

**SAMANTA CHANDRASEKHAR INSTITUTE
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SUBJECT LAND SURVEY PRACTICE-II



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SHEET NO. _____

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2	the Sfadia Method	3 to 5		05/05/22	4/5	Manisha 05/05/22
3	Distance and elevation formula for inclined sights by fixed Hair method	6 to 10		19/05/22	5/5	Manisha 19/05/22
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6	Simple curve setting by by offsets from the tangents method	22 to 26		23/06/22	4/5	Manisha 23/06/22
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			Evaluated Manisha 18/07/2022			Cummin Vira 13/15



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EXPT-1

SHEET NO. 01

Tacheometry:

Tacheometry is the branch of surveying in which both horizontal and vertical distance between stations are determined from instrumental observations. In this method measurements by a tape or a chain is completely dispensed with. Horizontal distances obtained by tacheometric observations do not require scope correction, tension correction etc. This method is very rapid and convenient. Though accuracy of tacheometric distances is low as compared to direct chaining on flat ground but accuracy achievable by tacheometry is better as compared to chaining in broken grounds. Deep ravines or across large water bodies.

Purpose of Tacheometric Surveying
It is considered to be rapid and accurate enough and has thus been widely used by engineers in location surveys for railways, canals, reservoirs, etc.



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SHEET NO. 08

Instrument used for Tacheometry Surveying :-

- 1- Tacheometer :- A Tacheometer which is essentially nothing more than a theodolite fitted with stadia hairs. is generally used for tacheometric surveying. the stadia diaphragm consists of one stadia hair above and the other at equal distance below the horizontal cross hairs.
- 2- Stadia rods :- For short distance say up to 200 meters ordinary revelling stones may be used. for greater distances the stadia rods 3 to 5 meters in length are generally used.

Systems of Tacheometric Measurements classification :-

- (i) The Stadia hair system fixed hair method
 movable hair method
- (ii) the tangential system

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EXPT NO-2

SHEET NO. 03

The Stadia Method :- i: Distance and elevation formulae for horizontal sights by fixed hair method.

(1) Horizontal distance of the staff position :-

Assume that o. is the optical centre of the object lens of the external focusing telescope a, b, c represent the three horizontal hairs A, B, C represent respective points on the staff which appear cut by three hairs ab, is the length of the image of the staff intercept AB.

Let F = Focal length of the object lens

i = stadia hair interval ab,

s = staff intercept AB,

d = horizontal distances from the axis of theodolite to staff.

d = the distance between the optical centre of the object glass and the axis of the theodolite.

With the elementary knowledge of optics - it is clear that the rays from A and B which pass through the intermediate principal focus of the objectives f. travel parallel to the principal axis after refraction at



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SHEET NO. 09

$A'B'$ record:

$A'B' = ab = \text{stadia hair distances}$
from similar $\triangle ABF$ and $A'B'F$, we get

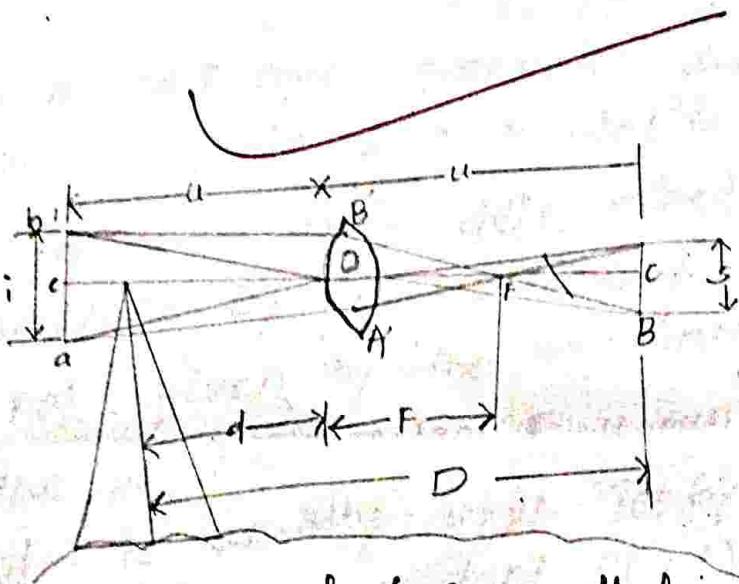


fig 13.3 Fixed hair method

$$\frac{CP}{OF} = \frac{AB}{A'B'}$$

$$cf = \frac{ab \times AB}{A'B'}$$

Substituting the values of AB , ab and $A'B'$
we get.

$$cf = \frac{f}{i} \cdot s$$

$$\text{but } D = cf - f + d \quad \dots \quad (13.1)$$



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SHEET NO. 05

Equation (13.2) is known as the tacheometric distance equation in which f , i and d are constants for a particular theodolite. The tacheometric distance formula may be stated as:

$$D = As + B$$

where A and B are generally known as tacheometric constants of a theodolite. The values of constants A and B are determined before making observations by a particular theodolite if these are not given by the manufacturer.

The value of the constant $\frac{f}{i}$ known as a multiplying constant is usually kept 100 by the manufacturer. The value of other constant ($f+i$), known as an additive constant is generally kept between 0.3 to

0.5 m

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EXPT NO - 3

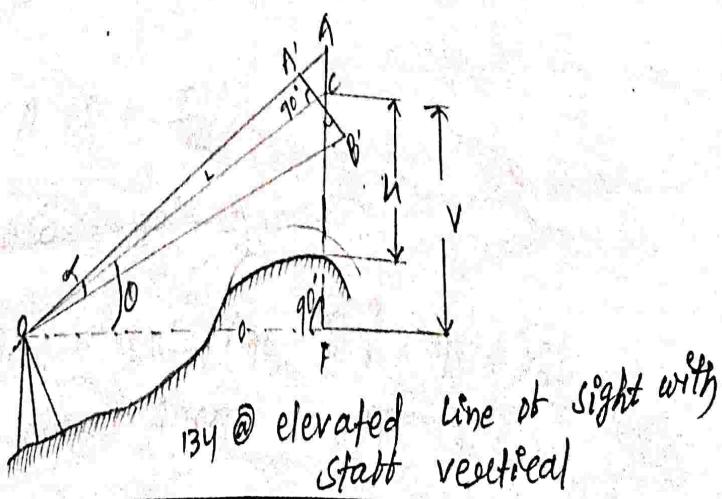
SHEET NO. 76

Distance and elevation formulae for inclined sights
by fixed hair method:

In this case, the staff may be held either vertical or normal to the line of sight. The line of sight may be either elevated or depressed depending upon the relative positions of the instrument and the staff station.

① Distance and elevation formulae for inclined sights with staff vertical (Fig 13.4)

① Horizontal distance formula. Let θ be the angle of elevation or depression of the line of sight from the horizontal as the staff is held vertical. The staff intercept AB is not normal to the line of sight or



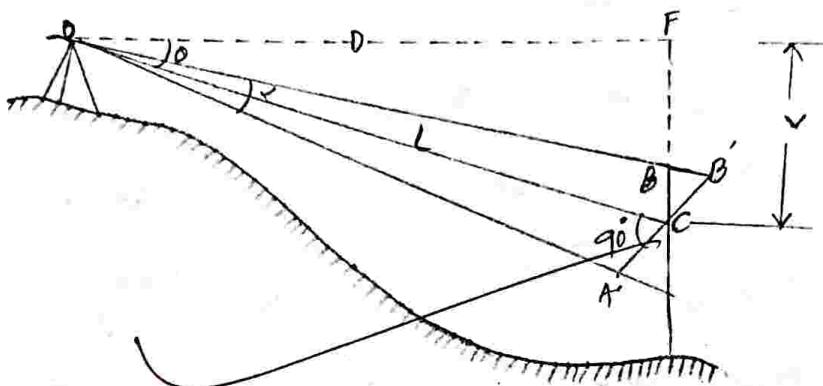
13.4 @ elevated line of sight with staff vertical



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SHEET NO. 07

Draw a line $A'B$ passing through C and perpendicular to oe , cutting OA at A' and OB produced at B'



(b) Depressed line of sight with staff vertical

In $\triangle ocb$, angle $oeb = 90^\circ - \alpha$

But angle $oeb = 90^\circ - \alpha$ being a perpendicular to $A'B'$.

$$\therefore \text{Angle } BCB' = 90^\circ - (90^\circ - \alpha) = \alpha$$

Angle $A'CA = \text{angle } BCB' = \alpha$ being opposite angles
Let angles $\angle A'OB'$ subtended by stadia hairs AB . be α

i.e. Angle $A'oe = \frac{\alpha}{2}$

or Angle $OA'C = 90^\circ - \frac{\alpha}{2}$

Or Angle $AA'C = 180^\circ - (90^\circ - \frac{\alpha}{2}) = 90 + \frac{\alpha}{2}$

Similarly from $\triangle oeb'$ we get



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SHEET NO. 08

The value of $i/2$ is generally very small if the ratio of OC and AB is 100, the value of $i/2$ equals to $17'11''$, ignoring $i/2$ both angles $AA'C$ and $BB'C$ may be assumed very nearly equal to right angles from $A \perp AA'C$ and $B \perp BB'C$

$$A'C = AC \cos \theta : B'C = BC \cos \theta$$

$$A'C + B'C = AC \cos \theta + BC \cos \theta$$

$$A'B' = AB \cos \theta = s \cos \theta$$

Inclined distance OC

$$= \frac{f}{i} \times A'B' + (b+d)$$

$$L = \frac{b}{i} s \cos \theta + (b+d)$$

Horizontal distance $\rightarrow D = L \cos \theta$

$$= \left[\frac{b}{i} s \cos \theta + (b+d) \right] \cos \theta$$

$$\text{or } D = \frac{f}{i} s \cos \theta + (f+d) \cos \theta \quad \text{--- (B.8)}$$

$$= A \cdot s \cos^2 \theta + B \cdot \cos^2 \theta \quad \text{--- (B.8a)}$$

where A and B are the theometric constants



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SHEET NO. 09

⑪ elevation formula

$$\text{from AOCF, } ct = v = L \sin \theta$$

$$= \frac{f}{i} [\cos \theta + (F+d)] \sin \theta$$

$$= \frac{F}{i} \cos \theta \sin \theta + (F+d) \sin \theta$$

$$= A \cdot s \cdot \sin \theta \cos \theta + B \sin \theta$$

$$v = A \cdot s \cdot \frac{\sin \theta}{2} + B \sin \theta \quad \dots \quad (13.9)$$

Oee

Thus equations (13.8) and (13.9) are the required distance and elevation formula for inclined line of sights.

⑫ elevation of the staff station for an angle of elevation (fig 13.4 (a))

Let the central hair reading on the staff be h .
the difference in level between θ and E

$$\delta E = v - h$$

If H. I. is the reduced level of the foundation axis above datum - the reduced

$$\text{level of } E = 4.1 + v - h \quad \dots \quad (13.10)$$



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SHEET NO. 10

(b) elevation for the staff station for an angle of depression [Fig 13.4 (b)]

Let the central hair reading on the staff be h .

The difference in level between O and E

$$FE = v + h$$

If 4.1 is the reduced level of the junction axis above datum, the reduced level of $E = 4.1 - (v + h)$

$$\text{Ans} = 4.1 - v - h \quad \dots \quad (13.4)$$

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EXPT NO - 4

SHEET NO. 11

Determination of Tacheometric constants

The tacheometric constants of stadia theodolites may be determined by one of the following method

- ① determination of multiplying constant $\frac{f}{l}$ by field measurement and the additive constant ($f+d$) by direct measurement along the telescope.
- ② determination of both the constants by field measurement.

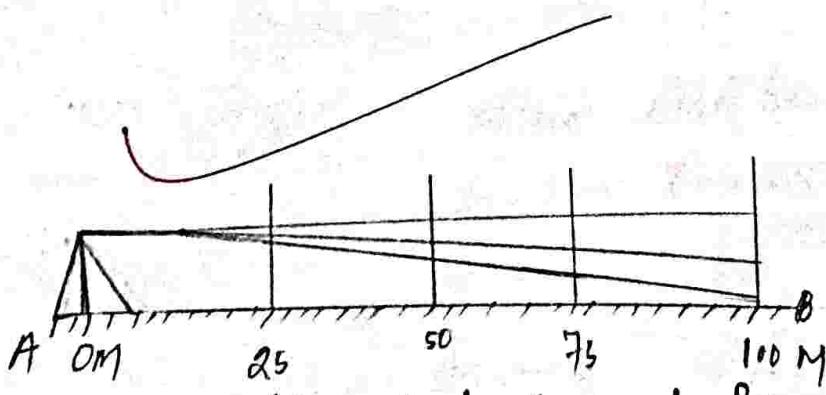
First method: following steps are followed.

- ① sight at sharp distant object and focus the telescope
- ② measure the distance along the top of the telescope between the object lens and the plane of the cross hairs accurately with a graduated scale. this is equal to the focal length (f) of the object lens.
- ③ measure the distance between the object lens & the vertical axis of the theodolite accurately this is equal to d .
- ④ Add the measured value of the focal length f and distance d to get the value of the theodolite constant i.e $Cb+d$.

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SHEET NO. 12

- (V) measures three lengths d_1 , d_2 and d_3 . From the instrument position along a straight line on a fairly flat ground and observe intercepts, s_1 , s_2 and s_3 on a staff held vertically at each point. the vertical circle vernier should read zero to have a horizontal line of sight.
- (VI) substitute the value of $(f+d)$ and different staff intercepts in the distance formula $D = \frac{f}{i} s + (f+d)$ to obtain three independent equations
- (VII) solve the three simultaneous equations to get the value of multiplying constants $\frac{F}{i}$
- (VIII) The mean of the three values of $\frac{F}{i}$ is the required value of the multiplying constant $\frac{F}{i}$ second method: this method is sometimes called field method.



Determination of tacheometric constants



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SHEET NO. 13

Following steps are followed:

- (i) measure a line AB 100 metres long on fairly level ground and six pegs at 25m intervals
- (ii) set up the instruments at A and, centre it over the ground point accurately
- (iii) obtain the staff intercepts s_1, s_2, s_3 and s_4 by taking stadia reading on a staff held vertically at each peg, keeping the telescope horizontal by setting the vertical circle vernier to read zero.
- (iv) substitute the different values of D and s in the tacheometric distance formula, i.e. $D = \frac{f}{i} s + (b + D)$ to get the quadratic equations in $\frac{f}{i}$ and $(b + D)$
- (v) solve the quadratic equations in $\frac{f}{i}$ to get the values of tacheometric constants
- (vi) mean values are the required values of the constants.

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SHEET NO. 14

Example:

A tacheometer has a diaphragm with threee cross hairs spaced at distances 1.15 mm. the focal length of the object glass is 23cm and the distance from the objects glass to the technician axis is 10cm calculate the tacheometric constants.

Sol:

$$\text{Hence } f = 23 \text{ cm} : d = 10 \text{ cm}$$

$$i = 23 \times 1.15 = 2.30 \text{ mm} = 0.23 \text{ cm}$$

Substituting the values in the standard formula

$$\frac{F}{i} = \frac{23}{0.23} = 100$$

Ans

$$\text{and } (f+d) = 23 + 10 = 33 \text{ cm}$$

Multiplying constant = 100

$$\text{Additive constant} = 0.33 \quad \left. \begin{array}{l} \\ \text{Ans} \end{array} \right\}$$

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SHEET NO. 15

Example - 2

A theodolite was set up on an intermediate station of the line AB and following readings were obtained

staff station	vertical angle	staff readings
A	- 6° 20'	0.445 1.675 2.905
B	+ 4° 20'	0.950 1.880 2.880

the instrument was fitted with an anallatic lens and the constant was 100. find the gradient of the line joining station A and station B.

80' staff held at A:

$$S = 2.905 - 0.445 = 2.460 \text{ m} : \theta_1 = 6^\circ 20'$$

Applying theodolitic formula, we get

$$\text{distance } CA = AS, \cos^2 \theta_1$$

$$= 100 \times 2.460 \times \cos^2 6^\circ 20'$$

$$= 243.0 \text{ m}$$

$$\text{vertical component } V_1 = \frac{AS, \sin 2\theta_1}{2}$$

$$= 100 \times 2.46 \times \frac{\sin 12^\circ 40'}{2}$$

$$= 26.97 \text{ m. (neg)}$$

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SHEET NO. 16

staff held at B:

$$s_2 = 2.810 - 0.950 = 1.860 : \alpha_2 = 4^\circ 20'$$

$$\therefore \text{distance } CB = 100 \times 1.860 \cos 4^\circ 20' \\ = 184.94m$$

vertical component $v_2 = As_2 \frac{\sin 8^\circ 40'}{2}$

$$= 100 \times 1.860 \times \frac{\sin 8^\circ 40'}{2}$$

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$$= 14.014m (+ve)$$

$$\therefore \text{the distance } AB = 243.0 + 184.94 = 427.94m$$

Let x be the reduced level of the terminion axis R.L of station A = $x - 14$ - central hair reading

$$\text{Reading} = x - 243.971 - 1.875 = x - 28.646$$

R.L of station B = $x + v_2$ - central hair reading
 $= x + 14.014 - 1.880 = x + 12.134$

Difference in elevation of A and B

$$= x + 12.134 - (x - 28.646) = 40.780m$$

∴ Gradient of line AB

$$= \frac{427.94}{40.780} \text{ or } 1 \text{ in } 10.49 \text{ upward}$$



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EXPT. NO. - 5

SHEET NO. 17

Simple Curve Setting By offsets from long chord method

Objectives:-

To set out a simple curve by linear method (offsets from long chord method)

Equipment:-

- Cross staff
- Anerous
- Ranging rod
- Tape

Theory:-

Linear methods are used when-

1. High degree of accuracy is not required

2. The curve is short

Linear methods for setting out curve include

1. By ordinates or offsets from long chord

2. By offsets from tangents (T)

a. perpendicular offsets

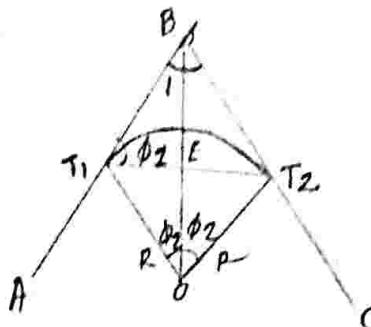
b. radial offsets



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SHEET NO. 18

Elements of simple circular curve.



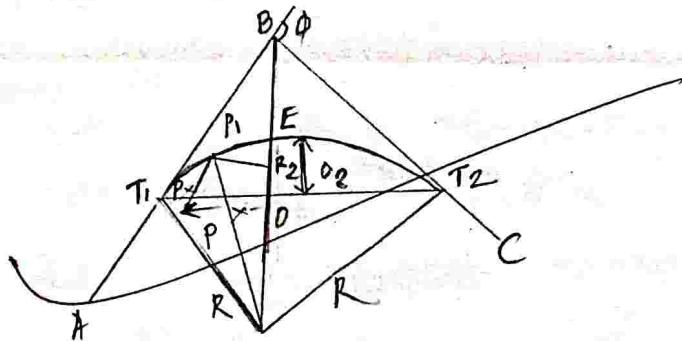
1. AB and BC are known as the ~~tangents~~ to the curve
2. B is known as the point of intersection or vertex
3. The angle ϕ is known as the angle of deflection
4. The angle ϕ is called the angle of intersection
5. points T_1 and T_2 are known as tangent points
6. distances BT_1 and BT_2 are known as tangent lengths
7. When the curve deflects to the right it is called a right-hand curve, when it deflects to the left it is said to be a left-hand curve
8. AB is called the rear tangent and BC the forward tangent
9. The straight line $T_1 D T_2$ is known as the long chord
10. The curved line $T_1 B T_2$ is said to be the length of the curve
11. the mid-point E of the curve $T_1 B T_2$ is known as the ~~rear~~ or sumif of the curve apex



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SHEET NO. 19

12. The distance DE is known as the apex distances or external distances.
13. The distance DE is called the versed sine of the curve.
14. R is the radius of the curve
offsets or ordinates from a 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.



offset from a long chord
calculated according to the formula

1. The tangent is calculated

$$TL = R \tan \theta/2$$

2. tangent points T_1 and T_2 are marked

3. length of the curve is calculated

according to the formula: $CL = \frac{\pi R \phi}{180}$



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SHEET NO. 20

4. The chainage of T_1 and T_2 are found out
5. the length of the long chord CL 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. hence the curve is symmetrical in both the halves

7. the mid-ordinates o_0 is calculated as follows

(a) $o_0 = DE = \text{reversed sine of curve} = RCL - \cos \phi/2)$

(b) again $OB = R$ and $OD = R - o_0$.

from triangle OT_1 , $R - OT_1^2 = OB^2 + T_1 D^2$

$$\text{or } R^2 = (R - o_0)^2 + (L/2)^2$$

$$\text{or } R - o_0 = \sqrt{R^2 - (L/2)^2}$$

$$o_0 = \sqrt{R^2 - (L/2)^2}$$

thus, the mid-ordinate o_0 can be calculated from eq. (10.3) or (10.4)

8. Considering the left half of the long chord the ordinates x_1, x_2, \dots are calculated at distance x_1, x_2, \dots taken from D towards the tangent point the formula for the calculation of ordinates is deduced as follows



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Let the P be a point at a distance x from o_1 . Then op (ox) is the required ordinate. A line PR_2 is drawn parallel to T_1T_2 from triangle OP_1P_2 .

$$op_1^2 = op \frac{2}{3} + p_3 p \frac{2}{3}$$

$$\text{or } R^2 = \{ (R - o_1) + ox \}^2 + x^2 \quad [\text{ whence. } op_2 = (R - o_1) + ox]$$

$$\text{or } ox = R - o_2 + ox = \sqrt{R^2 - x^2}$$

$$\text{or } ox = \sqrt{R^2 - x^2} = -(R - o_1) \quad (\text{ii. 5})$$

9. the ordinates to the right half are similar to those obtained to the left half.

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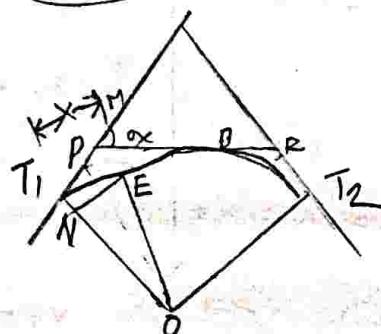
EXPT NO - 6

SHEET NO. 22

Simple curve setting by offsets from the tangents method :-
Limitation of the method : this method can be used conveniently if the deflection angle and radius of the curve are comparatively small.

The offsets from the tangents may be either perpendicular or radial.

① perpendicular offsets.



perpendicular offsets.

Let any point M on the back tangent of a curve of radius R be at a distance of x from T_1 . Length of the offset ME to the [curve perpendicular to the tangent T_1] be

αx construction, drop EN perpendicular to OT_1 .

$$\text{Now } OE^2 = NE^2 + NO^2$$

$$R^2 = n^2 + (R - \alpha x)^2$$

$$(R - \alpha x)^2 = R^2 - \alpha^2 x^2$$

$$\alpha - \alpha x = \frac{R^2 - \alpha^2 x^2}{R}$$

$$\alpha x = R - \sqrt{R^2 - \alpha^2 x^2} \quad (\text{exal}) \quad \dots \quad (5.8)$$



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$$\begin{aligned} OX &= R - R \left[1 - \left(\frac{r}{R} \right)^2 \right]^{1/2} \\ &= R - R \left[1 - \frac{x^2}{2R^2} - \frac{x^4}{8R^4} \right] \\ &= \frac{Rx^2}{2R^2} - \frac{Rx^4}{8R^4} \quad \text{or } OX = \frac{x^2}{2R} \quad (\text{approx}) \end{aligned}$$

"ignoring higher powers of x

Note: The following points may be noted.

- (i) one-half of the curve may be conveniently set out from the back tangent T_1 . the other half of the curve is to be set out from the forward tangent T_2 .
- (ii) if the curve is long. the offsets will also be long. in such cases it is advisable to set the middle third of the curve by calculating offsets from a tangent at the mid point B of the curve.
- fixed field operations. Before setting out a curve of radius say 250m a table of offsets corresponding to a number of points on the tangents may be made as shown in table



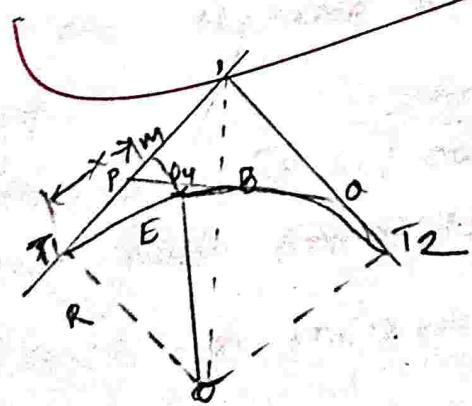
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SHEET NO. 24

SN	x(metres)	o(x)metres)
1	10	0.20
2	20	0.80
3	30	1.80
4	40	3.20
5	50	5.00

procedure:- from the point of commencement T_1 , measure distance $x_1, x_2, x_3 etc along the tangent T_1 . erect perpendiculars equal in lengths of the offsets corresponding to distances $x_1, x_2, x_3\dots$ etc. with the help of an optical square.$

As the offsets of the points. equidistant from point of commencement T_1 and point of tangency T_2 are equal the table may also be used for offsets from the toward tangent (2) Radial offsets



Radial offsets



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SHEET NO. 25

Let M be any point on the tangent at a distance a from the point of commencement T. ox be the radial offset from M to the curve R be the radius of the curve with O as its centre

$$\text{Now, } (R + ox)^2 = R^2 + x^2$$

$$\text{or } R + ox = \sqrt{R^2 + x^2}$$

$$ox = \sqrt{R^2 + x^2} - R \quad \text{(exact) ...}$$

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

$$= R \left[1 + \frac{x^2}{2R^2} + \frac{x^4}{8R^4} + \dots \right] - R$$

Ignoring higher powers of x .

Note. the following points may be noted

(i) the lengths of the offsets, whether perpendicular or radial - are the same when approximate formulae are accepted.

(ii) Half the curve may be set out from the back tangent and the other half from the forward tangent

(iii) As the distance x increases, the offset length also increase

(iv) From the mid-point of the curve the length of the offset is longest



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(v) When the length of the curve is large, the middle third of the curve may be set out from the tangent at the mid-point of the curve.

field operations: following steps are followed.

(1) fix swinging rods at T_1 , I, T_2 and O

(2) measure a distance equal to the $\frac{2}{3}$ along T_1 and fix a point M.

(3) from M measure a distance equal to the calculated offset length along the line joining the point M and the centre of the curve O.

(4) similarly locate other points on the first half of the curve.

(5) the other half of the curve is similarly set out from the forward tangent T_2 .

(6) To avoid large offsets, the setting out of the middle third of the curve may be done from the tangent pt. at the mid-point B of the curve.

~~Manisha~~
23/08/22

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EXPT NO - 7 offsets from chords produces SHEET NO. 27

Aim of the experiment :-

To setting out a simple circular curve by offsets from chord produces.

Theory :-

This methods is very much useful for setting long curve. In this method a point on the curve is fixed by taking offsets from the tangent taken at the start point of a chord.

Thus, point A of chord $T_1 A$ is fixed by taking offset $O_1 = AA$, where $T_1 A$ is tangent at T_1 . Similarly B is fixed by taking offset $O_2 = BB$, where AB is tangent of A.

Let $T_1 A = c$ be length of first sub-chord

$AB = c_2$ be length of full chord

$s_1 = \text{deflection angle } A_1 T_1 A$

$s_1 = \text{deflection angle } B_1 AB$

From the property of circular curve

$$T_1 O_1 A = 2s_1$$

$$c_1 = \text{chord } T_1 A = \text{arc } T_1 A = R 2 s_1$$



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$$\text{i.e } s_1 = \frac{q}{2R}$$

Now. offset $o_1 = \text{arc } AA_1$

$$= c_1 s_1$$

Substituting value of s_1 from equation (i) into equation (ii), we get $o_1 = c_1 \times \frac{c_1}{2R} = \frac{c_1^2}{2R}$

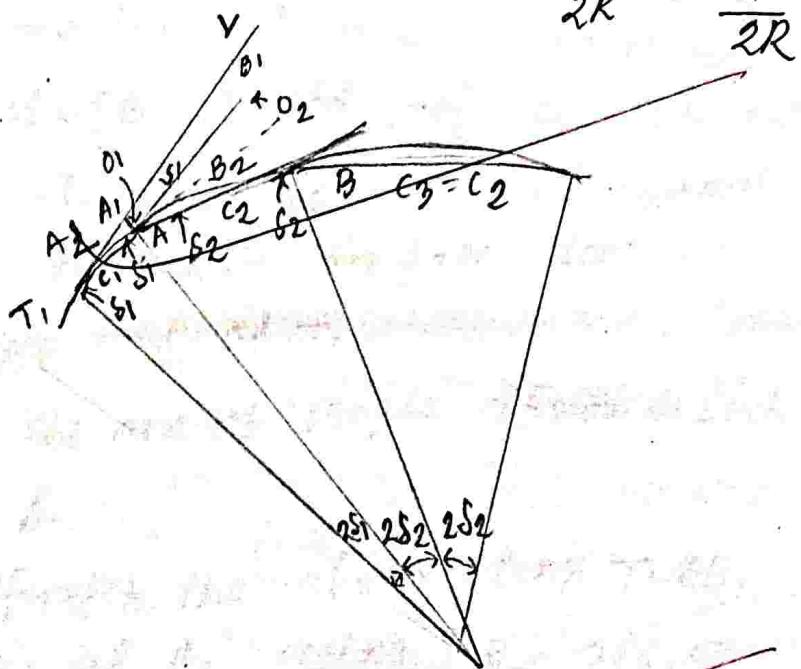


fig 2.11.

$$o_2 = c_2 (s_1 + s_2)$$

$$c_2 \left(\frac{c_1}{2R} + \frac{c_2}{2R} \right) = \frac{c_2}{2R} (c_1 + c_3)$$

$$\text{Similarly } o_3 = \frac{c_3}{2R} (c_2 + c_3)$$



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Thus, upto last full chord i.e. $n-1$ the chord. $ON_1 = \frac{c_2^2}{2R}$
If last sub-chord has length c_{n-1} then, $ON = \frac{c_1}{2R}$
 $(c_n + c_1)$ Note that c_{n-1} is full chord.

Procedure

- ① Locate the tangent point T_1 and T_2 and find the length of first (c_1) and last (c_2) sub. chord after selecting length ($c_2 = c_3 = \dots$) of normal chord
- ② Stretch the chain on tape along $T_1 V$ direction, holding its zero end at T_1 .
- ③ Swing the arc of length c_1 from A such that $A_1 A = \frac{c_1^2}{2R}$.
Locate A.
- ④ Now stretch the chain along $T_1 A_1 B$, with zero end of tape at A, swing the arc of length c_2 from B_1 till $B_1 B = c_2 = \frac{c_2(c_1+c_2)}{2R}$. Locate B.
- ⑤ Spread the chain along $A B$ and the third point C such that $c_2 c_3 = \frac{c_2^2}{R}$ at a distance $c_3 = c_2$ from B; continue till last but one point is fixed


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- (vi) Fixed the last point such that offset on = $c_2(c_2 + c_n)$
(vii) check whether the last point coincides with T_2
if the closing error is large check all the measurements again. if small: the closing error is proportional to the square of their distances from T_1 .

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