DI04006071: Railway, Harbour & Tunnel Engineering

Lecture 2.12: Lecture 12: Super Elevation and Safe Speed on Curves

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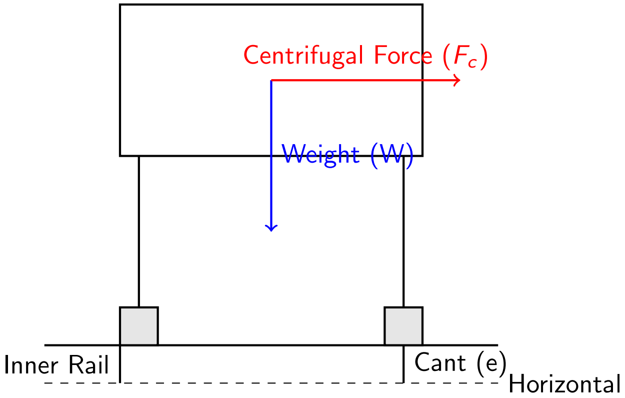
Introduction to Super Elevation (Cant) I

Super elevation, or cant, is the raising of the outer rail above the inner rail on a curve. Its primary purpose is to counteract the effect of centrifugal force, ensuring equal distribution of wheel loads on both rails. This reduces wear and tear, provides a comfortable ride for passengers, and allows for higher speeds on curves.

Key Points

- Counteracts centrifugal force acting on trains.
- Equalizes load distribution between inner and outer rails.
- Improves passenger comfort by reducing lateral acceleration.
- Prevents derailment due to overturning or high lateral forces.

Forces Acting on a Train on a Curve I



Forces acting: Weight (W) downwards, Centrifugal Force (F_c) outwards

Forces Acting on a Train on a Curve II

Key Points

- The weight of the train (W) acts vertically downwards.
- Centrifugal force ($F_c = \{}frac{Wv^2}{gR}$) acts horizontally outwards.
- The resultant force must ideally be perpendicular to the track plane.

Equilibrium Super Elevation I

Equilibrium super elevation is the exact amount of cant required so that the resultant of the weight and centrifugal force is perpendicular to the plane of the rails. At this state, the pressure on both rails is equal. The formula for equilibrium cant is given by $e = \{}frac{GV^2}{127R}$, where e is in cm, G is gauge in cm, V is speed in kmph, and R is radius of curve in meters.

Key Points

- Formula: $e = \{}frac{GV^2}{127R}$ (Metric units).
- $G = 167.6$ cm for Broad Gauge (BG), 100 cm for Meter Gauge (MG).
- Ensures equal wheel loads on inner and outer rails.
- Real trains travel at different speeds, so equilibrium cant is calculated for an average speed.

Maximum Super Elevation I

A track carries trains at various speeds, from slow freight to fast passenger trains. Providing equilibrium cant for the fastest train would make the outer rail too high, risking overturning of slow-moving trains inwards due to excessive cant. Therefore, railway authorities specify a maximum permissible super elevation.

Key Points

- Indian Railways limits max cant based on gauge.
- For Broad Gauge (BG): Max $e = 16.5$ cm (under normal conditions).
- For Meter Gauge (MG): Max $e = 10.0$ cm.
- For Narrow Gauge (NG): Max $e = 7.6$ cm.

Cant Deficiency I

Cant deficiency occurs when a train travels at a speed higher than the equilibrium speed for the provided super elevation. The provided cant is less than what is required for that higher speed. This results in a higher lateral force towards the outer rail and passenger discomfort.

Key Points

- $D = e_{theoretical} - e_{provided}$
- Maximum permissible cant deficiency for BG is typically 7.6 cm (up to 100 kmph) and 10.0 cm (for speeds $>$ 100 kmph).
- For MG, max cant deficiency is 5.1 cm.
- Limits are set to ensure safety against derailment and maintain passenger comfort.

Limiting Values of Super Elevation and Cant Deficiency I

Railway codes define strict limits for both maximum super elevation and maximum cant deficiency based on the gauge of the track to ensure safe operations across varying train speeds.

Gauge	Max Super Elevation (cm)	Max Cant Deficiency (cm)
Broad Gauge (BG)	16.5	7.6 (normal), 10.0 (high speed)
Meter Gauge (MG)	10.0	5.1
Narrow Gauge (NG)	7.6	3.8

Key Points

- Max Super Elevation (BG): 16.5 cm
- Max Cant Deficiency (BG): 7.6 cm to 10.0 cm
- Max Cant Excess: Typically limited to 7.5 cm (BG)

Safe Speed on Curves I

Safe speed on a curve is the maximum speed at which a train can negotiate the curve without the risk of derailment or excessive discomfort. It depends on the radius of the curve, the provided super elevation, and the allowable cant deficiency.

Key Points

- Safe speed $V = \{}sqrt{\{}frac{127R(e + D)}{G}}$ (where e is provided cant, D is cant deficiency).
- Martin's formula is also used: For BG/MG, $V = 4.35 \{}sqrt{R - 67}$ (transitioned) or $V = 4.4 \{}sqrt{R - 70}$ (non-transitioned, BG).
- The lowest of the speeds calculated from super elevation criteria and Martin's formula is taken as the safe speed.
- Also limited by the maximum sanctioned speed of the section.

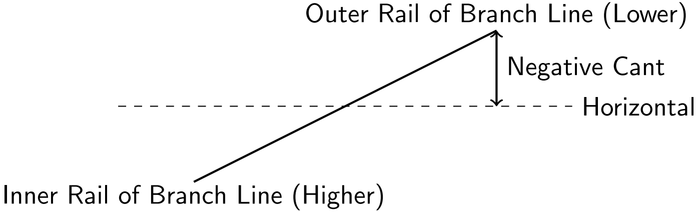
Example Calculation: Equilibrium Cant I

Let's consider a practical example. Calculate the equilibrium super elevation for a 2 degree curve on a Broad Gauge track, if the average speed of trains is 60 kmph.

Key Points

- Radius of a 2 degree curve $R = \{}frac{1720}{D} = \{}frac{1720}{2} = 860$ m.
- Gauge for BG $G = 167.6$ cm.
- Speed $V = 60$ kmph.
- $e = \{}frac{GV^2}{127R} = \{}frac{167.6 \{}times 60^2}{127 \{}times 860} = \{}frac{167.6 \{}times 3600}{109220} = 5.52$ cm.

Negative Super Elevation I



Branch line curving opposite to main line cant direction

Negative Super Elevation II

Key Points

- Occurs at turnouts where a branch line takes off in a direction contrary to the main line curve.
- The outer rail of the branch line is forced to be lower than its inner rail because it shares the inner rail of the main line curve.
- Speeds on branch lines with negative super elevation must be severely restricted.

Controlling Speed for Negative Cant I

Because negative cant is inherently unsafe for higher speeds as it adds to the centrifugal force effect rather than countering it, the speeds on such turnouts are heavily restricted.

Key Points

- The permissible speed on the branch line is calculated considering the negative cant as the "provided" cant (which is a negative value).
- $V_{branch} = \{}sqrt{\{}frac{127R(D_{max} - x)}{G}}$, where x is the negative cant.
- Typical speeds on such turnouts are restricted to 15 kmph or lower depending on the turnout angle and curvature.
- Avoided in new designs where possible, by locating turnouts on straight alignments.

Summary I

In this lecture, we discussed the critical role of super elevation in counteracting centrifugal forces on curves. We covered the limits of maximum super elevation, the concept of cant deficiency for varying train speeds, methods to calculate safe speeds, and the special condition of negative super elevation at turnouts.

Key Points

- Super elevation ensures equal load distribution and passenger comfort.
- Cant deficiency allows faster trains to safely navigate curves with average cant.
- Safe speed is dictated by gauge, radius, provided cant, and allowed deficiency.
- Negative cant at turnouts necessitates severe speed restrictions.