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PAPER II

SURVEYING



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Paper-II

Surveying

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CIVIL ENGINEERING

Paper – II

SURVEYING

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UNIT 1

Introduction

Structure

Concept of Surveying

Purpose of Surveying

Linear and Angular measurements

Classification of Surveying

Reconnaissance, Preliminary location survey, final location survey

Learning Objectives

After studying this unit, the student will be able to

- Understand what is surveying
- Purpose and principles of surveying
- Types of Surveying
- · Conversion of linear measurements from one system to other System

Concept of Surveying

Surveying is the art of determining the relative positions of different features on, above or beneath the earth's surface by taking measurements in the horizontal and vertical planes. Surveying is usually considered as a process of determining relative positions of different points in horizontal plane. Levelling is considered as a process of determining relative positions of points in vertical plane.

Fundamental principles of surveying

The two fundamental principles of surveying are

a) To locate a new station by measurements from at least two reference points.

b) To work from whole to part.

a) Locating a new station. It is always practicable to select two points in the field and to measure the distance between them. These can be represented on paper by two points placed in a convenient position. From these reference points other points can be located by two suitable measurements in the field and drawn in their relative positions on the sheet.

The common methods of locating a point such as C with respect to

two reference points such as A and B are illustrated in Fig.1.1



(a) Distances AC and BC are measured, and C is plotted as the intersection point of two arcs with centers A and B and radii from the measured distances.

(b) Perpendicular CD and distance AD or BD measured and C is plotted by the use of a setsquare.

(c) Distance AC and the angle BAC are measured, and C is plotted by means of a protractor.

(d) Angles ABC and BAC are measured, and C is plotted by a protractor or by solution of triangle ABC.

(e) Angle BAC and distance BC are measured, and C is plotted by a protractor.

One or more than one of the above methods may be used in the same survey according to the instruments available and purpose of survey.

b) Working from whole to part. In surveying an area, it is essential to establish a system of control points with great accuracy. Minor control points can then be established by less accurate methods and the details can be located afterwards by the method of triangulation or traversing between the control points. This way the minor errors are automatically controlled and localized and do not accumulate. On the other hand, if we

Purpose of Surveying

work from part to the whole, the small errors are magnified and become uncontrollable at the end.

The main purpose of surveying is to prepare a plan or map of the areas. Surveys are required before and during the planning and construction of works such as highways, buildings, bridges, canals etc.

The surveyor has to perform the following functions.

1. Recording measurements in the field.

2. Making necessary calculations to determine areas, volumes etc.

3. Plotting the measurements and drawing a map.

4. Setting out structures.

Linear and Angular Measurements

In surveying, a surveyor has to generally deal with linear and angular measurements both in horizontal and vertical planes. Linear measurements taken in the horizontal plane are horizontal distances whereas those taken in the vertical plane are called vertical distances. Similarly the angular measurements are horizontal angles and vertical angles when taken in the horizontal and vertical planes respectively.

Linear measurements: The unit of length is a meter in M.K.S system and a foot in F.P.S system. The units of length, area and volume in metric system and their conversion to F.P.S. system are given in the following tables.

| 10 millimeters(mm) | = 1 centimeter(cm) |
|------------------------------|--------------------|
| 10 centimeters(cm) | = 1 decimeter(dm) |
| 10 decimeters (dm) or | = 1 meter(m) |
| 100 cm | – 1 deca meter |
| 10 meter (m) | (dam) |
| 10 hectometers (hm) or 1000m | = 1 hecta meter |

Table1.1. Units of Length

Conversion: 1 inch = 2.54 cm

1 foot = 0.3048 m 1

mile = 1.6093km

Table1.2 Units of Area

| 100 sq.mm | = 1sq.cm |
|--------------|-------------|
| 100 sq.cm | = 1sq.dm |
| 100 sq.dm | = 1 sq.m |
| 100sq.m | = 1 Are(a) |
| 100Ares | = 1 Hectare |
| 100 Hectares | = 1 sq.km. |

Conversion: 1 Sq. inch = 6.4516 Sq. cm

1 Sq.ft = 0.0920Sq.m 1 Sq. mile = 2.59 Sq.km 1 acre = 0.4047 hectare

Table1.3Units of volume

| 1000 Cu.mm | = 1Cu.cm |
|------------|----------|
| 1000 Cu.cm | = 1Cu.dm |
| 1000 Cu.dm | = 1 Cu.m |

Conversion: 1 cu inch = 16.387 cucm.

1cufeet

=0.0283 cu. m

Angular Measurements: A radian is the unit of plane angle and is equal to the angle subtended at the centre of a circle by an arc equal in length to its radius.

 \Box radians = 2 rightangles

1 right angle = 100 grades or 90° .

A degree is the basic unit of angle used in India.

1 degree(0) = 60 minutes(0)

1 minute(,) = 60 seconds(,)

Classification of Surveying

Surveys are classified according to

- 1) Instrument sused.
- 2) Purpose of survey
- 3) Methods employed.
- 4) Nature of the field.

1. Classification Based on instruments used.

Based on instruments used the surveys are classified as follows.

- a) Chain survey
- b) Compass survey
- c) Plane table survey
- d) Levelling
- e) Theodolite survey
- f) Tachometric survey.

2. Classification based on purpose of survey

- a) Mine surveys to explore the mineral wealth.
- b) Geological surveys to determine different strata in the earth'scrust.
- c) Archeological surveys to trace relics of the past.
- d) Military surveys to prepare maps of military importance.

3. Classification according to the method employed

- a) Triangulation Survey
- b) Traverse survey.

4. Classification according to nature of thefield.

- a) Land surveys for objects on earth's surface.
- b) Marine surveys for objects underwater
- c) Astronomical survey for observations of heavenly bodies.

Land Surveys are further classified into following types

- a) Topographical surveys.
- b) Cadastral surveys
- c) City surveys

a) **Topographical surveys:** These surveys are performed for determining the natural features of the country like lakes, rivers, hills etc. and also the artificial features like roads, canals, towns, villages, etc.

b) Cadastral surveys: These surveys are similar to topographical survey except that additional details such as boundaries of fields, houses are also determined.

c) City surveys: These surveys are carried out for laying of plots, construction of roads, sewer lines, water supply systems.

Plane and Geodetic Surveying.

The surveying is mainly divided into following two types a) Plane surveying.

b) Geodetic surveying.

a) **Plane surveying:** Surveying in which the effect of curvature of the earth is not considered is known as plane surveying. It is applicable for small areas only.

b) Geodetic surveying: Surveying in which the curvature of the earth is considered is known as geodetic surveying. It is applicable to large areas and surveys where greater precession is required.

Classification based on instruments.

Based on instruments used the surveys are classified as follows.

- a) Chain survey
- b) Compass survey
- c) Plane table survey
- d) Leveling

e) Theodolite survey

f)Tachometric survey.

Engineering Surveys

These surveys are carried out in connection with engineering works such as roads, railways, reservoirs and works connected with water supply.

Reconnaissance, Preliminary Location Survey, Final Location Survey

Engineering surveys are further sub divided into

- a) Reconnaissance survey.
- b) Preliminary location survey.
- c) Final location survey.

a) **Reconnaissance survey:** Reconnaissance survey is the physical observation of the area for determining the feasibility of work, and to know rough cost of the work.

b) **Preliminary location survey:** In this survey more precise data is collected to select the best location for the work and to estimate the exact quantities and costs.

c) **Final location survey:** final location surveys are carried out for setting out the works on the ground surface.

Summary

- 1. Surveying is the art of determining the relative positions of different points on the earth's surface in horizontal plane.
- 2. In plane surveying the curvature of the earth is not considered.
- 3. In Geodetic surveying the curvature of the earth is considered
- 4. Surveys are classified based on
 - (a) Instruments (b) Purpose of survey
 - (c) Methods employed (d) Nature of the field.
- 5. Topographical survey is performed for determining the natural features like lakes, rivers, hills etc and also the artificial features like roads, canals etc.
- 6. Reconnaissance surveys the physical observation of the area for determining the feasibility of work.

Short Answer Type Questions

- 1. Define Surveying
- 2. What is reconnaissance survey?
- 3. Write the types of land surveys
- 4. Define Plane Surveying
- 5. Define Geodetic Surveying
- 6. What is preliminary location survey?
- 7. What is final location survey?

Long Answer Type Questions

- 1. Explain purposes of surveying
- 2. Explain classification of surveying.
- 3. Explain the fundamental principles of Surveying.

UNIT 2

Chain Surveying

Learning Objectives

After studying this unit, the student will be able to understand

- Chain surveying and purpose of the equipment
- Studying the metric chain and reading the length.
- Types of survey stations and survey lines and their purpose
- Conventional signs used in chain surveying and recording field notes in the field book.
- Various types of obstacles we need to overcome in the process of measuring distance between two points.
- Methods of calculating area of a given piece of land with

Introduction

irregular boundary.

Chain surveying is the simplest and the most accurate kind of surveying. In this the area is divided into network of triangles since the triangle is the only figure which can be plotted without any angular measurements. Chain surveying is adopted in the following situations.

1) When the ground is flat and with simple details.

2) When the area to be surveyed is small.

3) When large scale mapping is desired.

Purpose and Principle of Chain Survey

Chain surveying has the following purposes.

1) To collect necessary data for exact description of the land.

2) To calculate the area of the plot

3) To prepare the plan of the site

4) To demarcate the boundaries of the land

5) For division of land into smaller units.

Principle of chain surveying:

The triangle is the simplest figure that can be plotted from the lengths of its sides. Based on this, the principle of the chain surveying is to divide the area into a network of well conditioned triangles. The error will be least in plotting a triangle is when no angle of the triangle is less than 30^0 and more than 120° . Such triangles are called well conditioned triangles. Chain surveying is also called as chain triangulation.

Equipments Used in Chain Surveying and their Functions

The following equipments are used in chain surveying

1) Chain
 2) Tape
 3) Ranging rod
 4) Offset rod
 5) Cross staff
 6) Arrows
 7) Pegs
 8) Plumb bob etc.

1. Chain: This is an instrument used for measuring distance. There are four types of chains.

i) Metric chain.

- ii) Engineer's Chain.
- iii) Gunter Chain.
- iv) Revenue chain.

(i) Metric chain: In metric system the chains of 20m and 30m are commonly used. The chain is made with galvanized steel wire of 4mm diameter. Each meter is divided into 5 links of 20mm length. It is provided with brass handles on either ends. The tallies are fixed at every 5m length and small brass rings are provided at every meter length. The chain is shown in the fig2.1.



(ii) Engineer's chain: The Engineer's chain is 100ft length and made of 100 links.

(iii) Gunter chain: It is 66 feet long and having 100 links. It is useful for measuring the distance in miles and areas in acres. 10 square Gunter chain

= 1 acre = 4840 sq. yards.

(iv) **Revenue chain:** This chain is of 33ft length and is divided into16 links.

2. vided according to the material used as following (i))Metallic

tapes (ii) Steel tapes (iii) Invar tapes

(i) Metallic tapes: This tape is made with water proof linen with brass, copper wires to avoid stretching. The tapes available in lengths 2, 5, 10, 20 and 30m.



(ii) Steel tapes: This is most accurate tape for taking measurements. If carelessly handled it gets broken.

(iii) Invar tapes: If the measurements are to be made with highest precision this tape is used. These are 6mm wide and available in lengths of 30, 50 and 100m.

3. Ranging rods: Theses are wooden or metal poles2m or 3m long and having a diameter of 30mm. They are provided with iron shoes at the lower ends to facilitate easy driving in the ground. The yare painted in bands alternatively in black and white or red and white. Ranging rods used for ranging a line.

4. Offset rods: This is mainly used to measure offsets of shorter lengths. It is usually2mlong.

5. Cross staff: Cross staff is an instrument used for setting perpendicular offsets. These are three types.

Fig. 2.2 Ranging rod

- i) Open cross staff
- iii) Adjustable cross staff



iii) French cross staff

Fig. 2.3 Open Cross Staff

(i) **Open cross staff:** It consists of 4 metal arms at right angles to each other having eye vane at two adjacent ends and object vane at the other ends.

(ii) Adjustable cross staff: With this cross staff the object can be set at any angle.

(iii) French cross staff: This cross staff is an octagonal brass tube with slits on its eight faces. With this cross staff we can set the object at an angle of 45^0 also.



Fig. 2.4 French Cross Staff

Optical Square: This is an instrument used for setting out right angles to he chain lines and to find out the foot of the perpendicular on the chain line from an object. It works on the principle of reflection.

6. Arrows: These are used for marking the ends of a chain during the process of chaining. These are steel pins 400mm long and are pointed at one end.



Fig. 2.5 Arrows

7. Pegs: These are made from hard timber and tapered at one end. The lengths varies from 120 to 600mm. these are driven into ground to mark the instrument stations.

8. Plumb bob: It is used to define the vertical line while measuring distance along slopes.

2.3 Coventional Signs

Conventional signs are symbols of objects represented on a map or in the field book.

Some of the common conventional signs used in chain surveying are given in



fig.2.15.

Errors in Chaining

Errors will be introduced in chaining due to the following reasons.

a). Instrumental errors: these are due to defective conditions of instrument. E.g. a chain maybe either too long or too short.

b). Natural errors: These are due to variations in the natural phenomena e.g. changes in length due to temperature.

Correction Due to Incorrect Length of the Chain orTape

If a chain has been damaged and it may be too short or too long of the true length of the chain, and all the measurements taken will be too long or too short, conversely a contracted or stretched chain will give incorrect measurements of the true lengths.

The correct lengths of a measured distance is found from

Correct Length=Measured Length x $\frac{\text{Incorrect length of chain}}{\text{Correct length of chain}}$ Or Correct Length=Measured Lengthx $\frac{L^2}{}$

where L'= Incorrect length of chain or tape

L = Correct length of chain or tape

If an area has been calculated then,



If an volume has been calculated then,



Example 2.1: A 30m chain was found to be 10cm too long after chaining distance of 1360m. Find the true distance.

Correct length of the chain = 30m

Incorrect length of the chain = 30 + 0.10 = 30.10

Measured distance = 1360m

True distance = Measured distance x Incorrect length of chain $1360 \times \frac{30.10}{30.00} = 1364.53 \text{m}$

Example 2.2 : A road actually 1330 m long was found to be 1326 m when measured with a defective 30 m chain. How much correction does the chain need. ?

Solution :

True length = Measured length x Correct length of chain True length = Measured length x L'/ L True length = 1330 m Measured Length = 1326 m Length of the chain = 30 m. 1330 = 1326 x L' / 30 $L' = \frac{-1326}{1326} = 30.09 \text{ m}$

The chain is 0.09 m (9cm) too long

Correction = -9 cm (Ans).

Example 2.3 : A 20 m chain was found to be 6 cm too long at the end of the days work after measuring 6000 m. If the chain was correct before the commencement of the work, find the correct length of the line.

Solution : The increase of 6 cm should be taken as gradually.

mean in correct length of the chain L' = 20+(20.06/2) = 20.03 m.

Correct length of the chain , L = 20m. Measured Distance = 6000

m True distance = $6000 \times 20.03 / 20 = 6009 \text{ m}$ (Ans).

Example : 2.4 :A30 m chain was found to be 6 cm too long after chaining distance of 4000 m. It was tested again at the end of day's work and found to be 8 cm too long after changing a total distance of 7800 m. If the chain was correct before the commencement of the work, find the true distance.

Solution : Chain length before commencement of the work = 30 m

Chain length after measuring 4000 m = 30.06 m.

Mean incorrect length of the chain (L') = (30 + 30.06) / 2 = 30.03 m.

True distance = Measured distance x L'/L

True distance = 4000 x (30.03)/30 = 4004 m.(i)

Remaining distance measured after measuring 4000

m = 7800 - 4000 = 3800 m

The distance of 3800 m was measured with the chain which was 6 cm too long in the beginning and 8 cm too long at the end of the chaining.

L' = (30.06 + 30.08)/2 = 30.07 m

True distance = $3800 \times (30.07) / 30 = 3808.9 \text{ m}$(ii)

Total True distance = (i) + (ii)

=4004 + 3808.9 = 7812.9 m (Ans)

These are the lines joining the main survey stations following are the types of survey lines.

Types of Survey Lines

i) Base lineii)Tie lineiii)Checkline

2.6.1 Base Line : A line which is generally longest of all the survey lines and upon which the entire frame work is built up is known as a base line. It generally runs in the centre of the area to be surveyed and should laid off on the level ground.

Tie Line : A line joining two Tie stations is known as a Tie line. It is run to take the interior details which are far away from the main lines and also to avoid long offsets.

Check Line : A line which is used to check or prove the accuracy of the frame work as well as the plotting work is known as the check line. It is a line which runs from apex of a triangle to any other fixed points on any two sides f a triangle.



Types of Survey Stations

The beginning and end of a chain line is called survey station. There are two types of survey stations.

a) Main survey station b) Tie station or Subsidiary station.

a) Main survey station: These are important points at the beginning and at the end of the chainlines.

b) Tie station: These are points selected on the main survey linesfor locating the interiordetails.

Fixing of SurveyStations

The following points should be kept in mind while fixing a survey station

1) Main stations should be located on plane ground and shouldbe mutuallyvisible.

2) The fundamental principle of surveying i.e. working from whole to part should be observed. Along line should be laid across and other triangles should be built onit.

3) The network should consist only well conditioned triangles.

4) Long offsets should beavoided.

5) The number of survey lines is to be made minimum as far aspossible.

6) Survey stations should not be fixed onthoroughfares.

2.9. Different Operations in Chain Surveying

Ranging : In measuring the length of a survey line, it is necessarythat the chain should be laid on the ground in a straight line between the end stations. If the line is short, it is easyto put the chain in true alignment. But if the line is long, it is necessary to place intermediate ranging rods to maintain the direction. Fixing of intermediate points in a straight line between the two end stations is known as ranging.

Ranging is of two types: a) Direct ranging b) Indirect ranging.

(a) DirectRanging

Direct ranging is adopted when the two end stations are mutually visible. The ranging is carried out by an eye or a line ranger.

Ranging by Eye

The ranging by eye is done by the following steps.

1) Fix ranging rods at each end of theline.

2) Stand about 1.5m beyond the first rangingrod.

3) Direct the assistant to hold the ranging rod vertically where intermediate point to befixed.

4) Direct the assistant to move left or right using code of signals until the three ranging rods are in straightline.

5) Check the verticality of the rods by sighting the lower ends of therods.

6) As and when the intermediate point is in straight line, signal the assistant to fix the rangingrod.

The following code of signals may be used in directing the assistant into line.

Rapid sweep with right hand – move rapidly to the right.

Rapid sweep with left hand – move rapidly to the left.

Slow sweep with right hand – move slowly to the right.

Slow sweep with left hand – move slowly to the left.

| Right arm extended | move continuously to right. | | | |
|---|---|--|--|--|
| Left arm extended | - move continuously to left. | | | |
| Right arm up and moved to the right – plumb the rod to the | | | | |
| right. left arm up and moved to the left – plumb the rod to | | | | |
| the left. Both hands up and brought down – correct. Both | | | | |
| arms extended forward | | | | |
| horizontally and the hands depress briskly. | ssed – fix the ranging rod in position. | | | |

Ranging by Line Ranger

Line ranger is an optical instrument used for fixing intermediate points on a chain line. It consists of two right angled isosceles triangular prisms placed one above the other.



For fixing an intermediate station P on the line AB, the observer stands as near P as possible and holds the instrument at his eye level. Rays of light coming from the ranging rods at A and B are reflected by the upper and lower prisms respectively and reach the eye. If the images of A and B are in separate lines as shown in fig (b), the observer moves a little perpendicular to AB such that both images will be in the same line as in fig(c).

The required position of P will be then exactly below the center of the instrument. One of two prisms can be adjusted by a screw. To test the instrument it is held at the mid point of a line and the ranging rods at the end station observed. If both rods appear in the same line, the instrument is in adjustment. Otherwise, the fixing screw of the movable prisms slackened and the prism slightly rotated so that both ranging rods appear in one line. Then the prisms fixed by tightening the fixing screw.

(b) IndirectRanging

Indirect ranging is adopted when the ends of the line are not mutually visible due to high intervening ground or the distance is too long. The process is also known as reciprocal ranging.



Let A and B are the ends of a chain line which has a rising ground intervening between them. Two chainmen with ranging rods take the position M_1 and N_1 such that they are as nearly is line with A and B as they could judge and such that the chainman at M_1 could see N_1 and B and chainman at N_1 can see M_1 and A. First chainmen at N_1 direct M_1 to M_2 so that he comes in line with A and N_1 .Then the chainman at M_2 directs N_1 to N_2 such that he comes in line with B and M_1 .

This process is repeated so that they align each other successively directing each other until they are in the line AB.

Chaining a Survey Line

To chain survey line the follower holds the chain in contact with the peg at the beginning of the line and then leader moves forward in line with the ranging rod fixed at the end of the chain line. The follower gives necessary directions in this regard so that leader moves incorrect alignment. The leader takes ten arrows in one hand and the handle in the other hand along with a ranging rod. At the end of the chain the leader holds the ranging rod vertically in contact and the instructions are given by the follower to move left or right using the code of signals. The leader then holds the handle in both the hands keeping him self in a straight line and straightens the chain by jerking it and stretches over the mark. He then fixes an arrow at the end of the chain. The leader then moves forward with the remaining nine arrows in hand. The follower holding the rear handle of the chain comes up to the arrow fixed by the leader and calls chain so that the leader stops moving forward. The process is repeated till all the arrowsare fixed by the leader. The follower who collected all these arrows hands over to leader. The number of arrows in the hand of the follower shows number of chain lengths measured. In this way the whole length of a survey line is measured.

Setting out Right Angles

The easiest way of setting out a right angle to the chain line is by the 3, 4, 5 rule. Triangles with sides in proportion 3:4:5 will be right angled.

1) Let PQ is chain line and B is a point on chain line at which a perpendicular is to beerected.

- 2) By measuring 9m from B the point A islocated.
- 3) Keeping zero end of the tape at A and 12m atB.
- 4) Stretch the tape laterally and put an arrow at 15m mark i.e.at point C.



5) Now CB will be perpendicular to the chain line PQ.

The instruments commonly used for setting out rightangles

are

1) Cross staff 2) Optical square.

2.9.4 Chaining along a sloped Ground

Since the distances required for plotting purposes are horizontal distances however, as a matter of convenience, they are sometimes made on sloping ground, but they are afterwards reduced to their horizontal equivalents. There are two methods of determining horizontal distances when chaining on sloping ground

.(1) Direct method and (2) Indirect method.

Direct method: By stepping; in the stepping method, horizontal distances are directly measured on the ground by the process of stepping which consists in measuring the line in short horizontal lengths, for this purpose, the chain is

Stretched horizontally with one end resting on the ground at a convenient height less than 1.8m and the point vertically below this end is then accurately found on

the ground by suspending a plumb bob and then marked. The next step in then commenced from this point and the process is continued in correct alignment until the end of the line is reached.



Fig. 2.10

The total horizontal distance $PQ = PP_1 + P_2P_3 + P_4Q_1$

Indirect Method: First Method : This method of stepping is not a very accurate method. The best way is to horiz ontal by using a Clinometer.



Fig. 2.11

Knowing the sloping distance say L and angle of slope say \Box the horizontal distance D = L Cos \Box

Second Method : The distance along with the slope is measured with chain and the difference in the elevation between the first and the end stations is found with the help of a levelling instrument (Fig. 2.12) knowing the sloping distance I and the difference in the elevation h, the horizontal distance can be found from the relation, $D = t_1 I^2 - h^2$



Hypotenusal Allowance Method : Another method is to measure the distance along the slope and apply a correction to get the horizontal distance. Let \Box be the angle of the slope. Let AC be the distance measured along the slope and AC₁ horizontal distance, 1 chain or 100 links.

AC =100 Sec \Box links. Therefore

Correction BC = AC -AB = $100(\text{sec} \Box - 1)$ links per 100 link chain.



Fig. 2.13

This correction is known as the hypotenuse allowance. The leader must place the arrow ahead of his end of the chain on slopping ground by this amount so that the horizontal distance would be 1chain.

$$(504)^2 - (65)^2$$

Principles Used in ChainTriangulation

The principle of the chain triangulation is to divide the area into a network of well conditioned triangles. The error will be leastwhen plotting a triangle when no angle of the triangle is less than 300 and more than 1200.Such triangles are called well conditioned triangles. Chain surveying is also called as chaintriangulation.

Recording FieldNotes

Field book: It is a book in which the field measurements and relevantnotes are recorded. It is about 200mm x 120mm in size and opens length wise. Each page is ruled with a single line or central column about 15mmwide running up the long length of the pages. The pages of the field book are machinenumbered.

A specimen page of a field book is shown in the fig 2.14.

At the commencement of the line in the book is written

- (1) The name and number of the surveyline.
- (2) The name, number of the station, and

(3)The symbol denoting the station.

Tie and subsidiary stations should be indicated by a circle or oval round their chainage figures. Offsets written opposite of them on right or left of the column. As the work proceeds, the nature and form of the objects to which offsets are taken should be sketched with conventional signs and with names written along them. The sketch is not drawn toscale.

The following points should be kept in view while booking the field notes:



Fig. 2.14

1) Each chain line should be started on a separatepage.

2) The survey should always face the direction of chaining and all measurements should be recorded as soon as they aretaken.

- 3) The notes should be complete and nothing should be left tomemory.
- 4) Over writing and erasing of notes should be avoided. If any entry is wrong any change in the notes is necessary, a line should be drawn through it and a correct one written aboveit.
- 5) Explanatory notes and reference to other pages whereever necessary should beadded.
- 6) Sketches of the various features located should beneat.

7) The complete record of the survey should include the following:

(i) Name of the survey(ii) Site of the survey(iii) The date of survey (iv) The length of the chain used and whether tested or not.(v) The rough sketch of the area to be surveyed showing north direction, proposed stations, main and tie lines etc.(vi) The names of the members of the party, and (vii) The page index of the chain lines and stations.

Obstacles in ChainSurveying

Obstacles sometimes interfere with chaining. In such cases the obstructed distances are found indirectly using the help of geometrical constructions. Obstacles may be classified into three categories.

1) Chaining free but visionobstructed

2) Chaining obstructed but visionfree

3) Both chaining and vision areobstructed.

1. Chaining free but visionobstructed:

In this it is possible to move chain between the two end stations but they are not visible to each other due to obstructions. There are two cases i) it is not possible to see both ends from intermediate stations. Ex: a hillock in between twostations.

ii) It is possible to see both the ends from any intermediatestation.

Case (i): In this case, the problem may be overcome by indirect ranging.

Case (ii): This case occurs when a pond, a tree intervenes, preventing thefixing of intermediate stations. In this case random line method maybe used. Let AB be the line whose length is required. Fig (2.16).From A run a line AB₁ called a random line, in any convenient direction. Chain the line to B from A make BB₁ perpendicular to AB₁ and measure BB₁.

Then $AB = AB_1^2 + BB_1^2$

Intermediate points such as C can be located on the line AB by measuring AC_1 .



Thus C can be located.

2. Chaining obstructed but vision free.

This is the case when a pond, river or plant stations intervenes. Two convenient points have to be located on the chain line on either side of the obstacle and the distance between them found.

There are two cases.

i) In which it is possible to chain round the obstacle e.g. a pond, a bend in the riveretc.

ii)In which it is not possible to chain round the obstacle, e.g. ariver.

Case i): Several methods are available; however, a few are described below.

Let AB be chain line and a pond intervenes.

1) Two convenient points C and D are selected on the chain line on either side of the obstacle. Erect equal perpendiculars CE and DF and measure the length EF



2) Select a point C on the chain the AB (fig 2.18) on one side of the obstacle and setout CD to clear the obstacle. At D erect a perpendicular DEto

clear the ob<u>stacle, cutting</u> the chain line at E. Measure CD and DE then $CE = CD^2 + DE^2$



3) Select two points C and D (fig 2.19) on either side of the obstacle. Set out perpendicular CE of length such that DE clears the obstacle. Measure CE and DEthen.

$$CD = DE^2 - CE^2$$

Case ii): The typical example of this class of obstacle is a river. There are several methods, of which a few are given below.



Fig. 2.20

 Select two points A and B (fig 2.20) on the chain line PR on oppositebanksoftheriver.SetoutaperpendicularADandbisectitat
 At D erect a perpendicular DE and mark the point E in line with Cand
 B. Measure DE. Since the triangles ABC and CED are similar. AB = DE

2) As before select two points A and B. Fig (2.21). Set out a perpendicular AD at A. with cross staff erect a perpendicular to DB at D, cutting the chain line at C. Measure AD and AC.

Since the triangles ABD and ACD are similar

$$\frac{AB-AD}{AD AC} \qquad \text{Hence , } AB = \frac{AD_2}{AC}$$



Fig. 2.21

3. Chaining and vision both obstructed: In this case the problem consists prolonging the line beyond the obstacle and determining the distance acrossit

A building is a typical example of this type of obstacle. Point C is chosen on the chain line AB as near as possible to the building and rectangles EFGC, DHJK are setup on either side of the obstruction, JH is ranged in line with FG. Then EF= CG=DH=KJ, FGHJ is a straight line and GH = CD, the missing portion of the chain line AB.



Fig. 2.22



Calculatio n of Areas

AREA OF THE FIGERS:

i) Area of Triangle:1//2bh

Where, b = Breadth of triangle h =height of triangle

ii) Area of ScaleneTriangle

$$A = \sqrt{S(S-a)(S-b)(S-c)}$$
 where $S = (a+b+c)/2$

Area of parallelogram = $L(h_1 + h_2)$ where h_1, h_2

are heights of parallelogram.

Area of thecircle=

2 or $\pi d^2/4$ where r= radius of circle, d= diameter of circle.

The area of the field measured by Offset Survey method. The given field is divided into no. of parts and calculated the area

| Fig | Change | Offset | Average | Area | Total |
|-----|--------|--------|------------|------|-------|
| | | | of offsets | | Area |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

One of the purposes of land surveying is to find the area of a piece of land.

Following are the methods of finding the area of a piece of land with irregular boundary..

i)Average ordinate rule.

ii)Simpson'srule

iii) Trapezoidalrule.

i) Average ordinate rule: In this method, the base line is divided into a number of equal divisions and ordinates are drawn at each point of division and measured. The average length of the ordinate multiplied by the base line length and divided by the number of ordinates gives the requiredarea.



where O_0 , O_1 , O_2 O_n = Ordinates taken at eachdivision

L = Length of the base

n = no. of equal divisions of base line

(ii) **Simpson's rule:** In this method the area is divided into strips of equalwidth d and the number of these strips must be even and this rule is suitable for areas consisting long thin pieces ofland.



Area of the land = d (sum of first and last ordinates) + 2(sum of the 3 other odd Ordinates) + 4(sum of even ordinates)

where d = width of strip

iii) **Trapezoidal rule:** In this method the area is divided into a number of equal strips, but any number of strips may be used unlike the Simpson's rule which requires an even number of strips.



Fig. 2.28 The area land = $\left[width \text{ of strip } [((sum of 1st and last ordinates)/2) + (sum of all the other ordinates)] \right]$

(1) By trapezoidalrule:0

The area of land =

width of strip x [(sum of 1st and last ordinates)) + (sum of all other 2 ordinaes)]

SUMMARY

Accessories used in Chainsurvey:

- (i) Chain
 (ii) Tape
 (iii) Ranging Rods
 (iv) offset rod
 (v) Cross staff
 (vi) Arrows
 (vii) Plumb bob
 (viii) pegs
- 1) Ranging is the operation of establishingintermediate points on a straight line between two endstations.
- 2) Types of Ranging
- 3) Base line is the longest line of all the survey lines and which runs across thearea.
- 4) Check line is used to check the accuracy of the frame workas well as plottingwork.
- 5) Offset is a length measured from a point on a chain line to adetail.
- 6) Tie line is a line which joins two tiestations.
- 7) Types of Chains
 - (i) Metric chain(ii) Engineer's chain
 - (iii) Gunter chain (iv) Revenue chain
- 8) Obstacles in chainsurveying
 - (i) Chaining free but vision obstructed
 - (ii) Chaining obstructed but vision free
 - (iii)Both chaining and visionobstructed
- 9) Methods of calculating Landarea
 - (i) Average ordinate rule
- (ii) Simpson's rule
- (iii) Trapezoidalrule

Short Answer Type Questions

- 1. Write the principle of chainsurveying
- 2. Define Baseline
- 3. Define Ranging and write types ofranging
- 4. Write types of obstacles in chainsurveying
- 5. What is a checkline?
- 6. What is a tieline?
- 7. Write the types of surveystations
- 8. .What are the diffirent types of chains?
- 9. What is a well conditioned triangle?
- 10. What is the use of crossstaff?
- 11. A distance of 1200m is measured with 20m metric chain, after the measurement, it is found that the chain is 10cm long. Correct the measured distance.
- 12. Write the methods of calculatingareas.
Long Answer Type Questions

1. Name and explain the accessories used in chainsurveying.

2. Write types of obstacles in chain surveying and explain various methods

- 3. Explain the procedure of indirectranging.
- 4. Explain the procedure for chaining up a hillslope.
- 5. Explain the procedure of ranging bylineRanger.
- 6. Calculate the area in sq. meters enclosed between the survey line, the irregular boundary line and the first and last ordinates by i) Average ordinate rule ii) Simpson's rule and iii) Trapezoidal rule.

Activities

• Studythe making of metric chains and learn the procedure of unfolding and folding of chain.

- Range the given two points on the ground.
- Set out a right angle at a given point on the surveyline by 3.4.5 method.

UNIT 3

Compass Surveying

Learning Objectives

After studying this unit, the student will be able to

- Understand what is meridian and types of meridian
- Bearing and types ofbearings
- Representation ofbearing
- Conversion of whole Circle Bearing into QuadrantalBearing.
- Calculating included angles of a closed traverse from observedbearings.
- Local attraction, correcting the bearings for localattraction.

Introduction

According to the method employed, surveying is classified into Triangulation surveying and Traverse surveying. A series of connected survey lines of known lengths and directions is called a traverse. When triangulation is not possible, traversing method is used. In traversing, when compass is used for making angular measurements, it is known as compass traversing or compass surveying.

PURPOSEANDPRINCIPLES OFCOMPASSSURVEYING:

Compass surveying is suitable in the following situations:

- 1. When the survey work is to be completedquickly.
- 2. When the area is hilly and chaining is difficult.
- 3. When the area to be surveyed is relatively large.
- 4. When the details are toomany.

- 5. When the area is can't be divided into network oftriangles.
- 6. When the area to be surveyed is long and narrow e.g. road, streametc.
- 7. When the survey is to be done through denseforest.

Principle of Compass Surveying

In compass traversing the directions of survey lines are fixed by angular measurements and not by forming a network of triangles. A compass survey is one in which the traverse work consists of series of lines the lengths and directions of which are measured with a chain or a tape, and with an angular instrument respectively.

A traverse may be classified as:

- a) Closed traverse
- b) Opentraverse

A) Closed traverse: A closed traverse is a traverse in which the sides of a traverse form a closed polygon.

B) Open traverse: An open traverse is a traverse in which thesides oftraverse do not form a closedpolygon.



Description of Prismatic Compass

The prismatic compass consists of a circular box about 85 to 110 mm diameter. At the center of metal box a needle and pivot is provided. The pivot balances the magnetic needle which is attached to graduated aluminiumring. The graduations are in degrees to 30 minutes and from 0^0 to 360^0 in the clock wise direction. The 0^0 is marked at south end of magnetic needle because the readings are read at the opposite end of the object. At west it is marked 90^0 , north 180^0 and east 270^0 respectively. The graduations are marked inverted because they are viewed through a prism which is cut to 45^0 on one face and 90^0 for other two faces. The readings get reflected through prism resulting in erected image. A sighting slit is provided in the box carrying the prism. This box can be moved up and down for focusing by means of stud. The prism box is hinged so that it can be folded to the rim of the compass box. Two sun glasses are provided to observe bright objects. An object vane is provided in line of sighting slit. It is an open frame with a central vertical horse hair for sighting the object. The object vane ishinged

to compass. When it is not in use, it is folded flat on the glass cover. The base of object vane presses the lifting pin bringing the magnetic needle to rest with the help of lifting lever. A brake pin is provided to stop the oscillations of the graduated ring to facilitate the reading of the graduated ring. A glass cover is fitted over the box to protect the needle from dust. The compass is fitted to a tripod stand. A tripod stand consists of a ball and socket joint which helps in leveling the compassquickly.



Fig. 3.2

Method of using Prismatic Compass: The compass may be held in thehand, but for better results, it is usually mounted on a tripod which carries a vertical spindle in a ball and socket joint to which the box is screwed. By means of this arrangement the instrument can be quickly leveled and also rotated in a horizontal plane and clamped in any position.

Working of Prismatic Compass

This can be used while holding it in hand, but for better accuracy, it is usually mounted on a light tripod which carries a vertical spindle in the ball and socket arrangement to which compass is screwed. By means of this arrangement the compass can be placed in position easily. Its working involves the followingsteps.

(i) Centering (ii) Levelling, and (iii) observing the bearing

(i) Centering

The compass should be centered over the station where the bearing is to be taken by dropping a small piece of stone so that it falls on the top of the peg marking the station.

(ii) Levelling

The compass should then be leveled by eye, by means of a ball and socket joint so that the ring may swing quite freely. It should be clamped when leveled.

(iii) Observing theBearing.

To observe the bearing of a line AB

1) Centre the compass over the station A and levelit.

2) Having turned up vertical prism and the sighting vane, raise or lower the prism until the graduations are clearlyvisible.

- 3) Turn the compass box until the ranging rod at the station B is bisected by the hair when looked through the slit above the prism.
- 4) When the needle comes to rest, look through the prism and note the reading at which the hair line produced appears to cut the image of the graduated ring which gives the required bearing of the line AB. Readings are usually estimated to the nearest15'.

Concept of Meridian, True Median, Magnetic Meridian and ArbitraryMeridian

Meridian: Meridian is a standard direction from which, the bearings of survey lines are measured. There are three types of meridians.

1) Truemeridian

2) Magneticmeridian

3) Arbitrarymeridian.

True meridian: It is a line of intersection of earth's surface formed by aplane passing through north and south poles and the given place.

Magnetic meridian: It is the direction indicted by a freely suspendedmagnetic needle.

Arbitrary meridian: It is any convenient direction assumed asmeridian for measuring bearings of survey lines.

Bearing

It is a horizontal angle made by the survey line with reference to the meridian, based on the meridian the bearings are threetypes.

1) True bearing 2) Magnetic bearing 3) Arbitrarybearing

True bearing: The angle made by a survey line with reference to truemeridian is called true bearing. It is always remains constant.

Magnetic bearing: The angle made by a survey line with reference tomagnetic meridian is called magnetic bearing. It changes from place to place and time.

Arbitrary bearing: The angle made by a survey line with reference to arbitrary meridian is called arbitrary bearing.

3.3.1. Representation of Bearing

Bearings are expressed in the following two systems.

- 1) Whole circle bearingssystem.
- 2) Quadrantal bearingssystem.

1) Whole CircleBearing

In this system, the bearing of a line is always measured clock wise from the direction of the north of the meridian towards the line around the circle. Whole circle bearings of lines have been shown in fig 3.3



Fig. 3.3

2) QuadrantalBearings

In this system the bearings of a line is measured from either the north or the south, clock wise or counter clockwise whichever is nearer to the line towards the east or west. The angle at any station in a plane is divided into four quadrants by two lines at right angles to each other. These are the north south and east- west lines. The bearing is reckoned from 0^0 to 90^0 in each quadrant. Quadrantal bearings of lines have been shown in fig 3.4 Quadrantel bearings are also called as reducedbearings.



Fig. 3.4

Conversion of Whole Circle bearings into Quadrantal Bearings

The whole circle bearing of a line can be converted to quadrantal bearing by reducing it to an angle less than 90^0 which has the same numerical value of the trigonometric functions. Rule of conversion of whole circle bearings into quadrantel bearing.

| S.No. | W.C.B | QUADRANT | RULE |
|-------|---|----------|-------------------------------|
| 1. | Between 0 ^o to 90 ^o | N.E | Q.B = W.C.B |
| 2. | Between 90 ⁰ to | S.E | Q.B = 180 ⁰ -W.C.B |
| 3. | Between 180 ⁰ to | S.W | Q.B =W.C.B-180 ⁰ |
| 4. | 270 ⁰ | N.W | Q.B =180 ⁰ -W.C.B |

Example 3.1

1. Convert the following whole circle bearings of lines to quadrental

bearings. a) OA 32⁰ b) OB 109⁰ c) OC 211⁰ d) OD303⁰

Solution:

Refer to fig 3.5



a) W.C.B of $OA = 32^0$

b) W.C.B of OB =109⁰

Quadrantal bearing = $108^{0} - W.C.B = 180^{0} - 109^{0} = S \ 71^{0} E$ c) W.C.B of OC = 211^{0} Quadrantal bearing = W.C.B - $180^{0} = 211^{0} - 180^{0} = S \ 3^{10} W$

d) W.C.B of OD $=303^{0}$

Quadrantal bearing = 360° – W.C.B = 360° – 303° = N 57[°] W

Example 3.2

Convert following reduced bearings to the whole circlebearings:

(i)N52^o30'E (ii)S 30° 15'E (iii)S 85° 45'W (iv)N15^o10'W

Solution:

| (i) | R.B.=N52°30'E&whichisintheNEquadrant, |
|-------|---|
| | Therefore W.C.B =same as $R.B = 52^{\circ}30$ '(Ans.) |
| (ii) | S 30° 15'E which is in the SE quadrant, |
| | Therefore W.C.B = $180^{\circ}-30^{\circ}15' = 149^{\circ}45'$ (Ans.) |
| (iii) | S 85°45'W which is in the SWquadrant, |
| | Therefore W.C.B = $180^{\circ} + 85^{\circ} 45' = 265^{\circ} 45'$ (Ans.) |
| (iv) | N 15 ^o 10'Wwhich is in the NWquadrant, |
| | Therefore W.C.B = $360^{\circ} - 15^{\circ}10' = 344^{\circ}50'$ (Ans.) |

Compass Traversing in the Field

Compass survey requires the following instruments:

- 3) Prismaticcompass
- 4) Chain and arrows
- 5) Tape
- 6) Rangingrods
- 7) Pegs.

The compass traversing of an area involves the following steps:

1) Reconnaissance of area

2) Determining the direction of line

3) Measuring the traverse legs and offsets.

1. Reconnaissance of area: The area is divided into triangles and ofpolygons. Suitable stations are selected on the rough sketch and designated as A, B, Cetc.

2. Determining the directions of survey lines: The compass is set ateach successive stations i.e., A, B, C, D, E of the closed traverse ABCDEA and the fore bearings and back bearings of lines areobserved.

3. Measurement of traverse legs and offsets : A compass is centeredover a station A and after leveling the compass the fore bearing AB and back bearing EA are taken by sighting the ranging rods at A and E. The line AB is chained and the offsets to the detailed points are noted and entered in the field notes. The operation is repeated at other stations B, C, D, andE

Forward and Backward Bearings

In compass surveying, two bearings are observed for each line, one from each end of the line. The bearing of a line in the direction of the progress of survey is called the forward bearing or fore bearing while the bearing measured in the opposite direction is called as the backward bearing or back bearing.



The difference between the fore bearing and back bearing of a line is 180° .

Back bearing = fore bearing $\pm 180^{\circ}$.

Example 3.2: The following are the observed fore bearings of lines of atraverse.

Find their back bearings:

a) AB $42^{0} 45$, b) BC $128^{0} 15$, c) CD $232^{0} 15$, d) DE $301^{0} 30$, Solution: a) FB of AB = $42^{0} 45$, BB of AB = $42^{0} 45$, + $180^{0} = 222^{0} 45$, b) FB of BC = $128^{0} 15$, BB of BC = $128^{0} 15$, + $180^{0} = 308^{0} 15$, c) FB of CD = $232^{0} 15$, + $180^{0} = 52^{0} 15$, BB of CD = $232^{0} 15$, - $180^{0} = 52^{0} 15$, d) FB of DE = $301^{0} 30$, BB of DE = $301^{0} 30$, - $180^{0} = 121^{0} 30$,

Local Attraction

A compass needle is affected by the presence of masses of iron and steel such as lamp posts electric cables, steel girders etc., they deflect the needle and the effect of this disturbance is called local attraction. Due to local attraction, the difference between the fore bearing and back bearing of a survey line will not be equal to 180° . The observed bearings of lines affected by local attraction are corrected by starting from the unaffected line and the correct bearings of the successive lines are calculated.

Example 3.3

The following are the bearings of the lines of the closed traverse ABCDA taken with a compass in a place where local attraction was suspected.

| Line | F.B. | B.B. |
|------|----------------------|----------------------|
| AB | 35 ⁰ 30' | 215 ⁰ 30' |
| BC | 115 ⁰ 15' | 294 ⁰ 15' |
| CD | 180 ⁰ 45 | 3 ⁰ 45' |
| DA | 283 ⁰ 45' | 101 ⁰ 45' |

| | Correct the | bearings | of the | lines for | local | attraction |
|--|-------------|----------|--------|-----------|-------|------------|
|--|-------------|----------|--------|-----------|-------|------------|

Solution:

It is observed that the difference between the fore and back bearings of the line AB is exactly 180° , hence stations A and B are free from local attraction and the bearings observed A and B are correct. The difference of FB and BB of other lines is not 180° . Local attraction is present at those stations. The observed of BC is also correct since B is unaffected by local attraction.

| Observed F.B.ofBC | $= 115^{0}15'$ |
|-------------------------------|----------------------|
| Add | $=180^{0}0$ ' |
| Correct BBof BC | $= 295^{0}15'$ |
| Less Observed BBof BC | $= 294^{0}15'$ |
| Error due to local attraction | h at $C = 1^{0}00$ ' |

Since the error is negative all bearing observed at C must be corrected by adding $1^{0}00^{\circ}$

| Observed F.B.ofCD | =180°45' |
|------------------------------------|-----------------|
| Addcorrection | = 1°00' |
| Correct FBof CD | $= 181^{0}45'$ |
| Deduct180 ⁰ | $= 180^{0}00$ ' |
| Correct BBofCD | $=1^{0}45$ '. |
| ObservedBBofCD | $= 3^{0}45$ '. |
| Error due to local attraction at D | $=2^{0}00$. |

Hence all bearings observed at D must be corrected by -2^000 ' for local attraction.

| Observed F.B.ofDA | | =283 ⁰ 45' |
|-------------------|---|-----------------------|
| Add correctionatD | | $= -2^{0}00'$ |
| Correct FBofDA | | =281 ⁰ 45' |
| Less | | =180 ⁰ 00' |
| | Δ | |

Correct BBofDA $=101^{0}45'$

This is the same as the observed BB of DA which shows that there is no local attraction at A.

| Line | F.B. | B.B. |
|------|----------------------|----------------------|
| AB | 35 ⁰ 30' | 215 ⁰ 30' |
| BC | 115 ⁰ 15' | 295 ⁰ 15' |
| CD | 181 ⁰ 45 | 1 ⁰ 45' |
| DA | 281 ⁰ 45' | 101 ⁰ 45' |

The corrected bearings of the lines will be as follows:

Calculation of Included Angles of a Traverse in CompassTraverse

When two lines meet at a point two angles i.e., interior and exterior angles are formed. The sum of these two angles is equal to 360° . The following rules may be applied to find the included angle between two lines whose bearings are given.

Finding of included angles is divided into two cases as follows:

1. When the W.C.B of two lines measured from their point of intersection are given

2. When the W.C.B. of two lines not measured from their point of intersection are given.

Case (1) When the W.C. bearings of two lines measured from their pointof intersection are given

Rule: Subtract the smaller bearing from the greater one. The difference will give the included angle. If it is less than 180^{0} However if the difference exceeds 180° it will be the exterior angle.

The included angle is then 360° – exterior angle

.

Example 3.4

Find the angle between the lines OA and OB given their bearings. .

i)
$$25^{0}45'$$
 and $140^{0}00'$ ii) $35^{0}15'$ and $315^{0}15'$ iii) $115^{0}15'$ and $250^{0}15'$

~

Solution:

Since the difference is greater than 180° , it is the exterior angle, Interior angle

BOA =
$$360^{0}00' - 280^{0}00' = 80^{0}00'$$

iii) OA = $115^{0}15'$ and OB = $250^{0}15'$

$$= 250^{0}15' - 115^{0}15' = 135^{0}00'$$

Example 3.5

The bearing of a line AB is $133^{0}30$ ' and the angle ABC is $120^{0}32$ ' what is the bearing of BC?

Solution:

Bearing of $AB = 133^{0}30$ ' bearing of BA = $133^{0}30' + 180^{0} = 313^{0}30'$ bearing of BC = bearing of BA+ Angle ABC $= 313^{0}30' + 120^{0}32' = 434^{0}02'$ $=434^{0}02 - 360^{0} = 74^{0}02$

Example 3.6

| Side | Fore Bearing | Back Bearing |
|------|----------------------|----------------------|
| AB | 105 ⁰ 15' | 285 ⁰ 15' |
| BC | 20 ⁰ 0' | 200 ⁰ 0' |
| CD | 229 ⁰ 30' | 49 ⁰ 30' |
| DE | 187 ⁰ 15' | 7 ⁰ 15' |
| EA | 122 ⁰ 45' | 302 ⁰ 45' |

The bearings of the sides of a closed traverse ABCDE are as follows:

Compute the interior angles of the traverse.

A = Bearing of AE \square Bearing of AB = B.B. of EA \square FB of AB = $302^{0}45$, \square $105^{0}15$, \square $197^{0}30$, = exterior angle Interior angle A = Angle EAB = $360^{0} - 197^{0}30$, = $162^{0}30$,

= B.B. of AB \Box FB of BC = 285⁰15' \Box 20⁰00' = 265⁰15' = exterior angle Interior angle B = Angle ABC = 360⁰ - 265⁰15' = 94⁰45'

= B.B. of BC \Box FB of CD = 200⁰0' \Box 229⁰30' = 29⁰30' = interior angle D = Bearing of DC \Box FB of DE = B.B. of CD \Box FB of DE = 49⁰30'' \Box 187⁰15' = 137⁰45' = interior angle E = Bearing of ED \Box Fore bearing of EA

= B.B. of DE
$$\Box$$
 FB of EA
= 7⁰15'' \Box 122⁰45' = 115⁰30

Check: The sum of the interior angles of a closed traverse must equal to(2n-4) right angles, where n is the number of the sides of the traverse. In this case the sum of the angles must be equal (10-4) x $90^0 = 540^0$.

 $\underline{|A||B||C||D||E} = 162^{0}30' + 94^{0}45' + 29^{0}30' + 137^{0}45' + 115^{0}30' = 540^{0}00'.$ Hence checked.

Errors in CompassSurveying

Errors in compass surveying are classified as follows:

a) Natural Errors b) InstrumentalErrors

a) Natural Errors: Natural errors are of twotypes:

1. Errors of manipulation and sighting

2. Errors due to externalinfluences

1. Errors of manipulation and sighting

i) Inaccurate centering of the compass

ii) Inaccurate leveling of the compass box

iii) Imperfect bisection of the ranging rods atstations

iv) Carelessness in reading thegraduations

v) Carelessness in recording the observedreadings

2. Errors due to externalinfluences

i) Magnetic changes in atmosphere on a cloudy or stormyday

ii) Variations indeclinations

iii) Local attraction due to proximity of steelstructures

b) InstrumentalErrors:

i) The needle not being perfectlystraight

ii) The pivot beingbent

iii) The needle beingsluggish

iv)The needle not movingfreely.

- v) The line of sight is not beingvertical.
- vi) The graduated circle not beinghorizontal.
- vii) The line of sight not passing through the centre of the graduated ring and
- viii) The vertical hair beingloose.

Summary

- 1. Closed traverse is a traverse in which the sides of a traverse form a closedpolygon.
- 2. Open traverse is a traverse in which the sides of atraverse do not form a closedpolygon.
- 3. Meridian is a standard direction from which, the bearings of the lines are measured.
- 4. Types of Meridian.
- (i) True meridian. (ii) Magnetic meridian. (iii) Arbitrary meridian.
- 5. Bearing is a horizontal angle made by the survey line with reference to themeridian.
- 6. Bearings of survey lines are representedin
- (i) Whole Circle Bearing System. (ii) Quadrantal BearingSystem.
- 7. The difference between fore bearing and back bearing of a line should be1800.
- 8. Local attraction: A compass needle is affected by the presence of masses of iron and steel such as lamp posts, electric cables, steel girders etc. They deflect the needle and gives the

Short Answer Type Questions

wronging value of bearing the effect of this disturbance is called local attraction.

- 1. Definebearing
- 2. DefineMeridian
- 3. Write the methods of representingbearing.
- 4. Convert the following WCB in to the reduced

bearings. a) 30^045 , b) 215^015 ,

5. Define local attraction.

6. Write the types of meridian.

7. Find the angles between the lines AB and AC if their respective bearings are $145^{0}30$ ' and $56^{0}45$ '

8. Define fore bearing and back bearing of aline.

9. What is a closedtraverse?

Long Answer Type Questions

1. Explain the construction of prismatic compass with a neatsketch

2. Write the errors in compass survey, explain the instrumental errors

- 3. How do you detect local attraction in compasssurvey?
- 4. Calculate the interior angles of given traverseABCDA.

| LINE | F.B | B.B |
|------|---------------------|----------------------|
| AB | 40°. 0" | 220 0" |
| BC | 130 0" | 310 0" |
| | 220 [°] 0″ | 40 [°] 0″ |
| CD | 310 0" | 130 ^{°'} 0″ |
| DA | 510 0 | 150 0 |

UNIT 4

Levelling

- Understanding the concept and purpose oflevelling.
- Terms like Level surface, datum reduced level, and benchmake.
- Temporary adjustments of a dumpylevel
- · Recording the observations in the fieldbook
- Reduction of levels by H.I. method and Rise and fallmethods
- Errors, combined correction for curvature and refraction

Introduction.

Levelling is the process of finding the difference in elevation between points or relative heights and depths of the objects on the surface of the earth. It is the part of surveying which deals with the measurements in vertical plane. Levelling is veryimportant to an engineer for the purpose of planning, designing, estimating and executing various engineering works such as roads, railways,

Learning Objectives Purpose of Levelling

canals, dams, irrigation, pipe lines, buildings. Water supply schemes. Levelling is done for the following purposes.

1) To measure a contour map for fixing sites for reservoirs, dams, etc. and to fix the alignment of roads, railways, irrigation canals and soon.

2) To determine the altitudes of different important points on a hillor To know the reduced levels of different points on or below the surface of the earth.

3. To measure a longitudinal section and cross section of aproject (roads, railways, irrigation canals etc) in order to determine the volume of earthwork.

4. To prepare a layout map for water supply, sanitary or drainageschemes.

Definition of Terms

Level Surface: a level surface is any surface parallel to the mean spheroidsurface of the earth, e.g., the surface of a still lake. Each point on the level surface is perpendicular to the direction of gravity.

Datum: This is an arbitrary assumed surface with respect to the

mean sealevel above which the elevations of points are measured.

Level line: A line lying through out on a level surface is a level line. This is normal to the plumb line at allpoints.

Horizontal plane: Horizontal plane through a point is a plane tangential to the level surface at that point. It is, therefore, perpendicular to the plumb line through the point.

Horizontal Line: It is a straight line tangential to the level line at a point. It is also perpendicular to the plumb line.

Vertical Line: It is a line normal to the level line at a point. It is commonlyconsidered to be the line defined by a plumb line.

Mean sea Level: Mean sea level is the average height of the sea for allstages of the tides. At any particular place it is derived by averaging the hourly tide heights over a long period of 19 years.





Change Point

An intermediate staff station at which both back sight and fore sight are taken with the purpose of changing the position of the instrument is called a change point or turning point.

Reduced Level

Reduced level is the elevation of the point where the staff reading is taken with respect to the assumed datum.

Back Sight: It is the reading taken on a staff held at a point of knownreduced level or elevation. If the reading is added to the reduced level of the point or staff, the R.L of the height of the instrument, i.e., the height of collimation will be obtained. Hence back sight is considered to be positive. It is the first reading taken after the level is set up.

In fig 4.2 if the R.L of station A is 100.00 and B.S reading is 1.34, then the height of instrument is 100.00 + 1.34 = 101.34m.

Fore Sight: Fore sight is a staff reading taken on a point whose elevationis not known and has to be determined. It is the last staff reading before shifting the level to another position, if the fore sight

reading is subtracted from the height of instrument; the reduced level of the point is obtained. Therefore it is known as minussight.

Ex: if the height of collimation is 101.34 (fig 4.2) and the F.S reading on staff held at B is 2.21, then the R.L of the station B is 101.34 - 2.21 = 99.13m.



Fig. 4.2

Intermediate Sight: Any reading other then the Back sight and the foresight are taken on a point whose reduced level is not known is called an intermediate sight. For e.g. If the reading on a staff placed at an intermediate station C is 2.21 and the height of collimation is 101.34, then the R.L of the station C is 101.34 - 2.21 = 99.13.

Bench Mark

Bench mark is a relatively permanent point of reference whose elevation with respect to some assumed datum is known.

Types of Bench Marks

There are four kinds of bench marks viz.

1. G.T.S benchmarks.

2. Permanent benchmarks.

3. Arbitrary bench marksand

4. Temporarybenchmarks.

1. G.T.S BenchMarks

These bench marks are established in the course of the great trigonometric survey conducted by the survey of India department with sophisticated instruments and under highly accurate and precise conditions of work They are established all over the country. Their locations and reduced levels with reference to the mean sea level at Karachi are published by the government of India in the form of a catalogue.

2. Permanent BenchMarks

These bench marks are established by state government departments such as the Irrigation and power, Roads and Buildings, Panchayat raj Engineering etc. on well defined points such as the parapet wall of a bridge or culvert, corner of a building, plinth etc. these are connected to

G.T.S bench marks and their levels are marked on the point.

3. Arbitrary BenchMarks

These are points of reference with any assumed level. These are used only for limited purposes.

4. Temporary BenchMarks

In a continuous program of leveling work it is necessary to close a day's work on a reference point taken on a permanent location and continue the work the next day. Such points of reference for leveling are known as Temporary bench marks.

Types of LevellingInstruments

The instruments generally used in levelling are

1. Level 2. Levellingstaff.

Level: A level provides a horizontal line of sight from which the heightsof different points are determined. A level consists of the following essential parts.

a) A telescope to provide the line of sight.

b) A level tube to make the line of sighthorizontal.

c) A leveling head to bring the bubble to its center ofrun.

d) A tripod to support theinstrument.

Types of Levels

There are chiefly four different types of levels.

a) Dumpylevel

b) Wyelevel

c) Reversible level

d) Tiltinglevel.

Dumpy Level

Fig 4.3 shows the component parts of a Dumpy level



Fig. 4.3

Component Parts of Dump Level

1. Tripod Stand: The tripod stand consists of three legs which may besolid or framed. The legs are made of light and hard wood. The lower ends of the legs are fitted with steelshoes.

2. Leveling Head: The leveling head consists of two parallel triangularplates having three grooves to support the footscrews.

3. Foot Screws: Three foot screws are provided between the trivetand tribach. By turning the foot screws the tribach can be raised or lowered to bring the bubble to the centre of itsrun.

4. Telescope: The telescope consists of two metal tubes, onemoving with in the other. It also consists of an object glass and an eye piece on opposite ends. A diaphragm is fixed with the telescope just in front of the eyepiece. The diaphragm carries cross hairs. The telescope is focused by means of the focusing screw and may have either external focusing or internalfocusing.

5. Bubble Tubes: Two bubble tubes, one called the longitudinal bubbletube and other the cross bubble tube, are placed at right angles to each other. These tubes contain spirit bubble. The bubble is brought to the center of its run with the help of foot screws. The bubble tubes are fixed on tow of thetelescope.

6. Compass: A compass is provided just below the telescope for taking the magnetic bearing of a line when required.

Relationship between the fundamental lines of a Dumpy level

The following lines have been identified as the fundamental lines of leveling instrument.

1. Line of collimation.

2. Axis of bubbletube.

3. Axis oftelescope

4. Verticalaxis.

Line of collimation: It is an imaginary straight line joining theintersection of the cross hairs at diaphragm to the optical centre of the object glass and its continuation. It is also called the line of sight. When the bubble is in the center of its run, the line of collimation will be horizontal.

Axis of Bubble tube: It is an imaginary line tangential to the curvedsurface of the bubble tube at its middle point, it is also known as bubble line. When the bubble is in the centre of its run, the bubble line will be horizontal.

Axis of Telescope: It is the imaginary line joining the center of the eyepiece and the optical center of the object glass.

Vertical Axis: The axis about which the telescope can be turned in ahorizontal plane is known as the vertical axis of the instrument.

Relation between the fundamental lines of dumpy level.

1. Axis of bubble tube should be perpendicular to verticalaxis.

2. The line of collimation of telescope is parallel to the axis of bubble tube.

Types of LevellingStaffs

A levelling stave or staff consists of a straight rectangular piece of well seasoned wood on which graduations are painted. Reading on the staff with a leveling instrument shows the height of the station above or below the line of sight of the level.

Levelling staffs are of two types.

- 1. Self reading staffs.
- 2. Targetstaffs.

In the self reading staff, the level man observes the staff reading where the horizontal wire appears to intersect the face of the rod through the level. The level man records the readings. The Target staff is provided with a vernier which is adjusted by the staff man under the direction of the level man who observes through the level, until the horizontal cross hairs of the diaphragm coincides with the center of the vernier. The reading is recorded by the staff man. Target staffs are used where the sights are long. However, these are not commonly used in India.

Self reading staffs are available in 3 forms.

- 1. Telescopicstaff.
- 2. Folding metricstaff
- 3. Solid staff.

Telescopic Staff

The telescopic staff is available in 3 parts which telescope into one another. (Fig 4.4). It is 4 meter long when fully extended. The top length meters is solid and slides into the bottom box 1.5m long. The extended lengths are kept in position by means of brass spring catches. The smallest division in this staff is 5mm. The meter numbers are marked on the left side and are painted in red. The decimeter numbers are on the right and painted in black. The graduations are marked erect and hence are seen inverted through the telescope. This is the most commonly used staff in India.

Folding Metric Staff

The folding type staff is lighter, more convenient to handle and gives more accurate readings. The folding staff (Fig 4.4) is made of well seasoned wood. It is 75mm wide, 18mm thick and 4m long. It has two lengths of 2m each and connected at the middle by means of a locking device. It can be detached into two pieces or folded into two or can be attached together to form a rigid and straight staff. It is fitted with a circular bubble of 25 minutes sensitivity at the back and is provided with two handles. The minimum division on the staff is 5mm; each meter length is divided into 200 divisions. The meter numbers are painted on the right in red. The lines dividing the tenths of meter lengths are also painted in black and the entire background is painted in white. The graduations are inverted and hence when viewed through the telescope they appearerect.

Solid Staff

It has only one length and is usually 3m long. It is graduated in divisions of 5mm in the same way as the telescopic metric staff. It is used for precise levelingwork.

This is much used in America. It is graduated like a telescopic staff, but is fitted with a sliding vane or target of circular shape. The quadrants are painted black and white alternately round a square central hole through which the staff graduations are visible. The sighting vane is moved up and down until the center of the target coincides with the horizontal cross hair in the telescope of the level. The rod itself consists of two sliding lengths.

The target staff has the following advantages.

a) It can be used for longsights.

b) It is ideally suits to reciprocalleveling.

c) The surveyor travels with the staff instead of the level. This enables the surveyor to place the staff at all points on the ground where the slopechanges.



Temporary Adjustments of theLevel

Temporary adjustments are those which have to be performed at every Instrument setting and are done before the observations are taken with the instrument. Permanent adjustments are made when the fixed relationship between the fundamental lines of an instrument is disturbed. Once these adjustments are made, they last for a long time.

Temporary adjustments of dumpy Level

The temporary adjustments consist of the following two operations.

1. Settingup,

2. Levelling up, and

3. Elimination of parallax

1. Settingup

First the instrument is fixed on the tripod, whose legs are then adjusted for approximate leveling. The instrument is held in one hand and screwed onto the tripod firmly. Next the legs are adjusted to bring the telescope to eye level, and then further adjusted till the instrument is approximately level, judged by the eye and the circular spirit- bubble or cross-level tube. In adjusting the tripod, two legs are kept firmly in a convenient position, and the third is moved sideways in, or out. Asrequired.

2. Levelingup

The telescope is placed parallel to a pair of the foot screws and the long bubble is brought to the center of its run by turning both these foot screws in or out. The telescope is now turned through 90° , kept nearly over the third foot screw, and the bubble brought to the centre again. The process is repeated until the bubble remains central for all positions for permanent adjustment.

3. Elimination of parallax: Elimination of parallax involves two steps

i) Focusing of the eye piece for distinct vision of the cross hairs at diaphragm andii) focusing the object glass for bringing the image of the object into thediaphragm.

i). Focusing the eye piece: The telescope is turned towards the skyor a piece of white paper is held in front of the telescope the eye piece is adjusted moving it in or out till a sharp and distinct image of the cross hairs is seen.

ii). Focusing the object glass: The telescope is directed towards the staff and the focusing screw is turned until a clear and sharp image of the staff graduations is obtained. The eye is moved up and down if the reading is not changed, then parallax is completely eliminated, the object

Field Work and Principles of Levelling

glass is focused every time a staff reading is taken. **Simple levelling**

The steps involved in the process of simple levelling are:

a) Finding the height of the instrument i.e. R.L of line of sight by taking a sight on a knownB.M.

b) Finding how much the next point is below or above the line of sight. Suppose it is required to find the elevation of a point B (fig 4.5). Let A be apoint Whose elevation is known say 120.12m. The level is setup by approximately mid way between the points A and B. A staff is held on the point A and the back sight reading is taken say 1.52m. Next turn the telescope to the point B and take the fore sight on B say 2.66m. Height of instrument = elevation of A + backsight.

= 120.12 + 1.52 = 121.64m.

R.L of B = Height of instrument – foresight. = 121.64 - 2.66 = 118.98m.





DifferentialLevelling

When the difference in elevations of points far apart is required, then this cannot be found in one setting of the instrument. This is determined by differential leveling. Differential leveling is done by dividing the distance into stages by change points on which the staff is held and the difference of levels between successive pair of change points is found. Let A and B be two points very far apart whose difference in elevation is required (fig 4.6). The distance between the points has been divided into 4 parts by choosing three changepoints.



Fig. 4.6

Let R.L of the point A be 100.00m

The height of the first setting of the instrument is = 100 + 1.015 = 101.015m.

If the fore sight on first change point is 0.700.

The R.L of the C.P.1 = 101.015 - 0.700 = 100.315m.

Similarly R.L of C.P 2 is = 100.315 + 2.150 - 2.325 = 100.140m.

R.L of C.P.3 = 100.140 + 1.990 - 1.105 = 101.025m.

Level Book

The leveling field notes are entered in a note book called the level book. The pages are ruled with tabulated form to facilitate the booking of readings and reducinglevels.

Booking Staff Readings

The following points should be noted while booking readings in a level book.

- 1. The first entry in the level book is a back sight and the last is a fore sight.
- 2. All the readings should be entered in the level bookin the respective columns as soon as they aretaken.
- 3. At change points, the fore sight and back sight arerecorded in the sameline.
- 4. The height of instrument should be noted on the same line as backsight.

5. Brief descriptions with sketches of B.M's, change points, and other important points should be given in the remarks column.

Methods of Booking and Reducing Levels

There are two methods of booking and reducing the elevations of points from the observed staff readings.

- 1. Height of instrument or collimation method.
- 2. Rise and fallmethod.

1. Height of Instrument or Collimation Method: In this method, theheight of the instrument and the reduced levels of points are found with reference to the plane of collimation. The instrument is set up at a convenient point and

back sight is taken on the starting point whose R.L. is known. The height of the instrument is calculated by adding the back sight to the R.L of the starting point. The R.L of the intermediate points and the first change point are then obtained by subtracting the respective readings on staff held at these points from the height of instrument. The instrument is then shifted and set up at the next change point. The new height of instrument is found by adding the back sight reading taken on the change point. The Reduced levels of the successive points and the successive change points are found by subtracting the staff reading from the new height of instrument. The process is repeated until the R.L of all the points isfound.

The arithmetical check as given below is then applied. The difference between the sum of back sights and sum of fore sights should be equal to the difference between the last R.L and first R.L.

Thus \Box B.S – F.S = last R.L – First R.L.

The method affords a check for the H.I and R.L of change points but not for the intermediate points.

| Station | B.S | I.S | F.S | H.I | R.L | Remarks |
|---------|-------|-------|-------|---------|---------|---------|
| А | 1.700 | | | 101.700 | 100.000 | B.M |
| 1 | 2.600 | | 1.800 | 102.500 | 99.900 | CP1 |
| 2 | | 1.135 | | | 101.365 | |
| 3 | | 1.165 | | | 101.335 | |
| 4 | 2.050 | | 2.165 | 102.385 | 100.335 | CP2 |
| В | | | 1.810 | | 100.575 | |
| TOTAL | 6.350 | | 5.775 | | | |

The method of booking levels is shown below for the example given below.



Fig. 4.7

Arithmetical check

 \Box B.S - \Box F.S = 6.350 - 5.775 = 0.575m

Last R.L – First R.L = 100.575 – 100.000 = 0.575m

Rise and Fall Method

In this method, the R.L's of points are determined by the difference of level between consecutive points by comparing each point with the point preceding it. The difference between their staff readings indicates a fall or rise according as the reading is greater on smaller than that of the preceding point. The R.L is then determined by adding the rise or subtracting the fall from the preceding point.

Arithmetical Check: There are three checks on the accuracy of the calculations. The difference between the sum of the back sights and the sum of the fore sights is equal to the difference between the sum of the rises and the sum of the falls which is also equal to the difference between last R.L and the first R.L.

 \Box B.S - \Box F.S = \Box rise - \Box fall = last R.L - First R.L.

The previous example will now be worked out by the rise and fall method.

| Station | B.S | I.S | F.S | Rise | Fall | R.L | Remarks |
|---------|-------|-------|-------|-------|-------|---------|---------|
| A | 1.700 | | | | | 100.000 | B.M |
| 1 | 2.600 | | 1.800 | | 0.100 | 99.900 | C.P.1 |
| 2 | | 1.135 | | 1.465 | | 101.365 | |
| 3 | | 1.165 | | | 0.030 | 101.335 | |
| 4 | 2.050 | | 2.165 | | 1.000 | 100.335 | C .P2 |
| В | | | 1.810 | 0.240 | | 100.575 | |
| Tota | 6.350 | | 5.775 | 1.705 | 1.130 | | |

Arithmetical check

 $\Box B.S - \Box F.S = 6.350 - 5.775 = 0.575$

 \Box Rise - \Box fall = 1.705 - 1.130 = 0.575

Last R.L - First R.L = 100.575 - 100.000 = 0.575

Example 4.1: The following staff readings were taken with a level, theinstrument having been shifted after the 4th, 7th and 10th readings .R.L of the starting B.M is 100.00 enter the readings in the form of a level book page and reduce the levels by the rise and fall method .Apply usual checks. The readings are, 2.500, 3.700, 3.850, 3.250, 3.650, 0.370, 0.950, 1.650, 2.850, 3.480, 3.680 and 3.270m.

Solution: since the instrument was shifted after the 4th, 7th and 10threadings, 3.250, 0.950, and 3.480 are the fore sights and the readings immediately following them viz. 3.650,1.650 and 3.680are the respective back sights. The readings are tabulated and levels are reduced as shownbelow.

| Station | B.S | I.S | F.S | Rise | Fall | R.L | Remarks |
|---------|--------------|---|--------|---------------|------------|---------|-----------|
| 1 | 2.500 | 100000000000000000000000000000000000000 | | 3 | A MARCANON | 100.000 | B.M |
| 2 | | 3.700 | | | 1.200 | 98.800 | |
| 3 | | 3.850 | | | 0.150 | 98.650 | |
| 4 | 3.650 | | 3.250 | 0.600 | | 99.250 | C.P1 |
| 5 | | 0.370 | | 3.280 | | 102.530 | |
| 6 | 1.650 | SCREPARIASS: | 0.950 | \$36563715565 | 0.580 | 101.950 | C.P2 |
| 7 | CONTRACTOR . | 2.850 | | | 1.200 | 100.750 | CP9160007 |
| 8 | 3.680 | | 3.480 | | 0.630 | 100.120 | C.P3 |
| 9 | a | | 3.270 | 0.410 | | 100.530 | |
| Total | 11.480 | | 10.950 | 4.290 | 3.760 | | |

| \square B.S=11.480 | \Box F.S =10.950 |
|----------------------|--------------------|
| □ RISE= 4.290 | □FALL =3.760 |
| LAST R.L = 150.530 | FIRST R.L = 150.00 |

Arithmetical Check

 \Box B.S - \Box F.S = 11.480 - 10.950 = 0.530

 \Box RISE - \Box FALL = 4.290 - 3.760 = 0.530

LATS R.L - FIRST R.L = 100.530 - 100.00 = 0.530

 \Box BS - \Box FS = \Box Rise - \Box Fall = Last R.L - First R.L =

0.530 Hence Checked.

Example 4.2: The following staff readings were observed successively with a level, the instrument was shifted after the second, forth and eighth readings.

0.975,1.435,1.800,1.685,2.030,2.125,2.185,1.920,1.875,2.080 and 2.165. The first reading was taken with the staff held on a bench mark of elevation 122.500. Enter the readings in a level book page and reduce the levels by using Rise and Fall method. Apply the usual checks.

| Station | B.S | I.S | F.S | RISE | FALL | R.L | Remarks |
|---------|-------|-----------|-------|-------|-------|---------|---------|
| 1 | 0.975 | | | | | 122.500 | B.M |
| 2 | 1.800 | | 1.435 | | 0.460 | 122.040 | CP1 |
| 3 | 2.030 | | 1.685 | 0.115 | | 122.155 | CP2 |
| 4 | | 2.125 | | | 0.095 | 122.060 | |
| 5 | | 2.185 | | | 0.060 | 122.000 | |
| 6 | 1.875 | | 1.920 | 0.265 | | 122.265 | CP3 |
| 7 | | 2.080 | | | 0.205 | 122.060 | |
| 8 | | March 100 | 2.165 | | 0.085 | 121.975 | |
| Total | 6.680 | | 7.205 | 0.380 | 0.905 | | |

□B.S =6.680

□F.S =7.205

 \Box RISE = 0.380

 \Box FALL = 0.905

LAST R.L = 121.975

FIRST R.L =122.500

ArithmeticalCheck

 \square B.S - \square F.S = 6.680 - 7.205 = -0.525

 \Box RISE - \Box FALL = 0.380 - 0.905 = -0.525

LAST R.L - FIRST R.L = 121.975 - 122.500 = -0.525

 \Box BS - \Box F.S. = \Box RISE - \Box FALL = LAST R.L. - FIRST R.L = -0.525

Hence Checked.

Example 4.3: The following consecutive readings were taken with adumpy level.

0.795,1.655,2.890,3.015,0.655,0.625,0.955,0.255,1.635,0.860,2.375. The instrument was shifted after the 4th and 8th readings. The first reading was taken on a bench mark whose reduced level is 550.650 meters. Rule out a page of level field book and enter the above readings. Calculate the reduced levels by the rise and fall method apply arithmetical checks.

Solution: First reading is the back sight. The instrument shifted after 4th and 8th readings.

4th and 8th readings and 11th, the last are the foresights. 5th, 9th readings are back sights. All other sights are intermediate sights. The staff readings are tabulated as below.

| Station | B.S | I.S | F.S | RISE | FALL | R.L | Remarks |
|---------|---|-------|--------------|-------|-----------------|---------|---------------|
| 1 | 0.795 | | | | | 550.605 | B.M |
| 2 | | 1.655 | | | 0.860 | 549.745 | |
| 3 | | 2.890 | | | 1.235 | 548.510 | |
| 4 | 0.655 | | 3.015 | | 0.125 | 548.385 | CP1 |
| 5 | 100000000000000000000000000000000000000 | 0.625 | | 0.030 | ACKINES MILLION | 548.415 | 9.76007(2010) |
| 6 | | 0.955 | | | 0.330 | 548.085 | |
| 7 | 1.635 | | 0.255 | 0.700 | | 548.785 | CP2 |
| 8 | 1117.5-569919491 | 0.860 | VURDERPORTER | 0.775 | | 549.560 | AND THE CAL |
| 9 | | | 2.375 | | 1.515 | 548.045 | |
| Total | 3.085 | | 5.645 | 1.505 | 4.065 | | |

 \Box B.S = 3.085

 \Box F.S =5.645

 \Box RISE = 1.5.5

 \Box FALL = 4.065

LAST R.L = 548.045

FIRST R.L =550.605

ArithmeticalCheck

 \Box B.S - \Box F.S = 3.085 - 5.645 = -2.56

 \Box RISE – \Box FALL = 1.5.0 – 4.065 = - 2.56

LAST R.L - FIRST R.L = 548.045 - 550.625 = -2.56

 \square BS - \square FS = \square Rise - \square Fall = Last R.L - First R.L = - 2.56 Hence Checked.

Example 4.4:

The following consecutive readings were taken with a level and 5 meter leveling staff on continuously sloping ground at a common intervalof20meters,0.890m,1.535,2.430,3.330,4.235,5.190,0.625, 2.005, 3.110, and 4.485.

The reduced level of the first point was 108.120. Rule out a page of a level field book and enter above readings .calculate the reduced levels of the points by H.I. method.

Solution

Since the readings were taken on a continuously sloping ground, the maximum staff reading can be F.S and therefore sixth reading will be a fore sight taken on a turning point and the seventh reading will be a back sight. Also, the first reading will be a back sight and the last reading will be a fore sight. The levels can be entered as shown in the tabular form.

| Station | B.S | I.S | F.S | H.I | R.L | Remarks |
|---------|-------|-------|-------|---------|---------|---------|
| 1 | 0.890 | | | | 108.120 | B.M |
| 2 | | 1.535 | | | 107.475 | |
| 3 | | 2.430 | | | 106.580 | |
| 4 | | 3.330 | | | 105.680 | |
| 5 | | 4.235 | | | 104.775 | C .P1 |
| 6 | 0.625 | | 5.190 | 104.445 | 103.820 | |
| 7 | | 2.005 | | | 102.440 | |
| 8 | | 3.110 | | | 101.335 | |
| 9 | | | 4.485 | | 99.960 | |
| Total | 1.515 | | 9.675 | | | |

 $\Box B.S = 1.515$

 $\Box F.S = 9.675$

LAST R.L =99.960

FIRST R.L = 108.120

Arithmetical Check

□B.S - □F.S = 1.515 - 9.675 = - 8.160 LAST R.L - FIRST R.L = 99.960 - 108.120 = - 8.160 □BS - □FS = Last R.L - First R.L = -8.160 Hence Checked

Example 4.5

The following consecutive readings were taken with a level and 4 meter leveling staff on a continuously sloping ground at 30 m intervals 0.680, 1.455, 1.855, 2.330, 2.885, 3.380, 1.058, 1.860, 2.245, 3.450, 0.835, 0.645, 1.530, 2.250. The R.L of the starting point was 80.750.

a) Rule out a page of level book and enter the abovereadings.

b) Carry out reductions of heights by Height of Collimationmethod

c) Apply the arithmeticcheck.

| Station | B.S | I.S | F.S | HI | R.L | Remarks |
|---------|-------|-------------|-------|---------------------------|--------|--|
| 1 | 0.680 | | | 81.430 | 80.750 | B.M |
| 2 | | 1.455 | | A Providence and a second | 79.975 | 0- |
| 3 | | 1.855 | | | 79.575 | |
| 4 | | 2.330 | | | 79.100 | |
| 5 | | 2.885 | | | 78.545 | |
| 6 | 1.005 | | 3.380 | 79.055 | 78.050 | CP1 |
| 7 | | 1.860 | | | 77.195 | |
| 8 | | 2.245 | | | 76.810 | |
| 9 | 0.835 | COLOSION DE | 3.540 | 76.350 | 75.515 | CP2 |
| 10 | _ | 0.945 | | | 75.405 | |
| 11 | | 1.530 | | | 74.820 | |
| 12 | | | 2.250 | | 74.100 | |
| Total | 2.520 | | 9.170 | | | |

Check :

□B.S =2.520
□F.S =9.170
First R.L =80.750
Last R.L = 74.100.
□B.S- □F.S =2.520 -9.170 = -6.650
Last R.L - First R.L =74.100 -80.750 = -6.650
□BS - □FS = = Last R.L - First R.L = -6.650
Hence checked.

Curvature and Refraction

The surface of the earth is curved. Hence staffs readings will be get affected due to the curvature of the earth. As the line of sight passes through air of different densities, error will be introduced in staff readings due to refraction of light rays.

Due to curvature, we get larger staff readings than true readings and hence the points sighted appear to be lower than their true positions. Due to the refraction, we get smaller staff readings than true readings. Hence the points sighted appear to be higher than their true positions. Errors due to Curvature and Refraction correction should be considered in precise leveling works involving sights longer than about 100m.

Error due to Curvature and Correction

In fig. 4.8 given below, let the level be set up at A and let P be the staff station which is at a horizontal distance of d km. from the instrument. The line of sight through A which is horizontal cuts the staff held vertically at the point B and hence the observed staff reading will be PB. But the level line through A cuts the staff at C and hence PC should

be the true staff reading if error is not there due to curvature of the earth.



The error due to curvature in the staff readings is thus the difference of the two is CB.

Referring to the fig given below, let O be the centre of the earth .AC the horizontal line at the instrument station A, CD the error due to curvature at distance d km from A. Let R be the radius of the earth. Extend CD to cut the great circle through AD at E ,CDE being the vertical at D assuming the section of the earth to be circular.



Fig. 4.9

AC²=CD.CE=CD (CD+DE)
AC^2 =CD.DE neglecting CD² which is small.

Assuming radius of the earth as 6370 km

CD=Error due to curvature= $AC^2 / DE = d^2/12740$

 $= 0.0000785 d^2 km = 0.0785 d^2 meters.$

Correction for curvature for a distance of d km. = $-0.0785 d^2$ meters.

Error Due to Refraction and Correction.

The density of air is different at different levels of the earth surface .Hence a ray of light from the staff reaching the instrument under goes refraction. The error due to refraction is generally taken as about 1/7 of the error due to the curvature.

The correction for refraction to the staff reading is positive.

Correction for refraction= $+0.0785d^2/7 = 0.0112 d^2$ meters.

Where d is distance of the staff in km.

Combined correction due to curvature and refraction

 $= -0.0785 d^2 + 0.0112 d^2 = -0.0673 d^2.$

Summary

1. Levelling : Levelling is the process by which the relative heights ofpoints on the earth's surface are determined. Levelling deals with measurements in a verticalplane.

2. Datum : This is an arbitrary assumed surface with respect to themean sea level above which the elevations of points are measured.

3. Types Of BenchMarks

1. G.T.S benchmarks.

2. Permanent benchmarks.

3. Arbitrary bench marksand

4. Temporary benchmarks.

4. Back Sight : It is the reading taken on a staff held at a point ofknown reduced level or elevation. It is the first staff reading after setting thelevel.

5. Fore Sight: Fore sight is a staff reading taken on a point whoseelevation is not known and has to be determined. It is the last staff reading before shifting the level to another position.

6. Intermediate Sight: Any staff reading other than the Back sight andthe fore sight is taken on a point where reduced level is not known is called an intermediatesight.

7. Change point : An intermediate staff station at which both back sightand fore sights are taken with the purpose of changing the position

of the instrument is called a change point or turningpoint.

8 Reduced level: Reduced level is the elevation of the point where the staff reading is taken with respect to the assumed datum.

9. Line of collimation: It is an imaginary straight line joining the intersection of the cross hairs at diaphragm to the optical centre of the object glass and its continuation. It is also called the line of sight. When the bubble is in the center of its run, the line of collimation will behorizontal.

10. Curvature : Due to curvature, we get larger staff readings thantrue readings and hence the points sighted appear to be lower than their truepositions.

11. Refraction : Due to the refraction, we get smaller staff readings thantrue readings. Hence the points sighted appear to be higher than their true positions. Errors due to Curvature and Refraction correctionshould

Short Answer Type Questions

be considered in precise levelling works involving sights longer than about 100m

- 1. What islevelling?
- 2. What isbenchmark?
- 3. What is backsight?
- 4. Write the methods of reduction oflevels?
- 5. Define curvature?
- 6. What is profilelevelling?
- 7. What is checklevelling?
- 8. What is changepoint?
- 9. What is intermediatesight?
- 10. Name the types of levels

Long Answer Type Questions

- 1. Draw the neat sketch of dumpy level and name theparts
- 2. Explain the temporary adjustments of dumpylevel
- 3. Explain differentiallevelling
- 4. Write the types of levelling staffs and explain one ofthem.
- 5. Explain the procedure of reducing the levels by H.Imethod
- 6. Explain the procedure of reducing the levels by rise and fallmethod.
- 7. The following consecutive readings were taken with a level and levelling staff
 - on continuously sloping ground they are 1.500, 2.960,

3.980,0.800,1.920,2.950,3.750,and1.800,.The R.L of BM was m at the first

reading enter the readings in a page of fieldbook. Determine the R.L's of all the stations by rise and fall method.

8. The following staff readings were taken with a level the instrument has been shifted after the 4th, reading, R.L. of the starting BM is taken as 100.000m. Enter the readings in the form of a level book page and find reduced levels of the given points by height of instrument method. Apply usual checks 2.80, 3.60, 3.580, 3.250, 2.370,1,950, 0.650, 1.850, and 3.720.

ACTIVITY

- Study the dumpy level and identify theparts.
- Study the levellingstaff.
- Make temporary adjustments to the dumpy level and take staff reading at apoint.

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 linesby repetition and reiterationmethods.

- Measuring vertical angle by Theodolite and determination ofheight
- Determination of distances of remoteobjects.

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 cannot betransited.

Theodolites are also classified 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 25cmthe diameter of the graduated circle on the lower platedefining 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) TheTransit
- ii) The plain or Y
- iii) TheEverest

Principle of TheodoliteSurvey

Theodolite surveying in which we measure horizontal and vertical angles. In This survey, Theodolite, amost 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.

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 instrumentand screws on to a tripod. It comprises of twoparts.

(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 tangentscrew.

3. Upper Plate: Upper plate which is also known as the Vernier platecarries 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 detachablecompass.

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 thetelescope.



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 subdivisions on the vertical circle are similar to those of horizontal circle. A clamp and fine motion tangent screws are provided to the verticalcircle.

6. T-frame or Index Bar: It is T - Shaped and is centered on the horizontalaxis 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 bubbletube.

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

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

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 ofturning the telescope about its horizontal axis through 180^{0} in the vertical plane thus bringing it upside down and making it point exactly in oppositedirection.

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 counterclockwise.

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 leftobservation.

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 rightobservation.

6. **Changing Face** : It is the operation of bringing the vertical circle to theright 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 theimaginary 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 linejoining theoptical center of the object glass to the center of the yepiece.

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

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

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

Temporary Adjustments of Theodolite

There are three temporary adjustments of a theodolite.

1. Setting up the theodilite over astation

2. Levellingup

3. Focusing for elimination of parallax

Setting Up : It includes two operations, viz (a) Centering the theodoliteover 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, theinstrument 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 willthen

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 thesescrews.

(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 thesescrews.

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 apiece 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 isseen.

(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 maybe 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 VernierScales

Circular vernier scales are used in the dolites to measure horizontal and vertical angles. Fig. 5.2(a) and 5.2 (b) shows two typical arrangements of double direct circular verniers. In Fig. 5.1(a) the main scale is graduated 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 =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° 30' + 05' = 342° 35', and the counter clock wise angle reading (outer row) is 17° 0' + 26' = 17° 26'. Similarly in fig. 5.2(b) clockwise angle reading (inner row) is 49° 40'+ 10' $30''=49^{\circ}$ 50'30''and the counter clock wise angle (outer row) is 130° 0' + 9' $30''=130^{\circ}$ 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".

Measurement of HorizontalAngles

There are three methods of measuring horizontal angles.

- 1. Ordinarymethod
- 2. Repetitionmethod
- 3. Reiterationmethod

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

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

(ii) Set the vernier 'A'to the zero or 360° 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 coincidence with the point of intersection of cross hairs at diapharm by using the vertical 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 minimize the error due to non verticality of the object.

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

(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 Bexactly.

(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° . The mean of two vernier readings gives the value of the required angle AOB.



Fig.5.3

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

(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 form 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 tangentscrew.

(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 anglePQR.

(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 thelower.

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

(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 reading divided bythree.

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

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

Any number of repetitions maybe made. However, three repetitions with the telescope normal and three with the telescope inverted are quite sufficient for anything except very precise work. Table 5.4 gives the method of recording observations by method of repetition.

| | | F | ace | le | ft | | | | | | Sw | ing I | Righ | nt | Fa | cet | igh | t | | | | | Sv | ving | left | | A | vera | ige ntal |
|-------|-------------------|-----|-----|----|-----|----|----|-----|-----|----|---------------|-------|--------------|------------|-----|-----|-----|----|----|-----|-----|----|-------|------|--------------|------------|----|------|-------------|
| st ar | th led | , | • | | | в | | | Mea | n | o or Ition | Ho | rizo ngle | ntal es | , | • | | E | 3 | | Mea | n | o or | Hora | rizo ngle | ntal es | | angl | e |
| 4 | 5 | 0 | | | Ţ | | | 0 | | | reper | 0 | | | 0 | | | | | 0 | | | reper | • | | | 0 | | |
| Q | Ρ | 00 | 00 | 0 | | 00 | 00 | 00 | 00 | 00 | | | | | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | | | | | | | |
| | R | 58 | 43 | 2 | 04 | 3 | 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 | 2 | 0 1 | 1 | 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 TABLE5.4

By this procedure the following errors are eliminated or minimized.

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

(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 rightobservations.

(iii) The errors of graduations areminimized.

2. Measurement of Horizontal Angle by ReiterationMethod

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 (VernierA) should be the same as its initial reading. If not, the discrepancy is equally distributed among all the measured angles.



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 toZero

(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 accuratelybyusing 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.

| | | F | ace | left | 1 | | | | Sv | ving | Rigt | nt | Fa | ceı | righ | t | | | | 5 | Swin | g lef | t | A | vera | ge |
|-------|-------|------------|----------|----------|----|----|------------|-----|----------|------|---------------|------------|-----|-----|------|----|----|-----|----------|----|------|---------------|------------|-----|------|----|
| st at | 9hted | 1 | • | | B | 3 | | Mea | n | Hora | rizor ngle | ntal Is | 4 | • | | 8 | | ' | Mea | n | Ho | rizor ngle | ntal Is | no | angl | e |
| 4 | 5 | 0 | | | | | o | | | ø | | | 0 | | | | | 0 | • | | 0 | • | | 0 | | |
| 0 | Ρ | 0.0 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 43 | 53 | 10 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 43 | 53 | 10 | 43 | 53 | 10 |
| | Q | 43 | 53 | 10 | 53 | 10 | 43 | 53 | 10 | 54 | 30 | 50 | 43 | 53 | 00 | 53 | 00 | 43 | 53 | 10 | 54 | 30 | 50 | 54 | 30 | 50 |
| | R | 98 | 24 | 00 | 24 | 00 | 98 | 24 | 00 | 126 | 47 | 20 | 98 | 24 | 00 | 24 | 00 | 98 | 24 | 00 | 126 | 47 | 20 | 126 | 47 | 20 |
| | P | 225 360 | 11 00 | 20 00 | 11 | 20 | 225 360 | 11 | 20 00 | 134 | 46 | 40 | 360 | 00 | 20 | 00 | 20 | 360 | 11 00 | 00 | 134 | 48 | 40 | 134 | 48 | 40 |

REITERATION METHOD TABLE 5.5

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

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

(vii) The Vernier A should now read 360° . If not, note the reading and find theerror.

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

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 altitudebubble.

(ii) Set the zero of vertical verniers exactly to the zero of the vertical circle by using the vertical circle clamp and tangentscrew.

(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 readszero.

(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 requiredangle.

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

(i) Sight A as before, and take the mean of the twoVernier readings at the vertical circle let it be \Box .

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

| | | Ę | ace | e | ŧ | | | | | | | | Fa | e | lefi | - | | | | | | | | A > | rtic | al |
|-------|--------|-----|-----|----|----|----|-----|-----|----|-----|------|------|------|-----|------|------|-----|-------|------|----|------|------|------|------|------|-----|
| 10 78 | Derted | | | | • | | | Mea | 5 | Ve | rtic | s al | 0 | | | | | - | Aear | | ar | ngle | e al | 69 | ngle | |
| 4 | 215 | 0 | - | | - | | 0 | • | | 0 | | | 0 | | : | - | : | 0 | | | 0 | • | : | 0 | | |
| 0 | 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 |
| | В | -24 | 35 | 40 | 35 | 20 | -24 | 35 | 40 | -24 | 35 | 40 | -24 | 36 | 8 | 35 | 4 | -24 | 35 | 50 | -24 | 35 | 40 | -24 | 35 | 35 |
| | | | | | | | | | | | | | | | 1 | 1 | 1 | | | | Angl | e A(| l ë | = 23 | 26, | 55" |
| | | | | | | | | | | | | | ERTI | CAL | ANG | ILES | ΤAΕ | SLE5. | 9 | | | | | | | |

(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 andc)

The observations of vertical angles are shown in table 5.5



Fig. 5.5

Determination of Heights andDistances

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

 \Box = 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

H = h + hs

 $H = D Tan \Box + hs$

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 $10^{0}30^{\circ}$. The staff reading on a of

70.50 with the telescope horizontal was 0.982. Find the height of the chimney above the B.M.

D =175 m, $\Box = 10^0 30$,

 $h_s = 0.982$

The height of the top of the chimney above the

instrument axis $h = D Tan \square$

 $= 175 \text{ x Tan } 10^{0} 30^{1}$.

= 175 X 0.1853

= 32.43 m

The error due to curvature & refraction

 $= 0.0673 (175/1000)^2 = 0.002 \text{ m}$

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 the odolites

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 known as the face leftobservation.

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 rightobservation.

4. Temporary Adjustments of Theodolite

1. Setting up the theodolite over a station 2. Levelling up 3. Focusing

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 aTheodolite
- 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 faceleft?
- 6. What is meant by faceright?
- 7. What is meant by changing theface?
- 8. Define the line of collimation
- 9. Write methods of measuring horizontalangle
- 10. Write the temporary adjustments of Theodolite.
- 11. Define vertical axis
- 12. What are the Fundamental lines of a TransitTheodolite?

Long Answer Type Questions

- 13. Describe the parts of a Theodilote with transiting facilityor use in measurement in a horizontal plane.
- 14. Draw a neat sketch of transit Theodoliteand mention its components.
- 15. Explain clearly and sequentially the operations involved in the temporary adjustments of aTheodolite.
- 16. Explain how you would measure with aTheodolite.
 - (a) Horizontal angle byrepetition
 - (b) Horizontal angleby reiteration

UNIT 6

Total Station

Learning Objectives

After studying this unit, the student will be able to

- Understand the parts of Totalstation
- Temporary adjustments of totalstation
- Measurement of horizontal angle, horizontal distance by totalstation
- Measurement of difference in elevation between twopoints
- Setting out plan of a building on theground
- Measuring area of a closedtraverse
- Working ofDistomat

Introduction

A Total station is a combination of an electronic theodolite and an electronic distance meter (EDM). This combination makes it possible to determine the coordinates of a reflector by aligning the instruments cross-hairs on the reflector and simultaneously measuring the horizontal and vertical angles and slope distances. A Total station records, reads and performs necessary computations with the help of micro-processor in the instrument. Total stations also generate maps by transferring data to a computer.

Parts of a Total station. Following are the parts of a total station.

 Latch button. 2. On board battery 3. Telescope tangentscrew
Telescopic Clamp screw 5. Plate Vial. 5. Power Supply Switch 6. Clamp screw 7. Tangent screw 8. Tribrach locking lever 9. Leveling screw
Bottom plate 11. Focusing knob 12. Eyepiece lens 13. Plate vial
Display panel 15. Keyboard 16. Date out connector 17. External battery connector 18. Circularvial.



Fig.6.1

Functions of Total Stations

Total station performs the following functions.

1. Averaging multiple angles and distancemeasurements.

2. Correcting electronically measured distances for prism constants, atmospheric pressure and temperature.

3. Making curvature and refraction corrections to elevations determined by trigonometriclevelling,

4. Reducing slope distances to their horizontal and vertical components.

5. Calculating elevations of points from the vertical distance components.

Adjustments of Total station for taking observations.

For most surveys, prior to observing distances and angles the instrument must first be carefully set up over a specific point.

The set up process is mostly accomplished with the following steps:

1) Adjust the position of the tripod legs by lifting and moving the tripod as a whole until the point is roughly centered beneath the tripod head (by dropping a stone or using a plumbbob).

2) Firmly place the legs of the tripod in the ground.

3) Roughly center the tribrach leveling screws on theirposts.

4) Mount the tribrach approximately in the middle of the tripod head to permit maximum translations in step (9) in any directions.

5) Properly focus the optical plummet on thepoint,

6) Manipulate the leveling screws to aim the intersection of cross hairs of the optical plummet telescope at the pointbelow,

7) Center the bull's eye bubble by adjusting the lengths of the tripod extension legs,

8) Level the instrument using the plate bubble and levelingscrews

9) If necessary, loosen the tribrach screw and translate the instrument (do not rotate it) to carefully center the plummetcross hair on thepoint.

10) Repeat step (8) and (9) until precise leveling andcentering are accomplished.

To level a total station instrument, the telescope is rotated to place the axis of the level vial parallel to the line through any two leveling screws, as the line through A and B in Figure(a).

The bubble is centered by turning these two screws, then rotated 90° , as shown Figure(b), and centered again using the third screw (C)only.

The process is repeated and carefully checked to ensure that the bubble remains centered.



Fig.6.2

Total station measures only three parameters: These are Horizontal angle, vertical angle, and Slope distance. It does basic calculations and displays other parameters such as horizontal distance, coordinates of a point, area of a closed traverse etc.



S=slope distance, V = vertical distance between telescope and reflector H = Horizontal distance Z = Zenith angle HI= Instrument height, HR = Reflector height

Slope distance: Total station to reflector distance is measured using anElectronic Distance Meter (EDM).EDM emits an infrared light beam. The emitted beam reflected by the reflector and received and amplified by the total station. The received signal is then compared with a reference signal generated by the instrument and the phase-shift is determined. This phase-shift is a measure of the travel time and thus the distance between the total station andreflector.

Horizontal distance: From fig.6.3 the Horizontal distance from theinstrument to the reflector (H) is given by

 $H = S \cos (90^{\circ} - Z) = S \sin Z$ where S is the slope distance

And Z is Zenith angle.

Difference in heights between two points: From the

fig.6.3 HI = height of the instrument

HR = height of the reflector.

V = vertical distance between telescope and reflector.

difference in heights between two points A and B on theground

d = V + (HI - HR)

 $V=S Sin (90^{\circ}-Z) = Scos Z$ substituting V value inabove

equation. $d = S \cos Z + (HI - HR)$

Elevation of aPoint

From fig.6.3 the elevation of point B is given by

Elevation of point B = elevation of point A + HI + V - HR

where HI = height of the instrument.

HR = height of the reflector.

V = vertical distance between telescope and reflector.

Horizontal Angle and Distance between two Points Measuring Horizontal Angles with Total Station



Fig. 6.4

1. To measure a horizontal angle JIK, the instrument is firstset up and centered over station I, and leveled.

- 2. Then a back sight is taken on station J. This is accomplishedby:
- 3. Releasing the horizontal and verticallocks,
- 4. Turning the telescope in the approximate direction ofJ,
- 5. Clamping bothlocks,
- 6. Making a precise pointing, and
- 7. Setting the horizontal angle as0°00'00".

8. The horizontal motion is then unlocked, and the telescope turned clockwise toward point K to make thefore sight.

9. The value of the horizontal angle will automatically appear in the display.

To eliminate instrumental errors and increase precision, angle measurements should be repeated an equal number of times in each of the direct and reversed modes, and the average taken.

Distance between two points.

The distance between two points can be horizontal, slope, or vertical. A tape measure or an EDM device (such as a total station) can measure horizontal and slope distances. A distance measured on a slope can be trigonometrically converted to its horizontal equivalent by using the slope angle or vertical difference of elevation and the procedure is explained in article 6.2.

Setting Out Right angles at different points on a baseline

The most accurate way to set out a right-angle is to use a theodolite or a total station. Position the instrument on the point along the survey line from which the right-angle is to be set out, target the end point of thesurvey line, set the horizontal circle to zero and turn the total station until the horizontal circle reading is 90°

Setting out Plan of a Building on theGround



Fig 6.5

During building alignment, it is useful to extrapolate the sides of the building to beyond the limits of the excavation and there to erect profile boards on which the extensions are marked exactly by hammering in nails. These can be connected to strings or wires at any time during the construction sequence, indicating the required positions of the walls. In the following example, profile boards are to be erected parallel to the proposed walls of a large building and at distances of a and b respectively from the boundaries (fig. 6.5).

1. Establish a baseline AB parallel to the left-hand boundary and a freely selectable distancec.

2. Mark the point A at the defined distance d from the upper boundary; it will be the first location for the total station.

3. Using a boning rod, mark the point B at the end of thebaseline.

4. Set up the total station on point A, target point B, and set out the points A1, A2 and A3 in this alignment in accordance with the planned length of the side of thebuilding.

5. With point B sighted, set the horizontal circle to zero, turn the total station by 90° and set out the second line AC with the points A4, A5 and A6.

6. The points on the profile boards are then set out in a similar manner, starting from the points A1 to A6respectively.

If the foundations have not yet been excavated, you can set out the sides H1H2 and H1H3 of the building directly and use them as the starting line for marking the points on the profile boards.

For smaller buildings it is easier to set out the profile boards using an optical square (right-angle prism) and a measuring tape. A building-alignment software program incorporated into many total stations enables profile boards to be set out directly, starting with any instrument station.

Prolonging a StraightLine

By using a Total station, a straight line can be prolonged by double centre method.

The procedure is as follows.

- 1. Set up the instrument on the line to be rolonged.
- 2. Select a point A on theline.
- 3. Take Back sight on point A with telescope direct.Plunge and set a point C'.
- 4. Take Back sight on point A with telescope reverse. Plungeand set a point C".
- 5. Mark C at the mid point between C' and C".

Area of a ClosedTraverse



Fig 6.6

1. Set up the Total station in the terrain so that it is within view of the entire area to be surveyed. It is not necessary to position the horizontalcircle.

2. Determine the boundarypoints of the area sequentially in the clockwise direction. You must always measure adistance.

3. Afterwards, the area is calculated automaticallyat the touch ofa

Earth WorkCalculation

button and is displayed.

To calculate the required earth work, information is needed about both the current graded surface and proposed graded surface. These can be calculated by using contour data in the form of maps or coordinate data of points from Total station data. Softwares like Auto CAD civil 3D, E Survey CAD are used for calculation of earth work.

Summary

1. A Total station is a combination of an electronic theodoliteand an electronic distancemeter(EDM).

2. Fundamental measurements of a total station areHorizontal angle, Vertical angle and slopedistance.

3. Objectives of Total stationare

i). Measuring horizontal and vertical angles.

ii). Measuring Horizontal distance.

iii) Measuring difference in elevation between two points.

iv). Determining elevation of a point.

v).Setting out right angles. vi).

Prolonging a straightline.

vii). Measuring area of a closed traverse.

4. Distomats are latest in the series of EDM instruments. These instruments measure distances by using amplitude modulated infrared

Short Answer Type Questions

waves.

1. What is Totalstation?

2. Write functions of Totalstation.

3. Write the adjustments required for total stationfor taking observations.

4. What are the fundamental measurements of totalstation?

5. Write the objectives of totalstation.

6. What is aDistomat?

Long Answer Type Questions

- 1. Explain measurement of distance by totalstation.
- 2. Explain measurement of horizontal angle by totalstation.
- 3. Explain the procedure of setting out a building on the ground using a Totalstation.
- 4. Explain the procedure of measuring area of a closedTraverse usingTotal station.
- 5. Explain adjustments of Total station before takingobservations.

Activities

- Identify the parts of Totalstation.
- Make temporary adjustments to the Totalstation