DI04006071: Railway, Harbour & Tunnel Engineering

Lecture 2.10: Relation between radius and versine of a curve

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Civil Engineering

July 23, 2026

Introduction to Curves in Railways I

Curves are provided on railway tracks to bypass obstacles, connect important locations, and adapt to the natural topography. The geometry of a curve is primarily defined by its radius or degree of curvature, which dictates the maximum permissible speed and the required superelevation.

Key Points

- Facilitates smooth change in direction of motion.
- Defined by radius (R) in meters or degree (D).
- Sharp curves have smaller radii and higher degree.
- Proper maintenance of curve geometry is critical for safety.

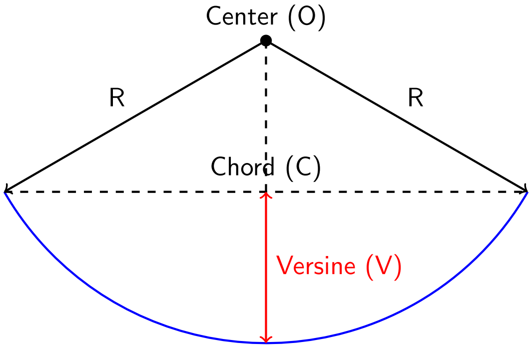
Definition of Chord and Versine I

In track maintenance and design, a chord is a straight string line stretched between two points on the inner face of the outer rail of a curve. The versine is the perpendicular distance from the midpoint of this chord to the gauge face of the rail.

Key Points

- Chord (C): Straight line connecting two points on a curve.
- Versine (V): Mid-ordinate of the chord.
- Versine provides a practical way to measure curvature in the field.
- Uniform versines indicate a perfectly circular curve.

Geometry of a Curve and Versine I



Geometry of a Curve and Versine II

Key Points

- Arc represents the railway track curve.
- Versine is measured at the exact midpoint of the chord.
- Radius R originates from the curve center O.

Derivation of the Relationship (Part 1) I

Let R be the radius of the curve, C be the length of the chord, and V be the versine. By applying the intersecting chords theorem or the Pythagorean theorem to the right-angled triangle formed by the radius, half-chord, and the remaining portion of the radius, we can establish an equation.

Key Points

- Hypotenuse = R
- Base = C/2
- Height = R - V
- Pythagoras: $R^2 = (C/2)^2 + (R - V)^2$

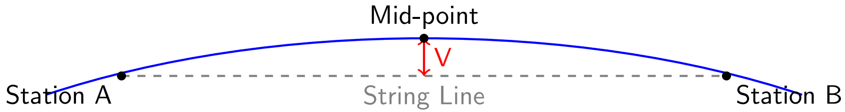
Derivation of the Relationship (Part 2) I

Expanding the equation gives $R^2 = C^2/4 + R^2 - 2RV + V^2$. Since the versine V is very small compared to the radius R, the term V^2 can be neglected. This simplification yields the practical formula used extensively in railway engineering for track alignment.

Key Points

- $0 = C^2/4 - 2RV$ (ignoring V^2)
- $2RV = C^2/4$
- Formula: $V = C^2 / 8R$
- V and C must be in the same units, or adjusted accordingly.

Field Measurement of Versine I



Key Points

- A string line of standard length (e.g., 20m) is used.
- Ends of the string are held against the running edge of the outer rail.
- Versine is measured using a graduated scale at the center of the chord.

Typical Versine Values for Standard Chords I

Degree (D)	Radius (m)	Versine for 20m chord (mm)
1°	1750	28.5
2°	875	57.1
3°	583.3	85.7
4°	437.5	114.3

Key Points

- Standard chord length of 20 meters is commonly used on Broad Gauge tracks.
- Formula used: $V = 114.6 \times D$ (in mm) for 20m chord.
- Higher degree of curve implies a smaller radius and larger versine.

Effect of Speed and Curvature I

The allowable speed on a railway curve depends heavily on the radius. Since the versine is inversely proportional to the radius, a larger versine indicates a sharper curve, which in turn necessitates a lower speed limit to ensure passenger comfort and prevent derailment.

Key Points

- Centrifugal force increases significantly on sharper curves.
- Maximum speed is restricted based on field versine measurements.
- Transition curves are provided to gradually increase the versine from zero.
- Sudden, irregular changes in versine indicate bad track alignment.

Super-elevation (Cant) and Versine I

Superelevation is the raising of the outer rail over the inner rail to counteract centrifugal force. The required superelevation is directly proportional to the curvature, meaning it can be correlated with the measured versine on a standard chord.

Key Points

- Required cant is inversely proportional to radius R.
- Since $1/R$ is proportional to Versine, Cant is proportional to Versine.
- Track maintainers adjust cant simultaneously with versine correction.
- Ensures equilibrium speed is maintained safely during train operations.

Curve Realignment using Versines I

Over time, traffic loads cause curves to distort from their ideal circular shape. Track maintainers use the string-line method to measure existing versines at regular stations, calculate the ideal versines, and determine the necessary slews (shifts) to restore the curve geometry.

Key Points

- String-lining method is simple and requires no heavy surveying instruments.
- Sum of existing versines equals the sum of proposed versines.
- Slew values dictate how much the track must be shifted laterally.
- Modern tamping machines use electronic versine measurement systems.

Summary and Conclusion I

The relationship between the radius and versine is a fundamental concept in railway engineering, essential for curve layout, track maintenance, and ensuring safe train operations. The simple formula $V = C^2 / 8R$ forms the basis of all practical field alignment corrections.

Key Points

- Versine is the mid-ordinate of a chord on a curve.
- The relation $V = C^2 / 8R$ is derived from basic geometry.
- The string-line method is the practical application of this relation.
- Regular versine checks prevent derailments and ensure a smooth ride.