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TRANSPORTATION ENGINEERING – I
DEPARTMENT OF CIVIL ENGINEERING
FACULTY OF ENGINEERING & TECHNOLOGY

TRANSPORTATION ENGINEERING – I (Highway Engineering) UNIT-2 LECTURE -1

Topics to be covered:

- Horizontal Transition Curves
- Type of Transition Curve
- Length of Transition Curve
- Gradient
- Types of Gradient
- Grade Compensation



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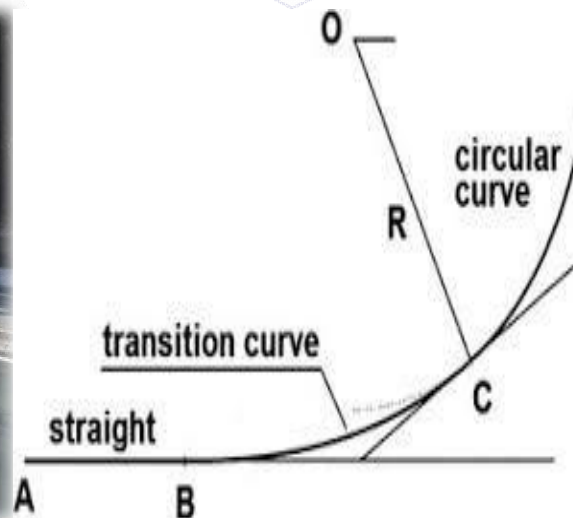
RAMA UNIVERSITY UTTAR PRADESH, KANPUR (INDIA)

HORIZONTAL TRANSITION CURVES :

Transition curve ensures a smooth change from straight road to circular curves. Setback distance looks in for safety at circular curves taking into consideration the sight distance aspects. Transition curve is provided to change the horizontal alignment from straight to circular curve gradually and has a radius which decreases from infinity at the straight end (tangent point) to the desired radius of the circular curve at the other end (curve point). Transition curve is a curve in plan which is provided to change the horizontal alignment from straight to circular curve gradually means the radius of transition curve varies between infinity to R or R to infinity.

OBJECTIVES FOR PROVIDING TRANSITION CURVES :

- For the gradual introduction Centrifugal force
- To enable the driver turn the steering gradually for his own comfort and security,
- To introduce super elevation gradually
- To introduce extra widening gradually
- To provide comfort for the driver that is to enable smooth vehicle operation.
- To enhance aesthetics of highways.



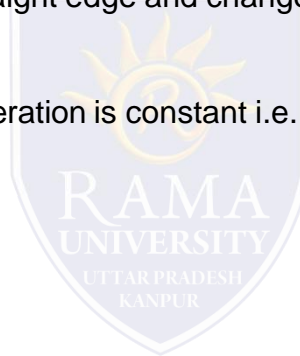
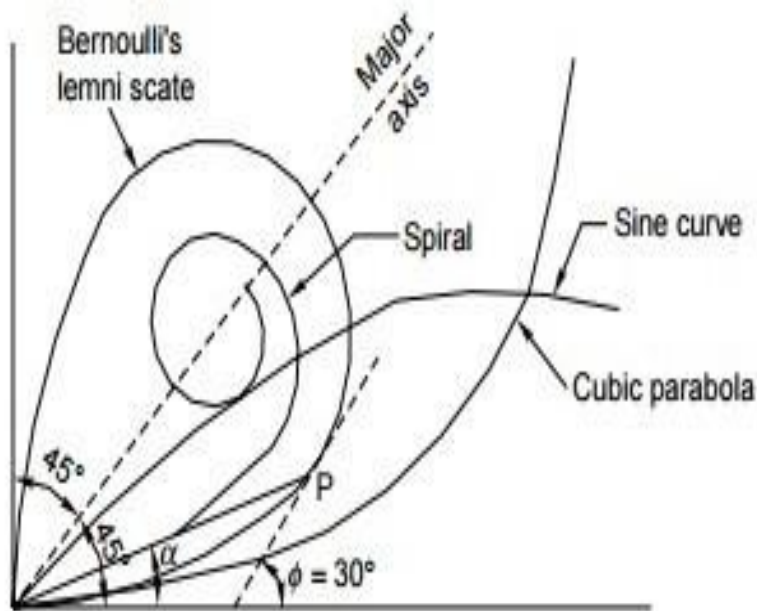
TYPE OF TRANSITION CURVE :

Different types of transition curves are :

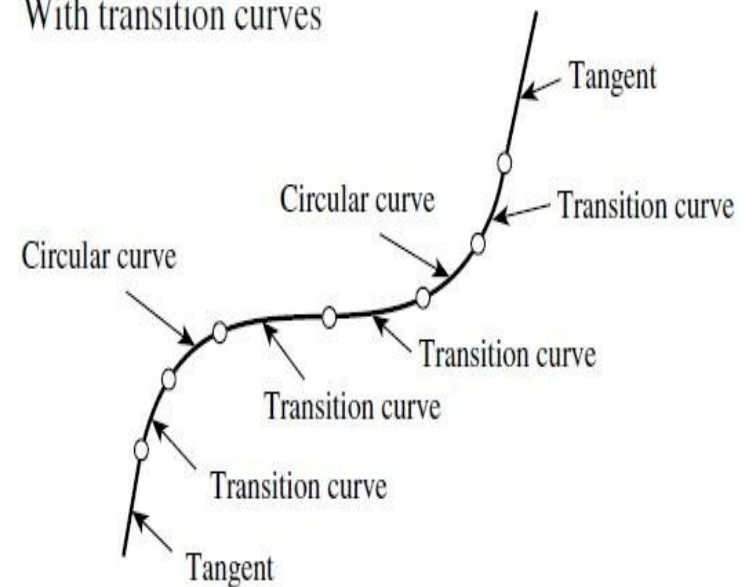
- Spiral or clothoid
- Cubic parabola
- Lemniscates

IRC recommends Spiral or clothoid as the ideal transition curve due to following reasons:

- Rate of change or centrifugal acceleration is consistent (smooth) and
- Radius of the transition curve is **Infinity** at the straight edge and changes to **R** at the curve point ($L_s \propto \frac{1}{R}$) and calculation and field implementation is very easy.
- It satisfies that rate of change of centrifugal acceleration is constant i.e., $L_s \cdot R = \text{constant}$. Where L_s = length of transition curve, R = Radius of curve.



With transition curves



LENGTH OF TRANSITION CURVE :

The length of the transition curve should be determined as the maximum of the following three criteria: rate of change of centrifugal acceleration, rate of change of super-elevation, and an empirical formula given by IRC.

BASED ON RATE OF CHANGE OF ACCELERATION :

Radius of curve is infinity at the tangent point and hence centrifugal acceleration is zero. Similarly at the straight end radius of curve has minimum value means centrifugal acceleration is maximum. So, the rate of change of centrifugal acceleration should be adopted such that the design should not cause any discomfort to the drivers. Let L_s be the length of transition curve and a vehicle is moving with a speed of V m/s.

$$\text{Force } P = (mV^2/R)$$

Since it is similar to :

$$F = ma$$

$$P = m (V^2/R)$$

Therefore, centrifugal acceleration = V^2/R

Let "C" be the coefficient of rate of change of centrifugal acceleration.

$$C = (V^2/R). (1/t)$$

Where t = time taken to travel the transition curve of length L_s , with a speed of V

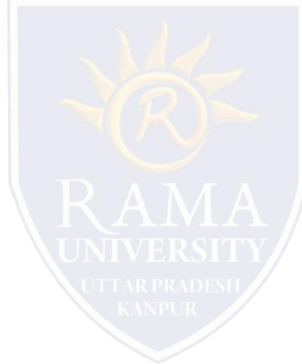
$$t = L_s/V$$

$$C = (V^2/R). (V/L_s)$$

$$L_s = (V^3/CR)$$

According to IRC, $C = 80/(75+V)$ and C should be $(0.5 < C < 0.8)$.

The value of C should be taken as 0.5, if it is less than 0.5 and should be taken as 0.8 if it is greater than 0.8.



LENGTH OF TRANSITION CURVE :

BASED ON RATE OF CHANGE OF SUPERELEVATION AND EXTRA WIDENING :

Let 1 in N is the allowable rate of introduction of super elevation and E is the raise of the outer edge with respect to inner edge. W is the normal width of pavement in meters. We is the extra width of pavement in meters and e is the rate of super-elevation.

$$E = (W+We).e$$

Therefore length of transition curve, $L_s = (W+We).e.N$

If the pavement outer edge is raised and inner edge is depressed with respect to center of pavement then,

$$L_s = [(W+We).e.N] / 2$$

Typical range of introduction of super elevation is as follows according to IRC :

TYPE OF TERRAIN	RATE OF SUPER ELEVATION 1 IN N
For plain and rolling terrains	1 in 150
For built up areas	1 in 100
For hilly and steep terrains	1 in 60

BASED ON IRC EMPIRICAL FORMULA : IRC given some direct formulae for finding the length of transition curve.

For plain and ruling terrain:

$$L_s = 2.7 (V^2/R)$$

For mountainous and steep terrains

$$L_s = V^2/R$$

Hence these are the three criteria to determine the length of transition curve.

The maximum of above three conditions will be considered as the length of transition curve.

PROBLEMS RELATED TO THE TOPICS DISCUSSED :

1. Calculate the length of transition curve for $V=65\text{kmph}$, $R=220\text{m}$, rate of introduction of super elevation is 1 in 150, $W+We=7.5$ m. (Hint: $c=0.57$) [Answer: $L_{s1}=47.1\text{m}$, $L_{s2}=39\text{m}$ ($e=0.07$, pavement rotated with reference to centerline), $L_{s3}=51.9\text{m}$, $L_s=52\text{m}$].
2. NH passing through rolling terrain of heavy rainfall area, $R=500\text{m}$. Design length of Transition curve. (Hint: Heavy rainfall. Pavement surface rotated with respect to inner edge. $V=80\text{kmph}$, $W=7.0\text{m}$, $N=1$ in 150) [Answer: $c=0.52$, $L_{s1}=42.3$, $L_{s2}=63.7\text{m}$ ($e=0.057$, $W+We=7.45$), $L_{s3}=34.6\text{m}$, $L_s=64\text{m}$]



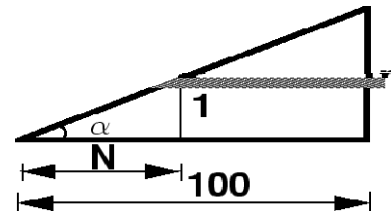
GRADIENT :

The vertical alignment of a road consists of gradients (straight lines in a vertical plane) and vertical curves. The vertical alignment is usually drawn as a profile, which is a graph with elevation as vertical axis and the horizontal distance along the centre line of the road as the horizontal axis. Just as a circular curve is used to connect horizontal straight stretches of road, vertical curves connect two gradients. When these two curves meet, they form either convex or concave. The former is called a summit curve, while the latter is called a valley curve.

Gradient is the rate of rise or fall along the length of the road with respect to the horizontal. While aligning a highway, the gradient is decided for designing the vertical curve. Before finalizing the gradients, the construction cost, vehicular operation cost and the practical problems in the site also has to be considered. Usually steep gradients are avoided as far as possible because of the difficulty to climb and increase in the construction cost.

EFFECT OF GRADIENT : The effect of long steep gradient on the vehicular speed is considerable. This is particularly important in roads where the proportion of heavy vehicles is significant. Due to restrictive sight distance at uphill gradients the speed of traffic is often controlled by these heavy vehicles. As a result, not only the operating costs of the vehicles are increased, but also capacity of the roads will have to be reduced. Further, due to high differential speed between heavy and light vehicles, and between uphill and downhill gradients, accidents abound in gradients.

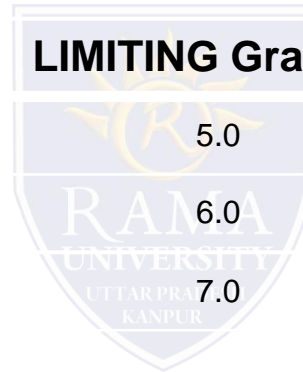
REPRESENTATION OF GRADIENT : The positive gradient or the ascending gradient is denoted as **+n** and the negative gradient as **-n**. The deviation angle **N** is: when two grades meet, the angle which measures the change of direction and is given by the algebraic difference between the two grades $(n_1 - (-n_2)) = n_1 + n_2 = \alpha_1 + \alpha_2$ Example: 1 in 30 = 3.33% $\approx 2^\circ$ is a steep gradient, while 1 in 50 = 2% $\approx 1^\circ 10'$ is a flatter gradient.



TYPES OF GRADIENT :

Many studies have shown that gradient up to seven percent can have considerable effect on the speeds of the passenger cars. On the contrary, the speeds of the heavy vehicles are considerably reduced when long gradients as flat as two percent is adopted. Although, flatter gradients are desirable, it is evident that the cost of construction will also be very high. Therefore, IRC has specified the desirable gradients for each terrain. However, it may not be economically viable to adopt such gradients in certain locations, steeper gradients are permitted for short duration. Different types of grades are discussed below and the recommended type of gradients for each type of terrain and type of gradient is given in table below :

TERRAIN	RULING Gradient	LIMITING Gradient	EXCEPTIONAL Gradient
Plain/Rolling	3.3	5.0	6.7
Hilly	5.0	6.0	7.0
Steep	6.0	7.0	8.0



Ruling gradient, limiting gradient, exceptional gradient and minimum gradient are some types of gradients:

RULING GRADIENT : The ruling gradient or the design gradient is the maximum gradient with which the designer attempts to design the vertical profile of the road. This depends on the terrain, length of the grade, speed, pulling power of the vehicle and the presence of the horizontal curve. In flatter terrain, it may be possible to provide flat gradients, but in hilly terrain it is not economical and sometimes not possible also. The ruling gradient is adopted by the designer by considering a particular speed as the design speed and for a design vehicle with standard dimensions. But our country has a heterogeneous traffic and hence it is not possible to lay down precise standards for the country as a whole. Hence IRC has recommended some values for ruling gradient for different types of terrain.

TYPES OF GRADIENT :

LIMITING GRADIENT :

This gradient is adopted when the ruling gradient results in enormous increase in cost of construction. On rolling terrain and hilly terrain it may be frequently necessary to adopt limiting gradient. But the length of the limiting gradient stretches should be limited and must be sandwiched by either straight roads or easier grades.

EXCEPTIONAL GRADIENT :

Exceptional gradient are very steeper gradients given at unavoidable situations. They should be limited for short stretches not exceeding about 100 meters at a stretch. In mountainous and steep terrain, successive exceptional gradients must be separated by a minimum 100 meters length gentler gradient. At hairpin bends, the gradient is restricted to 2.5%.

CRITICAL LENGTH OF THE GRADE :

The maximum length of the ascending gradient which a loaded truck can operate without undue reduction in speed is called critical length of the grade. A speed of 25 kmph is a reasonable value. This value depends on the size, power, load, grad-ability of the truck, initial speed, final desirable minimum speed etc.

MINIMUM GRADIENT :

This is important only at locations where surface drainage is important. Camber will take care of the lateral drainage. But the longitudinal drainage along the side drains require some slope for smooth flow of water. Therefore minimum gradient is provided for drainage purpose and it depends on the rain fall, type of soil and other site conditions. A minimum of 1 in 500 may be sufficient for concrete drain and 1 in 200 for open soil drains are found to give satisfactory performance.

CREEPER LANE AND GRADE COMPENSATION:

CREEPER LANE : When the uphill climb is extremely long, it may be desirable to introduce an additional lane so as to allow slow ascending vehicles to be removed from the main stream so that the fast moving vehicles are not affected. Such a newly introduced lane is called creeper lane. There are no hard and fast rules as when to introduce a creeper lane. But generally, it can be said that it is desirable to provide a creeper lane when the speed of the vehicle gets reduced to half the design speed. When there is no restrictive sight distance to reduce the speed of the approaching vehicle, the additional lane may be initiated at some distance uphill from the beginning of the slope. But when the restrictions are responsible for the lowering of speeds, obviously the lane should be initiated at a point closer to the bottom of the hill. Also the creeper lane should end at a point well beyond the hill crest, so that the slow moving vehicles can return back to the normal lane without any danger. In addition, the creeper lane should not end suddenly, but only in a tapered manner for efficient as well as safer transition of vehicles to the normal lane.

GRADE COMPENSATION : While a vehicle is negotiating a horizontal curve, if there is a gradient also, then there will be increased resistance to traction due to both curve and the gradient. In such cases, the total resistance should not exceed the resistance due to gradient specified. For the design, in some cases this maximum value is limited to the ruling gradient and in some cases as limiting gradient. So if a curve need to be introduced in a portion which has got the maximum permissible gradient, then some compensation should be provided so as to decrease the gradient for overcoming the tractive loss due to curve. Thus grade compensation can be defined as the reduction in gradient at the horizontal curve because of the additional tractive force required due to curve resistance ($T - T \cos \alpha$), which is intended to offset the extra tractive force involved at the curve. IRC gave the following specification for the grade compensation.

- a) Grade compensation is not required for grades flatter than 4% because the loss of tractive force is negligible.
- b) Grade compensation is $\frac{30+R}{R}$ %, where **R** is the radius of the horizontal curve in meters.
- c) The maximum grade compensation is limited to $\frac{75}{R}$ %.

“Thank you”



Have Any Query ?

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