LECTURE NOTE ON

Land survey II

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Lecture in

CIVIL ENGINEERING

DHABALESWAR INSTITUTE OF POLYTECHNIC,

RADHADAMODARPUR

ATHAGARH, CUTTACK-29

C. TOPIC WISE DISTRIBUTION

Chapter	Name of topics	Hours
1	TACHEOMETRY: (Only concepts; applications without derivation)	09
2	CURVES	08
3	BASICS ON SCALE AND BASICS OF MAP:	08
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6	MODERN SURVEYING METHODS :	10
7	BASICS ON GPS & DGPS AND ETS:	10
8	BASICS OF GIS AND MAP PREPARATION USING GIS	10

D. COURSE CONTENTS:

1 TACHEOMETRY:
(Only concepts; applications without derivation)

1.1 Principles, stadia constants determination

1.2 Stadia tacheometry with staff held vertical and with line of collimation horizontal or inclined, numerical problems

1.3 Elevations and distances of staff stations – numerical problems

2 CURVES :

2.1 compound, reverse and transition curve, Purpose & use of different types of curves in field

2.2 Elements of circular curves, numerical problems
2.3 Preparation of curve table for setting out
2.4 Setting out of circular curve by chain and tape and by instrument angular methods (i) offsets from long chord, (ii) successive bisection of arc, (iii) offsets from tangents, (iv) offsets from chord produced, (v) Rankine's method of tangent angles (No derivation)
2.5 Obstacles in curve ranging – point of intersection inaccessible

BASICS ON SCALE AND BASICS OF MAP:

3.1 Fractional or Ratio Scale, Linear Scale, Graphical Scale
3.2 What is Map, Map Scale and Map Projections
3.3 How Maps Convey Location and Extent
3.4 How Maps Convey characteristics of features
3.5 How Maps Convey Spatial Relationship
3.5.1 Classification of Maps
- 3.5.1 Physical Map
- 3.5.2 Topographic Map
- 3.5.3 Road Map
- 3.5.4 Political Map
- 3.5.5 Economic & Resources Map
- 3.5.6 Thematic Map
- 3.5.7 Climate Map

SURVEY OF INDIA MAP SERIES:

- 4.1 Open Series map
- 4.2 Defense Series Map
- 4.3 Map Nomenclature
  - 4.3.1 Quadrangle Name
  - 4.3.2 Latitude, Longitude, UTM's
  - 4.3.4 Contour Lines
  - 4.3.5 Magnetic Declination
  - 4.3.6 Public Land Survey System
  - 4.3.7 Field Notes

BASICS OF AERIAL PHOTOGRAPHY, PHOTOGRAMMETRY, DEM AND ORTHO IMAGE GENERATION:

5.1 Aerial Photography:
- 5.1.1 Film, Focal Length, Scale
- 5.1.2 Types of Aerial Photographs (Oblique, Straight)

5.2 Photogrammetry:
- 5.2.1 Classification of Photogrammetry
- 5.2.2 Aerial Photogrammetry
- 5.2.3 Terrestrial Photogrammetry

5.3 Photogrammetry Process:
- 5.3.1 Acquisition of Imagery using aerial and satellite platform
- 5.3.2 Control Survey
- 5.3.3 Geometric Distortion in Imagery
  - Application of Imagery and its support data
  - Orientation and Triangulation
  - Stereoscopic Measurement
    - 19.9.1 X-parallax
    - 19.2.2 Y-parallax

5.4 DTM/DEM Generation
5.5 Ortho Image Generation

MODERN SURVEYING METHODS :
6.1 Principles, features and use of (i) Micro-optic theodolite, digital theodolite
6.2 Working principles of a Total Station (Set up and use of total station to measure angles, distances of points under survey from total station and the co-ordinates (X,Y & Z or northing, easting, and elevation) of surveyed points relative to Total Station position using trigonometry and triangulation.

BASICS ON GPS & DGPS AND ETS:
7.1 GPS: - Global Positioning
- 7.1.1 Working Principle of GPS,GPS Signals,
- 7.1.2 Errors of GPS,Positioning Methods

7.2 DGPS: - Differential Global Positioning System
- 7.2.1 Base Station Setup
- 7.2.2 Rover GPS Set up
- 7.2.3 Download, Post-Process and Export GPS data
- 7.2.4 Sequence to download GPS data from flashcards
- 7.2.5 Sequence to Post-Process GPS data
- 7.2.6 Sequence to export post process GPS data
- 7.2.7 Sequence to export GPS Time tags to file

7.3 ETS: - Electronic Total Station
- 7.3.1 Distance Measurement
- 7.3.2 Angle Measurement
- 7.3.3 Leveling
- 7.3.4 Determining position
- 7.3.5 Reference networks
- 7.3.6 Errors and Accuracy

BASICS OF GIS AND MAP PREPARATION USING GIS
- 8.1 Components of GIS, Integration of Spatial and Attribute Information
- 8.2 Three Views of Information System
  - 8.2.1 Database or Table View, Map View and Model View
- 8.3 Spatial Data Model
- 8.4 Attribute Data Management and Metadata Concept
- 8.5 Prepare data and adding to Arc Map.
- 8.6 Organizing data as layers.
- 8.7 Editing the layers.
- 8.8 Switching to Layout View.
- 8.9 Change page orientation.
- 8.10 Removing Borders.
- 8.11 Adding and editing map information.
- 8.12 Finalize the map

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Chapter:-01 (TACHEOMETRY) **Topic:-Introduction**

WHAT IS TACHEOMETRY?

- Tacheometric is a branch of surveying in which horizontal and vertical distances are determined by taking angular observation with an instrument known as a tachometer.
- Tacheometric surveying is adopted in rough and difficult terrain where direct levelling and chaining are either not possible or very tedious.
- The accuracy attained is such that under favourable conditions the error will not exceed 1/100. and if the purpose of a survey does not require accuracy, the method is unexcelled.
- Tacheometric survey also can be used for Railways, Roadways, and reservoirs etc. Though not very accurate. Tacheometric surveying is very rapid, and a reasonable contour map can be prepared for investigation works within a short time on the basis of such survey.

Use of Tacheometry:

- When obstacle (Step, broken ground, stretches of water)
- In rough country both horizontal and vertical measurement are tedious and chaining is inaccurate, difficult and slow.
- This method is used for find out the contour.

Purposes of Tachometry:

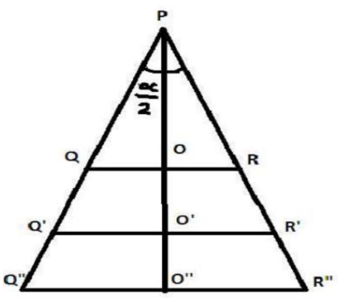
- Prepare contour map.
- Used in hydrographic survey.
- Location survey for road, railway, reservoir etc.
- Checking of the distance which measured with the help of the tap.
- To measure the horizontal distance at which the distance measured by the tap or chain is difficult.

Principle of Tacheometry:

- The principle of tacheometry is based on the property of isosceles triangle.
- Statement :-

  • In isosceles triangle the ratio of the perpendiculars from the vertex on their bases.

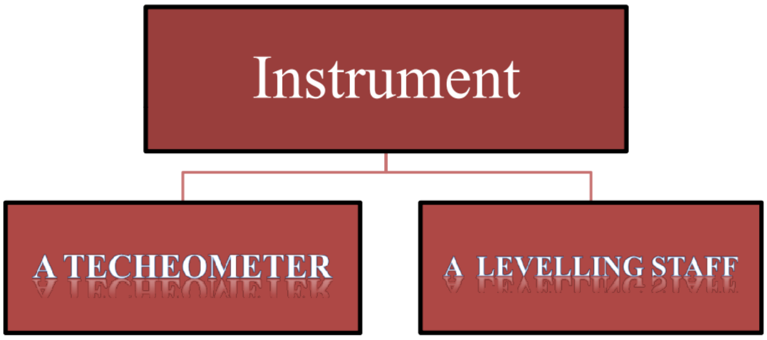
  • Here; PQR, PQ'R', PQ"R" are all isosceles triangle whose base are QR, Q'R' and Q"R" and their vertex is at P. and here PO, PO' and PO" are the perpendicular to their respective bases.



$$\frac{PO}{QR} = \frac{PO'}{Q'R'} = \frac{PO"}{Q"R"} = \text{constant K} = 2\cot\frac{\alpha}{2}$$

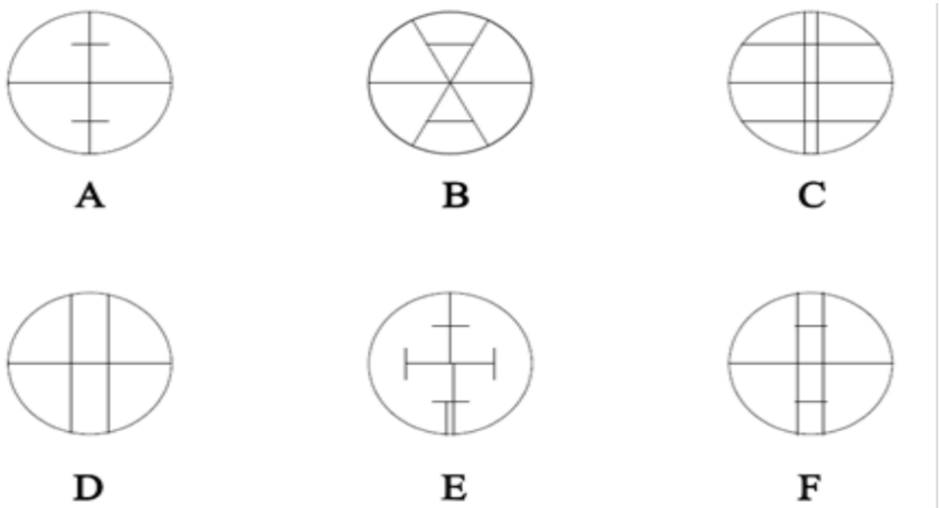
here constant K = $\frac{f}{i}$

Instrument used:



A Tacheometer:

- A tacheometry is usually transit theodolite having a stadia diaphragm.
- The diaphragm is equipped with two horizontal hairs called stadia hair in addition to regular cross hair.
- The additional hairs are equidistance from the central.

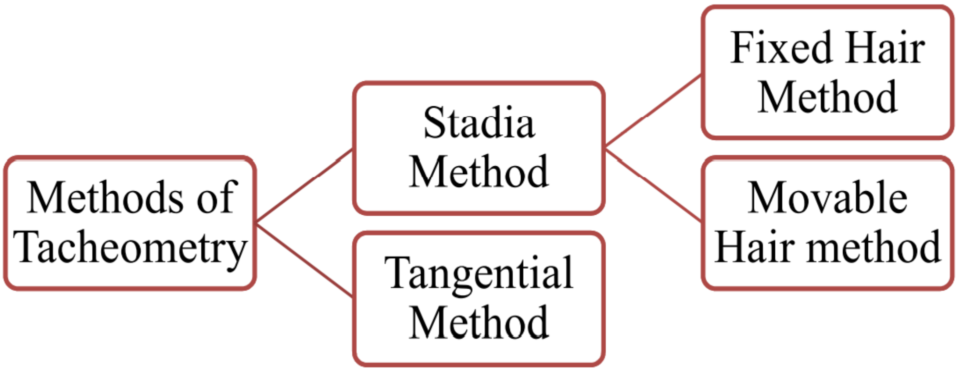


STADIA DIAPHRAGMS

Levelling Staff or Stadia Rod

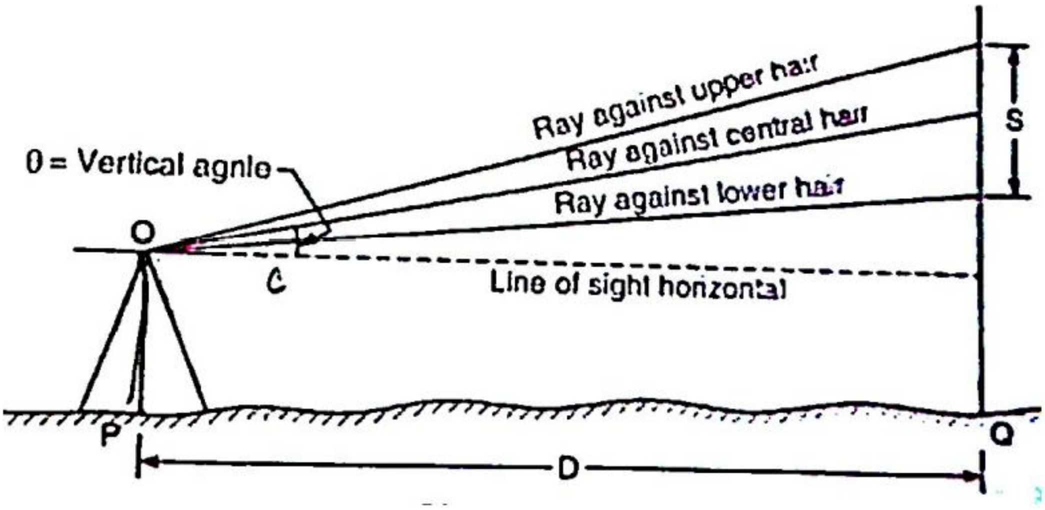
- The stadia rod or staff used with tacheometry may be usual type of levelling staff having least count of 0.005m.
- Stadia rod is usually in one piece but for easy transport it may be folding.
- Width of the staff is 5cm to 15cm.
- Height may be 3m to 5m.
- It is graduated in meter, Centimetre.
- The graduation must be simple and clear.

Methods of Tacheometry



Stadia Method:

- In the stadia method, a tacheometry is setup at a station P and a staff is held at another station Q.



- The staff intercept (S) between the upper stadia hair and the lower stadia hair is measured.
- The vertical angle (θ) is also measured.
- The horizontal distance D between P and Q, and the difference of elevation of P and Q is calculated from the staff intercept (S) and the vertical angle(θ) by using formula.

Fixed hair method

- The upper and lower stadia hair is fixed. (stadia interval is fixed)
- The distance between the upper stadia hair and lower stadia hair, called stadia interval (i) is fixed.
- The value of the staff interval (S) varies with the distance.
- Generally, stadia method means fixed hair method.

Movable hair method

- In this method the stadia hairs (i) is not fixed.
- Stadia hairs can be moved or adjusted by the micrometre screws.

- In this method the staff intercept (S) is fixed.
- The stadia interval measured corresponding to the staff intercept.

Difference

Fixed hair method	Movable hair method
❖ Stadia interval (i) is fixed. ❖ Staff intercept (S) is not fixed. ❖ Fixed hair method is most commonly used to take staff reading speedy. ❖ Tacheometry and staff are used.	❖ Stadia interval (i) is not fixed. ❖ Staff intercept (S) is fixed. ❖ This method is not generally used because inconvenient to measure the stadia interval accurately.

Tangential Method

- In this method diaphragm of the tacheometer is not provided with the stadia hair.
- Reading are taken by the central horizontal hair.
- Staff with two targets at a fixed distance (S) is used for taking reading.
- The vertical angles θ_1 & θ_2 are measured.
- The vertical angle and fixed distance(S) are used to determine the horizontal distance(D).

Difference

Stadia hair method	Tangential method
❖ Diaphragm of the tacheometer is provided with three stadia hair. ❖ Looking through the telescope three stadia hair reading taken. ❖ One vertical angle is observed. ❖ This method is most commonly used in practice.	❖ Diaphragm of the tacheometer is not provided with stadia hair. ❖ The readings are taken by the single horizontal hair adjust upper and lower target respectively. ❖ Two vertical angles are observed. ❖ This method is not commonly used in practice

• There are main three cases for finding the distance and Elevation.

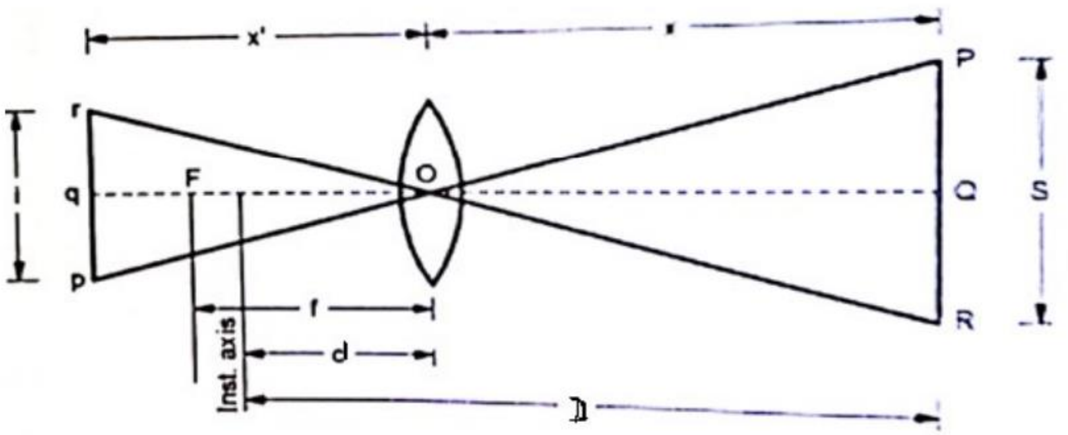
• **Case : 1** When the line of sight is horizontal and staff is held Vertical.

• **Case : 2** When the line of sight is inclined and staff is held Vertical. ((a) considering angle of elevation +θ (b) considering angle of depression -θ)

• **Case : 3** When the line of sight is inclined but staff is held normal to the line of sight.

Case : 1 When the line of sight is horizontal and staff is held Vertical.

Horizontal Distance Formula(D)



O = The optical centre of the object glass.

• p,q,r = the top, axial, and bottom hair reading.

• pr = i = Length of the image.

• f = Focal length of the image glass.

• S = Staff in intercept on PQ.

• x = Horizontal distance from O to the staff.

• x' = Horizontal distance from O to the plane of the hairs.

• d = Horizontal distance from O to the vertical axis of the instrument.

• D = Horizontal distance from axis to the staff

- The rays Pop and Qoq passing through O are the straight lines.
- Triangle POQ and poq are similar hence $\frac{x}{x'} = \frac{s}{i}$

But x and x′ are conjugate focal length (distance)

$$\frac{1}{f} = \frac{1}{x'} + \frac{1}{x}$$

Multiplying both by fx

$$x = \frac{x}{x'}f + f$$

Substituting $\frac{x}{x'} = \frac{s}{i}$

$$x = \frac{s}{i}f + f$$

Add c on both the side

$$x + d = \frac{s}{i}f + f + d$$

But x + d = D

$$\mathbf{D} = \frac{\mathbf{f}}{\mathbf{i}}\mathbf{S} + (\mathbf{f} + \mathbf{d})$$

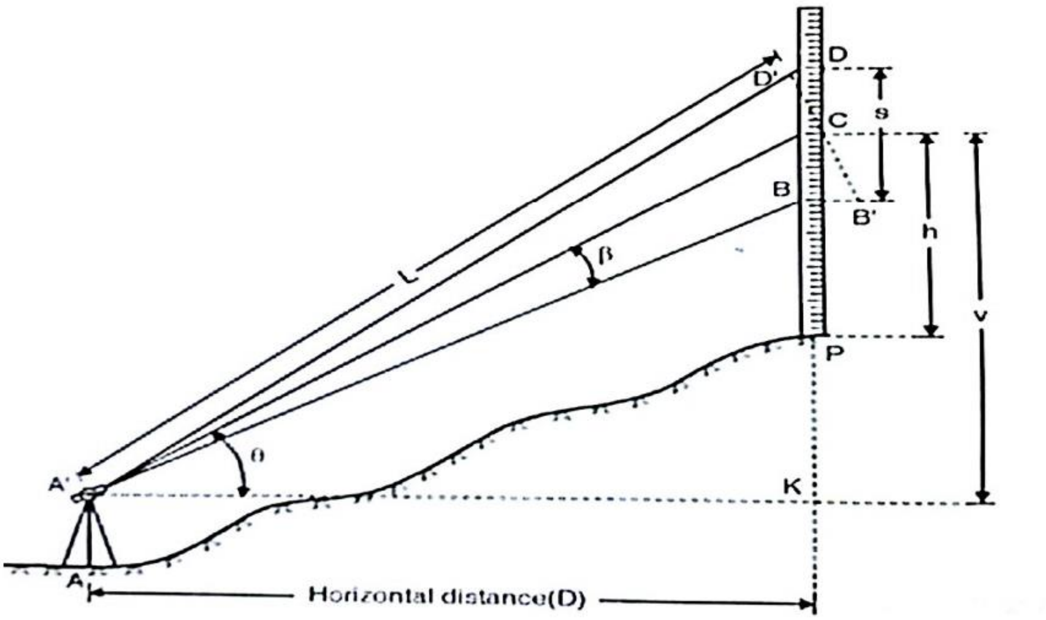
The constant $K = \frac{f}{i}$ is known as the multiplying constant or stadia interval factor and the constant $C = f + d$ is known as the additive stadia of the instrument.

Vertical Distance formula(V)

- When the line of sight is horizontal V = 0

Case : 2 When the line of sight is inclined and staff is held Vertical.

Considering angle of elevation +θ



- Let A is the instrument station
- A' is the position of the instrument axis
- P is the staff station
- DBC are the points on the staff cut by the hair of the diaphragm.
- ∠CA'K = is an inclined of the line of sight A'C to the horizontal
- BD = S is the staff intercept (difference between the top and bottom hair reading)

- CP = h is the central hair or axial hair reading.
- A'C = L is the distance along the line of collimation from A' to C
- A'K = D is the horizontal distance from the instrumer station P
- CK = V is the vertical distance from the instrument axis to point C (Central hair reading)
- Draw a perpendicular line through C to the line of sight A'C so that it cuts A'D in D' and A'B in B' is the projection of DB perpendicular to A'C as shown in figure
- Line BD is perpendicular to the line A'K and B'D' is perpendicular to A'C

- ∠DCD’ = ∠BCB’ = and
  ∠DA’C = ∠BA’C = β
- ∠A’D’C = $90^0 - \beta$
- Angle ∠DD’C = $180^0 - (90^0 - \beta)$
- $= 90^0 + \beta$
- Angle ∠BB’C = $90^0 - \beta$

- From ΔS DD’C and BB’C
- D’C = DC Cosθ
- B’C = BC Cosθ
- D’C + B’C = DC Cosθ + BC Cosθ
- D’B’ = (DC + BC) Cosθ
- D’B’ = DB Cosθ
- D’B’ = S Cosθ

Horizontal Distance D

Horizontal Distance D,When the line of sight is horizontal, then:

$$\mathbf{D = \frac{f}{i}(DB) + (f + d)}$$

Here DB = S

So,

$$\mathbf{D = \frac{f}{i}(S) + (f + d)}$$

Now inclined distance A’C = $\mathbf{L = \frac{f}{i}(D'B') + (f + d)}$

But here D’B’ = S Cosθ

$$\mathbf{L = \frac{f}{i}(S\ Cos\theta) + (f + d)}$$

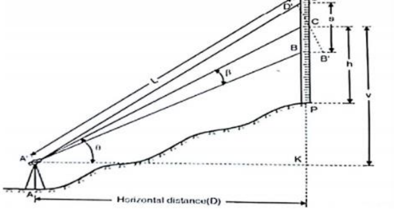
Horizontal distance D = L Cosθ

$D = L = \frac{f}{i}(S\ Cos\theta)(Cos\theta) + (f + d)(Cos\theta)$

$D = \frac{f}{i} S\ Cos^2\theta + (f + d) Cos\ \theta$

Here $\frac{f}{i} = K$ and $(f + d) = C$

$\mathbf{D = \frac{f}{i} S\ Cos^2\theta + (f + d) Cos\ \theta}$



Vertical distance

From $\Delta A'CK$, $CK = V = L \sin\theta$

Put the value of $L = \frac{f}{i}(S \cos\theta) + (f + d)$

$V = \frac{f}{i}(S \cos\theta)(\sin\theta) + (f + d)(\sin\theta)$

$V = \frac{f}{i}\frac{S \sin 2\theta}{2} + (f + d) \sin\theta$

Here $\frac{f}{i} = K$ and $(f + d) = C$

So, $V = \frac{KS \sin 2\theta}{2} + (C) \sin\theta$

* Elevation of the staff station for angle of elevation

• Elevation of staff station= Elevation of instrument + R.L. of B.M. + V- h

* Elevation of the staff station for the angle of depression.

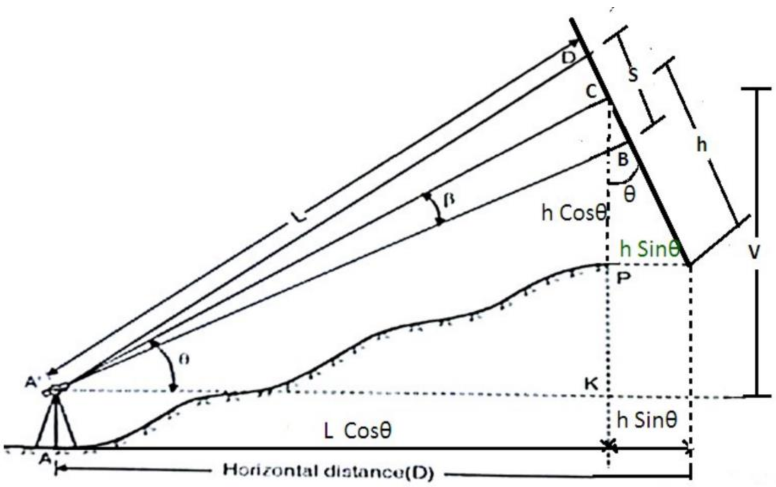
• Elevation of staff station= Elevation of instrument + R.L. of B.M. - V- h

Horizontal distance (D) = f/i× S $\cos^2\theta$ + (f+d) cosθ

Vertical distance(V)= f/i× S $\cos^2\theta$/2+(f+d) sinθ

Case : 3 When the line of sight is inclined and staff is held normal to the line of sight.

Considering angle of Elevation +θ



Horizontal distance (D)=f/i × S cos θ + (f+d) cos θ + h sin θ

Vertical distance(V)=f/I × S sin θ + (f+d) sin θ

Elevation of the staff station :-

• Elevation of staff station= Elevation of instrument + R.L. of B.M. + V- h Cos θ

Considering angle of depression – θ

Horizontal distance D=f/i × S × cos θ + (f+d) cos θ – h sin θ

Vertical distance(V)= f/i × S sin θ + (f+d) sin θ

- Elevation of the staff station :-

Elevation of staff station = Elevation of instrument + R.L. of B.M. - V- h Cosθ

Inst. station	Staff station	Vertical angle	Hair readings (m)	Remark
C	BM	-5°20’	1.150,1.800,2.450	RL of BM = 750.50 M
C	D		0.750,1.500,2.250	

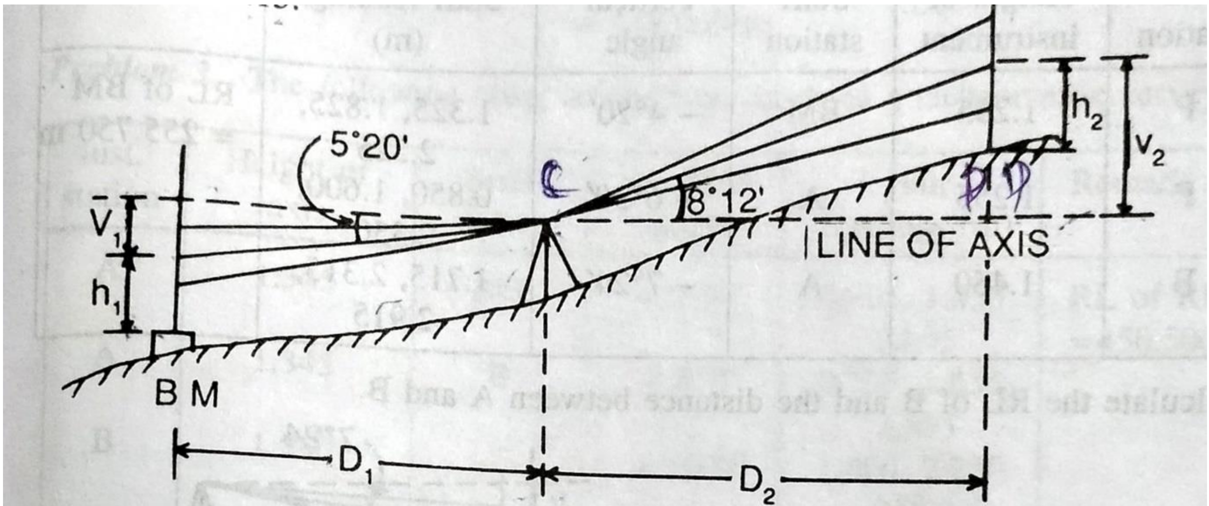


Fig. P.11.1

SOLUTION: -

When the staff is held vertically, the horizontal and vertical distances are given by the relation

Horizontal distance (D) = $f/i \times S \cos^2\theta + (f+d) \cos \theta$

Vertical distance(V)= $f/i \times S \sin 2\theta/2+(f+d) \sin \theta$

Here f/i = 100 and (f+d)=0.15

In the first observation, S_1 =2.450-1.150=1.500

Θ_1=5°20’ (depression)

V_1= 100 × 1.300 × sin 2(5°20’)/2 + 0.15 × sin 5°20’ = 12.045 m.

In second observation, S_2 = 2.250-0.750 =1.500

Θ_2 =8°12' (elevation)

V_2 = 100 × 1.500 × sin 16°24'/2 + 0.15× sin8°12' = 21.197 m.

D_2 = 100 × 1.500 × $\cos^2$ 8°12' + 0.15 × cos 8°12' = 147.097 m.

RL of instrument axis = RL of BM + h_1 + V_1

= 750.500 + 1.800 12.045 = 764.345 m.

RL of D = RL of instrument axis + V_2 – h_2

=764.345 + 21.197 – 1.500

= 784.042 m.

So, the CD = 147.097m. and RL of D = 784.042 m. (Ans...)

Problem: - 2

The following observation were taken with a tacheometer fitted with an anallatic lens , the staff being held vertically. The constant of the tacheometer is 100.

Int. station	Height of instrument	Staff station	Vertical angle	Staff readings(m)	Remark
P	1.255	BM	-4°20'	1.325,1.825,2.325	RL of BM = 255.750m.
P	1.255	A	+6°30'	0.850,1.600,2.350	
B	1.450	A	-7°24'	1.715,2.315,2.915	

Calculate the RL of B and the distance between A and B.

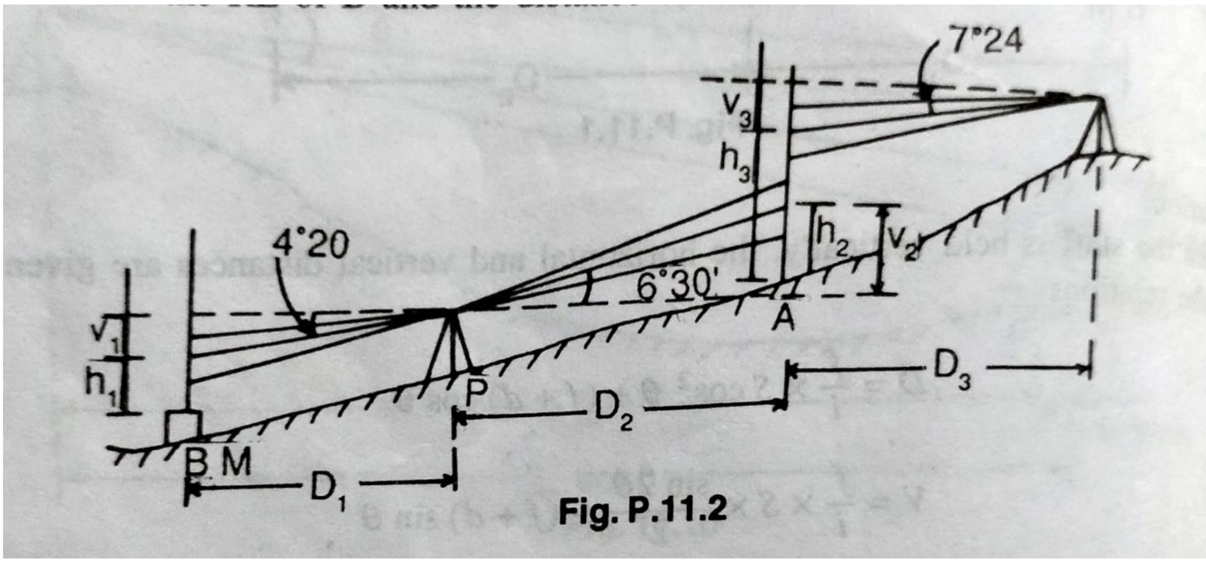


Fig. P.11.2

SOLUTION:

Here, multiplying constant, f/i = 100 and additive constant f + d = 0

Since, the staff held is vertically, the vertical distance is given by

$$V = f/i \times S \times \sin 2\theta/2$$

In the first observation,

$$V_1 = 100 \times (2.325 – 1.325) \times \sin 2(4^o20')/2 = 7.534 \text{ m.}$$

In the second observation,

$$V_2 = 100 \times (2.350 – 0.850) \times \sin 2(6^o30')/2 = 16.871 \text{ m.}$$

In the third observation,

$$V_3 = 100 \times (2.915 – 1.715) \times \sin 2(7^o24')/2 = 15.326 \text{ m.}$$

RL of axis when inst. At P = RL of BM + h_1 + V_1

= 255.750 + 1.825 + 7.534

= 265.109 m.

RL of A = 265.109 + V_2 – h_2

= 265.109 + 16.871 – 1.600

= 280.380 m.

RL of axis when inst. At B = 280.380 +h_3 + V_3

=298.021 m.

RL of B = 298.021 – HI

= 298.021 – 1.450

= 296.571 m.

Distance between A and B , $D_3 = f/i \times S \cos^2\theta$

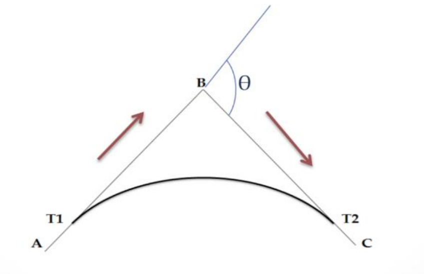
$= 100(2.915 – 1.715) \times \cos^2(7^o20')$

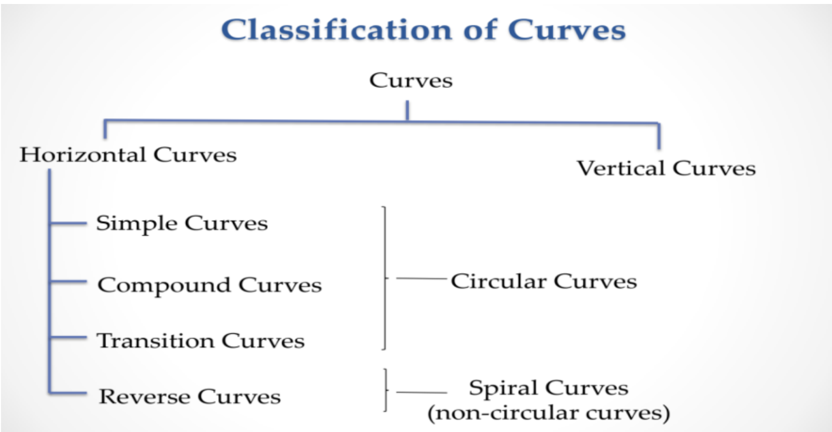
= 118.009 m. **(Ans….)**

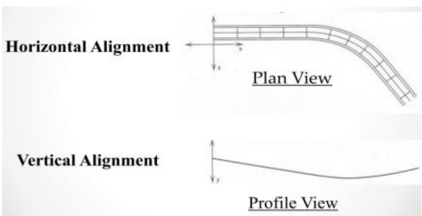
Chapter: -02 (CURVE)

What is curve ?

- Curves are usually employed in lines of communication in order that the change in direction at the intersection of the straight lines shall be gradual.
- The lines connected by the curves are tangent to it and are called Tangents or Straights.
- The curves are generally circular arcs but parabolic arcs are often used in some countries.
- Most types of transportation routes, such as highways, railroads, and pipelines, are connected by curves in both horizontal and vertical planes.
- The purpose of the curves is to deflect a vehicle travelling along one of the straights safely and comfortably through a deflection angle θ to enable it to continue its journey along the other straight.







Horizontal curve:-

Horizontal curves are provided to change the direction or alignment of a road. Horizontal Curve are circular curves or circular arcs.

Horizontal curve

Vertical curve :-

Vertical curves are provided to change the slope in the road and may or may not. be symmetrical. They are parabolic and not circular like horizontal curves.

Vertical curve

10.3 TYPES OF HORIZONTAL CURVES

The following are the different types of horizontal curves:

1. Simple circular curve When a curve consists of a single arc with a constant radius connecting the two tangents, it is said to be a circular curve (Fig. 10.5).

2. Compound curve When a curve consists of two or more 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 (Fig. 10.6).

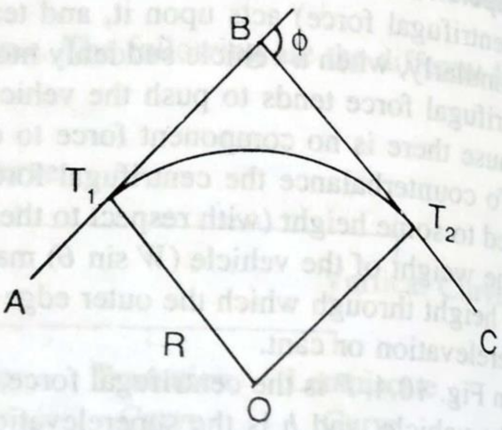


Fig. 10.5

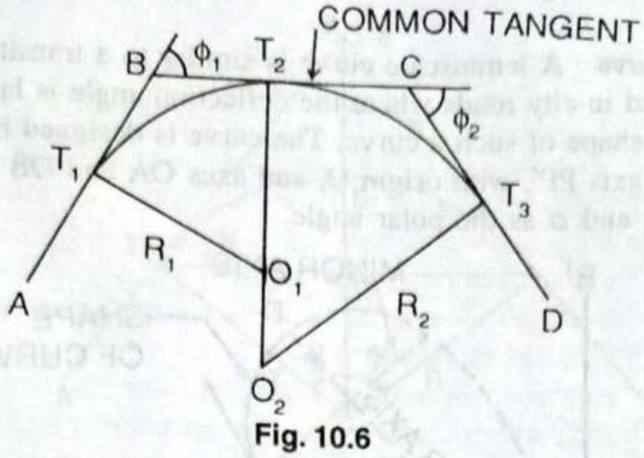


Fig. 10.6

3. Reverse curve A reverse curve consists of two arc bending in opposite directions. Their centres lie on opposite sides of the curve. Their radii may be either equal or different, and they have one common tangent (Fig. 10.7).

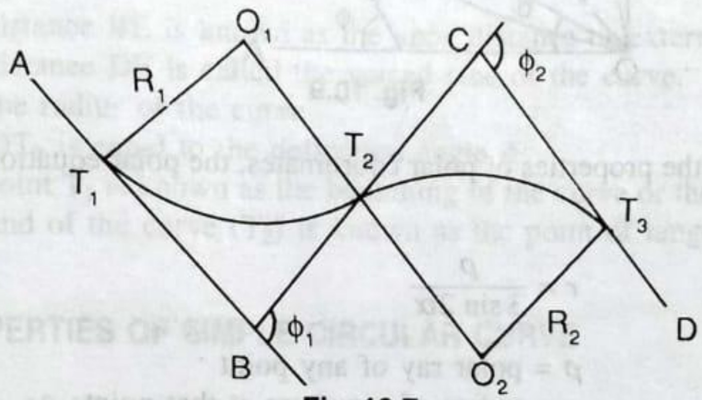


Fig.10.7

4. Transition curve A curve of variable radius is known as a transition curve. It is also called a spiral curve or easement curve. In railways, such a curve is provided on both sides of a circular curve to minimise superelevation. Excessive superelevation may cause wear and tear of the rail section and discomfort to passengers (Fig. 10.8).

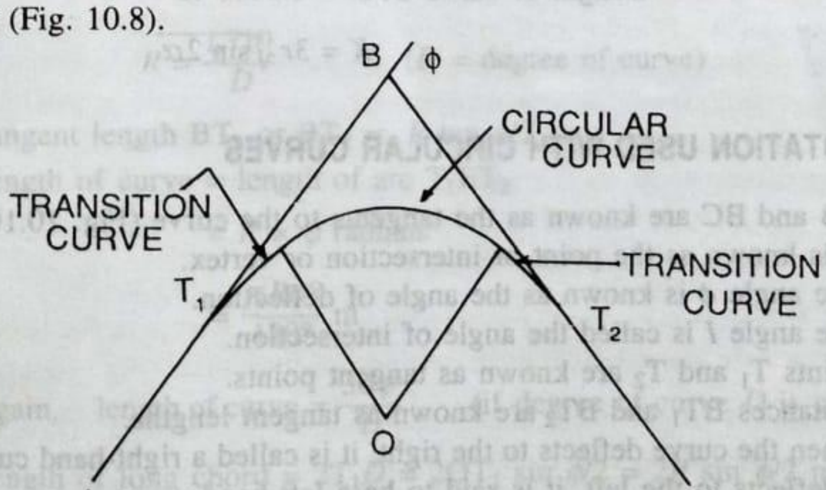


Fig. 10.8

5. *Lemniscate curve* A lemniscate curve is similar to a transition curve, and is generally adopted in city roads where the deflection angle is large. In Fig. 10.9, OPD shows the shape of such a curve. The curve is designed by taking a major axis OD, minor axis PP′, with origin O, and axes OA and OB. OP(ρ) is known as the polar ray, and α as the polar angle.

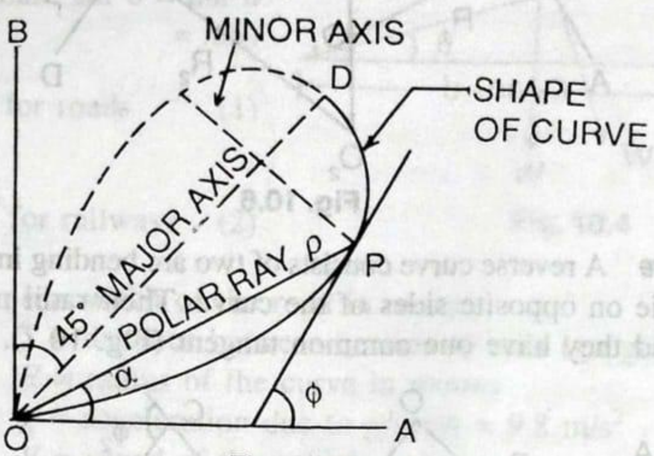


Fig. 10.9

Considering the properties of polar coordinates, the polar equation of the curve is given by

$$r = \frac{\rho}{3 \sin 2\alpha}$$

where ρ = polar ray of any point
r = radius of curvature at that point
α = polar deflection angle

At the origin, the radius of curvature is infinity. It then gradually decreases and becomes minimum at the apex D.

$$\text{Length of curve OPD} = 1.3115\ K$$

where $K = 3r\sqrt{\sin 2\alpha}$

10.6 HORIZONTAL CURVE SETTING BY CHAIN-AND-TAPE METHOD

The following are the general methods employed for setting out curves by chain and tape:

1. Taking offsets or ordinates from the long chord
2. Taking offsets from the chord produced
3. Successively bisecting the arcs
4. Taking offsets from the tangents

A. Offsets or Ordinates from Long Chord

Let AB and BC be two tangents meeting at a point B, with a deflection angle ϕ. The following data are calculated for setting out the curve (Fig. 10.11).

1. The tangent length is calculated according to the formula; TL = $R \tan \phi/2$
2. Tangent points T_1 and T_2 are marked.
3. The length of the curve is calculated according to the formula:

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

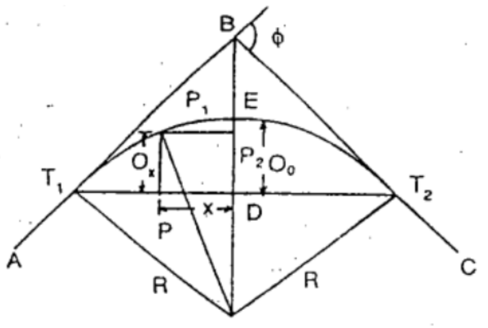


Fig. 10.11

4. The chainages of T_1 and T_2 are found out.
5. The length of the long chord (L) is calculated from:

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

6. The long chord is divided into two equal halves the left half and the 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 = $R(1 - \cos \phi/2)$ (1)

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

From triangle OT_1D, $OT_1^2 = OD^2 + T_1D^2$

or $$R^2 = (R - O_0)^2 + \left(\frac{L}{2}\right)^2$$

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

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

Thus, the mid-ordinate O_0 can be calculated from Eq. (1) or (2).

8. Considering the left half of the long chord, the ordinates O_1, O_2, ... are calculated at distances X_1, X_2, ... taken from D towards the tangent point T_1.
   The formula for the calculation of ordinates is deduced as follows.
   Let P be a point at a distance x from D. Then PP_1 (O_x) is the required ordinate. A line P_1P_2 is drawn parallel to T_1T_2. From triangle OP_1P_2,

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

or $$R^2 = \{(R - O_0) + O_x\}^2 + x^2 \qquad [\text{where, } OP_2 = (R - O_0) + O_x]$$

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

or $$O_x = \sqrt{R^2 - x^2} - (R - O_0) \tag{3}$$

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

PROBLEM:

Example Two tangents AB and BC intersect at a point B at chainage 150.5 m. Calculate all the necessary data for setting out a circular curve of radius 100 m and deflection angle 30° by the method of offsets from the long chord.

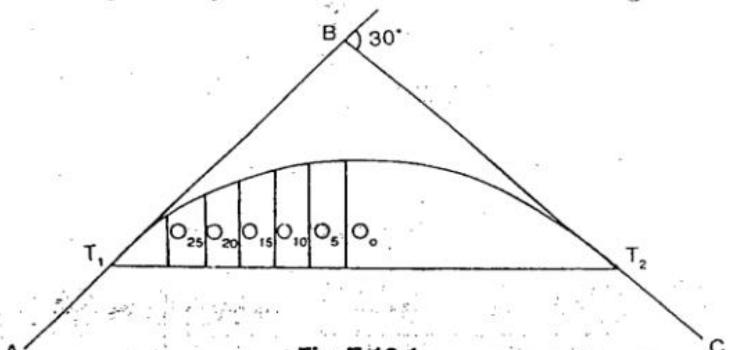


Fig. E.10.1

Solution

1. Tangent length $= R \tan \dfrac{\phi}{2}$

$$= 100 \times \tan 15° = 26.79 \text{ m}$$

2. Chainage of $T_1 = 150.50 - 26.79 = 123.71$ m

3. Curve length $= \dfrac{\pi R \phi°}{180°} = \dfrac{3.14 \times 100 \times 30°}{180°} = 52.36$ m

4. Chainage of $T_2 = 123.71 + 52.36 = 176.07$ m

5. Length of long chord $(L) = 2R \sin \phi/2$

$$= 2 \times 100 \times \sin 15° = 51.76 \text{ m}$$

6. The long chord is divided into two equal halves.

   Each half = $1/2 \times 51.76 = 25.88$ m

7. Mid-ordinate, $O_0 = R - \sqrt{R^2 - \left(\dfrac{L}{2}\right)^2}$

$$= 100 - \sqrt{100^2 - 25.88^2} = 3.41 \text{ m}$$

8. The ordinates are calculated at 5 m intervals starting from the centre towards T_1 for the left half.

$$O_5 = \sqrt{R^2 - x^2}\,(R - O_0)$$
$$= \sqrt{(100^2 - 5^2)} - (100 - 3.41)$$
$$= 99.87 - 96.59 = 3.28 \text{ m}$$

$$O_{10} = \sqrt{(100^2 - 10^2)} - 96.59$$
$$= 99.50 - 96.59 = 2.91 \text{ m}$$

$$O_{15} = \sqrt{(100^2 - 15^2)} - 96.59$$
$$= 98.87 - 96.59 = 2.28 \text{ m}$$
$$O_{20} = \sqrt{(100^2 - 20^2)} - 96.59$$
$$= 97.97 - 96.59 = 1.38 \text{ m}$$
$$O_{25} = \sqrt{(100^2 - 25^2)} - 96.59$$
$$= 96.82 - 96.59 = 0.23 \text{ m}$$
$$O_{25.88} = \sqrt{(100^2 - 25.88^2)} - 96.59 = 0 \qquad \text{(checked)}$$

9. The ordinates for the right half are similar to those for the left half.

problem no 2

Two tangents intersect at a chainage of 1250.50 m having deflection angle of 60^o . If the radius of the curve to be laid out is 375 m, calculate the Length of the curve, Tangent distance, Length of the long chord, Apex distance, Mid-ordinate, Degree of curve and Chainage of P.C. and P.T.

Ans:-

Length of the curve, $l = (\pi R)\, \Delta/180^o$, where Δ is in degrees.

$= \pi \times 375 \times 60^o/180^o$

$= 392.69$ m

Tangent Length, $T = R \tan \Delta/2$

$= 375 \times \tan 60^o/2$

$= 216.50$ m

Length of the long chord, $L = 2 R \sin \Delta/2$

$= 2 \times 375 \times \sin 60^o/2$

$= 375.00$ m

Apex distance, $E = R (\sec \Delta/2 - 1)$

$= 375 \times (\sec 60^o/2 - 1)$

$= 58.01$ m

Mid-ordinate, $M = R (1 - \cos \Delta/2)$

$= 375 \times (1 - \cos 60^o/2)$

$= 50.24$ m

Degree of Arc, $D^o{}_a = 1718.9/R$

$= 1718.9/375$

$= 4.58^o$

Chainage of PC = Chainage of I – T

= 1250.50 – 216.50

= 1034.00 m

Chainage of PT = Chainage of I + l

= 1250.50 + 392.69

= 1634.19 m

Offsets from the chord produced

This method is very much useful for setting long curves. In this method, a point on the curve is fixed by taking offset from the tangent taken at the rear point of a chord.

Thus, point A of chord T_1A is fixed by taking offset $O_1 = AA_1$ where T_1A_1 is tangent at T_1. Similarly B is fixed by taking offset $O_2 = BB_1$ where AB_1 is tangent at A.

Let $T_1A = C_1$ be length of first sub-chord
$AB = C_2$ be length of full chord
δ_1 = deflection angle A_1T_1A
δ_2 = deflection angle B_1AB

Then from the property of circular curve

$$T_1OA = 2\delta_1$$

$$\therefore \quad C_1 = \text{chord } T_1A \approx \text{Arc } T_1A = R\,2\delta_1$$

i.e. $$\delta_1 = \frac{C_1}{2R} \quad \ldots\text{(i)}$$

Now, offset $$O_1 = \text{arc } AA_1$$
$$= C_1\delta_1 \quad \ldots\text{(ii)}$$

Substituting the value of δ_1 from equation (i) into equation (ii), we get

$$O_1 = C_1 \times \frac{C_1}{2R} = \frac{C_1^2}{2R} \quad \ldots(2.16)$$

From Fig. 2.11,

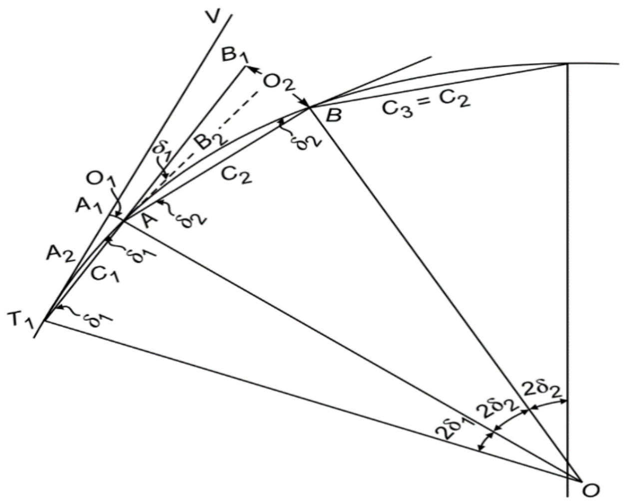


Fig. 2.11

$$O_2 = C_2\,(\delta_1 + \delta_2)$$

$$= C_2\left(\frac{C_1}{2R} + \frac{C_2}{2R}\right)$$

$$= \frac{C_2}{2R}(C_1 + C_2) \qquad \ldots(2.17)$$

Similarly, $$O_3 = \frac{C_3}{2R}\,(C_2 + C_3)$$

But, $$C_3 = C_2 \qquad \therefore\; O_3 = \frac{C_2^2}{R}$$

Thus, upto last full chord i.e. $n - 1$ the chord,

$$O_{n-1} = \frac{C_2^2}{2R}$$

If last sub-chord has length C_n, then,

$$O_n = \frac{C_n}{2R}(C_{n-1} + C_n) \qquad \ldots(2.18)$$

Note that C_{n-1} is full chord.

(Q.1) Two tangents intersects at a chainage of 1,000m, the deflection angle being 30°. calculate all the necessary data for setting out of a circular curve of radius 200m. by the method of offsets from the chord produced, taking a peg interval of 20m.

Solution Given data

$\phi = 30°$, $R = 200$ m, chainage of intersection point $= 1000$ m, and full chord $= 20$ m

1. Tangent length $= R \tan \dfrac{\phi}{2}$

$= 200 \times \tan 15° = 53.58$ m

2. Curve length $= \dfrac{\pi R \phi°}{180°} = \dfrac{\pi \times 200 \times 30}{180} = 104.72$ m

3. Chainage of first tangent point $= 1{,}000 - 53.58 = 946.42$ m

4. Chainage of second tangent point $= 946.42 + 104.72$
$= 1{,}051.14$ m

5. Initial sub - chord $= 950.00 - 946.42 = 3.58$ m

6. No. of full chords of length 20 m $= 5$
Chainage covered $= 950.00 + 100.00 = 1{,}050.00$ m

7. Final sub-chored $= 1{,}051.14 - 1{,}050.00 = 1.14$ m

8. First offset for initial sub-chord,

$$O_1 = \frac{b_1^2}{2R}$$

$$O_1 = \frac{(3.58)^2}{2 \times 200} = 0.03 \text{ m}$$

Second offset for full chord,

$$O_2 = \frac{b_2(b_1 + b_2)}{2R} = \frac{20(3.58 + 20)}{2 \times 200} = 1.18 \text{ m}$$

Third offset for full chord, $O_3 = \dfrac{b_3^2}{R} = \dfrac{20^2}{200} = 2.0$ m

Fourth offset for full chord, $O_4 = \dfrac{b_4^2}{R} = \dfrac{20^2}{200} = 2.0$ m

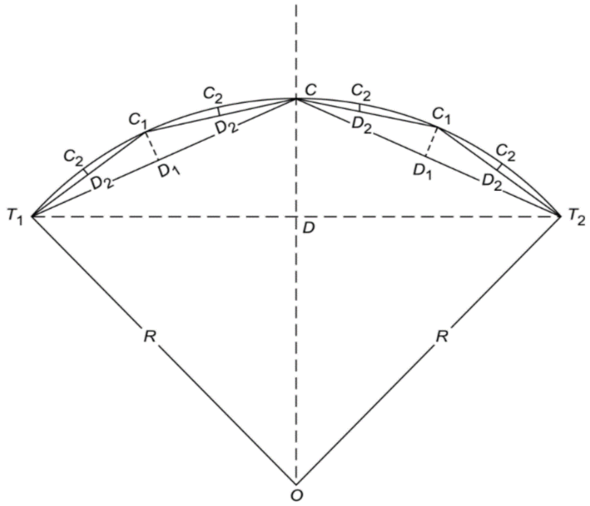
Fifth offset for full chord, $O_5 = \dfrac{b_5^2}{R} = \dfrac{20^2}{200} = 2.0$ m

Sixth offset for full chord, $O_6 = \dfrac{b_6^2}{R} = \dfrac{20^2}{200} = 2.0$ m

Seventh offset for final sub-chord, $O_7 = \dfrac{1.14(20 + 1.14)}{2 \times 200} = 0.06$ m

Successively Bisection of arc

In this method, points on a curve are located by bisecting the chords and erecting the perpendiculars at the mid-point.



Perpendicular offset at middle of long chord (D) is

$$CD = R - R \cos \frac{\Delta}{2} = R\left(1 - \cos \frac{\Delta}{2}\right) \quad \ldots(2.11a)$$

Let D_1 be the middle of T_1C. Then Perpendicular offset

$$C_1D_1 = R\left(1 - \cos \frac{\Delta}{4}\right) \quad \ldots(2.11b)$$

Similarly,

$$C_2D_2 = R\left(1 - \cos \frac{\Delta}{8}\right) \quad \ldots(2.11c)$$

Using symmetry points on either side may be set.

Offsets from the tangent

The offsets from tangents may be calculated and set to get the required curve. The offsets can be either radial or perpendicular to tangents.

(i) Radial offsets: Referring to Fig. 2.8, if the centre of curve O is accessible from the points on tangent, this method of curve setting is possible.

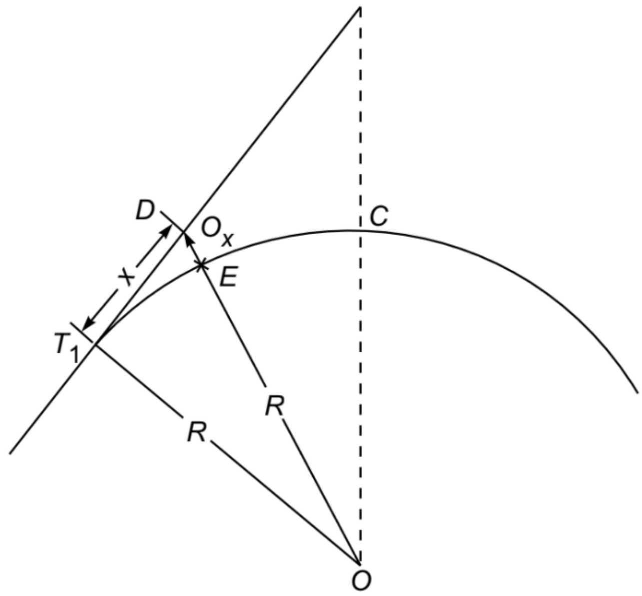


Fig. 2.8

Let D be a point at distance x from T_1. Now it is required to find radial ordinate $O_x = DE$, so that the point C on the curve is located.

From $\Delta\ OT_1D$, we get

$$OD^2 = OT_1^2 + T_1D^2$$

$$(R + O_x)^2 = R^2 + x^2$$

i.e. $$O_x + R = \sqrt{R^2 + x^2}$$

or $$O_x = \sqrt{R^2 + x^2} - R \qquad \text{...(2.12)}$$

An approximate expression O_x may be obtained as explained below:

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

$$= R\sqrt{1 + \left(\frac{x}{R}\right)^2} - R$$

$$\approx R\left(1 + \frac{x^2}{2R^2} - \frac{x^2}{8R^4} + \ldots\right) - R$$

Neglecting small quantities of higher order,

$$O_x = R\left(1 + \frac{x^2}{2R^2}\right) - R$$

$$= \frac{x^2}{2R^2} \quad \text{(approx)} \qquad \text{...(2.13)}$$

(ii) Perpendicular offsets: If the centre of a circle is not visible, perpendicular offsets from tangent can be set to locate the points on the curve.

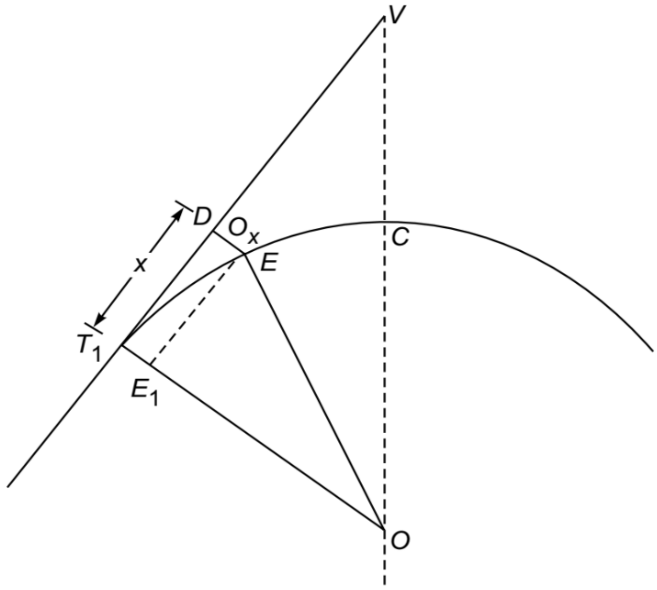


Fig. 2.9

The perpendicular offset O_x can be calculated as given below:
Drop perpendicular EE_1 to OT_1. Then,

$$O_x = DE = T_1 E_1$$

$$= OT_1 - OE_1$$

$$= R - \sqrt{R^2 - x^2} \quad \text{(Exact)} \qquad \ldots(2.14)$$

$$= R - R\left(1 - \frac{x^2}{2R^2} - \frac{x^4}{8R^4} \ldots\right)$$

$$= \frac{x^2}{2R} \quad \text{(approx)} \qquad \ldots(2.15)$$

From equations (2.13) and (2.15) it is clear that they are equations for parabola. Hence, the approximation is circular curve is replaced by a parabola. If the versed sin of the curve is less than 1/8th of its chord, the difference in parabola and circular curve is negligible.

If the exact equations (2.12) and (2.14) are used, the circular curve is correctly found. However, when offsets become longer, the errors in setting offsets creep in. Hence, it is better to find the additional tangents and set offsets, if the curve is long. The additional tangent at *C* can be easily set, because it is parallel to long chord. One can even think of finding intermediate tangents also. Fig. 2.10 shows a scheme of finding additional tangent *NK* at *K*, in which *NL* is perpendicular to $T_1 K$ at its mid-point *L*.

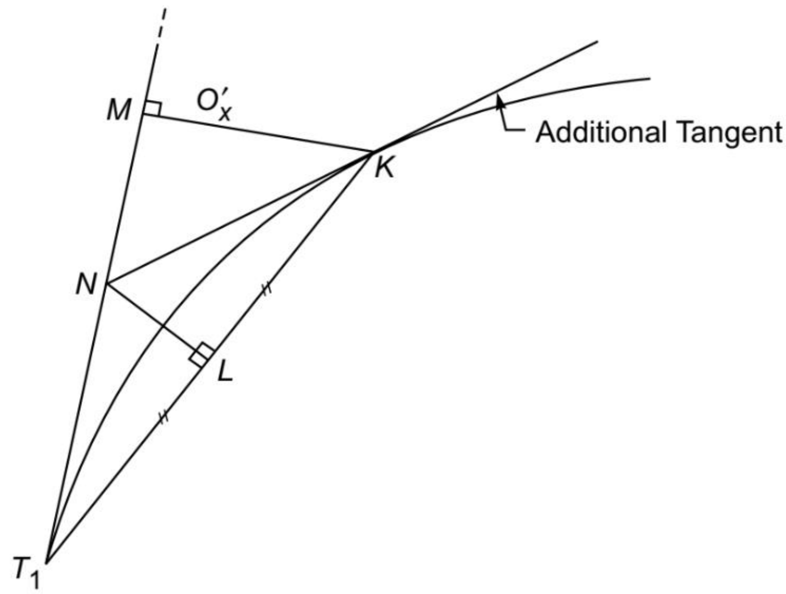


Fig. 2.10

Problem

Two roads having a deviation angle of 45° at apex point V are to be joined by a 200 m radius circular curve. If the chainage of apex point is 1839.2 m, calculate necessary data to set the curve by:

(a) method of bisection to get every eighth point on curve

(b) radial and perpendicular offsets from every full station of 30 m along tangent.

Solution:

R = 200 m θ = 45°

Length of tangent = 200 tan $45^o/2$

= 82.84 m.

Chainage of T_1 = 1839.2 – 82.84

= 1756.36 m.

Length of curve = R × 45 × π/180

= 157.08 m

Chainage of forward tangent T_2 = 1756.36 + 157.08

= 1913.44 m.

(a) Method of bisection:

Central ordinate at D = R (1- cos θ/2)

= 200(1 – cos $45^o/2$)

=15.22m.

Ordinate at D_1 = R (1- cos θ/4)

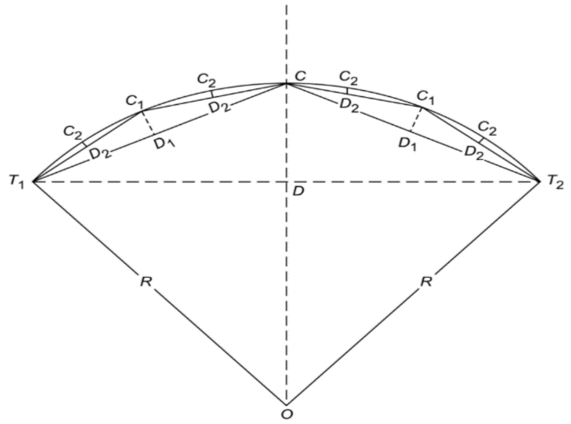
= 200(1 – cos $45^o/4$)

= 3.84m.

Ordinate at D_2 = R (1- cos θ/4)

= 200(1 – cos 45°/8)

= 0.96m.



(b) Offsets from tangents:

Radial offsets:

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

Chainage of T_1 = 1756.36 m

For 30 m chain, it is at

= 58 chains + 16.36 m.

$\therefore \quad x_1 = 30 - 16.36 = 13.64$

$x_2 = 43.64$ m

$x_3 = 73.64$ m

and the last is at x_4 = tangent length = 82.84 m

$$O_1 = \sqrt{200^2 + 13.64^2} - 200 = 0.46 \text{ m}$$

$$O_2 = \sqrt{200^2 + 43.64^2} - 200 = 4.71 \text{ m}$$

$$O_3 = \sqrt{200^2 + 73.64^2} - 200 = 13.13 \text{ m}$$

$$O_4 = \sqrt{200^2 + 82.84^2} - 200 = 16.48 \text{ m}$$

10.7 INSTRUMENTAL METHOD—HORIZONTAL CURVE SETTING BY DEFLECTION ANGLE METHOD OR RANKINE'S METHOD

Let AB and BC be two tangents intersecting at B, the deflection angle being ϕ (Fig. 10.18). The tangent length is calculated and tangent points T_1 and T_2 are marked.

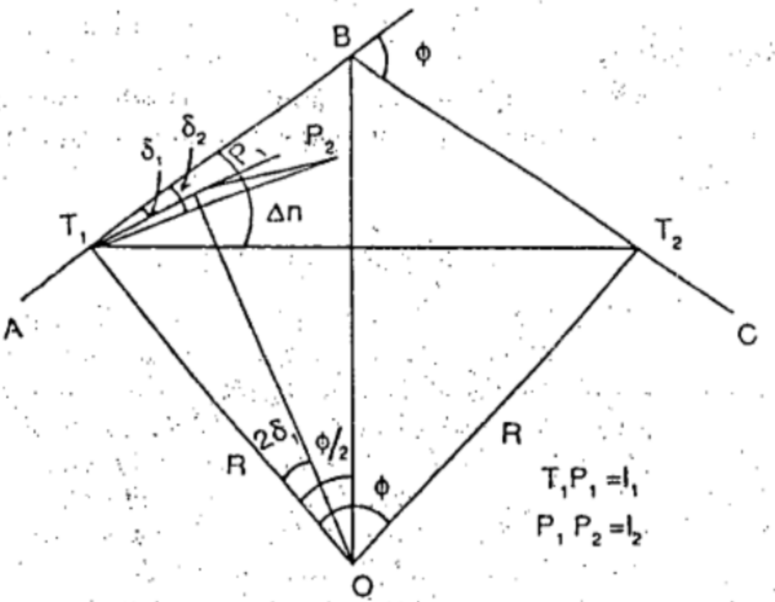


Fig. 10.18

Let P_1 = first point on the curve,

T_1P_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

$$\text{Chord } T_1P_1 \sim \text{arc } T_1P_1$$

Now,

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

$$2\delta_1 = \frac{360° \times l_1}{2\pi R}$$

or

$$\delta_1 = \frac{360° \times l_1}{2 \times 2\pi R} \text{ degrees}$$

or

$$= \frac{360 \times 60 \times l_1}{2 \times 2 \times \pi R} \text{ mins}$$

$$= \frac{1{,}718.9 \times l_1}{R} \text{ mins}$$

Similarly,

$$\delta_2 = \frac{1{,}718.9 \times l_2}{R} \text{ mins}$$

$$\delta_3 = \frac{1{,}718.9 \times l_3}{R} \text{ mins} \quad \text{and so on.}$$

Finally,

$$\delta_n = \frac{1{,}718.9 \times l_n}{R} \text{ mins}$$

Again, when degree of curve D is given,

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

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

Finally,

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

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

Steps to remember for calculating data

1. Tangent length
2. Curve length
3. Chainage of first tangent point
4. Chainage of second tangent point
5. Initial sub-chord
6. Number of full chords
7. Final sub-chord
8. Deflection angle for initial sub-chord
9. Deflection angle for full chord
10. Deflection angle for final sub-chord
11. Arithmetical check
12. Data for field check
13. Setting out table

Example Two tangents intersect at chainage 1,250 m. The angle of intersection is 150°. Calculate all data necessary for setting out a curve of radius 250 m by the deflection angle method. The peg intervals may be taken as 20 m. Prepare a setting out table when the least count of the vernier is 20″. Calculate the data for field checking.

Solution Given data:

Radius = 250 m
Deflection angle $\phi = 180° - 150° = 30°$
Chainage of intersection point = 1,250 m
Peg interval = 20 m
LC of vernier = 20″

1. Tangent length $= R \tan \phi/2$
$= 250 \times \tan 15° = 67.0$ m
2. Curve length $= \dfrac{\pi R \phi°}{180°} = \dfrac{\pi \times 250 \times 30°}{180°} = 130.89$ m
3. Chainage of first TP, $T_1 = 1{,}250.0 - 67.0 = 1{,}183.0$ m
4. Chainage of second TP, $T_2 = 1{,}183.0 + 130.89 = 1{,}313.89$ m
5. Length of initial sub-chord = 1,190.0 − 1,183.0 = 7.0 m
6. No. of full chords (20 m) = 6

   Chainage covered = 1,190.0 + (6 × 20) = 1,310.00 m
7. Length of final sub-chord = 1,313.89 − 1,310.00 = 3.89 m
8. Deflection angle for initial sub-chord,
$$\delta_1 = \frac{1{,}718.9 \times 7.0}{250} \text{ mins} = 0°48'8''$$
9. Deflection angle for full chord,
$$\delta = \frac{1{,}718.9 \times 20}{250} \text{ mins} = 2°17'31''$$
10. Deflection angle for final sub-chord,
$$\delta_n = \frac{1{,}718.9 \times 3.89}{250} = 0°26'45''$$
11. Arithmetical check:
$$\text{Total deflection angle } (\Delta_n) = \delta_1 + 6 \times \delta + \delta_n$$
$$\phi/2 = \frac{30°}{2} = 15°$$
    Here,
$$\Delta_n = 0°48'8'' + 6 \times 2°17'31'' + 0°26'45'' = 14°59'59''$$
$$= 15° \text{ (approximately)}$$
    So, the calculated deflection angles are correct.
12. Data for field check:

    (a) Apex distance $= R(\sec \phi/2 - 1)$
    $= 250 (\sec 15° - 1) = 8.82$ m

    (b) Versed sine of curve $= R(1 - \cos \phi/2)$
    $= 250 (1 - \cos 15°) = 8.52$ m

13. Setting out table

Point	Chainage	Chord length	Deflection angle for chord	Total deflection angle (Δ)	Angle to be set	Remark
T_1	1,183.0	—	—	—	—	Starting point of curve
P_1	1,190.0	7.0	0°48′8″	0°48′8″	0°48′0″	LC of vernier = 20″
P_2	1,210.0	20.0	2°17′31″	3°5′39″	3°5′40″	
P_3	1,230.0	20.0	2°17′31″	5°23′10″	5°23′0″	
P_4	1,250.0	20.0	2°17′31″	7°40′41″	7°40′40″	
P_5	1,270.0	20.0	2°17′31″	9°58′12″	9°58′0″	
P_6	1,290.0	20.0	2°17′31″	12°15′43″	12°15′40″	
P_7	1,310.0	20.0	2°17′31″	14°33′14″	14°33′20″	
T_2	1,313.89	3.89	0°26′45″	14°59′59″	15°0′0″	Finishing point of curve.

DHABALESWAR INSTITUTE OF POLYTECNIC

Subject: -Land surveying -II **Class no: -12**

Chapter: -02 (CURVE)

Obstacles in setting out simple circular curve:

Obstacles in setting out of curves may be classified as due to inaccessibility, due to non-visibility and/or obstacles to chaining of some of the points.

Inaccessibility of point

This type of obstacles can be further classified as inaccessibility of:

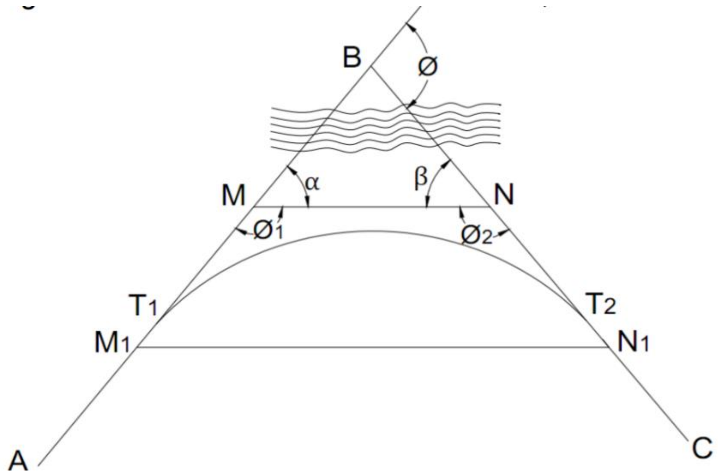
(a) Point of Intersection (PI)

(b) Point of Tangency (PT)

(c) Point of Curve and Point of Intersection (PC and PI).

The method of overcoming these problems are presented below:

(a) **Point of Intersection is Inaccessible**: When the intersection point V falls in a lake, river, wood or behind a building, there is no access to the point V. Referring to Fig. 2.16, T1 and T2 be the tangent points and V the point of intersection. It is required to determine the value of the deflection angle D between the tangents and locate the tangent points T1 and T2.



Procedure:

a) Fix points M and N suitably on the tangents AB and BC resp. so that M and N are intervisible, and the line MN runs on moderately level ground in order that accurate chaining may be possible. If the ground beyond the curve is not suitable, the points may be fixed inside the curve as at M and N. Measure MN accurately..

b) Set up the instrument at M and measure the angle AMN(ϴ1) between AB and MN.

Transfer the instrument to N and measure the angle CNM (ϴ2) between BC and MN.

Now in the Δ ∠BMN, ∠BMN = α =180^0 – ∠AMN = 180^0 – Θ_1, ∠BNM = β = 180^0 – ∠CNM = 180^0 – Θ_2.

The deflection angle (ø) = ∠BMN + ∠BNM = α + β or = 360^0 – sum of measured angles. = 360^0 – (Θ_1 + Θ_2).

c) Solve the triangle BMN to obtain the distance BM and BN

$$BM = \frac{MN \sin\beta}{\sin[180° - (\alpha+\beta)]}; \quad BN = \frac{MN \sin\alpha}{\sin[180° - (\alpha+\beta)]}$$

d) Calculate the tangent length BT_1 and $BT_2$from the formula T= R (tan ø/2).

e) Obtain the distances MT_1 and NT_2. MT_1 = BT_1 – BM and NT_2 = BT_2 – BN.

f) Measure the distance MT_1 from M along the tangent line BA. Thus locating the first tangent point T_1. similarly, locate the second tangent point T_2 by measuring the distance NT_2 from N along the tangent BC. If the point fixed inside the curve, the procedure is same as above, except for the distances to be measured from the points M_1 and N_1 to locate the tangent point T_1 and T_2.

If the point fixed inside the curve, the procedure is same as above, except for the distances to be measured from the points M1 and N1 to locate the tangent point T1 and T2. MT1 and NT2 being respectively equal to (BM1 – BT1) and (BN1 = BT2). When it is found impossible to obtain a clear line MN, a traverse is run between M and N to find the length and bearing of the line MN. From the known bearing of the tangent lines and the calculated bearing of the line MN, the angles α and β may easily be obtained. The distances BM and BN are then calculated as before.

(b) **Point of Tangency T2 is Inaccessible:** Fig. 2.18 shows this situation. In this case there is no difficulty in setting the curve as close to the obstacle as possible but the problem continues with the line beyond the obstacle. This problem can be overcome by selecting two points A and B on either side of the obstacle and finding length AB by any one method of chaining past obstacle. Measure VA. Then, chainage of B can be found as shown below:

Chainage of T2 = chainage of T1 + length of curve

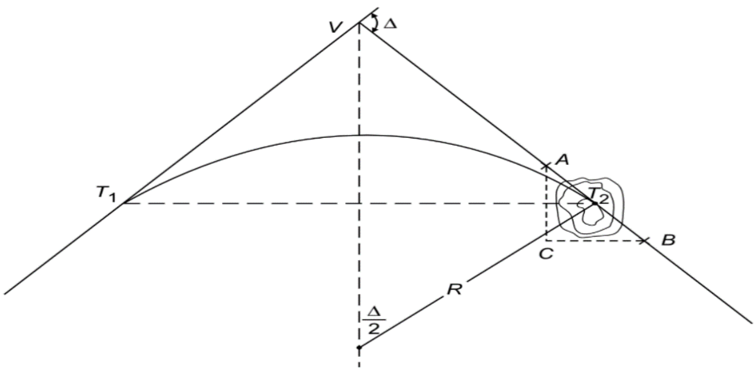


Fig. 2.18

$AT_2 = VT_2 – VA$

$= R \tan\Delta/2 – VA$

AB is found by chaining past the obstacle.

Chainage of B = chainage of T2 + AB – AT2.

Since all the three terms on the right-hand side of the above equations are known, chainage of B is found with this value surveying is carried beyond B.

(c) **Point of Curve and Point of Intersection Inaccessible:** Select point A on rear tangent such that it is clear of the obstacle. Then select point B on forward tangent such that there is no difficulty in measuring AB. Measure line AB.

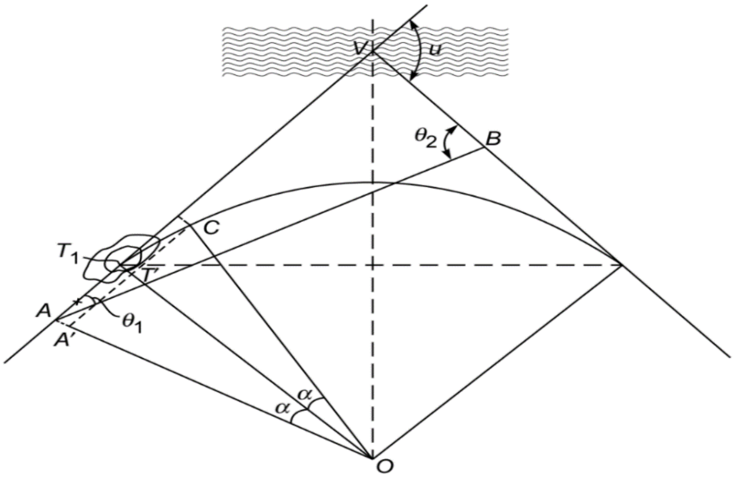


Fig. 2.19

Set instrument at A and measure $\angle VAB = \theta_1$. Shift the instrument to B, set it and measure $\angle VBA = \theta_2$.

$$\therefore \quad \angle AVB = 180 - (\theta_1 + \theta_2) = \Delta$$

Applying sine rule to ΔVAB,

$$\frac{VA}{\sin \theta_2} = \frac{AB}{\sin \Delta}$$

$$\therefore \quad VA = \frac{\sin \theta_2}{\sin \Delta} AB \qquad \ldots(1)$$

$$VT_1 = R \sin \frac{\Delta}{2} \qquad \ldots(2)$$

Set the theodolite at V. Find $\angle TVT_2 = \phi$. Set the telescope at $\phi/2$ to VT_1. Locate C along this line such that

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

Now, chainage of C = chainage of $T_1 + l/2$, where l is length of the curve. Shift theodolite to point C, back orient by sighting V and set the curve in both directions.

Non-visibility of points:

This case is shown in Fig. 2.21. In this case point E is not visible from T_1. Points A, B, C and D have been set as usual, without any difficulty.

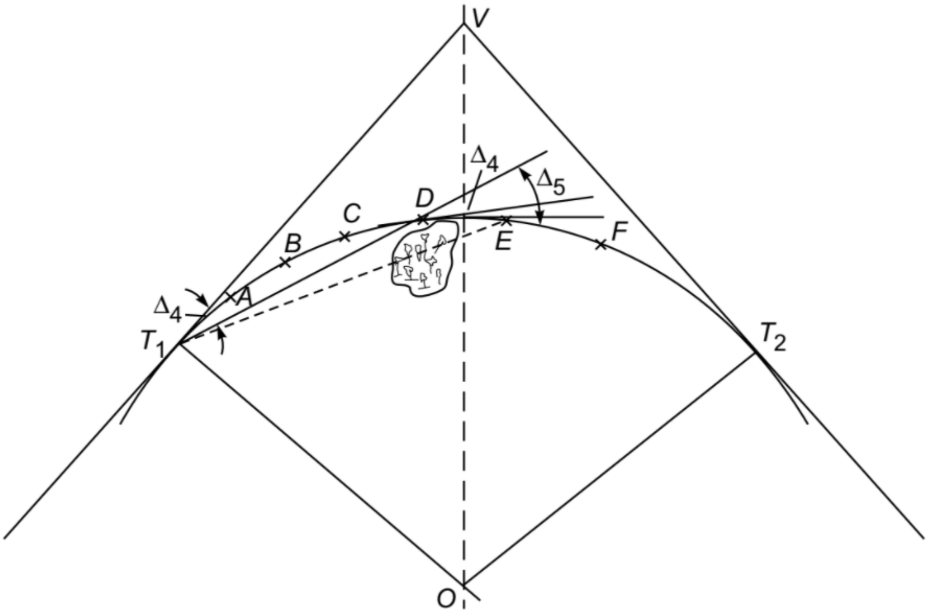


Fig. 2.21

To overcome this problem, after setting point D shift the instrument to that point. Set the vernier to read zero and back sight DT_1. When telescope is plunged it is directed along T_1D. Then set the angle Δ_5 and locate E. Continue the procedure to locate the remaining points.

What is scale?

A scale is the ratio of the distance marked on the plan to the corresponding distance on the ground. A good draughtsman can plot a length to accuracy within 0.25 mm. **Types of Scales** are generally classified as large, medium and small.

- Large scale : 1 cm = 10 m or less than 10 m.
- Medium scale : 1 cm = 10 m to 100 m.
- Small scale : 1 cm = 100 m or more than 100 m.

Types of Scale:

Fractional scale: It is the ratio of the distance on the map to the corresponding distance on the ground taken as same units. Scale of 1 cm = 50 m, 1 cm on the map represents 50 m (5000 cm) on the ground. Therefore, the representative fraction (R.F.) is 1/5000 or 1: 5000.

Graphical scale: A graphical scale is a line drawn on the map so that its map distance corresponds to a convenient units of length on the ground. It has the advantage over the numerical scales that the distances on the maps can be determined by actual scaling even when the map has shrunk.

Vernier Scale :

It is a device for measuring accurately the fractional part of the smallest division on a graduated scale. It divided into,

- **Direct Vernier** : 'n' divisions on the vernier scale are equal in length to (n – 1) divisions on the main scale. Thus 'n' divisions of vernier = {n -1) of main scale :
  ∴ n 'v' = (n-1) 's' or v = {(n-1)/n}*s

Where, n = total No. of divisions on vernier scale, v = length of one division on the vernier, s = length of one division on the main scale. The least count (L.C) is, therefore given by

L.C = s – v.
L.C = s – {(n-1)/n}*s.
L.C = s/n.

- **Retrograde Vernier** : 'n' divisions of the vernier scale are equal to '(n+1)' divisions on the main scale. ***∴ n 'v' = (n+1) 's'***
- **Extended Vernier** : 'n' divisions of the vernier scale are equal in length to (2n – 1) divisions of the main scale. Therefore,
  ∴ n 'v' = (2n-1)s
  ∴ v = {(2n-1)/n}s

- **Double Vernier** : It is used when the graduations on the main scale are numbered in both directions. It is a combination of both direct and retrograde verniers.
- **Double folded vernier** : Its length is half of corresponding double verniers

What is map?

As stated in the definition of **surveying** the objective of measurements is to show relative positions of various objects on paper. Such representations on paper is called **plan** or **map**. ... Representation of a particular locality in a municipal area is a **plan** while representation of a state/country is a **map.**

What is map scale?

A map scale is the map distance ratio that corresponds to the actual ground distance. The scale on the map presents a distance measurement between each landmark. As an example on a 1: 1000000 cm scale map shows that 1 centimetre is equal to 1 kilometre on the ground.

Photogrammetry

Photogrammetry is the science of obtaining information about physical objects through process of recording, measuring and interpreting of photographs of the area.

- In other words, ‘photogrammetry can be defined as the process of developing a map by combining different photographs of the earth’s surface.

Advantage & Disadvantage of Photogrammetry

Advantage	Disadvantage
Covers large area	Complex system, highly trained human resource needed
Less time consuming/fast	Costly at the time of installation/initiation
Cheap/cost effective for large area and in a long run	Heavy and sophisticated equipment’s needed
Easy to interpret, understand	Lengthy administrative procedure for getting permission to fly
Can ‘reach’ inaccessible and restricted area	Weather dependent

Types of Photogrammetry

There are two types of photogrammetry.

- Terrestrial Photogrammetry.
- Aerial Photogrammetry.

Terrestrial Photogrammetry (Horizontal Photograph)

- Terrestrial photogrammetry is the branch of the photogrammetry in which photographs are taken with a camera fixed on or near the ground.
- It is also called as Ground Photogrammetry.
- In terrestrial photogrammetry camera axis is horizontal.
- In terrestrial photogrammetry the instrument used is a photo-theodolite. (Photo-theodolite is nothing but a conventional camera fitted on a tripod with the camera axis horizontal and a theodolite.)
- Use of terrestrial photogrammetry is limited to the plotting of special features eg. Vertical cliff, mountainous terrain etc.
- Similar to plane tabling, the plotting work is done in the field only.

Aerial Photogrammetry

- Aerial photogrammetry is the branch of photogrammetry in which photographs of the area are taken with a camera mounted on an aircraft.

- It Is also called as Ground Photogrammetry.
- In aerial photogrammetry, the same camera is used but the camera axis is vertical.
- Use of aerial photograph is used for topographical surveys, forest and agricultural surveys, preliminary route surveys, i.e. highways, railways pipelines, etc.,
- In aerial photogrammetry, large area can be covered in less time, no detail is missed, can also be used for inaccessible areas.

Difference Between a Map and An Aerial Photograph

Map Aerial Photograph

It is an orthogonal projection. It is a central projection, i.e., perspective projection.

Selected details are shown. A vast number of details are available.

More clarity due to use of legends and other symbolic representations. Less clarity due to no symbolic representations etc.

It has a constant scale. Here the scale differs due to variation of elevations.

Types of Photographs

Aerial photographs are classified into two types:

- Vertical Photograph
- Oblique Photograph

Types of Photographs-min

1. Vertical Photograph

- A vertical photograph is an Aerial photograph made with camera axis coinciding with the direction of gravity.

In truly vertical photograph, the photo plane is parallel to the datum plane.

Tilted Photograph: When the camera axis is tilted from vertical, the resulting photographs is known as tilted photograph. The tilt is generally less than 3°.

2. Oblique Photograph

- When the vertical axis of the camera is intentionally inclined to the vertical then the resultant photograph is known as oblique photograph.

A high-oblique photograph is one that includes the horizon, whereas a low-oblique photograph does not include it.

Terminologies in Aerial Surveying

1.Scale of Photograph

Scale of Photograph-min

Scale of a vertical photograph is define as the ratio of image distance to object distance. For vertical photographs taken over variable terrain, there are an infinite number 0f different scales. This is one the principle difference between a photograph and a map.

The scale of the flat terrain photograph,

S= photo distanceground distance = abAB

From similar triangle ΔLab & ΔLAB

abAB = fH' = fH−h

S = fH−h

The scale of the variable terrain photograph,

S= abAB = cdCD

From similar triangle ΔOab & ΔOAB

abAB = fH−h1 = fH−h

from similar triangle ΔOcd & ΔOCD

cdCD = fH−h2 = fH−h

In general, the scale S of a photograph for any ground elevation is

S= fH−h

Where

H= altitude of the aircraft above mean sea level,

H= elevation of the ground above mean sea level

F= focal length of the camera.

2.Datum Scale of Photograph

Datum Scale-min

The datum scale is the scale effective over the entire photograph when all the ground points were projected vertically downwards on the datum.

Sd= fH

3.Average Scale of Photograph

Average Scale of Photograph min e1635737850826

The average scale is the scale of vertical photograph, that would be effective over the entire photograph if all the ground points were projected vertically downward or upward on the plane of the average elevation of the ground before being photographed.

Savg= fH−havg

4.Flying Height

The elevation of camera lens above datum is called as flying height. Generally mean sea level (MSL) is taken as the datum.

We know that scale of photograph,

S= fH−h

So

(H-h)= fS

Where

H-h= flying height above ground

F= focal length of camera

S= scale of photographs

This method can give best result only when the ground is level or elevation of two point are same.

5.Crab

Crab of a photograph is the angle between the flight line of the aircraft and the edges of the photograph in the direction of flight.

Crab & Drift-min

6.Drift

Drift is the lateral shifting of the the photograph. The photograph does not stay on the predetermined flight line due to winds. If the aircraft is set on its course without considering the wind velocity, drift will occur.

Ground Co-Ordinates & Length of a Line From a vertical Photograph

Ground Co-Ordinates & Length of a Line From a vertical Photograph

The lengths of the lines can be determined from the photographic coordinates (x, y) and ground coordinates (X, Y).

$xX=fH-h$

and

$yY=fH-h$