

## Chapter Six- Tacheometry

### 6.1. Definition

#### **Tacheometry:**

It is the procedure for obtaining horizontal distance and differences in elevation by rapid indirect methods, which are based on the optical geometry of the instruments employed. This tacheometry is applied for leveling, traversing, field surveys etc.

Methods that are used in tachometric surveying are Stadia, substance bar, staff and alidade.

### 6.2 Stadia method

For the measurement of stadia distance, the reticule in the telescope of the theodolite is equipped with three horizontal cross hairs; the upper and lower cross hairs (used for distance measurement) are called stadia hairs. The actual separation of the upper and lower stadia hairs in the reticle is taken as  $i$ . The distance from the instrument to the rod held vertically is obtained from a stadia interval  $s$  in the rod, which crosses the upper and lower cross hairs.

#### **Use and Adjustment of Theodolites**

Theodolites are manufactured to determine horizontal and vertical angles and for the purpose of prolonging straight lines, leveling, stadia tachometry etc. Optically read theodolite, however, usually enable the user to make single observations of angles as precisely or more precisely and in less time.

Theodolites have horizontal and vertical circles for angle measurements, but circles are made of glass instead of metal. Light passes through the glass circles, and with the aid of glass prisms the readings from the circles are reflected in to the eyepiece. The values are greatly magnified enabling the user to make readings with out eye strain.

The graduated vertical and horizontal circles are of glass and are relatively small; they are viewed simultaneously from the eye end of the telescope by means of a system of microscopes, prisms, and mirrors.

Theodolites may be either repeating or directional. Repeating theodolites can measure angles as many times by adding them successively on the instrument circle, while the directional theodolite is a non-repeating type of instrument and doesn't have a lower motion. The horizontal circle remains fixed during a series of readings. The

telescope is sighted on each of the points in question and direction to those points is read. Horizontal angles are determined by calculating the differences between the directions.

### **Terms Used in theodolite surveys**

**1. Face left face right observations**

Face left  $\Rightarrow$  with the vertical circle on the left side of the eyepiece.

Face right  $\Rightarrow$  with the vertical circle on the right side of eyepiece.

**2. Swinging the telescope  $\Rightarrow$  rotating the telescope by  $180^\circ$  in the horizontal plane.**

**3. Transiting or plunging  $\Rightarrow$  rotating the telescope by  $180^\circ$  in the vertical plane.**

**4. Telescope normal and telescope reverse  $\Rightarrow$  Reading with normal telescope and reading with swinging and transiting of telescope.**

**5. Double centering  $\Rightarrow$  observing angles twice with telescope normal & reverse.**

### **Conditions of perfect adjustment**

When theodolite is in perfect adjustment,

- 1. Axis of telescope is at right angle to horizontal axis.**
- 2. Horizontal axis is at right angle to vertical axis.**
- 3. Axis of telescope level tube is parallel to axis of telescope.**
- 4. The vertical axis is truly vertical when the plate bubble is central**
- 5. The vertical circle is at zero when the line of sight is horizontal and bubble is central.**
- 6. The cross hairs are truly vertical and horizontal.**

### **Measurement of horizontal angles**

To measure angle AOB, the instrument is set up over station O and carefully leveled by means of the foot screws. The face of the instrument must be checked at this stage and then the eyepiece focused on the cross hairs, starting with all clamps tightened.

- The plates are untightened and horizontal circle is set to zero or near zero. The upper clamp is locked, holding the two plates together.

- The telescope is directed and targeted to station and A and when the telescope is closely pointing on A the lower clamp is also locked and the vertical cross hair is accurately sighted on to the station using the lower tangent screw. The horizontal circle reading is now taken.
- With the lower clamp fixed, release the upper clamp. This frees the telescope to swing over a vertical axis. Swing the telescope on a clockwise direction on to the signal at B and again bisect the signal using the upper clamp and upper slow motion screw and record the angle read.
- The upper clamp is released, and the theodolite is swing through  $180^0$  and transiting by  $180^0$  in the vertical plane. The telescope is sighted on B by fixing upper clamp and using upper tangent screw and horizontal angle is recorded.
- Releasing the upper clamp, the telescope is directed towards station A. The upper clamp is tightened and using upper tangent screw the telescope is targeted on A and the angle is taken.

For two cases as telescope normal and telescope reverse the angles AOB are recorded and their mean is taken for the value of given angle.

### Example:

To measure angle ABC the theodolite is set up at B and the telescope is fixed at A and an angle of  $27^000'35''$  was recorded on targeting through C. Reversing the telescope by swinging and plunging at C and then turning to A a horizontal angle of  $207^000'30''$  was recorded. What is the mean value of the angle ABC?

| <u>Pointing</u> | <u>Face left</u>               | <u>Face right</u>                |
|-----------------|--------------------------------|----------------------------------|
| Station C       | $27^000'35''$                  | $207^000'36''$                   |
| Station A       | <u><math>0^000'00''</math></u> | <u><math>180^000'07''</math></u> |
|                 | $27^000'35''$                  | $27^000'29''$                    |

$$mean = \frac{27^000'35'' + 27^000'29''}{2} = 27^000'32''$$

The mean value of angle ABC =  $27^000'32''$

### Measurement of vertical angles

The vertical angles are measured with respect to the horizontal plane defined by vertical bubble. After setting up the instrument over a station, the telescope is directed to the point and coincides on the mark using horizontal and

vertical tangent screws. The angle read on the point may be a (+ or -) angle related to the horizontal plane and recorded.

The telescope is then directed to the other station and coincides on the mark, the vertical circle reading gives an angle measurement (+ or -) and applying this reading to the other gives the vertical angle subtended at the instrument.

Observations should be made on both faces of the instrument for increasing accuracy and the mean value gives the required vertical angle.

### Example:

In order to determine the vertical angle between two lines OA&OB in a hilly ground with an instrument set some distance from points. The readings were taken with both farces of the instrument and the following readings were recorded.

| <u>Pointing</u> | <u>Face left</u> | <u>Face right</u> |
|-----------------|------------------|-------------------|
| Station A       | 237°36'          | 57°25'            |
| Station A       | <u>181°20'</u>   | <u>01°17'</u>     |
|                 | 56°16'           | 56°08'            |

$$mean = \frac{56^{\circ}16' + 56^{\circ}08'}{2} = 56^{\circ}12'$$

The mean value of angle ABC=56°12'

### Errors in Stadia Measurement

Most of the errors associated with stadia measurement are those that occur during observations for horizontal angles (Lesson 22) and differences in elevation (Lesson 16). Specific sources of errors in horizontal and vertical distances computed from observed stadia intervals are as follows:

#### 1. Error in Stadia Interval factor

This produces a systematic error in distances proportional to the amount of error in the stadia interval factor.

#### 2. Error in staff graduations

If the spaces on the rod are uniformly too long or too short, a systematic error proportional to the stadia interval is produced in each distance.

#### 3. Incorrect stadia Interval

The stadia interval varies randomly owing to the inability of the instrument operator to observe the stadia interval exactly. In a series of connected observations (as a traverse) the error may be expected to vary as the square root of the number of sights. This is the principal error affecting the precision of distances. It can be kept to a minimum by proper focusing to eliminate parallax, by taking observations at favorable times, and by care in observing.

#### 4. Error in verticality of staff

This condition produces a perceptible error in measurement of large vertical angles than for small angles. It also produces an appreciable error in the observed stadia interval and hence in computed distances. It can be eliminated by using a staff level.

#### 5. Error due to refraction

This causes random error in staff reading.

#### 6. Error in vertical angle

Error in vertical angle is relatively unimportant in their effect upon horizontal distance if the angle is small but it is perceptible if the vertical angle is large

## Errors in elevations

- The main sources of error in elevation are (1) error in vertical angles and (2) additional errors
- arising from errors in the computed distance. *Figure 2.49* clearly shows that whilst the error
- resulting from (1) remains fairly constant, that resulting from (2) increases with increased elevation:

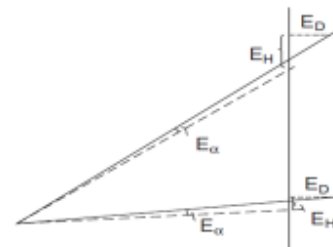


Fig. 2.49

## Principle Of Stadia Method

Figure 6.9 Optical distance measurement (ODM)

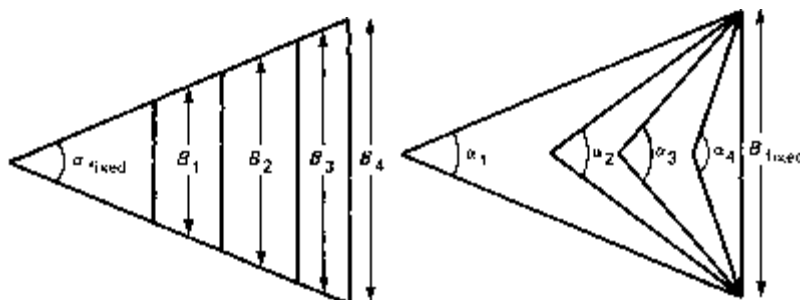


**Figure 6.10** ODM: fixed angle, variable base **Figure 6.11** ODM fixed base, variable angle

spaced either side of it. These stadia lines define the fixed parallaxes angle. If the theodolite telescope is sighted on to a leveling staff and the readings of the outer lines noted, the difference in the readings, the staff intercept ( $s$ ), will be directly proportional to the horizontal distance between the instrument and the staff. Generally, the distance between the stadia lines is designed in such a manner that the horizontal distance  $Z > H$  between the instrument and staff is given by:

where  $Z$  = slope distance, and  $\theta$  = vertical angle measured by the theodolite. Therefore:

where  $z$  = difference in height between A and B,  $h$  = height of instrument (trunnion axis to ground),  $m$  = middle hair reading, and  $V$  = difference in height between middle-hair reading and trunnion axis =  $50s \sin 2\theta$  (6.11)

Several self-reducing tacheometers have also been designed. The main advantage of these instruments is their ability to compensate for the effect of the inclination of the theodolite telescope and, hence, allow the direct determination of horizontal distance without additional computation.