CE 380

Highway and Traffic Engineering

Lec 4

Geometric Design (Horizontal Alignment)

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Geometric design

Geometric design: for transportation facilities includes the design of geometric cross sections, horizontal alignment, vertical alignment, intersections, and various design details. These basic elements are common to all linear facilities, such as roadways, railways, and airport runways and taxiways. Although the details of design standards vary with the mode and the class of facility, most of the issues involved in geometric design are similar for all modes. In all cases, the goals of geometric design are to maximize the comfort, safety, and economy of facilities, while minimizing their environmental impacts.

Road alignment :

Alignment : *is an arrangement in a straight line or in correct relative positions.*

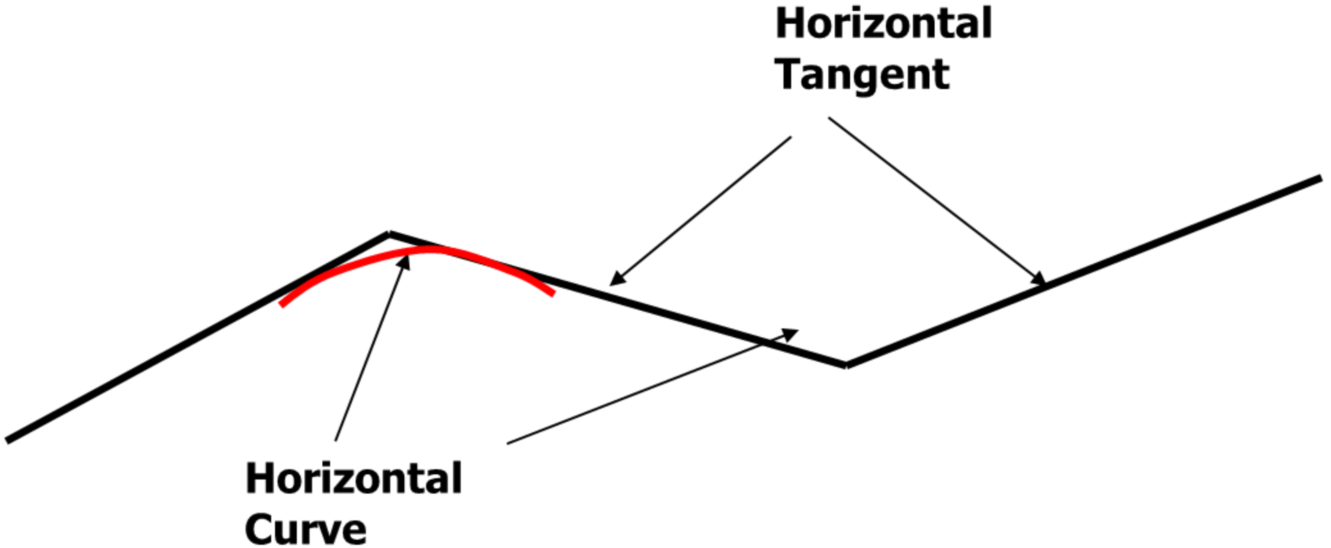
- *The position or the layout of the central line of the highway on the ground is called the alignment.*
- *Horizontal alignment includes straight and curved paths.*
- *Vertical alignment includes level and gradients.*

- **Horizontal Alignment** *: Horizontal alignment in road design consists of straight sections of road, known as tangents, connected by circular horizontal curves.*

- *It is the design of the road in the horizontal plane.*

- *Consists of a series of tangents (straight lines), circular curves and transition curves.*

- *Should provide safe travel at a uniform design speed.*



Plan of hwy.

GENERAL CONTROLS

1. Consistency:

Alignment should be consistent by avoiding sharp curves. Also, avoid the use of compound curves on highway mainline. These may "fool" the driver when judging the sharpness of a horizontal curve.

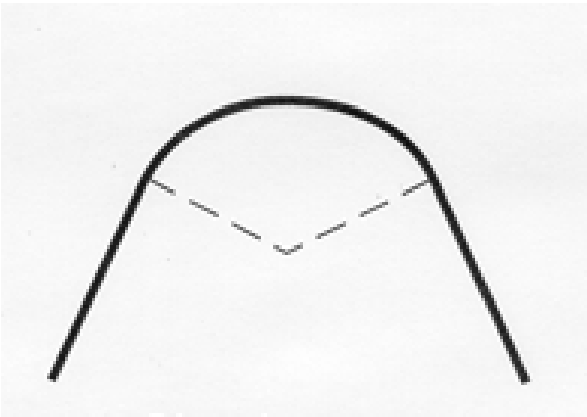
2. Directional:

Alignment should be as directional as practical and consistent with physical and economic constraints. Avoid abrupt reversals in alignment ("S" or reverse curves).

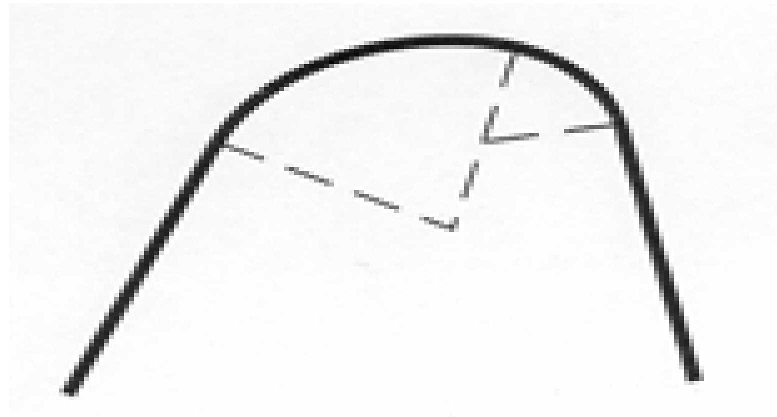
3. Use of Minimum Radii:

The use of minimum radii should be avoided if practical.

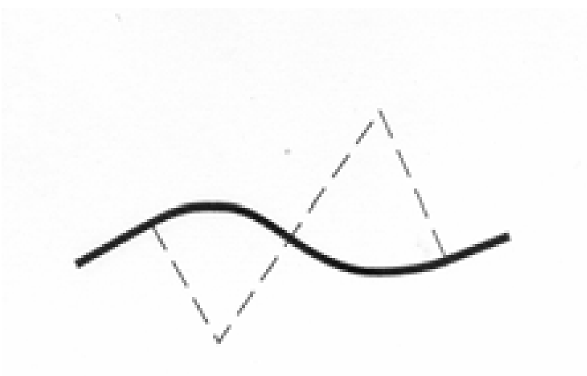
HORIZONTAL CURVES



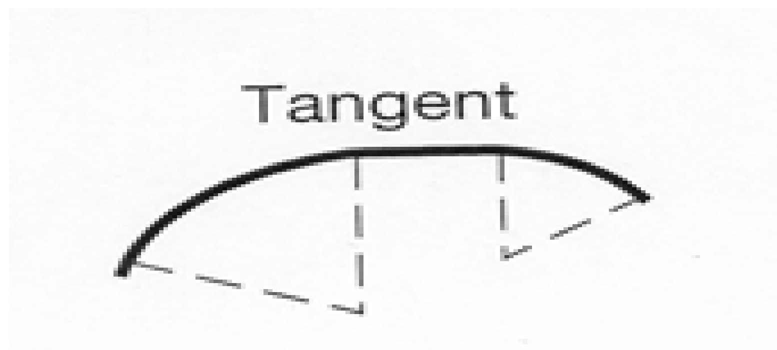
Simple Curve



Compound Curves

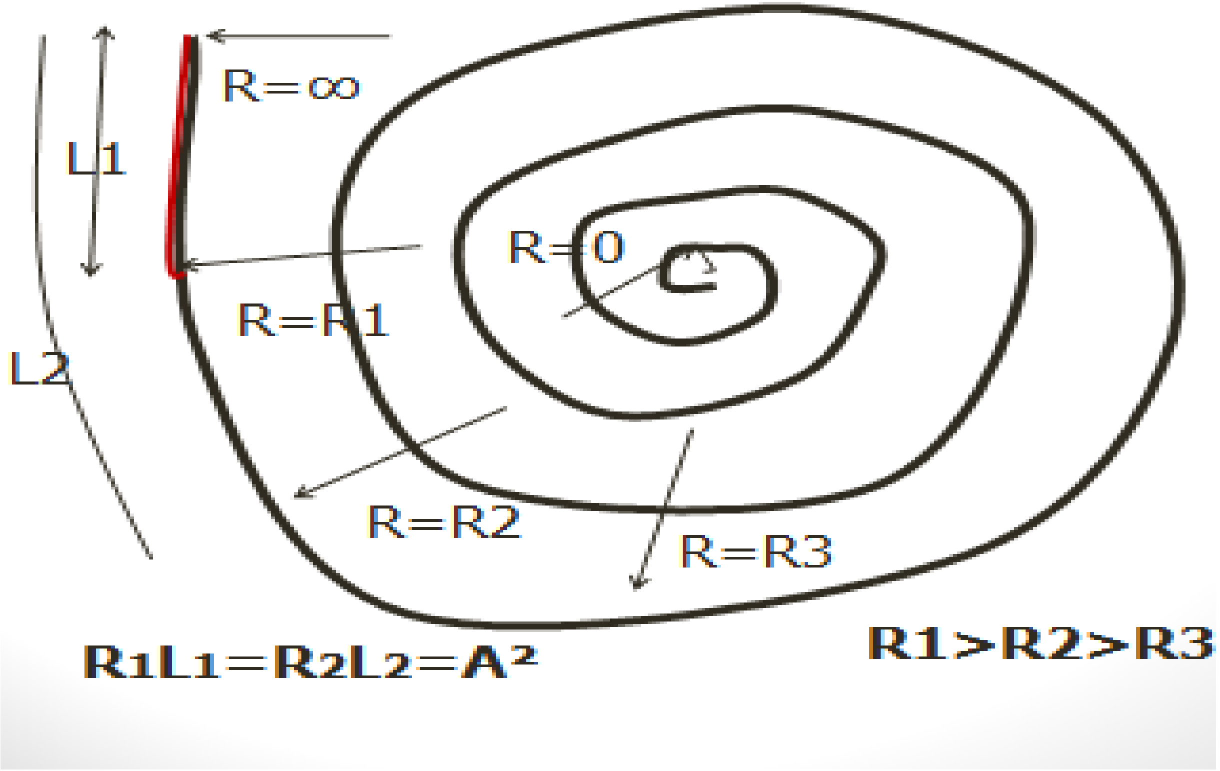


Reverse Curves



Broken-Back Curves

Spiral(Part of spiral curve):



HORIZONTAL CURVES TYPES

1. **Simple Curves:** These are continuous arcs of constant radius which achieve the necessary highway deflection without an entering or exiting transition.

2. **Compound Curves:** These are a series of two or more horizontal curves with deflections in the same direction immediately adjacent to each other.

3. **Spiral Curves:** These are curvature arrangements used to transition between a tangent section and a simple curve which are consistent with the transitional characteristics of vehicular turning paths. When moving from the tangent to the simple curve, the sharpness of the spiral curve gradually increases from a radius of infinity to the radius of the simple curve.

4. **Reverse Curves:** These are two simple curves with deflections in opposite directions which are joined by a common point or a relatively short tangent distance.

5. **Broken-Back Curves:** Broken-back curves are two closely spaced horizontal curves with deflections in the same direction and a short intervening tangent.

Selection of Curve Type

1. Rural State Highways and High-Speed (V > 70 km/h) Urban Roadways. Based on the curve radii, the following will apply:

- **R ≤ 1165 m use a spiral curve.**
- **R > 1165 m use a simple curve.**

Compound curves are not allowed on these facilities, except in transitional areas.

2. Low-Speed (V ≤ 70 km/h) Urban Roadways/Non-State Highways. Typically, simple curves will be used on low-speed urban roadways and non-State highways. In urban areas, if necessary, it is acceptable to use compound curves on the mainline to:

a. avoid obstructions,
b. avoid right-of-way problems, and/or
c. fit the existing topography.

HORIZONTAL CURVES PROPERTIES

Simple Curve

$$T = R\tan\frac{\Delta}{2}$$

$$C = 2R\sin\frac{\Delta}{2}$$

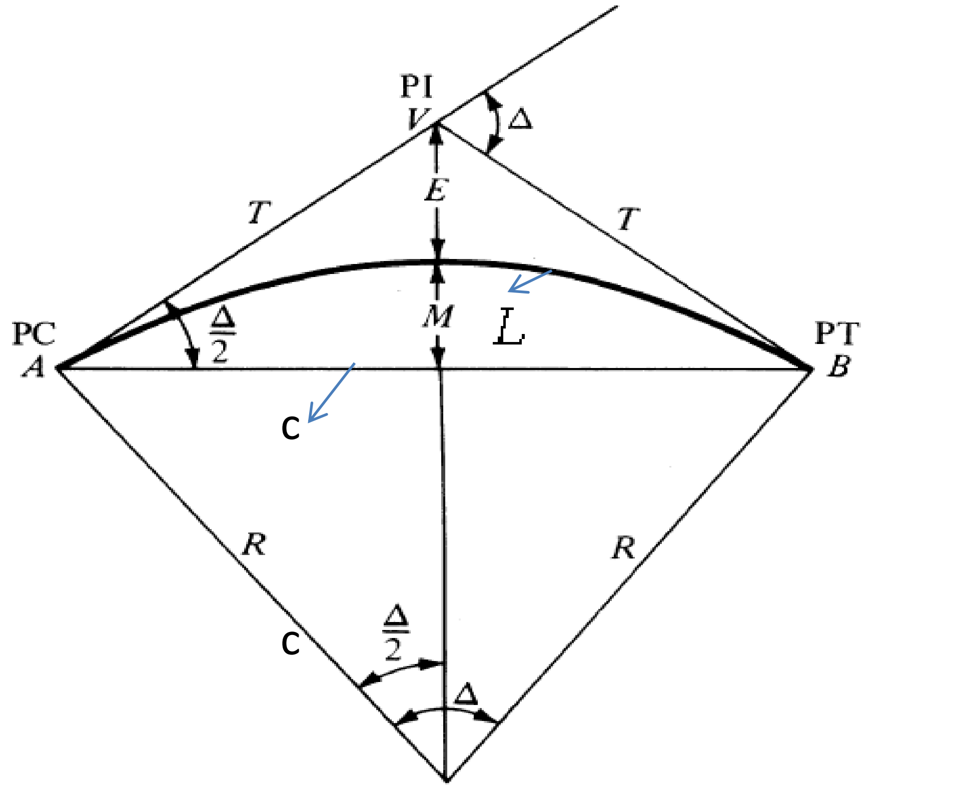
$$E = R\sec\frac{\Delta}{2} - R$$

$$E = R\left(\frac{1}{\cos\frac{\Delta}{2}} - 1\right)$$

$$M = R - R\cos\frac{\Delta}{2}$$

$$= R\left(1 - \cos\frac{\Delta}{2}\right)$$

$$L = \frac{R\Delta\pi}{180}$$



R = radius of circular curve
T = tangent length
Δ = intersection angle
M = middle ordinate

PC = point of curve
PT = point of tangent
PI = point of intersection
E = external distance

L = length of the curve

Layout of a Simple Horizontal Curve

Elements Of A Simple Curve

Point of Intersection (PI)
The point of intersection marks the point where the back and forward tangents intersect. The surveyor indicates it one of the stations on the preliminary traverse.

Intersecting Angle (I)
The intersecting angle is the deflection angle at the PI. The surveyor either computes its value from the preliminary traverse station angles or measures it in the field.

Radius (R)
The radius is the radius of the circle of which the curve is an arc.

Point of Curvature (PC)
The point of curvature is the point where the circular curve begins. The back tangent is tangent to the curve at this point.

Point of Tangency (PT)
The point of tangency is the end of the curve. The forward tangent is tangent to the curve at this point.

Length of Curve (L)
The length of curve is the distance from the PC to the PT measured along the curve.

Tangent Distance (T)
The tangent distance is the distance along the tangents from the PI to the PC or PT. These distances are equal on a simple curve.

External Distance (E)
The external distance is the distance from the PI to the midpoint of the curve. The external distance bisects the interior angle at the PI.

Middle Ordinate (M)
The middle ordinate is the distance from the midpoint of the curve to the midpoint of the long chord. The extension of the middle ordinate bisects the central angle.

Central Angle
The central angle is the angle formed by two radii drawn from the center of the circle (0) to the PC and PT. The central angle is equal in value to the I angle.

Compound Curves

$$\Delta = \Delta_1 + \Delta_2$$

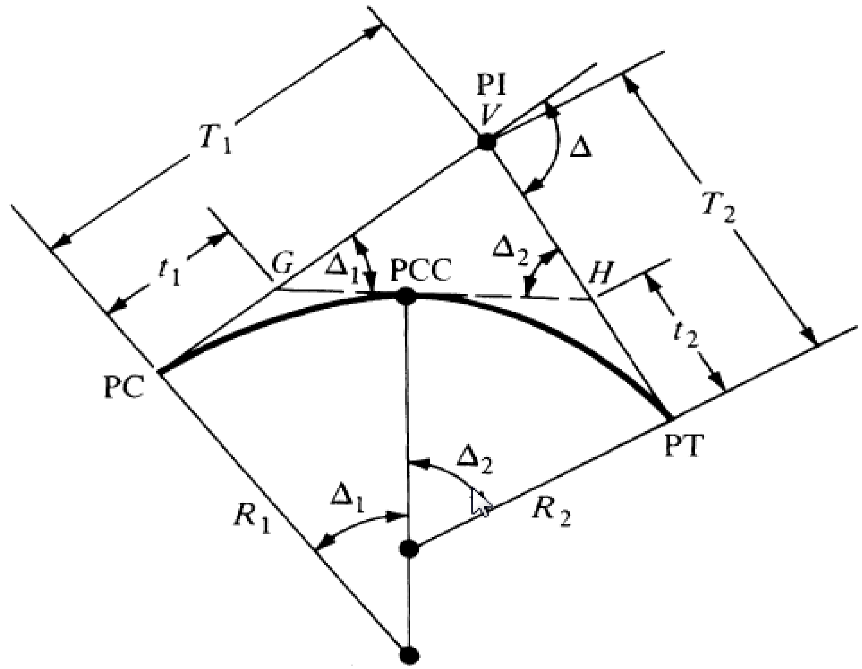
$$t_1 = R_1 \tan\frac{\Delta_1}{2}$$

$$t_2 = R_2 \tan\frac{\Delta_2}{2}$$

$$\frac{\overline{VG}}{\sin\Delta_2} = \frac{\overline{VH}}{\sin\Delta_1} = \frac{t_1 + t_2}{\sin(180 - \Delta)} = \frac{t_1 + t_2}{\sin\Delta}$$

$$T_1 = \overline{VG} + t_1$$

$$T_2 = \overline{VH} + t_2$$



R_1, R_2 = radii of simple curves forming compound curve
Δ_1, Δ_2 = intersection angles of simple curves
Δ = intersection angle of compound curve
t_1, t_2 = tangent lengths of simple curves
T_1, T_2 = tangent lengths of compound curve
PCC = point of compound curve
PI = point of intersection
PC = point of curve
PT = point of tangent

Layout of a Compound Curve

Reverse Curves

$$\Delta = \Delta_1 = \Delta_2$$

$$\text{Angle } OWX = \frac{\Delta_1}{2} = \frac{\Delta_2}{2}$$

$$\text{Angle } OYZ = \frac{\Delta_1}{2} = \frac{\Delta_2}{2}$$

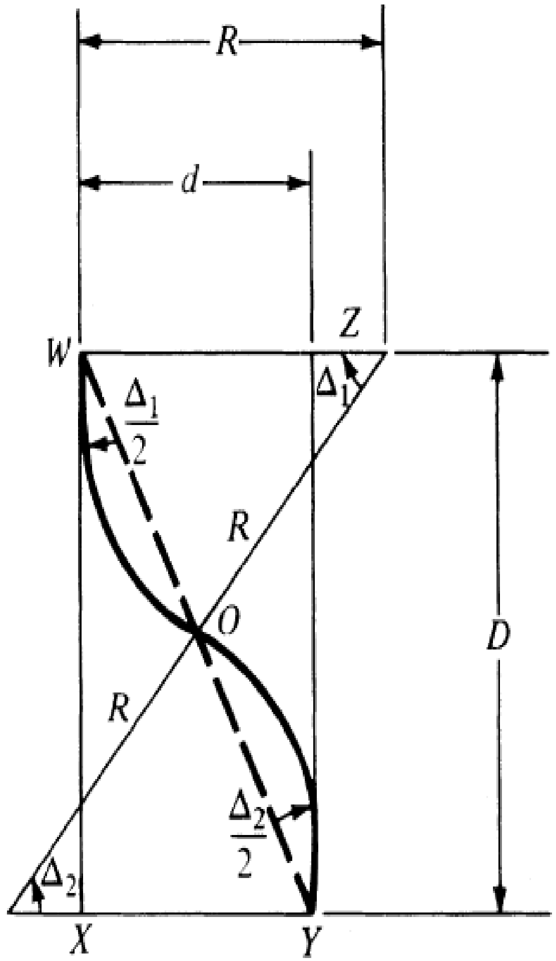
$$\tan\frac{\Delta}{2} = \frac{d}{D}$$

$$d = R - R\cos\Delta_1 + R - R\cos\Delta_2$$
$$= 2R(1 - \cos\Delta)$$

$$R = \frac{d}{2(1 - \cos\Delta)}$$

$$\cos\Delta = 1 - \frac{d}{2R}$$

$$D = d\cos\frac{\Delta}{2}$$



R = radius of simple curves

Δ_1, Δ_2 = intersection angles of simple curves

d = distance between parallel tangents

D = distance between tangent points

Geometry of a Reverse Curve with Parallel Tangents

HORIZONTAL CURVES DESIGN

Design = Calculate (R)

1. ***Degree of Curvature***

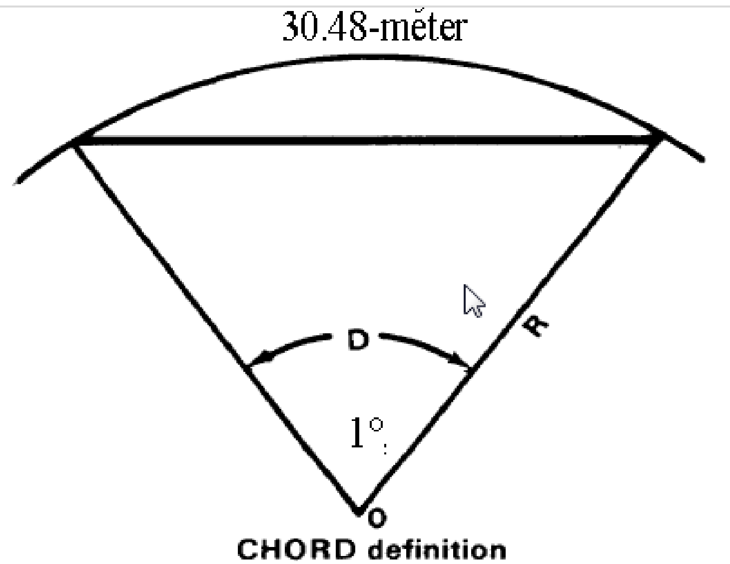
2. ***Sight Distance***

3. ***Superelevation***

1- Degree of Curve (D)

The degree of curve defines the “sharpness” or “flatness” of the curve (figure below).

The arc definition states that the degree of curve (D) is the angle formed by two radii drawn from the center of the circle (point O) to the ends of an arc 30.48 meters long. In this definition, the degree of curve and radius are inversely proportional using the following formula:



$$\frac{\text{Degree of Curve}}{360^\circ} :: \frac{\text{Length of Arc}}{\text{Circumference}}$$

$$\text{Circumference} = 2\,\pi\ \text{Radius}$$

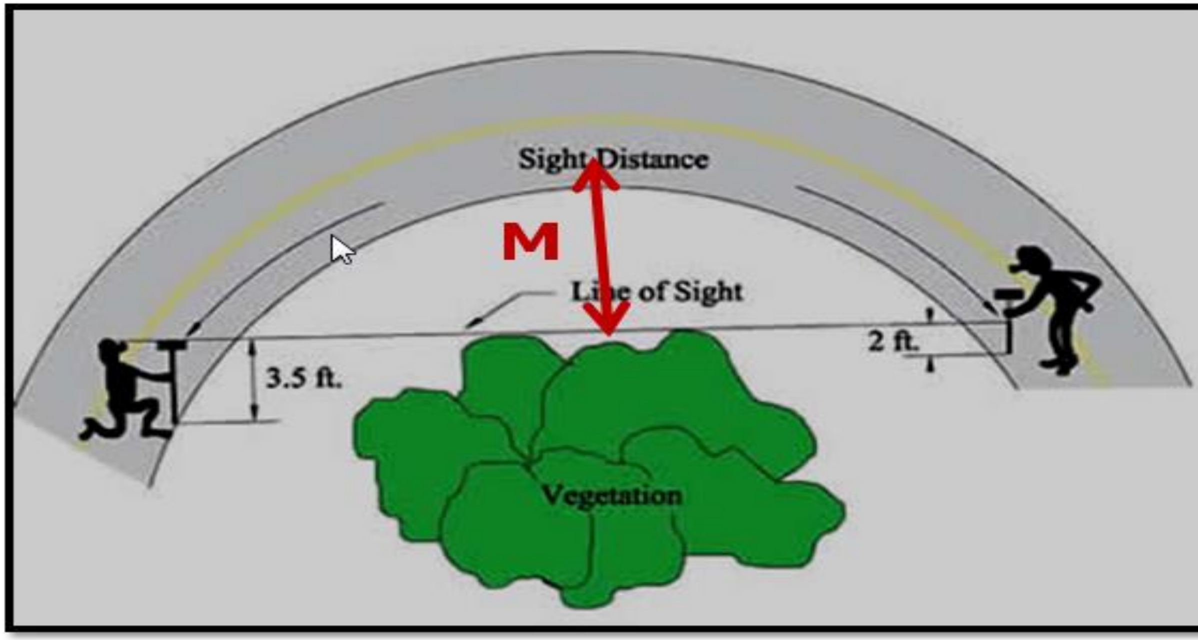
$$\pi = 3.141592654$$

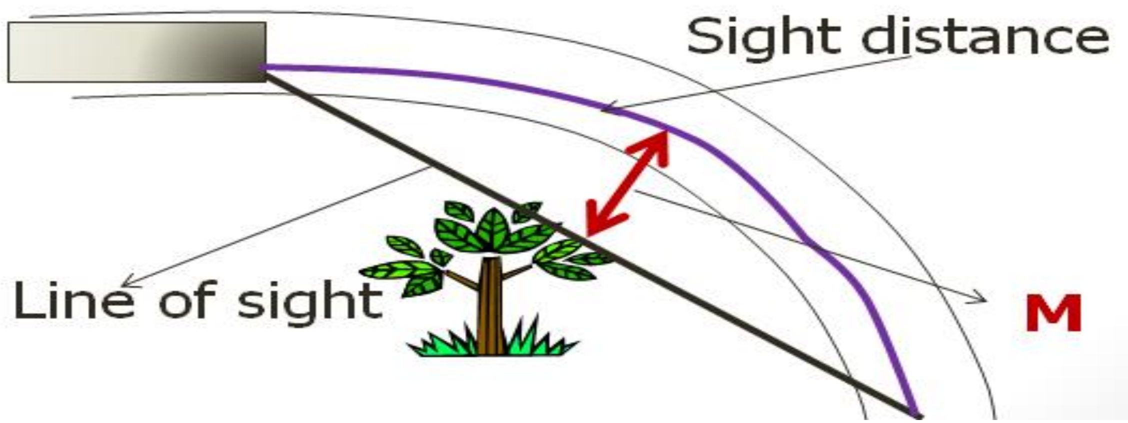
$$\frac{1^\circ}{360^\circ} :: \frac{30.48}{2\pi R} = \frac{1}{360} :: \frac{30.48}{6.283185308\ R}$$

Therefore, $R = 10{,}972.8$ divided by 6.283185308

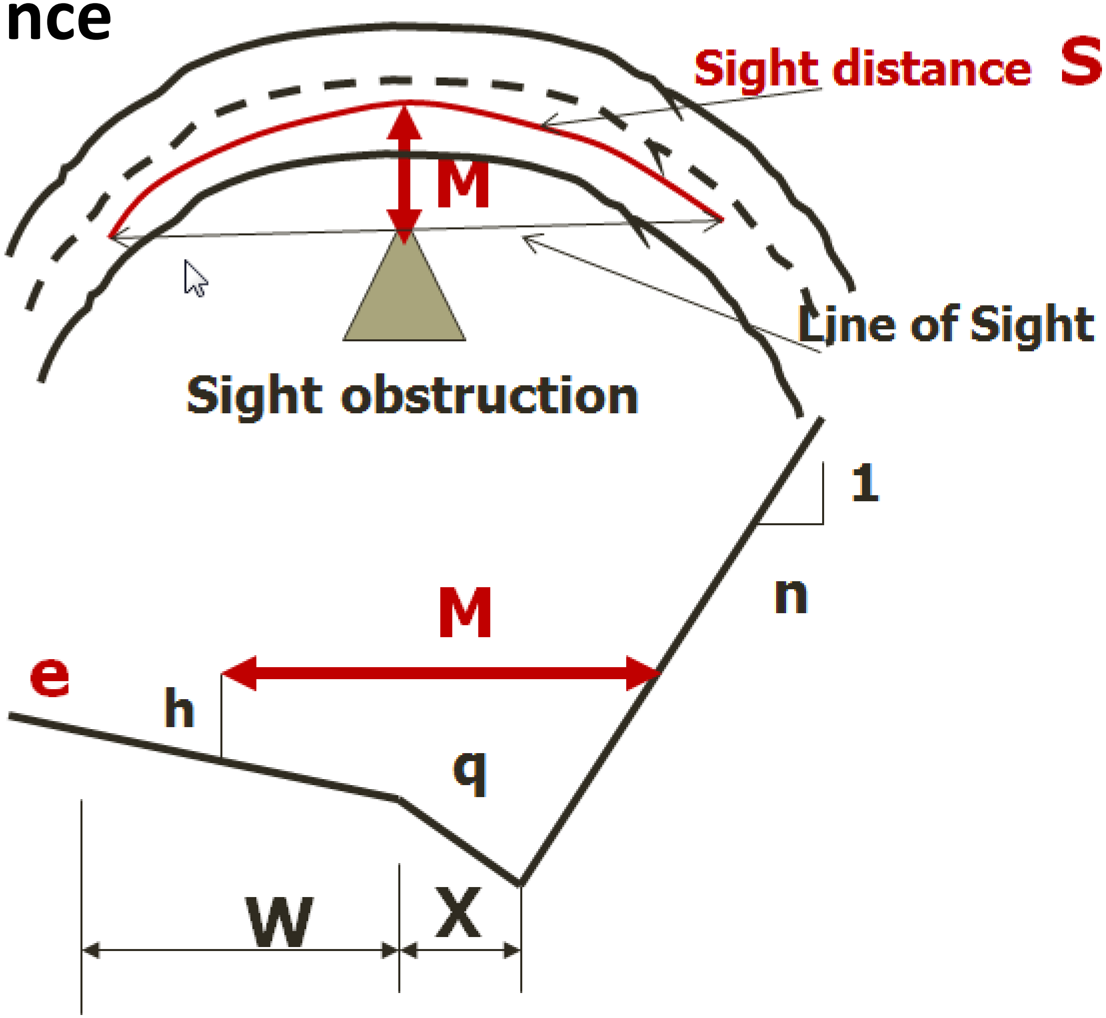
$R = 1{,}746.38$ m

2-Sight Distance





2-Sight Distance



$$M = W/2 + X + n\,(W/2 \times e + X q + h)$$

At : $S < L$ $M = S^2 / 8R$

At : $S > L$ $M = L(2S - L) / 8R$

Where:

M = Obstruction distance, m;

S = Stopping sight distance, m;

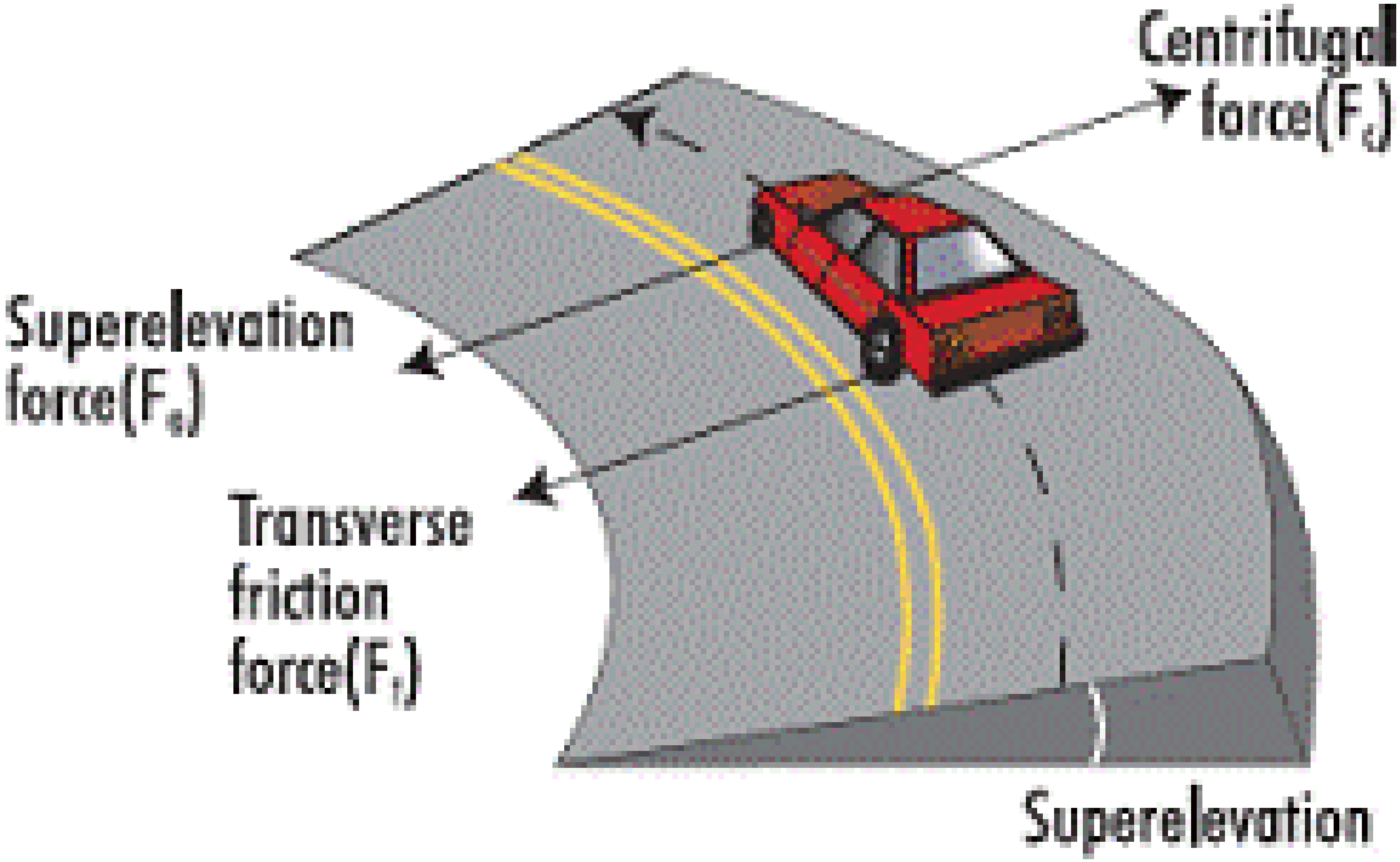
R = Radius of the circular curve, m;

L = length of the circular curve, m.

3- Superelevation

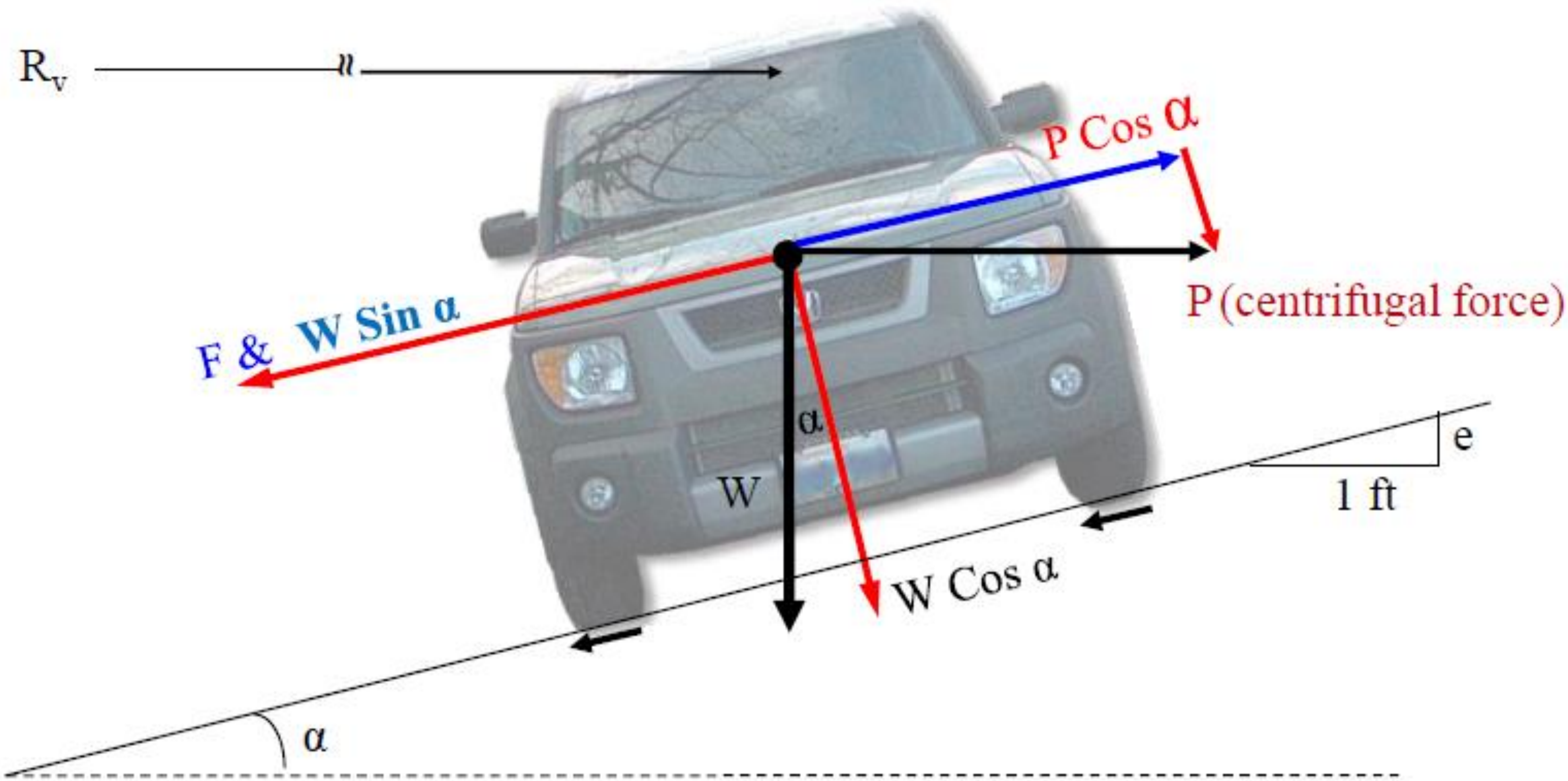
In order to counteract the effect of centrifugal force and to reduce the tendency of the vehicle to overturn or skid, the outer edge of the pavement is raised with respect to the inner edge, thus providing a transverse slope throughout the length of the horizontal curve, this transverse inclination to the pavement surface is known as Superelevation.

The Superelevation (e) is expressed as the ratio of the height of outer edge with respect to the horizontal width.



Centrifugal
force(F_c)
Superelevation
force(F_e)
Transverse
friction
force(F_f)
Superelevation

Superelevation



$$W\sin\alpha + f\left(W\cos\alpha + \frac{WV^2}{gR}\sin\alpha\right) = \frac{WV^2}{gR}\cos\alpha$$

Superelevation cont…

$$W\sin\alpha + f\left(W\cos\alpha + \frac{WV^2}{gR}\sin\alpha\right) = \frac{WV^2}{gR}\cos\alpha$$

OR $$\tan\alpha + f = \frac{V^2}{gR}(1 - f\tan\alpha)$$ Dividing Cos α on both sides

OR $$e + f = \frac{V^2}{gR}(1 - fe)$$ (1-fe)=1-0.15x.o7=0.99≈ 1

OR $$R = \frac{V^2}{g(f+e)}$$

OR $$\boxed{e + f = \frac{V^2}{gR}}$$ **OR** $$\boxed{e + f = \frac{V^2}{127R}}$$

V in m/Sec
R in 'm'

V in kmph
R in 'm'

Cont…

- e = rate of Superelevation = tan Θ
- f = design value of lateral friction coefficient = 0.15
- v = speed of the vehicle, m/sec
- R = radius of the horizontal curve, mg = acceleration due to gravity = 9.8 m/sec^2

Calculation of Curve Radius

Basic Curve Equation

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

where:

R = radius of curve, m

e = superelevation rate, decimal

f = side-friction factor, decimal

V = vehicular speed, km/h