R. C. Patel College of Engineering & Polytechnic, Shirpur

Department of Civil Engineering

Name of Subject: - **ADVANCED SURVEYING (ASU)**

Course Code: - **313321**

Scheme:- **CE-3K**

Semester:- **Third**

Unit No. 02- Curves setting

CO2 - Set out a Simple Circular curve to finalize the alignment of the given element.

Unit	Title	COs	Learning hours	R Level	U Level	A Level	Total Marks
II	**Curves setting**	CO2	08	02	04	06	12

THEORY SYLLABUS CONTENT

Unit - II Curves setting

2.1 Curve: Definition, Necessity of Curves, Types of curves used in roads and railway alignments.

2.2 Elements of simple circular curve, Designation of the curve by Radius and Degree of curve.

2.3 Radius and Degree of curve.

2.4 Setting out a simple circular curve by offsets from long chord and Rankine's method of deflection angles.

Subject Incharge

Mr. D. B. Wagh

Unit - 02 - Curve Setting

* Curve :-

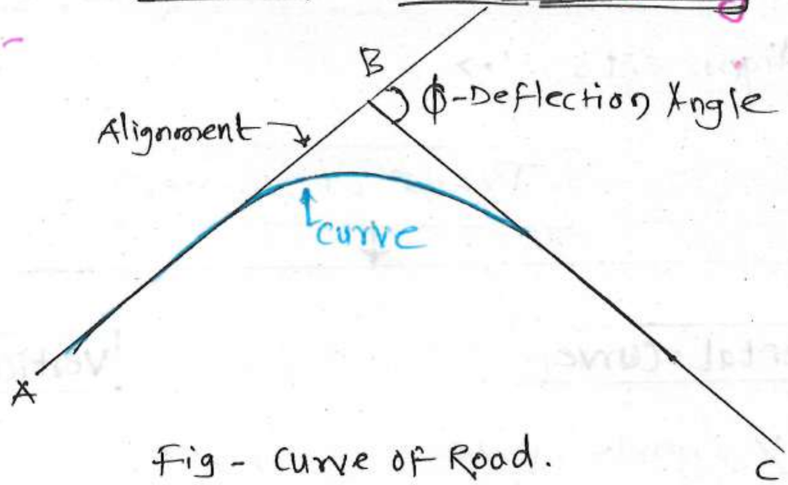


Fig - Curve of Road.

- During a road or Railway alignment survey, the line direction may shift due to unavoidable circumstance.
- The deflection angle is defined as the angle at which the direction changes.
- Definition of curve :-

To allow for vehicle movement on a road or railway track, the two straight lines (original and deflected) are joined by ~~arch~~ arc (fig) also known as the curve of the road or track.

* Necessity of curves

1) To provide smooth change of gradient (or direction), a curve is introduced between two straight lines.
2) The obstruction can be avoided by providing smooth curve. (i.e. Agricultural land, pond, Religious structure etc)
3) To avoid excessive cutting & filling ~~curves~~ by balancing the earth work while providing curves.
4) In hill roads made stable and safe by changing it alignment by provinding curve.

Types of curves used in Roads and Railway Alignments :→

Types of curves

- **Horizontal curve**
  - 1) simple curve
  - 2) compound curve
  - 3) Reverse curve
  - 4) Transition curve
  - 5) Lemiscate curve
- **Vertical curve**
  - 1) summit curve
  - 2) valley curve

1) simple curve

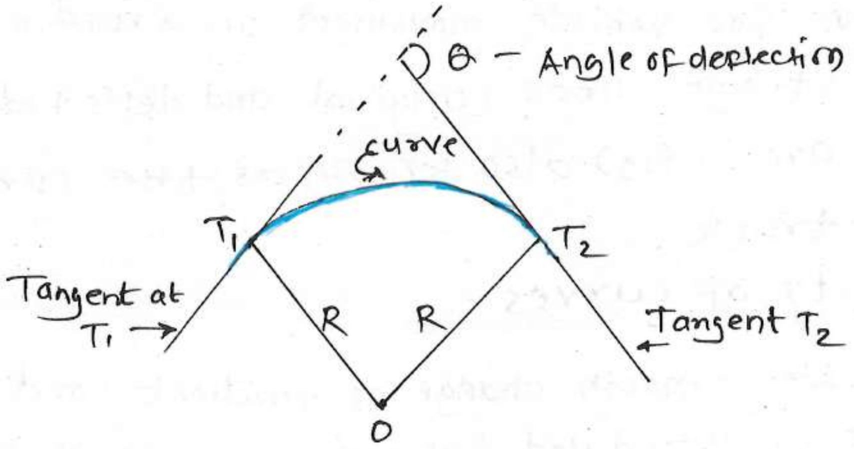


fig. simple curve.

Definition :→

· When a curve consists of a single arch with a constant radius connecting the two tangents, it is said to be a circular curve.

- simple curves are provided a every change in alignment of road or railway track in plain or hilly area.

2> Compound curve

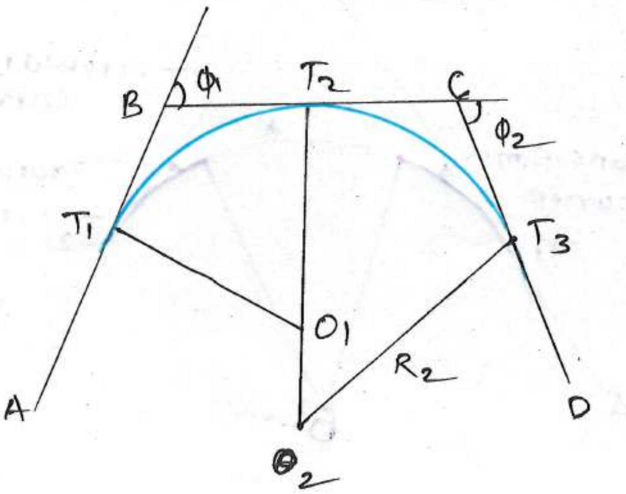


fig. compound curve

Definition :- When a curve consists of two arcs with different radii, It is called a compound curve.

- Such a curve lies on the same side of a common tangent and the centres of the different arcs lie on the same side of their respective tangents.
- To avoid excessive cutting or filling compound curves are provided.

3> Reverse curve :-

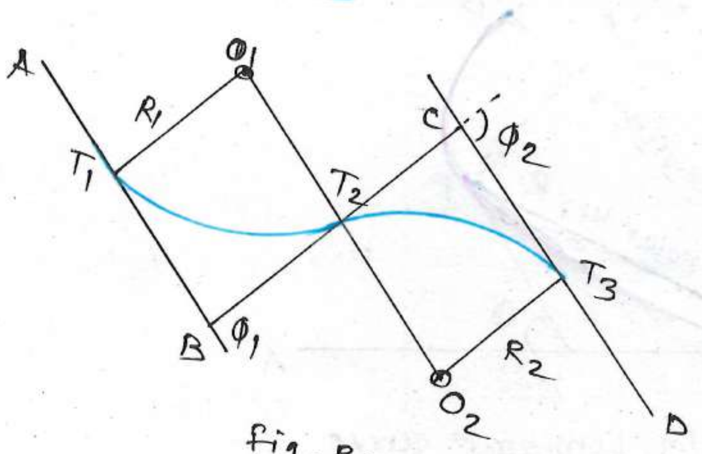


fig. Reverse curve.

Definition :- A reverse curve consists of two arcs bending in opposite directions. Their centres lie on opposites sides of the curves

- Their radii may be either equal or different, and they have one common tangent.

4) Transition curve

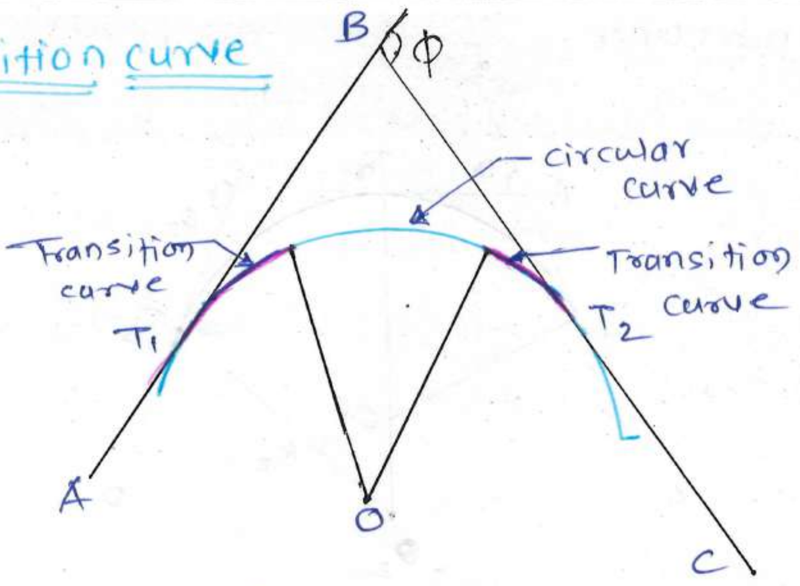


fig. Transition curve

Definition :→ A curve of variable radius is known as a Transition curve or spiral curve or easement curve.

→ In railways, such a curve is provided on both sides of a circular curve to minimise superelevation to ~~discom~~ avoid discomfort to passengers.

5) Lemniscate curve :-

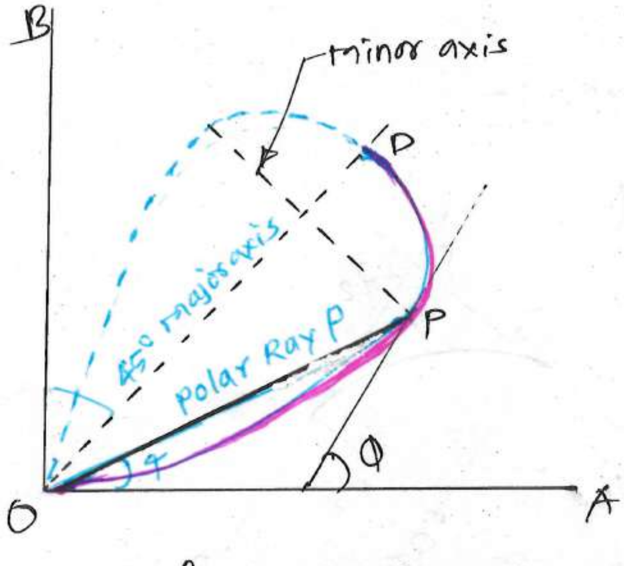


fig. Lemiscate curve

A lemiscate curve is similar to transition curve, and is generally adopted in city roads where the deflection angle is large.

Vertical Curves

curves used to connect two gradient lines to smoothen out the change from one gradient to another is known as vertical curves.

Types

1) summit curve
2) Valley curve

1) Summit curve :-

The curves having convex surface upward are known as summit curve.

- following are cases:-

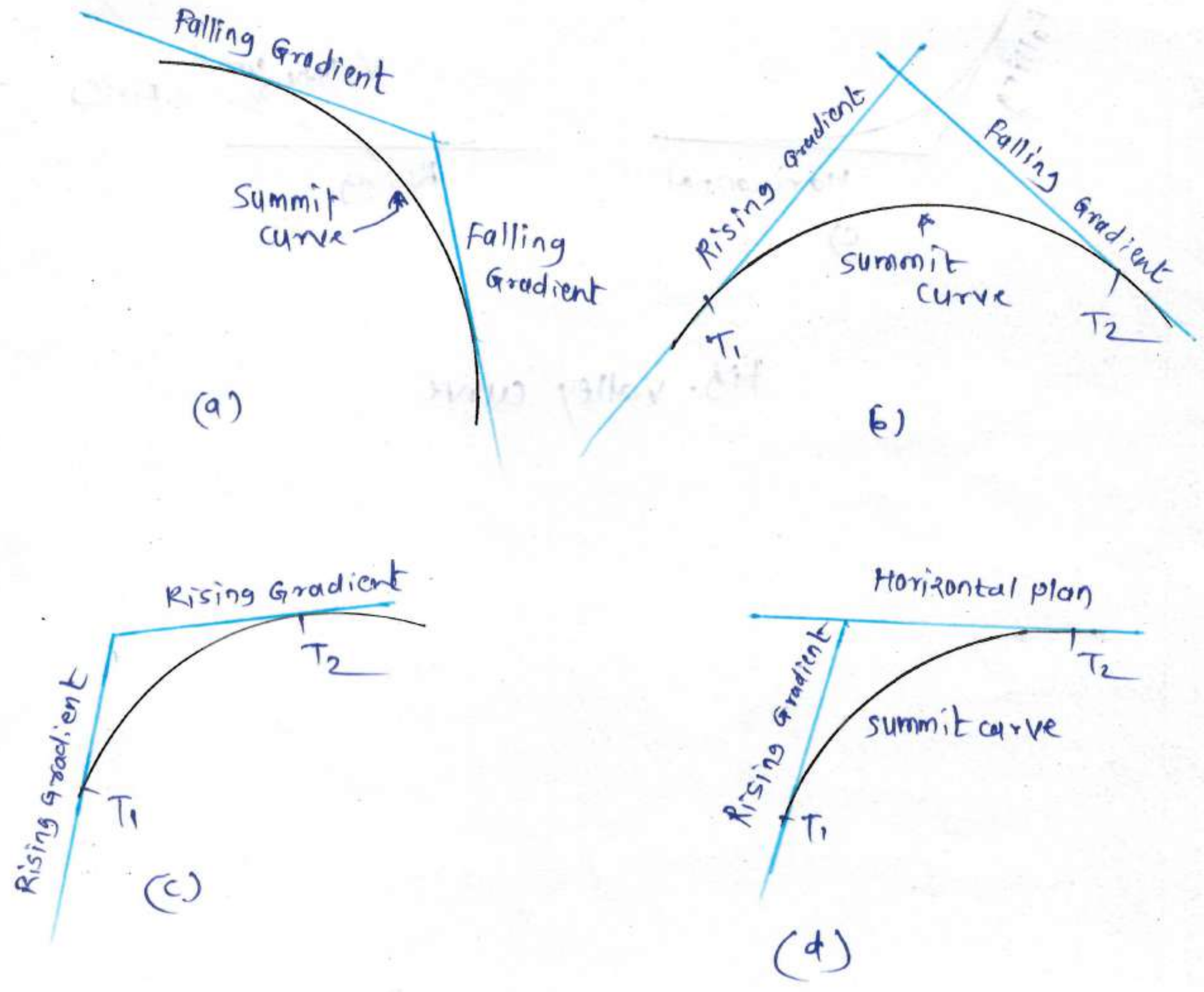


fig. summit curve.

2) Valley curve

The curve having convex surface downward is known as Valley curve.

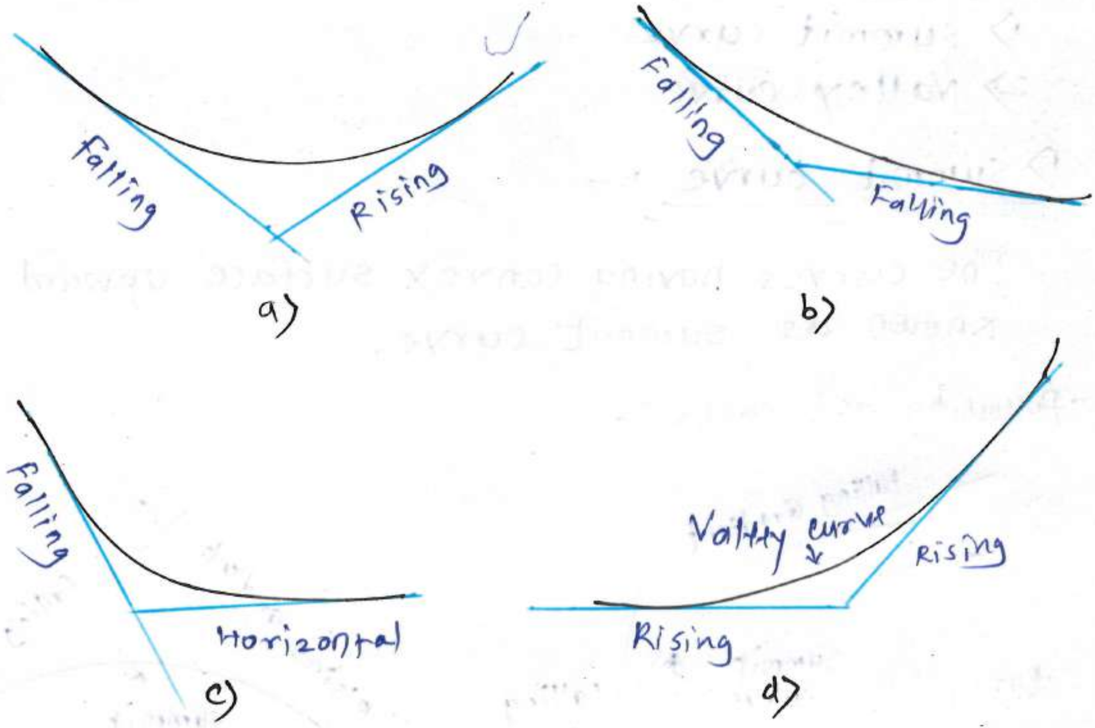


fig. valley curve

Elements of simple curve :-

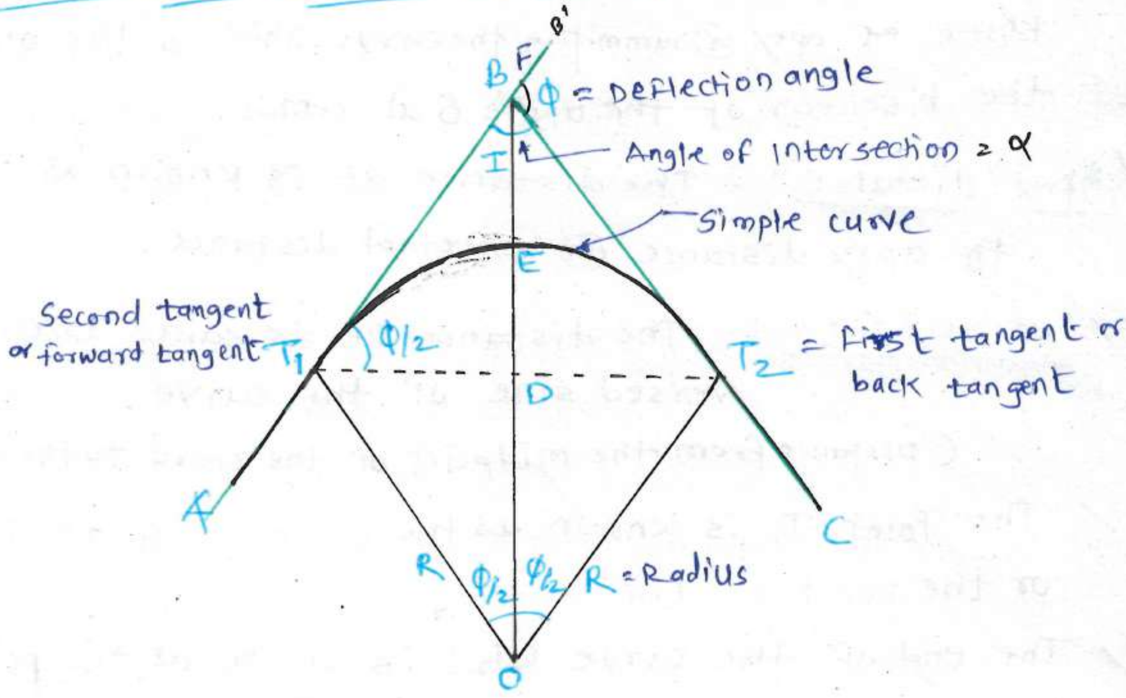


fig. Notations for circular curves.

1) Tangent :- AB and BC are known as the tangents of the curve.

2) Intersection point or vertex :- Point 'B' is known as point of intersection / vertex where the two tangents to the curve intersect.

3) Angle of Deflection :- The angle (θ) between the line FT_1 Produced and the BT_1, BT_2 is the deflection angle

$$\alpha + \theta = 180$$

4) Tangent point :- Point T_1 and T_2 are known as tangent point

5) When the curve deflects to right, it is called a right-hand curve, when it deflects to the left, it is said to be left-hand curve

6) AB is called the rear tangent and BC, the forward target

7) Tangent length :- The length of T_1B or T_2B are known as tangent length.

8) Long chord :- The straight line T_1DT_2 is known as the long chord.

9) Length of curve :- The curved line T_1ET_2 is said to be the length of the curve.

10) Apex or summit :- The mid-point E of the curve is known as apex or summit of the curve which is lies on the bisector of the angle θ at center.

11) Apex distance :- The distance BE is known as the ~~th~~ apex distance or external distance.

12) Versed sine :- The distance DE is called the versed sine of the curve.

(Distance from the midpoint of the chord to the apex E)

13) The Point T_1 is known as the beginning of the curve or the point of the curve.

14) The end of the curve (T_2) is known as the point of tangency.

→ Degree of curve :-

Definition :- The angle a unit chord of 20m or 30m length subtends at the centre of the circle formed by the curve is known as the degree of the curve.

- It is designated as 'D' (in fig.)

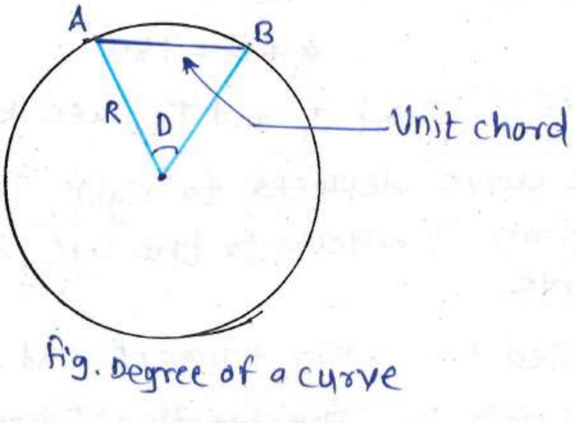


fig. Degree of a curve

- A curve may be designated according to either the radius or the degree of the curve.
- When the unit chord subtends an angle of 1°, it is called a one-degree curve, when the angle 2°, a two degree curve, and so on.
- It may be calculated that the radius of one-degree curve is 1719 m

Relation between Radius and Degree of curve

Let 'AB' be the unit chord of 30 m, 'O' the centre, 'R' the radius and 'D' the degree of the curve

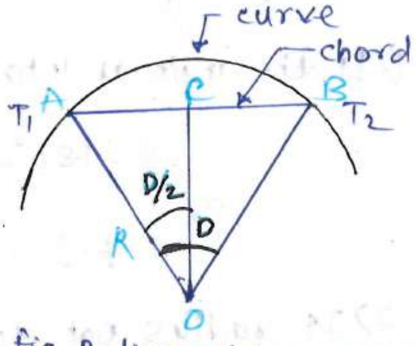


fig. Radius and degree of a curve

Here, $OA = R$

$AB = 30\ m$

$AC = 15\ m$

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

from triangle OAC,

$$\sin\frac{D}{2} = \frac{AC}{OA} = \frac{15}{R}$$

Rearranging,

$$\boxed{R = \frac{15}{\sin D/2}}$$

ΔOAC,
$\sin\theta$ = opposite/Hypotenuse
here, Angle = $D/2$
opposite side = $AC = 15\ m$
Hypotenuse = $OA = R$
$\sin D/2 = \frac{15}{R}$

When D is very small, $\sin D/2$ may be taken as $D/2$ radians

$$R = \frac{15}{\left(D/2\right) \times \left(\frac{\pi}{180}\right)}$$

$$= \frac{15 \times 360}{\pi D}$$

$$= \frac{1718.9}{D}$$

$$\boxed{R = \frac{1719}{D}}$$ (Approximate).

For very small angle: $\sin\theta \approx \theta$,
But angle must be in radians
so,
$\sin D/2 = D/2 \Rightarrow R = \frac{15}{D/2}$
But D is in degree, must be convert into Radians,
$1° = \pi/180$
so, $D/2$ radians $= \frac{D}{2} \times \frac{\pi}{180}$

Properties of simple circular curves :-

1) If the angle of Intersection is given then

$$\phi = 180^\circ - I \,,\ \text{or}\ \phi = 180^\circ - \alpha \qquad \{ \because I \text{ or } \alpha = \text{angle of Intersection}$$

or,

$$I + \phi = 180^\circ$$

2) If radius not given then

$$R = \frac{1719}{D} \qquad (D = \text{degree of curve})$$

3) Tangent length BT_1 or $BT_2 = R \tan\left(\frac{\phi}{2}\right)$

4) Length of curve = Length of arc T_1ET_2

$$= R \times \phi \text{ radians}$$

$$\boxed{= \frac{\pi R \phi^\circ}{180^\circ}} \text{ — m}$$

Again, Length of curve $= \frac{30\phi}{D}$ — (If degree of curve is given)

5) Length of long chord $= 2T_1D = 2OT_1 \sin\phi/2$

$$\boxed{= 2R\sin\frac{\phi}{2}} \text{ .. m}$$

6) Apex distance $= BE = OB - OE$

$$= R\sec\phi/2 - R$$

$$\boxed{= R\left(\sec\frac{\phi}{2} - 1\right)} \text{ ... m}$$

7) Versed sin of curve $= DE = OE - OD$

$$= R - R\cos\phi/2$$

$$\boxed{= R\left(1 - \cos\frac{\phi}{2}\right)} \text{ ... m}$$

Methods of setting out simple circular curve

followings are methods used to set curves on ground

1) Linear method
2) Angular method

1) Linear Method :-

These methods use only a tape or chain, this method is used when curve is short and when an angle measuring instruments are not available.

- Following methods are commonly executed.
  - a) Offsets from the long chord
  - b) Radial offsets from tangents
  - c) Perpendicular offsets from tangents
  - d) Offsets from the chord produced.
  - e) successive bisections of arcs.

a) Offsets from the long chord :-

- Let AB and BC be two tangents meeting at a point B, with a deflection angle ϕ.
- following data are calculated for setting out the curve.

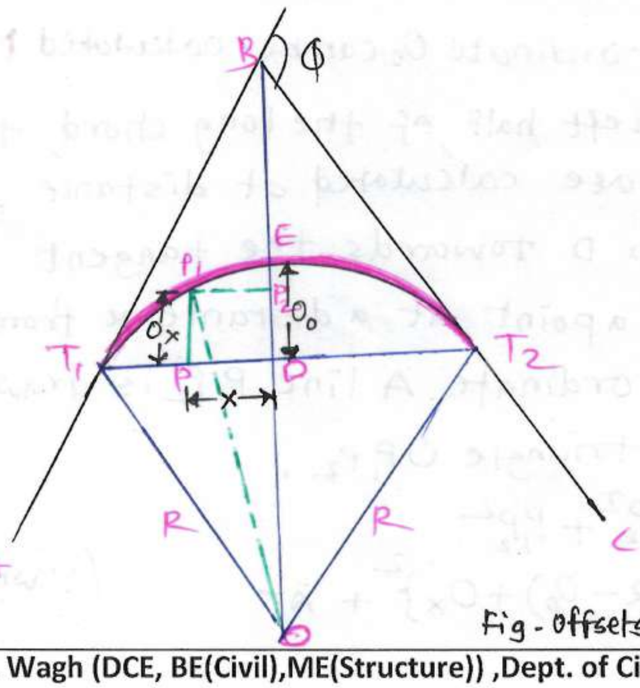


Fig - Offsets from long chord

1) The Tangent length is calculated, $TL = R\tan(\phi/2)$

2) Tangent points T_1 and T_2 are marked

3) Length of curve is calculated according to the formula

$$CL = \frac{\pi R \phi^\circ}{180^\circ}$$

4) The chainage of T_1 and T_2 are found out

5) The length of the ~~curve is calculated accordir~~ long chord (L) is calculated from

$$L = 2R\sin(\phi/2)$$

6) The long chord is divided into two equal halves. the half and right half. Here the curve is symmetrical in both the halves.

7) the mid-ordinate O_0 is calculated as follows!

a) $O_0 = DE =$ versed sine of curve $\boxed{= R(1-\cos\phi/2)}$ — ①

b) Again, $OF = R$ and $OD = R - O_0$

from tringle OT_1D, $OT_1^2 = OD^2 + T_1D^2$

$$R^2 = (R-O_0)^2 + (L/2)^2$$

$$R - O_0 = \sqrt{R^2 - (L/2)^2}$$

$$\boxed{O_0 = R - \sqrt{R^2 - (L/2)^2}} \quad \text{— ②}$$

Thus, the mid-ordinate O_0 can be calculated from eq ① OR ②

8) considering left half of the long chord, the ordinates $O_1, O_2, \ldots$ are calculated at distance $x_1, x_2, \ldots$ taken from D towards the tangent point T_1

Let P be a point at a distance x from D, then PP_1 (O_x) is required ordinate. A line P_1P_2 is drawn parallel to T_1T_2. from triangle OP_1P_2,

$$OP_1^2 = OP_2^2 + P_1P_2^2$$

$$R^2 = \{(R-O_0)+O_x\}^2 + x^2 \qquad (\because \text{where } OP_2 = (R-O_0)+O_x)$$

$$R - O_0 + O_x = \sqrt{R^2 - x^2}$$

$$\boxed{O_x = \sqrt{R^2 - x^2} - (R - O_0)}$$

9) The ordinates for right half are similar to these obtained for the left half.

* procedure to set out the curve

1. set the curve by first locating the intersection point of the tangents.
2. measure the tangent length backward and forward from I to locate the tangent point T_1 and T_2 respectively.
3. Measure the distance of the long chord $T_1 T_2$ and get midpoint D of the chord.
4. If the distance x is measured from D, then measured a chain length of 20 or 30m from D.
5. set out a right-angle offset of the calculated length from the point.
6. similarly locate further points
7. Repeat the procedure on the other side of D.

2) Angular Method

⇒ Angular methods of laying curve use an angle measuring instrument such as theodolite.

⇒ The point on the curve is set with angle measured with or without measuring distance.

⇒ There are three types of angular methods:

(a) Rankine's method of deflection angles

(b) Two-theodolite method

(c) Tacheometric method.

⇒ Rankine's Method of Deflection Angle

[fig. P.T.O.]

⇒ The deflection angle to any point on the curve is the angle between the tangent and the chord from the tangent point to the point on the curve.

⇒ Also, from the properties of a circle, the deflection angle is half the angle subtended by the arc at the centre.

⇒ from fig (on Back page), The angle IT_1P is δ, and the angle subtended at the centre by the arc T_1P is 2δ.

⇒ Assuming the arch length and chord length to be nearly equal, the value of the angle δ_1 can be derived as follow.

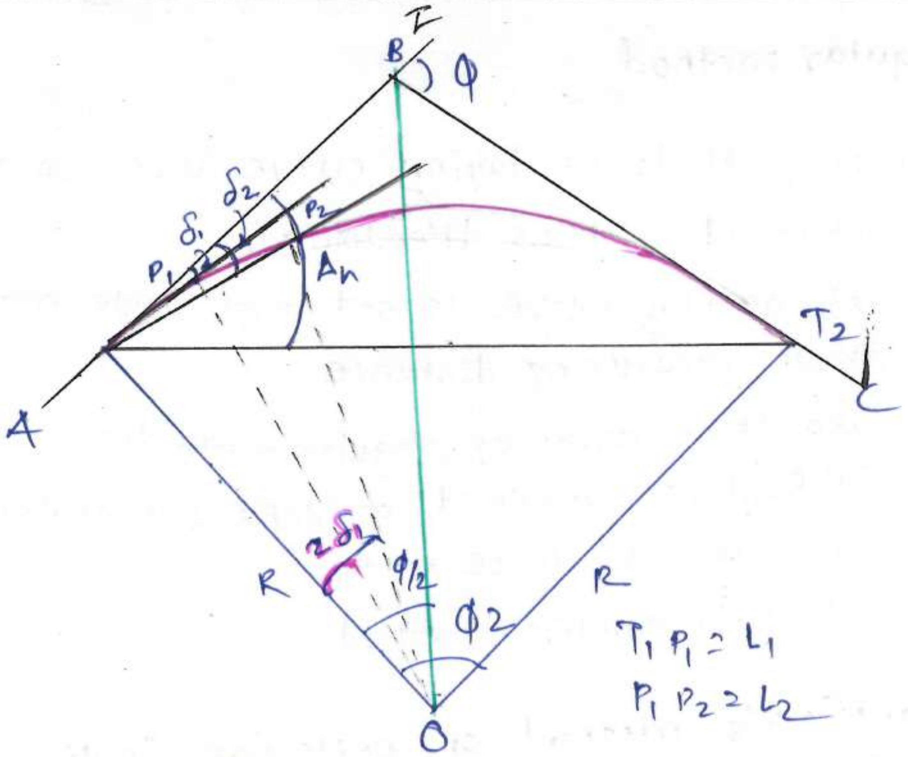


fig. Instrumental method.

Let,

P_1 = first point on the curve

$T_1 P_1$ = L_1 length of first chord (initial sub-chord)

δ_1 = deflection angle for first chord

R = radius of the curve

Δ_n = total deflection for the chords.

Here, $\angle T_1OP_1 = 2 \times \angle BT_1P_1 = 2\delta_1$

Again, chord $T_1P_1 \sim$ Arc T_1P_1

Now,

$$\frac{\angle T_1OP_1}{l_1} = \frac{360^\circ}{2\pi R}$$

$$2\delta_1 = \frac{360^\circ \times L_1}{2\pi R}$$

$$\delta_2 = \frac{360^\circ \times L_1}{2 \times 2\pi R} \text{ degree}$$

$$= \frac{360 \times 60 \times L_1}{2 \times 2 \times \pi R} \text{ mins}$$

$$\delta_3 = \frac{1718.89 \times l_3}{R} \text{ mins} \quad \text{and so on}$$

finally $$\boxed{\delta_n = \frac{1718.9 \times l_n}{R}} \text{ mins}$$

Again, when degree of curve D is given

$$\delta_1 = \frac{D \times l_1}{60} \text{ degrees}$$

$$\delta_2 = \frac{D \times l_2}{60} \text{ degrees and so on.}$$

Finally $$\boxed{\delta_n = \frac{D \times l_n}{60}} \text{ degrees.}$$

Arithmetical check; $\delta_1 + \delta_2 + \delta_3 + \ldots + \delta_n = \Delta_n = \phi/2$

Procedure of setting out curve

1) locate the point of intersection B and the tangent points
2) from the chainage of B and the tangent length BT_1, calculate the chainage of T_1
3) from the chainage of T_1, calculate the length of first subchord.
4) calculate the tangential for this subchord and designate it δ_1. This is also Δ_1 for this chord.
5) Depending upon peg interval 10m, 20m or 30m calculate the deflection angles for the remaining chords. the tangential angle δ remains the same for any length of constant peg interval.
6) calculate the deflection angles for all the pegs to be set out from T_1
7) from these values, work out and tabulate in the format given in table, the angle to be set out with theodolite

for obtaining the deflection of the pegs.

Point	chainage	chord	Tangential angle 'δ'	Deflection angle 'Δ'
1				

8) set up the theodolite on the ground at T_1. Both the verniers reading zero, sight the signal at B and Bisect it accurately. measure all angles from this line out but chordwise

9) Release the upper clamp and set the verniers read the deflection angle of the first chord. set theodolite to read angle accurrately. measure a distance equal to the chord length accurately along this line, in the line of sight of the instrument and fix the first peg.

10) set the theodolite to read second reading and proceed similarly to fix more points on T_2.

11)

Ex. calculate the ordinates at every 12 m interval to set out a simple circular curve having long chord of 120m and radius of 200m. Illustrate your answer with neat sketch.

Ans :-

Given

Interval between ordinates = 12 m

R = Radius of the curve = 200m

L = Length of long chord = 120m

Versed sine is the offset at the middle of long chord.

$$O_0 = R - \sqrt{R^2 - (L/2)^2}$$

$$O_0 = 200 - \sqrt{200^2 - \left(\frac{120}{2}\right)^2}$$

$$O_0 = 200 - \sqrt{(200)^2 - (60)^2} = 9.21\,m$$

The ordinates at distance x from the mid-point can be calculated from the following formula as.

$$O_x = \sqrt{R^2 - x^2} - (R - O_0)$$

$$O_{12} = \sqrt{200^2 - 12^2} - (200 - 9.21) = 8.849\,m$$

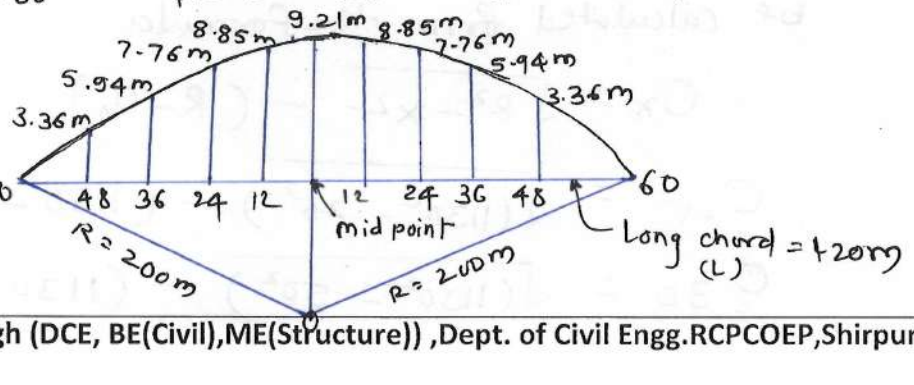
$$O_{24} = \sqrt{200^2 - 24^2} - (200 - 9.21) = 7.74\,m$$

$$O_{36} = \sqrt{200^2 - 36^2} - (200 - 9.21) = 5.44\,m$$

$$O_{48} = \sqrt{200^2 - 48^2} - (200 - 9.21) = 3.36\,m$$

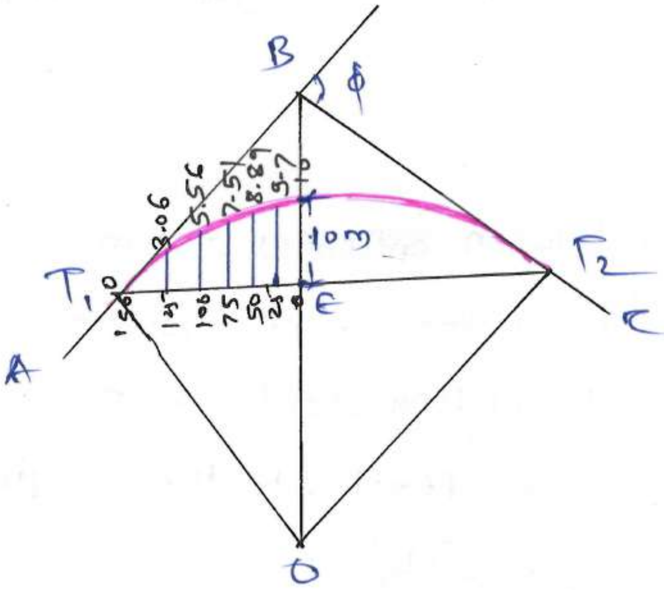
$$O_{60} = \sqrt{200^2 - 60^2} - (200 - 9.21) = 0\,m$$

Sketch -



Ex. calculate the ordinates at 25 m interval to set a circular curve having long chord of 300 m and versed sine of 10m.

Soln



∴ A versed sine is the offset of the middle of long chord.

$$O_0 = R - \sqrt{R^2 - (L/2)^2}$$

where, $R = ?$

$L = 300m$

$O_0 = 10\ m$

$$\therefore 10 = R - \sqrt{R^2 - 150^2}$$

$$\boxed{\therefore R = 1130\ m}$$

∴ The ordinates at distance x from the mid-point may be calculated from the formula.

$$O_x = \sqrt{R^2 - x^2} - (R - O_0)$$

$$O_{25} = \sqrt{(1130^2 - 25^2)} - (1130 - 10) = 9.7\ m$$

$$O_{30} = \sqrt{(1130^2 - 50^2)} - (1130 - 10) = 8.89\ m$$

$$O_{75} = \sqrt{(1130^2 - 75^2)} - (1130 - 10) = 7.51 m$$

$$O_{100} = \sqrt{(1130^2 - 100^2)} - (1130 - 10) = 5.56 m$$

$$O_{125} = \sqrt{(1130^2 - 125^2)} - (1130 - 10) = 3.06 m$$

$$O_{150} = \sqrt{(1130^2 - 150^2)} - (1130 - 10) = 0 m$$

Ex. Two straights meet at chainage 1800 m with deflection angle 60°. The radius of curve is 100 m find.
i) Tangent length ii) Long chord
iii) length of curve iv) Chainage of T

Soln

Given

Assume 20 m chain, Deflection angle 60°, R = 100 m

chainage distance = 1800 m

1) Tangent length $= R \tan\frac{\theta}{2}$

$$= 100 \times \tan\left(\frac{60^\circ}{2}\right)$$

$$= 57.73 m$$

2) Long chord $= 2R \sin\phi/2$

$$= 2 \times 100 \times \sin(60/2)$$

$$= 100 m$$

3) length of curve $= \frac{\pi R \phi}{180}$

$$= \frac{\pi \times 100 \times 60}{180}$$

$$= 104.71$$

4) i) Chainage of T_1 = 1800 - 57.73
= 1742.27 m

ii) Chainage of T_2 = Chainage of T_1 + length of curve
= 1742.27 + 104.71
T_2 = 1846.98 m

Ex. Two tangents intersect at a chainage of 1250 m. the angle of intersection is 145°. calculate all the necessary data for setting out a curve of radius 250 m by deflection angle method. Take peg interval as 20 m and prepare setting out table.

soln -

Given:

Intersection angle = 145°

Radius, R = 250 m

Peg Interval = 20 m

chainage Intersection = 1250 m

Step 1:

Chainage at Intersection = 1250 m

Deflection angle θ = 180 - 145
= 35°

Step 2:

length of tangent = $R \tan\theta$

$= 250 \tan \frac{35}{2}$

= 78.82 m

Step 3: length of curve $= \frac{R\theta\pi}{180} = \frac{250 \times 35 \times \pi}{180} = 152.72$ m

$\therefore$ chainage of 1st tangent point T_1

$= 1250 - 78.82$

$= 1171.18m$

$\therefore$ chainage of 2nd tangent point T_2

$= T_1 +$ length of curve

$= 1171.18 + 152.72 = \underline{1323.9}\ m$

Step 4 :-

length of unit chord = 20m

length of curve $= 140 + 12.72$

$= \frac{140}{2} + 12.72\ m$

Total chord $= 7 + 1 = 8$

length of $C_1 + C_2 = 20m$

$C_8 = 12.72\ m$

Step 5 :-

$\delta_1 + \delta_7 = 1178.9 \times \frac{20}{250}$

$= 2^\circ 17' 30''.72$

$\delta_8 = 1718.9 \times \frac{12.72}{250}$

$= 1^\circ 27' 2''.46'$

Step 6 :-

$\Delta_1 = \delta_1 = 2^\circ 17 3''$

$\Delta_2 = \Delta_1 + \delta_2 = 2^\circ 17' 3'' + 2^\circ 17' 30''$

$= 4^\circ 35'$

$\Delta_3 = \Delta_2 + \delta_3 = 4^\circ 35' + 2^\circ 17' 30''$

$= 6^\circ 52' 30''$

$\Delta_4 = \Delta_3 + \delta_4 = 6^\circ 52' 30'' + 2^\circ 17' 30'' = 9^\circ 10'$

$$\Delta_5 = \Delta_4 + \delta_5$$
$$= 9^\circ 10' + 2^\circ 17' 30'' = 11^\circ 27' 3''$$

$$\Delta_6 = \Delta_5 + \delta_6$$
$$= 11^\circ 27' 30'' + 2^\circ 17' 30'' = 13^\circ 45'$$

$$\Delta_7 = \Delta_6 + \delta_7$$
$$= 13^\circ 45' + 2^\circ 17' 30'' = 16^\circ 2' 30''$$

$$\Delta_8 = \Delta_7 + \delta_8$$
$$= 16^\circ 2' 30' + 1^\circ 27' 27'' = 17^\circ 30'$$

$$\frac{\theta}{2} = \frac{35^\circ}{2}$$
$$= 17^\circ 30'$$ ___ hence checked

Important Questions

1) classify horizontal and vertical curve. (W-25, 23)
2) state the necessity of curve. (W-24)
3) Define Horizontal curve and vertical curve. (S-25)
4) Write the relationship between radius and degree of curve.
5) Define compound curve. (W-25)
6) Write the relationship between radius and degree of curve. (W-24)(S-25)
7) Write the procedure of setting out a curve by Rankine's method of deflection angles. (W-25)(S-25)
8) Explain four properties of a simple circular curve.
9) Draw a neat sketch of circular curve and show notation there on. (W-25)
10) Enlist types of curves used in road and railway alignment (W-25)
11) Define Degree of curve (W-24)
12) Write the steps of horizontal curve setting by offset from long chord method. (W-24)
13) State the relation between degree of curve and radius of curve for unit chord of 30m.
14) Calculate the ordinates at 25m interval to set a circular curve having long chord of 300m and versed sign of 10m (W-24)
15) Calculate the ordinates from long chord to set out a simple circular curve at 5m interval of radius 250m and a long chord length of 80m. Justify your answer with neat sketch.
16) Calculate the ordinate at every 12m. interval to set out simple curve having long chord of 120m and radius of 200 m Illustrate your answer with neat sketch. (W-25)

17> Two straights AB and BC intersect at chainage 1900 m. the intersecting angle being 120°. calculate the radius and chainage of tangent points of circular curve. the degree of curve is 6°. (S-23)