Roadway Horizontal Alignments

An Online Continuing Education Course for Engineers

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Roadway Horizontal Alignments

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INTRODUCTION

The **roadway horizontal alignment** is a series of horizontal tangents (straight roadway sections), circular curves, and spiral transitions. It shows the proposed roadway location in relation to the existing terrain and adjacent land conditions. Together with the vertical alignment (grades and vertical curves) and roadway cross-sections (lanes, shoulders, curbs, medians, roadside slopes, ditches, sidewalks), the horizontal alignment (tangents and curves) helps to provide a three-dimensional roadway layout.

This course focuses on the geometric design of **horizontal alignments** for modern roads and highways. Its contents are intended to serve as guidance and not as an absolute standard or rule.

Upon course completion, you should be familiar with the general design of horizontal roadway alignments. The course objective is to give engineers and designers an in-depth look at the principles to be considered when designing horizontal alignments.

Subjects covered include:

- Sight Distance
  Stopping

  Decision

  Passing

  Intersection

- Design Considerations
  Cross slopes

  Superelevation

  Radii

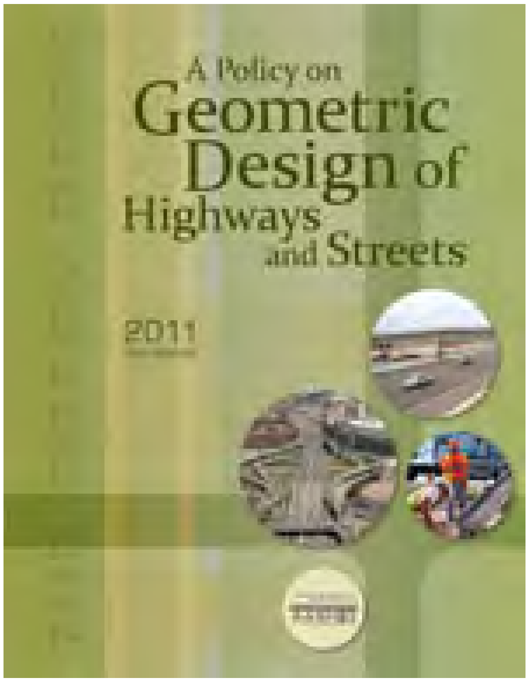
  Grades

- Horizontal Curves
  Compound

Spiral

- Coordination of Horizontal & Vertical Curves

A Policy on Geometric Design of Highways and Streets (also known as the "Green Book") published by the American Association of State Highway and Transportation Officials (AASHTO) is considered to be the primary guidance for U.S. roadway design. For this course, Chapter 3 (Section 3.3 Horizontal Alignment) will be used exclusively for fundamental roadway geometric design principles.



BACKGROUND

Roadway geometric design consists of the following fundamental three-dimensional features:

Vertical alignment - grades and vertical curves

Horizontal alignment - tangents and curves

Cross section - lanes and shoulders, curbs, medians, roadside slopes and ditches, sidewalks

Combined, these elements contribute to the roadway's operational quality and safety by providing a smooth-flowing, crash-free facility.

Engineers must understand how all of the roadway elements contribute to overall safety and operation. Applying design standards and criteria to 'solve' a problem is not enough.

The fundamental objective of good geometric design will remain as it has always been **– to produce a roadway that is safe, efficient, reasonably economic and sensitive to conflicting concerns.**

HORIZONTAL ALIGNMENT

The **horizontal alignment** is a series of horizontal tangents (straight roadway sections), circular curves, and spiral transitions used for the roadway's geometry. This design shows the proposed roadway location in relation to the existing terrain and adjacent land conditions. The main objective of geometric roadway design is to integrate these elements to produce a compatible speed with the road's function and location. Safety, operational quality, and project costs can be significantly influenced by coordinating the horizontal and vertical alignments.

Design Speed

AASHTO defines design speed as "the maximum safe speed that can be maintained over a specified section of highway when conditions are so favorable that the design features of the highway govern". It is an **overall design control** for horizontal alignments in roadway design that may equal or exceed the legal statutory speed limit. The level of service is directly related to the speed of operation - it should meet driver expectations and be consistent with the facility's functional classification and location.

Design speed selection is a critical decision that should be done at the beginning of the planning and design process. This speed should balance safety, mobility, and efficiency with potential environmental quality, economics, aesthetics, social and political impacts. Roadway design features (curve radii, superelevation, sight distance, etc.) are impacted by the design speed, as well as other characteristics not directly related to speed. Therefore, any changes to design speed may affect many roadway design elements.

Design speeds for **rural roads** should be as high as practicable to supply an optimal degree of safety and operational efficiency. Data has shown that drivers operate quite comfortably at speeds that are higher than typical design speeds.

Lower design speeds may be appropriate for certain **urban roadways** (residential streets, school zones, etc.). Traffic calming techniques have proven to be a viable option for residential traffic operations. Designers should evaluate high speed compatibility with safety (pedestrians, driveways, parking, etc.) for urban arterials.

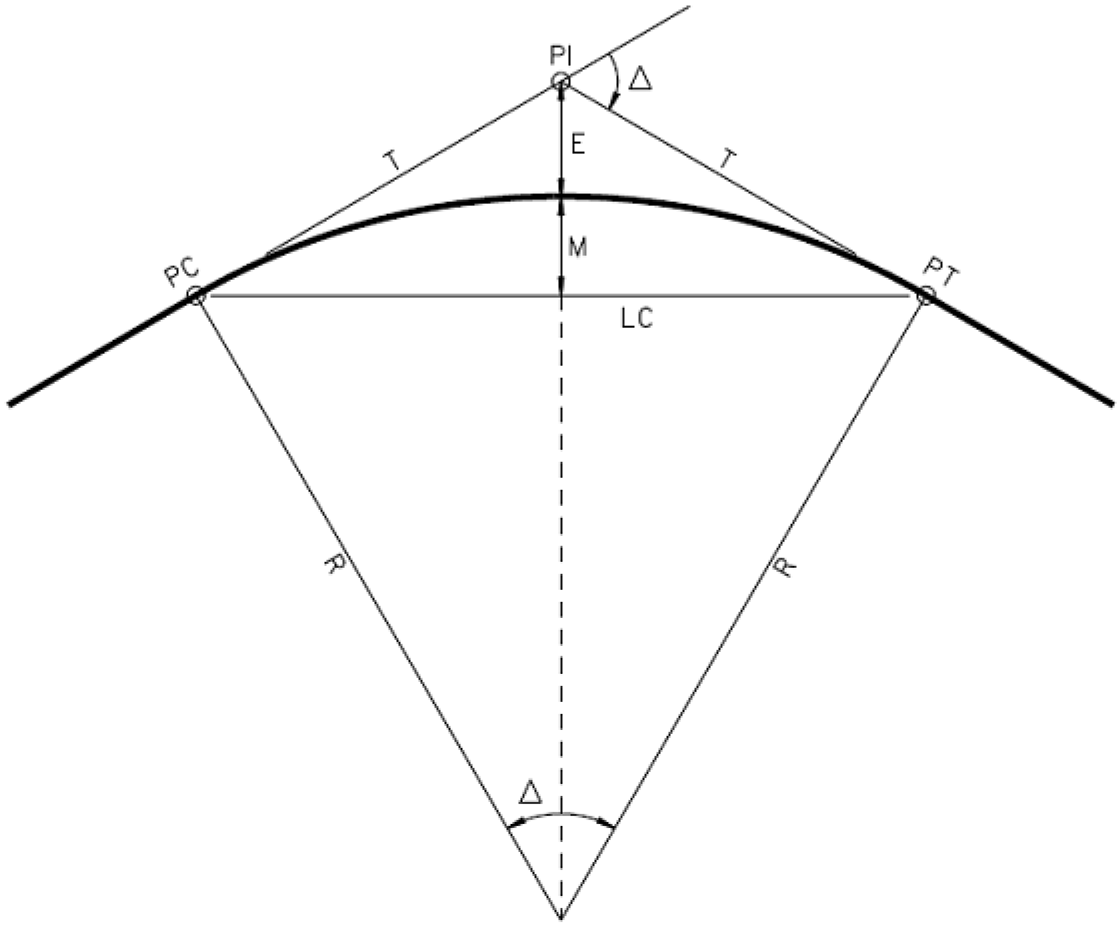
HORIZONTAL CURVES

Roadway horizontal curve design is based on the laws of physics and driver reaction to lateral acceleration. Any geometric alignment needs to address curve location; curve sharpness; tangent lengths; and how they relate to the vertical profile. All of these components should be balanced to operate at appropriate speeds under normal conditions.

Elements of Curve Design

- Curve radius
- Superelevation
- Side friction
- Assumed vehicle speed

Horizontal curves depend on specific values for a minimum radius (based on speed limit), curve length, and sight obstructions (sight distance). An increased superelevation (bank) may be required to assure safety for high speed locations with small curve radii. Designers must confirm sufficient sight distance around corners or curves in order to avoid crashes.



<u>Terms</u>

R = Radius

PC = Point of Curvature (point at which the curve begins)

PT = Point of Tangent (point at which the curve ends)

PI = Point of Intersection (point at which the two tangents intersect)

T = Tangent Length (distance from PC to PI or PI to PT)

LC = Long Chord Length (straight line between PC and PT)

L = Curve Length (distance from PC to PT measured along the curve)

M = Middle Ordinate (distance from midpoint of LC to midpoint of the curve)

E = External Distance (distance from vertex to curve)

Δ= Deflection Angle (change in direction of two tangents)

The upper limits for superelevation on horizontal curves address constructability, land usage, slow-moving vehicles, and climate. For regular snow or ice locations, the superelevation should not exceed rates where slow-moving vehicles would slide toward the center of the curve. Hydroplaning can occur at high speed locations with poor drainage that allow a build-up of water.

<u>Side Friction Factor</u>

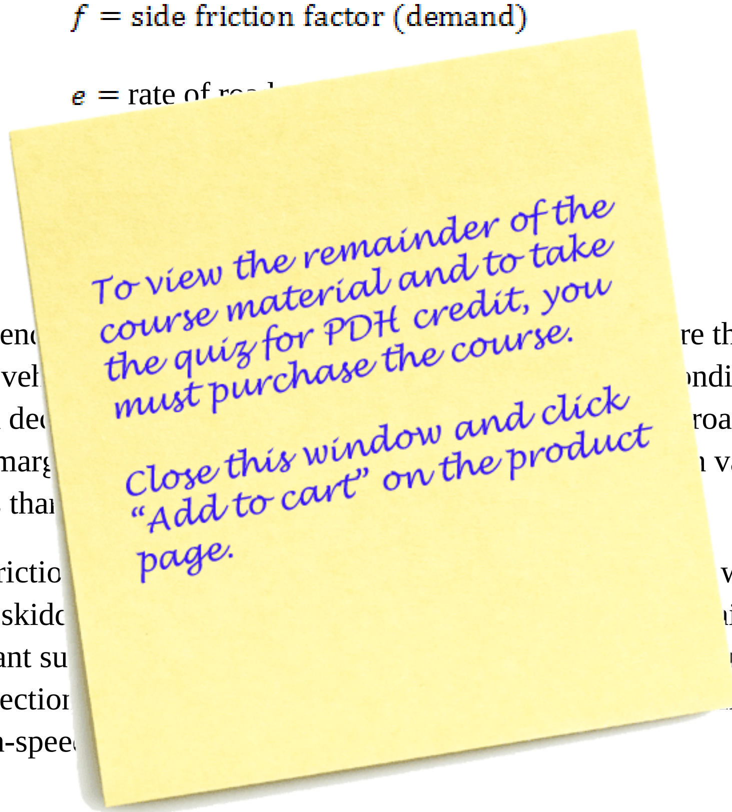
A vehicle's need for side friction (*side friction demand*) is represented by the **side friction factor.** This term also depicts the lateral acceleration acting on a vehicle which is the product of the side friction demand factor and the gravitational constant. Vehicle speeds on horizontal curves create tire side thrust which is offset by the frictional forces between the tires and the riding surface.

AASHTO's "simplified curve formula" (shown below) is a basic side friction equation that produces slightly higher friction estimates than those resulting from the "basic curve formula".

$$f = \frac{V^2}{15R} - 0.01\ e$$

f = side friction factor (demand)

e = rate of roa



The point of impen … re the tires begin to skid. This depends on vel … ndition/type. Historical data has shown a dec … roadway curves are designed with a marg … values should be substantially less tha

Maximum side frictio … with an ample margin of safety against skid … is shows the need for using skid-resistant su … ng maneuvers (braking, lane changes, directio … riction factors need to be lower for high-spee