UNIT 5

Theodolite Surveying

Learning Objectives

After studying this unit, the student will be able to

- Identify the component parts of Theodolite
- Temporary adjustments of Theodolite
- Measuring horizontal angle between two lines by repetition and reitration methods.
- Measuring vertical angle by Theodolite and determination of height
- Determination of distances of remote objects.

5.0 Introduction

The theodolite is one of the most versatile and accurate surveying instrument used for the measurement of horizontal and vertical angles.

Theodolites are primarly classified as (i) Transit (ii) Non – transit

A theodolite is called a transit theodilote, when its telescope can be revolved through a complete revolution about its horizontal axis in a vertical plane, where as in non – transit type, the telescope can not be transited.

Theodolites are also calssified as (i) Vernier theodolites and (ii) Micrometer theodolites, according as verniers or micrometers are fitted to read the graduated circles. Theodolites are made of various sizes varying from 8cm to 25cm the diameter of the graducated circle on the lower plate defining the size. 8cm to 12 cm instruments are used for general survey and engineering work, while 14 cm to 25 cm instruments are used for triangulation work. There are three main types.

i) The Transit

ii) The plain or Y

iii) The Everest

5.1 Principle of Theodolite Survey

Theodolite surveying in which we measure horizontal and vertical angles. In This survey, Theodolite,a most accurate instrument is used .Theodolite consists a telescope by means of which distant objects can be sighted. The telescope has two distinct motions one in the horizontal plane and the other in the vertical plane. It can also be used for locating points on a line, prolonging survey lines, establishing grades, determining differences in elevations etc.

5.1.1 Component Parts and Description of a Transit Theodilite

A. Transit Theodolite consists of the following parts (shown in Fig 5.1)

1. Levelling Head : This supports the main working parts of the instrument and screws on to a tripod. It comprises of two parts.

(i) Tribrach and trivet stage fitted with leveling screws and (ii) Centre shifting arrangement for centering the instrument quickly and accurately.

2. Lower circular plate: This carries the circular scale graduated from 0^0 to 360^0 in degrees and half degrees or degrees and third of a degree in clockwise direction and a tapered spindle which works in the outer axis. The lower plate can be fixed in any position by operating the lower clamp. Adjustment can be done with the help of the lower tangent screw.

3. Upper Plate: Upper plate which is also known as the Vernier plate carries the upper circular horizontal plate. The upper plate can be rotated relative to the lower plate about the spindle as axis. It carries two verniers marked A and B, which are used for taking readings accurately up to 2' on the lower graduated circle. This plate also carries a level tube and two vertical standards for supporting telescope, vertical circle and detachable compass.

4. Telescope: The telescope of theodolite may be (i) external focusing, and (ii) internal focusing. The first type is used in older type of theodolites, while the later is used in modern instruments. It is mounted near its center on a horizontal axis at right angles to the main longitudinal axis of the telescope.

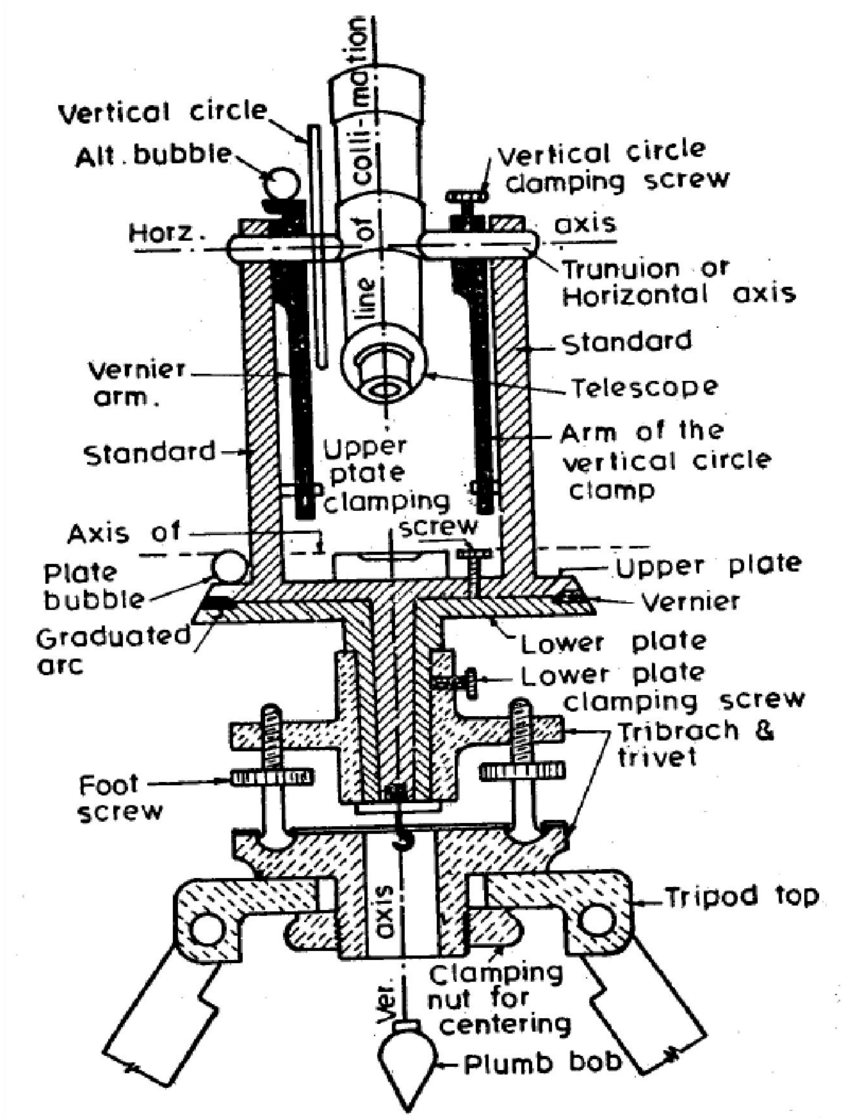

Fig. 5.1

5. Vertical Circle: The vertical circle is rigidly fixed to the horizontal axis of the telescope and moves with it. It is usually divided into four quadrants. The graduations in each quadrant are numbered from 0^0 to 90^0 in opposite directions from the two zeros placed at the ends of the horizontal diameter of the vertical circle so that the line joining the zeros is parallel to the line of collimation of the telescope when it is horizontal. The sub- divisions on the vertical circle are similar to those of horizontal circle. A clamp and fine motion tangent screws are provided to the vertical circle.

6. T-frame or Index Bar: It is T - Shaped and is centered on the horizontal axis of the telescope in front of the vertical circle. The two verniers C and D are provided on it at the ends of the horizontal arms called the index arm. A vertical leg, known as clipping arm is provided with a fork and two clipping screws at its lower extremity. The index and clipping arms together are known as T - frame. At the top of this frame a bubble tube is attached which is called the altitude bubble tube.

7. Plumb - Bob: A plumb - bob is suspended from the hook fitted to the bottom of the vertical axis for centering the instrument exactly over a station point.

8. Tripod Stand: The theodolite is supported on a tripod when in use.

5.1.3 Technical Terms

1. Centering: It means setting the thedolite exactly over an instrument station so that its vertical axis immediately above the station mark. It can be done by means of plumb - bob suspended from a small hook attached to the vertical axis of the theodolite.

2. Transiting : It is also known as plunging or reversing. It is the process of turning the telescope about its horizontal axis through 180^0 in the vertical plane thus bringing it upside down and making it point exactly in opposite direction.

3. Swinging the Telescope : It means turning the telescope about its vertical axis in the horizontal plane. A swing is called right or left according as the telescope is rotated clockwise or counter clockwise.

4. Face Left : If the vertical circle of the instrument is on the left of the observer while taking a reading, the position is called the face left and the observation taken on the horizontal or the vertical circle in this position is known as the face left observation.

5. Face Right: If the vertical circle of the instrument is on the right of the observer while taking a reading, the position is called the face right and the observation taken on the vertical circle in this position is known as the face right observation.

6. Changing Face : It is the operation of bringing the vertical circle to the right of the observer, if originally it is to the left, and vice versa. It is done in two steps. Firstly revolve the telescope through 180^0 in a vertical plane and then rotate it through 180^0 in the horizontal plane.

7. Line of Collimation : It is also known as the line of sight. It is the imaginary line joining the intersection of the cross hairs of the diaphragm to the optical center of the object-glass and its continuation.

8. Axis of the Telescope : The axis of the telescope is the line joining the optical center of the object glass to the center of the eyepiece.

9. Axis of the level Tube : Axis of the level or bubble tube is the straight line tangential to the longitudinal curve of the level tube at the center of the tube. It is also called the bubble line.

10. Vertical axis : It is the axis about which the telescope can be rotated in a horizontal plane.

11. Horizontal axis : The horizontal axis is the axis about which the telescope can be rotated in a vertical plane. It is also called the trunnion axis or transverse axis.

5.1.4 Temporary Adjustments of Theodolite

There are three temporary adjustments of a theodolite.

1. Setting up the theodilite over a station
2. Levelling up
3. Focussing for elimination of parallex

Setting Up : It includes two operations, viz (a) Centering the theodolite over a station and (b) approximately leveling it by tripod legs only. Centering of a theodolite over a station can be done by means of a plumb bob suspended from the hook beneath the center of the instrument.To do this

(i) Place the instrument over the station by spreading the legs of the tripod well apart, keeping the telescope at a convenient height, the plumb bob approximately over the station mark. (ii) Lift the instrument bodily without disturbing the relative positions of the legs and move it until the plumb bob hangs about 2 cm above and within about 1 cm or less horizontally of the station mark.(iii) Move each leg radially as well as circumferentially so as to bring the plumb bob exactly over the station mark. Press the legs firmly into the ground.

Levelling up : Having centered and approximately levelled, the instrument should be levelled accurately with reference to the plate levels by means of foot - screws so that the vertical axis is made truly vertical. To level the instrument.(a) Loosen all clamps and turn the instrument about either of its axis until the longer plate level is parallel to any pair of foot - screws, the other plate level will then be parallel to the line joining the third foot - screw and the mid - point of the line joining the first pair. (b) Bring the long bubble to the center of its run by turning both screws equally, either inward or both outwards.

(c) Repeat this until both the bubbles are exactly centered. Now rotate the instrument about the vertical axis through a complete revolution. Each bubble will now remain central provided the plate levels are in correct adjustment. The vertical axis is thus made truly vertical.If the vertical angles are to be measured, the instrument should be leveled with reference to the altitude level fixed on the index arm. To do this (a) First level the instrument by plate levels. Then turn the telescope so that the altitude level is parallel to the line joining a pair of foot - screws and bring the bubble to the center of its run by means of these screws. (b) Turn the telescope through 90^0 in the horizontal plane and make the bubble central by the third foot screw. (c) Repeat this until the bubble remains central in these two positions. (d) Bring the altitude level over the third foot – screw and swing the telescope through 180^0. If now the bubble does not remain central, correct half its deviation by clip screw and the other half by the third foot - screw swing the telescope through 90^0 so that it is again parallel to the two foot screws and then make the bubble central by means of these screws.

Focusing: Focusing is done in two steps

(a) Focusing of the eye - piece for distant vision of the cross - hairs at diaphragm, and

(b) Focusing the object glass for bringing the image of the object into the plane of the diaphragm.

(a) Focusing the Eye - Piece: Point the telescope to the sky or hold a piece of white paper in front of the telescope. Move the eye - piece in and out until a distant and sharp black image of the cross - hairs is seen.

(b) **Focusing the Object -Glass:** Direct the telescope towards the object and turn the focusing screw until a clear and sharp image of the object is obtained. It may be noted that parallax is completely eliminated if there is no movement of the image of the object when the eye is moved up and down.

Reading the Circular Vernier Scales

Circular vernier scales are used in thedolites to measure horizontal and vertical angles. Fig. 5.2(a) and 5.2 (b) shows two typical arrangements of double direct ciruclar verniers. In Fig. 5.1(a) the main scale is gruaduated to 30’ (s=30’) and the number of divisions n=30 on the vernier.

Hence the least count is s/n=30’/30 = 1’ .

In Fig. 5.1(b), the main scale is graduated to 20’ (s=20’) and the number of vernier divisions n=40.

Hence least count= s/n = 20’ / 40 = 0.5’ = 30”

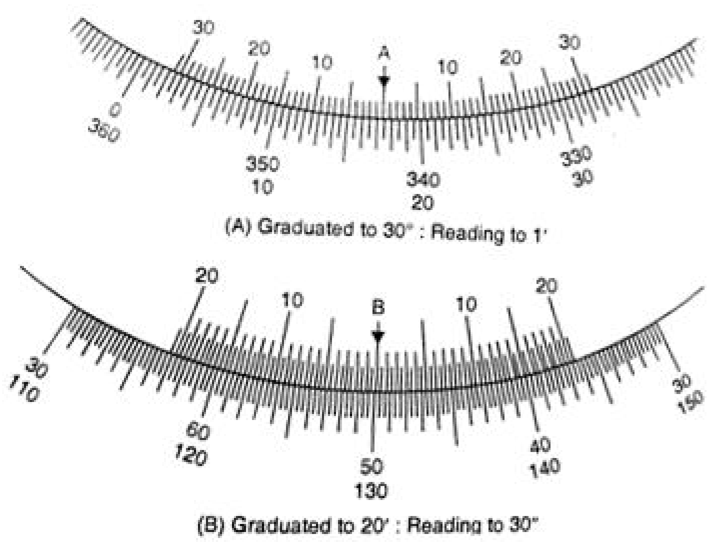

Fig. 5.2

Thus in fig. 5.2 (a) the clock wise angle reading (inner row) is 342^{o} 30’ + 05’ = 342^{o} 35’, and the counter clock wise angle reading (outer row) is 17^{o} 0’ + 26’ = 17^{o} 26’. Similarly in fig. 5.2(b) clockwise angle reading (inner row) is 49^{o} 40’ + 10’ 30’’ = 49^{o} 50’ 30’’ and the counter clock wise angle (outer row) is 130^{o} 0’ + 9’ 30’’ = 130^{o} 9’ 30’’.

In both the cases, the verneir is always read in the same direction as the scale.

Now a days theodolites are available with least count of 20’’.

5.2 Measurement of Horizontal Angles

There are three methods of measuring horizontal angles.

1. Ordinary method

2. Repitation method

3. Reiteration method

1. Ordinary Method : to measure horizontal angle AOB show in fig. 5.3

(i) Setup the instrument over '0' and level it accurately.

(ii) Set the vernier 'A' to the zero or 360^o of the horizontal circle. To do this loosen the upper clamp and turn the upper plate until the zero of verner A nearly coincides with the zero of the horizontal circle. Tighten the upper clamp and turn its tangent screw to bring the two zeros into exact coincidence.

(iii) Loosen the lower clamp, turn the instrument and direct the telescope approximately to the left hand object (A) by sighting over the top of the telescope. Tighten the lower clamp and bisect, exactly by turning the lower tangent screw. Bring the point A into exact coindence with the point of intersection of cross hairs at diapharm by using the verticle circle clamp and tangent screws. Alternatively bring the vertical cross hairs exactly on the lowest visible portion of the arrow or the ranging rod representing the point A in order to minimise the error due to non verticality of the object.

(iv) Having sighted the object A, see whether the vernier A still reads zero. Read the vernier B and record both vernier readings.

(v) Loosen the upper clamp and turn the telescope clockwise until the line of the sight is set nearly on the right hand object (B). Then tighten the upper clamp and by turning its tangent screw, bisect B exactly.

(vi) Read both Verniers : The readings of the vernier A which was initially set at zero gives the values of angle AOB directly and that of the other vernier B by deducting 180^o. The mean of two vernier readings gives the value of the required angle AOB.

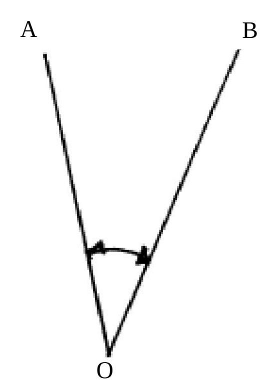

Fig.5.3

(vii) Change the face of the instrumnet and repeat the whole process. The mean of the two vernier readings gives the second value of the angle.

(viii) The mean of the two values of the angle AOB, one with the face left and the other with the face right, gives the required angle free from all instrumental errors.

2. Measurement of Horizontal angle by Repetition Method: In this method, the angle is added several times mechanically, and the value of the angle obtained by dividing the accumulated reading by the number of repetitions.

To measure the angle PQR

(i) Set the instrument at Q and level it. With the help of upper clamp and tangent screw, set 0^o reading on vernier A. Note the reading of vernier B.

(2) Loose the lower clamp and direct the telescope towards the point P. clamp the lower clamp and bisect point P accurately by lower tangent screw.

(3) Unclamp the upper clamp and turn the instrument clockwise about the inner axis towards R. Clamp the upper clamp and bisect R accurately with the upper tangent screw. Note the reading of verniers A and B to get the approximate value of the angle PQR.

(4) Unclamp the lower clamp and turn the telescope clockwise to sight P again. Bisect P accurately by using the lower tangent screw. It should be noted that the vernier readings will not be changed in this operation since the upper plate is clamped to the lower.

(5) Unclamp the upper clamp, turn the telescope clockwise and sight R. Bisect R accurately by upper tangent screw.

(6) Repeat the process until the angle is repeated the required number of times (usually 3). The average angle with face left will be equal to final reding divided by three.

(7) Change face and make three more repetitions as described above. Find the average angle with face right, by dividing the final reading by three.

(8) The average horizontal angle is then obtained by taking the average of the two angles obtained with face left and face right.

Any number of repetitions may be made. How ever, three repetitions with the telescope normal and three with the telescope inverted are quite sufficient for any thing except very precise work. Table 5.4 gives the method of recording observations by method of repetition.

		Face left								Swing Right				Face right								Swing left				Average horizontal angle		
Inst. at	Sighted to	A			B		Mean			No. of repetition	Horizontal angles			A			B		Mean			No. of repetition	Horizontal angles					
		°	'	"	'	"	°	'	"		°	'	"	°	'	"	'	"	°	'	"		°	'	"	°	'	"
Q	P	00	00	00	00	00	00	00	00					00	00	00	00	00	00	00	00							
	R	58	43	20	43	20	58	43	20	1	58	43	20	58	43	40	43	40	58	43	40	1	58	43	40	58	43	30
	R	176	11	20	11	40	176	11	30	3	58	43	50	176	11	20	11	40	176	11	30	3	58	43	50	58	43	50

REPITITION METHOD TABLE 5.4

By this procedure the following errors are eliminated or minimized.

(i) The errors due to the eccentricity of the centers and of the verniers are eliminated by reading both verniers and averaging the readings.

(ii) The errors due to imperfect adjustment of the line of collimation and the horizontal axis of the telescope are eliminated by face left and face right observations.

(iii) The errors of graduations are minimized.

2. Measurement of Horizontal Angle by Reiteration Method

Reiteration is another method of measuring horizontal angles with high precision. It is less tedious. It is generally preferred when several angles are measured at a particular station. In this method several angles are measured successively, and finally the horizon is closed. The final reading of the leading verneir (Vernier A) should be the same as its initial reading. If not, the discrepancy is equally distributed among all the measured angles.

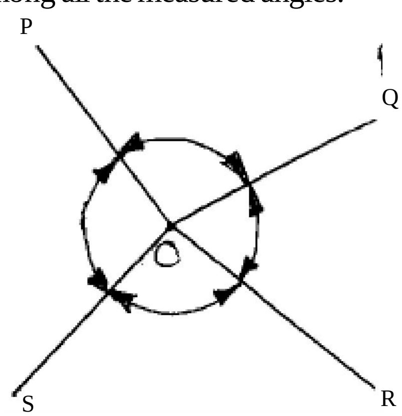

Fig. 5.4

Suppose it is required to measure the angles POQ, QOR and ROS

(i) Set up the instrument over O and level it correctly.

(ii) Setup the Verneir A to Zero

(iii) Direct the telescope to some well – defined object P or the station point A, which is known as the Referring object and bisect it accurately by using the lower clamp and lower tangent screw. Note the Vernier readings.

(iv)Loosen the Upper plate and turn the telescope clockwise until the point Q is exactly bisected by turning the upper tangent screw. Read both Verniers. The mean of two vernier readings will give the value of the angle POQ.

Inst. at	Sighted to	Face left, Swing Right: A			B		Mean			Horizontal angles			Face right, Swing left: A			B		Mean			Horizontal angles			Average horizontal angle		
		°	'	"	'	"	°	'	"	°	'	"	°	'	"	'	"	°	'	"	°	'	"	°	'	"
O	P	00	00	00	00	00	00	00	00				00	00	00	00	00	00	00	00						
	Q	43	53	10	53	10	43	53	10	43	53	10	43	53	00	53	00	43	53	10	43	53	10	43	53	10
	R	98	24	00	24	00	98	24	00	54	30	50	98	24	00	24	00	98	24	00	54	30	50	54	30	50
	S	225	11	20	11	20	225	11	20	126	47	20	225	11	20	11	20	225	11	20	126	47	20	126	47	20
	P	360	00	00	00	00	360	00	00	134	46	40	360	00	00	00	00	360	00	00	134	48	40	134	48	40

REITERATION METHOD TABLE 5.5

(v) Similarly, bisect R and S successively, reading both verniers at each bisection

(vi) Finally close the horizon by sighting the referring object (p) or the station point P.

(vii) The Vernier A should now read 360^0. If not, note the reading and find the error.

(viii) If the error is small, it is equally distributed among the several observed angles. If large, the readings should be discarded and a new set taken.

5.2.1. Measuring a Vertical Angle

A Vertical angle is an angle between the inclined line of sight and the horizontal. It may be an angle of elevation or depression according as the object is above or below the horizontal plane.

To measure the vertical angle of an object A at a station O

(i) Set up the theodolite at a station O and level it accurately with reference to the altitude bubble.

(ii) Set the zero of vertical verneir exactly to the zero of the vertical circle by using the vertical circle clamp and tangent screw.

(iii) Bring the bubble of the altitude level in the central position by using the clip screw. The line of sight is made horizontal, while the vernier reads zero.

(iv) Loosen the vertical circle clamp screw and direct the telescope towards the object A and sight it exactly by using vertical circle tangent screw.

(v) Read both verniers on the vertical scale. The mean of the two vernier readings gives the value of the required angle.

(vi) Change the face of the instrument and repeat the process. The mean of the two vernier readings gives the second value of the required angle.

(vii) The average of the two values of the angle thus obtained is the required value of the angle free from instrumental errors.

To measure the vertical angle between two points A and B

(i) Sight A as before, and take the mean of the two vernier readings at the vertical circle let it be α .

(ii) Similarly sight B and take the mean of the two Vernier readings at the vertical circle. Let it be β.

Inst. at	Sighted to	Face left											Face left											Average vertical angle		
		C			D		Mean			Vertical angles			C			D		Mean			Vertical angles					
		°	'	"	'	"	°	'	"	°	'	"	°	'	"	'	"	°	'	"	°	'	"	°	'	"
O	A	+28	24	20	24	00	+28	24	10	+28	24	10	+28	24	40	24	20	+28	24	30	+28	24	30	+28	24	30
	B	-24	35	40	35	20	-24	35	40	-24	35	40	-24	36	00	35	40	-24	35	50	-24	35	40	-24	35	35

Angle AOB = 53^0 59' 55"

VERTICAL ANGLES TABLE 5.6

(iii) The sum or difference of these readings will give the value of the vertical angle between A and B according as one of the points is above and the other below the horizontal plane (Fig a) or both points are on the same side of the horizontal plane (Fig b and c)

The observations of vertical angles are shown in table 5.5

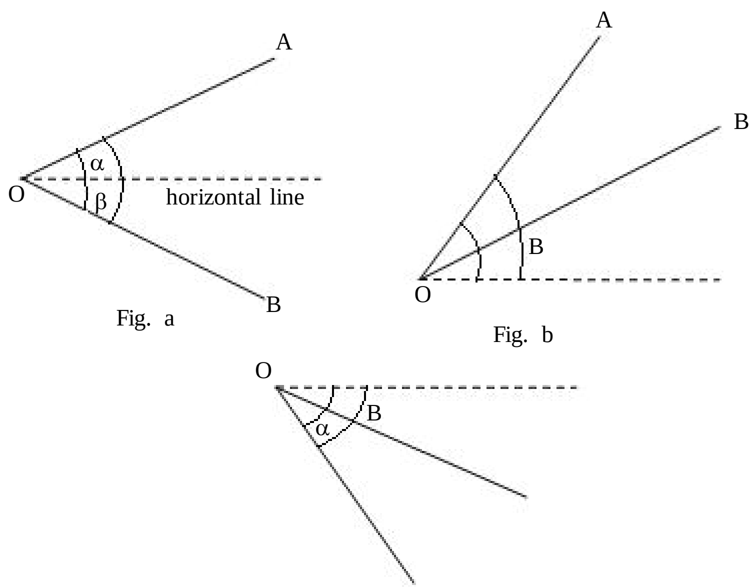

Fig. 5.5

5.3 Determination of Heights and Distances

When the base of the object being accessible:

To find the height of the object above a Bench Mark (or above the instrument station)

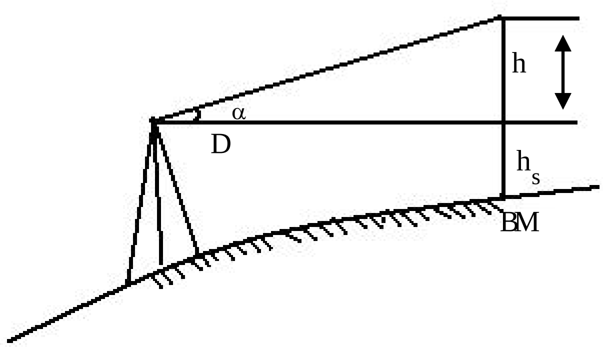

Fig. 5.6

Let H = the height of the object above the B.M

h_s = height of the instruments axis above the B.M

h = height of the object above the instrument axis

α= the vertical angle observed at the instrument station

D = the horizontal distance in meters measured from the instrument station to the base of the object.

Then h = D Tan α

H = h + hs

H = D Tanα + hs

When the distance D is large, the correction for curvature and

refraction $\{0.0673 (D/1000)^2\}$ shall have to be applied.

Example : A Theodolite was setup at a distance of 175 m from a chimney, and the angle of elevation to its top was $10^0 30'$. The staff reading on a B.M of R.L 70.50 with the telescope horizontal was 0.982. Find the height of the chimney above the B.M.

D = 175 m, $\alpha = 10^0 30'$

h_s = 0.982

The height of the top of the chimney above the instrument

axis h = D Tanα

= 175 x Tan $10^0 30^1$.

= 175 X 0.1853

= 32.43 m

The error due to curvature & refraction

= $0.0673 (175/1000)^2$ = 0.002 m

The height of the top of the chimney above the B.M=

H= h + h_s + correction due to curvature and refraction

H = 32.43 + 0.982 + 0.002

= 33.414 m. Ans.

Summary

1. Types of levels

i) The Transit ii) The plain or Y iii) The Everest

2. Face Left : If the vertical circle of the instrument is on the left of the observer while taking a reading, the position is called the face left and the observation taken on the horizontal or the vertical circle in this position is knowns as the face left observation.

3. Face Right : If the vertical circle of the instrument is on the right of the observer while taking a reading, the position is called the face right and the observation taken on the vertical circle in this position is known as the face right observation.

4. Temporary Adjustments of Theodolite

1. Setting up the theodilite over a station 2. Levelling up 3. Focussing

5. Repetition: In this method, the angle is added several times mechanically, and the value of the angle obtained by dividing the accumulated reading by the number of repetitions.

Short Answer Type Questions

1. State any four uses of a theodolite
2. What is meant by Centering ?
3. What is meant by Transiting ?
4. What is meant by swinging the telescope?
5. What is meant by face left?
6. What is meant by face right?
7. What is meant by changing the face?
8. Define the line of collimation
9. Write methods of measuring horizontal angle
10. Write the temporary adjustments of Theodolite.
11. Define vertical axis
12. What are the Fundamental lines of a Transit Theodolite?

Long Answer Type Questions

13. Describe the parts of a Theodilite with transiting facility for use in measurement in a horizontal plane.

14. Draw a neat sketch of transit Theodolite and mention its components.

15. Explain clearly and sequentially the operations involved in the temporary adjustments of a Theodolite.

16. Explain how you would measure with a Thodolite.

(a) Horizontal angle by repetition

(b) Horizontal angle by reiteration

Activities

- Study the Theodolite and identifying the parts.
- Making temporary adjustments to the Theodolite
- Reading the Verniers and recording the observation in the field book.