TRANSPORTATION ENGINEERING

DIPLOMA WALLAH

CIVIL

JHARKHAND UNIVERSITY OF TECHNOLOGY (JUT)

TRANSPORTATION ENGINEERING - WEEK 2 NOTES

Realignment of Highways

Definition

Highway realignment refers to the process of modifying the horizontal or vertical alignment of an existing highway to improve its geometric standards, operational efficiency, safety, and capacity. This involves changing the route or profile to eliminate deficiencies such as sharp curves, steep gradients, narrow carriageways, or poor sight distances. Realignment may involve minor adjustments or complete rerouting of sections. It becomes necessary when existing roads fail to meet current traffic demands, safety standards, or face problems like landslides, flooding, or urban expansion. The process requires careful planning to minimize disruption to existing traffic and optimize resource utilization.

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Objectives of Realignment

1. **Improve Safety:** Eliminate accident-prone sections with sharp curves, blind spots, and inadequate sight distances.
2. **Enhance Capacity:** Widen roads and improve geometry to accommodate increasing traffic volumes.
3. **Reduce Travel Time:** Straighten curves and reduce gradients for higher operating speeds.
4. **Address Environmental Issues:** Avoid landslide zones, flood-prone areas, or ecologically sensitive regions.
5. **Improve Connectivity:** Better serve developing areas and bypass congested urban zones.
6. **Meet Modern Standards:** Upgrade roads to comply with current IRC specifications.

7. **Reduce Maintenance Costs:** Eliminate problematic sections requiring frequent repairs.
8. **Facilitate Development:** Support regional economic growth and urban expansion.

Explanation (8 key points)

1. Realignment addresses deficiencies in existing highway alignment.
2. It involves horizontal changes (curves, directness) and vertical changes (gradients).
3. Safety improvement is a primary driver for realignment projects.
4. Traffic growth and capacity enhancement necessitate realignment.
5. Environmental and geological factors like landslides trigger realignment.
6. Realignment must balance cost, disruption, and benefits.
7. Modern surveying technologies like GPS and Total Station enable precise realignment.
8. Stakeholder consultation and traffic management during construction are critical.

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Steps to be Followed in Highway Realignment

Step 1: Problem Identification

- Analyze accident data and identify hazardous sections.
- Assess traffic congestion and capacity deficiencies.
- Identify geometric deficiencies through field inspection.
- Review maintenance records for problematic sections.

Step 2: Preliminary Investigation

- Conduct reconnaissance surveys of the existing alignment.
- Identify potential alternative routes or modifications.
- Gather topographic, geological, and hydrological data.
- Study land use and ownership patterns.

Step 3: Traffic Studies

- Current traffic volume and composition analysis.
- Projected traffic growth over design period (typically 20-30 years).
- Origin-destination studies.

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Speed and delay studies on existing alignment.

Step 4: Geometric Design

- Develop alternative realignment proposals.
- Apply IRC geometric design standards.
- Design horizontal and vertical alignments.
- Ensure adequate sight distances and safe curve radii.

Step 5: Detailed Surveys

- Topographic surveys using Total Station or GPS.
- Geotechnical investigations for soil and rock properties.
- Drainage and hydrological surveys.
- Utility mapping (power lines, pipelines, telecom).

Step 6: Economic Analysis

- Cost estimation for construction and land acquisition.
- Benefit analysis (reduced travel time, accidents, vehicle operating costs).
- Cost-benefit ratio calculation.
- Financial feasibility assessment.

Step 7: Environmental and Social Assessment

- Environmental Impact Assessment (EIA).
- Social impact analysis and resettlement planning.
- Public consultations and stakeholder feedback.
- Mitigation measures for environmental impacts.

Step 8: Design Finalization and Approval

- Prepare detailed engineering drawings.
- Obtain statutory clearances and approvals.
- Finalize construction methodology.
- Prepare tender documents.

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Step 9: Construction and Traffic Management •

Phase construction to minimize traffic disruption.

- Implement temporary diversions.

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Quality control during construction.

Safety measures for workers and road users.

Step 10: Commissioning and Monitoring •

Final inspections and defect

rectification.

- Road opening and inauguration.
- Post-construction monitoring of performance.
- Periodic maintenance planning.

Real-Life Example

The realignment of NH-44 through the Himalayan terrain involved bypassing landslide-prone sections, reducing sharp curves, and improving sight distances, significantly enhancing safety and travel time.

Working (Flow)

Problem identification → Reconnaissance → Traffic studies → Geometric design → Detailed surveys → Economic & environmental assessment → Approvals → Construction with traffic management → Commissioning → Monitoring.

Applications

- Eliminating accident-prone curves and gradients.
- Bypassing congested urban areas.
- Avoiding natural hazards like landslides and floods.
- Accommodating increased traffic volumes.
- Improving connectivity to developing regions.

Advantages/Disadvantages

Advantages:

- Improved safety and reduced accidents.
- Enhanced road capacity and reduced congestion.
- Lower vehicle operating costs.

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- Reduced travel time.
- Better environmental sustainability.

Disadvantages:

- High construction costs.

Land acquisition challenges.

Traffic disruption during construction.

- Environmental impacts during construction.
- Social displacement issues.

Summary (Hinglish)

Highway realignment existing roads ko improve karne ka process hai. Isme sharp curves, steep gradients aur accident zones ko theek karte hain. Traffic capacity badhane, safety improve karne aur modern standards meet karne ke liye realignment zaroori hota hai. Process mein surveys, design, approvals aur construction phases hote hain.

Keywords

Realignment, Geometric Design, Safety Improvement, Capacity Enhancement, IRC Standards

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Road Patterns

Definition

Road patterns refer to the geometric layout and configuration of road networks within urban or regional areas. The pattern determines how roads interconnect, distribute traffic, provide accessibility, and shape urban form. Different patterns suit different topographies, traffic demands, and urban planning objectives. Selection of appropriate road pattern influences traffic flow efficiency, land use, construction costs, and overall urban livability. **Types of Road Patterns 1. Rectangular or Grid Pattern**

Description:
Roads intersect at right angles forming a grid of rectangular blocks. This is the most common urban road pattern, providing systematic connectivity and easy navigation.

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Characteristics:

- Roads form perpendicular intersections creating rectangular blocks.
- Provides multiple alternative routes between any two points.
- Simple and easy to understand for navigation.
- Facilitates regular property subdivision and land development.

Advantages:

Simple layout and easy navigation.

Multiple route options reduce congestion.

- Systematic property division.
- Easy expansion and extension.
- Facilitates utility installation.
- Good for flat terrain.

Disadvantages:

- Not suitable for hilly terrain.
- Monotonous appearance.
- Frequent intersections reduce average speeds.
- High number of conflict points at intersections.
- May not respect natural features.

Real-Life Example:
Manhattan, New York City; Chandigarh, India; many North American cities.

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2. Radial or Star Pattern

Description:
Roads radiate outward from a central point (usually a city center, monument, or important landmark) like spokes of a wheel. This pattern concentrates traffic toward the center.

Characteristics:

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- Roads emanate from central focal point.
- Facilitates movement to and from city center.
- Often combined with ring roads (radial-circular pattern).
- Historically evolved around fortified cities or important centers.

Advantages:

- Excellent connectivity to city center.
- Shorter travel distances to center.
- Facilitates commercial concentration at center.
- Aesthetically pleasing with monumental center.

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Natural traffic distribution from periphery to center.

Disadvantages:

- Heavy traffic congestion at center.
- Limited cross-town connectivity without traveling through center.
- Central area becomes bottleneck.
- Difficult to expand symmetrically.
- Requires large central area.

Real-Life Example:
Connaught Place, New Delhi; Paris, France; Moscow, Russia.

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3. Radial or Star and Block Pattern

Description:
Combination of radial roads emanating from center with rectangular grid blocks in between radial roads. This hybrid pattern combines advantages of both systems.

Characteristics:

- Radial roads provide connectivity to center.
- Grid blocks between radials offer alternative routes.
- Better traffic distribution than pure radial.
- Flexible land development options.

Advantages:

- Good central accessibility with radial roads.
- Alternative routes through grid blocks.
- Reduced central congestion compared to pure radial.
- Flexible urban form.
- Accommodates various traffic patterns.

Disadvantages:

- Complex planning and design.
- Irregular block sizes.

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- More difficult navigation.
- Higher construction and maintenance costs.

Real-Life Example:
Washington D.C., USA combines radial avenues with grid streets.

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4. Radial or Star and Circular Pattern (Ring-Radial)

Description:
Radial roads connect to concentric circular or ring roads at various distances from center. This is one of the most efficient urban road patterns for large cities.

Characteristics:

- Radial roads for center-periphery movement.
- Circular/ring roads for cross-town traffic.
- Minimizes through traffic in city center.
- Hierarchical road system.

Advantages:

- Excellent for cross-town connectivity via ring roads.
- Reduces central congestion by diverting traffic to rings.
- Hierarchical traffic distribution.
- Facilitates staged urban expansion along rings.
- Good balance between radial and tangential movement.
- Efficient for large metropolitan areas.

Disadvantages:

- Expensive construction of ring roads.
- Requires large land area.
- Complex intersections where radials meet rings.
- Long construction periods.
- Land acquisition challenges for outer rings.

Real-Life Example:
Moscow with multiple ring roads; Delhi with Inner, Outer, and new ring roads; Paris with multiple Périphériques.

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5. Hexagonal Pattern

Description:
Roads form hexagonal (six-sided) blocks instead of rectangular. This pattern is theoretically efficient but rarely implemented in practice.

Characteristics:

- Six roads meet at each intersection (120° angles).
- Reduces number of intersections compared to grid.
- Provides more direct routes diagonally.
- Theoretically optimal for minimizing travel distances.

Advantages:

- Fewer intersections than rectangular grid.
- More direct diagonal routes.
- Reduced total road length for same area.
- Lower construction and maintenance costs.
- Efficient traffic distribution.

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Disadvantages:

- Difficult to implement in existing developed areas.
- Unfamiliar pattern for navigation.
- Complex property subdivision.
- Irregular building plots.
- Rarely used due to practical implementation challenges.

Real-Life Example:
Limited practical implementations; mostly theoretical urban planning studies.

Comparison Table of Road Patterns

Pattern	Best Terrain	Central Connectivity	Crosstown Movement	Implementation Cost	Expansion Ease
Rectangular	Flat	Moderate	Excellent	Low	Easy

Radial	Any	Excellent	Poor	Moderate	Difficult
Radial-Block	Any	Good	Good	High	Moderate
Ring-Radial	Any	Good	Excellent	Very High	Moderate
Hexagonal	Flat	Good	Good	Moderate	Difficult

Summary (Hinglish)

Road patterns urban areas mein roads ki layout ko define karte hain. Rectangular pattern simple aur common hai. Radial pattern central point se roads nikalti hain. Ring-radial pattern cities ke liye best hai kyunki central aur cross-town dono traffic handle kar sakta hai. Hexagonal pattern theoretically best hai par practically kam use hota hai.

Keywords

Road Pattern, Grid Layout, Radial Pattern, Ring Roads, Urban Planning

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Importance of Curves in Road and Railway Alignment

Definition

Curves are curved sections in horizontal or vertical alignment of roads and railways that provide gradual change in direction or gradient. Curves are essential for adapting transportation routes to natural terrain, connecting straight sections at angles, and providing safe transitions. Properly designed curves ensure vehicle safety, passenger comfort, and operational efficiency by controlling centrifugal forces, sight distances, and drainage requirements.

Explanation (8 key points)

1. Curves adapt alignment to topography, avoiding excessive cutting and filling.
2. They connect straight sections intersecting at angles.
3. Horizontal curves change direction; vertical curves change gradient.
4. Proper curve design controls centrifugal and gravitational forces.
5. Curves must provide adequate sight distance for safety.
6. Transition curves gradually introduce curvature for comfort and safety.
7. Curve radius and superelevation work together for vehicle stability.

8. Railway curves have stricter radius requirements than roads due to train dynamics.

Importance of Curves

1. Topographic Adaptation:
Curves allow alignment to follow natural terrain contours, minimizing earthwork, construction costs, and environmental impact.

2. Directional Changes:
Enable roads and railways to change direction to reach destinations or avoid obstacles like buildings, water bodies, and protected areas.

3. Safety:
Properly designed curves with adequate radii and superelevation prevent vehicle skidding and overturning due to centrifugal forces.

4. Comfort:
Gradual curves with transition sections provide comfortable riding quality by avoiding sudden jerks and lateral forces.

5. Sight Distance:
Curves must be designed to provide adequate stopping and overtaking sight distances for safe operation.

6. Drainage:
Curves with superelevation facilitate water drainage from pavement surface, preventing hydroplaning and pavement deterioration.

7. Aesthetic Appeal:
Gentle, flowing curves create visually pleasing alignments that blend with landscape.

8. Operational Efficiency:
Properly designed curves allow vehicles to maintain reasonable speeds without excessive braking or acceleration.

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Elements of Curves

For Horizontal Curves:

1. **Point of Curvature (PC) or Tangent Point (T1):**
   Point where straight (tangent) section transitions into circular curve.
2. **Point of Tangency (PT) or Tangent Point (T2):**
   Point where circular curve transitions back to straight section.
3. **Point of Intersection (PI) or Vertex (V):**
   Intersection point of two tangent lines (straights) if extended.
4. **Radius (R):**

Radius of the circular curve measured from curve center to centerline.

5. **Tangent Length (T):**
   Distance from PI to PC (or PI to PT); equal on both sides for simple curves.
6. **Length of Curve (L):**
   Arc length from PC to PT along the curve centerline.
7. **Deflection Angle (Δ) or Intersection Angle (I):**
   Angle between two tangent sections; also equals central angle of curve.
8. **Degree of Curve (D):**
   Central angle subtended by a standard chord length (20m in India, 100ft in USA).
9. **Chord Length (C):**
   Straight-line distance from PC to PT.
10. **Mid-ordinate (M):**
    Perpendicular distance from midpoint of chord to midpoint of curve.
11. **External Distance (E):**
    Distance from PI to midpoint of curve measured perpendicular to chord.

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Relation Between Radius and Degree of Curve

Two standard definitions exist:

Arc Definition (Used in India):
Degree of curve (D) is the central angle subtended by an arc of 20 meters (standard chain length).

$$R = \frac{1718.87}{D} \text{ meters}$$

Where:

- R = Radius in meters
- D = Degree of curve

Derivation:
For arc length = 20m

$$\text{Arc} = \frac{\pi R D}{180}$$

$$20 = \frac{\pi R D}{180}$$

$$R = \frac{20 \times 180}{\pi D} = \frac{3600}{\pi D} = \frac{1145.916}{D} \approx \frac{1146}{D}$$

More precisely, using 2πR/360° = 20m/D:

$$R = \frac{1718.87}{D}$$

Chord Definition (Used in USA):
Degree of curve is the central angle subtended by a chord of 100 feet.

$$R = \frac{5729.58}{D} \text{ feet}$$

Relationship:

- Sharper curves → Larger D → Smaller R
- Flatter curves → Smaller D → Larger R

Real-Life Example

On NH-7 through Western Ghats, curves with R=200m to 400m are common in mountainous terrain, while plains sections have R>1000m for higher speeds.

Working (Flow)

Design speed selection → Calculate minimum radius → Determine curve length → Calculate tangent lengths → Mark PC, PI, PT → Set out curve → Apply superelevation → Ensure sight distance → Implement safety measures.

Applications

- Mountain roads with sharp curves to navigate terrain.
- Railway curves for directional changes.
- Highway interchanges and exit ramps.
- Urban roads adapting to city layout.
- Aesthetic landscape design. **Formula/Key Equations**

Tangent Length:

$$T = R\tan\left(\frac{\Delta}{2}\right)$$

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Length of Curve:

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

Chord Length:

$$C = 2R\sin\left(\frac{\Delta}{2}\right)$$

Mid-ordinate:

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

External Distance:

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

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Summary (Hinglish)

Curves road aur railway alignment mein direction change karne ke liye zaroori hain. Ye terrain ko follow karte hain aur safety provide karte hain. Curve ki radius aur degree of curve inverse relation mein hote hain. Proper curve design se centrifugal force control hoti hai aur vehicles safe speeds pe chal sakti hain.

Keywords

Curves, Radius, Degree of Curve, Deflection Angle, Tangent Length, Point of Curvature

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Types of Curves

Horizontal Curves

Definition :
Horizontal curves are curves in the plan view (bird's eye view) that change the horizontal direction of the alignment. They are provided to connect two straight sections (tangents) intersecting at an angle.

1. Simple Curve

Description:
A simple curve is a circular arc of constant radius connecting two straight sections (tangents). It is the most basic and commonly used horizontal curve.

Elements:

- Single constant radius throughout.
- PC (Point of Curvature) where curve begins.
- PT (Point of Tangency) where curve ends.
- PI (Point of Intersection) of tangents.
- Equal tangent lengths on both sides.

Characteristics:

- Uniform curvature throughout.
- Simplest to design and set out.
- Requires superelevation along entire length.
- May cause discomfort at entry and exit due to sudden curvature change.

Applications:

- Roads and railways where moderate deflection angles exist.
- Locations where space constraints don't allow transition curves.
- Low-speed roads and rural highways.

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Advantages:

- Simple design and calculation.
- Easy field setting out.
- Lower construction cost.

Disadvantages:

- Sudden change from straight to curved path.
- Passenger discomfort at high speeds.
- Safety concerns at entry and exit.

Real-Life Example:
Rural district roads and village connecting roads commonly use simple curves due to lower speeds and cost constraints.

2. Compound Curve

Description:
A compound curve consists of two or more consecutive simple curves with different radii curving in the same direction. The curves join without any straight section between them.

Elements:

- Two or more circular arcs of different radii.
- PC (Point of Curvature) at start of first curve.

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Point of Compound Curvature (PCC) where first curve ends and second begins.

- PT (Point of Tangency) at end of last curve.
- Common tangent at PCC.

Characteristics:

- Each section has different radius.
- All curves turn in same direction.
- Used when simple curve cannot fit terrain or right-of-way.
- More complex design and setting out.

Applications:

- Mountain roads adapting to varying terrain.
- Railway curves in hilly regions.
- Situations with space or obstacle constraints.
- Urban road intersections and ramps.

Advantages:

- Better adaptation to terrain than simple curve.
- Can fit in restricted right-of-way.
- Flexibility in design.

Disadvantages:

- Complex design calculations.
- Difficult field setting out.
- Potential discomfort at PCC due to curvature change.
- Higher cost than simple curve.

Design Considerations:

- Radius of sharper curve should not be less than 2/3 of flatter curve.
- Longer radius curve should be provided first when approaching from tangent.
- Avoid excessive difference between radii.

Real-Life Example:

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Ghat sections of Mumbai-Pune Expressway and mountain roads in Himalayas use compound curves to navigate steep terrain changes.

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3. Reverse Curve

Description:
A reverse curve (or serpentine curve) consists of two simple curves with opposite curvature directions, forming an S-shape. One curve bends left, the other bends right.

Elements:

- Two circular curves curving in opposite directions.
- PC (Point of Curvature) at start of first curve.
- Point of Reverse Curvature (PRC) where first curve ends and second begins with opposite direction.
- PT (Point of Tangency) at end of second curve.

Characteristics:

- Curves turn in opposite directions.
- Creates S-shaped alignment.
- No tangent section between curves (or very short tangent ideally).
- Centrifugal force changes direction suddenly at PRC.

Applications:

- Connecting parallel railway lines or roads.
- Transition between highway lanes.
- Valley crossings where alignment must reverse.
- Limited use on main highways due to safety concerns.

Advantages:

- Useful for connecting parallel alignments.
- Saves space compared to two separate curves with long tangent.
- Aesthetic appeal in landscape design.

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Disadvantages:

- Sudden reversal of centrifugal force causes discomfort and safety issues.
  Difficult to maintain sight distance at PRC.
- Drainage problems at PRC (requires special attention).
- Should be avoided on high-speed roads.

IRC Recommendations:

- Minimum tangent length between reverse curves should be provided.
- For design speed ≥80 km/h: Minimum tangent = design speed in m.
- Lower speeds: Shorter tangent acceptable but not less than 20m.
- Reverse curves should be avoided on main highways if possible.

Real-Life Example:
Railway yard layouts use reverse curves to connect parallel tracks. Some mountain roads use reverse curves with adequate tangent between them.

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4. Transition Curve (Spiral Curve)

Description:
A transition curve is a curve of gradually changing radius inserted between a straight section and a circular curve (or between two curves). The radius decreases gradually from infinity at the tangent to the radius of the circular curve.

Purpose:

- Provide gradual change in curvature.
- Allow gradual application of superelevation.
- Ensure comfortable and safe transition.
- Reduce centrifugal force shock.

Types:

- **Spiral (Clothoid):** Most commonly used; radius inversely proportional to length.
- **Lemniscate:** Based on lemniscate geometric curve.
- **Cubic Parabola:** Third-degree parabola approximation.

Elements:

- T.S. (Tangent to Spiral): Point where transition curve leaves tangent.

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- S.C. (Spiral to Curve): Point where transition curve joins circular curve.
- C.S. (Curve to Spiral): Point where circular curve joins exit transition.

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S.T. (Spiral to Tangent): Point where transition curve rejoins tangent.

Characteristics:

- Radius varies continuously from ∞ to R.
- Length depends on design speed and curve radius.
- Superelevation introduced gradually along transition.
- Provides comfortable vehicle dynamics.

Length of Transition Curve:

IRC specifies minimum length based on:

$$L = \frac{V^3}{C \times R}$$

Where:

- L = Length of transition curve (m)
- V = Design speed (km/h)
- C = Rate of change of centrifugal acceleration (0.5 to 0.8 m/s^3)
- R = Radius of circular curve (m)

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Alternative formula:

$$L = 2.7 \times \frac{V^2}{R}$$

Minimum values:

- For V = 100 km/h, L(min) = 40m
- For V = 80 km/h, L(min) = 30m
- For V = 65 km/h, L(min) = 25m

Applications:

- All modern highways with design speed ≥60 km/h.
- High-speed railways.

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- Expressways and national highways.
- Between compound curves of significantly different radii.

Advantages:

Smooth and comfortable transition.

- Gradual superelevation introduction.
- Improved safety at high speeds.
- Better vehicle handling characteristics.
- Reduced maintenance requirements.

Disadvantages:

- Increases total curve length.
- Complex design and setting out.
- Higher construction cost.

Real-Life Example:
All expressways like Mumbai-Pune Expressway, Yamuna Expressway, and Golden Quadrilateral highways use transition curves at every horizontal curve for smooth high-speed operation.

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Vertical Curves

Definition :
Vertical curves are curves in the longitudinal profile (elevation view) that provide smooth transitions between different gradients (slopes). They ensure comfortable vehicle dynamics and adequate sight distance at grade changes.

Types:

1. Summit Curve (Crest Curve):

- Connects an ascending gradient to a descending gradient (or flatter ascending).
- Convex upward curve.
- Critical for stopping sight distance.
- Driver's line of sight may be obstructed by curve.

2. Valley Curve (Sag Curve):

- Connects a descending gradient to an ascending gradient (or flatter descending).
- Concave upward curve.
- Critical for headlight sight distance at night.
- Provides smoother riding quality.

Design Considerations:

- Radius based on sight distance requirements.
- Comfort considerations (vertical acceleration limits).
- Drainage at summit and valley points.
- Aesthetic appearance.

Applications:

- All highway and railway grade changes.
- Bridge approaches.
- Underpass and overpass transitions.
- Hilly terrain roads.

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Procedure for Setting Out Curves Using Total Station

Setting Out Simple Curve by Rankine's Method (Deflection Angle Method)

Principle:
Rankine's deflection angle method uses the principle that the deflection angle to any point on the curve is proportional to the length of the curve from PC to that point.

Equipment Required:

- Total Station
- Prism/Reflector
- Ranging rods
- Marking pegs/stakes

Field Procedure:

Step 1: Preliminary Calculations

Calculate curve elements:

- Tangent length: $T = R\tan(\Delta/2)$

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- Length of curve: $L = (\pi R\Delta)/180$
- Chord length for setting: Usually 20m (standard)
- Number of chords: n = L/chord length
- Deflection angle per chord: $\delta = (D \times \text{chord})/2$

Where D = Degree of curve = 1718.87/R

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Step 2: Locate PC and PT

- Set up theodolite/Total Station at PI.
- Measure back tangent length T to locate PC.
- Measure forward tangent length T to locate PT.
- Mark PC and PT with stakes.

Step 3: Setup at PC

- Move Total Station to PC.
- Sight backward to PI and set horizontal circle to 0°00'00".
- Transit (turn 180°) to sight forward tangent.

Step 4: Calculate Deflection Angles

For each point at chord length c from PC:

$$\delta_n = \frac{1718.87 \times c}{2R} \text{ (in degrees)}$$

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Cumulative deflection angles:

- Point 1: δ_1
- Point 2: $\delta_1 + \delta_2$
- Point n: $\Sigma\delta$

Step 5: Set Out Points

- Set horizontal angle to first deflection angle δ_1.
- Direct assistant with prism to move until Total Station shows chord distance.
- Mark point 1.
- Set angle to cumulative deflection angle for point 2.
- Measure distance from previous point (chord length).
- Mark point 2.
- Continue until PT is reached.

Step 6: Check

- Final deflection angle should equal $\Delta/2$.

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- Distance from last point to PT should equal last chord.
- Check PT location from PI using tangent length.

Step 7: Mark Curve

- Drive stakes at all marked points.
- Paint or mark centerline.
- Mark offsets for edge of pavement.

Setting Out Compound Curve by Rankine's Method

Principle:
Similar to simple curve but applied sequentially to each circular arc with its respective radius.

Field Procedure:

Step 1: Calculations

For Curve 1 (Radius R_1):

- Calculate all elements (T_1, L_1, etc.)
- Calculate deflection angles for all points

For Curve 2 (Radius R_2):

- Calculate all elements (T_2, L_2, etc.)
- Calculate deflection angles for all points

Step 2: Locate PC, PCC, PT

- Setup at PI
- Locate PC using T_1
- Calculate PCC location
- Locate PT using T_2 from PCC

Step 3: Set Out First Curve

- Setup Total Station at PC
- Follow Rankine's method for simple curve
- Set out all points up to PCC

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Step 4: Set Out Second Curve

- Setup Total Station at PCC
- Orient instrument toward last point of Curve 1
- Set horizontal circle to continuation angle

  Apply deflection angles for Curve 2
- Set out all points from PCC to PT

Step 5: Verification

- Check PT position from both directions
- Verify smooth transition at PCC
- Check tangent directions at PC and PT

Setting Out Reverse Curve Between Two Parallel Lines

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Application:
Commonly used to connect parallel railway tracks or highway lanes.

Given Data:

- Distance between parallel lines (d)
- Desired radii (R_1 and R_2)
- Or: Distance between parallel lines and available length

Field Procedure:

Step 1: Design Calculations

For equal radii ($R_1 = R_2 = R$):

$$d \sin(\Delta/2) = \frac{}{2R}$$

Calculate:

- Deflection angle Δ
- Tangent lengths
- Curve lengths
- PRC location

Step 2: Locate PC and PT

- Mark starting point on first parallel line (PC)
- Mark ending point on second parallel line (PT)
- Calculate and mark PRC (midpoint location)

Step 3: Set Out First Curve

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  Setup Total Station at PC
- Orient toward first parallel line direction
- Calculate deflection angles for Curve 1
- Set out points up to PRC using Rankine's method

Step 4: Set Out Second Curve

- Setup Total Station at PRC
- Orient continuing tangent from Curve 1
- Turn instrument to begin Curve 2 (opposite direction)
- Set out points from PRC to PT

Step 5: Check Alignment

- Verify PT is on second parallel line
- Check smooth transition at PRC
- Verify both curves maintain parallel separation

Step 6: Apply Transition (if required)

- Insert short tangent between curves if speeds warrant
- Mark transition zones
- Apply appropriate superelevation transition

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Summary (Hinglish)

Curves roads aur railways mein direction change aur gradients ko connect karne ke liye use hote hain. Simple curve ek radius ka hota hai, compound curve different radii ke curves ka combination hai, reverse curve opposite direction mein curves ka S-shape hota hai, aur transition curve gradual curvature change provide karta hai. Vertical curves gradients ko connect karte hain - summit curves upward aur valley curves downward transitions provide karte hain. Total Station se deflection angle method use karke curves accurately set out kiye jate hain.

Keywords

Simple Curve, Compound Curve, Reverse Curve, Transition Curve, Deflection Angle, Rankine's Method, Total Station, Vertical Curves

Common Errors or Misconceptions

-

- Reverse curves are safe for high-speed roads (They should be avoided or provided with adequate tangent between them).

  Transition curves are optional (They are mandatory for highways with design speed ≥60 km/h).

Diagrams to Draw

1. Highway Realignment Process Flowchart

- Show sequential steps: Problem Identification → Surveys → Design → Approvals → Construction → Monitoring
- Use boxes connected with arrows

2. Road Patterns Diagrams

a) Rectangular/Grid Pattern:

- Draw perpendicular roads forming rectangular blocks
- Label intersections and blocks

b) Radial/Star Pattern:

- Draw central point with roads radiating outward like spokes
- Mark central area

c) Radial and Circular (Ring-Radial) Pattern:

- Draw central point with radial roads
- Add 2-3 concentric circular/ring roads intersecting radials
- Label inner ring, outer ring

d) Radial and Block Pattern:

- Combine radial roads with rectangular grid blocks between them

e) Hexagonal Pattern:

- Draw hexagonal blocks with roads forming 120° angles at intersections

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3. Elements of a Simple Horizontal Curve

- Draw two intersecting tangent lines (straights)
- Show circular arc connecting them
- Label clearly:
  - PI (Point of Intersection) ○ PC (Point of Curvature) ○ PT (Point of Tangency) ○ Radius (R) - draw from center to curve ○ Tangent length (T) - both sides ○ Deflection angle (Δ) ○ Length of curve (L) ○ Chord (C) ○ Mid-ordinate (M)
  - External distance (E)

4. Types of Horizontal Curves - Comparison

a) Simple Curve:

- Two tangents with single circular arc of radius R

b) Compound Curve:

- Two tangents connected by two consecutive circular arcs (R_1 and R_2)
- Mark PC, PCC (Point of Compound Curvature), PT

c) Reverse Curve:

- Draw S-shaped curve
- Mark PC, PRC (Point of Reverse Curvature), PT
- Show curves bending in opposite directions

d) Transition Curve:

- Show tangent → spiral → circular curve → spiral → tangent
- Label T.S., S.C., C.S., S.T.
- Show radius changing gradually

5. Relation Between Radius and Degree of Curve

- Draw a circle with center O
- Mark arc of 20m
- Show central angle D
- Draw radius R

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- Write formula: R = 1718.87/D **6. Vertical Curves Diagrams**

a) Summit Curve (Crest):

- Draw upward then downward gradient
- Show convex curve connecting them
- Mark gradient lines (g_1% up, g_2% down)
- Show sight distance line

b) Valley Curve (Sag):

- Draw downward then upward gradient
- Show concave curve connecting them
- Mark gradient lines (g_1% down, g_2% up)
- Show headlight beam at night

7. Setting Out Simple Curve - Deflection Angle Method

- Draw curve from PC to PT
- Show Total Station setup at PC
- Draw deflection angles (δ_1, δ_2, δ_3...)
- Mark chord lengths (usually 20m)
- Show cumulative deflection angles

8. Setting Out Compound Curve

- Draw two curves with different radii
- Mark PC, PCC, PT
- Show Total Station setup at PC and PCC
- Label R_1 and R_2
- Show deflection angles for each curve section

9. Reverse Curve Between Parallel Lines

- Draw two parallel lines (distance d apart)
- Show S-curve connecting them
- Mark PC, PRC, PT
- Label both radii (R_1, R_2)

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- Show parallel separation distance

10. Superelevation Diagram (Side View)

- Draw cross-section of road on curve
- Show outer edge raised
- Mark superelevation height
- Label inner edge, outer edge, centerline

11. Transition Curve Layout

- Draw complete curve system:
  - Straight (Tangent) ○ Transition curve (spiral) ○ Circular curve ○ Transition curve (spiral)
  - Straight (Tangent)
- Show how radius changes from ∞ to R
- Mark all transition points **12. Comparison Table - Road Patterns** Draw a table showing:

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Pattern	**Sketch**	**Advantages**	**Disadvantages**	**Best Use**
Grid	[mini sketch]	Simple	Monotonous	Flat terrain
Radial	[mini sketch]	Central access	Congestion	Historic centers
Ring-Radial	[mini sketch]	Cross-town	Expensive	Large cities

Drawing Tips:

1. **Use Scale:** Mention "Not to scale" or use approximate scale
2. **Label Everything:** Clear labels with arrows
3. **Use Different Colors:**
   - Black/Blue for main lines ○ Red for important points (PC, PT, PI) ○ Green for measurements
   - Dotted lines for construction lines

4. **Keep It Simple:** Clear, neat diagrams better than complex ones
5. **Add Dimensions:** Show typical values (R=200m, chord=20m, etc.)
6. **North Direction:** For road pattern diagrams, show North arrow
7. **Legend:** If using symbols, provide a legend box

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