx 50\%$ of rail की strength]

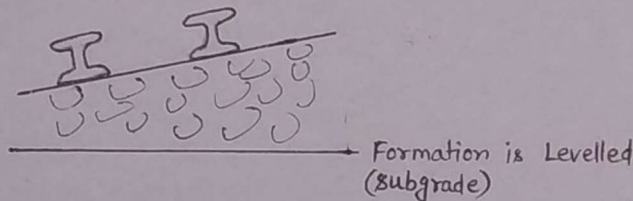
Permanent Way / Railway Track :

— Combination of rails, fitted on sleepers, resting on ballast & subgrade is called permanent way.



Lec-2 (12:20)

— On curve, superelevation is maintained by ballast and formation is levelled.



— On this way, rails are joined by fish plates & bolts.

— Permanent way is regarded as semi-elastic in nature.

→ कई बार material transportation के point of view से temporary tracks भी बनाए जाते हैं, तो यहाँ ये 'permanent' word से signify करता है कि ये track हमेशा यहीं रहेगा, ये permanent है।

Requirements of an Ideal Permanent Way :

- The gauge should be correct and uniform.
 - It should be elastic to absorb the vibrations of track.
 - Drainage should be perfect otherwise settlement will occur.
 - It should be properly maintained and designed.
 - It should have sufficient lateral strength.
- Uniform sleeper space, proper depth of ballast, sustain temp. stresses etc.



Lec-2 (18:30)

Defects in Rails :

(1) Corrugated Rail :

- The corrugation of rails are minute depressions on the surface of the rails.
- These are created at the place where either brakes are applied (i.e., on curves) or, where trains starts.
- When train passes over it, it makes roaring sound.



Corrugated Rails

(2) Kink in Rails :

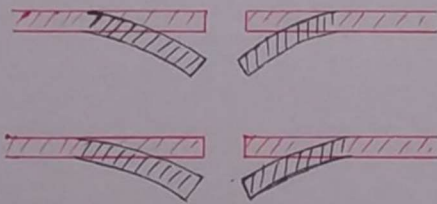
- When ends of the adjoining rails move slightly out of position, kinks are formed.
- These occur due to loose packing of joints.



Kink in Rails

(3) Hogged Rails :

- If head of the rail gets bend down due to impact action of rail, it is termed as hogged rails.



Hogged Rails

(4) Buckling of Rail :

- During summers, due to rise in temp., the expansion of rails occur.
- To allow this expansion, certain gap in b/w two rails is provided at the end joints.
- If gap is not sufficient or not available, the thermal expansion would cause thermal stresses, that leads to buckling.



- Buckling may also take place if fish plates are tightly bolted due to which rails are not allowed to slip.



Lec-2 (32:30)



Buckling of Rails

Gauges in Railway Track :

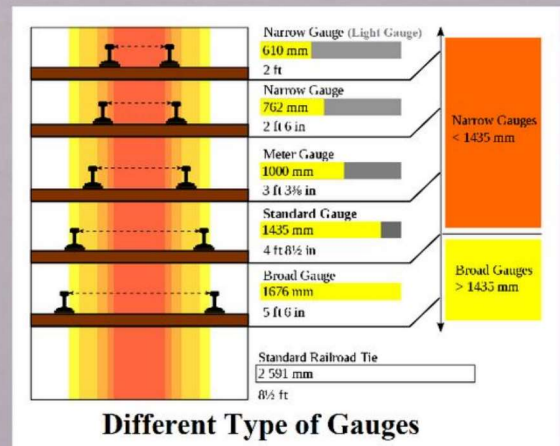
- It is defined as clear distance b/w inner or running faces of two tracks rails.

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Different Types of Gauge :

- (1) Narrow Gauge : 762 mm (2 ft. 6 in)
- (2) Meter Gauge : 1000 mm (3 ft. 3 $\frac{3}{8}$ in)
- (3) Standard Gauge : 1435 mm (4 ft. 8 $\frac{1}{2}$ in)
- (4) Broad Gauge : 1676 mm (5 ft. 6 in)

- Standard gauge is not used in India.
- BG is preferred over MG and NG, as:
 - (a) It gives more stability.
 - (b) It offers higher speed.
 - (c) It can take more load.
 - (d) It is more economical.



Different Type of Gauges

BG gives more stability, means:

→ stability in train operations such as moving on crossings, switching tracks, providing joints etc. is more in BG.



Lec-3

Coning of Wheels :

- The wheels of the train are made at a slope of 1:20, this is known as coning of wheels.
- Coning is done on a straight track to keep the train just in central position during movement, so that distance travelled by two wheels is always same.
- Coning on curved track is also done to overcome the effect of centrifugal force.
- Here, skid permitted is 0.029m per 1° of central angle.

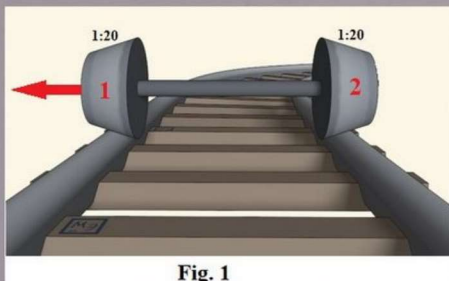
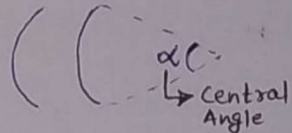


Fig. 1

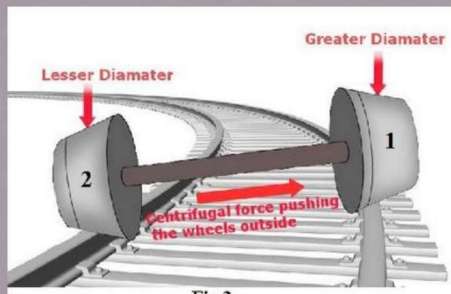
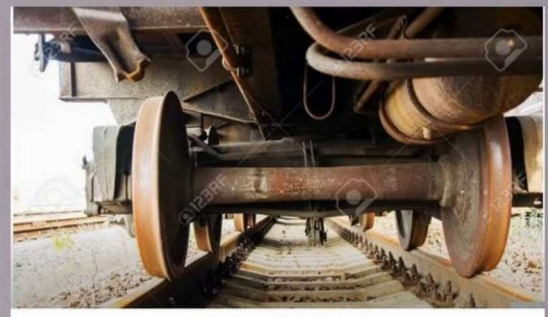


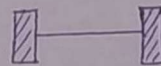
Fig 2



Coning of Wheels

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● Wheels of train are never made straight.



● Purpose of coning on both straight track and curved track is same. Coning of wheels always keeps the train in central position. How??

Train में bogies की lateral movement इसी coning of wheels की वजह से ही मिलती है।

Suppose, train की movement (lateral movement) left side में हुई (refer fig. 1) तो wheel ① का बड़ा diameter, track के contact में आया और wheel ② का छोटा diameter, track के contact में आया। अगर wheel ① का बड़ा dia, track के contact में आया तो wheel ① ज्यादा distance चलेगा, wheel ② का छोटा dia, track के contact में आया तो wheel ② कम distance चलेगा। ऐसा practically possible नहीं है कि एक wheel कम distance चले और दूसरा wheel ज्यादा distance चले। जैसे ही wheel ① ज्यादा distance

चलता है तो wheel ② उसको अपनी तरफ pull करता है जिससे कि दोनों wheel की चली हुई distance same आए। ये तो बात हुई straight track पर।

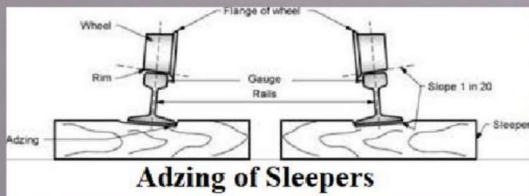
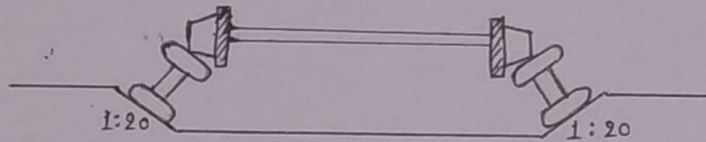
- Curved track पर (refer fig. 2) centrifugal force का role आएगा जिससे train की movement, outward side में होगी जिससे wheel ① का बड़ा dia, track के contact में आएगा और wheel ② का छोटा dia, track के contact में आएगा जिससे wheel ① ज्यादा distance travel करने लगेगा और wheel ② कम distance travel करने लगेगा। So, wheel ②, wheel ① को अन्दर की तरफ pull करेगा so that दोनों wheels same distance travel करें क्योंकि दोनों अलग-अलग distance travel नहीं कर सकते, axle से connected हैं।
- अगर coning of wheels ना हो तो train का derailment हो जाएगा।



Lec-3 (17:40)

Adzing of Sleepers :

- For the effective use of coning of wheels, the rails are not laid horizontally. These are laid at an slope 1:20 on sleeper, termed as Adzing of Sleepers.



Adzing of Sleepers

Rails Joints :

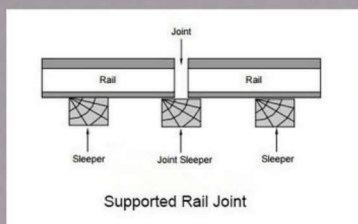
- Rail joints are necessary to hold together the adjoining ends of the rails in correct position both in horizontal and vertical direction.
- Joints are of following types :



Lec-3 (25:35)

(1) Supported Rail Joint :

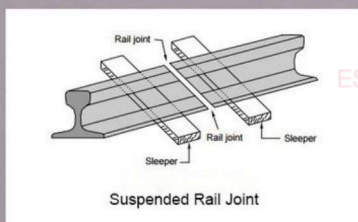
- When the rail ends rest on a single sleeper called joint sleeper, the joint is termed as supported rail joint.



Supported Rail Joint

(2) Suspended Rail Joint :

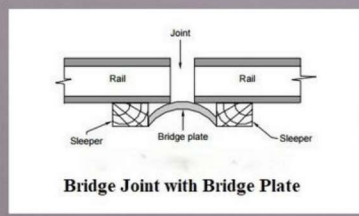
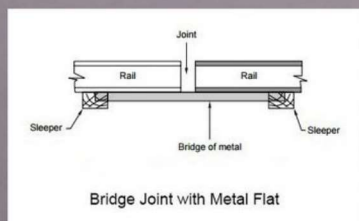
- When rail ends are projected beyond sleepers called shoulder sleeper, the joint is termed as suspended rail joint.



Suspended Rail Joint

(3) Bridge Rail Joint :

- When rail ends are projected beyond sleepers as in case of suspended joint and they are connected by a flat or corrugated plate, the joint is termed as Bridge Rail Joint.



Bridge Joint with Metal Flat

(4) Compromise Joints :

— When two different rail sections are joined by fish plate, the joint is termed as compromise joint.

● ये different rail sections provide क्यों करते हैं?

↳ Soil profile अलग-अलग हो सकती है।

↳ पुराना track 52MR का बना है, इसको आगे बढ़ाना है 60MR का use करके, speed बढ़ाने के purpose से



Lec-3 (41:35)



Compromise Joint

(5) Expansion Joint :

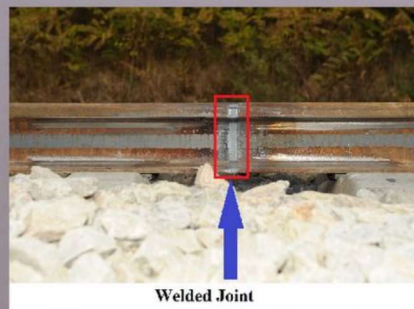
— To allow the thermal expansion at the end joints of rails, gap is provided. This type of joint is termed as expansion joint.



Expansion Joint

(6) Welded Joint :

— These are considered to be the most strongest joint in rails.



Welded Joint

Need of Welding of Rails :



Lec-6

- To increase the length of rail by joining two or more rails.
- To increase the life of rail track and reduce maintenance cost.
- To avoid the use of expansion joint at the ends of rails.
- To reduce creep & buckling of rail ends.
- To maintain proper gauge and alignment of rails.

- Rail की length increase करने से joints की requirement कम हो जाएगी, fasteners कम लगाने पड़ेंगे तो economical होगा। (Joints are weakest point)
- अगर हम welding कर रहे हैं तो हम degree of fixidity बढ़ा रहे हैं, इसका मतलब हम rail के ends पर buckling avoid कर रहे हैं।

Non-welded rail है तो बीच में तो fasteners लगा रखे हैं तो resistance available है पर जहाँ पर rail end होगी वहाँ कोई fastener नहीं है, तो वहाँ rail buckle हो जाती है। इसको avoid करने के लिए ends पर welding कर देते हैं।

Types of Welded Rails :

(1) Short Welded Rails (SWR) :

- If 3 or 5 or 10 rails lengths are welded together at both ends, it is termed as SWR.
- India में 3 rails को standardize किया हुआ है।

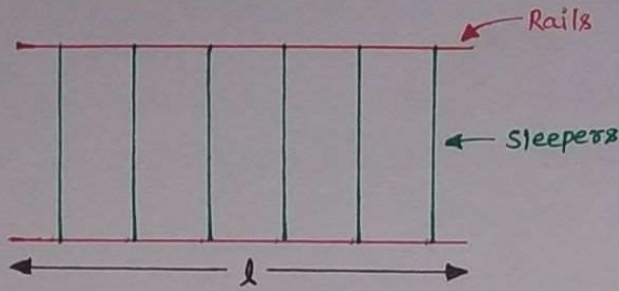
(2) Long Welded Rails (LWR) :

- If 200m length of rail (for BG) and 300m (for MG) is welded at both the ends, it is termed as LWR.
- Its maximum length can go upto 1000m (1km).

(3) Continuous Welded Rails (CWR) :

- If welded rails are longer than 1km, extending from one station to another is termed as CWR.

Length of Welded Rail :



Lec-6 (14:00)

- Increase in length 'l' of rail due to temp rise ' Δt ' is :

$$\Delta l = l \alpha \Delta t$$

- Strain in rails, $\epsilon = \frac{\Delta l}{l} = \alpha \Delta t$

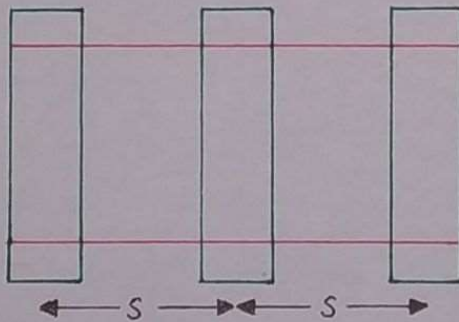
- Thermal stress in rails, $\sigma_T = \epsilon E_s = \alpha \Delta t E_s$

- Force developed in rail, $F = \sigma_T A = \alpha \Delta t E_s A$ (यै सारा force, sleepers resist करेंगे)

$A \rightarrow$ c/s area of rails

- Let force resisted by one sleeper is f_{s1}

- No. of sleepers, $n = \frac{F}{f_{s1}} = \frac{\alpha \Delta t E_s A}{f_{s1}}$



$S \rightarrow$ sleeper spacing

$$\text{Length of welded rail} = (n-1) S$$

Length of welded rail on both ends of tracks = $2(n-1) S$

- This length of welded rail is also termed as 'Breathing Length'.

NOTE: Breathing Length:

- It is the minimum length of welded rail on both ends of track required such that portion of rail b/w it does not undergo expansion or contraction.

Que: Theoretical length of LWR beyond which central portion of 52 kg/m rail would not be subjected to any longitudinal movement due to 35°C temp. increase, if:

$$A_s = 66.15 \text{ cm}^2$$

$$\alpha = 11.5 \times 10^{-6}$$

$$E_s = 21 \times 10^6 \text{ kg/cm}^2$$

$$S = 60 \text{ cm}$$

$$f_{s1} = 300 \text{ kg}$$

$$\Delta t = 35^\circ\text{C}$$



Lec-6 (21:10)

Sol: Force developed in rail, $F_s = \alpha \Delta t E_s A_s$

$$= 11.5 \times 10^{-6} \times 35 \times 21 \times 10^6 \times 66.15$$
$$= 559132.8 \text{ kg}$$

No. of sleepers reqd, $n = \frac{F_s}{f_{s1}} = \frac{559132.8}{300} = 1864$

$S = 60 \text{ cm}$

Breathing length reqd $= 2(n-1)S = 2(1864-1) \times 60 \times 10^{-2} \times 10^{-3} \text{ km}$

$$= 2.235 \text{ km}$$

SLEEPERS



Lec-6 (32:40)

SLEEPERS :

- These are members which support the rails and are laid transverse to rail.
- They are provided to :
 - (a) To hold the rail to correct gauge
 - (b) To allow adzing of rails
 - (c) To act as elastic medium
 - (d) To provide longitudinal and lateral stability.
 - (e) To distribute load from rail to ballast

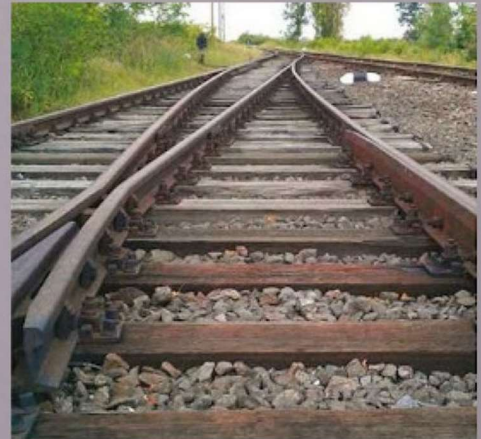
Classification of Sleepers :

- (1) Wooden Sleepers
- (2) Metal Sleepers
 - (i) Cast Iron
 - (ii) Steel
- (3) Concrete Sleepers
 - (i) RCC - 2.6 m X 250 mm X 250 mm
 - (ii) PSC - 2.6 m X 250 mm X 125 mm

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(1) Timber/Wooden Sleepers :

- These are regarded as best sleepers as it has low initial cost, low maintenance cost, easy to lay, pack, lift and maintain.
- Sal and teak is commonly used for sleepers.
- These are easily subjected to wear & tear, decay, attack of white ants.
- Their life is short, 12-15 years.
- It can be increased by creosoting.



Timber/Wooden Sleepers

Composite Sleeper Index (CSI) :

- It measures the mechanical strength of timber, derived from its composite properties of strength and hardness.

$$CSI = \frac{S + 10H}{20}$$

S = Strength at 12% moisture content

H = Hardness at 12% moisture content



Lec-6 (46:25)

(2) Metal Sleepers :

- Metal sleepers are in the form of inverted channel with corners bent or folded.

Cast Iron Sleepers :

- Life of cast iron sleepers is comparatively more (35-50 years).
- Cast iron sleepers can be used for any type of ballast.
- Maintenance cost of cast iron sleepers is comparatively less and scrap value is more, initial cost is high because of more no. of fasteners.
- Cast iron sleepers do not provide elastic bed b/w rails and ballast.

Steel Sleepers :

- Steel sleepers are light weight, so handling is comparatively easy.
 - Fasteners reqd. in steel sleepers are comparatively less.
 - Maintenance is comparatively easy than cast iron sleepers but it has rusting problem.
- ★ Metal sleepers cannot be used for track circuiting bcoz of short-circuit problem.



Cast Iron Sleepers



Steel Sleepers



Concrete Sleepers

(3) Concrete Sleepers :

- No decay (as in timber sleepers)
- Track circuiting can be done easily.
- It provides elastic bed b/w rails and ballast.
- Since it has high modulus of elasticity, it is able to resist high stresses.
- No scrap value for concrete.
- Its weight is 2-4 times more than timber sleepers, so transportation becomes difficult.



Lec-6 (53:05)

SLEEPER DENSITY :

- No. of sleepers per rail length is termed as sleeper density.
- In India, sleeper density is represented as ' $M+x$ '.
where, M : is rail length
 x : is number which varies b/w 3-7
- For BG, it is ' $M+5$ '



Lec-7 (26:55)

Que: Using sleeper density $M+5$, find out the number of sleepers required for construction of a railway track 1280 m long (BG track).

Sol: No. of rails in 1280 m = $\frac{1280}{12.8} = 100$ rails

$$\begin{aligned}\text{No. of sleepers per rail length} &= M+5 \\ &= 12.8+5 \\ &= 17.8 \simeq 18\end{aligned}$$

$$\text{Total no. of sleepers} = 18 \times 100 = 1800$$

TRACK FASTENERS



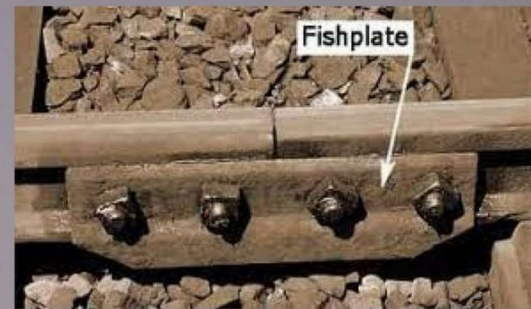
Lec-7

TRACK FASTENERS :

- | | |
|----------------|--------------------|
| (i) Fish Plate | (iv) Bolts |
| (ii) Spikes | (v) Key |
| (iii) Chair | (vi) Bearing Plate |

(i) Fish Plate :

- It is used at rail joints in order to maintain continuity of rail joints and permit thermal expansion and contraction.



Fish Plate

(ii) Spikes :

- It is used to hold rails on wooden sleepers.
- For holding flat footed rails on wooden sleeper, dog spikes are used.
- Screw spikes have double holding power than dog spike.



(iii) Chair :

- Chairs are used to support bull headed rails on the sleepers.



Chair

(iv) Bolts :

- These are used to connect rails with either sleepers or chair or bearing plate.

(v) Key :

- These are small tapered piece of timber coated with steel that is used to fix rails to chairs on sleepers.

(vi) Bearing Plate :

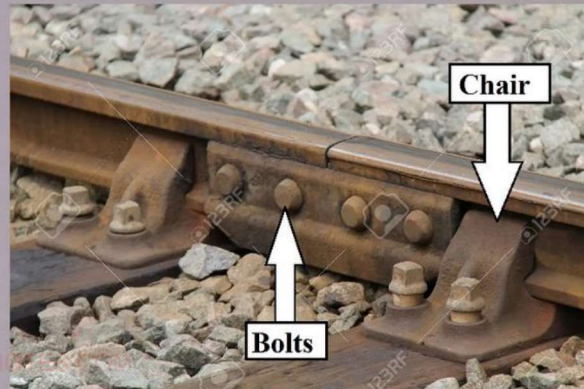
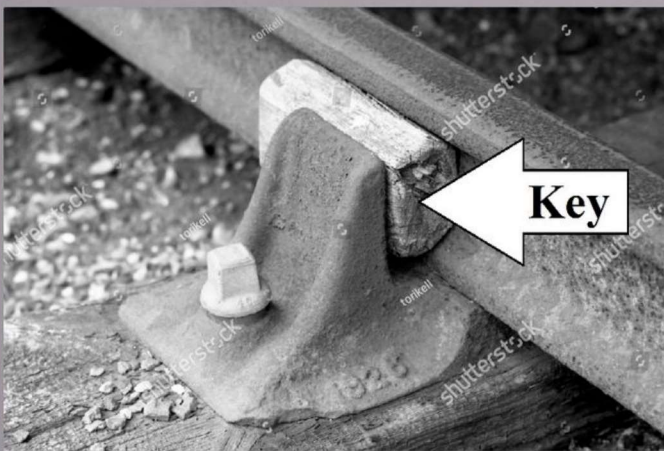
- These are rectangular plates of either mild steel or cast iron, and are used below flat footed rails to distribute the load on a larger area of timber sleepers.
- These are not used in concrete or metal sleepers.



Bearing Plates



Lec-7 (18:30)



BALLAST & SUBGRADE



Lec-7 (37:20)

BALLAST :

- It is the granular material usually made of broken stones or brick, or kankar/gravel/sand etc. which is placed below the sleeper and is used to transmit the load from sleeper to subgrade.

Functions of Ballast :

- (a) Load transfer
- (b) Drainage
- (c) Superelevation on curves
- (d) imparts elasticity to track
- (e) imparts longitudinal and lateral stability to sleepers.
- (f) absorbs shocks and vibration
- (g) helps in controlling vegetation

Types of Ballast :

- (a) Broken stones
- (b) Gravel
- (c) Sand
- (d) Ashes
- (e) Brick
- (f) Blast furnace slag.



Broken Stone Ballast



Gravel Ballast



Sand Ballast



Ashes



Blast Furnace Slag



Broken Bricks

- Broken stone is the best material for ballast. Igneous rocks such as granite, quartz etc. are used for broken stone. It is provided in almost every track. Size of broken stones varies from 1.9 cm to 5.08 cm.
- River pebbles or gravels are used in gravel ballast. Since these are smooth, they don't provide proper interlocking.
- Sand in sand ballast provides good drainage and there is no vegetation. Track made of sand ballast is silent, i.e., does not produce noise. But, during vibrations, sand is removed off. And, sand also drains off in the situation of flood.
- Ash ballast also offers good drainage but it is very soft, so it breaks very easily when train runs over it. Also, It becomes slippery during rainy season. Hence, it is avoided.
- Broken bricks can also be used as ballast.
- Blast furnace slag is the residue left after the extraction of metal.

Specification of Ballast :

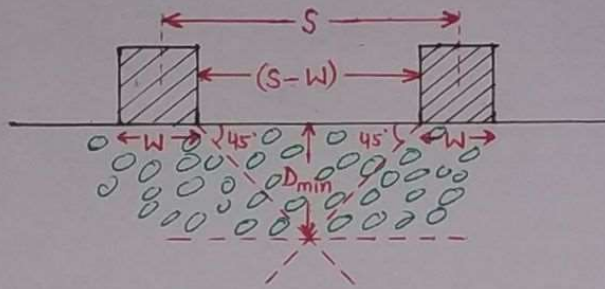
- Size : 1.9 cm – 5.1 cm
 - ↳ Interlocking comes out to be good for this size.
- For different types of sleeper, size of ballast used is :
 - for wooden sleepers = 5.1 cm
 - for steel sleepers = 3.8 cm
 - in case of crossings = 2.64 cm
 - for concrete sleepers = 4.5 cm
- The depth of the ballast layer affects bearing capacity and distribution of load on subgrade.
- Greater the depth of ballast, greater will be load bearing capacity.
- Load distribution below the sleepers is assumed to be 45° to the vertical, so minimum depth is given as :



Lec-8



Lec-8 (9:15)



$$\tan 45^\circ = \frac{D_{\min}}{\frac{S-W}{2}}$$

$$1 = \frac{D_{\min}}{\frac{S-W}{2}}$$

$$D_{\min} = \frac{S-W}{2}$$

— The quantity of ballast (stone) required per meter length is :

for BG : 1.036 m^3

for MG : 0.71 m^3

for NG : 0.5 m^3

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SUBGRADE :

— It is naturally occurring soil which is prepared to receive ballast, sleepers, rails for construction of railway track.

— Subgrade must have :

(a) stability

(b) good drainage

(c) property to prevent punching of ballast into it.

(d) ability to bear the transmitted load.

Que: If the spacing of the sleeper is 1.2 m and width of sleeper is 30 cm. Find the minimum depth of ballast cushion.

Sol:
$$D_{\min} = \frac{S-W}{2} = \frac{1.2-0.3}{2} = 0.45\text{m} = 45\text{cm}$$



Lec-8 (23:45)

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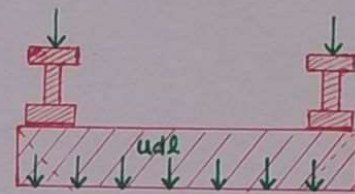
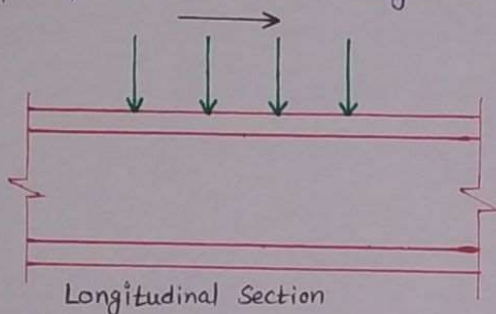
STRESSES ON TRACK



Lec-8 (26:20)

Stress on Railway Track :

- Since railway track is not embedded into the ground (like foundation) and rest over the ground surface, analysis of the stresses on railway track is done by theory of elasticity.
- Overall elastic property of track is represented by Track Modulus (u).
- Track modulus is defined as load per unit length required to produce unit deformation in track.
- It depends on gauge, type of rails, type of sleepers, density of sleeper, type of ballast and subgrade.



- Rails act as continuous beam which support moving load. Sleeper convert this rolling load into point load. Rails load is also acting on sleepers. So, sleeper is supporting two point loads - One is permanent load, i.e., load from rails and another is rolling load converted into point load. Sleeper transmits these loads to ballast and finally, ballast transfer it to subgrade.
- Moving Load $\rightarrow$ converted into point load $\rightarrow$ converted into udl $\rightarrow$ Finally, distributed over the subgrade

CREEP OF RAIL :

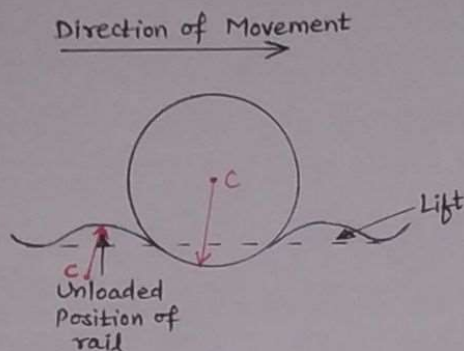
- It is the longitudinal movement of rail with respect to sleepers.
- Creep of rail can be understood by following theories :
 - longitudinal movement of rails जिससे motion की दिश में expansion joints fill होते जाते हैं और opposite दिश में expansion joints का gap बढ़ जाता है।

(1) WAVE ACTION THEORY :

- According to this theory, wave motion is setup by moving loads of the wheels and vertical reverse curve is formed in rails.



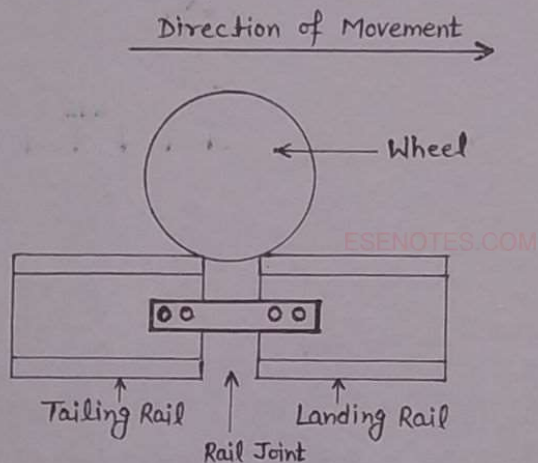
Lec-8 (43:07)



- दोनों curve का centre, opposite dirⁿ में हो तो इसको vertical reverse curve बोलते हैं।

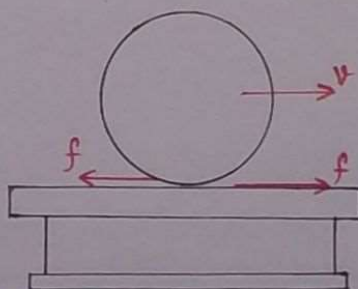
(2) PRECURSION THEORY :

- This theory states that the creep is due to the impact of wheels at the rail end ahead at joints.
- The horizontal component of resultant force 'P' causes creep.



(3) DRAG THEORY :

- According to this theory, creep is due to frictional drag.
- Wheel पर friction, motion के opposite तो rails पर friction, motion की dirⁿ में। इसी से rails आगे move कर जाती हैं।



Effects of Creep :

- Sleepers are disturbed from their position, hence gauge may change.
- Joints are opened up to their limit, that causes stresses in fish plate.
- It may do buckling and derailment.

Prevention of Creep :

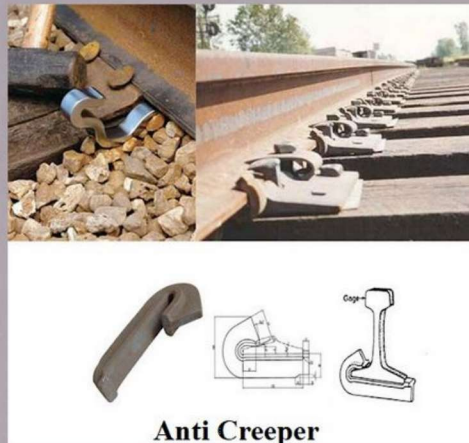
- By pulling back the rails into their position. (when creep is visible)
- By use of anti-creeper and crib ballast
- By use of steel sleepers.



Lec-9

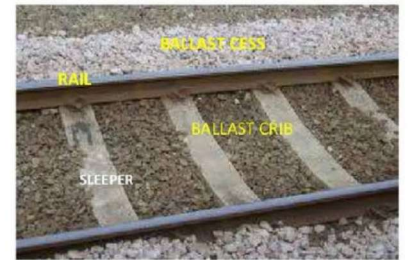


Anti Creeper



Anti Creeper

Ballast Crib & Ballast cess



Factors Governing the Creep of Rail :

(1) Alignment of Track :

- Creep is observed to be more on curve & less on straight track.

(2) Graded Track :

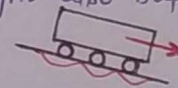
- Creep is more with steep gradient (component of weight also supports the creep)

(3) Type of Rails :

- Creep is more for old rails than in new rails.

(4) Direction of Heaviest Traffic :

- Creep is more in the direction of heaviest traffic.



GEOMETRICAL DESIGN OF TRACK

- Visible features of railway tracks & its alignment are known as geometric design of the track.
- Visible features :
 - (1) Gradient and Grade Compensation
 - (2) Radius and Degree of Curve
 - (3) Cant or Superelevation
 - (4) Curves
 - (5) Widening of gauges on curve



Lec-9 (18:10)

(1) Gradients :

- Any rise or fall in track level is known as gradient.
- It is represented either "1 in x" or in form of "percentage".
- Gradients on a railway track are as follows :
 - (i) Ruling Gradient
 - (ii) Momentum Gradient
 - (iii) Pusher/Helper Gradient
 - (iv) Gradient in Station Yard

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(i) Ruling Gradient :

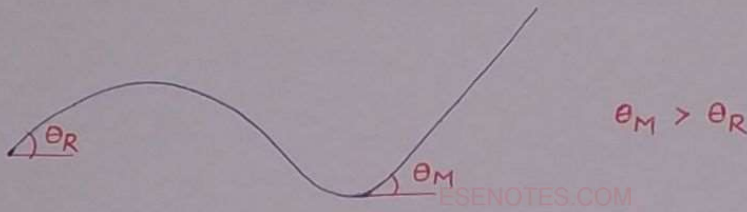
- In most general cases, the maximum gradient allowed is ruling gradient.
- Steep gradient requires more power, hence transportation on them is costly.
- Rising gradient must be followed by falling gradient.
- In plain terrain : 1 in 150 - 1 in 200
- In hilly areas : 1 in 100 - 1 in 150



Lec-9 (34:50)

(ii) Momentum Gradient :

- If rising gradient is followed by falling gradient, the train while coming down in falling gradient, attains sufficient momentum which gives additional kinetic energy to the train.
- Hence, now it can overcome steeper rising gradient than ruling gradient termed as momentum gradient.



(iii) Pusher/Helper Gradient :

- If severe ruling gradient is concentrated in certain specific section such as monotonous section, an assistant engine or helper engine is used in such case to push the train.
- Such severe gradients are termed as pusher/helper gradient.
- In general, for gradient 1 in 75 & above, pusher engine is used.

(iv) Gradient in Station Yard :

- It is provided to drain-off water used for cleaning of trains.
- It should be sufficiently low :

- (a) to prevent the movement of standing train.
- (b) to prevent additional resistance at start of vehicle.
- Maximum gradient permitted on station yard is 1 in 400 and minimum is 1 in 1000.

Grade Compensation :

- Ruling gradient is the maximum gradient provided on straight tracks.
- Due to curvature on grade, resistance to motion of train increases.
(beoz ruling gradient + curve resistance due to centrifugal force, both work)
- In order to avoid resistance beyond the allowable limits, the gradients are reduced on the curve.
- This reduction in gradient is known as Grade Compensation.
- For BG : -0.04% per degree of curve
MG : -0.03% per degree of curve
NG : -0.02% per degree of curve



Lec-10

Que : If ruling gradient is 1 in 200 on a particular section of BG and at same time a curve of 4° is situated on this ruling gradient, What should be allowable ruling gradient.

Sol : Prevailing gradient = 1 in 200 = $\frac{1}{200} \times 100 = 0.5\%$

Grade Compensation = $0.04 \times 4 = 0.16\%$

Allowable ruling gradient = $0.5 - 0.16$
 $= 0.34\%$
 $= \frac{1}{294.1}$

Speed of Train :

- The speed of train depends on strength of track and power of locomotive
- Safe speed on a railway track should be minimum of following :

- (a) safe speed on curve (as per Martins Formula)
- (b) speed calculated as per cant formula
- (c) max. speed as per length of transition curve
- (d) max. speed specified by railway board.



Lec-10 (13:15)

(a) Safe Speed on Curve (as per Martin's Formula) :

(i) For low speed (< 100 kmph) :

- On a transitioned curve

$$V_{\max} = 4.35 \sqrt{R-67}, \text{ for BG \& MG}$$

$$V_{\max} = 3.6 \sqrt{R-61}, \text{ for NG}$$

- On non-transitioned curve

$$V_{\max} = 80 \% \text{ of speed allowed on transitioned curve}$$

(ii) For High Speed (> 100 kmph) :

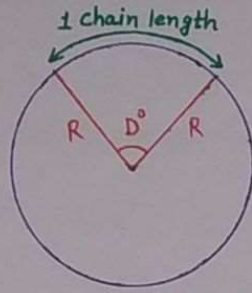
$$V_{\max} = 4.58 \sqrt{R}, \text{ for BG only}$$

Where, R is the radius of curve, in metre

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(2) Radius and Degree of Curve :

- Degree of curve is angle formed by one chain length of the curve at the centre.



Lec-10 (21:50)

For whole circumference $2\pi R$,
Angle subtended at centre $= 360^\circ$

$\therefore$ For 1 chain length of '30m'
Angle at centre $D^\circ = \frac{360}{2\pi R} \times 30$

$$D^\circ = \frac{1720}{R} \rightarrow \text{for 30m chain length}$$

If one chain length is, D° of '20m' $= D^\circ = \frac{1150}{R} \rightarrow \text{for 20m chain length}$

- Max. degree of curve or minimum radii of Indian railways :

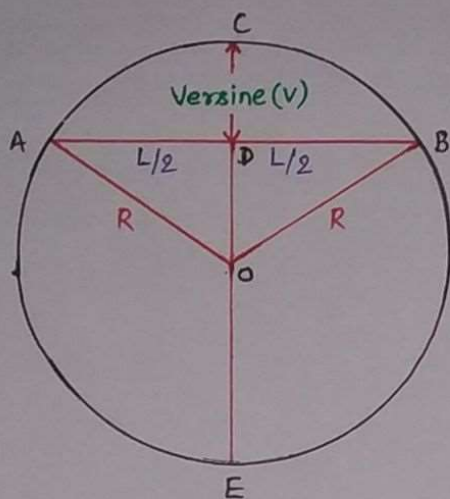
BG	10°	175 m
MG	16°	109 m
NG	40°	44 m

NOTE :

- In order to check the accuracy of the laid railway curve track, a geometrical parameter 'Versine' is used, which is the ^{max} lateral distance of the curve from the chord.



Lec-10 (32:35)



Using property of circle :

$$AD \cdot DB = CD \cdot DE$$

$$\frac{L}{2} \cdot \frac{L}{2} = V(2R - V)$$

$$\text{Since, } 2R \gg V \Rightarrow 2R - V \simeq 2R$$

$$\frac{L^2}{4} = 2RV$$

$$V = \frac{L^2}{8R}$$

$$V \rightarrow \text{cm}$$

$$L, R \rightarrow \text{m}$$

Que: If the length of chord of a circular curve is used on BG track is 200m and its radius is 400m, what would be safe speed as per Martin's formula and versine of curve.

Sol: Assume low speed (< 100 kmph)

Acc- to Martin's Formula :

$$V_{\max} = 4.35 \sqrt{R - 67}$$

$$= 4.35 \sqrt{400 - 67}$$

$$= 79.38 \text{ kmph} \rightarrow \text{Assumption is right.}$$

$$\text{Versine, } V = \frac{L^2}{8R} = \frac{(200)^2}{8 \times 400} = 12.5 \text{ cm}$$

NOTE :

— As per new code, Martin's Formula is revised (but will be used in problems, if all required parameters are given)

$$V_{\max} = 4.4 \sqrt{R - 70}, \text{ for BG, MG (When speed } \leq 100 \text{ kmph)}$$

$$V_{\max} = 4.6 \sqrt{R}, \text{ (for speed } > 100 \text{ kmph)}$$

$$\text{Also, } e_{th} = e_{act} + \text{cant Deficiency (e = cant)}$$

$$e_{th} = \frac{G_1 V_{max}^2}{127 R} \times 1000$$

$$V_{max} = \sqrt{\frac{e_{th} \times 127 R}{G_1 \times 1000}} = \sqrt{\frac{(e_{act} + CD) \times 127 R}{G_1 \times 1000}}$$

$$V_{max} = 0.27 \sqrt{R (e_{act} + CD)}$$

(mm) (mm)



Lec-10 (50:20)

(3) Superelevation :

- When train negotiates on a horizontal curve, it is subjected to centrifugal force, which acts away from centre of curve.
- This results in increase of the pressure on outer rail
- To encounter the effect of centrifugal force, the level of outer rail is raised above the inner rail by certain amount known as superelevation or cant.

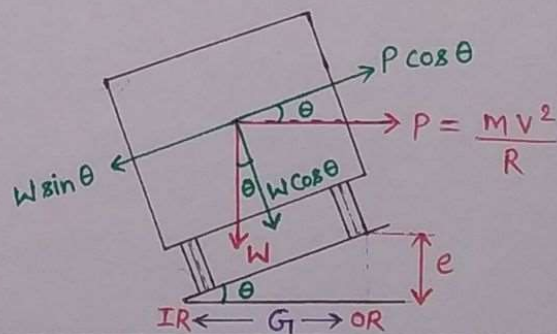
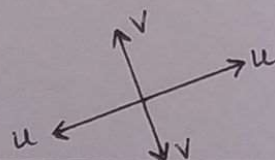
Objective of providing superelevation :

Lec-11



- To encounter the effect of centrifugal force, this would result in faster movement of the trains on curve.
- To provide equal distribution of wheel load on both rails, so that outer rail do not move out from track.
- To provide even and smooth running track to ensure comfortable ride to the passenger.

Calculation of Superelevation :



— For eq^m of train, $\Sigma F_u = 0$

$$W \sin \theta - P \cos \theta = 0$$

$$\tan \theta = \frac{P}{W} = \frac{m v^2}{R \cdot mg} = \frac{v^2}{gR} \text{ ---- (i)}$$

$$\text{Also, } \tan \theta = \frac{e}{G} \text{ ---- (ii)}$$

$$\text{from (i) \& (ii): } \frac{e}{G} = \frac{v^2}{gR}$$

$$e = \frac{G v^2}{gR}$$

$$\begin{aligned} G, R &\rightarrow m \\ v &\rightarrow m/sec \\ g &\rightarrow m/sec^2 \end{aligned}$$

If 'V' is in kmph:

$$e = \frac{G (0.278 V)^2}{9.81 R}$$

$$e = \frac{G V^2}{127 R}$$

$$\begin{aligned} G, R &\rightarrow m \\ V &\rightarrow kmph \end{aligned}$$

— As per new code, $BG = 1.75 m$ but take $BG = 1.676 m$ as per old code, if specifically not mentioned in ~~code~~ question.

Max. Limit of Superelevation :

Track	Speed < 120 kmph	Speed > 120 kmph
BG	16.50 cm	18.5 cm
MG	10 cm	
NG	7.6 cm	

— Here, $BG = 1.676 m$ [but in new code $BG = 1.75 m$]

— max. value of superelevation is $\frac{1}{10}$ of gauge.



Lec-11 (8:15)

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E_q^m Cant :

- Cant provided when load or pressure on the both rail is equal.

E_q^m Speed :

- On a same railway track, trains like passenger train, rajdhani, shatabdi, duranto etc. will run.
- The cant ~~provi~~ required for all the trains will be different and will not be suitable for other trains.
- Hence, actual cant should be provided for an average speed, termed as e_q^m speed, so that all the trains with different speed can be allowed to run on same track.

- This e_q^m speed is given by :

(a) When speed > 50 kmph

(i) $V_{eq} = \frac{3}{4} V_{max} = 0.75 V_{max}$

(ii) Safe speed as per Martin's formula } min.

(b) When speed < 50 kmph

(i) $V_{eq} = 50 \text{ kmph}$

(ii) Safe speed as per Martin's formula } min.

(c) Weighted average speed can also be calculated.

$$V_{eq} = \frac{\sum n_i V_i}{\sum n_i}$$

Cant Deficiency :

- The actual cant is provided on the basis of e_q^m speed. (e_{act})
- For the trains running at higher speed than e_q^m speed, the cant requirement is more, than provided (e_{th})
- This shortage of cant is termed as cant deficiency (CD).



Lec-11 (14:20)

- Hence, cant deficiency is the difference of eq^m cant necessary for the max. speed and actual cant provided

$$e_{cd} = e_{th} - e_{act}$$

- This cant deficiency gives discomfort to the passenger & increases the pressure on outer rail, hence cant deficiency is limited.



Lec-11 (28:10)

Gauge	Speed < 100 kmph	Speed > 100 kmph
BG	7.6 cm	10 cm
MG	5.1 cm	—
NG	3.8 cm	—

Que: On a 2° curve, for a BG track, an actual cant is provided for a speed of 80 kmph. What is cant deficiency for a train with speed of 120 kmph. If it exceeds the permissible limit, find the safe speed.

Sol: $D^\circ = \frac{1720}{R} \Rightarrow R = \frac{1720}{D^\circ} = \frac{1720}{2} = 860 \text{ m}$

$V_{eq} = 80 \text{ kmph}$

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$$e_{act} = \frac{G V^2}{127 R} = \frac{1.676 (80)^2}{127 \times 860} = 0.0982 \text{ m} = 9.82 \text{ cm}$$

$$e_{th} = \frac{G V_{max}^2}{127 R} = \frac{1.676 \times 120^2}{127 \times 860} = 22.095 \text{ cm}$$

$$e_{cd} = e_{th} - e_{act} = 22.095 - 9.82 = 12.27 \text{ cm} > 10 \text{ cm}$$

Now, for $e_{cd} = 10 \text{ cm}$, max. theoretical speed V_{max} is given by:

$$e_{th} = e_{cd} + e_{act} = 10 + 9.82 = 19.82 \text{ cm}$$

$$e_{th} = \frac{G V_{max}^2}{127 R}$$

$$19.82 \times 10^{-2} = \frac{1.676 V_{max}^2}{127 \times 860}$$

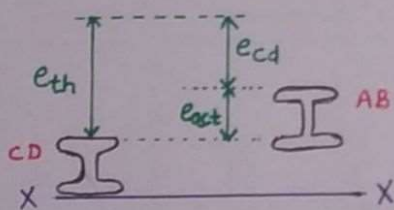
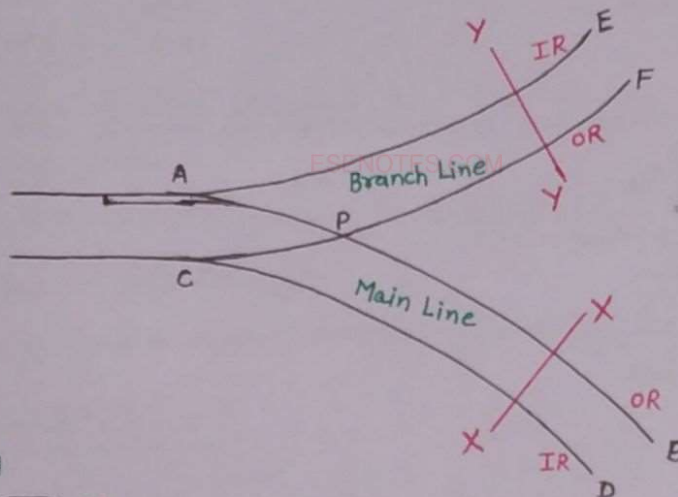
$$V_{max} = 113.6 \text{ kmph} \quad \text{Ans.}$$



Lec-11 (40:15)

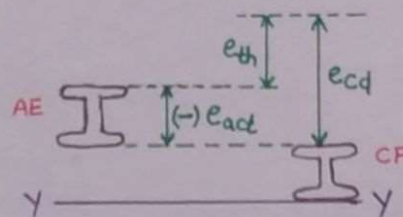
Negative Superelevation :

- If the level of outer rail is above the level of inner rail, superelevation is known as +ve superelevation.
- If the level of outer rail is below the level of inner rail, it is known as -ve superelevation.
- When the main line on a curve has a turnout of opposite curvature leading to the branch line, then the level of rail in branch line is always kept lower than level of inner rail. This leads to -ve superelevation of branch line.



For main line :

$$e_{th} = e_{cd} + e_{act}$$



For branch line :

$$e_{cd} = e_{th} + e_{act}$$



Lec-12

Que: If branch curve of 8° diverge from main curve of 5° in an opposite direction in a layout of a BG track. Compute the superelevation and speed on the branch line, if the max. speed permitted on main line is 45 kmph.



Lec-12 (16:50)

Sol: Radius of main line, $R_{\text{main}} = \frac{1720}{D^\circ}$

$$= \frac{1720}{5^\circ} = 344 \text{ m}$$

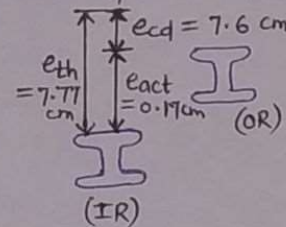
Radius of branch line, $R_{\text{branch}} = \frac{1720}{8^\circ} = 215 \text{ m}$

For main line: $e_{th} = \frac{GV^2}{127R} = \frac{1.676 \times 45^2}{127 \times 344} = 0.0777 \text{ m}$

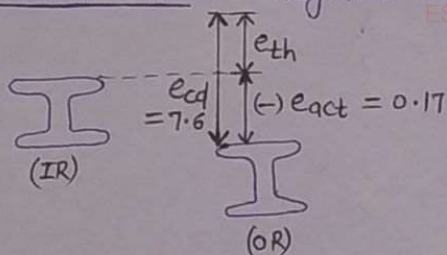
$$e_{th} = 7.77 \text{ cm}$$

max. cant deficiency on BG for $V_{\text{max}} < 100 \text{ kmph} = 7.6 \text{ cm}$

$$\begin{aligned} e_{act} &= e_{th} - e_{cd} \\ &= 7.77 - 7.6 \\ &= 0.17 \text{ cm} \end{aligned}$$



For branch line: negative superelevation on branch line = 0.17 cm



$$\text{max. } e_{cd} = 7.6 \text{ cm}$$

$$\begin{aligned} e_{th} &= e_{cd} - e_{act} \\ &= 7.6 - 0.17 \\ &= 7.43 \text{ cm} \end{aligned}$$

$$e_{th} = \frac{GV_{\text{max}}^2}{127R}$$

$$7.43 \times 10^{-2} = \frac{1.676 \times V_{\text{max}}^2}{127 \times 215}$$

So, max. speed on branch line = 34.8 kmph

$$V_{\text{max}} = 34.8 \text{ kmph} \text{ Ans.}$$

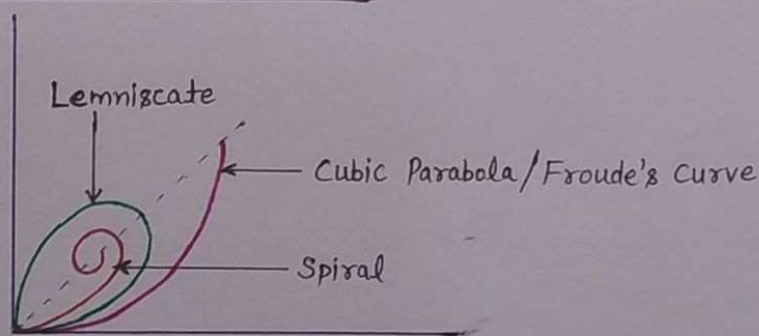
(4) Curves :

- The use of curve is necessary for the change in alignment through horizontal curve and change in gradient through vertical curve.
- The use of curve is necessary in following condition :
 - (a) To bypass natural or artificial obstruction.
 - (b) To provide easier gradient by diverging from straight track.
 - (c) To route the line from populated area.
 - (d) To balance the earthwork.
- Curves are of two types :
 - (i) Horizontal curve
 - (ii) Vertical curve
- Horizontal curve is provided to change the alignment, whereas vertical curve is provided to change the gradient.
- Simple circular curves accompanied by two transition curves ~~at~~ is used in horizontal curves.

Transition Curves :

- This is the curve which is provided b/w the circular and straight portion of track at both the ends.
- The radius of the transition curve is reduced from infinity to minimum at the starting of circular curve.
- It is provided to induce superelevation gradually and avoid jerks.

Types of Transition Curves :



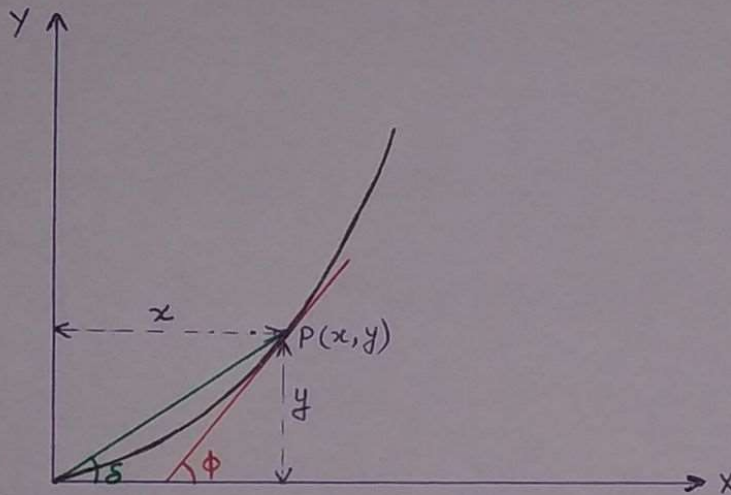
Lec-12 (36:40)

- Spiral curve is used in highway bcoz deflection of curve comes more than 9° and it is ok in case of spiral curve.
- Cubic parabola is used in railways because here deflection is generally less than 9° .
- Spiral and cubic parabola both behave in same manner deflection of around upto 4° .
- Lemniscate curve is provided when the deflection angle in transition curve comes out to be very large, even more than 9° .



Lec-12 (49:50)

Analysis of Transition curve (cubic parabola) for railway :



Lec-13

General eqn of cubic parabola :

$$y = ax^3 + bx^2 + cx + d$$

(i) at $x=0$, $y=0$

$$0 = 0 + 0 + 0 + d \Rightarrow d=0$$

(ii) at $x=0$, $\frac{dy}{dx} = 0$

$$\frac{dy}{dx} = 3ax^2 + 2bx + c$$

$$0 = 0 + 0 + c \Rightarrow c=0$$

(

(iii) at $x=0$, $\frac{d^2y}{dx^2} = 0$

$$\frac{d^2y}{dx^2} = 6ax + 2b$$

$$0 = 0 + 2b \Rightarrow b = 0$$

Lec-13 (8:38)

(iv) at the end of transition curve, the radius of transition curve is equal to radius of circular curve.

at $x=L$, radius of transition curve = radius of circular curve

$$\frac{d^2y}{dx^2} = \frac{1}{R}$$

$$\frac{1}{R} = 6aL \Rightarrow a = \frac{1}{6RL}$$

Hence, eqⁿ of transition curve: $y = \frac{1}{6RL} \cdot x^3$

Slope of transition curve: $\tan \phi = \frac{dy}{dx} = \frac{x^2}{2RL}$

at $x=L$, $\tan \phi_{\max} = \frac{L^2}{2RL}$

$$\tan \phi_{\max} = \frac{L}{2R} \text{ max. slope}$$

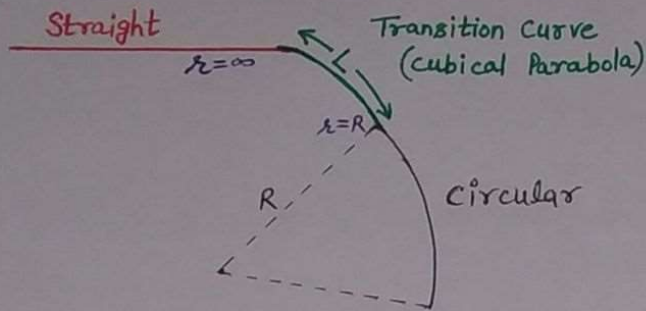
Deflection: Slope of line joining origin with any point on curve.

$$\tan \delta = \frac{y}{x} = \frac{x^3}{6RL \cdot x}$$

$$\tan \delta = \frac{x^2}{6RL}$$

Also, $\tan \delta = \frac{1}{3} \tan \phi$

Length of Transition Curve :



Lec-13 (15:50)

- Length of transition curve is length along the centre line of the track from its meeting point with the straight to that of circular curve.
- It can be computed by any of two approaches :

(1) 1st Approach :

As per old code

(a) $L = 7.2 e$

(b) $L = 0.073 e \cdot V_{max}$

(c) $L = 0.073 e_{cd} \cdot V_{max}$

} max

$L \rightarrow m$

$e \rightarrow$ actual cant (in cm)

$e_{cd} \rightarrow$ cant deficiency (cm)

$V_{max} \rightarrow$ kmph

As per new code

(a) $L = 0.72 e$

(b) $L = 0.008 \cdot e \cdot V_{max}$

(c) $L = 0.008 \cdot e_{cd} \cdot V_{max}$

} max

$L \rightarrow$ in m

$e \rightarrow$ actual cant (in mm)

$e_{cd} \rightarrow$ cant deficiency (mm)

$V_{max} \rightarrow$ kmph

(2) 2nd Approach :

(a) Railway board Formula : $L = 4.4 \sqrt{R}$

(m) (m)

(b) Based on radial change accⁿ : $L = \frac{3.28 v^3}{R}$

(m) (m/sec) (m)

(c) As per rate of change of superelevation : $L = 3.6 e$

(m) (cm)

} max

NOTE :

- Use new code formula when any of following is mentioned in question :

(i) gauge = 1.75m (ii) $D = \frac{1750}{R}$ (iii) As per new code

NOTE:

— Here, maximum speed based on length of transition curve can also be analyzed:

(a) for normal speed < 100 kmph

$$V_{\max} = \frac{134 L}{e_{\text{act}}} \quad \text{or} \quad \frac{134 L}{e_{\text{cd}}}$$

(b) for normal speed > 100 kmph

$$V_{\max} = \frac{198 L}{e_{\text{act}}} \quad \text{or} \quad \frac{198 L}{e_{\text{cd}}}$$

$$\begin{bmatrix} L \rightarrow \text{m} \\ e_{\text{act}} \rightarrow \text{mm} \\ e_{\text{cd}} \rightarrow \text{mm} \end{bmatrix}$$

Que: Calculate the cant deficiency and permissible speed for 4° curve of BG track. Also find the eq^m cant and length of transition curve.

Sol: $R = \frac{1720}{D^\circ} = \frac{1720}{4} = 430 \text{ m}$

Using Martins formula, $V_{\max} = 4.35 \sqrt{R - 67}$

$$V_{\max} = 4.35 \sqrt{430 - 67}$$

$$V_{\max} = 82.87 \approx 83 \text{ kmph}$$

$$e_{\text{th}} = \frac{GV^2}{127R} = \frac{1.676 \times 83^2}{127 \times 430} = 0.211 \text{ m} = 21.1 \text{ cm}$$

For speed < 120 kmph on BG, $e_{\text{max}} = 16.5 \text{ cm}$

$$\therefore e_{\text{act}} = e_{\text{max}} = 16.5 \text{ cm}$$

$$e_{\text{cd}} = e_{\text{th}} - e_{\text{act}} = 21.1 - 16.5 = 4.6 \text{ cm}$$

For eq^m cant:

$$e_{\text{cdmax}} = 7.6 \text{ cm} \quad (V < 100 \text{ kmph})$$

$$e_{\text{act}} = e_{\text{th}} - e_{\text{cdmax}} = 21.1 - 7.6 = 13.5 \text{ cm}$$



Lec-13 (31:10)

Length of transition curve :

$$(a) L = 4.4 \sqrt{R} = 4.4 \sqrt{430} = 91.24 \text{ m}$$

$$(b) L = \frac{3.28 v^3}{R} = \frac{3.28 \times \left(\frac{5}{18} \times 83\right)^3}{430} = 93.48 \text{ m}$$

$$(c) L = 3.6 e = 3.6 \times 13.5 = 48.6 \text{ m}$$

$$\therefore L = \text{max. of (a), (b), (c)}$$

$$L = 93.48 \text{ m}$$

Que: On a transition curve on BG track, the speed by railway board is given as $V_s = 4.35 \sqrt{R-67}$ which is 1.25 times the max. speed obtained by cant formula, after allowing the cant deficiency of 7.6 cm. If the eq^m cant is provided for the speed 60 kmph. Compute —

(a) Radius (b) max. speed permitted (c) Actual cant provided

Sol: $V_s = 4.35 \sqrt{R-67} = 1.25 V_m \text{ ---- (1)}$

$$e_{th} = e_{act} + e_{cd}$$

$$\frac{G V_m^2}{127 R} = \frac{G V_{avg}^2}{127 R} + 7.6 \times 10^{-2}$$

$$\frac{1.676 V_m^2}{127 R} = \frac{1.676 \times 60^2}{127 R} + 7.6 \times 10^{-2}$$

$$V_m^2 = 60^2 + \frac{7.6 \times 10^{-2} \times 127 R}{1.676}$$

$$V_m^2 = 3600 + 5.76 R$$

$$\left(\frac{4.35 \sqrt{R-67}}{1.25} \right)^2 = 3600 + 5.76 R$$

$$(a) R = 694.66 \text{ m}$$

$$(b) V_m = \frac{4.35 \sqrt{R-67}}{1.25} = 87.18 \text{ kmph}$$

$$(c) e_{act} = \frac{G V^2}{127 R} = \frac{1.676 \times 60^2}{127 \times 694.66} = 6.84 \text{ cm}$$

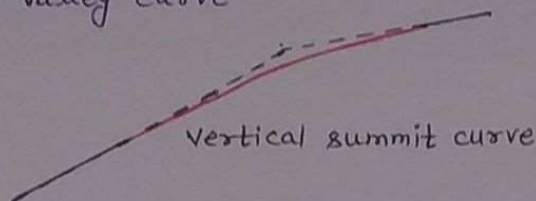
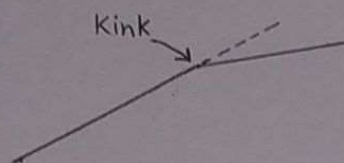


Lec-13 (43:10)

Vertical Curves :

— Vertical curves are of two types :

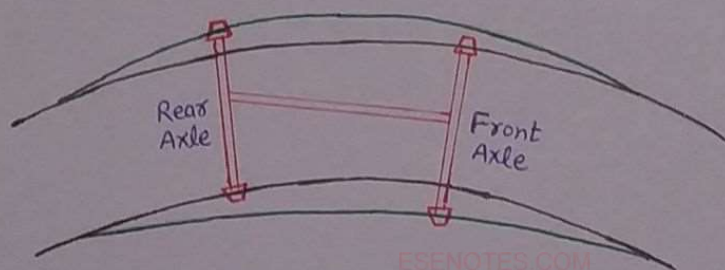
(a) Summit curve (b) Valley curve



Lec-15

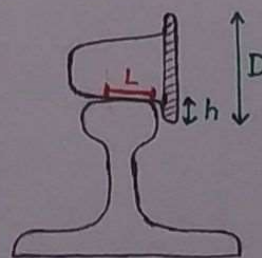
- Whenever there is change in gradient of the track, an angle is formed at the junction of the gradients. Thus, vertical kink is observed at junction which is smoothened by use of curve so that jerk is not experienced.
- The curve provided is parabola (not cubic parabola).

(5) Widening of Gauge on the Curves :



- Due to rigidity of wheel base, when the outer wheel of rear axle do not follow the same path as by the front axle, there would be always gap with outer rail.
- Provision must be made for this gap, otherwise tilting of rail may take place.
- So, on the curve, gauge is a bit widened, where its value is given by

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



B = Rigid wheel base (m)

B = 6 m for BG

4.88 m for MG

L = Lap of Flange (m)

$$L = \sqrt{h^2 + Dh}$$

h = depth of flange below top of the rail (cm)

D = Dia of wheel (m)

R = Radius of curve (m)

d = Extra widening (cm)



Lec-15 (17:10)

Que: Find out the extra widening of gauge on BG track of circular curve of radius 450 m, using the following data:

(i) Length of rigid wheel base = 6 m

(ii) Depth of flange below the top of rail = 4 cm

(iii) Dia of wheel = 1.3 m

Sol: Extra widening, $d = \frac{13(B+L)^2}{R}$

$$L = \sqrt{h^2 + Dh} = \sqrt{4^2 + 1.3 \times 4} = 4.6 \text{ m}$$

$$\therefore d = \frac{13(6 + 4.6)^2}{450}$$

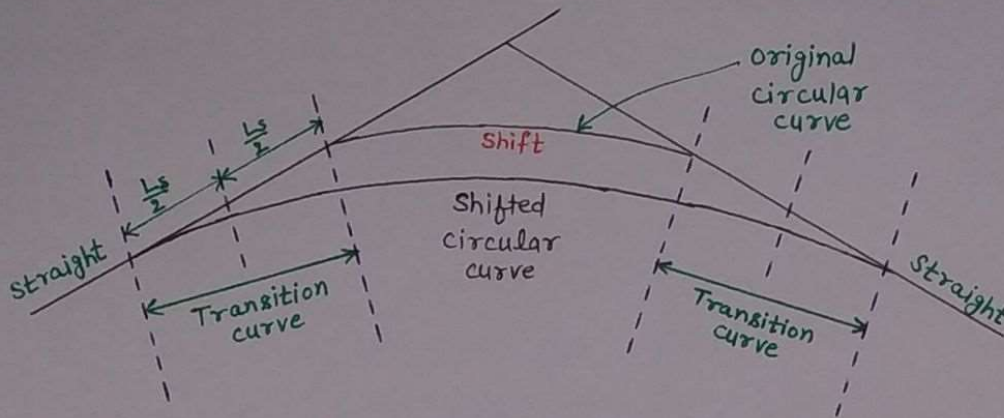
$$d = 3.25 \text{ cm}$$

$$\begin{aligned} \text{So, Total gauge} &= 1.676 + 0.0325 \\ &= 1.7085 \text{ m} \end{aligned}$$

Shift :



Lec-15 (32:00)

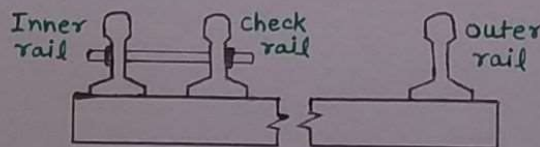


- Whenever a transition curve is fitted in b/w the straight and circular track, original curve is to be displaced inward by a certain distance, termed as shift.
- It is given by :
$$S = \frac{L_s^2}{24 R}$$

S : Shift (m)
 L_s : Length of transition curve (m)
 R : Radius of curve (m)

Check Rail :

- Due to centrifugal force on the curve, wheel diameter on the ~~curve~~ outer rail becomes more due to the lateral movement of wheel.
- If centrifugal forces are high, flange of rail may start touching head of the rail, which will cause huge wear of the flange of wheel and outer rail.
- To avoid it, the check rail parallel to the inner rail of track is provided.
- The gap b/w the check rail and inner rail should not be more than thickness of flange.





Lec-15 (52:45)

Que: Determine the length of transition curve and offsets at 15m for a BG track having 4° curvature & cant of 12 cm. The max permissible speed is 85 kmph.

Sol: $R = \frac{1720}{D^\circ} = \frac{1720}{4^\circ} = 430 \text{ m}$

$V_{\text{max, permissible}} = 85 \text{ kmph}$

V_{max} as per Martins formula, $V_{\text{max}} = 4.35 \sqrt{R-67}$
 $= 4.35 \sqrt{430-67}$
 $= 83 \text{ kmph}$

$e_{\text{act}} = 12 \text{ cm}$

$e_{\text{cd, max}} = 7.6 \text{ cm}$

$e_{\text{th}} = e_{\text{act}} + e_{\text{cd}} = 12 + 7.6 = 19.6 \text{ cm}$

$e_{\text{th}} = \frac{G \cdot V_{\text{max}}^2}{127 R}$

$V_{\text{max}} = \left(\frac{e_{\text{th}} \times 127 R}{G} \right)^{1/2} = \left(\frac{19.6 \times 127 \times 430}{100 \times 1.676} \right)^{1/2} = 80 \text{ kmph}$

Safe speed, i.e. $V_{\text{max}} = 80 \text{ kmph}$

Now, Length of transition curve, as per 2nd approach :

(a) $L_s = 4.4 \sqrt{R} = 4.4 \sqrt{430} = 91.24 \text{ m}$

(b) $L_s = 3.6 e = 3.6 \times 12.0 = 43.2 \text{ m}$

(c) $L_s = \frac{3.28 V_{\text{max}}^3}{R} = \frac{3.28 (0.278 \times 80)^3}{430} = 83.7 \text{ m}$ } max

Adopt length of transition curve, $L_s = 91.24 \text{ m} \approx 92 \text{ m}$

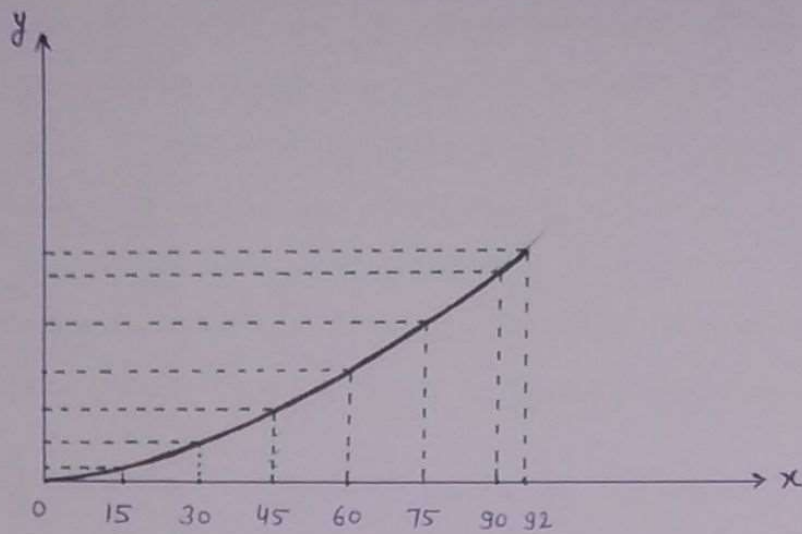
Now, offsets: $y = \frac{x^3}{6RL} = \frac{x^3}{6 \times 430 \times 92}$

$y = \frac{x^3}{237360}$

x (m)	0	15	30	45	60	75	90	92
y (cm)	0	0.014	0.114	0.384	0.91	1.777	3.071	3.281



Lec-15 (1:06:40)



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POINTS AND CROSSINGS



Lec-16

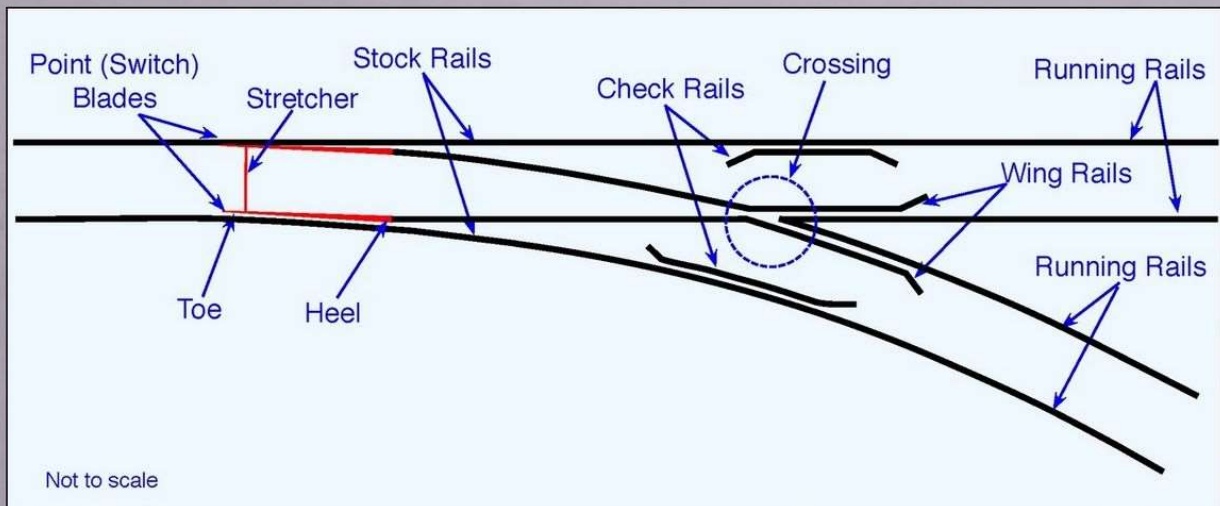
- Points and crossings are special arrangements which are used to move the trains from one track to another track.
- The simplest combination of points and crossing which enable the branch line to take-off from main line is termed as Turnout.

NOTE:

- High manganese steel is used for making points & crossings, as its resistance against wear & tear & impact is comparatively more.
- Following are the different parts of turnouts :
 - (i) 2 points
 - (ii) 2 (a pair) stock rail
 - (iii) a pair of check rail
 - (iv) a V crossing
 - (v) 4 lead rails
 - (vi) a pair of stock rail



Turnout



- One turnout provides facility for turning vehicles from one direction only and not from both the dirⁿ of straight path.
- Turn out works in combination of point and crossing.
- Point consists of stock rail (part of outer straight lead rail) & tongue rail (part of outer curved lead rail)
- Tongue rail is tapered having toe at one end and heel at other end.
- If there is a gap in b/w outer straight lead and the toe of the tongue rail, the train will pass through the straight track.
- If toe of the tongue touches the outer straight lead rail, train will be diverted on curved track.
- Check rails are provided on the opposite sides of the crossings for guiding one wheel of the train.
- Tongue rail is kept 6 mm higher than stock rail.



Lec-16 (20:20)

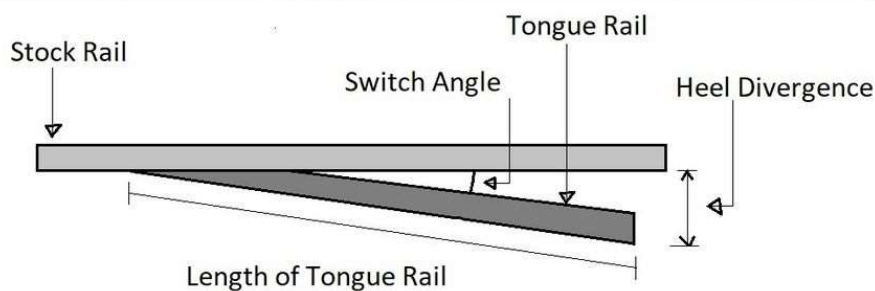


Lec-17

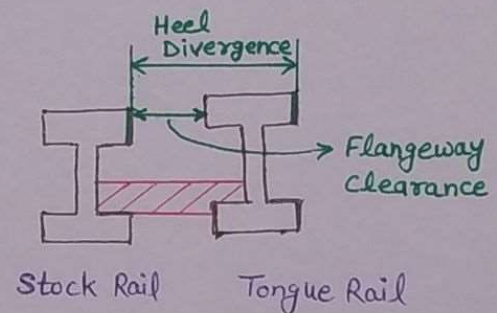
(1) Heel Divergence : (d)

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- It is a distance b/w running faces of stock rail & tongue rail at heel of switch.



Heel Divergence



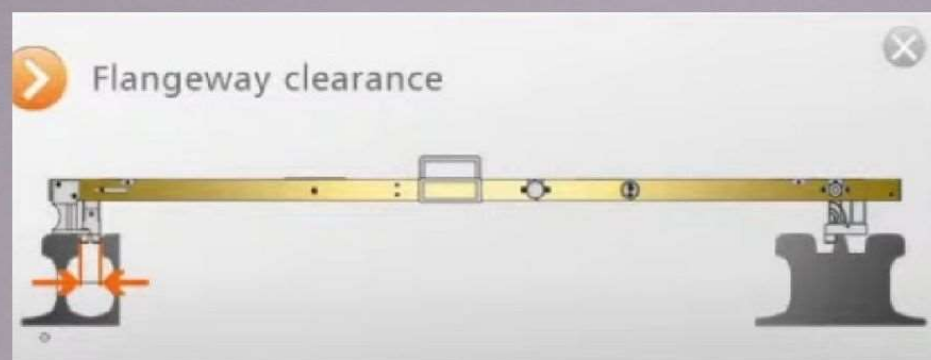


Lec-17 (16:00)

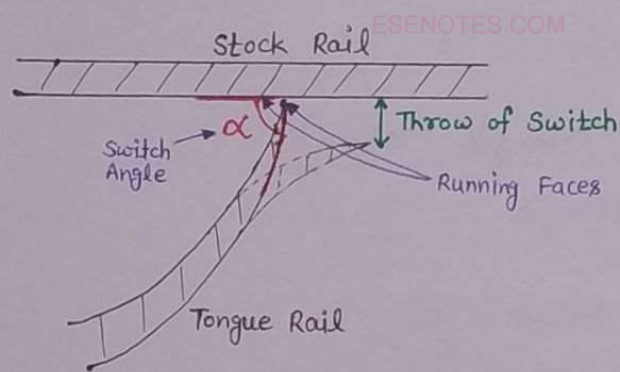
- Heel divergence for BG : 13.3 cm - 13.7 cm
MG : 12.1 cm - 11.7 cm
NG : 9.8 cm

(2) Flangeway Clearance:

- Distance b/w the adjacent faces of tongue rail & stock rail at the heel of the switch is termed as flangeway clearance.
- Flangeway clearance is always less than heel divergence.
- Its value is generally 6.3 cm - 6.6 cm.



(3) Throw of Switch:



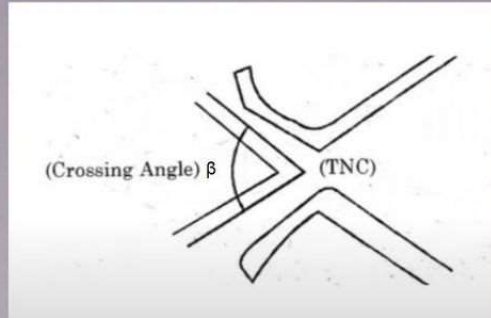
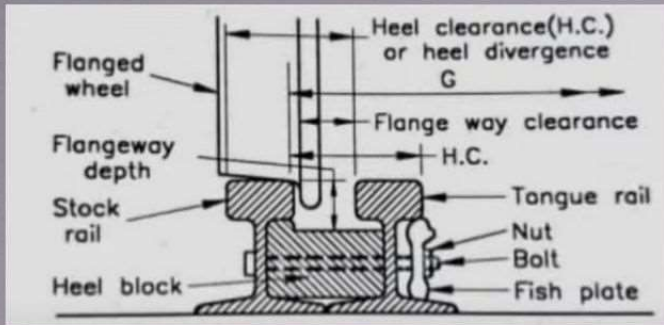
- The maximum distance by which the toe of tongue rail can move sideways is termed as throw of switch.
- For BG : 9.5 cm
MG/NG : 8.9 cm



Lec-17 (29:00)

(4) Flangeway Depth :

- Vertical distance b/w top of rail and its heel block is termed as flangeway depth.



(5) Switch Angle : (α)

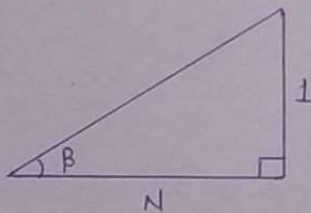
- This is the angle b/w running faces of stock rail and tongue rail when tongue rail touches the stock rail.

(6) Crossing Angle (β) :

- Acute angle crossings are designated by the angle that the gauge faces makes with each other.
- Crossing angle can be designated by any of the following method :

(i) Cole's Method (Right Angle Triangle Method) :

- It is used by Indian Railways.



$$\tan \beta = \frac{1}{N}$$

$$\beta = \cot^{-1}(N)$$

Crossing No. (N)	β	Used in
1 in 6	$9^{\circ} 27'$	In symmetrical split
1 in $8\frac{1}{2}$	$6^{\circ} 4'$	In station yard where space is limited
1 in 12	$4^{\circ} 45'$	In station yard of main line
1 in 16	$3^{\circ} 34'$	High speed turnouts

- More the angle of crossing, lesser will be the permissible speed.
- Generally, permissible speed in kmph is 2.4 times the number of crossing (N).

eg: for 1 in 12, permissible speed = 2.4×12
= 28.8 kmph

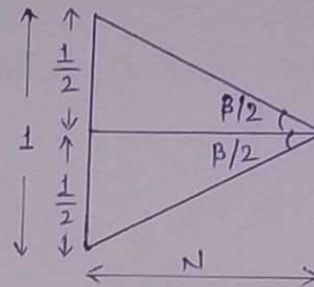


Lec-17 (49:00)

(ii) Center Line Method :

$$\tan \frac{\beta}{2} = \frac{1/2}{N}$$

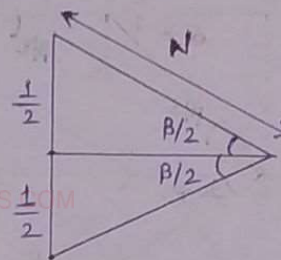
$$\beta = 2 \cot^{-1}(2N)$$



(iii) Isosceles Triangle Method :

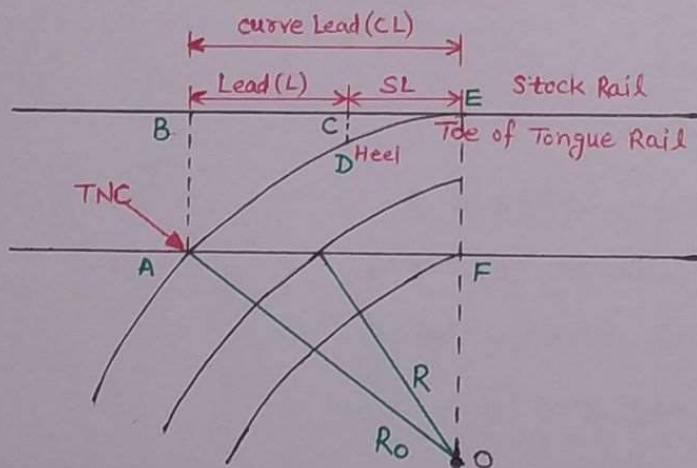
$$\sin \frac{\beta}{2} = \frac{(1/2)}{N}$$

$$\beta = 2 \operatorname{cosec}^{-1}(2N)$$



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Design Calculations of a Turnout :



Lec-18

(i) Curve Lead (CL) :

- It is a distance measured along stock rail b/w the toe of switch and TNC (Theoretical Nose of Crossing).

(ii) Switch Lead (SL) :

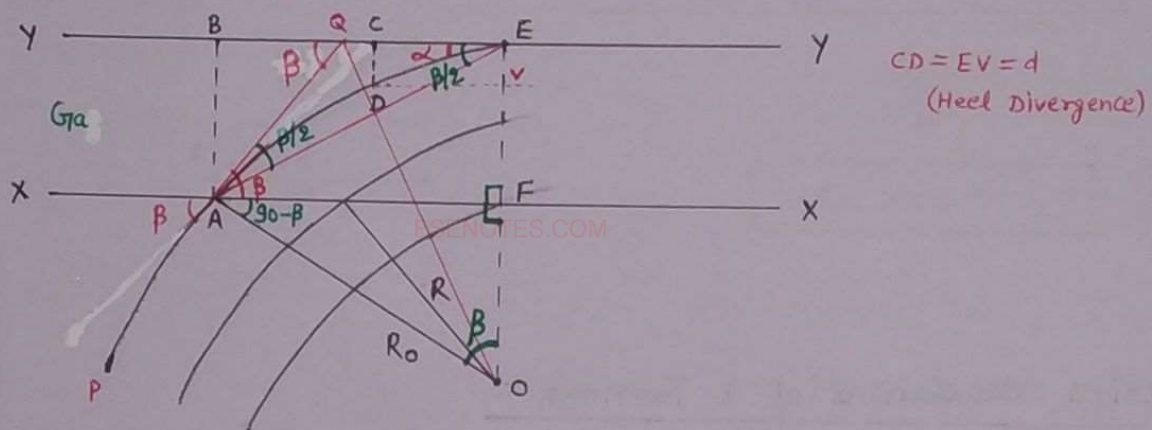
- It is a distance b/w heel of switch and toe of switch, measured along stock rail.

(iii) Lead (L) :

- It is the distance b/w heel of switch and TNC, measured along the stock rail.

$$\text{Here, } CL = SL + L$$

$$\text{or, } L = CL - SL$$



$\angle CED \rightarrow$ switch angle (α)

$\angle XAP \rightarrow$ crossing angle (β)

Join A & E points, then, $\angle BEA = \beta$

Make tangent at point A, cutting YY at Q

then $\angle BQA = \beta$, so $\angle AQE = 180 - \beta$

Join Q and O, & A and E.



Lec-18 (15:00)

Now, in $\triangle ABE$:

QE and QA both are tangents to circle from outside point

$$\therefore QE = QA$$

Now, in $\triangle AQE$:

$$\angle AQE = 180 - \beta$$

$$\therefore \angle QAE + \angle QEA = \beta$$

and, since $QE = QA$

$$\angle QAE = \angle QEA = \frac{\beta}{2}$$

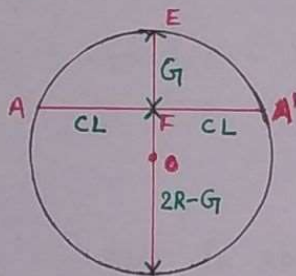
Now, in $\triangle ABE$:

$$\tan \frac{\beta}{2} = \frac{AB}{BE}$$

$$\frac{1}{2N} = \frac{G_1}{CL}$$

$$\left\{ \begin{array}{l} \text{from center line method} \\ \tan \frac{\beta}{2} = \frac{1}{2N} \end{array} \right\}$$

$$CL = 2G_1N$$



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Also, using property of circle

$$CL \cdot CL = G_1(2R - G_1) \simeq 2RG_1$$

$$CL = \sqrt{2RG_1}$$

Now, $\angle QAO = 90^\circ$ (angle b/w tangent and radius)

$$\therefore \angle FAO = 90 - \beta$$

$$\therefore \angle AOF = \beta$$

$$\text{So, in } \triangle AOF, \tan \beta = \frac{AF}{OF} \Rightarrow OF = AF \cot \beta = CL \cot \beta \quad (AF = BE = CL)$$

Now, Radius (R) = OE = OF + FE

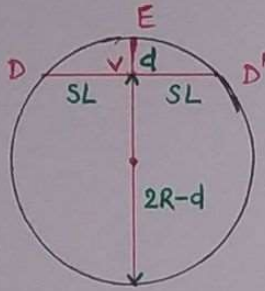
$$R = CL \cot \beta + G$$

$$R = (2GN)(N) + G \quad \left\{ \begin{array}{l} \cot \beta = N \\ CL = 2GN \end{array} \right\}$$

$$R = 2GN^2 + G$$

But, as per Indian Railways, $R = 2GN^2 + 1.5G$

Now, for switch lead (SL) :



$d \rightarrow$ heel divergence

$$(CD = EV = d)$$

Using property of circle

$$SL \cdot SL = d(2R-d) \approx 2Rd$$

$$SL = \sqrt{2Rd}$$

Hence, $\text{Lead (L)} = CL - SL$

Que: For a turnout on BG track, following properties are known -

Number of crossing = 1 in 12

Heel divergence (d) = 12cm

The curve is starting from toe of the switch & ends at TNC.

Compute (a) CL (b) R (c) SL (d) L (e) Central radius

Sol: (a) $CL = 2GN = 2 \times 1.676 \times 12 = 40.224 \text{ m}$

(b) $R = 2GN^2 + 1.5G = 2 \times 1.676 \times 12^2 + 1.5 \times 1.676 = 485.2 \text{ m}$

(c) $SL = \sqrt{2Rd} = \sqrt{2 \times 485.2 \times 12 \times 10^{-2}} = 10.78 \text{ m}$

(d) $L = CL - SL = 40.224 - 10.78 = 29.432 \text{ m}$

(e) Central Radius = $R - \frac{G}{2} = 485.2 - \frac{1.676}{2} = 484.36 \text{ m}$



Lec-18 (20:55)

Types of Switches :

(i) Stub Switch :

- In this type of switch, no separate tongue rail is provided and same portion of the track is moved from side to side.

(ii) Split Switch :

- In this type of switch, tongue rail is combined with the stock rail.
- It is further of two types :

(a) Loose Heel Type :

- In this, tongue rail is joined to the lead rail by means of fish plate.

(b) Fixed Heel Type :

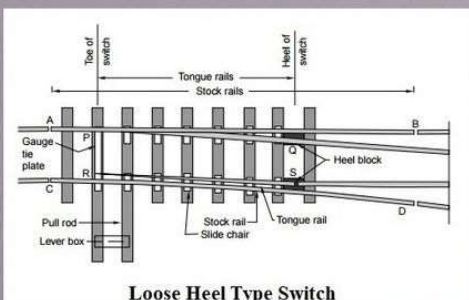
- It is the modification of loose heel type in which the joint is formed just before the heel.

NOTE :

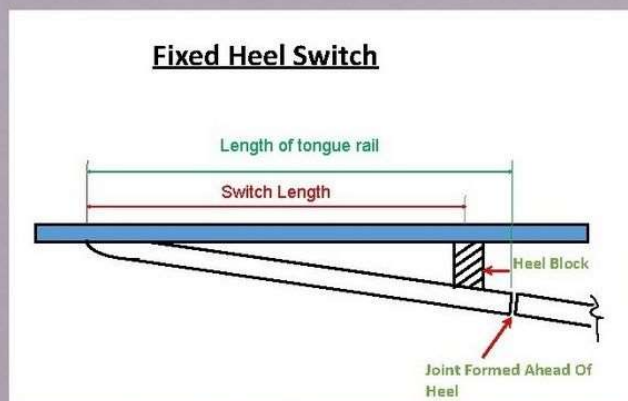
- Check rail is provided to guide the wheels of train so that wheels don't climb over the crossings.
- Wing rails help in channelising the wheels while changing the route.



Stub Switch



Loose Heel Type Switch



Lec-18 (37:40)

TRACK JUNCTION



Lec-20

— Track junctions are formed by combinations of points & crossings with curves and straights, to transfer train from one track to another.

— Track junctions are of following types :

(1) Turnouts : Already discussed.

(2) Symmetrical Split / Eq^v Turnout :

- When a straight track is split-up in two different directions with equal radii, it is known as symmetrical split.
- Crossing number used in this case is 1 in 6.
- It consists of 4 curved lead rails, 2 check rails and 1 acute crossing.

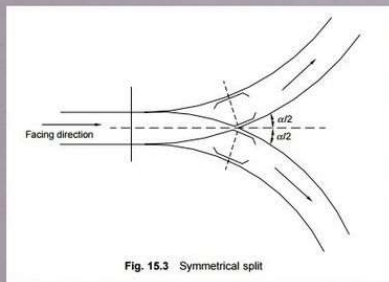


Fig. 15.3 Symmetrical split



Symmetrical Split

(3) Three Throw Switches :

- When two turnouts take-off from the same point of a main straight track, it is called three throw switch.
- It is generally used in congested areas where space is limited.

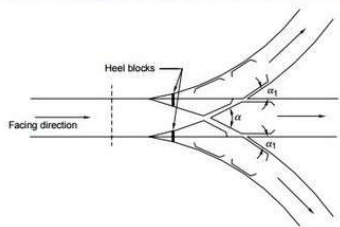


Fig. 15.4 Three-throw switch (contrary flexure)



Three Throw Switch



Three Throw Switch



Lec-20 (15:45)

(4) Diamond Crossing :

- When 2 straight tracks or curved tracks cross each other at an angle less than 90° , a diamond shape crossing is formed.
- It consists of 2 acute angle crossing and 2 obtuse angle crossing and 4 check rails.
- It is avoided on curves.

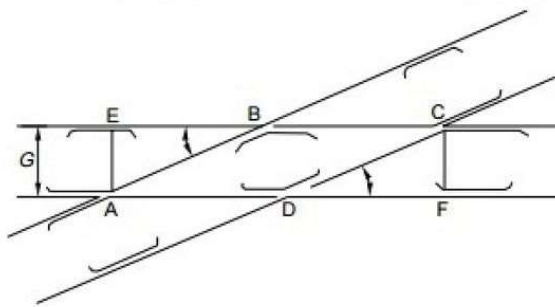


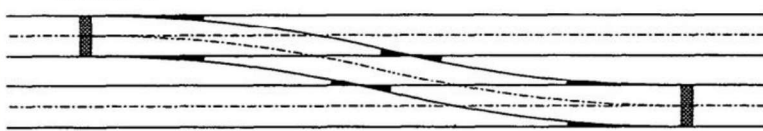
Fig. 15.9 Diamond crossing



Diamond Crossing

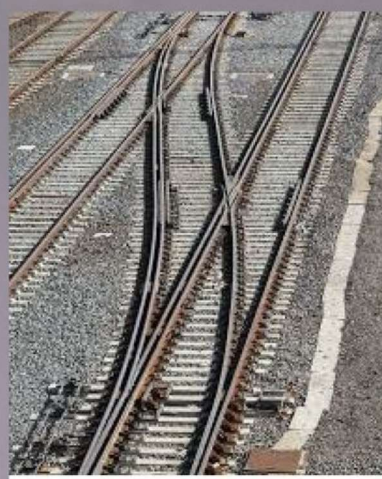
(5) Cross Over :

- When two adjacent parallel tracks which may be straight or curved, are connected by two sets of turnouts, the connection portion is known as cross-over.
- Use of reverse curve b/w the two crossings reduces the length of cross-over.



Cross Over

TURNOUT A



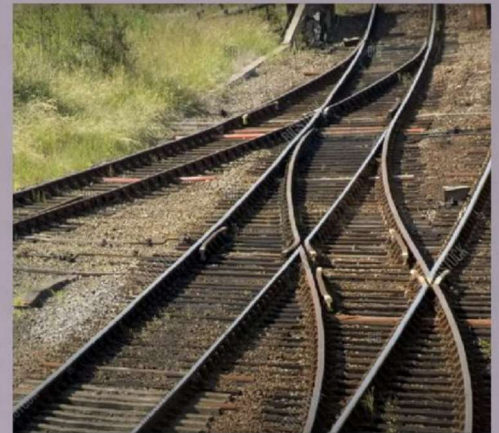
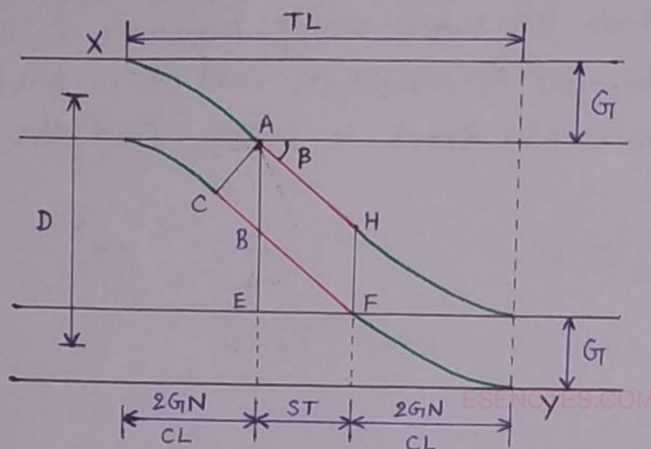
Cross Over



Lec-20 (26:15)

Design of Cross-over :

Case (i) : Cross-over with straight intermediate portion and equal crossing angles for both tracks :



Cross Over

$$\text{Now, } AE = D - \frac{G_1}{2} - \frac{G_1}{2} = D - G_1$$

In $\triangle ACB$, $\cos \beta = \frac{G_1}{AB} \Rightarrow AB = G_1 \sec \beta$

$$\text{Now, } BE = AE - AB = (D - G_1) - G_1 \sec \beta$$

In $\triangle BEF$, $\tan \beta = \frac{BE}{EF} \Rightarrow EF = BE \cot \beta$

$$EF = \{(D - G_1) - G_1 \sec \beta\} \cot \beta$$

$$\{\because \cot \beta = N\}$$



Lec-20 (40:35)

$$\begin{aligned}
 EF &= (D - G_1)N - G_1 N \sec \beta \\
 &= (D - G_1)N - G_1 N \sqrt{1 + \tan^2 \beta} \\
 &= (D - G_1)N - G_1 N \sqrt{1 + \frac{1}{N^2}}
 \end{aligned}$$

$$EF = (D - G_1)N - G_1 \sqrt{1 + N^2}$$

$$\therefore \text{Total length of cross-over} = 2 \times CL + EF$$

$$l = 2 \times 2G_1N + (D - G_1)N - G_1 \sqrt{1 + N^2}$$

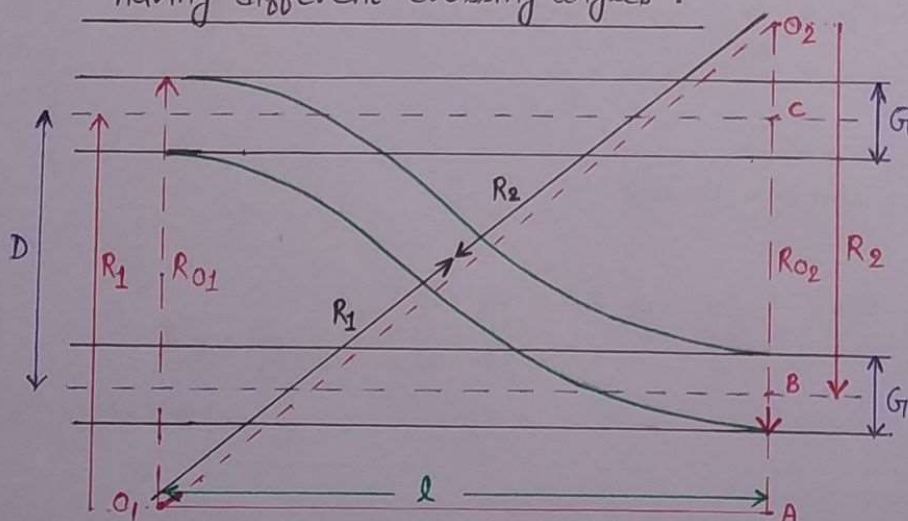
$$l = 4G_1N + (D - G_1)N - G_1 \sqrt{1 + N^2}$$

Que: A cross-over occurs b/w two BG track using turnouts & same crossing no. 1 in 12, with straight intermediate portion in between, reverse curve. If c/c distance b/w track is 6.5 m, find the total length of cross-over.

Sol:
$$\begin{aligned}
 l &= 4G_1N + (D - G_1)N - G_1 \sqrt{1 + N^2} \\
 &= 4 \times 1.676 \times 12 + (6.5 - 1.676) \times 12 - 1.676 \sqrt{1 + 12^2} \\
 &= 118.18 \text{ m}
 \end{aligned}$$

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Case (ii): Cross over with curved path b/w two turnouts having different crossing angles:



Lec-21

$$R_{O1} = 2G_1N_1^2 + 1.5G_1$$

$$R_1 = R_{O1} - \frac{G_1}{2}$$

$$R_{O2} = 2G_2N_2^2 + 1.5G_2$$

$$R_2 = R_{O2} - \frac{G_2}{2}$$



Lec-21 (16:50)

$$O_1O_2 = R_1 + R_2$$

$$O_2A = R_1 + R_2 - D$$

$$O_1A = l = \sqrt{O_1O_2^2 - O_2A^2}$$

$$\left\{ \begin{array}{l} O_2A = O_2C + CB + BA \\ \text{or } O_2A = O_2C + CB + BA + CB - CB \\ = R_2 + R_1 - D \end{array} \right\}$$

Que : If a cross-over is formed b/w two turnouts in for 1 in 12 at one end and 1 in 16 at another end, with a waved portion b/w two turnouts. c/c distance in b/w tracks is 6.2 m. Compute the overall length of cross-over.

Sol : $R_{O1} = 2GN_1^2 + 1.5G = 2 \times 1.676 \times 12^2 + 1.5 \times 1.676 = 485.2 \text{ m}$

$$R_1 = R_{O1} - \frac{G}{2} = 485.2 - \frac{1.676}{2} = 484.4 \text{ m}$$

$$R_{O2} = 2GN_2^2 + 1.5G = 2 \times 1.676 \times 16^2 + 1.5 \times 1.676 = 860.6 \text{ m}$$

$$R_2 = R_{O2} - \frac{G}{2} = 860.6 - \frac{1.676}{2} = 859.8 \text{ m}$$

$$O_1O_2 = R_1 + R_2 = 484.4 + 859.8 = 1344.2 \text{ m}$$

$$O_2A = R_1 + R_2 - D = 1344.2 - 6.2 = 1338 \text{ m}$$

$$O_1A = \sqrt{(1344.2)^2 - (1338)^2} = 129 \text{ m}$$

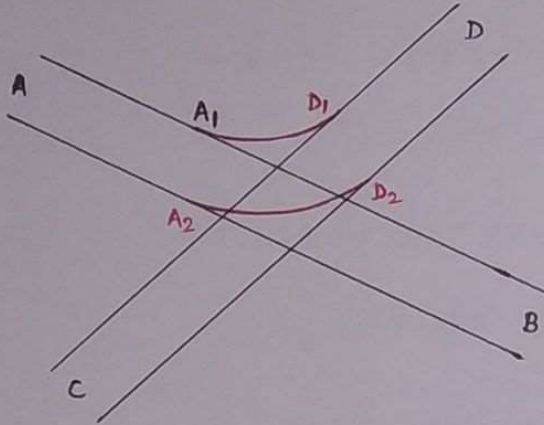
Exam में diagram भी बनाकर दिखाना होगा।



Lec-21 (37:20)

(6) Single Slip and Double Slip Crossing :

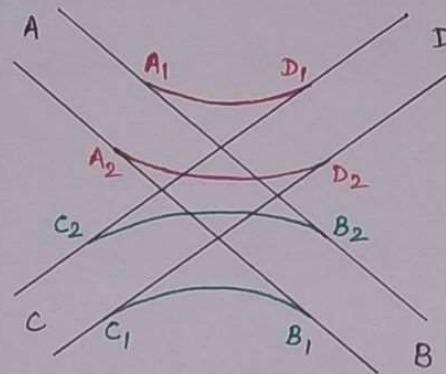
- It is improvement over diamond crossing.
- In diamond crossing, the trains cannot be taken from one track to another track.
- But in the slip arrangement, train can move from one track to another.
- A single slip is one in which the tracks can be changed from one direction only and in double slip, tracks can be changed from both directions.



$A \rightleftharpoons B$
 $C \rightleftharpoons D$

} Diamond Crossing

$A \rightleftharpoons D$ Single slip
 $A_1 D_1$ and $A_2 D_2$

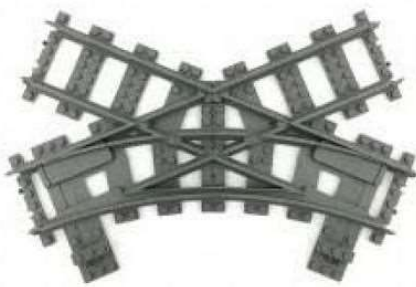


$A \rightleftharpoons B$
 $C \rightleftharpoons D$

} Diamond Crossing

$A \rightleftharpoons D$
 $C \rightleftharpoons B$

} Double slip
 $A_1 D_1 + A_2 D_2$
 $C_1 B_1 + C_2 B_2$



Single Slip Crossing



Double Slip Crossing



Lec-21 (45:25)

(7) Scissor Cross Over / Double Cross Over :

- It is combination of one cross-over over the other cross-over in the opposite dirⁿ.
- It enables the trains to change the track from the either dirⁿ along the main track.

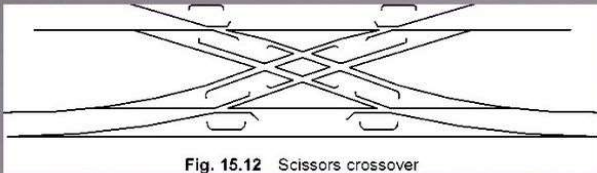
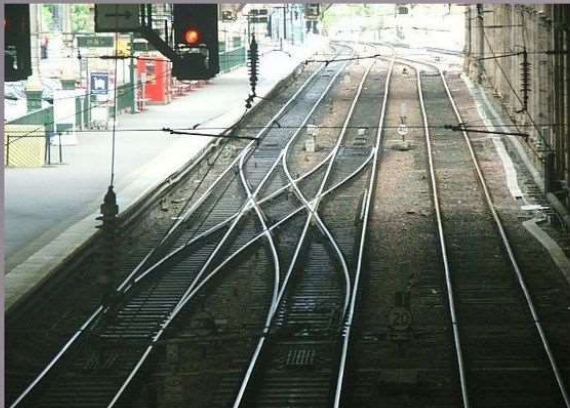


Fig. 15.12 Scissors crossover



Scissor Cross Over



Scissor Cross Over

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STATIONS, YARDS AND EQUIPMENTS



Lec-24

Railway Stations :

- It is a place where trains halt for following purposes :
 - (i) To exchange passengers and goods
 - (ii) To control movements of trains (overtaking, detaching, connecting engine)
 - (iii) To take fuel and water.
- Site selection of station is done on the basis of :
 - (i) Site drainage
 - (ii) Availability of land (acc. to number of platforms)
 - (iii) Approach road to the station
 - (iv) Accessibility to town or city
 - (v) Site alignment

Classification of Stations :

- Stations can be classified on the basis of following :

(i) Operational Classification :

(a) Block Station :

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- Class A to C
- It is the station at which the driver has to obtain an authority to proceed in other block station.

(b) Non-Block Station :

- Class D
- No permission is required to stop or to cross this station

(c) Special Class Station :

- Not covered in class A to D.

(ii) Functional Classification :

(a) Junction Station :

- Station at which trains can pass in different directions.

(b) Non-Junction Station :

- Stations at which trains cannot pass in different directions.

(c) Terminal Station :

- Train terminates at this station.



Lec-24 (13:32)

NOTE :

- (i) minimum distance b/w platforms should be 60 m.
- (ii) minimum length of passenger platform is 180 m.

Loop :

- If the branch line from a main line again terminates at the same main line, it is called a loop.

- It is of following types :

(i) Split Loop

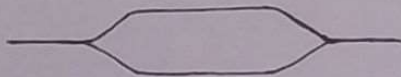
(ii) Trailing Loop

(iii) Straight End Loop

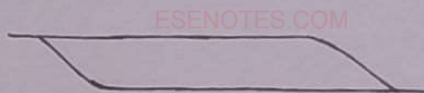


Lec-25

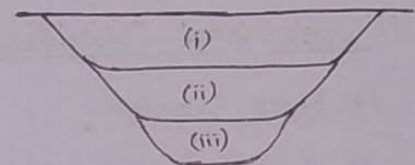
(i) Split Loop



(ii) Trailing Loop



(iii) Straight End Loop



Sidings :

- When a branch line from main line or a loop terminates at a dead end, it is termed as siding.
- It act as a temporary storage of wagons.



Siding

Station Yard :

- It is a system of tracks laid for receiving, sorting, making of new train & dispatching of trains.
- These are of following types :
 - (i) Passenger Yard : permitting safe movement of passengers
 - (ii) Goods Yard
 - (iii) Marshalling/Shunting/ Machine Yard



Lec-25 (10:00)



Station Yard



Station Yard



Station Yard

Equipments Used in Station Yard :

(i) Cranes :

- In large stations, cranes are used for loading and unloading of heavy goods.

(ii) Weigh Bridge :

- These are provided in goods yard to get the weight of loaded wagon.
(Like धर्मकोट)

(iii) Loading Gauge :

- It is used to restrict the dimension of loaded articles.

(iv) Engine Shed/Loco Shed :

- It is provided for the purpose of cleaning, repairing and maintaining the locomotive.

(v) Ash Pits :

- It is provided to receive ashes from locomotive boilers.



Lec-25 (28:30)

(vi) Drop Pits :

- The purpose of drop pits is to remove the wheels of the engine.

(vii) Triangle :

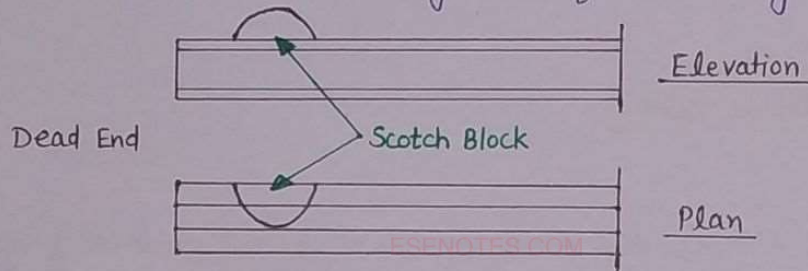
- It consists of three sides of short length tracks in the form of a triangle.
- These are used for changing the direction of engine.
- 'Turn Table' can also be used for this purpose.

(viii) Traverser :

- This is used to transfer the wagons or locomotives to and from one track to another parallel track.
- It is preferred to turnouts where space is less.

(ix) Scotch Block :

- It is used to separate the shunting lines from running lines.



(x) Fouling Mark :

- These are the points fixed b/w a pair of converging tracks to indicate a foul or possibility of collision of vehicles beyond these points.

(xi) Sand Hump/ Snag Dead End :

- This is also a method to prevent the vehicles from jumping off the track at the end of siding.
- In this method, hump of sand with a rising gradient at dead end of siding is provided



Crane



Weigh Bridge



Weigh Bridge



Loading Gauge



Loading Gauge



Engine Shed



Engine Shed



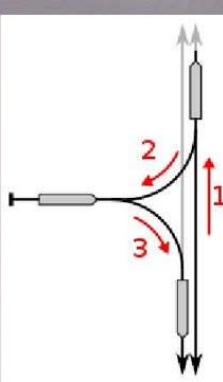
Ash Pit



Ash Pit



Drop Pit



Triangle



Turn Table



Turn Table



Traverser



Scotch Block



Fouling Mark



Sand Hump/Snag Dead End

SIGNALLING



Lec-26

- Signalling consists of the systems, devices and means by which trains are operated efficiently and tracks are used to maximum extent and maintaining the safety of passengers.
- Signals are classified on the basis of following :

I Operating Characteristics :

(1) Detonating Signals :

- Detonators are placed on rails, which explode when train passes over it and creates loud sound, so as to make the locopilot conscious.
- For safety point of view, it is placed 400-500m ahead of actual signal.
- Typical uses of detonator include :
 - (a) A warning, caution or stop signal in dense fog when signals are difficult to see.
 - (b) A warning of a train stopped on the line ahead by accident.
 - (c) A warning of ongoing engg. work ahead.
 - (d) To alert the crew working on rail if a silent train is approaching.

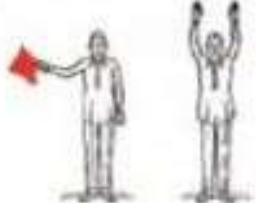
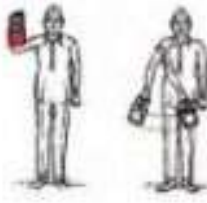
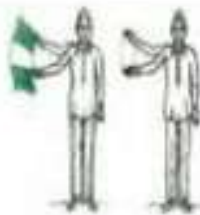
(2) Hand Signal :

- These are the gestures made by hand in order to give indications to locopilot.
- These gestures suggest :
 - (a) Stop hand signal
 - (b) Proceed hand signal
 - (c) Proceed with caution hand signal
 - (d) Hand signals for shunting
- In day time, red or green flag may be used.
- In night time, lalten (lantern) may be used.

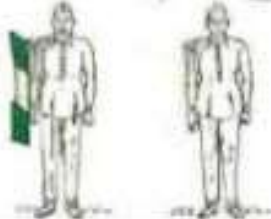


Detonating Signal

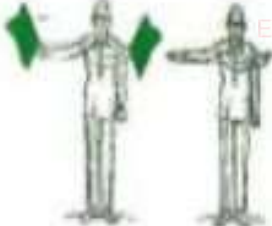
Display of STOP, PROCEED and PROCEED with CAUTION hand signals

Types of Hand Signal	How displayed by showing		Indication
	During Day	During Night	
STOP	By showing a red flag or by raising both arms with hand above the head 	By showing a red light or by vigorously waving a white light horizontally across ones body 	Stop Dead
PROCEED	By holding a green flag or by holding one arm steadily. 	By holding a green light steadily. 	Proceed
PROCEED CAUTIOUSLY	By waving a green flag vertically up and down or by waving one arm similarly. 	By waving a green light vertically up and down. 	Proceed Cautiously.
Note:-When the speed is to be reduced further, this signal shall be given at a slower and slower rate and when a stop is desired, the stop hand signal shall be shown.			

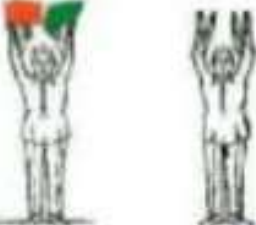
Display of hand signal for shunting

MOVE AWAY FROM THE PERSON SIGNALLI- NG	By a green flag or one arm moved slowly up and down.	By a green light moved slowly up and down.	Move away from the person signalling
			

Note:-The hand signals for 'Move away from the person signalling' shall be displayed slower and slower, until the stop hand signal is given if it is desired to stop.

MOVE TOWARDS THE PERSON SIGNALLI- NG	By a green flag or one arm moved from side to side across the body.	By a green light moved from side to side across the body.	Move towards the person signalling
			

Note:-The hand signals for 'Move towards the person signalling' shall be displayed slower and slower, until the stop hand signal is given if it is desired to stop.

MOVING SLOWLY FOR COUPLIN-G	By a green and a red flag held above the head or both hands raised over the head and moved towards and away from each other.	By a green light held above the head and moved by twisting the wrist.	MOVING SLOWLY FOR COUPLIN-G
			

(3) Fixed Signal :

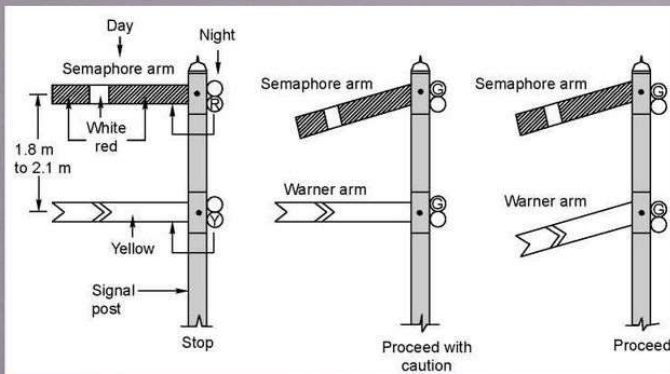
- These are the signals which are fixed at a place.

(i) Semaphore/Stop Signal :

- The principle of design of semaphore signal is to show the stop position due to any failure.
- The signal mechanism is so arranged that in normal position, it indicates stop position.
- It has a movable arm which remains horizontal in normal position.
- The side of the arm facing the driver is painted red with white band in between.
- It is placed at height of 7.5 m.
- If arm is inclined at $45-60^\circ$, it indicates proceed.

(ii) Warner Signal :

- Warner signal is similar to semaphore except V-notch at the end and on the warner arm, paint is yellow.
- This signal is placed at the same post of semaphore signal at 1.8–2.1 m below the semaphore signal.
- If warner arm is horizontal, it indicates 'stop'. And, if warner arm is inclined, it indicates 'proceed'.



Semaphore Signal



Warner Signal



Lec-26 (21:00)

II Based on Functional Characteristics :



Lec-26 (38:50)

- (1) Stop/Semaphore Signal : } Discussed earlier
- (2) Warner Signal :
- (3) Shunting Signal :

- These signals are used for shunting operation in shunting yards.
- They are of circular shape disc with white background and red band in between.
- If red band is horizontal, it indicates 'Stop', whereas if red band is inclined it means 'proceed'.



Shunting Signal

III Based on Location Characteristics :

- | | |
|----------------------|-----------------------|
| (1) Reception Signal | (2) Departure Signal |
| (i) Outer signal | (i) Starter |
| (ii) Home signal | (ii) Advanced Starter |

(1) Reception Signal :

- It controls the reception of train into a station

(i) Outer signal :

- It is the first stop signal at station, which indicates the entry of train.

(ii) Home Signal :

- Due to its location at the door of station, it is termed as home signal.

(2) Departure Signal :

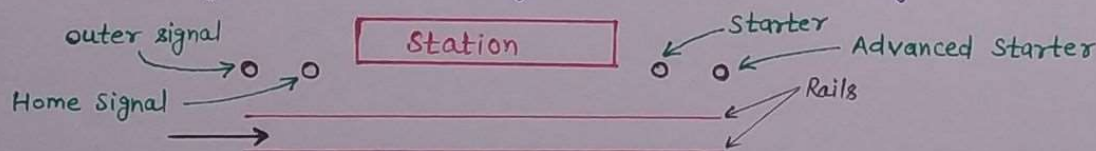
- The signal which controls the dispatch of train from the station are termed as departure signal.

(i) Starter Signal :

- It marks the limit upto which the train stop at station.

(ii) Advanced Starter Signal :

- These signals are placed beyond (180m) the trailing points and switches.



IV Based on Special Characteristics :

(1) Repeater/Co-Acting Signal :

- If driver's vision is obstructed by (a) an overbridge b/w the signals (b) due to sharp curve, a signal is provided with duplicate arm of smaller size at suitable position which repeats the indication of signal ahead.
- Repeating and co-acting signal serves same purpose of providing visibility but co-acting signal is provided on same post at lower level of main signal.

(2) Routing Signal :

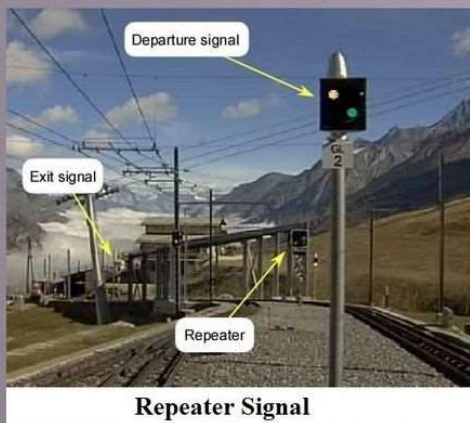
- These signals are provided at the point of diversion where no. of lines exist at the station, taking off in different location from main line.
- These are provided beside the home signal.
- Lowering at any of the signal indicates the track which the point are set.

(3) Calling On Signal :

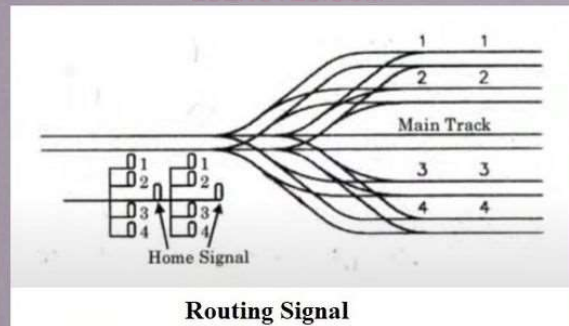
- These signal consists of arm below and parallel to home semaphore signal.
- It indicates the movement of train with caution.
- It is very much useful when repair work is going on.



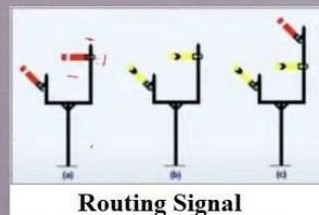
Lec-27



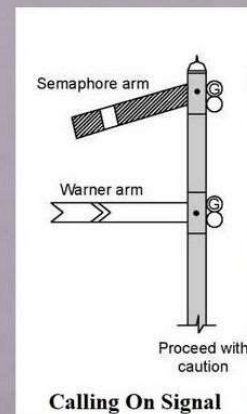
Repeater Signal



Routing Signal



Routing Signal



Calling On Signal

TRACTIVE RESISTANCE



Lec-27 (21:40)

- During the movement of train, following forces comes into the action :

(i) Tractive Effort (T_e) :

- It is the pull applied by engine on the driving wheel for the movement of train.

(ii) Hauling Capacity (F) :

- It is the maximum value of friction force that can be obtained b/w rails and driving wheels.

$$F = \mu N = \mu n W_d$$

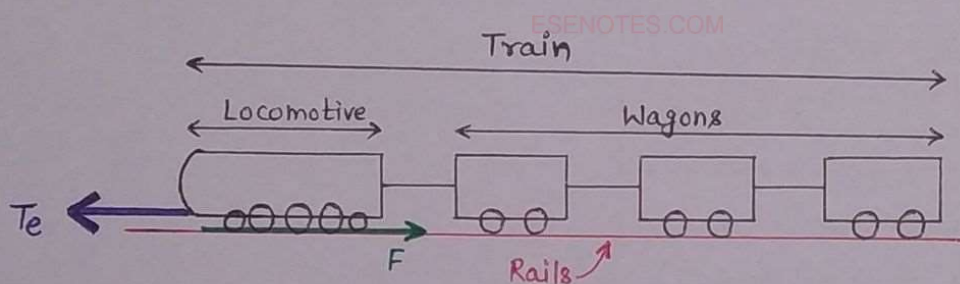
$\mu \rightarrow$ coeff. of friction (0.1 - 0.3)

$n \rightarrow$ no. of pair of driving wheels

$W_d \rightarrow$ axle load

$W_d = 28.56$ tonnes for BG

$= 17.34$ tonnes for MG



For movement of train, $T_e \geq F$ (hauling capacity/ Total Resistance)

(iii) Tractive Resistance :

- These are forces which resist the movement and speed of train.
- These are of following types :
 - (a) Train Resistance
 - (b) Resistance due to Track Profile
 - (c) Resistance due to starting & accⁿ
 - (d) Wind Resistance

(a) Train Resistance :

Resistance Independent of Speed (R_{T_1}) : (Rolling Resistance)

$$R_{T_1} = 0.0016 W \text{ (tonnes)}$$

W = weight of train (locomotive + wagons)
↳ (in tonnes)

- It includes :
 - friction b/w internal parts of engine & wagon.
 - friction b/w wheels and rails.
 - resistance due to wave action.

Resistance Dependant on the Speed (R_{T_2}) :

$$R_{T_2} = 0.00008 W V \text{ (tonnes)}$$

W = weight of train (tonnes)

V = speed of train (kmph)

Atmospheric Resistance (R_{T_3}) :

- This resistance develops on the ends & sides of train, even if wind speed is zero.
- This is not wind resistance.

$$R_{T_3} = 0.0000006 W V^2 \text{ (tonnes)}$$

W = weight of train (tonnes)

V = speed of train (kmph)

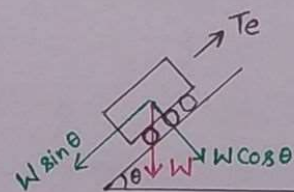
Hence, Total Train Resistance (R_T) = $R_{T_1} + R_{T_2} + R_{T_3}$

(b) Resistance due to Track Profile :

Resistance due to Gradient :

$$R_g = W \sin \theta$$

If θ is small, $\theta \simeq \sin \theta \simeq \tan \theta$



$$\therefore R_g = W \tan \theta$$

$\tan \theta \rightarrow$ gradient

Resistance due to Curvature (R_c):

— Since the wheel base is rigid, it does not allow the train to take curved path, resulting in development of skid/transverse resistance.

$$\left. \begin{aligned} R_c &= 0.0004 WD^\circ, \text{ for BG} \\ &0.0003 WD^\circ, \text{ for MG} \\ &0.0002 WD^\circ, \text{ for NG} \end{aligned} \right\} (\text{tonnes})$$

Total Resistance due to Track Profile
 $= R_g + R_c$

(C) Resistance due to Starting & Accⁿ:

Resistance due to Starting (R_s):

$$R_s = \underbrace{0.15 W_1}_{\text{due to locomotive}} + \underbrace{0.005 W_2}_{\text{due to wagons}} (\text{tonnes})$$

W_1 = weight of locomotive (tonnes)

W_2 = weight of wagon (tonnes)

Resistance due to Accⁿ (R_a):

$$R_a = 0.28 W \left(\frac{V_2 - V_1}{t} \right) (\text{tonnes})$$

' V_1 ' and ' V_2 ' are speed of train in kmph

' t ' is time (seconds)

Hence, Total Resistance due to Starting & Accⁿ $= R_s + R_a$



Lec-27 (44:20)

(d) Wind Resistance (R_W) :

$$R_W = 0.000017 a V_W^2 \text{ (tonnes)}$$

a = exposed area of train (m^2)

V_W = speed of wind (kmph)



Lec-27 (52:30)

Que: A locomotive is designated by 4-6-2 is to haul train at a speed of 75 kmph. Load of each axle is 22 t.

$\mu = 0.2$. Compute :

(i) What is the max. load, engine can pull on straight and level track.

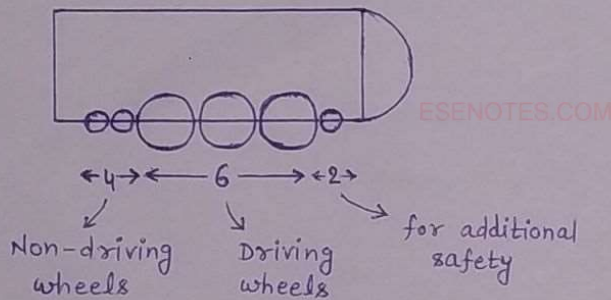
(ii) When it is to be run on profile of slope 1 in 180, then the max speed it can take ?

(iii) When it goes on 2° curve and same slope, then the max speed it can take ?



Lec-28

NOTE :



Sol : T_e or Hauling Capacity $_{(HC)} = \mu n W_d = 0.2 \times 3 \times 22 = 13.2 \text{ tonnes}$

(i) For movement of train, $HC \geq \text{Train Resistance } (R_T)$

R_{T1} = Resistance independent of speed = $0.0016 W$

R_{T2} = Resistance dependant on speed = $0.00008 \times W \times 75$
 $= 0.006 W$



Lec-28 (13:40)

$$\begin{aligned}
 R_{T_3} &= \text{Atmospheric Resistance} \\
 &= 0.0000006 W V^2 \\
 &= 0.0000006 \times W \times 75^2 \\
 &= 0.003375 W
 \end{aligned}$$

$$\therefore 13.2 = 0.0016 W + 0.006 W + 0.003375 W$$

$$W = 1202 \text{ tonnes}$$

(ii) Now, $HC \geq \text{Train Resistance } (R_T) + \text{Resistance due to Gradient } (R_g)$

$$13.2 = 0.0016 W + 0.00008 W V + 0.0000006 W V^2 + W \tan \theta$$

$$13.2 = \left(0.0016 + 0.00008 V + 0.0000006 V^2 + \frac{1}{180} \right) \times 1202$$

$$V = 37.4 \text{ kmph}, \quad -170 \text{ kmph}$$

✓ ✗

(iii) $HC \geq \text{Train Resistance} + \text{Grade Resistance} + \text{Curve Resistance}$

$$13.2 = 0.0016 W + 0.00008 W V + 0.0000006 W V^2 + W \tan \theta + 0.0004 W D^\circ$$

$$13.2 = \left(0.0016 + 0.00008 V + 0.0000006 V^2 + \frac{1}{180} + 0.0004 \times 2^\circ \right) \times 1202$$

$$V = 30.7 \text{ kmph}, \quad -164 \text{ kmph}$$

✓ ✗

Que: Find out the steepest gradient on a straight track using the following data for train having 20 wagons.

wt. of each wagon = 18 tonnes

Rolling resistance of wagon = 2.5 kg/tonnes

speed of train = 50 kmph

wt. of locomotive = 120 tonnes

Tractive effort of locomotive = 12 tonne

Rolling resistance of locomotive = 3.5 kg/tonnes

Sol: Total Resistance = Train Resistance (R_T) + Resistance due to grade (R_g)

$$= R_{T1} + R_{T2} + R_{T3} + R_g$$



Lec-28 (35:00)

R_{T1} = Resistance independent of speed / Rolling Resistance

$$= \underbrace{2.5 \times 18 \times 20}_{\text{wagon}} + \underbrace{3.5 \times 120}_{\text{locomotive}}$$

$$= 1320 \text{ tonnes kg}$$

$$= 1.32 \text{ tonnes}$$

$$R_{T2} = 0.00008 W V = 0.00008 \times [20 \times 18 + 120] \times 50$$

$$= 1.92 \text{ tonnes}$$

$$R_{T3} = 0.0000006 W V^2 = 0.0000006 \times [20 \times 18 + 120] \times 50^2$$

$$= 0.72 \text{ tonnes}$$

$$R_g = W \tan \theta = 480 \times \frac{1}{n} \text{ tonnes}$$

For movement of trains, $T_e \geq H_C \geq T_R$

$$12 = 1.32 + 1.92 + 0.72 + \frac{480}{n}$$

$$n = 59.7$$

$\therefore$ Gradient = 1 in 59

Que: A locomotive having 8 driving wheels, can haul a train with maximum speed of 80 kmph on the straight level BG track. Load on each axle is 25t and $\mu = 0.2$. Compute

(a) Total wt. of the train that can be hauled with speed of 80 kmph.

(b) Total wt. of the train that can be hauled with speed of 80 kmph on a straight track with grade of 1 in 200.

(c) Total weight of train that can be hauled with speed of 80 kmph on a grade of 1 in 200 and curve of 2° .

Sol: $T_e = HC = unWd = 0.2 \times \frac{8}{2} \times 25 = 20 \text{ tonnes}$



Lec-28 (47:30)

For movement of train, $T_e \geq HC \geq T_R$

(a) $HC = R_T$

$$20 = 0.0016 W + 0.00008 W \times 80 + 0.0000006 \times W \times 80^2$$

$$W = 1689 \text{ tonnes}$$

(b) $HC = R_T + R_G$

$$20 = 0.0016 W + 0.00008 W \times 80 + 0.0000006 \times W \times 80^2 + W \times \frac{1}{200}$$

$$W = 1187 \text{ tonnes}$$

(c) $HC = R_T + R_G + R_c$

$$20 = 0.0016 W + 0.00008 \times W \times 80 + 0.0000006 \times W \times 80^2 + W \times \frac{1}{200} + 0.0004 \times W \times 2^\circ$$

$$W = 1133 \text{ tonnes}$$

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MAINTENANCE OF TRACKS



Lec-29

- Maintenance of the tracks is required if the strength goes on deteriorating due to the movement of high speed trains, heavy axle loads etc.
- The track is also subjected to other deteriorating effects like rain, temp, humidity and wind.
- Maintenance of tracks can be divided as :
 - (a) Daily Maintenance : One gang is attached to 5-6 km length of the section.
 - (b) Periodic Maintenance : It is carried out at the interval of 2-3 years for gauge levels, alignments, points, crossings etc.
- Maintenance of following items is being carried out :
 - (A) Maintenance of Surface of rail
 - (B) Maintenance of Track Alignment
 - (C) Maintenance of gauge
 - (D) Maintenance of track components (rails, sleepers, fish plates etc.)

NOTE :

Track Imprest : A stock of all the useful materials such as rails, sleepers, fish plates, bolts, spikes and other fittings are permanently maintained to be used in situations when required is termed as 'TRACK IMPREST'

Instruments Used for Maintenance of Track :



Lec-29 (18:50)

(1) Shovel / Ballast Fork :

- The track is opened out and ballast round the sleepers is pulled aside by means of ballast fork / shovel.

(2) Crowbar :

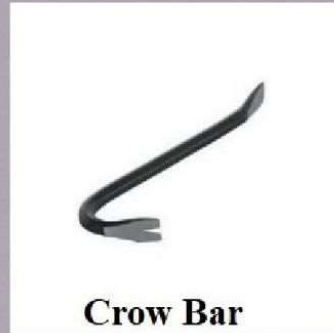
- It is used to raise the sleeper to a desired height and for replacement of track.

NOTE :

- The process of maintaining the spacing b/w the sleepers is termed as squaring of sleepers.



Shovel



Crow Bar

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(3) Cant Board :

- To check the superelevation on curve, cant board is used.



Cant Board



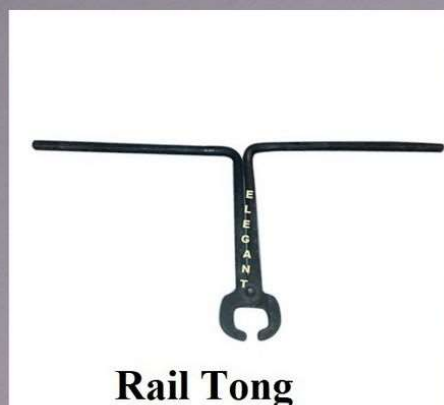
Lec-29 (33:30)

(4) Rail Tong :

- It is used to lift and carry rails.

(5) Claw Bar :

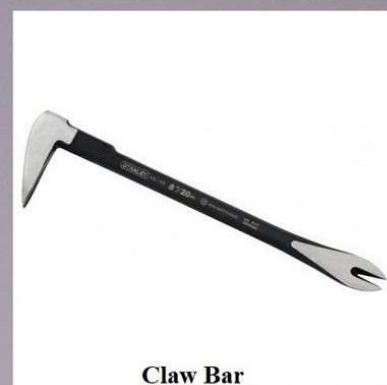
- It is used to remove spikes out of sleeper.



Rail Tong



Rail Tong



Claw Bar

(6) Sleeper Tong :

- It is used to lift up the sleepers.



Sleeper Tong



Sleeper Tong



Sleeper Tong

(7) Viseur's Mire :

- It is used for measuring the unevenness of the rail and also used for rectification of track alignment.



Viseur's Mire

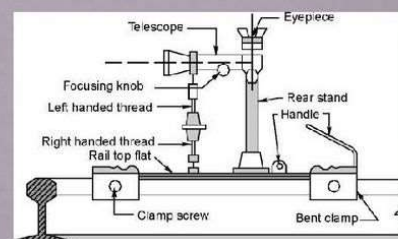


Fig. 20.9 (a) Viseur

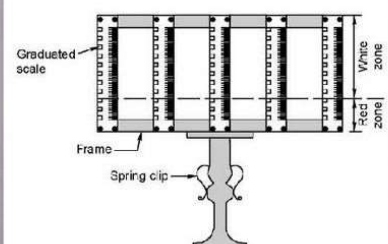


Fig. 20.9 (b) Mire

Viseur's Mire

(8) Cotters :

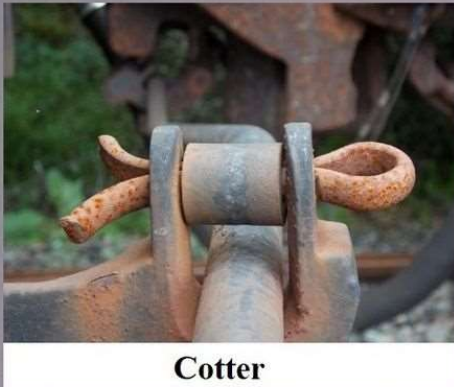
- It is used to fix tie bars with cast iron sleepers.

(9) Jim Crow :

- It is used to bend the rails or break the rails.



Lec-29 (48:10)



Cotter



Jim Crow



Jim Crow

Concepts of High Speed Trains :

- In Indian Railways :

High Speed : Speed greater than 120 kmph

Super high Speed : Speed greater than 250 kmph



Lec-30

- Following techniques are available for development of high speed train :

(i) Linear Motor and Wheel :

- Speed is developed upto 200 kmph.

(ii) Linear Motor and Air Cushion Vehicle :

- Here, speed upto 500 kmph is developed.

(iii) Gas Turbine and Air Cushion Vehicle :

- Here, speed upto 300 kmph is developed.

(iv) Magnetic Levitation Technique (MagLev) :

- Here, speed greater than 500 kmph can be developed.



Lec-30 (9:35)

— Superhigh speed trains have following limitations :

(a) Wave Formation :

- As speed of the trains exceed 250 kmph, the waves are formed in rails and travels at speed faster than that of train, which increases the creep.

(b) Adhesion b/w Wheels and Rails :

- As we know, for movement of train : $T_e \geq HC > \text{Total Resistance}$.
- Now, as $HC = \mu N$, with increase in speed, μ decreases, thereby heavy load of locomotive is reqd. to run the train.

(c) Problem on Curved Track :

- As centrifugal force $\propto v^2$, so maintaining superelevation and cant deficiency is very difficult.

(d) Vibrational Limitations :

- Due to high speed, high vibrations are observed.

NOTE :

(i) For speed > 130 kmph, CST-10, 11, 12 sleepers are used.

(ii) CST-9 sleepers are used upto speed 130 kmph.

↳ central standard Tial

— Elastic fasteners used for high speed trains include :

(a) Pandrol Clip

(b) Spring Steel Clip

Track Recording :

- For quantitative assessment of track, its parameters like unevenness, twist, superelevation, versines are noted with the help of 'Track Recording Car'.

Track Tolerance :

(a) Gauge tolerance recommended by IR for speed of 120 kmph :

on straight track : +6 mm to -3 mm

on curve upto 4° : +13 mm to -3 mm

on curve sharper than 4° : +19 mm

(b) Alignment Variations :

— On 7.5 chord length, the alignment variations are as follows :

(i) On straight track : ± 5 mm

(ii) On Curved track : ± 5 mm



Lec-30 (33:50)



Track Recording Car



Track Recording Car

New Methods of Track Maintenance :

(1) Mechanised Maintenance or Tamping :

(i) Off Track Tamping :

— These work in pairs from opposite sides of the sleeper under the soil rail seat to ensure maximum consolidation of the ballast.

(ii) On Track Tamping :

— Here, self propelled vehicles are used to tamp the sleepers.
— It offers higher control, efficiency and quality of work.



Off Track Tamper



Off Track Tamping



Off Track Tamping

(2) Measured Shovel Packing (MSP) :

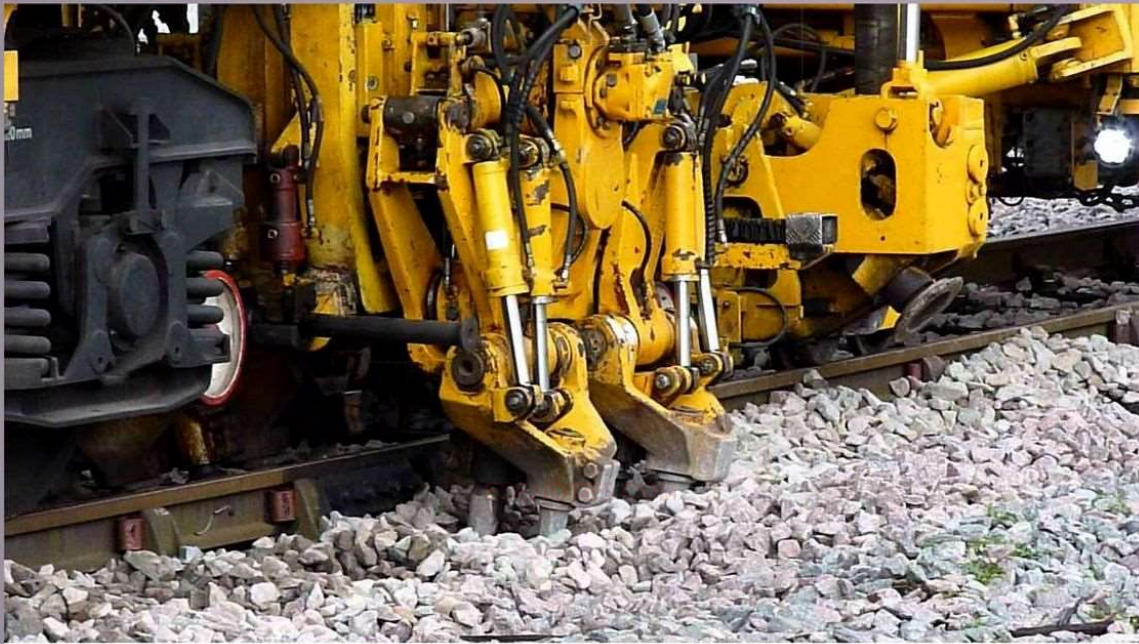
- In this, manual maintenance of the track is done without the use of highly sophisticated equipments.
- In this case, densometer, fleximeter, viscer's mire and shovel is used.



Lec-30 (43:05)

(3) Directed Track Maintenance (DTM) :

- Unlike conventional maintenance system, only specified track length is supervised and checked for track defects.



On Track Tamping