

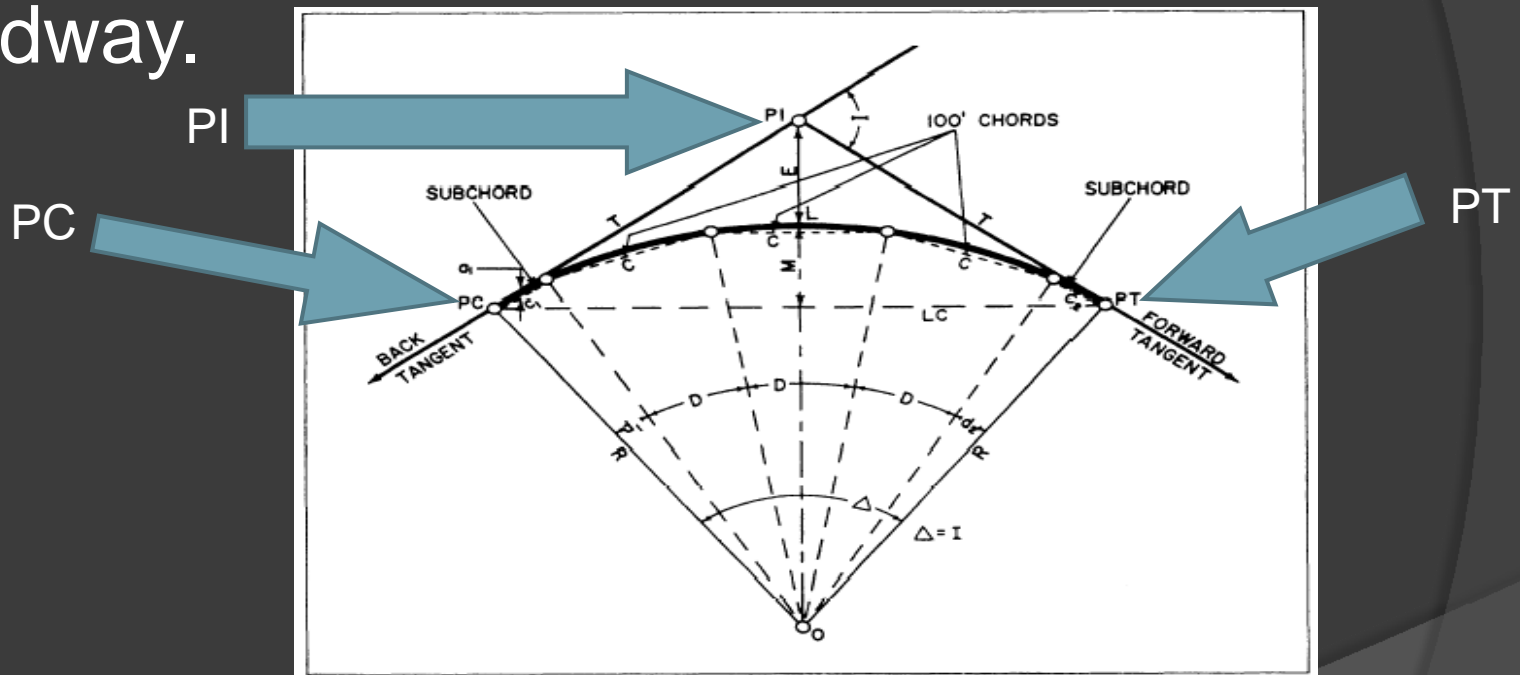


# DESIGN OF HORIZONTAL CURVES

Paul Deutsch

# What is a Horizontal Curve?

- Provides a transition between two tangent lengths of roadway.



- PC (Point of Curvature at beginning of curve)
- PI (Point of Intersection of tangents)
- PT (Point of Tangency at end of curve)

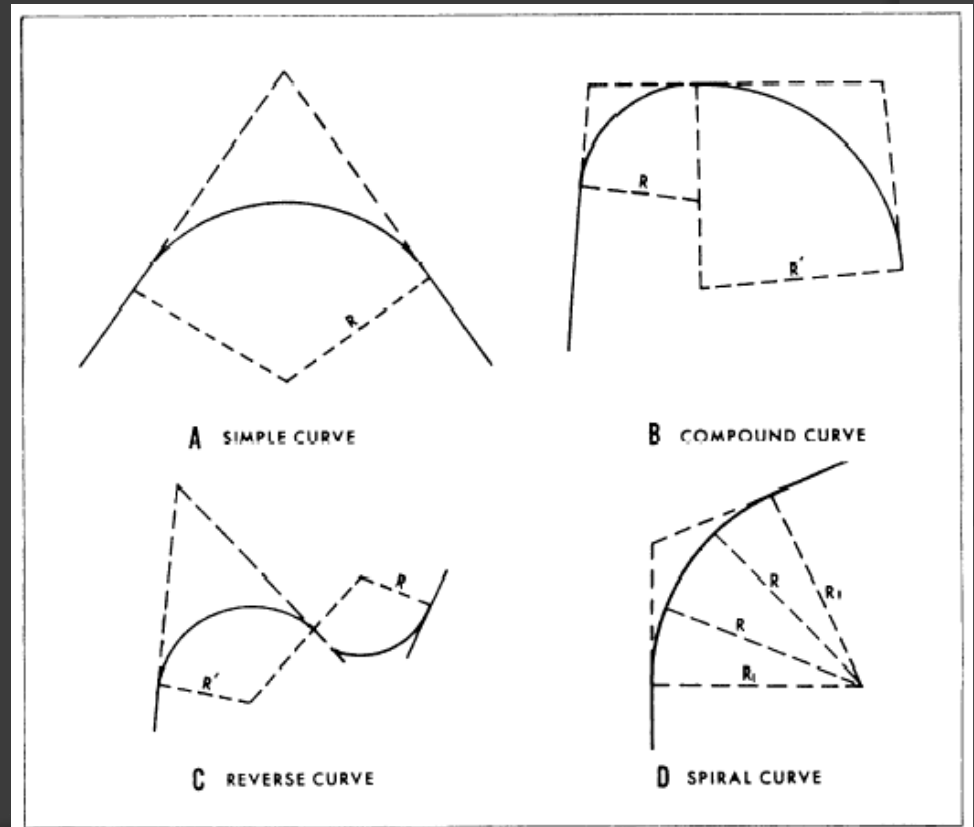
# Why are Horizontal Curves Needed?

- Necessary for gradual change in direction when a direct point of intersection is not feasible
- Ex. Highways, Interstates, high speed roads with constant flow of traffic



# Types of Curves

- Simple Curve
- Compound Curve
- Reverse Curve
- Spiral Curve



# Guidelines to Horizontal Curves

- A Policy on Geometric Design of Highways and Streets
  - Horizontal Alignment (pg.131-234) Considerations
    - Radius
    - Design Speed
    - Side Friction Factor
    - Superelevation
      - Runoff
      - Runout

Equation on pg. 133



# Design Considerations

- Safe
- Economically Practical
  - For the most part, **Design Speed** is used as the overall design control
  - **Radius**



# Parameters

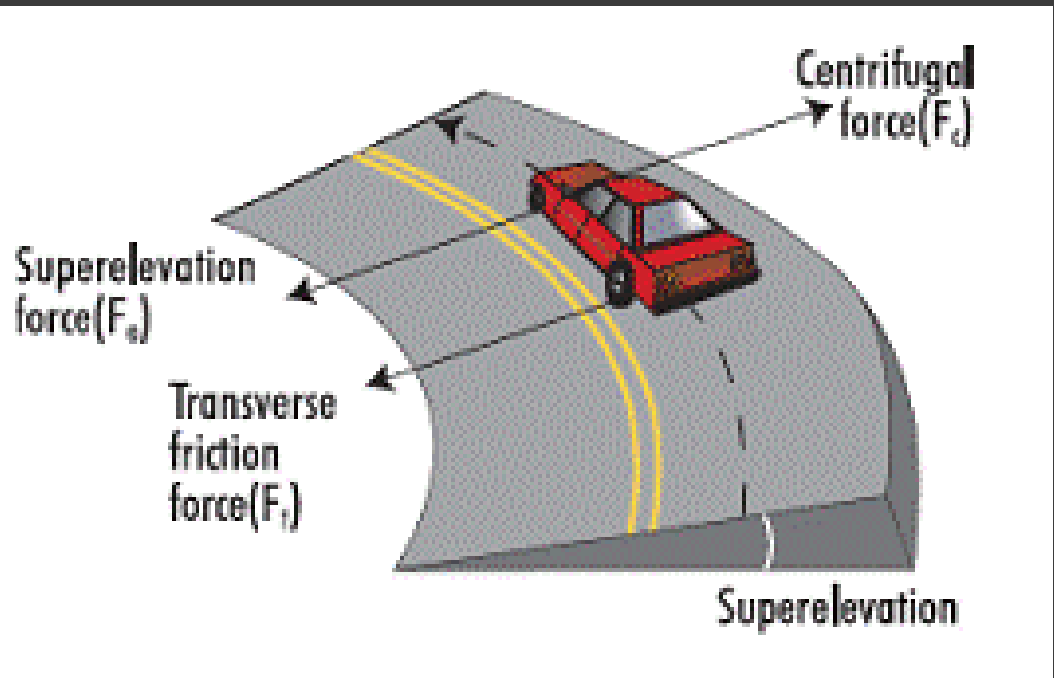
- Design of roadway curves should be based on an appropriate relationship between design speed and curvature and on their joint relationships with superelevation and side friction



# Superelevation

- Super elevation is tilting the roadway to help offset centripetal forces developed as the vehicle goes around a curve. Along with friction, they are what keeps a vehicle from going off the road.
- Must be done gradually over a distance without noticeable reduction in speed or safety





# Superelevation

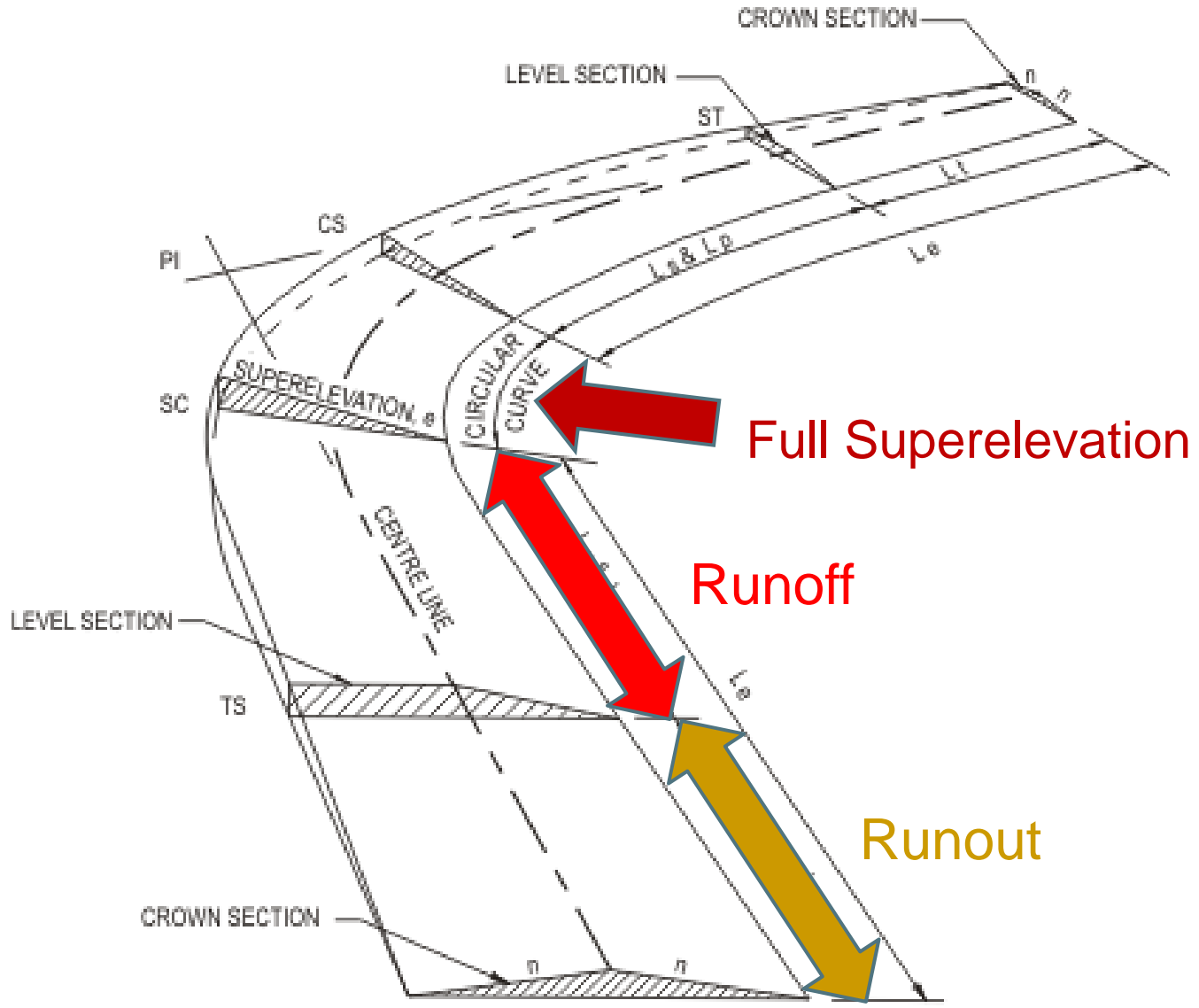
- ⦿ Practical upper limits – 6% (NDDOT)
  - Climate
    - Water
    - Ice
  - Terrain conditions
    - Flat
    - Mountainous
  - Adjacent land use (rural or urban)
  - Frequency of slow moving vehicles
    - Tractors, Etc.

# Methods of Attaining Superelevation

- ① Revolve traveled way with normal cross slopes about the **centerline** profile
- ② Revolve traveled way with normal cross slope about the **inside-edge** profile
- ③ Revolve traveled way with normal cross slope about the **outside-edge** profile
- ④ Revolve traveled way with **straight cross slope** about the **outside edge** profile

# Superelevation Transitions

- Consists of Runoff and Tangent Runout sections
- **Runoff**: length of roadway needed to accomplish a change in outside lane cross slope from zero to full
- **Runout**: length of roadway needed to accomplish a change in outside lane cross slope from normal rate to zero

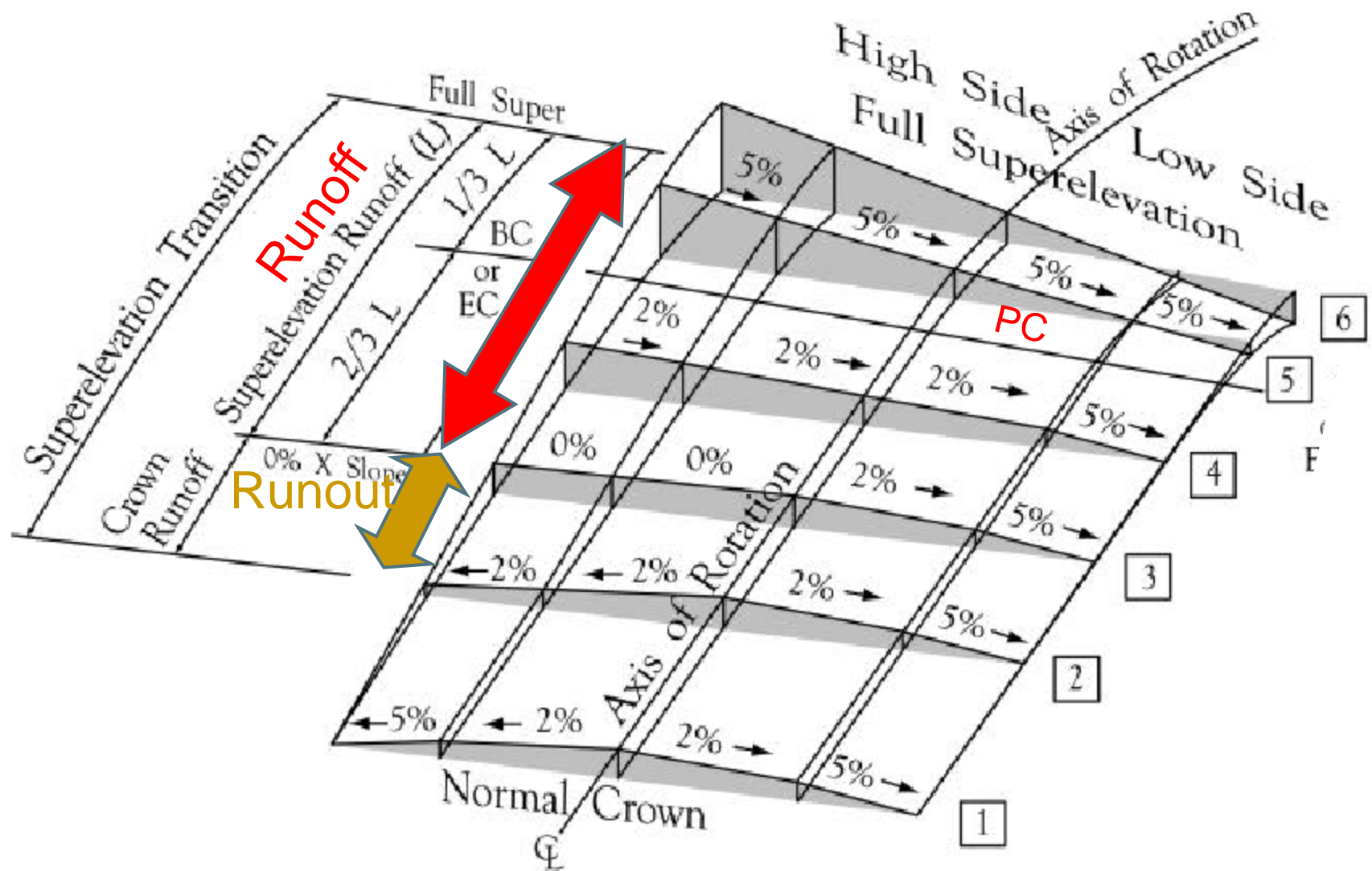


# Runoff

- ① For appearance and comfort, the length of superelevation runoff should be based on a maximum acceptable difference between the longitudinal grades of the axis of rotation and the edge of pavement
- ① Proper runoff design can be attained through the exclusive use of the maximum relative gradient.

# Runoff

- ⦿ Locating a portion of the runoff on the tangent, in advance of the PC, is preferable, since this tends to minimize the peak lateral acceleration and resulting side friction demand.
- ⦿ For non-spiral curves, the NDDOT places  $2/3$  of the runoff on the **tangent**, and  $1/3$  of the runoff on the **curve**.



Elements of a Superelevation Transition (Right Curve)



# Runoff

- Placing a larger portion of the runoff length on the approach tangent is desirable. It decreases lateral velocity in an outward direction, which can lead to undesirable side friction due to corrective steering by the driver.



$$L = \frac{(wN_1) e_d * (b_w)}{G}$$

- Equation for minimum length of superelevation runoff
- Where  $w$  = width of one traffic lane (ft)
  - $N$  = number of lanes rotated
  - $e$  = design superelevation rate (%)
  - $b$  = adjustment factor for # of lanes
  - $G$  = max relative gradient (%)

# Runout

- Determined by the amount of adverse cross slope to be removed and the rate at which is removed. To effect a smooth edge of pavement profile, the rate of removal should equal the relative gradient used to define the superelevation runoff length

# Methods of Distribution of Superelevation and Side Friction

- ⑤ 5 methods

- Methods #2 and #5 are the most common

**Method #2:** Side friction is such that a vehicle has all lateral acceleration sustained by side friction. Superelevation is used once  $f$  is equal to  $f_{\max}$ .

**Method #5:** Side friction and superelevation are in a curvilinear relation with the inverse of the radius of the curve.

# Methods of Distribution of Superelevation and Side Friction

## ◎ Method #2

- Used mostly for urban streets
  - Where speed is not uniform
  - Where constraints do not allow for superelevation
- Superelevation is not needed on flatter curves that need less than maximum side friction for vehicles.

# Methods of Distribution of Superelevation and Side Friction

## Method #5

- Superelevation and side friction distributed concurrently
- Most practical



# Finding Minimum Radius

- Minimum Radius and Design Speeds are the common limiting values of curvature determined from max rate of superelevation and max side friction factor
  - Equation found on pg. 133 and pg. 143
  - Can use this equation to solve for R\_min

$$R_{\min} = \frac{V^2}{15(.01e_{\max} + f_{\max})}$$

# Example/Handout

- According to NDDOT Cadd Standards
  - 6% max table on pg. 159
  - Max Relative Gradient (MRG) table on pg. 170
    - Determine Desired Relative Gradient (DRG)
    - NDDOT uses DRG as 83.3 % of MRG



# Main Points

- ⦿ Horizontal curves provide transitions between two tangent lengths of roadway
- ⦿ Simple Curves have 4 variables
  - Radius
  - Design Speed
  - Side Friction Factor
  - Superelevation



# Main Points

- ⦿ Considerations for Horizontal Curves
  - Safety
  - Economically Practical
  
- ⦿ Superelevation Transitions
  - Runout
  - Runoff

# Sources

- A Policy on Geometric Design of Highways and Streets, 2001
- Cadd Standards  
<http://www.dot.nd.gov/manuals/design/caddmanual/caddmanual.pdf>