Highway Pavement

Civil Engineering Department

4th stage, 2nd Semester, 2019-2020

4th Lecture: Horizontal Alignment

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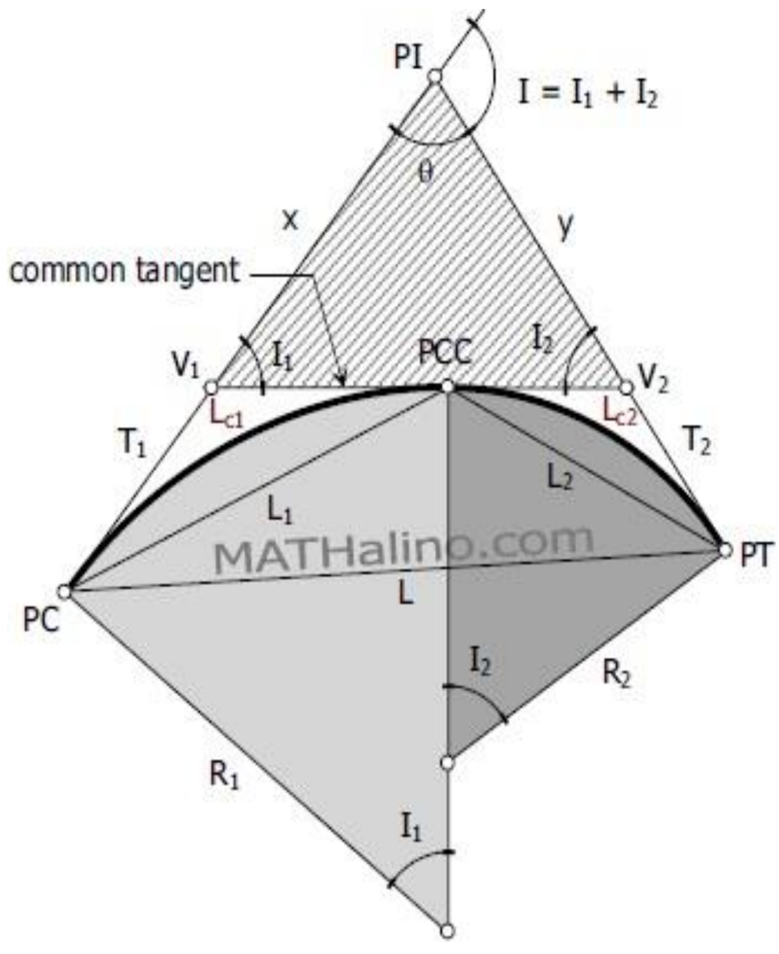
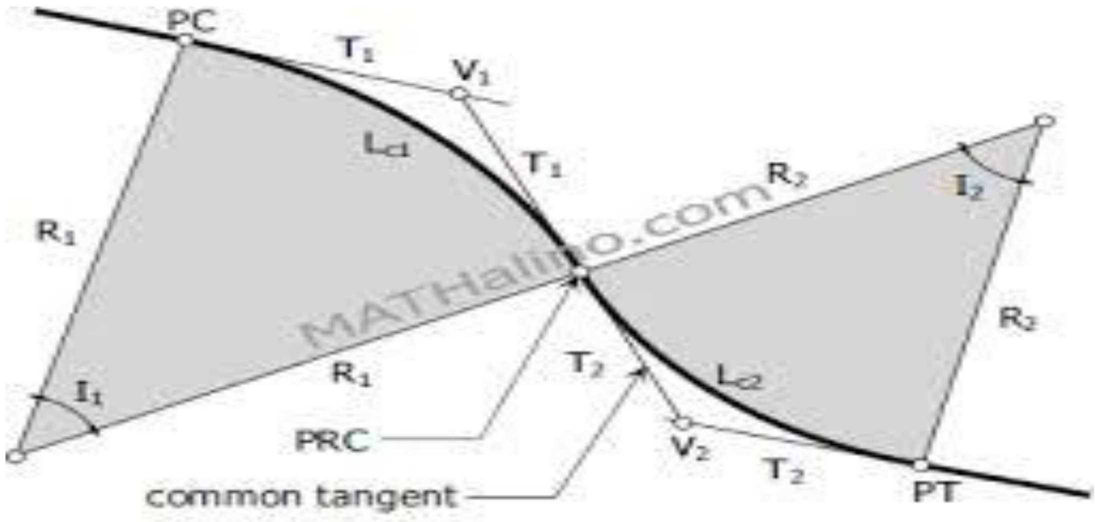
Compound Circular Curves; which consist of 2 or more circular curves having two or more radiuses & deflection angles.



Compound Curves

Reverse Circular Curves consist of two simple curves with two radii turning in opposite direction with a common tangent.



Reversed Curve

Transition or Spiral curves; which are placed between tangents and circular curves or between two adjacent circular curves with substantially different radii. Spiral curves are continuously changing radius curves. Needed where $R_c < 1000$ m

a- Spiral or clothoid

b- Cubic spiral

c- Cubic parabola

d- Lemniscates

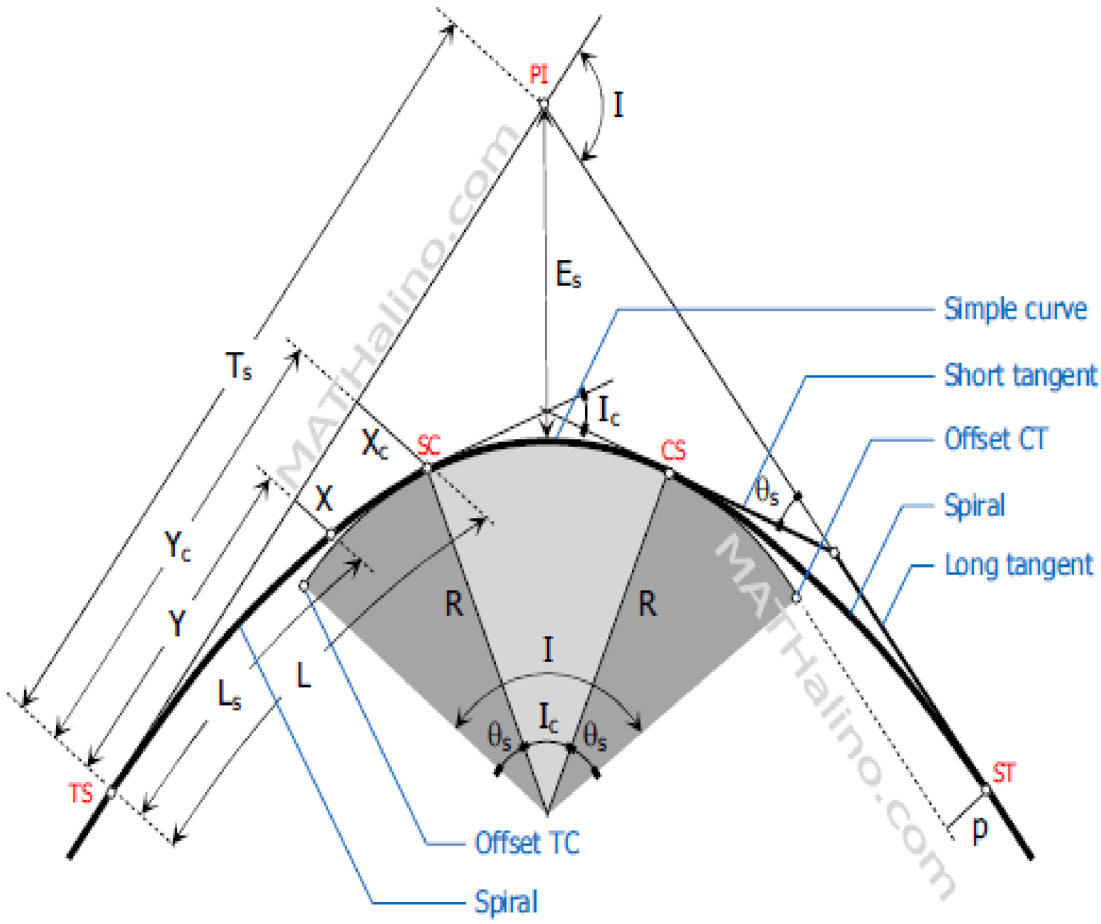
Function:

1. To introduce gradually centrifugal force between the tangent point (0) and the beginning of the circular curve $\frac{v^2}{R_c}$

2. To enable the driver turn steering gradually for his own comfort.

3. To enable gradual introduction of the designed super elevation and extra widening.

Elements of Spiral Curves:



- TS = Tangent to spiral SC = Spiral to curve
- CS = Curve to spiral ST = Spiral to tangent
- LT = Long tangent ST = Short tangent
- R = Radius of simple curve T_S = Spiral tangent distance
- T_C = Circular curve tangent L = Length of spiral from TS to any point along the spiral
- L_S = Length of spiral PI = Point of intersection
- I = Angle of intersection I_C = Angle of intersection of the simple curve

$$L_S = \frac{V^3}{46.5 * C * R_C}$$

$$C = radial\ acceleration = centripeted\ acceleration = 0.3 - 0.6\ \frac{m}{sec^3}$$

$$\theta_s = \frac{L_S}{2\,R_C}$$

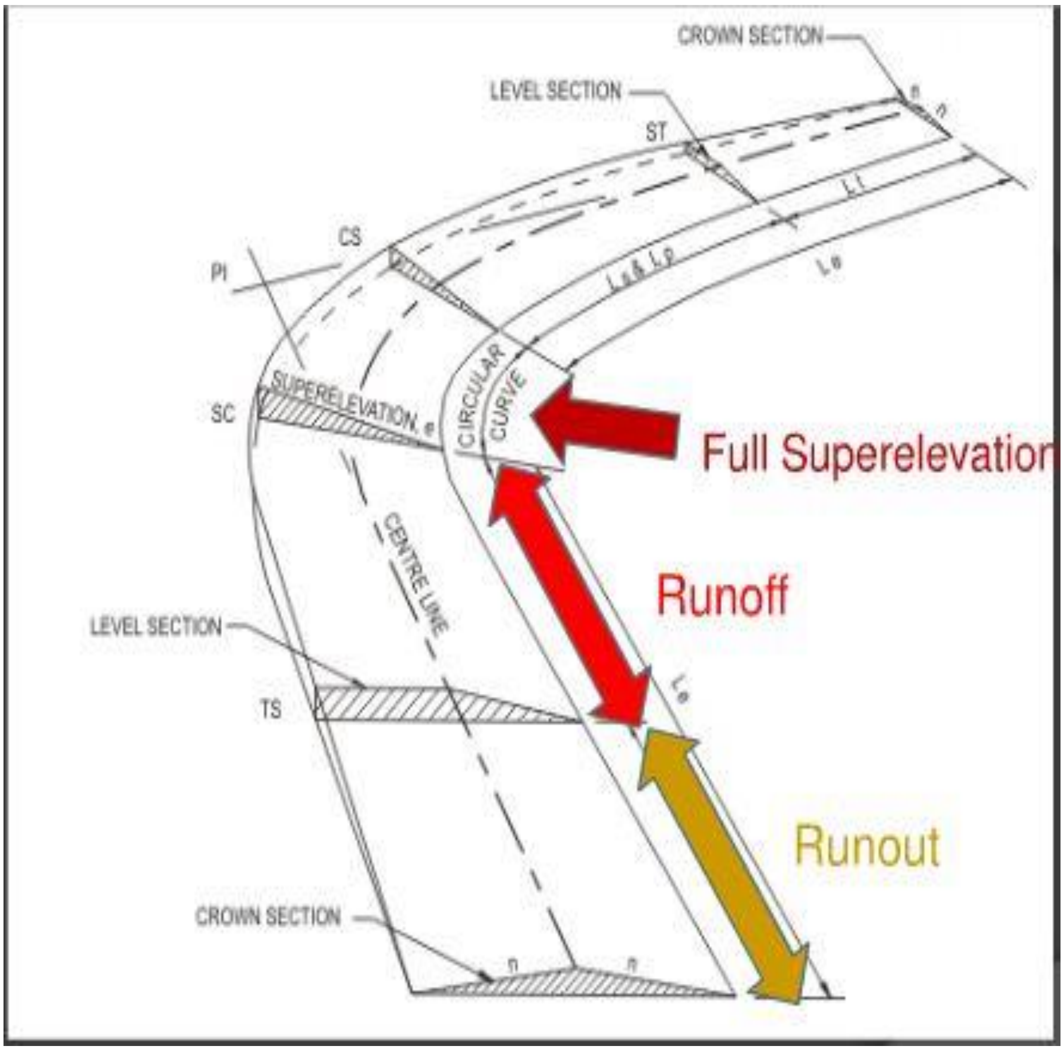
$$\theta_C = \Delta - 2\,\theta_S$$

$$L_C = \theta_C * R_C$$

$$\frac{100}{D} = \frac{L_C}{\theta_C}$$

Transition spiral curve needed where $R_C \leq 1000$m

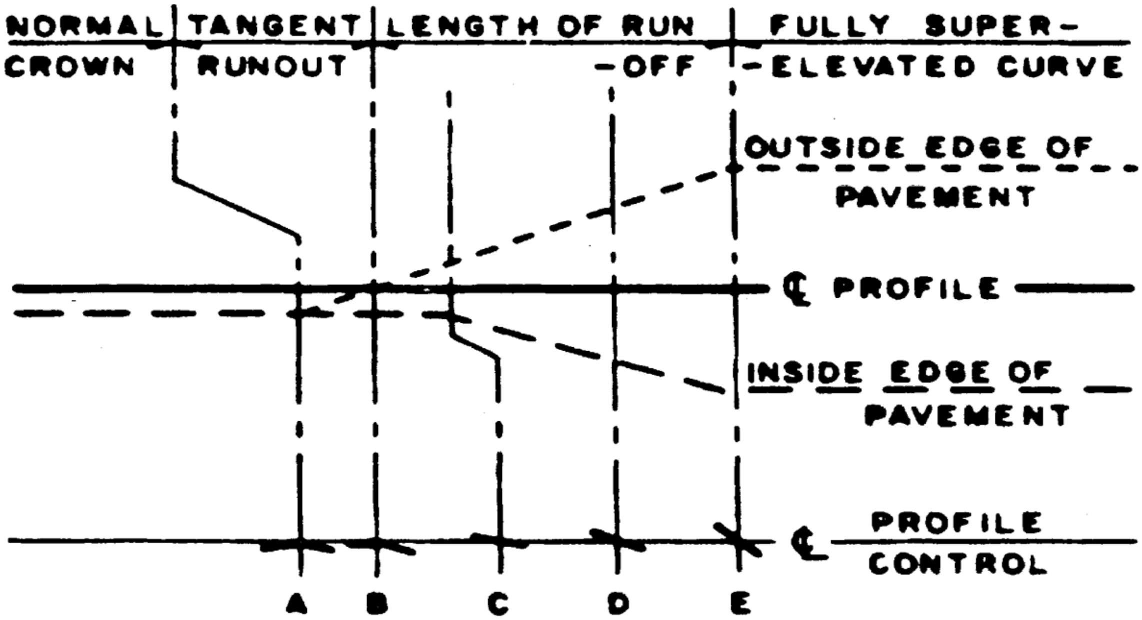
Superelevation Transition



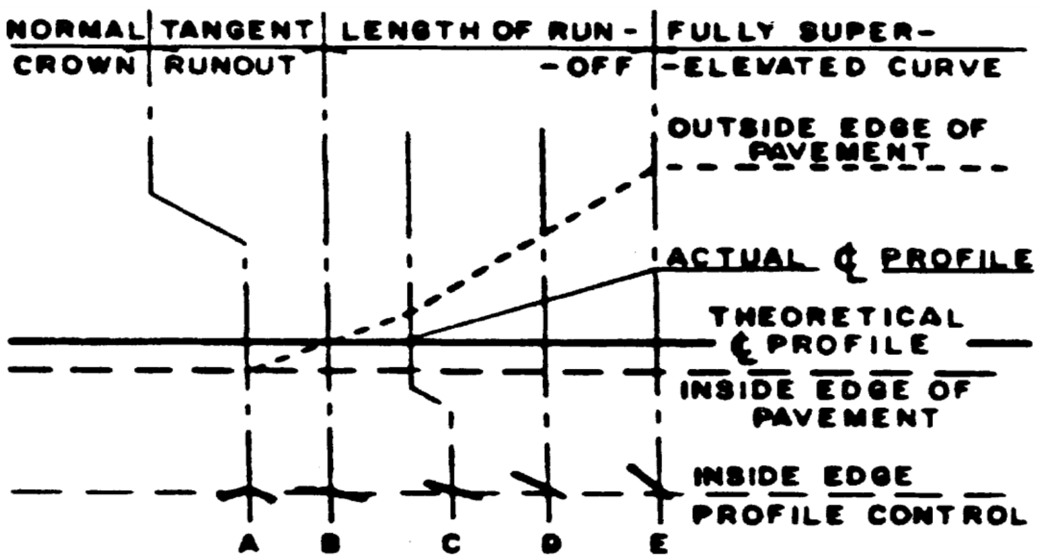
Consist of Tangent Runout and Superelevation Runoff section.

Runout: length of roadway needed to accomplish a change in outside lane cross slope from normal rate to zero.

Runoff: length of roadway needed to accomplish a change in outside lane cross slope from zero to full.



(a) Crowned pavement revolved about centerline



(b) Crowned pavement revolved about inside edge

Ex1: A section of 4-lanes rural highway is following a circular horizontal curve around a hill located at a distance of 10m from the inside edge of pavement. Determine the desired superelevation rate required for adopting a safe speed of 110 Km/hr assuming that pavement surface provided the following coefficients: braking friction= 0.35, sliding friction = 0.12

Solution:

Ex 1:

$$R = \frac{S^2}{8M}$$

$$M = 10 + \frac{4}{2} = 12m$$

$$S = 0.278Vt + \frac{V^2}{254\,(f_b \mp g)}$$

$$S = 0.278 * 2.5 * 110 + \frac{110^2}{254\,(0.35)} = 212.6m$$

$$R = \frac{(212.6)^2}{8 * 12} = 471m$$

$$R = \frac{V^2}{127(e + f_s)}$$

$$471 = \frac{110^2}{127(e + 0.12)} \rightarrow e = 0.08$$

Ex2: Determine the rate of centripeted acceleration on a section of highway (design speed = 130 Km/hr) following the horizontal circular curve by a transition spiral (200m in length)? f_s= 0.12, e= 0.1

Solution:

Ex2:

$$R = \frac{V^2}{127(e + f_s)} = \frac{130^2}{127(0.1 + 0.12)} = 604.8m$$

$$L_S = \frac{V^3}{46.5\ C\ R}$$

$$200 = \frac{130^3}{46.5 * C * 604.8} \rightarrow C = 0.47 \frac{m}{sec^3}$$

Ex3: For the vertical alignment of a rural highway section a +5% grade meets a -3% grade at a point located on the underside of an over passing bridge which is leaving a clearance of 6m above pavement surface. Determine the minimum radius of the circular horizontal alignment required at this section? Braking coefficient of friction = 0.45, Sliding coefficient of friction = 0.15, Super elevation rate = 0.1

Solution:

Ex3:

$$e = \frac{AL}{8}$$

$$A = |g_2 - g_1|$$

$$= |-3-5| = 8$$

$$\therefore 6 = \frac{8 * L}{8} \rightarrow L = 6\ st = 600m$$

$$S \leq L$$

$$L = \frac{8\,S^2}{658}$$

$$600 = \frac{8 * S^2}{658} \rightarrow S = 222.1m$$

$$S = 0.278Vt + \frac{V^2}{254(f_b \mp g)}$$

$$222.1 = 0.278 * V * 2.5 + \frac{V^2}{254(0.45 - 0.05)}$$

$$\rightarrow V = 119Km/hr$$

$$R = \frac{V^2}{127(e + f_s)}$$

$$= \frac{119^2}{127(0.1 + 0.15)} = 446m$$

$$L_{min}(m) = \frac{AS^2}{200\,(\sqrt{h_1} + \sqrt{h_2})^2}$$

(A: %, S: m)

h_1: height of driver eye above pavement surface (m)

h_2: height of hazardous object (m)

* ***For safety:***

→ *S stopping: h_1 = 1.08m, h_2 = 0.6m (height of object)*

$$200\,(\sqrt{h_1} + \sqrt{h_2})^2 = 658$$

→ *S passing: h_1 = 1.08 m, h_2 = 1.08 m (height of vehicle)*

$$200\,(\sqrt{h_1} + \sqrt{h_2})^2 = 864$$

Ex 4: Determine the length of a circular curve that provided with a two transition curves if the following is known: V = 130 Km/hr, D = 10°, Δ = 120°.

$$R = \frac{5730}{D} = \frac{5730}{10} = 573\,m$$

$$L_S = \frac{V^3}{46.5\,C\,R} = \frac{130^3}{46.5 * 0.45 * 573} = 183\,m$$

$$\theta_S = \frac{L_S}{2\,R} = \frac{183}{2 * 573} = 0.16\ in\ radian$$

$$\therefore \theta_S = 0.16 * \frac{180}{\pi} = 9.14^\circ$$

$$\Delta = \theta_C + 2\,\theta_S \rightarrow \theta_C = 120 - 2 * 9.14$$

$$\therefore \theta_C = 101.72^\circ$$

$$\frac{100}{D} = \frac{L_C}{\theta_C}$$

$$\therefore L_C = 100 * \frac{101.72}{10} = 1017.2\,m \approx 1017\,m$$