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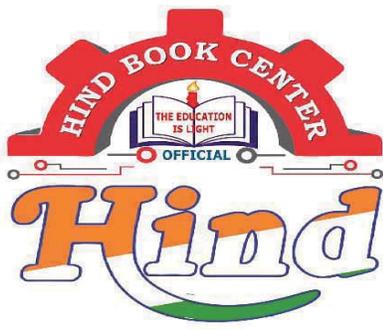
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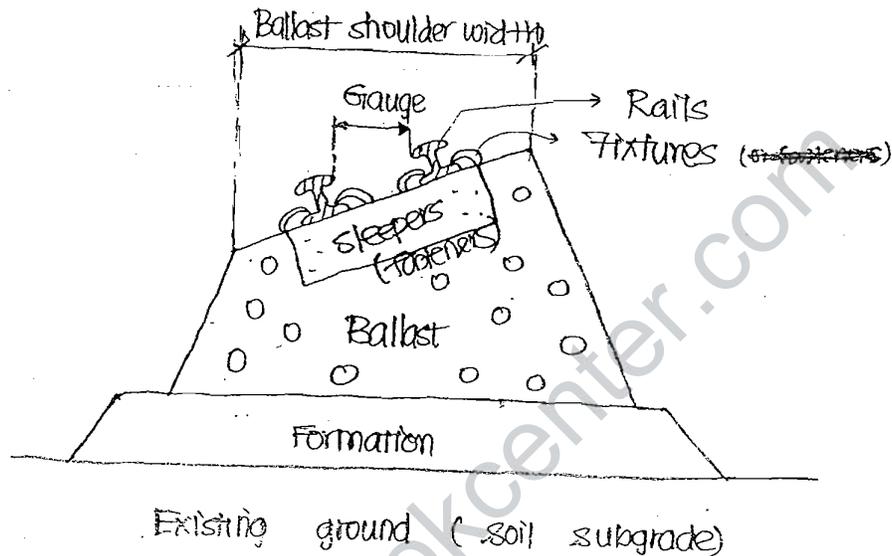
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## Railway Engineering

### # Introduction :

#### 1. Cross section of a railway track :



#### Important components :

(i) formation

(iv) Fixtures

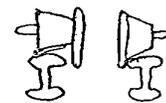
(ii) Ballast

(v) Rails.

(iii) sleeper

#### 2. Gauge :

Distance between inner faces of the two rails (running face) - Running face is the face on which flange of wheel will be there.



1. Broad Gauge (B.G) = 1.676 m

2. Meter Gauge (M.G) = 1.0 m

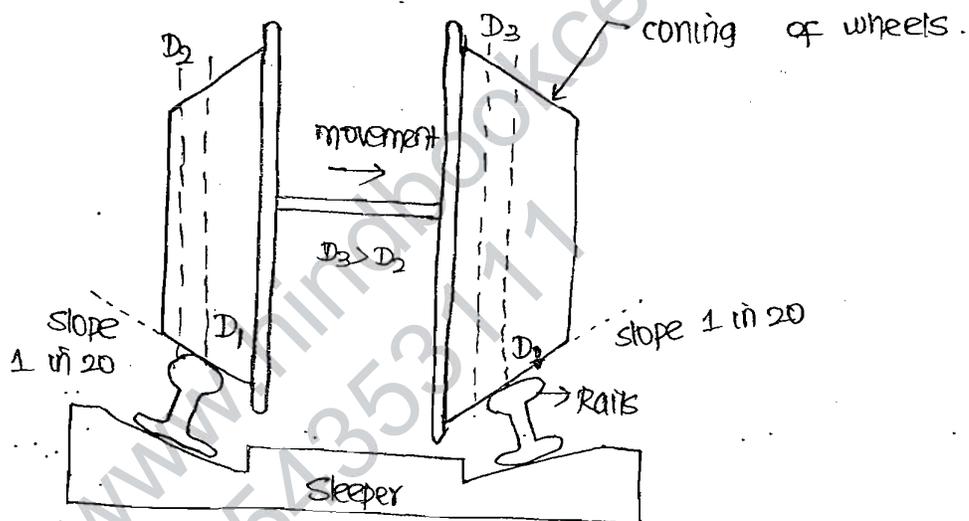
3. Narrow Gauge (N.G) = 0.762 m

4. light gauge (L.G) (Feeder track gauge) =  $0.610 \text{ m}^{1+2}$

5. standard gauge S.G) = 1.435 m (other countries & metro).

Coning of wheels :

#. The wheels are made cone shaped having different diameter at different cross section. Diameter near flange is more than diameter near other ends. The rails are also laid at a slope of 1 in 20 (same slope of wheel face). This is called coning of wheels.



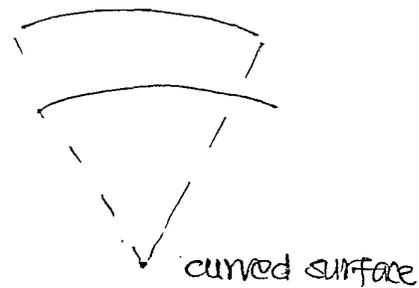
Purpose : ① on a straight track : to keep the wheel assembly in central position to avoid derailment.

② To reduce wear & tear of wheels as well as rails.

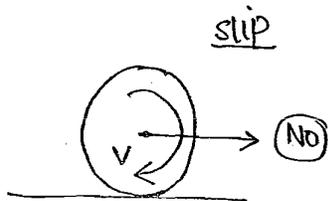
③ on a curved track : Due to centrifugal force, the wheel assembly will move in outward direction, so diameter on outer rail will increase. so the distance travelled in

outer rail will become more as required.

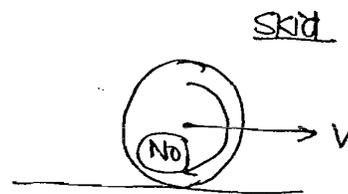
Due to difference of dia on two rails, the train will be moving on a circular track will be adjusted as



required. Only some part of difference is adjusted by coning. Remaining part is covered by slip or skid on the surface.



At the time of acceleration



At the time of brake

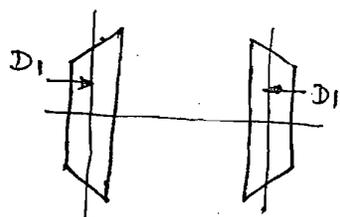
Theory :

Due to cone shaped wheels, dia of wheel is not same at each cross section.

on a straight track :

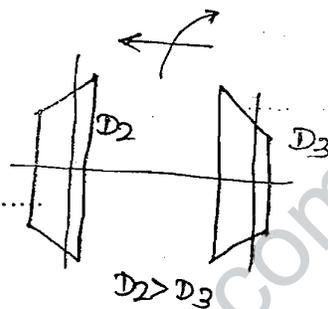
The wheel will always move in central position in such a way that diameter at contact point with rail is same on the two rails. If the train (axe of wheel) try to move in any direction, diameter of wheel on one rail will increase so the axle will

start moving on a circular track, thus the wheel assembly will be automatically returned back in its central position.



$$D_1 = D_1$$

central position



$$D_2 > D_3$$

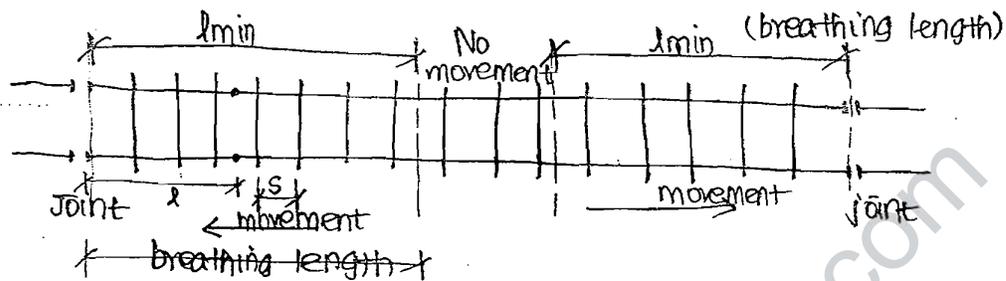
On a curved track: The distance on the two rails are partially adjusted due to centrifugal force due to which the train moves in outward direction, due to which dia on outer rail becomes more than dia. on inner rails.

### 3. Welded Rails (Long Welded Rails) LWR :

The rails are made of a particular length (for BG track, max. length 12.8 m is used). The joints to be provided in the railway tracks are one of the weakest locations. To avoid joints, rails are welded together.

⊕ Long welded rails are used where all the rails are welded for a long length. The stresses caused due to difference of temperature are arrested by the fixtures

and rails are not allowed to move. so no expansion joints are required. A minimum length is required to avoid the movement of rail due to temperature variation.



If  $l$  = length of rail on one side. Increase in length due to  $T^\circ$  temp. variation.

$$\delta l = l \cdot \alpha \cdot T$$

If no movement is allowed in the rail (strain not allowed)

$$= \frac{\delta l}{l} = \alpha T$$

$$\frac{\text{stress}}{\text{strain}} = E_s \quad (\text{Young's modulus of steel})$$

stress developed in rails due to not allowing the movement of rail.

$$\text{stress} = \text{strain} \times E_s$$

$$p = \alpha \cdot T \cdot E_s$$

Force developed in rails,  $P = A \times p$

$$P = A \cdot \alpha \cdot T \cdot E_s$$

This force will be resisted by the fasteners (sleepers)

If one sleeper can resist 'R' force, min. no of sleepers required to stop the movement of rail.

$$n = \frac{P}{R} = \frac{A \cdot \alpha \cdot T \cdot E_s}{R}$$

Min. length in one direction so that there is no movement in rail due to temp. variation.

$$(\Delta_{min})_{\text{one direction}} = (n-1)s$$

Minimum length of long welded rail (so that there is no movement at central position) =  $2\Delta_{min}$ .

⊕ In central position There is no movement of rail because sufficient number of sleepers are available in both direction to stop the movement.

⊕ Breathing length: At both ends upto  $\Delta_{min}$  distance from expansion joints, some movement of rail will be observed because no. of sleeper is less in one direction.

These two end portions are called breathing length.

Q.5.a Define & explain breathing length of LWR

ES2001

ii) Determine the min. theoretical length of LWR beyond which the central portion of a 52 kg rail would not be

subjected to longitudinal movement due to  $30^\circ\text{C}$  temp variation.

Use following data.

A. rails

$$C_s \text{ area} = 66.15 \text{ cm}^2$$

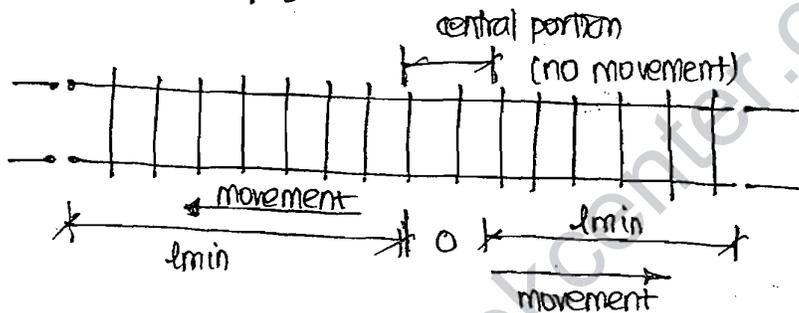
$$E_s = 2.1 \times 10^6 \text{ kg/cm}^2$$

$$\alpha = 11.5 \times 10^{-6} / ^\circ\text{C}$$

B. sleepers

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

$$\text{Average resistance force / sleeper / rail} = 300 \text{ kg.}$$



#. Due to temp. variation force developed in rail section.

$$P = A \cdot \alpha \cdot T \cdot E_s$$

$$= 66.15 \times 2.1 \times 10^6 \times 11.5 \times 10^{-6} \times 30$$

$$P = 47925.625 \text{ kg}$$

#. min. no. of sleepers req. to resist this force

$$n = \frac{47925.625}{300} = 159.75 \text{ i.e., } 160.$$

#. min. length in one direction

$$l_{\min} = (n-1) s = (160-1) \times 60 = 9540 \text{ cm}$$

$$= 95.4 \text{ m.}$$

(breathing length)

$$\#. \text{ min. length of LWR} = 2l_{\min} = 2 \times 95.4 = 190.8 \text{ m}$$

#### 4. Sleeper density :

#. Number of sleepers used for one rail is called sleeper density.

#. denoted by  $(n+x)$

$n \rightarrow$  length of one rail in meter (for BG track  
 $= 12.8 \text{ m} \approx 13 \text{ m}$ )

#. Generally sleeper density is kept from  $(n+3)$  to  $(n+6)$ .

Eg. calculate total no. of sleepers req. for 5 km railway track if sleeper density is  $n+5$  for a BG track.

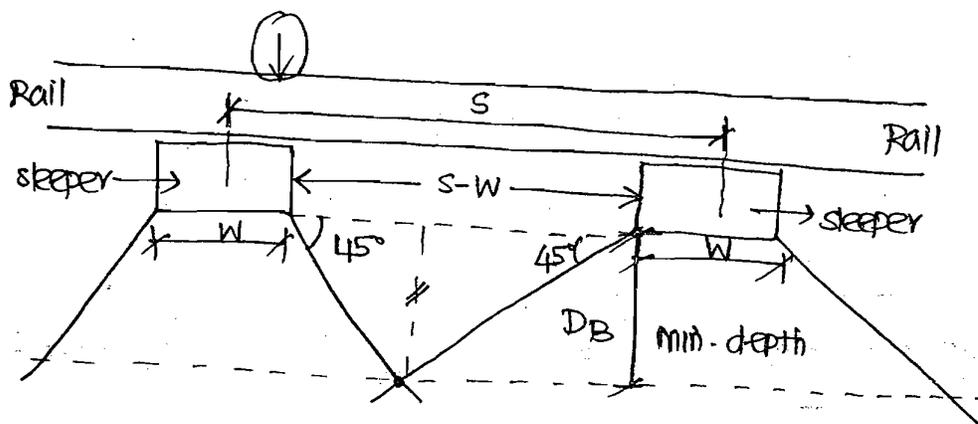
One rail length  $= 12.8 \text{ m} \approx 13 \text{ m}$

No. of sleepers used  $= (n+5) = (13+5) = 18$

Total no. of sleepers for 5 km  $= \frac{5000}{12.8} \times 18 = 7031.25$

say 7032 sleepers.

#### #. Minimum depth of Ballast cushion :



$DB \rightarrow$  depth of ballast.

If  $s$  = spacing of sleepers

$w$  = width of one sleeper

min. depth of ballast cushion required,  $D_g = \frac{s-w}{2}$  ✓

Geometrical design :

① Design speed :

Design speed shall be minimum of the following :-

- (i) max. speed allowed by railway (max. sanctioned speed)
- (ii) max. speed allowed on a curved track (as per radius)  
(speed as per Martin's formula).
- (iii) As per super elevation provided (super elevation or cant).
- (iv) As per length of transition curve.

#. Martin's formula :

(i) For transition curve : (where transition curve have been provided with simple curve).

a) for BG and M.G track :

$$V = 4.35 \sqrt{R-67} \quad (\text{kmph})$$

b) for N.G track :

$$V = 3.6 \sqrt{R-6.1} \quad (\text{kmph})$$

$R \rightarrow$  radius of curve in meters.

2. For non-transitioned curve: (only simple curve is provided)

$V = 80\%$  of design speed for transitioned curve.

a) for B.G and M.G track:

$$V = 0.8 \times 4.35 \times \sqrt{R - 67}$$

b) for N.G track:

$$V = 0.8 \times 3.6 \times \sqrt{R - 6.1}$$

3. For high speed train:

$$V_{\max} = 4.58 \sqrt{R} \quad (\text{kmph})$$

$R \rightarrow$  radius in meter.

#. Martin's formula is used for calculating max. speed

allowed on a curve location. (be'z all formulae depends on R).  $R \rightarrow$  radius of curve in meter.

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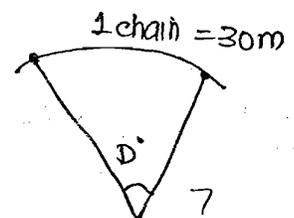
#. Radius of curve / Degree of curve:

$\rightarrow$  Degree of curve is the angle formed at centre by 1 chain length of the curve.

1. For 30m chain:

$$D^\circ = \frac{1718.9}{R}$$

$$\frac{2\pi R}{360} = \frac{30m}{D^\circ} \Rightarrow \boxed{D^\circ = \frac{1720}{R}}$$



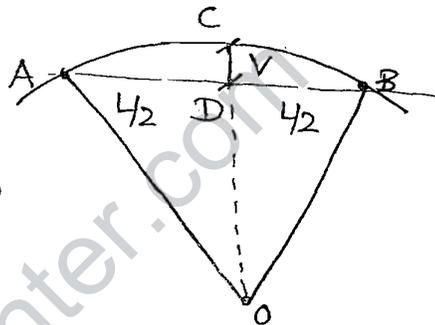
2. For 20m chain :

$$D^\circ = \frac{1146}{R}$$

	1°	2°	3°	4°	5°
30m	1720	860	573	430	344
20m	1146	573	382	287	230

#. versine of curve :

For a chord AB of length L as shown in fig, distance CD is called versine of curve.



Using property of circle,

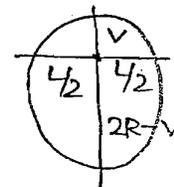
$$\frac{L}{2} \times \frac{L}{2} = V(2R - V)$$

$$= 2R \cdot V$$

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

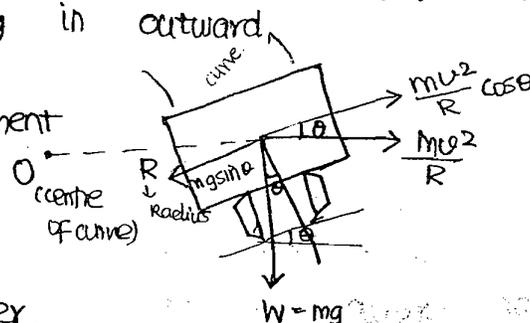
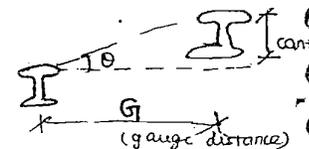
(versine of curve).

$$2R - V \approx 2R$$



# Cant (super elevation) :

When the train is moving on a horizontal curve, centrifugal force will be acting in outward radial direction. To avoid the derailment of train due to centrifugal force outer rails are provided at higher elevation w.r to inner rails to counteract the effect of centrifugal force.



Curve horizontal  $\rightarrow$  centrifugal force horizontal.

Curve inclined  $\rightarrow$  centrifugal force inclined.

$W =$  weight of train

In this case, there is no force of friction between rail and wheel in lateral direction.

outward force along surface of rail = component of weight in inward direction.

$$\frac{mv^2}{R} \cos \theta = mg \sin \theta \Rightarrow \boxed{\tan \theta = \frac{v^2}{gR}} \rightarrow (1)$$

$$\tan \theta = \frac{\text{cant}}{G} \Rightarrow \text{cant} = G \cdot \tan \theta = \frac{G \cdot v^2}{gR} \rightarrow (2)$$

If  $V \rightarrow$  speed in kmph

$$v = \frac{1000 V}{3600} = 0.278 V$$

$$\text{cant} = \frac{G \times (0.278 V)^2}{g \cdot R} = \frac{GV^2}{127R}$$

$$\boxed{\text{cant} = \frac{GV^2}{127R}} \rightarrow (A) \quad \underline{\text{cant formula}}$$

$G = 1.676 \text{ m}$  for B.G.

$= 1.0 \text{ m}$  for M.G.

# Equilibrium speed :

Different trains move with different speeds on a track. So an average cant is provided so that all

type of trains can safely run on the track avoiding the chance of derailment.

1. If max. speed ( $V_{max}$ ) > 50 kmph

Equilibrium speed =  $\frac{3}{4} V_{max}$  (or) safe speed as per Mann's formula. (minimum of two).

2. If max. speed ( $V_{max}$ ) < 50 kmph

Equilibrium speed =  $V_{max}$ . (or) safe speed by Mann's formula.

3. Equilibrium speed based on weighted average :

$$V_{eq} = \frac{n_1 V_1 + n_2 V_2 + n_3 V_3 + \dots}{n_1 + n_2 + n_3 + \dots}$$

where  $n_1, n_2, n_3, \dots$  are no. of trains running at  $V_1, V_2, V_3, \dots$  speed.

#. Max. limit of Actual super elevation (cant) provided on the track :

	When speed < 120 kmph	When speed > 120 kmph
B.G	16.50 cm	18.50 cm
M.G	10.0 cm	— x —
N.G	7.6 cm	— x —