UNIT -2

Curves

Unit Specifies

Through this unit, we have discussed the following aspects:

- Horizontal and vertical curves
- Various types of curves
- Various components of curves
- Computation of parameters to set out the curves in the field
- Requirement of Super-elevation
- Computation of parameters for setting out various curves

In this unit, the necessity of curves on roads, and railway lines are discussed. The characteristics of each types of curves are given that would help selecting the right kind of curve for roads, and railways. The relationships given would help in computing various essential parameters of curves. A large number of questions of short and long answer types following lower and higher order of Bloom's taxonomy, assignments through problems, and a list of suggested readings and references are given in the unit so that the students can go through them for practice.

Rationale

This unit on curves helps students to get an idea about the design and establishment of various types of curve in the field. It explains the characteristics of each curve, including the computation of essential components required for layout of curves. All these are discussed at length to develop the understanding of subject matter. Some related problems are given which can help further for getting a clear idea of the concern topics on layout of curves. The provision of curves is to connect two points which can't be otherwise connected by a straight line due to topography of the ground and natural features present. The selection of right type of curve is important to provide a smooth and comfortable ride to the passengers. The super-elevation further helps in smooth riding when a vertical curve is introduced.

Pre-Requisites

Mathematics: geometry and trigonometry; Surveying: Use of theodolite and distance measuring instruments.

Unit Outcomes

List of outcomes of this unit is as follows:

U2-O1: Describe various types of curves

U2-O2: Describe the essential components and characteristics of curves

U2-O3: Realize the role of curves in roads and railways for smooth movement of vehicles

U2-O4: Explain the role of superelevation in vertical curves

U2-O5: Apply the parameters to solve complex problems and layout the curves

Unit-2 Outcomes	**Expected Mapping with Programme Outcomes** *(1- Weak correlation; 2- Medium correlation; 3- Strong correlation)*					
	CO-1	**CO-2**	**CO-3**	**CO-4**	**CO-5**	**CO-6**
U2-O1	3	2	2	2	1	2
U2-O2	3	1	2	1	2	-
U2-O3	2	2	2	3	-	2

U2-O4	3	2	3	2	1	-
U2-O5	2	3	2	1	-	2

2.1 Introduction

Curves are regular bends provided in the lines of communication, like highways, railways, etc., to make gradual change in the horizontal and vertical directions. Those curves that change the alignment or direction are known as *horizontal curves*, and those that change the slope are called *vertical curves*. Horizontal curves are provided in the horizontal plane to have the gradual change in direction, whereas vertical curves are provided in the vertical plane to obtain the gradual change in the grade. For example, the center line of a road consists of series of straight lines interconnected by curves that are used to change the alignment, direction, or slope of the road. Curves are laid out on the ground along the centre line of the alignment using various surveying equipment, such as theodolite, tape, levels, total station, etc. Various curves are shown in Figure 2.1.

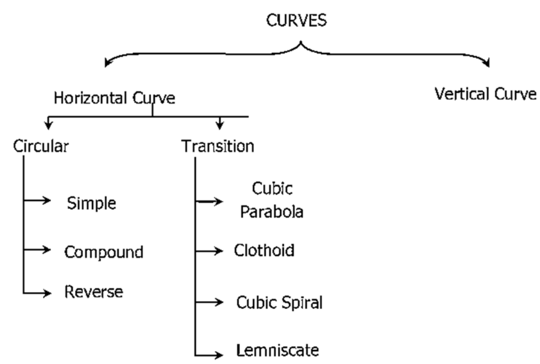

Figure 2.1 Various types of curves

This unit covers the need of horizontal and vertical. Various types of curves and their various components are explained. Various relationships can be established to compute the essential parameters to set up horizontal and vertical curves. Briefly, super-elevation which is necessary to provide in horizontal curves, and sight distance which is required in vertical curves, are also discussed.

2.2 Classification of Horizontal Curves

Circular curves are classified as: (*i*) Simple, (*ii*) Compound, (*iii*) Reverse, and (*iv*) Transition curves.

2.2.1 Simple curves

A simple curve consists of a single arc of a circle connecting two straights. It has the same radius throughout. In Figure 2.2a, a simple curve is shown which is passing through T_1 and T_2 with as OT_1 or OT_2 as its radius.

2.2.2 Compound curves

A compound curve consists of two or more simple curves having different radii bending in the same direction and lying on the same side of the common tangent. Their centres would lie on the same side of the curve. In Figure 2.2b, T_1PT_2 is the compound curve (two curves join at P) with T_1O_1 and T_2O_2 as its different radii.

2.2.3 Reverse curves

A reverse curve is made up of two equal or different radii bending in opposite directions with a common tangent at their junction. Their centres would lie on opposite sides of the curve. In Figure 2.2c, T_1PT_2 is a reverse curve with T_1O_1 and T_2O_2 as its radii. Point P is the junction of two curves in opposite direction. Reverse curves are used when the straights are parallel or intersect at a very small angle. They are commonly used in railway sidings, and sometimes on railway tracks, and is meant for low speeds. They should be avoided as far as possible on main railway lines and highways where speeds are high.

2.2.4 Transition curves

A transition curve is provided in between the straight line and circular curve (Figure 2.2d). It is a curve of varying radius of infinity at tangent point to a circular curve radius provided in between the straight line and circular curve in order to provide gradual centrifugal force. The objectives of providing a transition curve is mainly to gradually introduce the centrifugal force between the tangent point and the beginning of the circular curve, thereby avoiding sudden jerk on the vehicle.

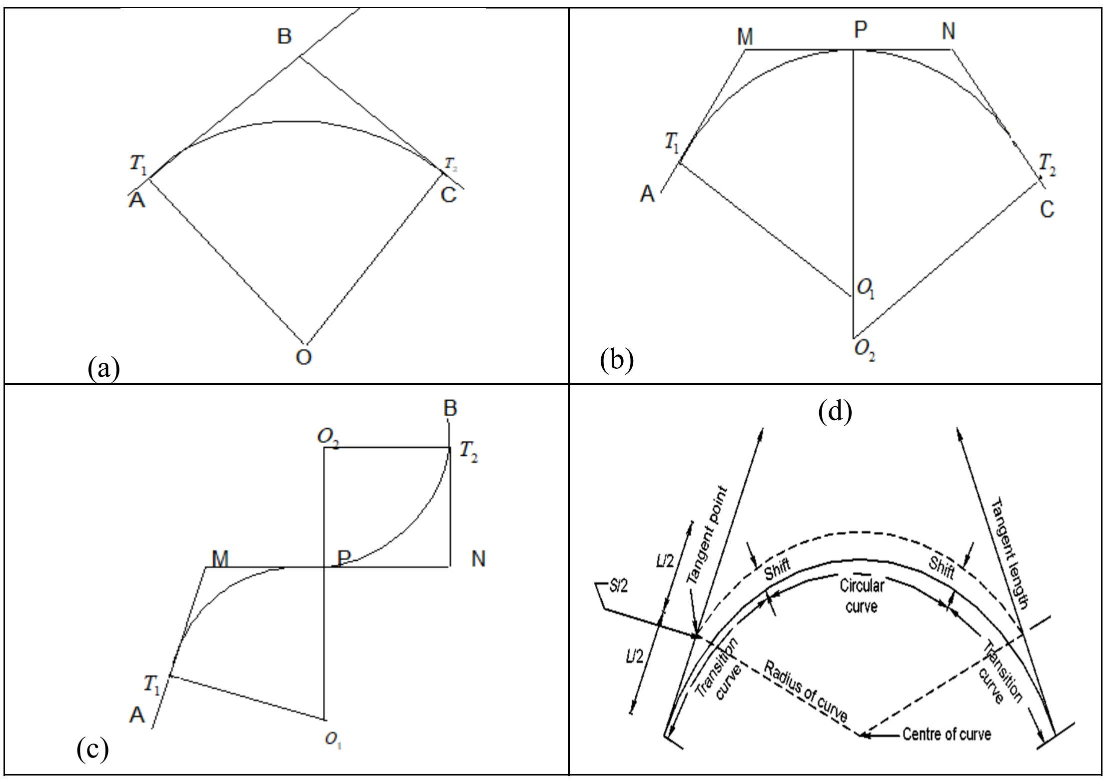

Figure 2.2 Various curves (a) simple, (b) compound, (c) reverse, and (d) transition curve

2.3 Simple Circular Curves

In order to compute various parameters of a simple circular curve for its layout, it is necessary to understand various part of the curve, as shown in Figure 2.3, and explained below.

2.3.1 Various parts of a curve

Tangents or straights: The two straight lines AB and BC, which are connected by the curve, are called the tangents or straights to the curve. The lines AB and BC are tangents to the curve. Line AB is called the first tangent or the rear tangent, and line BC is called the second tangent or the forwarded tangent.

Intersection point: The points of intersection of the two straights (B) is called the intersection or vertex point.
Tangent length: The distance between the two tangent point of intersection to the tangent point (BT_1 and BT_2) is called the tangent length.
Right handed curve: When the curve deflects to the right side of the progress of survey, it is termed as right handed curve.
Left handed curve: When the curve deflects to the left side of the progress of survey, it is termed as left handed curve.
Tangent points: The points (T_1 and T_2) at which the curve touches the tangents are called the tangent points. The beginning of the curve at T_1 is called the tangent curve point and the end of the curve at T_2 is called the curve tangent point.
Long chord: The line joining the two tangent points (T_1 and T_2) is known as the long chord.
Summit or apex: The mid-point (F) of the arc (T_1FT_2) is called summit or apex of the curve.
Length of the curve: The arc T_1FT_2 is called the length of the curve.
Angle of intersection: The angle between the tangent lines AB and BC ($\angle ABC$) is called the angle of intersection (I).
The deflection angle: It is the angle (ϕ) by which the forward tangent deflects from the rear tangent (180^0-I) of the curve.
Apex distance: The distance from the point of intersection to the apex of the curve BF is called the apex distance.
Central angle: The angle subtended at the centre of the curve by the arc T_1FT_2 is known as the deflection angle (ϕ).

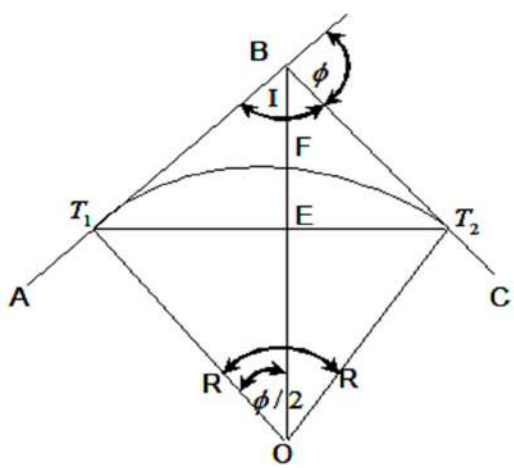

Figure 2.3 Representations of a simple circular curve

2.3.2 Designation of horizontal curves

A simple circular curve may be designated either by its radius or by the angle subtended at the centre by a chord of a particular length. In India, a simple circular curve is designated by the angle (in degrees) subtended at the centre by a chord of 30 m (100 ft.) length. This angle is called the *degree of curve* (D). The relation between the radius and the degree of the curve may be established as follows (Refer Figure 2.4).

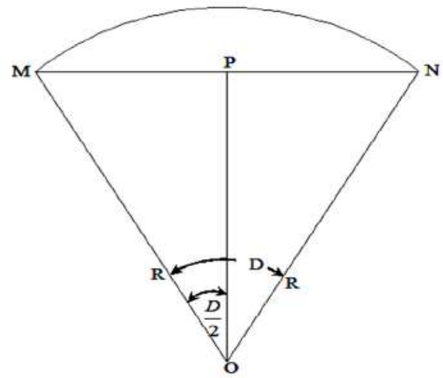

Figure 2.4 Representation of the degree of curve

If R is the radius of the curve in meters, D is the degree of the curve, MN is the chord of 30 m length, and P is the mid-point of the chord, then-

In ΔOMP, OM = R

MP = $\frac{1}{2}$ MN = 15 m

$$\angle MOP = \frac{D}{2}$$

Then, $\sin\frac{D}{2} = \frac{MP}{OM} = \frac{15}{R}$

or $$R = \frac{15}{\sin\frac{D}{2}} \quad \text{(Exact)} \qquad (2.1)$$

But when D is small, $\sin\frac{D}{2}$ may be assumed approximately $= \frac{D}{2}$ in radians.

$$R = \frac{15}{\frac{D}{2}\times\frac{\pi}{180^0}} = \frac{15\times 360}{\pi D}$$

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

or $$R = \frac{1719}{D} \quad \text{(approximate)} \qquad (2.2)$$

The approximate relation is used for curves up to 5^0, but for higher degree curves, the exact relation should be used.

2.3.3 Elements of a simple circular curve

From Figure 2.3, $I + \phi = 180^0$

$\angle T_1OT_2 = 180^0 - I = \phi$ (central angle = deflection angle) (2.3)

Tangent length = $BT_1 = BT_2 = OT_1 \tan\frac{\phi}{2} = R \tan\frac{\phi}{2}$ (2.4)

Length of the long chord = $2T_1E = 2\times OT_1 \sin\frac{\phi}{2}$

$$= 2R \sin\frac{\phi}{2} \qquad (2.5)$$

Length of the curve = Length of the arc T_1FT_2 = $R\phi$ (in radians)

$$= \frac{\pi R\phi}{180^0} \qquad (2.6)$$

Apex distance = BF = BO – OF

$$= R \sec\frac{\phi}{2} - R \quad = R\left(\sec\frac{\phi}{2} - 1\right) \qquad (2.7)$$

Versine of the curve = EF = FO – OE

$$= R - R\cos\frac{\phi}{2}$$

$$= R\left(1 - \cos\frac{\phi}{2}\right) = R\ versine\frac{\phi}{2} \qquad (2.8)$$

2.3.4 Methods of horizontal curve setting

A curve may be set out either by (a) linear methods, where chain, tape or EDM is used, or (b) angular methods, where a theodolite with or without a tape or total station is used. Before starting to setting out a curve by any method, the exact positions of the tangent points between which the curve would lie, is to be determined. The steps to be used for setting up the curve between two points A and B (Figure 2.3) are as follows:

1. After fixing the directions of the straights, extend them to intersect at point B.
2. Set up a theodolite at the intersection point B and measure the angle of intersection *I*, using repetition method of angle measurement. Determine the deflection angle ϕ as (180^0-*I*).
3. Calculate the tangent length $\left(length = R\tan\frac{\phi}{2}\right)$
4. From the intersection point B, measure the tangent length BT_1 backward along the rear tangent BA to locate T_1.
5. Similarly, locate the position of T_2 by measuring the same distance from B along the forward tangent BC.
6. The chainages of tangent points T_1 and T_2 are determined. The chainage is the distance of point T_1 and T_2 with respect to reference point on the road with known chainage. The chainage of T_1 is obtained by subtracting the tangent length (BT_1) from the known chainage of the intersection point B, while the chainage of T_2 is found by adding the length of the curve (T_1FT_2) to the chainage of T_1.
7. The pegs are then fixed at equal intervals (normally 30 m) on the curve. This distance should actually be measured along the arc, but in practice it is measured along the chord, as the difference is very small and negligible, and the length of the chord should not be more than $(1/20)^{th}$ of the radius of curve.
8. All the pegs on the ground are joined to form the curve.

The distances along the centre line of the curve are continuously measured from the point of beginning of the line up to the end, i.e., the pegs along the centre line of the work should be at equal interval from the beginning of the line to the end. For this reason, the first peg on the curve is fixed at such a distance from the first tangent point T_1 that its chainage becomes the whole number (Integer value). The length of the first chord thus may be less than the peg interval, which is called as a *sub-chord*. Similarly, there may be be a sub-chord at the end of the curve at T_2. Thus, a curve will usually consist of two sub-chords (one at the beginning and another at the end) and all other chords as whole number (equal to peg interval).