Chapter 4: Geometric Design

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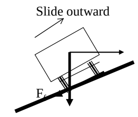
Vehicle Cornering - *cont*

Two Possible Safety Issues:

•To avoid vehicle sliding outward:

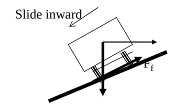
$$\frac{WV^2}{gR_v}\cos\alpha \le W\sin\alpha + f_s W$$



•To avoid vehicle sliding inward:

$$W\sin\alpha \le \frac{WV^2}{gR_v}\cos\alpha + f_s W$$

$$\sim \quad e \le f_s$$

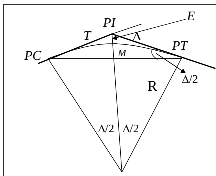


Example 4.1

- A roadway is designed for a speed of 100km/h. At of the horizontal curve, a superelevation of 6% is used and the coefficient of side friction is 0.08.
  - a). What is the minimum radius of curve that will provide safe vehicle operation ?
  - b). If the maximum radius that can be used at this location is 500 m, what superelevation has to be used in order to provide safe vehicle operation?

Basic Relationships in Horizontal Curve

Simple Horizontal Curve



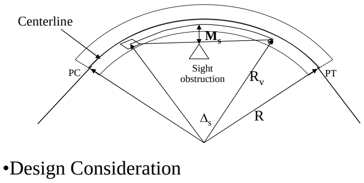
Δ - intersection angle (or angle of curve)
PI - point of intersection
PC - point of curve
PT - point of tangent
T - tangent length
L - length of curve
E - external distance
M - middle ordinate

Example 4.2

If the intersection angle in Example 1 is 30 and a radius of 800-m is finally used. The PI is at station 4 + 102.450. Determine the stationing of the PC and PT.

Sight Distance and Horizontal Curve

•Potential Sight Distance Problem in Horizontal Curve



•Design Consideration

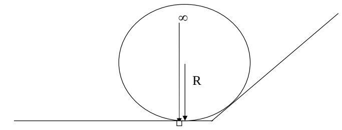
Available sight distance (Ls) > Required sight distance (e.g. SSD):

Example 4.3

The corner of a building is situated inside a horizontal curve with a radius of 150-m on a rural highway and superelevation of 8%. The inside lane is 3.75 wide and the inside edge of the road is 2 m from the corner of the building. Determine what speed limit should be imposed on this section of the highway.

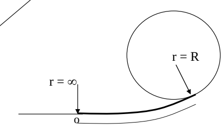
Transition Curve

Need for transition curve - change of centrifugal force



Advantages of using transition curves

- Allow gradual change in centrifugal force at PC and PT
- Improve visual appearance
- Provide convenient cross-slope transition
- Provide transition for change in lane width

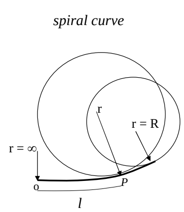


Form of Transition Curve

Spiral curves defined by

$$l \cdot r = A^2$$

l - length of the spiral curve from original to point P
r - curve radius at point P
A - spiral curve parameter



Required curve length (L) to connect a straight section to circular curve with a radius of R:

$$L = A^2 / R$$ ⇨ How to select A?

Design of Spiral Curve (A?)

- For <u>comfort</u>: change rate of lateral acceleration rate should be less than 0.6

$$A \geq 0.189\, V^{1.5}$$

V - design speed (km/h)

- For aesthetics: the driving time on the spiral curve should at least 2 seconds

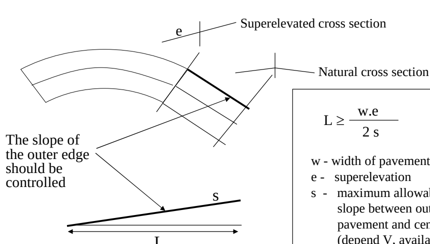
$$A^2 \geq 0.56\, RV$$

V - design speed (km/h)
R - curve radius (m)

- For superelevation runoff

Development of Superelevation

- Superelevation Runoff: the length of highway section required to achieve a full superelevation section from a section with adverse crown



$$L \geq \frac{w.e}{2\,s}$$

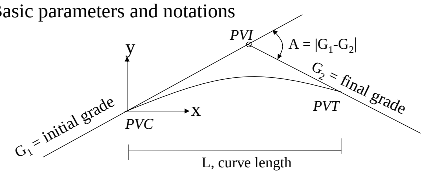
w - width of pavement
e - superelevation
s - maximum allowable relative slope between outer edge of pavement and centerline. (depend V, available from design guideline)

Example 4.4

A four-lane undivided highway is designed with design speed of 90 km/h and lane width of 3.75 m. A curve section has a radius of 340 m and superelevation of 0.06. What length of spiral curve should be used for this curve. (note that the profile control is along the centerline.)

Vertical Curve Fundamentals

•Basic parameters and notations



•Parabolic curve has been found suitable

$y = ax^2 + bx$

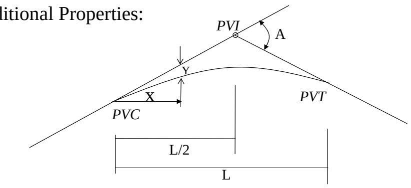
s.t. $dy/dx = G1$ (when x=0, or at *PVC*) → $b = G_1$

$dy/dx = G2$ (when x=L, or at *PVT*) → $a = \frac{(G_2-G_1)}{2L}$

L is the only design variable!!

Vertical Curve Fundamentals

Additional Properties:



•Offset at any distance x (Y)

$Y = (A/200L)\ x^2$

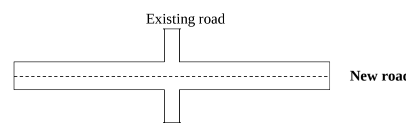
•Equal tangent:

Example 4.5

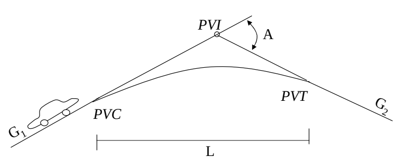
A 200-m sag vertical curve has the PVC at station 3+700.000 and elevation 321 m. The initial grade is -3.5% and the final grade is 0.5%. Determine the elevation and stationing of the PVI, PVT, and lowest point on the curve.

Example 4.6: Design L to Meet Certain Location Elevation Requirements (Curve-through-a-point problem)

An vertical curve is to be constructed between grades of -2% (initial) and 1% (final). The PVI is at station 10 + 000.000 and at elevation 400 m. Due to a street crossing the roadway, the elevation of the roadway at station 10 + 071.000 must be at 401.5m. Design the curve.



Design L to Meet Sight Distance Requirement: <u>Crest Vertical Curve</u>



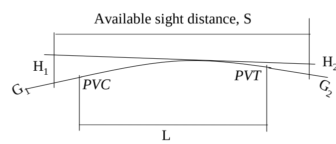
Available sight distance (at critical point) depends on

- driver eye height (H_1) - vehicle?
- The height of object (H_2)
- G_1, G_2 -- A
- L
- Location of the vehicle

Available Sight Distance On a Crest Vertical Curve

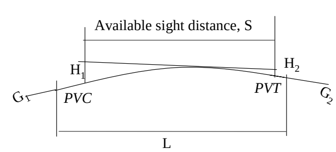
Case I : S>L

S =



Case II : S<L

S =



Example 4.7

A highway is being designed to AASHTO guidelines with a 120 km/h design speed. At a section an equal tangent vertical curve must be designed to connect grades of 1% and -2%. Determine the length of curve required assuming provisions are to be made for SSD.

Simplified Equation for L_m

Based on assumption SSD < L_m:

L_m = K A

where K = SSD² / 404 (Guidelines usually directly give K)

Why?

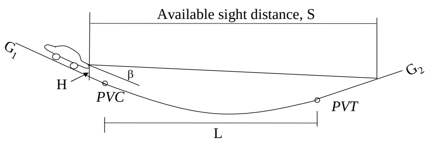
Simpler

linear function of A

In many cases: SSD < L

It is conservative estimate for the case SSD > L

Design L to Meet Sight Distance Requirement: Sag Vertical Curve



Available sight distance (at critical point) depends on

- Headlight height (H) - vehicle?
- Angle of headlight beam relative to horizontal plane of the vehicle, β
- G_1, G_2 -- A
- L
- Location of the vehicle

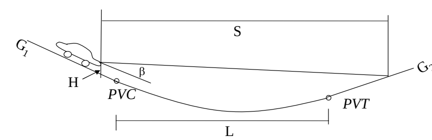
Available Sight Distance On a Sag Vertical Curve

Case I : S>L

S =

Case II : S<L

S =



Simplified Equation for L_m

Based on assumption SSD < L_m:

L_m = K A

where K = SSD² / (120+3.5SSD) (Guidelines usually directly give K)

Why?

Simpler

linear function of A

In many cases: SSD < L

It is a safe and conservative estimate for the case SSD > L

Example 4.8

A highway has a design speed of 100km/h, but an engineering mistake has resulted in the need to connect an already constructed tunnel and bridge with sag and crest vertical curves. Devise a vertical alignment to connect the tunnel and bridge by determining the highest possible common design speed (for SSD) for the sag crest vertical curves needed. Compute the stationing and elevation of PVC, PVI and PVT curve points.