VISVESVARAYA TECHNOLOGICAL UNIVERSITY
BELGAUM

ENGINEERING SURVEY

(Subject Code: BCV302)

LECTURE NOTES

(MODULE-4)

III-SEMESTER

Ms. Deeksha Anand

Assistant Professor, Department of Civil Engineering

AJIET

A J INSTITUTE OF ENGINEERING & TECHNOLOGY

DEPARTMENT OF CIVIL ENGINEERING

(A unit of Laxmi Memorial Education Trust. (R))

NH - 66, KottaraChowki, Kodical Cross - 575 006

MODULE -4- PART 1

Syllabus: Curves –Types of Curves- Application of curves in civil engineering. Setting out of Horizontal curve by Theodolite (Rankine's method) and using Total Station. Components of Compound, Reverse curve. Transition Curve and Combined curve. Various types of vertical curves and its applications. (L1, L2, L3, L4)

Definition of Curves:

Curves are regular bends provided in the lines of communication like roads, railways etc. and also in canals to bring about the gradual change of direction. They are also used in the vertical plane at all changes of grade to avoid the abrupt change of grade at the apex.

Curves provided in the horizontal plane to have the gradual change in direction are known as Horizontal curves, whereas those provided in the vertical plane to obtain the gradual change in grade are known as vertical curves. Curves are laid out on the ground along the center line of the work. They may be circular or parabolic.

Classification of Curves:

(i) Simple,

(ii) Compound

(iii) Reverse and

(iv) Deviation

(i) Simple Curve:

A simple curve consists of a single arc of a circle connecting two straights. It has radius of the same magnitude throughout. In fig. 11.1 T1 D T2 is the simple curve with T1O as its radius.

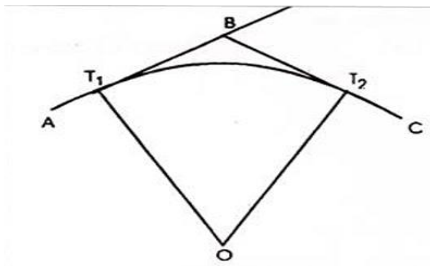
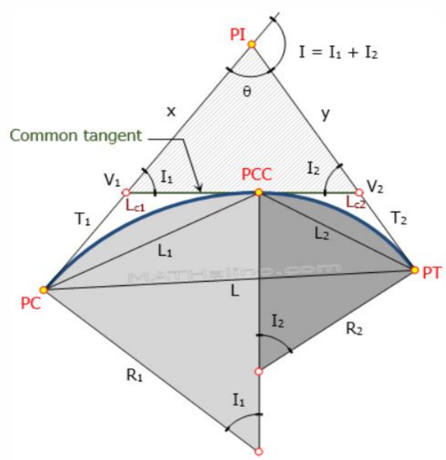


Fig 11.1

(ii) Compound Curve: A compound curve consists of two (or more) circular curves between two main tangents joined at point of compound curve (*PCC*). Curve at *PC* is designated as 1 (R_1, L_1, T_1, etc) and curve at *PT* is designated as 2 (R_2, L_2, T_2, etc).



Elements of compound curve

- *PC* = point of curvature
- *PT* = point of tangency
- *PI* = point of intersection
- *PCC* = point of compound curve
- T_1 = length of tangent of the first curve
- T_2 = length of tangent of the second curve
- V_1 = vertex of the first curve
- V_2 = vertex of the second curve

- I_1 = central angle of the first curve
- I_2 = central angle of the second curve
- I = angle of intersection = $I_1 + I_2$
- L_{c1} = length of first curve
- L_{c2} = length of second curve
- L_1 = length of first chord
- L_2 = length of second chord
- L = length of long chord from PC to PT
- $T_1 + T_2$ = length of common tangent measured from V_1 to V_2
- $\theta = 180° - I$
- x and y can be found from triangle V_1-V_2-PI.
- L can be found from triangle PC-PCC-PT

Finding the stationing of PT

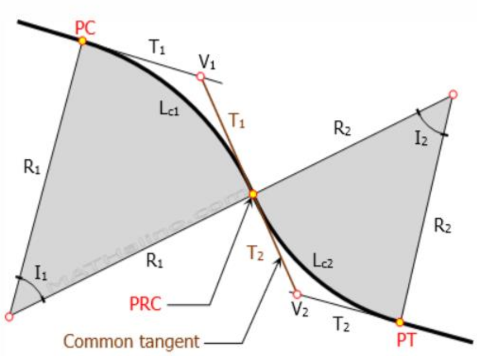
Given the stationing of PC

Sta PT=Sta PC+Lc1+Lc2

Given the stationing of PI

Sta PT=Sta PI−x−T1+Lc1+Lc2

(iii) Reverse (or Serpentine) Curve: A reverse or serpentine curve is made up of two arcs having equal or different radii bending in opposite directions with a common tangent at their junction. Their centres lie of opposite sides of the curve.



Reverse curves are used when the straights arc parallel or intersect at a very small angle. They are commonly used in railway sidings and sometimes on railway tracks and roads meant for low speeds. They should be avoided as far as possible on main railway lines and highways where speeds are necessarily high.

Elements of Reversed Curve

PC = point of curvature

PT = point of tangency

PRC = point of reversed curvature

T1 = length of tangent of the first curve

T2 = length of tangent of the second curve

V1 = vertex of the first curve

V2 = vertex of the second curve

I1 = central angle of the first curve

I2 = central angle of the second curve

Lc1 = length of first curve

Lc2 = length of second curve

L1 = length of first chord

L2 = length of second chord

T1 + T2 = length of common tangent measured from V1 to V2

Finding the stationing of PT

Given the stationing of PC

Sta PT=Sta PC+Lc1+Lc2

Given the stationing of V1

Sta PT=Sta V1−T1+Lc1+Lc2

(iv) Deviation Curve:

A deviation curve is simply a combination of two reverse curves. It is used when it becomes necessary to deviate from a given straight path in order to avoid intervening obstructions such as a bend of river, a building, etc. In fig. 11.4. T1 EDFT2 is the deviation curve with T1O, EO2 and FO2 as its radii.

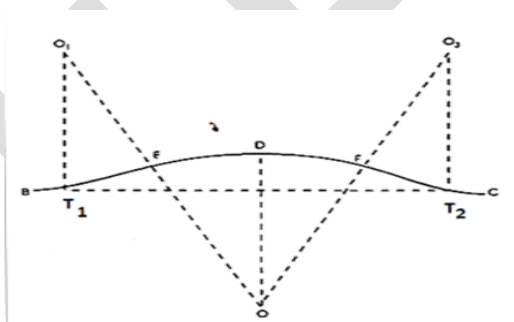


Fig 11.4

Names of Various Parts of a Curve:

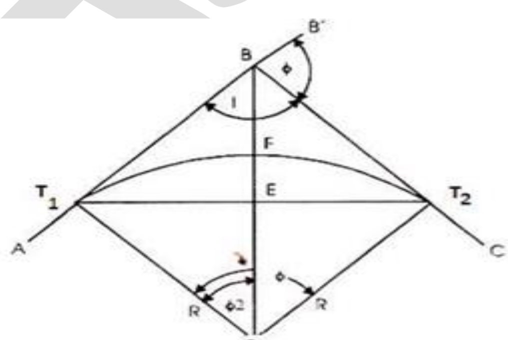


Fig 11.5

(Fig. 11.5):

(i) The two straight lines AB and BC, which are connected by the curve are called the tangents or straights to the curve.

(ii) The points of intersection of the two straights (B) is called the intersection point or the vertex.

(iii) When the curve deflects to the right side of the progress of survey as in fig. 11.5, it is termed as right-handed curve and when to the left, it is termed as left-handed curve.

(iv) The lines AB and BC are tangents to the curves. AB is called the first tangent or the rear tangent BC is called the second tangent or the forward tangent.

(v) The points (T1 and T2) at which the curve touches the tangents are called the tangent points. The beginning of the curve (T1) is called the tangent curve point and the end of the curve (T2) is called the curve tangent point.

(vi) The angle between the tangent lines AB and BC (ABC) is called the angle of intersection (I)

(vii) The angle by which the forward tangent deflects from the rear tangent is called the deflection angle (ϕ) of the curve.

(viii) The distance the two-tangent point of intersection to the tangent point is called the tangent length (BT1 and BT2).

(ix) The line joining the two tangent points (T1 and T2) is known as the long-chord

(x) The arc T1FT2 is called the length of the curve. (xi) The mid-point (F) of the arc (T1FT2) in called summit or apex of the curve.

(xii) The distance from the point of intersection to the apex of the curve BF is called the apex distance.

(xiii) The distance between the apex of the curve and the midpoint of the long chord (EF) is called the versed sine of the curve.

(xiv) The angle subtended at the center of the curve by the arc T1FT2 is known as the Central angle and is equal to the deflection angle (ϕ).

Applications of curves:

Curves are needed on Highways, railways, and canals for bringing about gradual change of direction of motion.

They are provided for following reasons: -

i) To bring about gradual change in direction of motion.

ii) To bring about gradual change in grade and for good visibility.

iii) To alert the driver so that he may not fall asleep.

iv) To layout Canal alignment.

v) To control erosion of canal banks by the thrust of flowing water in a canal.

Angular Methods for Setting out Curves

The following two methods are the methods of setting out simple circular curves by angular or instrumental methods:

1. By Rankine's Tangential Angles.

2. By Two Theodolites. Method

1. Rankine's Method of Tangential or Deflection Angles: (Fig. 11.14): In this method, the curve is set out by the tangential angles (also known as deflection angles) with a theodolite and a chain (or tape). The method is also called as chain and theodolite method. The deflection angles are calculated as follows:

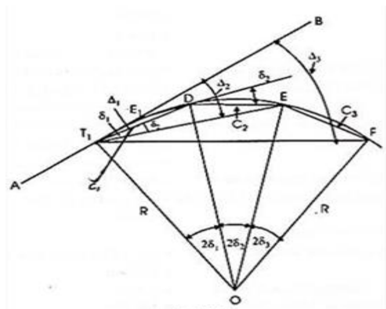


Fig. 11.14

Let T1 and T2 be the tangent points and AB the first tangent to the curve.

D, E, F, etc. =the successive points on the curve,

R = the radius of the curve.

C1, C2, C3 etc. = the lengths of the chords T1D, DE, EF etc., i.e., 1st, 2nd, 3rd chords etc.

: δ 1, δ 2, δ 3 etc. = the tangential angles which each of the chords T1 D1, DE, EF, etc., makes with the respective tangents T1, D, E. etc.

Δ1, Δ2, Δ 3 etc. = the total tangential or deflection angles which the chords T1D, DE, EF, etc. make with the first tangent AB.

Now the chord T_1D is approximately equal to arc $T_1D = C_1$

$$\angle BT_1D = \delta_1 = \frac{1}{2}\angle T_1OD = 2\delta_1 \quad \angle T_1OD = 2\delta_1$$

$$\frac{\text{arc}\, T_1D}{\text{Radius}\, OT_1} = \angle T_1OD \text{ in radians}$$

or $$\frac{C_1}{R} = 2\delta_1 \text{ radians}$$

or $$\delta_1 = \frac{C_1}{R} \text{ radians}$$

$$= \frac{C_1}{2R} \times \frac{180}{\pi} \text{ degrees}$$

$$= \frac{C_1}{2R} \times \frac{180}{\pi} \times 60 \text{ minutes} \quad \ldots \quad \ldots\text{(Eqn. 11.20)}$$

Similarly, $\delta_2 = 1718.9\,\frac{C_2}{R}$; $\delta_3 = 1718.9\,\frac{C_3}{R}$; and so on

$$\delta_n = 1718.9\,\frac{C_n}{R} \text{ minutes} \quad \ldots \quad \ldots\text{(Eqn. 11.21)}$$

Since each of the chord lengths C2, C3, C4………… Cn-1 is equal to the length of the full chord, δ2 = δ3 = δ4………….. δ n-1.

The total tangential angle (Δ_1) for the first chord (T_1D)

$$= \angle BT_1D = \delta_1$$

$$\therefore \quad \Delta_1 = \delta_1$$

The total tangential angle (Δ_2) for the second chord (DE) = $\angle BT_1E$

But $\angle BT_1E = \angle BT_1D + \angle DT_1E$

It is well known preposition of geometry that the angle between the tangent and a chord equals the angle which the chord subtends in the opposite segment. Now ∠DT1E is the angle subtended by the chord DE in the opposite segment, therefore, it is equal to the tangential angle (δ2) between the tangent D and the chard DE

$$\therefore \quad \Delta_2 = \delta_1 + \delta_2 = \Delta_1 + \delta_2$$

Similarly,

$$\Delta_3 = \delta_1 + \delta_2 + \delta_3 = \Delta_2 + \delta_3$$

$$\Delta_n + \delta_1 + \delta_2 + \delta_3 \ldots\ldots\ldots\ldots + \delta_n$$

$$= \Delta_{n-1} + \delta_n \quad \ldots \quad \ldots\text{(Eqn. 11.22)}$$

Check:

The total deflection angle BT1 T2 $= \Delta n = \frac{\phi}{2}$

where ϕ is the deflection angle of the curve.

If the degree of die curve (D) is known, the deflection angle for 30 m chord is equal 1/2D degrees, and that for the sub-chord of length C1,

$$= \frac{C_1}{30} \times \frac{D}{2} \text{ degrees}$$

$$\delta_1 = \frac{C_1 \times D}{60}\ ; \quad \delta_2 = \delta_3 \ldots\ldots\ldots \delta_{n-1} = \frac{D}{2}\ ;$$

$$\delta_n = \frac{C_n \times D}{60} \quad \ldots \quad \ldots \quad \ldots\text{(Eqn. 11.23)}$$

Procedure of Setting out the Curve:

(i) Locate the tangent points (T1 and T2) and find out their changes. From these changes, calculate the lengths of first and last sub-chords and the total deflection angles for all points on the curve as described above.

(ii) Set up and level the theodolite at the first tangent point (T1).

(iii) Set the Vernier A of the horizontal circle to zero and direct the telescope to the ranging rod at the intersection point B and bisect it.

(iv) Loosen the Vernier plate and set the Vernier A to the first deflection angle Δ1, the telescope is thus directed along T1D. Then along this line, measure T1D equal in length to the first sub-chord, thus fixing the first point D on the curve.

(v) Loosen the upper clamp and set the Vernier A to the second deflection angle Δ2, the line of sight is now directed along T1E. Hold the zero end of the chain at D and swing the other end until the arrow held at that end is bisected by the line of sight, thus fixing the second point (E) on the curve.

(vi) Continue the process until the end of the curve is reached. The end point thus located must coincide with the previously located point (T2). If not, the distance between them is the closing error. If it is within the permissible limit, only the last few pegs may be adjusted; otherwise the curve should be set out again.

Note: In the case of a left-handed curve, each of the values Δ1, Δ 2 Δ 3 etc, should be subtracted from 360° to obtain the required value to which the vernier is to be set i.e. the vernier should be set to (360° – Δ1), (360° – Δ2), (360° – Δ 2) etc. to obtain the 1st, 2n, 3rd etc, points on the curve. This method gives highly accurate results and is most commonly used for railway and other important curves.

Table of Deflection Angles

Point	Chainage in metres	Length of chord in metres	Deflection Angle (δ)	Total Angle (Δ)	Theodolite vernier Reading	Remarks
T_1	39 + 6.30	° ′ ″	° ′ ″	° ′ ″		
1	40 + 00	23.70	1 58 30	1 58 30	1 58 40	The curve is a
2	41 + 00	30	2 30 00	4 28 30	4 28 40	right-handed
3	42 + 00	30	2 30 00	6 58 30	6 58 40	one.
4	43 + 00	30	2 30 00	9 28 30	9 28 40	The least
5	44 + 00	30	2 30 00	11 58 30	11 58 40	count of the
6	45 + 00	30	2 30 00	14 28 30	14 28 40	instrument in
7	46 + 00	30	2 30 00	16 58 40	16 58 40	20 ″
T_2	46 + 12.30	12.30	1 01 30	18 00 00	18 00 00	

TRANSITION CURVE A curve of varying radius is known as 'transition curve'. The radius of such curve varies from infinity to certain fixed value. A transition curve is provided on both ends of the circular curve. The transition curve is also called as spiral or easement curve.

OBJECTS OF PROVIDING TRANSITION CURVES: -

1. To accomplish gradually the transition from the tangent to the circular curve, and from the circular curve to the tangent.

2. To obtain a gradual increase of curvature from zero at the tangent point to the specified quantity at the junction of the transition curve with the circular curve.

3. To provide the superelevation gradually from zero at the tangent point to the specified amount on the circular curve.

4. To avoid the overturning of the vehicle.

REQUIREMENT OF IDEAL TRANSITION CURVES: -

1. It should meet the original straight tangentially.

2. It should meet the circular curve tangentially.

3. Its radius at the junction with the circular curve should be the same as that of the circular curve.

4. The rate of increase of curvature along the transition curve should be same as that of in increase of superelevation.

5. The length should be such that the full superelevation is attained at the junction with the circular curve.

The types of transition curve which are in common use are

1. A Cubic parabola

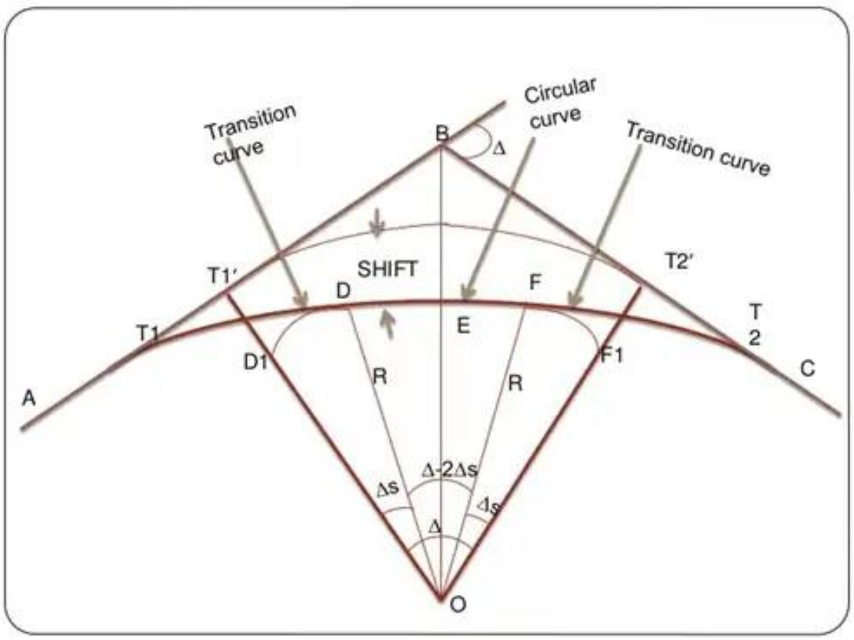
2. A clothoid or spiral

3. A lemniscate

The first being used on railways and third one on highways

COMBINED CURVE:- when the transition curves are inserted at each end of the main circular curve, the resulting curve is known as combined curve.

The combination of a simple circular curve and a transition curve, is known as a combined curve. Combined curves are mostly preferred in highways and railways. When transition curves are provided at both ends of a circular curve, the curve formed is known as a combined or a complete curve.



Vertical curves:

A vertical curve is a curve lying in a vertical plane which connects two different gradients. Such a curve is introduced in highway and railway work to round off the angle and to obtain a gradual change in grade. Abrupt changes in grade are thus avoided at the apex of the curve. The vertical curve can be of any shape i.e., circular or parabola but for simplicity of calculation work, the latter is preferred and used invariably. Grade: The gradient or grade may be defined as a proportional rise or fall between two points along a straight line.

It is expressed either as a percentage or ratio. 1. As a percentage (%): - Vertical rise or fall per 20 m chain horizontals e.g: 1%, 2%, 5%. Etc. 2. As a ratio: – one vertical rise or fall in horizontals e.g: 1 in 200, 1 in 500 etc.

REQUIREMENTS

1. It gives adequate visibility and safety to the traffic.
2. It gives gradual change in grade or slope.
3. It gives adequate comfort to the passengers

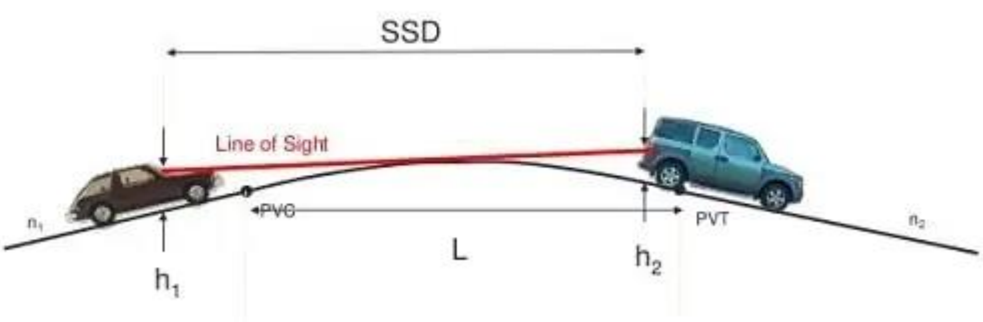
Vertical curves are usually provided when a highway or a railway crosses a ridge or a valley. Vertical curves are provided when there is a difference of level between two points. So to make the movement easy between these points, a vertical curve is provided. It makes the transition of the vehicle smooth and comfortable.

There are two main types of vertical curves.

- Summit curve, and
- Valley curve

a. Summit Curve

A vertical curve having its convexity in the upwards direction is known as a summit curve.



Summit curves are usually provided in the following cases:

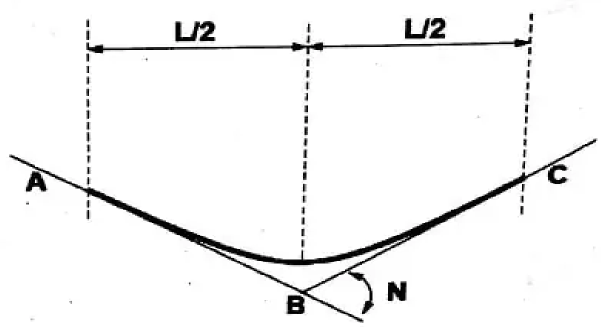
i) When an upgrade is followed by a downgrade,

ii) When a steeper upgrade is followed by a milder upgrade, and

iii) When a milder downgrade is followed by a steeper upgrade.

b. Sag Curve Or Valley Curve

A vertical curve having its convexity in the downwards direction or when it is concave upwards is known as a valley curve. It is also known as sag curve.



A sag curve or a valley curve is usually formed in the following cases:

i) When a downgrade is followed by an upgrade,

ii) When a steeper downgrade is followed by a milder upgrade, and

iii) When a milder upgrade is followed by a steeper upgrade.

The grades are further classified into two categories.

a) Up-grades or positive grades.

b) Down grades or negative grades.

A grade is classified as upgrade if elevations along it increase whereas it is classified as downgrade if the elevations decrease. It is important to note that these classifications depend upon the direction of the movement of the vehicles. An up grade becomes a down grade if the direction of motion of the vehicle is reversed.

The gradient of a highway or railway is expressed in two ways.

(i) As a percentage, e.g.: 3% and

(ii) as 1 in n where n is the horizontal distance in meters corresponding to 1 m rise or fall. E.g: 1 in 50.

An ascending or up grade rising to the right denoted by a plus (+) sign and a descending or down grade falling to the right by a minus (-) sign. The permissible rate of change in gradient for first class railways is recommended as 0.06% per 20 m station at summits and 0.05% per 20 m station for sags. For second class railways permissible rate of change of gradient is 0.12% per 20 m station at summits and 0.1% per 20 m station for sags.

For small gradient angles there is no difference between a parabola and a circular arc. Suppose the gradient at the beginning of a summit curve is 1.25% and if the rate of change of gradient is 0.05% per 20 m station, the gradients at the various stations will be as follows:

Station	Distance from the beginning of the vertical curve (m)	Gradients
0	0	1.25%
1	20	1.20%
2	40	1.15%
3	60	1.10%
4	80	1.05%
5	100	1%

Change in gradient between two gradients:

When two gradients are like gradients

Change in gradient = Numerical difference between the gradients.

When two gradients are unlike gradients

Change in gradient = Numerical sum of the gradients.

Numericals on Rankeins Method

1. **Two tangents intersect at a chainage 1000m. The deflection angle being 28°. Calculate the necessary data to set out the simple curve of radius 250m. by Rankeins deflection angle method and tabulate the results. Take peg interval 20m and least count of theodolite 20sec.**

Solution

Given Data

PI = 1000m,

Δ = 28°,
R=250m,
Peg interval = 20m,
Least count = 20''
Tangent length, T = R tan $\frac{\Delta}{2}$ = 250 tan(28/2) = 62.33mm

Length of curve l = $\frac{\prod R\Delta}{180} = \frac{\prod * 250 * 28°}{180}$ = 122.17m

Chainage of T_1 (P.C) = PI – T = 1000 – 62.33 = 937.67m

Chainage of T_2 (P.T) = PC + l = 937.67 + 122.17 = 1059.84m

Approximate length of chord = 100

Number chords = 100/20 =5

Length of sub-chord = 122.17-100 = 22.17

Length of the first cord C_1 = 10m

Length of Last chord = 22.17-10 = 12.17m

No of Chords = C_1 + C+ C_n = 1 + 5 + 1 = 7

Rankeins Method

$\delta_1 = 1718.9 \frac{C_1}{R} = 1718.9 \frac{10}{250} = 1°8'15.36''$

$\delta_2 = 1718.9 \frac{C_2}{R} = 1718.9 \frac{20}{250} = 2°17'30.72''$

δ_3 to $\delta_6 = 2°17'30.72''$

$\delta_7 = 1718.9 \frac{C_1}{R} = 1718.9 \frac{12.17}{250} = 1°23'40.56''$

Chainage	Deflection angle			Theodolite angle		
$\Delta_1 = \delta_1$	1°	8'	45.36''	1°	9'	0''
$\Delta_2 = \Delta_1 + \delta_2$	3°	26'	16.08''	3°	26'	20''
$\Delta_3 = \Delta_2 + \delta_3$	5°	43'	46.8''	5°	44'	0''
$\Delta_4 = \Delta_3 + \delta_4$	8°	1'	17.52''	8°	1'	20''
$\Delta_5 = \Delta_4 + \delta_5$	10°	18'	48.24''	10°	19'	0''
$\Delta_6 = \Delta_5 + \delta_6$	12°	36'	18.96''	12°	36'	20''
$\Delta_7 = \Delta_6 + \delta_7$	13°	59'	59.52''	14°	0'	0''

Check $= \frac{\text{Total deflection angle}}{2} =$ theodolite angle

$\Delta_7 = 28°/2 = 14° 0' 0'' = 14° 0' 0''$

Review questions:

1. What are the different methods of setting out a simple circular curve?
2. Two tangents interest at a chainage 1000mt, the deflection angle being 28°. Calculate the necessary data to set out a simple circular curve of radius 250 mts. by Rankine's deflection angle method and tabulate the results. Peg interval= 20mt. Least count of theodolite = 20".
3. Explain the method of setting out simple curve by Rankine’s method
4. Explain the Elements of curve with neat sketch
5. Explain the elements of Transition and combined curve with a neat sketch.
6. Define vertical curve and explain the types of vertical curve with a neat diagram.
7. Two straights intersect at a chainage of 1764m and at a deflection angle of 320. They are to smoothly joined by a 50 curve. Taking the peg interval at 30m work out the data required to set out the curve by the deflection angle method. Least count of the theodolite is 20’. Take length of chain = 30m.

MODULE -4- PART 2

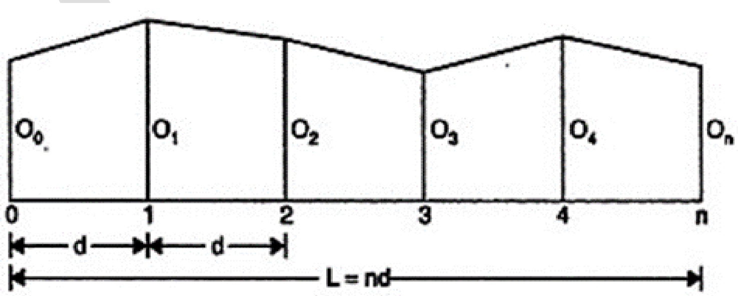
Syllabus: Areas and Volumes- Methods of determining areas by trapezoidal and Simpsons' rule. Measurement of volume by prismoidal and trapezoidal formula. Earthwork volume calculations from spot levels and from contour maps; Earthwork calculation in Embankments.

The main objective of the surveying is to compute the areas and volumes. Generally, the lands will be of irregular shaped polygons. There are formulae readily available for regular polygons like, triangle, rectangle, square and other polygons. But for determining the areas of irregular polygons, different methods are used. Earthwork computation is involved in the excavation of channels, digging of trenches for laying underground pipelines, formation of bunds, earthen embankments, digging farm ponds, land levelling and smoothening. In most of the computation the cross-sectional areas at different interval along the length of the channels and embankments are first calculated and the volume of the prismoids is obtained between successive cross section either by trapezoidal or prismoidal formula.

Methods of determining areas by trapezoidal and Simpsons' rule.

Trapezoidal rule

This rule is based on the as-assumption that the figures are trapezoids. The rule is more accurate than the previous two rules which are approximate versions of the trapezoidal rule. Referring to Fig. the area of the first trapezoid is given by,



$$\Delta_1 = \frac{O_0 + O_1}{2} d$$

$$The\ area\ of\ second\ traezoid\ \Delta_2 = \frac{O_1 + O_2}{2} d$$

Area of the last trapezoid is given by

$$\Delta_n = \frac{O_{n-1} + O_n}{2} a$$

Hence the total area of the figure is given by

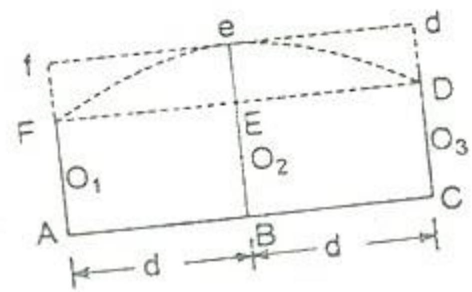
$$\Delta = \Delta_1 + \Delta_2 + \cdots \dots \dots . \Delta_n = \frac{O_0 + O_n}{2} + O_1 + O_2 + \cdots \dots \dots + O_{n-1}) d$$

$$AREA = \frac{\text{common distance ((1}^{st}\text{ ordinate +last ordinate) +2(sum of other ordinates)}}{2}$$

The equation may be expressed as below, Add the average of the end offsets to the sum of the intermediate offset. Multiply the total sum thus obtained by the common distance between the ordinates to get the required area.

Simpson's rule

This rule assumes that the short lengths of boundary between the ordinates are parabolic arcs. This method is more useful when the boundary line departs considerably from the straight line. Thus, in Fig, the area between the line AC and the curve FeD may be considered to be equal to the area of the trapezoid AFDC plus the area of the segment between the parabolic arc FeDEF and the corresponding chord FD.



Let

O1, O2, O3= three consecutive ordinates

d= common distance between the ordinates

area AFeDC= area of trapezium AFDC+ area of segment FeDEF Here

$$\text{Area of trapezium} = \frac{O_1+O_3}{2} * 2d$$

Area of segment= 2/3 x area of parallelogram FfdD

= 2/3 x eE x 2d

= $2/3 \times \{ O_2 - O_1+O_3 /2 \} \times 2d$

So, the area between the first two divisions,

$$\Delta_1 = \frac{O_1+O_3}{2} * 2d + 2/3 * \{ O_2 - O_1+O_3 /2 \} * 2d$$

= $d/3(O_1+4O_2+O_3)$

Similarly, the area of next two divisions

$\Delta_2 = d/3(O_1+4O_2+O_3)$ and so on

Total area = $d/3[O_1+O_n+4(O_2+O_{4+\ldots\ldots}+O_{n-1}) + 2(O_3+O_{5+\ldots\ldots\ldots\ldots\ldots\ldots+\ldots\ldots}+O_{n-2})]$

$$= \frac{\text{Common distance}}{3} \{\text{1st ordinate} + \text{last ordinate}) + 4(\text{sum of even ordinates}) + 2(\text{sum of remaining odd ordinate})\}$$

It is clear that the rule is applicable only when the number of divisions of the area is even i.e., the total number of ordinates is odd

Simpson's one third rule may be stated as follows : The area is equal to the sum of the two end ordinates plus four times the sum of the even intermediate ordinates + twice the sum of the odd. intermediate ordinates, the whole multiplied by one-third the common interval between them.

Comparison of rules

Sl. No.	Trapezoidal Rule	Simpson's rule
1	The boundary between the ordinates is considered	The boundary between the
	to be straight	ordinates is considered to be an arc of parabola
2	There is no limitation. It can be applied for any number of ordinates	To apply this rule, the number of ordinates must be odd
3	It gives approximate result	It give more accurate result

Volume Formulae

The volume of earthwork may be calculated either by the trapezoidal formula (Average End area method) or the prismoidal formula. The prismoidal formula usually yields a volume less than that obtained by the trapezoidal formula. The difference between the volume obtained by the two formulae is known as prismoidal correction. In rock excavations and concrete work the prismoidal formula is normally unjustified. This is because of the low precision of the field data. In such cases, it is preferable to compute volume by the trapezoidal formula method to which when a prismoidal correction is added, gives the prismoidal volume.

The trapezoidal formula is not exact when the end areas of the prismoids are unequal. The greater the difference in the end areas, the greater will be the error in the volume computed by the end area formula. The maximum value of this error can be 16.66% when one of the end areas is zero, e.g., when a cut changes to a fill on a side hill. The error in volume computation by the trapezoidal formula is usually less than even 2%. Though approximate, its precision is usually consistent with the field method used in determining the end areas, and since it involves less computations, it is preferred over the prismoidal formula.

Use of the prismoidal formula is justified only when there is a large difference between the end areas of a prismoid, when the cross sections are spaced at short intervals, and when the surface irregularities have been measured in the field. Usually, the trapezoidal formula is used for preliminary estimates, whereas prismoidal formula is used for final estimates.

Prismoid:

It is a solid that has parallel plane bases or ends and is bounded on the sides either by planes or warped surfaces. It may be composed of any combination of prisms, pyramids, wedges, cylinders, cones, or frustums whose bases and apices lie in the bases of the prismoid. Since cylinders and cones are special forms of prisms and pyramids, it may be said that prismoids may be resolved into prisms, pyramids and wedges, and any formula for volume applicable to all the three, will also be applicable to a combination of these.

Trapezoidal Formula (Average end area method)

This is also known as trapezoidal formula. The volume is assumed to be equal to the average of the areas of the two ends multiplied by the distance between them.

Volume between first two sections = $V_1 = \frac{A_1 + A_2}{2} L$

Volume between next two sections $V_2 = \frac{A_2 + A_3}{2} L$

Total volume $V = V_1 + V_2 + V_3 + \ldots\ldots\ldots\ldots\ldots + V_n$

Or $V = [\frac{A_1 + A_n}{2} + A_2 + A_3 + \cdots \ldots\ldots + A_{n-1}]$

Where $A_1, A_2, \ldots\ldots A_n$ are the consecutive area and L is the distance between them

Prismoidal formula

This is also known as Simpson's rule for volumes. The meanings of the various symbols used in this formula and its derivation, as given here, are listed below.

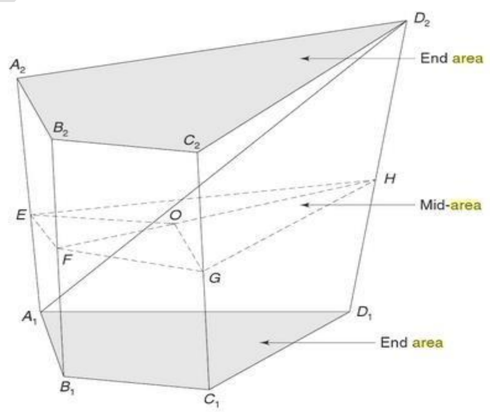
L = length of prismoid (the distance between two end areas)

A_1, A_2 = the two end areas $A_1B_1C_1D_1A_1$ and $A_2B_2C_2D_2A_2$ as shown in Fig.

A_n = mid-area EFGHE (the area of the cross section midway between the end

areas) h = perpendicular distance of EF from O

Select a point O in the plane of the mid cross section and join it to the vertices of the end cross sections. The prismoid is thus divided into several pyramids with O as the apex and the bases as side and end faces of the prismoid



Volume of pyramid $OA_1B_1C_1D_1 = \frac{1}{3}\left(\frac{L}{2}\right)A_1 = \frac{A_1L}{6}$

Volume of pyramid $OA_2B_2C_2D_2 = \frac{1}{3}\left(\frac{L}{2}\right)A_2 = \frac{A_2L}{6}$

Volume of pyramid $OA_1B_1A_2B_2 = \frac{1}{3}\, h\,(L\ X\ EF)$

$$= \frac{1}{3}\, L\,(h\ X\ EF)$$

$$= \frac{1}{3}\, L\,(2\ X\ area\ EFO)$$

$$= \frac{2}{3}\, L\,(\,area\ EFO)$$

Volume of pyramid $OC_1D_1C_2D_2 = \frac{2}{3}\, L\,(\,area\ GHO)$

Volume of pyramid $OA_1D_1A_2D_2 = \frac{2}{3}\, L\,(\,area\ EHO)$

Volume of pyramid $OB_1C_1B_2C_2 = \frac{2}{3}\, L\,(\,area\ FGO)$

Total volume $= \frac{1}{6} A_1 L + \frac{1}{6} A_2 L + \frac{2}{3} L\,(rea\ EFO) + \frac{2}{3} L\,(\,area\ GHO) + \frac{2}{3} L\,(\,area\ EHO) + \frac{2}{3} L\,(\,area\ FGO)$

$$= \frac{1}{6} A_1 L + \frac{1}{6} A_2 L + \frac{2}{3} L\,(area\ of\ EFGH)$$

$$= \frac{1}{6} A_1 L + \frac{1}{6} A_2 L + \frac{2}{3} L A_n$$

$$= \frac{L}{6}\,(A_1 + A_2 + 4A_n)$$

Let $A_1, A_2, \ldots, A_n$ be the areas of various cross sections spaced at a uniform interval L.

Volume between first three sections constituting the first prismoid,

$V_1 = \frac{L}{6}(A_1 + 4A_2 + A_3)$

$= \frac{L}{3}(A_1 + 4A_2 + A_3)$

Volume of next prismoid $= \frac{L}{3}(A_3 + 4A_4 + A_5)$ and so on

Total volume V$= \frac{L}{3}(A_1 + 4A_2 + A_3 + (A_3 + 4A_4 + A_5 + A_5 + \ldots + A_{n-2} + A_{n-2} + 4A_{n-1} + A_n)$

$= \frac{L}{3}(A_1 + 4A_2 + 2A_3 + 4A_4 + 2A_5 + \ldots + 2A_{n-2} + 4A_{n-1} + A_n)$

$= \frac{L}{3}[(A_1 + A_n) + 4(A_2 + A_4 + \ldots + A_{n-1}) + 2(A_3 + A_5 + \ldots + A_{n-2})]$

It is necessary to have an odd number of cross sections to use this formula. In case of even number of cross sections, the end strip is treated separately and the volume of the remaining strips is calculated by the prismoidal formula. The volume of the last strip is calculated either by the trapezoidal or prismoidal rule. In case if the latter is to be applied, the area half way between the sections is interpolated by averaging the dimensions of the end sections and not by averaging the end areas.

PRISMOIDAL CORRECTION (Cp)

As defined before, it is the difference between the volume computed by the end area formula and the prismoidal formula. If the area is calculated by the end area formula, the prismoidal correction is subtracted to obtain the exact volume. The value of the correction for various cases is as follows,

Level section, $Cp = \frac{Ls}{6}(h - h')^2$

Two-level section, $Cp = \frac{Ls}{6}(d - d')(d_1 - d_1')$

Side two level section $= Cp = \frac{L}{12s}(d - d')\left[\left(\frac{b}{2} + nh\right) - \left(\frac{b}{2} + n'h'\right)\right]$ for cut

$Cp = \frac{L}{12s}(d_1 - d_1')\left[\left(\frac{b}{2} - nh\right) - \left(\frac{b}{2} - n'h'\right)\right]$ for fill

Three level section $Cp = \frac{L}{12}(h - h')[(d + d_1) - (d' + d_1')]$

where d, d_1, h and n refer to the cross section at one end and d', d_1', h' and n' refer to the same at the other end.

VOLUME USING SPOT HEIGHT METHOD

This method is generally used for calculating the volumes of excavations for basements or tanks, i.e. any volume where the sides and base are planes, whilst the surface is broken naturally (Figure 11.22(a)). Figure 11.22(b) shows the limits of the excavation with surface levels in metres at A, B, C and D. The sides are vertical to a formation level of 20 m. If the area ABCD was a plane, then the volume of excavation would be:

V = plan area ABCD × mean height

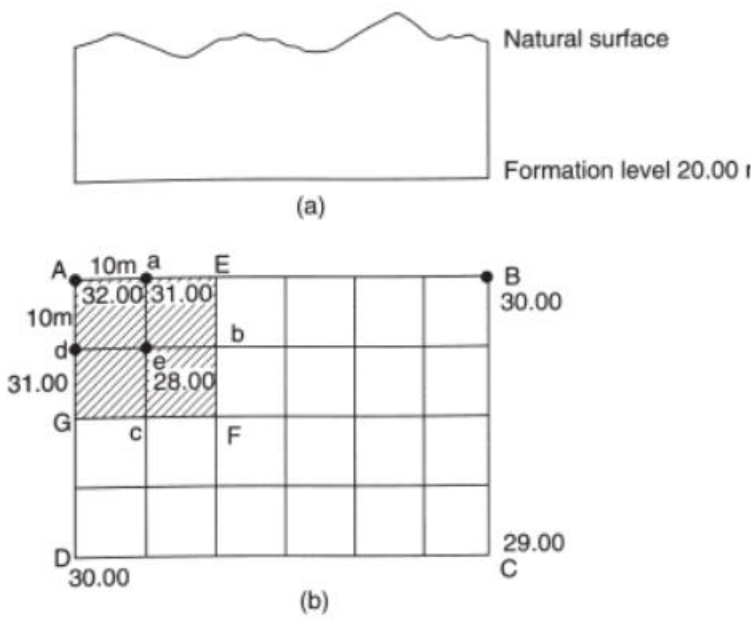


Fig. 11.22 *(a) Section, and (b) plan*

However, as the illustration shows, the surface is very broken and so must be covered with a grid such that the area within each 10-m grid square is approximately a plane. It is therefore the ruggedness of the ground that controls the grid size. If, for instance, the surface Aaed was not a plane, it could be split into two triangles by a diagonal (Ae) if this would produce better surface planes. Considering square Aaed only:

V = plan area × mean height

$$V = 100 * \frac{1}{4}(12 + 11 + 8 + 11) = 1050\, m^3$$

If the grid squares are all equal in area, then the data is easily tabulated and worked as follows: Considering AEFG only, instead of taking each grid square separately, one can treat it as a whole

$$V = \frac{100}{4}(h_A + h_E + h_F + h_G) + 2(h_a + h_b + h_c + h_d) + 4h_e$$

Computation of Volume from Contours

Figure 18.15 shows a dam with full water level of 100 m and contours on upstream side. Capacity of reservoir to be found is nothing but volume of fill with water level at 100 m. The whole area lying within a contour line is found by planimeter. It may be noted that area to be measured is not between two consecutive contour lines.

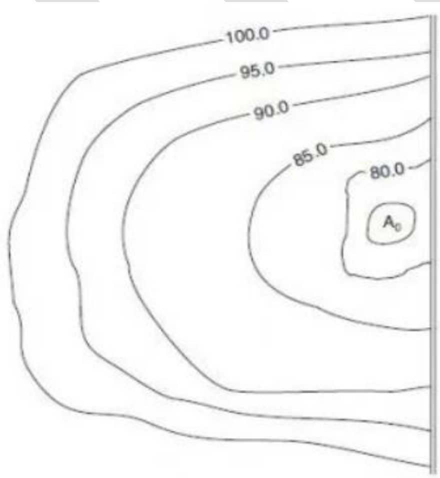


Fig. 18.15

Let $A_0, A_1, A_2, \ldots, A_n$ be area of contours and h be contour interval. Then from trapezoidal rule:

$$V = h\left[\frac{A_0 + A_n}{2} + A_1 + A_2 + \cdots + A_{n-1}\right]$$

and by prismoidal rule:

$$V = \frac{h}{3}\left[(A_0 + A_n) + 4(A_1 + A_3 + \cdots + A_{n-1}) + 2(A_2 + A_4 + \cdots + A_{n-2})\right]$$

where there are n segments and n is even number.

Numerical Problem

1. A railway embankment is 12 m wide. The ground is level in a direction transverse to the centre line. Calculate the volume contained in a 100 m length by trapezoidal rule and prismoidal rule, if the side slope is 1.5:1. The center heights at 20 m interval are 3.7 m, 2.6 m, 4.0 m, 3.4 m, 2.8 m, 3.0 m, 2.2 m.

   Solution:

   For a level section A= b+sh) h Slope = 1.5:1, hence s= 1.5, b=12 m

   Let the area ar different sections be A1,A2, …. A1= (12 + 1.5 x 3.7) x 3.7 = 64.935 m2

   A2= (12 + 1.5 x 2.6) x 2.6 = 41.34 m2

   A3= (12 + 1.5 x 4) x 4 = 72.00 m2

   A4= (12 + 1.5 x 3.4) x 3.4 = 58.14 m2

   A5= (12 + 1.5 x 2.8) x 2.8 = 45.36 m2

   A6= (12 + 1.5 x 3.0) x 3.0 = 49.50 m2

   A7= (12 + 1.5 x 2.2) x 2.2 = 33.66 m2

Trapezoidal Rule

$$V = \left[\frac{A_1+A_n}{2} + A_2 + A_3 + \cdots \ldots \ldots + A_{n-1}\right]$$

$$= 20 \times \left[\frac{64.935+33.66}{2} + 41.34 + 72.00 + 58.14 + 45.36 + 49.5\right]$$

$$= 6312.75 \text{ m}^2$$

Prismoidal Rule

$$V = \frac{L}{3}\left[(A_1 + A_7) + 4(A_2 + A_4 + \ldots + A_6) + 2(A_3 + A_5)\right]$$

$$= \frac{20}{3}\left[(64.935 + 33.66) + 4(41.34 + 58.14 + 49.5) + 2(72 + 45.36)\right] = 6194.9 \text{m}^2$$

2. A series of offsets were taken from a chain line to a curved hour, line at intervals of 15 metres the following order.

0, 2 .65, 3.80, 3.75, 4.65, 3.60, 4.95, 5.85 m .

Compute the area between the chain line, the curved boundary and the end offsets by:

(a) trapezoidal rule, and (b) Simpson 's rule.

By trapezoidal rule

$$\Delta = \left(\frac{O_0 + O_n}{2} + O_1 + O_2 + \cdots \ldots \ldots + O_{n-1}\right) d$$

Here d= 15 m $\frac{O_1 + O_n}{2} = \frac{0 + 5.85}{2} = 2.925\ m$

$$O_1 + O_2 + \cdots \ldots \ldots + O_{n-1} = 2.65 + 3.80 + 3.75 + 4.65 + 3.60 + 4.95 = 23.40$$

$$\Delta = (2.925 + 23.40)\ 15 = 394.87\ sq.m = 3.9487\ acres$$

By Simpson's rule

Total area = $d/3[O_1+O_n+4(O_2+O_4+\ldots\ldots+O_{n-1}) + 2(O_3+O_5+\ldots\ldots+\ldots\ldots+O_{n-2})]$

d/3 = 15/3 = 5m

O_1+O_n = 0 + 4.95 = 4.95 4

$4(O_2+O_4+\ldots\ldots+O_{n-1})$ = 4 (2.65 + 3.75 + 3.60) = 40

$2(O_3+O_5+\ldots.+O_{n-2})$ = 2 (3.80 + 4.65) = 16.90

$$\Delta' = 5\ (4.95 + 40 + 16.90) = 309.25\ sq.m.$$

Area of the last trapezoid is (4.95 +5.85) x (15/2) = 81 $sq.m.$

Total area = = 309.25 + 81.0 = 390.25 sq. m = 3.9025 acres

IMPORTANT QUESTIONS:

1. What is a prismoid? Derive the prismoidal formula.
2. A series of offsets were taken from a chain line to a curved boundary line at intervals of 15m in the following order

   0, 2.65, 3.80, 3.75, 4.65, 3.60,4.95, 5.85m

   Compute the area the chain line curved boundary and the end offset by Trapezoidal and Simpson Rule
3. A railway embankment is 10 m wide with side slopes of 1:1.5 (V: H). Assuming the ground transverse to the centerline, calculate the volume contained in a length of 120 m, the heights at 20m intervals being and 2.5 in 'm' 2.2, 3.7, 3.8, 4.0, 3.8, 2.8 and 2.5. Compute the volume by Trapezoidal and prismoidal rule.
4. What is Simpson rule. Derive and expression for Simpson rule

MODULE -4- PART 3

Syllabus: Construction Surveying - Setting out works using Total Station, Setting out buildings by Centre line method.

SETTING OUT CENTRE LINE OF A SMALL RESIDENTIAL BUILDING

AIM: To set out Central line for a Small Residential Building

EQUIPMENTS REQUIRED: Tape, Rope, Lime, Arrows

PROCEDURE:

Setting out the central line of a small residential building involves marking the precise position of the building's central axis or reference line on the ground. This central line serves as a guide for the construction of the building, ensuring accuracy and proper alignment of walls, columns, and other structural elements.

Here are the general steps to set out the central line:

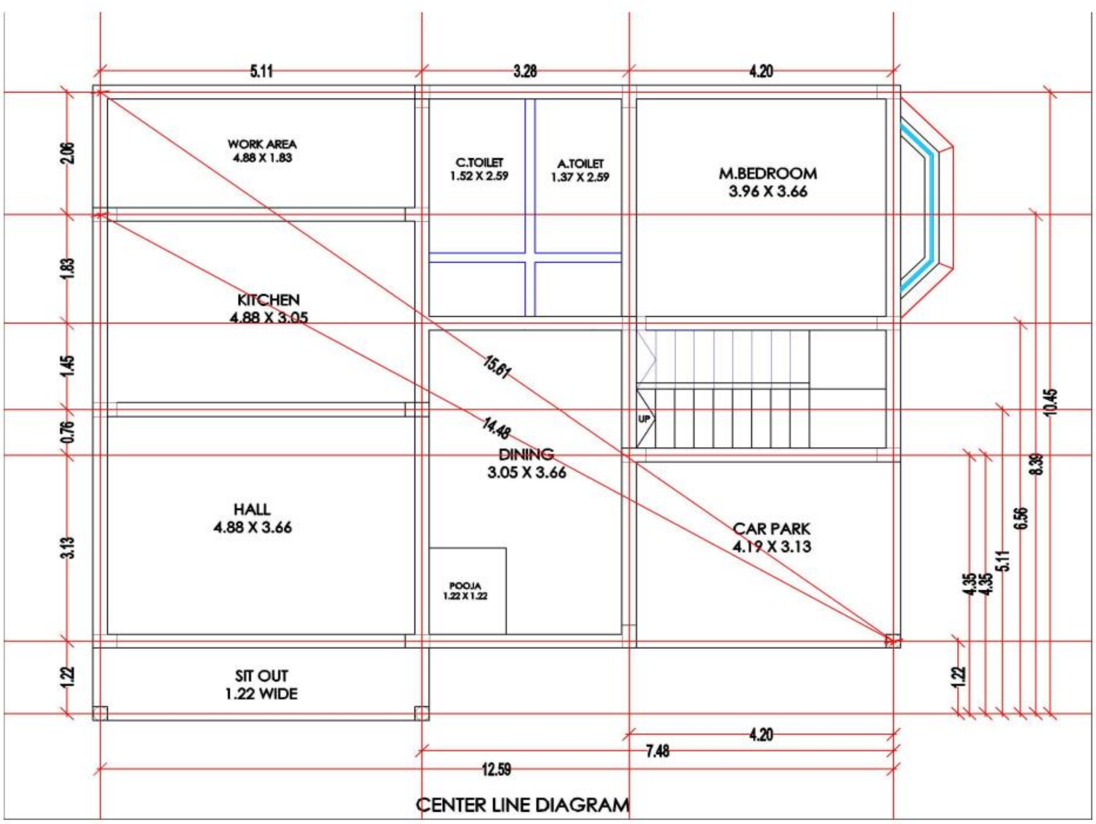
1. **Blueprint Study**: Begin by thoroughly studying the architectural plans or blueprints of the building to understand the dimensions, layout, and measurements. Identify the central axis or reference line indicated on the plans.
2. **Site Preparation**: Prepare the building site by clearing any debris, ensuring a flat surface, and marking the boundaries where the building will be constructed.
3. **Establish Baseline**: Use a measuring tape or laser distance meter to establish a baseline from a fixed reference point or a known boundary of the property. Measure and mark the starting point accurately.
4. **Measure and Mark Central Line**: Using the blueprint dimensions and the central axis reference provided, measure and mark the central line perpendicular to the established baseline. This can be done

by taking accurate measurements from the baseline and marking the points for the central line at regular intervals.

5. **Verify Accuracy**: Double-check the measurements and alignment of the central line by measuring diagonals from opposite corners. The measurements should be equal if the central line is accurate and perpendicular to the baseline.
6. **Marking Out:** Use stakes, pegs, or marking paint to clearly indicate the central line on the ground. Stretching a string or using a chalk line can help maintain a straight line between the marked points.
7. **Cross-Check**: Revisit the marked central line and confirm its accuracy before proceeding with further construction. Adjustments can be made at this stage if needed.

Remember, precision is key in setting out the central line as it forms the basis for the entire building's layout. It's advisable to use professional surveying equipment or seek assistance from a qualified surveyor if necessary, especially for larger or more complex projects.

Plan of the building



Observation and Calculation:

DIMENSIONS OF EACH COMPONENT OF A BUILDING

Area calculation:

1. Work area = 4.88*1.83=8.9304m^2
2. C. Toilet = 1.52*2.59 = 3.9368m^2
3. A Toilet = 1.37*2.59 = 3.5483m^2
4. M. Bedroom = 3.96*3.66 = 14.4936m^2
5. Kitchen = 4.88*3.05 = 14.88m^2
6. Hall = 4.88*3.66 = 17.860m^2
7. Dining = 3.05*3.66= 11.163m^2
8. Pooja = 1.22*1.22 = 1.488m^2
9. Carpark = 4.19*3.13= 13.114m^2

Result: Total horizontal distance = 12.59m

Total vertical distance:10.45m

Sloping distance=S_1=15.61M

S_2=14.48M

Review question:

1. Explain setting out of residential building by center line method