Horizontal Alignment

Horizontal Alignment

- Objective:
 - Geometry of directional transition to ensure:
 - Safety
 - Comfort
- Primary challenge
 - Transition between two directions
- Fundamentals
 - Circular curves
 - Superelevation or banking

Vehicle Cornering



 $W_p + F_f = F_{cp}$

Vehicle Cornering

 $W_p + F_f = F_{cp}$





Curve is a circle, not a parabola

Superelevation

- Banking
- number of vertical feet of rise per 100 ft of horizontal distance
- e = 100tanα



Superelevation

 $W\sin\alpha + f_s \left(W\cos\alpha + \frac{WV^2}{gR_s}\sin\alpha \right) = \frac{WV^2}{gR_s}\cos\alpha$ $\tan\alpha + f_s = \frac{V^2}{gR} \left(-f_s \tan\alpha \right)$ $\frac{e}{100} + f_s = \frac{V^2}{gR_s} \left(1 - f_s \frac{e}{100} \right)$ $R_{\nu} = \frac{r}{g\left(f_s + \frac{e}{100}\right)}$ Divide both sides by $Wcos(\alpha)$

Superelevation

- Minimum radius that provides for safe vehicle operation
- Given vehicle speed, coefficient of side friction, gravity, and superelevation
- R_v because it is to the vehicle's path (as opposed to edge of roadway)



Selection of e and $\rm f_s$

• Practical limits on superelevation (e)

- Climate
- Constructability
- Adjacent land use
- Side friction factor (f_s) variations
 - Vehicle speed
 - Pavement texture
 - Tire condition
 - Maximum side friction factor is the point at which tires begin to skid.
 - Design values are chosen below maximum.

Minimum Radius Tables

US Customary					
Design Speed (mph)	Maximum e (%)	Maximum f	Total (<i>e</i> /100 + <i>f</i>)	Calculated Radius (ft)	Rounded Radius (ft)
10 15 20 25 30 35 40 45 55 60	4.0 4.0 4.0 4.0 4.0 4.0 4.0 4.0 4.0 4.0	0.38 0.32 0.27 0.23 0.20 0.18 0.16 0.15 0.14 0.13 0.12	0.42 0.36 0.31 0.27 0.24 0.22 0.20 0.19 0.18 0.17 0.16	15.9 41.7 86.0 154.3 250.0 371.2 533.3 710.5 925.9 1186.3 1500.0	16 42 86 154 250 371 533 711 926 1190 1500
10 15 20	6.0 6.0	0.38	0.44	15.2 39.5	15 39

WSDOT Design Side Friction Factors

For Open Highways and Ramps				
Design Speed	Side Friction Factor			
(mph)	(f)			
<u>15</u>	17.5			
20	17			
25	16 <u>.5</u>			
30	16			
35	15 <u>.5</u>			
40	15			
45	14 <u>.5</u>			
50	14			
<u>55</u>	<u>13</u>			
60	12			
<u>65</u>	<u>11</u>			
70	10			
75	<u>9</u>			
80	8			

Design Superelevation Rates - AASHTO



from AASHTO's A Policy on Geometric Design of Highways and Streets 2004

Design Superelevation Rates - WSDOT



Example

A section of SR 522 is being designed as a high-speed divided highway. The design speed is 70 mph. Using WSDOT standards, what is the minimum curve radius (as measured to the traveled vehicle path) for safe vehicle operation?



JEE 320





Example

A horizontal curve is designed with a 1500 ft. radius. The tangent length is 400 ft. and the PT station is 20+00. What is the PC station?

Stopping Sight Distance

 Looking around a curve Measured along horizontal curve from the center of the traveled lane Need to clear back to M_s (the middle of a line that has same arc length as SSD)

 $SSD = \frac{\pi}{180} R_{\nu} \Delta_s = \frac{100 \Delta_s}{D}$

Assumes curve exceeds required SSD



Stopping Sight Distance



Example

A horizontal curve with a radius to the vehicle's path of 2000 ft and a 60 mph design speed. Determine the distance that must be cleared from the inside edge of the inside lane to provide sufficient stopping sight distance.

Superelevation Transition



Spiral Curves



No Spiral

Spiral

from AASHTO's A Policy on Geometric Design of Highways and Streets 2004

Spiral Curves

- Ease driver into the curve
- Think of how the steering wheel works, it's a change from zero angle to the angle of the turn in a finite amount of time
- This can result in lane wander
- Often make lanes bigger in turns to accommodate for this



No Spiral



Spiral Curves

- WSDOT no longer uses spiral curves
- Involve complex geometry
- Require more surveying
- If used, superelevation transition should occur entirely within spiral

Operating vs. Design Speed



85th Percentile Speed vs. Inferred Design Speed for Rural Two-Lane Highway Limited Sight Distance Crest Vertical Curves

CEE 320 Fall 2008



Inferred Design Speed on Crest (mph)