

UNIT III

CONTROL SURVEYING AND ADJUSTMENT

Horizontal and vertical control - Methods - Specifications - triangulation
base line - Satellite stations - reduction to centre - trigonometric levelling - Single and reciprocal observations - traversing - Gau's table - Errors sources - Precautions and corrections - Classification of errors - true and most probable values. Weighted observations - method of equal shifts - principle of least squares - normal equation - Correlates - level nets - adjustment of simple triangulation - networks.

Control Surveying:

Horizontal Controls & Its methods:

The horizontal control consist of reference marks of known plan position, from which salient points of designed structures may be staked. For large structures primary and secondary control points are used. The primary control points are triangulation stations. The secondary control points are reference to the primary control stations.

Reference Grid:

Reference grid are used for accurate setting out works of large magnitude. The following types of reference grids are used.

1. Survey grid
2. Site grid
3. Structural grid.
4. Secondary grid.

Survey grid is one which is drawn on a Survey plan, from the original traverse. Original traverse stations form the control points of the grid. The site grid used by the designer is one with help of which actual setting out is done. As far as possible the site grid should be actually the survey grid.

All the design points are related in terms of grid co-ordinates. The structural grid is used when the structural components of the building are large in numbers and are so positioned that these components cannot be set out from the site grid with sufficient accuracy. The structural grid is set out from the site grid points. The secondary grid is established inside the structure, to establish internal details of the building, which are otherwise not visible directly from the structural grid.

Vertical control & its methods:

The vertical consist of establishment of reference marks of known height relative to some special datum. All levels at the site are normally reduced to the nearby bench marks, usually known as master bench marks.

The setting out point in the vertical direction is usually done with the help of following rods.

1. Bonding rods & travellers.

2. Sight rails.

3. Shape rails or batter boards.

4. Profile Boards.

A bonding rod consist of an upright pole having a horizontal board at its top, forming a 'T' shaped rod. Bonding rods are made in set of three, and may consist of three T shaped rods, each of equal size and shape, or two rods identical to each other and a third one consisting of longer rod with a detachable or movable 'T' piece. The third one is called travelling rod or traveller.

Sight rails:

A sight rails consist of horizontal cross piece nailed to a sight upright or pair of uprights driven into the ground. The upper edge of the cross piece is set to a convenient height above the required plane of the structure, and should be above the ground to enable a man to conveniently align his eyes with the upper edge.

Slope rails or Batter boards:

These are used for controlling the side slopes in embankments and in cuttings. They consist of two vertical poles with a sloping board nailed near their top. The slope rails define a plane parallel to the proposed slope of the embankment, but at suitable vertical distance above its

A bonding rod consist of an upright pole having a horizontal board at its top, forming a 'T' shaped rod. Bonding rods are made in set of three, and may consist of three T shaped rods, each of equal size and shape, or two rods identical to each other and a third one consisting of longer rod with a detachable or movable 'T' piece. The third one is called "traveling rod or traveller.

Sight rails:

A sight rails consist of horizontal cross piece nailed to a sight upright or pair of uprights driven into the ground. The upper edge of the cross piece is set to a convenient height above the required plane of the structure, and should be above the ground to enable a man to conveniently align his eyes with the upper edge.

Slope rails or Batter boards:

These are used for controlling the side slopes in embankments and in cuttings. They consist of two vertical poles with a sloping board nailed near their top. The slope rails define a plane parallel to the proposed slope of the embankment, but at suitable vertical distance above it.

Height of the vane above

$$\text{instrument} = 334.68 + 0.27 = 334.95$$

$$\text{RL of vane} = 334.95 + 2650.38 = 2985.33 \text{m}$$

$$\text{RL of Q} = 2985.33 - 4 = 2981.33 \text{m.}$$

If an instrument set up at P and the angle of depression to a vane 2m above the foot of the staff held at Q was $5^{\circ} 36'$. The horizontal distance b/w p & Q was known to be 3000metres. Determine the R.L of the staff station Q given that staff reading on a B.M of elevation 436.050 was 2.865 metres.

Solution:

The difference in elevation

b/w vane and the instrument

$$\text{axis} = D \tan \alpha$$

$$= 3000 \tan 5^{\circ} 36'$$

$$= 274.453.$$

combined correction due to

$$\text{curvature \& refraction, } c = 0.66735 D^2 \text{ metres, when } D \text{ in km}$$
$$= 0.606 \text{ m.}$$

Since the observed angle is negative, the combined correction due to curvature and refraction is subtractive.

Difference in elevation b/w the vane

$$\text{and the instrument axis} = 294.153 - 0.606$$
$$= 293.547 = h$$

$$\text{RL of instrument axis} = 436.05 + 2.865 = 438.915$$

$$\text{RL of the vane} = \text{RL of instrument axis} - h$$

$$= 438.915 - 293.547 = 145.368$$

$$\text{RL of Q} = 145.368 - 2$$

$$= 143.368 \text{ m.}$$

In order to ascertain the elevation of the top (Q) of the signal on a hill, observations were made from two instrument stations, P & R at a horizontal distance 100 metres apart, the stations P and R being in the line with Q. The angles of elevation of Q at P and R were $28^\circ 42'$ and $18^\circ 6'$ respectively. The stabs reading upon the bench mark of elevation 287.28 were respectively 2.870 and 3.750 when the instrument was at P and at R, the telescope being horizontal. Determine the elevation of the foot of the signal if the height of the signal above its base is 3 metres.

Solution :

$$\text{Elevation of instrument axis at P} = \text{RL of BM} + \frac{\text{Stab}}{\text{readily}}$$

$$= 287.28 + 2.870 = 290.15m$$

$$\begin{aligned}\text{Elevation of Instrument axis at R} &= \text{RL of BM} + \frac{\text{Stab}}{\text{readily}} \\ &= 287.28 + 3.750 = 291.03m\end{aligned}$$

Difference in level of the instrument

$$\text{axes at the two stations, } S = 291.05 - 290.15 \\ = 0.88 \text{ m.}$$

$$\alpha = 28^\circ 42' \quad \cancel{+ 90^\circ}$$

$$\beta = 18^\circ 6'.$$

$$S \cot \beta = 0.88 \cot 18^\circ 6' = 2.69 \text{ m.}$$

$$L = 152.1 \text{ m.}$$

$$h = \text{Stand} = 152.1 \tan 28^\circ 42' \\ = 83.272 \text{ m.}$$

RL of the foot of signal = RL of instrument axis or P +
- ht of signal + h

$$= 290.15 + 83.272 - 3$$

$$= 370.422 \text{ m.}$$

Check $(b+D) = 100 + 152.1 = 252.1 \text{ m}$

$$h-- = (b+D) \tan \beta = 252.1 \times \tan 18^\circ 6' \\ = 82.399 \text{ m}$$

RL of foot of signal = RL of instr. axis or R + h-- + ht of
signal

Classification of Triangular System:

The basis of the classification of triangulation figures is the accuracy with which the length and azimuth of the line of triangulation are determined. Triangulation systems of different accuracies depend on the extent and the purpose of survey. The accepted grades of triangulation are -

1. First order or primary triangulation
2. Second order or secondary triangulation.
3. Third order or Tertiary triangulation

Survey Adjustments:

Errors of measurement are three kinds (i) mistakes
(ii) systematic errors and (iii) accidental errors.

(i) Mistakes : are errors that arise from inattention, inexperience, carelessness and poor judgement or confusion in the mind of the observer. If mistake is undetected, it produces a serious effect on the final result. Hence every value to be recorded in the field must be checked by some independent field observations.

(ii) Systematic error: is an error that under the same conditions will always be of same size and sign. A systematic error always follows some definite mathematical or physical law, and a correction can be determined and applied. Such errors are of constant character and are regarded as positive or negative according as they make the result too great or too small.

The Law of Accidental Errors:

Investigations of observations of various types show that accidental errors follow a definite law, the law of probability. This law defines the occurrence of errors and can be expressed in the form of equation which is used to compute the probable value or the probable precision of a quantity. The most important features of accidental errors which usually occur are.

1. Small errors tend to be more frequent than the large ones; that is they are the most probable.
2. Positive and negative errors of the same size, happen with equal frequency; that is they are equally probable.
3. Large errors occur infrequently and are impossible.

Principles of least Squares :

It is found from the probability equation that the most probable values of a series of errors arising from observations of equal weight are those for which the sum of the squares is a minimum. The fundamental law of least squares is derived from this. According to the principle of least squares, the most probable value of an observed quantity available from a given set of observations is the one for which the sum of the squares of the residual errors is a minimum. When a quantity is being deducted from a series of observations, the residual errors will be the difference b/w the adopted value and the several observed values. Let v_1, v_2, v_3 etc. be the observed values.

$$x = \text{most probable value}$$

Laws of weights:

From the method of least squares the following laws of weights are established.

1. The weight of the arithmetic mean of the measurements of unit is equal to the number of observations.

For example, let an angle A be measured six times, the following being the values:

A	weight	A	weight
30° 20' 8"	1	30° 20' 10"	1
30° 20' 10"	1	30° 20' 9"	1
30° 20' 7"	1	30° 20' 10"	1

Arithmetic mean

$$= 30^\circ 20' + \frac{1}{6} (8'' + 10'' + 7'' + 10'' + 9'' + 10'')$$

$$= 30^\circ 20' 9''$$

Weight of arithmetic mean = number of observations = 6

- 2. The weight of the weighted arithmetic mean is equal to the sum of the individual weight.

For example

A	weight	A	weight
$30^{\circ} 20' 8''$	2	$30^{\circ} 20' 10'$	3
$30^{\circ} 20' 10''$	3	$30^{\circ} 20' 9''$	4
$30^{\circ} 20' 6''$	2	$30^{\circ} 20' 9''$	2

$$\text{Sum of weight} = 2 + 3 + 2 + 3 + 4 + 2 = 16.$$

$$\begin{aligned}\text{Arithmetic mean} &= 30^{\circ} 20' + \frac{1}{16} (8'' \times 2 + 10'' \times 3 + 7'' \times 2 + 10'' \times 3 \\ &\quad + 9'' \times 4 + 10'' \times 2) \\ &= 30^{\circ} 20' 9''.\end{aligned}$$

$$\text{weight of Arithmetic mean} = 16.$$

- 3. A weight of algebraic sum of two or more quantities is equal to the reciprocals of the individual weights.

$$\text{For example } A = 30^{\circ} 20' 8' \text{ weight 2}$$

$$l_3 = 15^{\circ} 20' 8'' \text{ weight 3}$$

4. If a quantity or given weight is multiplied by a factor, the weight of the result is obtained by dividing its given weight by the square of the factor.

5. If a quantity of given weight is divided by a factor, the weight of the result is obtained by multiplying its given weight by the square of the factor.

6. If the equation is multiplied by its own weight, the weight of the resulting equation is equal to the reciprocal of the weight of the equation

7. The weight of the equation remains unchanged, if all the signs of the equation are changed or if the equation is added or subtracted from a constant.