



Transportation Engineering II: Highway Design & Railways

Lecture 8 GEOMETRIC DESIGN

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Geometric Design



- Necessity
 - Carry maximum possible load
 - Ensure smooth and safe running
 - Achieve maximum speed
 - Avoid accidents and derailments due to errors in permanent way
 - Ensure minimum maintenance
 - Ensure good aesthetics
- Design parameters
 - Gradients
 - Curvature
 - Alignment

Track Resistance



- When a train moves along the track, the following resistive forces are in action:
 1. Frictional resistance
 2. Resistance due to wave action
 3. Wind resistance
 4. Resistance due to gradient
 5. Resistance due to curves
- Train moves forward when
 - Hauling power of train > Resistive forces

1. Frictional Resistance



- Trains are subjected to two types of frictional resistance:
 - Internal: moving parts of locomotive and wagon, depends on type of internal joints, lubricant used, temperature, etc.
 - Rolling: due to rail-wheel interaction, at the contact surface of wheels and rail

Total frictional resistance, which is **independent of speed**, is given by the following empirical formula:

$$R_1 = 0.0016W; \quad \text{where } R_1 = \text{the frictional resistance independent of speed} \\ W = \text{the weight of train in tonnes}$$

2. Resistance due to Wave Action



- Moving trains are subjected to additional resistance due to wave action of wheels
 - Deflection of rail just under the wheel
 - As wheels move, depression also moves forward, previous version springs back
 - Causes 'creep of rail'

To calculate these resistances precisely the following empirical formula has been evolved:

$R_2 = 0.00008 WV$; where R_2 = the resistance due to wave action and track irregularities on account of the speed of the train
 W = the weight of train in tonnes
 V = speed of train in kmph

Creep of Rail



- The gradual longitudinal movement of the rail with respect to the sleepers
 - Occurs in the direction of dominant traffic
 - Magnitude can vary from several cm / month to negligible
 - More prominent in unidirectional tracks
- Checked as part of routine maintenance

3. Resistance due to Wind



- Moving trains are subjected to wind resistance
- Magnitude depends on
 - Exposed area of train
 - Velocity of train
 - Velocity of wind
 - Direction of wind

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3. Resistance due to Wind

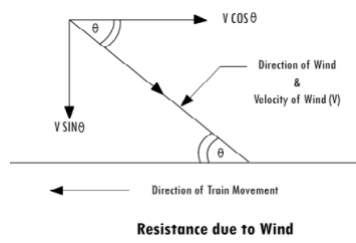


In fig., V = velocity of wind at an angle θ . The horizontal component of the wind $V \cos \theta$ opposes the movement of train. The wind resistance can be obtained by the following formula :

$$R_3 = 0.000017 AV^2; \quad \text{where } A = \text{Exposed area of vehicle in sqm} \\ V = \text{Velocity of wind in Kmph.}$$

Alternatively,

$$R_3 = 0.0000006 WV^2; \quad \text{where } R_3 = \text{Wind resistance} \\ V = \text{Velocity of wind in kmph} \\ W = \text{Weight of the train}$$



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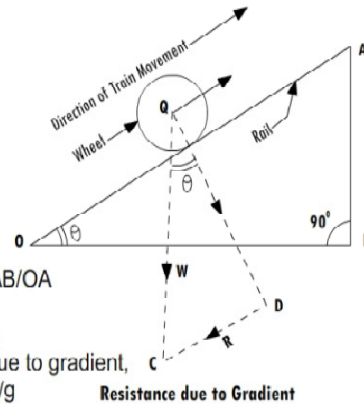
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4. Resistance due to Gradient



- Movement against gravity
- Forces
 - Weight W
 - Normal pressure N
 - Friction R

The above three forces meet at a common point Q and the triangle QCD can be taken as a triangle of forces. It can also be proved geometrically that the two triangles QCD and AOB are similar.



From $\triangle QCD$, $R = W \sin \theta$ From $\triangle OAB$, $R = W \frac{AB}{OA}$

In actual practice gradients are very small and OA is approximately equal to OB . Therefore; Resistance due to gradient,
 $R_4 = W \frac{AB}{OB} = (W \times \text{rate of slope}) = W/g$

Resistance due to Gradient