

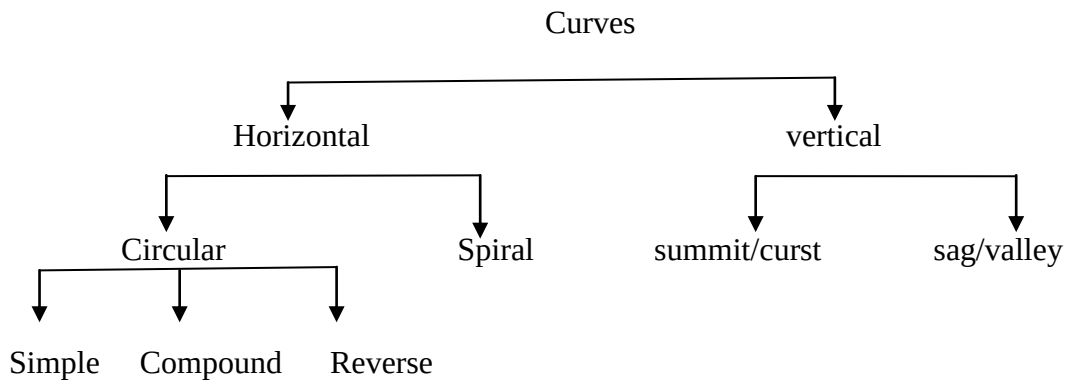
## CHAPTER 2

### CURVE SETTING

#### 2.1 Introduction

Curves are provided in the line of communication like roads, railways, canals etc. to bring about the change of direction gradually. Horizontal curves are curves that are used to connect straight line called tangent. The curves employed normally are circular. Although spiral curves may be used to provide gradual transitions to or from the circular curves.

#### 2.2 Types of curves and their uses



#### I. Horizontal Curves

- ✓ Curves are provided to bring about the change of direction gradually.
- ✓ Horizontal curves are curves that are used to connect straight line called tangent.
- ✓ Their design & their construction are considered in the horizontal plane.

Circular curves can be classified as

- ❖ **Simple circular curves:** consist of one arc of constant radius
- ❖ **Compound Circular curves:** Consist of two or more circular curve of different radii. and the centers of the curve lie the same side of common tangent.
- ❖ **Reverse Circular Curves :** Consist of two consecutive circular curves, May or may not have the same radii( $R_1=R_2$ ) ,and the centers of the curve lie on opposite side of common tangent.

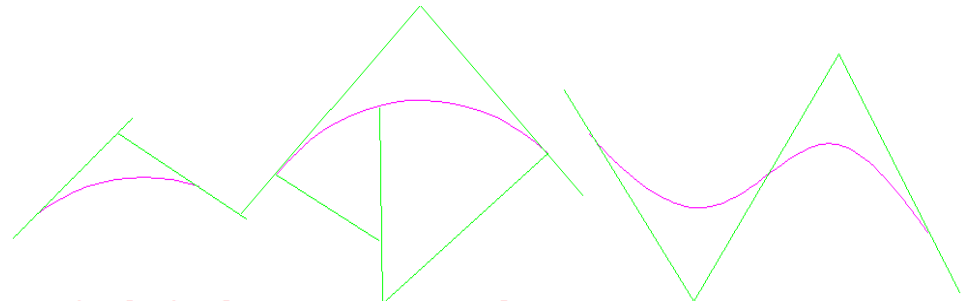


**figure 2.1 types of curve    simple circular    curve compound curve    reverse curve**

### 2.3 Simple Circular Curves

A Simple Curve is a circular arc joining two intersecting tangents. The radius of the circle determines the sharpness or flatness of the curve.

Elements of the simple circular curve

1. Vertex (V) - the point of intersection (PI) of two intersecting tangents.
2. Point of curvature (PC) the point of tangency where the curve leaves the tangent.
3. Point of tangency (PT) - the point of tangency where the curve meet the other tangent.
4. Tangent distance (T) - the distance from the vertex or PI to the PC.
5. Deflection angle ( $\Delta$ ) or D- the angle by which the back tangent deflects from the forward tangent
6. Radius (R) - the radius of the circle of which the curve is made.
7. External distance (E) is the distance from the vertex or PI to the mid-point of the circular curve.
8. Long chord (C) - is the distance from the chord joining the PC and PT along a straight line
9. Middle Ordinate (M) -is the distance from the mid-point of the long chord to the mid-point of the circular curve.
10. Arc length ( $\ell$ ): length of the curve from PC to PT.

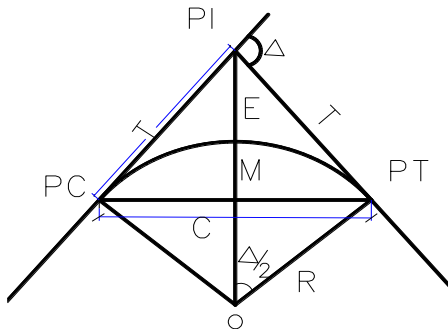


Figure 2.2

## Equations for Circular Curves

The relationships involving the radius  $R$  of a circular curve, the deflection angle  $\Delta$  between the tangents, and other elements of the curve.

$$\text{Tangent distance } T = R \tan \frac{\Delta}{2}$$

$$\text{External distance } E = R \left( \sec \frac{\Delta}{2} - 1 \right)$$

$$\text{Middle ordinate } M = R \left( 1 - \cos \frac{\Delta}{2} \right)$$

$$\text{Long chord } C = 2R \sin \frac{\Delta}{2}$$

$$\text{Arc length } (l) = \frac{\pi R \Delta}{180}$$

Station PC = station PI - tangent length ( $T$ )

Station PT = Station PC + Arc length ( $l$ )

**Example:** the chain age intersecting of two straight having the intersection angle of  $130^\circ$  is 1+680.5m. if the radius of the curve is 450m Calculate the elements of the curve & determine the chain age of the tangent pc & pt.

Solution:

Given data:  $R=450\text{m}$

Station I=1+680.5m

Angle of intersection ( $\angle I$ ) =  $130^\circ$

$$\Delta = 180^\circ - \angle I = 50^\circ$$

### 2.4 Designation of curve

The sharpness of curves is designated either by their radius (R) or by their degree of curve.

The degree of curve can be:

- Chord definition:** the central angle of the curve that is subtended by a chord of standard length (20m).
- Arc definition:** the central angle of the curve that is subtended by an arc of standard length (20m).

Note: the sharpness of circular curve may be described by its radius or by the degree of curve ( $D^\circ$ ) subtending & standard arc length as defined above.

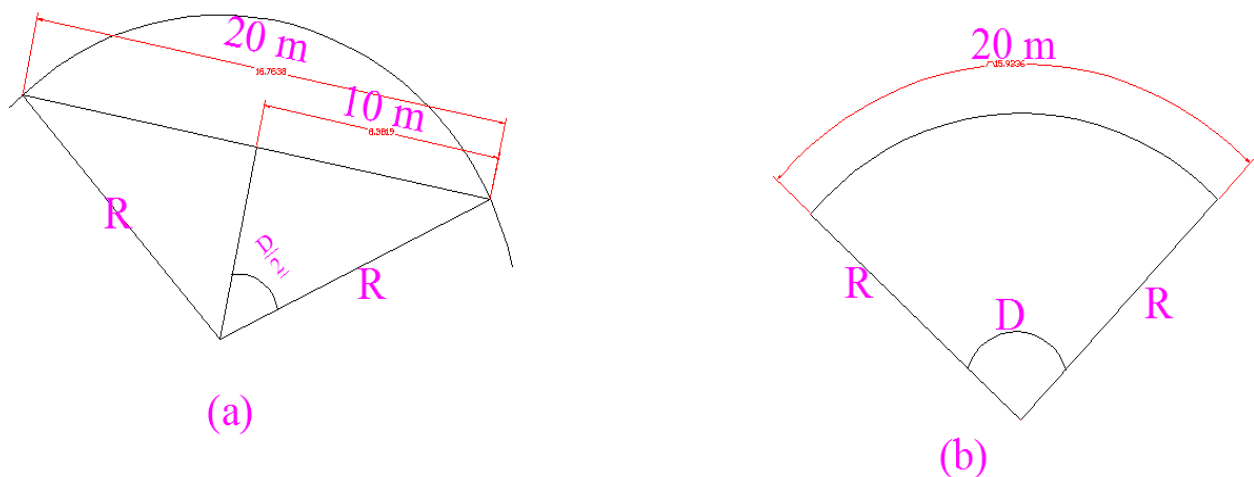


Figure 2.4 Relation between radius and degree of a curve a) by chord and b) by arc definitions.

By chord definition

$$\sin D/2 = 10/R$$

$$D = 2\sin^{-1}(10/R)$$

By arc definition (from fig. 2.4b)

$$\frac{D^\circ}{20} = \frac{360}{2\pi R} \Rightarrow D^\circ = \frac{360 \times 20}{2\pi R} = \frac{1145.916}{R} M$$

**Example:** a circular curve having a radius 250m what is their degree of curve.

a) By chord definition

b) By arc definition

Solution : by chord definition

$$D = 2\sin^{-1}(10/R) = 4^\circ 35' 6''$$

By arc definition

$$\frac{D^\circ}{20} = \frac{360}{2\pi R} \Rightarrow D^\circ = \frac{360 \times 20}{2\pi R} = \frac{1145.916}{R} M = 4^\circ 35' 9''$$

### 2.5 Compound Curves

A compound curve has two or more circular curves contained between the two main straights or tangents. The individual curves meet tangentially at their junction point. Smooth driving characteristics require that the larger radius be more than 1 times larger than the smaller radius.

The elements of a compound curve

Tangent lengths

$$t_s = R_s \tan \Delta_s / 2$$

$$t_L = R_L \tan \Delta_L / 2$$

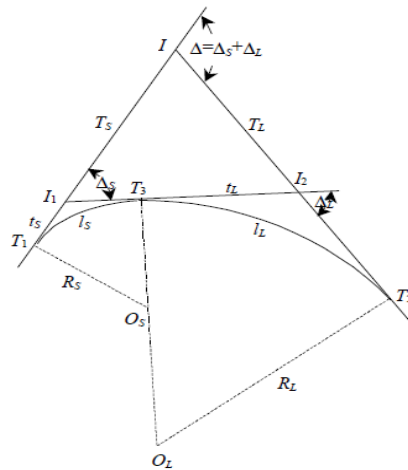


Figure 2.5 element of compound curve.

$$T_s = (t_s + t_L) \sin \Delta_L / \sin \Delta + t_s$$

$$T_L = (t_s + t_L) \sin \Delta_s / \sin \Delta + t_L$$

Where

$$\Delta = \Delta_s + \Delta_L$$

Length of the curve

$$l_s = \frac{\pi R_s \Delta_s}{180}$$

$$l_L = \frac{\pi R_L \Delta_L}{180}$$

$$L = l_L + l_s$$

$$= \frac{\pi}{180} (R_s \Delta_s + R_L \Delta_L)$$

Chainage of point of curve (T1) = chainage of intersection point (PI) -  $T_s$

Chainage of point of compound curve (T3) = chainage of point curve (T1) +  $l_s$

chainage of point of tangency (T2) = chainage of point of compound curve (T3) +  $l_L$



### 2.6 Reverse Curves

A reverse curve is one in which two circular curves of same or different radii have their center of curvature on the opposite sides of the common tangent. Two straights to which a reverse curve connects may be parallel or non-parallel.

They are used to when the straights are parallel or intersect at a very small angle.

Non-parallel straights when  $R_1 = R_2 = R$ , given  $\delta_1$ ,  $\delta_2$ , and  $L$

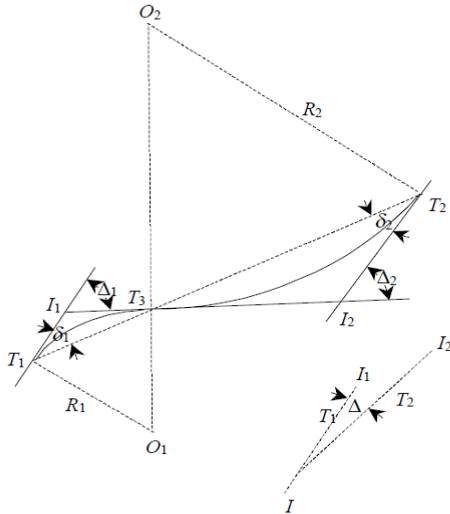


Figure 2.6 revers curve

$$R = \frac{L}{\sin \delta_1 + 2 \cos \theta + \sin \delta_2}$$

Where

$$\theta = \sin^{-1} \left( \frac{\cos \delta_1 + \cos \delta_2}{2} \right)$$

$$\Delta_1 = \delta_1 + (90^\circ - \theta)$$

$$\Delta_2 = \delta_2 + (90^\circ - \theta)$$

**Example:** a revers curve is to run from a point T1 on AA' to the point T2 on CC'. Determine the common radius and the length of the two part of curves given that T1T2=720m and the angle AT1T2 and T1T2C' are 47°30' and 25°12' respectively.

Solution:

$$R = \frac{L}{\sin \delta_1 + 2 \cos \theta + \sin \delta}$$

$$\theta = \sin^{-1} \left[ \frac{(\cos \delta_1 + \cos \delta_2)}{2} \right] = 52^\circ 12' 18''$$

$$R = 720 / (\sin \delta_1 + 2 \cos \theta + \sin \delta) = 301.42 \text{ m}$$

### 2.7 Transition curve

Transition Curves are curves in which the radius changes from infinity to a particular value. The radius starts from infinity at a straight and end at some specified value (R) of a circular curve. The effect of this is to gradually increase the radial force P from zero to its highest value & thereby reduce its effect.

For a Vehicle traveling from PC to PT, the force gradually increases from zero to its maximum on the circular curve and then decreases to zero again. This greatly reduces the tendency to skid & reduces the discomfort experienced by passengers in the vehicles.

This is one of the purposes of transition curves; and also use to increase the curvature of the curve gradually and uniformly and uniformly they minimize passenger discomfort.

If the transition curve is to introduce the radial force in a gradual & uniform manner it must have the property that the product of the radius of curvature at any point on the curve and the length of the curve up to that point is a constant value.

Length of transition curve

- i. By arbitrary gradients

$$L_t = n \cdot e \quad R - \text{radius of the circular curve}$$

$L_t$  - length of transition curve

$n$  - arbitrary gradients b/n 3% to 12%

$e$  - super elevation

- ii. Time rate

$$L_t = v \cdot e / a \quad v - \text{speed of vehicle}$$

$a$  - time rate to be provided in sec (2.5 to 5cm)/sec

- iii. Rate of radial acceleration (c)m/sec<sup>3</sup> mostly (1/3)

$$L_t = V^3 / c \cdot R$$

Where

$v$  - speed of vehicle

$R$  - radius of circular curve

$c$  - rate of radial acceleration in m/sec<sup>3</sup>

Another purpose of transition curves is to gradually introduce super elevation

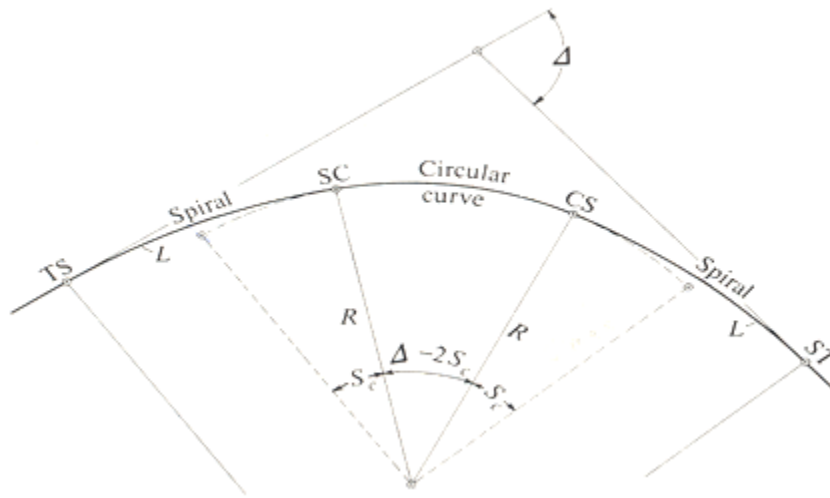


Figure 2.7 transition curve

### 2.8 Vertical Curves

Whenever roads or railways change gradient, a vertical curve is required to take traffic smoothly from one gradient to the other. When the two gradients form a hill, the curve is called a summit curve and when the gradient form a valley, a sag or valley curve is produced.

**Crest Curves:** - Which can also be referred to as a summit or hogging curve, is one for which the algebraic difference is negative when calculated from right to left.

**Sag Curves:-** A sag curve (valley or sagging) curve is one for which the algebraic difference of the gradients is positive when calculated from right to left.

#### Purposes of vertical curves

There are two general purposes of Vertical curves:

- 1) Adequate visibility (Sight distance)- For a vehicle to stop or to over take safely, it is essential that on coming or any obstructions in the road can be seen clearly at good time.
- 2) Passenger comfort & safety- As the vehicle travels along the curve a radial force acts on the vehicle in the vertical plan.

#### Types of Vertical Curves

Vertical curves are usually parabolic since parabola curves provide constant rate of change of curvature.

- a) Symmetrical parabola curve: The curve lengths from PVC to PVI and from PVI to PVT are equal.

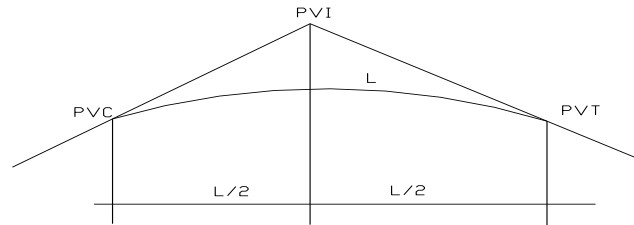


figure 2.10 symmetrical parabola curve

- b) Unsymmetrical parabolic curve: The curve lengths from PVC to PVI and from PVI to PVT are not equal.

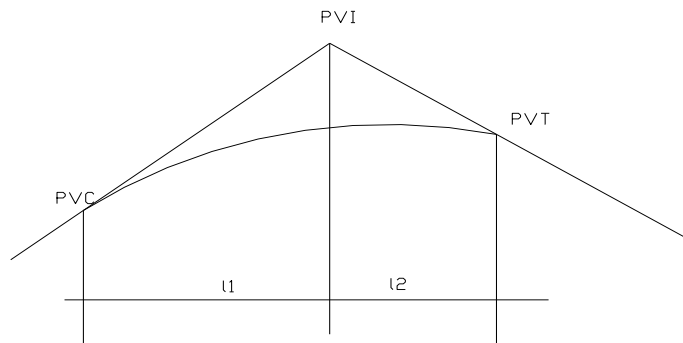


figure 2.11 unsymmetrical parabolic curve

### Elements of Parabolic Vertical Curve

Vertex (V) the point of intersection of the grade line (PVI) point of V. Curvature (PVC)- The pt of tangency where the parabolic V. curve leaves initial grade.

Point of Vertical tangency (PVT)- The pt of tangency where the parabolic V. curve meets the forward grade.

Length of vertical curve (L)- the horizontal distance b/n PVC to PVT.

### Element of symmetrical parabolic vertical curve

1. Compute the algebraic difference in grade  
 $A = g_2 - g_1$  (in %)
2. Compute the chainage of (i.e station) of VPC and VPT as follows:  
 $\text{Station of PVC} = \text{Station of PVI} - L/2$   
 $\text{Station of PVT} = \text{Station of PVI} + L/2$
3. Compute the distance from VPC to high or low point as follows:  
 $X = -Lg_1/A$
4. Compute the elevation of VPC and VPT by using  $g_1, g_2$ , and  $L$
5. Compute the curve elevation at every required station by using the following equations:  
 $Y = ax^2 + bx + c$  where  
 $Y$  = curve elevation at every required station  
 $a = (g_2 - g_1)/200L$   
 $b = g_1/100$   
 $c$  = elevation of VPC  
 $x$  = horizontal distance from VPC to station of interest.

Example: A vertical curve is to connect two tangents that intersect at station 5 + 000 & elevation 500m. The back tangent gradient is - 4 percent, the forward tangent gradient is 2 percent. The length of the curve is 160m. setup a table that shows elevations at PVC, PVT and at full stations along the curve. The V.C. is symmetrical parabolic curve.

Solution:

1. Compute the algebraic difference in grade  
 $A = g_2 - g_1$  (in %) =  $2\% - (-4\%) = 6\%$
2. Compute the chainage of (i.e station) of VPC and VPT as follows:  
 $\text{Station of PVC} = \text{Station of PVI} - L/2$   
 $= 5000\text{m} - 80\text{m}$   
 $\text{Station of PVC} = 4920\text{m}$   
 $\text{Station of PVT} = \text{Station of PVC} + L$   
 $= 4920 + 160$   
 $\text{Station of PVT} = 5080\text{m}$
3. Compute the distance from VPC to high or low point as follows:  
 $X = -Lg_1/A$   
 $= -160\text{m} * -4\% / 6\% = 106.667\text{m}$

4. Compute the elevation of VPC and VPT by using  $g_1, g_2$ , and  $L$

$$\text{Elevation of VPC} = \text{Elevation of PVI} - g_1 L/2$$

$$= 500 + \frac{4}{100} * \frac{160}{2}$$

$$= 503.20\text{m}$$

$$\text{Elevation of VPT} = \text{Elevation of PVI} + g_2 L/2$$

$$= 500 + 2/100 * 80$$

$$= 501.6\text{m}$$

### 2.9 Method of Setting Out

Setting out a simple circular curve

Setting out a curve means locating various points at equal and convenient distances along the length of a curve.

The methods of setting out curves can be mainly divided into two heads depending upon instruments used.

**a) Linear methods:** In the linear methods, only a chain or tape is used. Linear methods are used when:

- A high degree of accuracy is not required,
- The curve is short.

**b) Angular methods:** In this method, an instrument such as a theodolite is used with or without a chain (or tape).

1) By linear methods

The various linear methods of setting out a simple circular curve are:

- a. offsets from the long chord
- b. perpendicular offsets from the tangent.
- c. radial offsets from the tangent
- d. successive bisection of arcs

Let it be required to set out a curve  $T_1CT_2$  between the two intersecting straight lines  $T_1I$  and  $T_2I$ .

a)  $R$  is the radius of the curve,

b)  $O_0$  the mid-ordinate, and

c)  $O_x$  the offset at a point  $P$  at a distance  $x$  from the mid-point ( $M$ ) of the long chord.

3) By angular methods

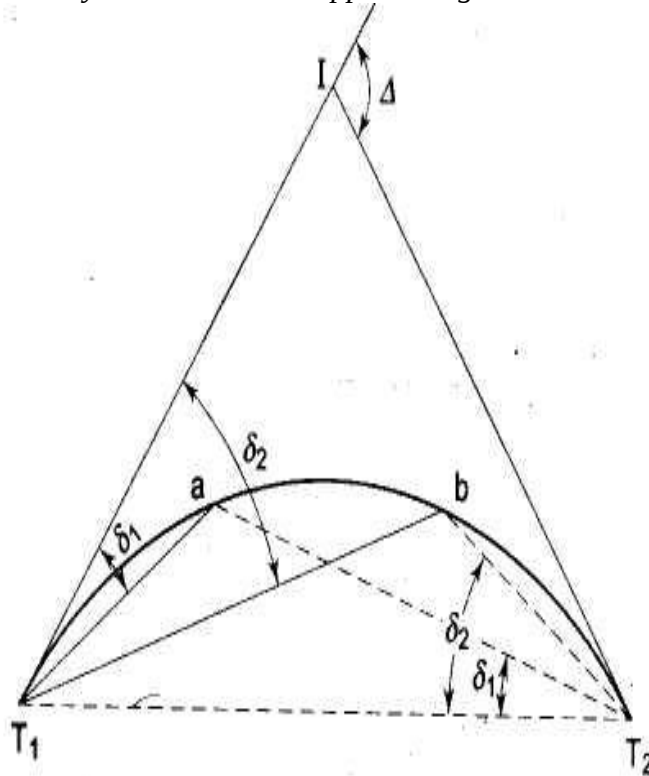
The following angular methods are commonly used for setting out curves.

- i. Rankine's method of deflection angle (one-theodolite method)
- ii. Two-theodolite method

**Two-theodolite method**

This method is most convenient when the ground is undulating, rough and not suitable for linear measurements. In this method, two theodolites are used and linear measurements are completely eliminated. Hence, this is the most accurate method.

It is based on the principle that *the angle between the tangent and the chord is equal to the angle subtended by the chord in the opposite segment*

**Field procedure**

1. Set up one theodolite at P.C. (T1) and the other at P.T. (T2).
2. Set the vernier A of both the theodolites to zero.
3. Direct the theodolite at T1 towards I, and the theodolite at T2 towards T1.
4. Set an angle  $\delta$  in both the theodolites so as to direct the line of sights towards T1a and T2a, thus the point a, the point of intersection of the two line of sights, is established on the curve.
5. Similarly, point b is established by setting  $\delta$  in both the theodolites and bisecting the ranging rod at b.
6. The same steps are repeated with different values of  $\delta$  to establish more points