MODULE 1

INTRODUCTION

Surveying is an art of determining the relative positions of points lying above or beneath the surface of the earth. It is an art of preparing plan or a map.

APPLICATIONS OF SURVEYING:

1. Topographical maps showing natural features like rivers, streams, hills, forests help in planning irrigation projects and flood control measures.
2. Road maps help travelers and tourists to plan their programmers.
3. Locality plan help in identifying location of houses and offices in the area
4. Maps and plans help in planning and estimating various transportation projects like roads, bridges, railways and airports.
5. For planning and executing water supply and sanitary projects one has to go for surveying first.
6. Marine and hydrographic surveys help in planning navigation routes and harbours.
7. Military surveys help in strategic planning
8. For exploring mineral wealth mine surveys are required.
9. Geological surveys are necessary for determining different strata in the earth's crust

Primary Classifications of Surveying:

1. **Plane surveying**: Curvatureness of the earth is neglected & the area to be surveyed is small.
2. **Geodetic surveying**: Curvatureness of the earth is considered and the area to be surveyed is large.

Plan & Map:

A plan or a map is the graphical representation to some scale, the features existing on the surface of the earth as projected on a horizontal plane. If the scale is small, it will be called as map and if the scale is large it is called as plan.

Scale:

It is the fixed ratio that every distance on the surface of the plan bears with the corresponding distance on the ground. Eg: 1 cm = 10 m, 1:1000 etc,

Scale may be also represented by drawing a graphical scale on the drawing sheet.

If the plan or map is to be used after few years the numerical scale may vary due to shrinkage of sheet. If graphical scale is also drawn it will also shrink proportionally. That is why graphical scales are drawn on map or plan.

Principles of surveying:

1. **Location of a point by measurement from two points of reference.**
   For fixing new control points with respect to already fixed points, at least two independent processes should be followed. If A and B are two already located control points and with respect to them new control point C is to be located, minimum two measurements are required. Fixing of check lines and tie lines will also serve this purpose.

2. **Working from whole to part**: In surveying large areas, a system of control points is identified and they are located with high precision. Then secondary control points are located using less precise methods. With respect to the secondary control points details of the localized areas are measured and plotted. This is called working from whole to part. This principle in surveying helps in localizing the errors. If the surveying is carried out by adding localized areas, errors accumulate.

Measurement of Distance:

As the definition of surveying is an art of locating the position of point, the main work in surveying is measurement of distance.

Various methods of measuring the distances are:
A) Chaining: Accurate and common method. For this work a chain or tape will be used.

Types of chain:

a) Metric chain – 20 m, 30 m etc.,

b) Gunter's chain – 66 ft, 100 links

c) Revenue chain – 33 ft, 66 links

d) Engineers chain – 100 ft, 100 links

Types of tapes:

1. Cloth or linen
2. Metallic tapes
3. Steel tapes
4. Invar tape – (Alloy of steel & nickel.)

b**) Pacing:** Counting the number of paces.

c) Odometer: Registers the number of rotations of the wheel and multiplying by circumference distance can be obtained.

d) Speedometer: Modified form of odometer, which gives directly the distance.

e) By optical means.
f) By electronic methods.

Instruments for chaining:

The process of measuring the distance is called chaining. Measured distance is called chainage.

1. Chain/tape

2. Ranging rods: Made of steel rod, 2 to 3m length. Painted in white & black or red. It has got a shoe. Used for marking the positions of stations and ranging the line.

3. Arrows: It is made up of hardened steel wire of 4 to 6 mm diameter. It is used to mark the end of the each chain length.

4. Plumb bob: To transfer the station on to the ground while measuring the distance along a slope.

Procedure for measuring a line:-

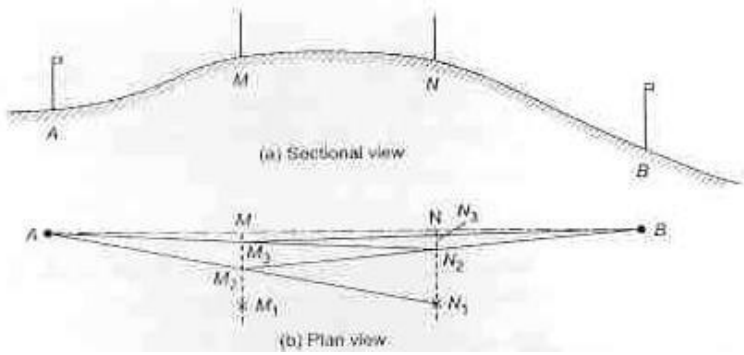
In measuring a chain line it is necessary that chain should be laid out in a straight line between end stations. If the chain line is long, it is necessary to place intermediate ranging rods to maintain the direction along the line joining the end stations.

Thus the process of fixing the intermediate stations in known as ranging.

a) Direct ranging (ranging by eye): When the stations are intervisible this method can be followed.

1. Fix the two ranging rods at the end stations.
2. One surveyor should stand at about 2 m behind the initial ranging rod and coinciding the position by observing other station.
3. Another surveyor holds a ranging rod and first surveyor should guide to move inline with AB.

b) Indirect ranging (Reciprocal ranging): If the two end points of the line to be measured are not intervisible, the surveyor has to go for indirect ranging. This is also called reciprocal ranging. The invisibility of points may be due to unevenness of the ground or due to long distance Fig (a) shows cross – section of the ground which is a typical case of invisibility of point B of the line from point A. Fig (b) shows the plan .M and N are the two points to be fixed on AB such that both points are visible from A as well as B. It needs four people to fix points M and N, one person near each point A, B, M and N. The persons at M and N position themselves near M and N say at M1 and N1. First person at A directs the person at M to come to M2 so that AM2N1 are in a line. Then person at B directs the person at N1 to move to N2 so that BN1M2 are in a line. In the next cycle again person at A directs the person to M to move to M3 such that AM3N2 are in a line which is followed by directing person at N2 to move to N3 by person at B. the process continues till AM NB



(a) Sectional view

(b) Plan view

Error in length due to incorrect chain or tape:

If the distances are measured with the incorrect length of chain or tape, then the correct distance can be obtained by the formula.

Correct length = L'/L x measured length

Where L' = Incorrect length (may be too short or too long)

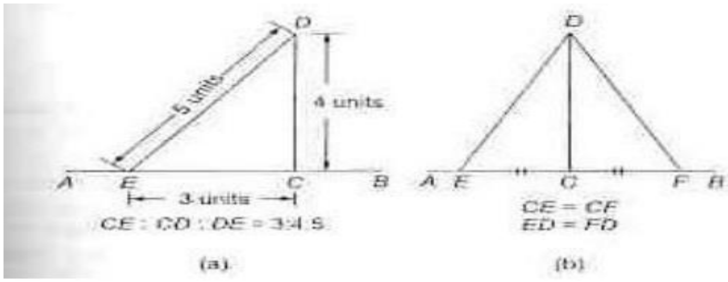
L = designated length of chain or tape.

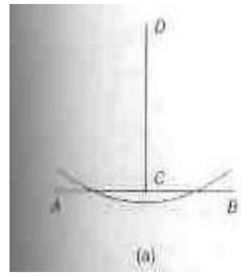
Setting out of perpendiculars:

1) Instrumental method:

a) Cross staff: Wooden, Open, French
b) Optical square
c) Prism square

2) Linear methods: i) **The 3-4-5 method:**





Obstructions in chaining:

a) Chaining is free, vision obstructed: Eg: A small hill
b) Chaining obstructed ,vision free: Eg: River, Pond
c) Chaining and vision both obstructed Eg: Building

Case 1: Chaining is free, vision obstructed

This type of obstacles can be overcome by the method of reciprocal ranging or random line ranging,

Case 2: Chaining obstructed vision free:

i) If it is possible to chain round the obstacles. Eg : Pond
ii) When it is not possible to round the obstacle. Eg: River

Case 3: Chaining and vision both abstracted: Egx: Building

ERRORS IN CHAINING

Errors in chaining may be classified as: 1. Personal errors 2. Compensating errors, and 3. Cumulative errors

Personal errors: Personal errors like wrong reading, wrong recordings, reading from wrong end or chain and miscounting of the chains are serious errors. It is not easy to detect unless they are too big. Hence, care should be taken to avoid such errors.

Compensating errors: These errors can be positive or negative. Hence, they are likely to get compensated when a large number of readings are taken. The following are the examples of such errors:

1) Incorrect marking of the end of chain

2) Fractional parts of the chain may not be correct when the chain is corrected by adding or removing a ring.

3) Graduation in the tape may not be exactly of same length throughout

4) In the method of stepping for measuring sloping ground, method of plumbing may be crude.

Cumulative errors: These are the errors which occur always in the same direction. Hence, as more number of chain lengths is required while measuring a line they go on accumulating. Hence, even if each one of such errors are small they are considerable when longer lengths are measured. Examples of such errors are:

1. Bad ranging (+ve) 2. Bad straightening 3. Non – horizontality 4. Sag in the chain

5. Erroneous length of chain 6. Temperature variation 7. Variation in pull.

First four errors are always + ve since they make measured length more than actual. Last three errors may be + ve or –ve.

CHAIN SURVEYING

In this, surveying is conducted by taking linear measurements only. In this method the area to be surveyed is divided into number of well-conditioned, inter-connected triangles and the sides of each triangle are measured. The details are located by taking offset measurements. Then it is plotted on the drawing sheet to a proper scale and the plan is prepared. (The triangle can be plotted on paper easily by knowing its sides).

This method is useful when

1. The area to be surveyed is flat, open and small
2. The details to be plotted are simple
3. Plan to be prepared are to be drawn on a large scale

Definition of terms:

1) **Surveying stations**: It is a beginning or end point. There are two types of stations.

a) Main station b) Subsidiary or tie station

2) **Selection of main station:**

a) Survey line should be preferably on a level ground
b) The station should be mutually visible
c) The number of main station should be brought to a minimum
d) Triangles found should be minimum.

3) **Base line**: Longest lines in the survey with respect to which direction of other lines are fixed.

4**) Tie line:** A tie line connects two stations. It helps in taking offsets of additional details.

5) **Check line**: A check line or a proof line is measured in the field to check the accuracy of fieldwork and plotting work.

6) **Offsets: I**t is the distance measured from the chain line to locate the position of point with respect to the chain line. Perpendicular or oblique offsets may be taken. Normally the length of the offset is less than the chain or tape length.

Entering measurements in the field book:

Instruments required for chain surveying:-

1) Chain 2) Tape 3) Ranging rods 4) Arrows 5) Cross staff 6) Field book, Pencil, Eraser, Sharpener

7) Miscellaneous items such as pegs, hammer, nails etc.,

Procedure for carrying out chain surveying:

Following steps should be carried out

1) Reconnaissance surveying 2) Marking stations

3) Preparation of reference sketches 4) Running survey liner

1) Reconnaissance surveying: A surveyor should walk around the area to be survey plan of the map selecting station point and should check the inter visibility of the points.

2) Marking stations: Stations selected during reconnaissance surveying should be properly marked on ground by fixing ranging rods or by driving wooden pegs or nails or fixing stones.

3) Preparation of reference sketches: In order to locate the station when ever we need, it should be refered to two or three permanent objects near by.

4) Running survey liner: Survey lines are measured and details are taken by measuring offsets and entered in the field book.

Plotting work: The details taken on the field are plotted on paper in office using proper symbols.

Chain line:	Fence:
Power line	Telephone line:
Roads	Railway line:
River:	Cultivated land
Houses:	Station:

MODULE 2 : COMPASS SURVEYING

Compass survey is used to survey an area in which network of lines starts from a point, goes around the area and ends at the same point. This is called closed traverse. In case of road project or canal project surveying goes along many interconnected lines and ends at some other point called and it is called open traverse.

The direction of a survey line may be defined by

1) Horizontal angle between the line and adjacent to it

2) The angle between a reference lines called meridian and the survey line.

The reference line is called meridian and the angle between the line and the meridian is called bearing. The direction of a survey line can either be established with relation to each other or with relation to any meridian. The first will give angle between two lines. The second will give the bearing of the line. The common instruments used for direction measurements are prismatic and surveyor's compass. The common instruments used for angle measurements are theodolite and sextant.

COMPASS:
A compass consist of i) A magnetic Needle ii) A graduated circle iii) The line of sight iv) Box to house the above

The two forms of compass that are used commonly for bearing are:

1. Prismatic compass 2. Surveyor's compass

1. Prismatic Compass: Parts of Prismatic compass: 1. Box 2. Needle 3. Graduated circle 4. Object vane 5. Eye vane 6. Prism 7. Prism cap 8. Glass cover 9. Lifting pin 10. Lifting lever 11. Break pin 12. Spring break 13. Mirror 14. Pivot 15. light spring 16. Agate cap 17. Focusing stud 18. Dark sun Glasses.

Difference between prismatic compass & surveyor's compass.

Prismatic compass	Surveyor's compass
The graduation circle is fixed to broad needle. It does not rotate with line of sight.	The graduation circle is fixed to the box and rotates with line of sight
There is a prism at viewing end.	No prism. Only slit
The graduations are in WCB system.	The graduations are in QB system.
The graduations are marked inverted.	The graduations are marked directly.
Magnetic needle does not act as index.	Magnetic needle acts as index.
Tripod may or may not be required.	The instrument can't be used without tripod.

Temporary adjustments: 1. Centering 2.Levelling 3.Focusing the prism

True meridian and Magnetic meridian: The points of intersection of earth's axis with the surface of earth are known as geographical north & south poles. At any point on earth's surface the line passing through the point and north & South Pole of the earth is called true meridian. The angle made by a line with true meridian is called the true bearing of the line. The north & south pole of the earth are established by astronomical observations.

Whole Circle Bearing (WCB) and Quadrantal Bearing system (QB).

In whole circle bearing (WCB) the bearing of line at any point is measured w.r.t magnetic meridian. Its value may vary from 0^o to 360^o from magnetic north & the bearing increases in clockwise direction. This type of bearing system is used in prismatic compass.

In quadrantal bearing system (QB) : the bearing are read from north or from south, towards east or west. The angle measured w.r.t magnetic meridian is designated with letter N or S in the beginning to indicate whether it's from North or from south. The letters E or W indicates whether bearing read is to the east or west respectively.

Reduced bearing (RB): This system is also known as reduced bearing system.

Magnetic dip and Magnetic declination

A balanced needle after magnetisation will dip towards north in northern hemisphere and towards south in southern hemisphere. If it is taken to the pole of earth it will take vertical position. The vertical angle between the horizontal at the point and direction shown by perfectly balanced needle is known as dip.

All important surveys are plotted with reference to true meridian since the direction of magnetic meridian at a place changes with time. The horizontal angle made between the two meridians such as magnetic and true meridian is known as magnetic declination.

Determination of true bearing

True bearing = Magnetic bearing (+ or -) declination.

Errors in compass survey

The errors may be classified as

a. Instrumental errors b. Personal errors c. Errors due to natural causes.

1. Instrumental errors:

They are those which arise due to the fault adjustments in instruments.

1. The needle not being perfectly straight 2. Sluggish needle. e) Pivot bent f) Improper balancing weight g) Blunt pivot point

2. Personal errors:

a. Inaccurate levelling b. Inaccurate centering c. Inaccurate bisection

3. Natural errors:

a. Variation in declination b. Local attraction due to forces around

c. Irregular variations due to storms

COMPASS TRAVERSING

LOCAL ATTRACTION

A magnetic meridian at a place is established by a magnetic needle which is uninfluenced by other attracting forces. However, sometimes, the magnetic needle may be attracted and prevented from indicating the true magnetic meridian when it is in proximity to certain magnetic substances. Local attraction is a term used to denote any influence, such as the above, which prevents the needle from pointing to the magnetic north in a given locality. Some of the sources of local attraction are : magnetite in the ground, wire carrying electric current, steel structures, railroad rails, underground iron pipes, keys, steel – bowed spectacles, metal buttons, axes, chains, steel tapes etc., which may be lying on the ground nearby.

Detection of local attraction.

The local attraction at a particular place can be detected by observing the fore and back bearings of each line and finding its difference. If the difference between fore and back bearing is 180^{o}, it may be taken that both the stations are free from local attraction, provided there are no observational and instrumental errors. If the difference is other than 180^{o}, the fore bearing should be measured again to find out whether the discrepancy is due to avoidable attraction from the articles on person, chains, tapes etc. If the difference still remains, the local attraction exists at one or both the stations. Strictly speaking, the term local attraction does not include avoidable attraction due to things about the person or to other sources not connected with the place where the needle is read.

Elimination of local attraction: If there is local attraction at a station, all the bearings measured at that place will be incorrect and the amount of error will be equal in all the bearings. Bearings of the lines are calculated on the basis of the bearing of aine which has a difference of 180^{o} in its fore and back bearings. It is however, assumed that there are no observational and other instrumental errors. The amount and direction of error due to local attraction at each of the affected station is found. If, however, there is no such line in which the two bearings differ by 180^o, the corrections should be made from the mean value of the bearing of that line in which there is least discrepancy between the back sight and fore sight readings. If the bearings are expressed in quadrantal system, the corrections must be applied in proper direction.

MODULE 3: LEVELLING

Levelling is the art of determining the elevation of given points above or below a datum line. It involves measurement in vertical plane.

Objectives of Levelling:

1) To find the elevations of given points with respect to a given or assumed datum.
2) To establish points at a given elevation.

Uses:

- For estimating Reservoir capacity,
- For setting out grades for sewers,
- For calculating depth of cut or fill etc.

Definition of basic terms used in levelling:

Level surface: Any surface parallel to the mean spheroid of the earth is called level surface and the line drawn on level surface is known as level line.

Horizontal surface: Any surface tangential to level surface at a given point is called - Horizontal surface at point. Hence horizontal line is at right angles to plumb line.

Vertical surface: It is the line connecting the point & centre of earth. Vertical & horizontal line is normal to each other.

Datum: The point or the surface with respect to which levels of other points or planes are calculated is called – Datum or surface.

Mean sea level (MSL): Mean sea level is the average height of sea of all stages of tides. Any particular place is derived by averaging over a long period of 19 years. In India the mean's sea level used is at Karachi (Pakistan). In all important survey this is taken as datum.

Reduced level: Levels of various points are taken as heights above the datum surface are known as – Reduced level.

Bench mark: Bench mark is a relatively permanent point of reference whose elevation with respect to some assumed datum is known. There are four types of bench marks

1. G.T.S (Great trigonometry survey) 2. Permanent bench mark

3. Arbitrary bench mark. 4. Temporary bench mark.

LEVELLING INSTRUMENTS:

A level is an instrument giving horizontal line of sight & magnifying the reading far away from it. It consists of following 4 parts.

1. Telescope to provide line of sight.
2. Level tube to make the line of sight horizontal.
3. The levelling head to bring the bubble in its centre of run.
4. A tripod to support instrument

TYPES OF LEVELS:

1.Dumpy level 2. Wye level 3. Cooke's – Reversible level

4. Tilting level 5. Auto level 6. Cushing's level

Working principle of Dumpy level

Parts of the Instrument:

1. Telescope 2. Eye piece 3. Shade 4. Objective end
5. Longitudinal bubble 6. Focusing screw 7. Foot screws
8. Upper parallel plate 9. Diaphragm adjusting screws 10. Bubble tube adjusting screw 11. Transverse bubble tube 12. Foot plate.

The dumpy level originally designed by – Gravatt consists of a telescope tube firmly secured in two collars fixed by adjusting screws to the stage carried by the vertical spindle. The modern form of dumpy level has the telescope tube & the vertical spindle cast as one piece & a long bubble tube is attached to the top of the telescope. This form is known as – solid dumpy. Levelling head generally consists of two parallel plates with either three- foot screws or four – foot screws. The upper plate is known as – tribrach. Lower part is known as – trivet which can be screwed on to a tripod.

Levelling staff: It is a straight rectangular rod having graduations. The foot of the staff represents Zero reading. During levelling, staff is held vertical at the point and from level horizontal sight is taken.

Parts of telescope

1. Objective lens 2. Eye piece 3. Diaphragm 4. Focusing device

Fundamental axis of a level:

1. **Vertical axis:** It is the centre line of axis of rotation of the level.
2. **Axis of level tube:** It is an imaginary line tangential to the longitudinal curve of the tube at its middle point. It is horizontal when the bubble is central.
3. **Axis of telescope**: It is the line joining the optical centre of the object glass & the centre of eye piece.
4. **Line of collimation or line of sight:** It is the line joining the intersection of cross hairs & optical centre of the object glass.

Temporary staff adjustment of a level

1. Setting up 2. Levelling up 3. Focusing

Setting up: It is to set the tripod stand to a convenient height by bringing bubble to the centre of run through the movement of tripod legs radially.

Levelling up: To make the vertical axis truly vertical, the levelling is made with the help of foot screws.

1. Loosen the clamp and turn the instrument until bubble axis is parallel to line joining any two screws.

2. Turn the two screws inward or outward equally till bubble is centered.

3. Turn the telescope through 90 degrees so that it lies over the third screw and rotate the screw clockwise or anti clockwise till bubble is centered. Repeat it 2 or 3 times.

Focusing: For quantitative measurements it is essential that the image should always be formed in the fixed plane in the telescope where the cross – hairs are situated The operation of forming or bringing the clear image of the object in the pane of cross hairs is known as – focusing

Complete focusing involves two steps

1. Focusing the eye – piece
2. Focusing the objective Telescope

Sensitivity of a bubble tube: **-** It is defined as the angular value of one division of the bubble tube. Usually the linear value is kept as 2mm.

Level Tube: -

Level tube or bubble tube gives the direction of horizontal plane because the surface of a still liquid at all points is at right angle to the direction of gravity.

Spirit level or Bubble tube consists of a glass tube partially filled with a liquid, the inner surface of which is grounded so that a longitudinal section of it by a vertical plane through the axis of the tube is part of a circular arc. The tube is graduated on its upper surface.

The tube is partially filled with a liquid of low viscosity such as Alcohol, chloroform or sulphuric ether leaving a small space, which forms a bubble.

Procedure to determine the sensitivity of bubble tube: -

1) Set the Instrument at 'O' and level it accurately.
2) Sight a staff kept at a distance 'd' from 'O'. Note down the staff reading -S_1.
3) Using a foot screw, deviate the bubble tube over 'n' No. of divisions and again sight the staff. Note down the staff reading- S_2
4) Note down the distance between graduations on the level tube.

If the tilting is 20″ of arc when the bubble moves by 2mm, the sensitivity of level tube is expressed as 20″ for 2mm. A tube is said to be more sensitive of the bubble moves by more divisions for a given change in the angle.

Methods to improve Sensitiveness:

1) Increase the internal radius of the tube. (Arc radius)
2) Increase the diameter of the tube.
3) Increase the length of bubble.
4) Decreasing the roughness of wall.
5) Decreasing viscosity of the of the liquid.

CURVATURE AND REFRACTION:

Since the surface of the earth is spherical, a horizontal line departs from a level line, and also in long sights the horizontal line of sight does not remain straight but it bends downwards towards the earth surface due to Refraction.

Consider a level line AB. AC represents Horizontal line of sight. Since A and B represents same level a correction equal to BC should be applied which is known as correction due to curvature.

Distance to Visible horizon

Let 'P' be the point of observation, it's being equal to 'C' and let 'A' be the point on the horizon is a point where the tangent from 'P' meets the level line.

Error due to Curvature: The horizontal line of sight does not remain straight but it slightly bends towards having concavity towards earth surface due to refraction.

$\mathbf{C_C = d^2/2R}$

Error due to Refraction: As the line of sight is curved downwards towards the earth surface reading gets decreased. To make the objects appear higher than they really are, this correction is applied to staff readings, $\mathbf{C_R = 1/7\ d^2/2R}$ where d is in Km.

Combined correction for curvature and refraction is $C= (6/7)\ d^2/2R$

TERMS USED IN LEVELLING:

1. **Station:** Station is the point where levelling staff is held & not the point where level is kept.
2. **Height of instrument:** For any set up of the level the height of instrument is the elevation of the plane of sight respect to assumed datum. This also known as – plane of collimation.
3. **Back sight:** It is sight taken on a level staff held at a point of known elevation with an intension of determining plane of collimation or sight.
4. **Intermediate sight (I.S):** Sight taken on after taking back sights before taking last sight from an instrument station is known as – intermediate sight.
5. **Fore sight (F.S): T**his is the last reading taken from instrument just before shifting the instrument.
6. **Change point (C.P):** This is a point on which both fore sight & back sight are taken.
7. **Reduced level:** Reduced level of a point is the level of the point with respect to assumed datum.

TYPES OF LEVELLING

1. Simple levelling
2. Differential levelling
3. Fly levelling
4. Profile levelling
5. Cross sectioning
6. Reciprocal levelling

Simple levelling: It is the difference in levels of two near by points. It is obtained by simple levelling **Differential levelling:** When the distance between two points is very large it may not be possible to take readings from single setting of instruments. Each shifting is facilitated by taking CP.

Fly levelling: It is to carry out levelling with respect to temporary bench mark in convenient direction taking number of CP

Cross sectioning: In many engineering projects to calculate earth work involves not only LS, but CS of ground is taken in regular intervals.

Reciprocal levelling: As we know from the previous cases that by equating BS and FS distance the correction for non-collimation, curvature and retraction can be eliminated.

But when carrying level across a river, valley it is not possible to set up the instrument at centre. Special method (i.e. Reciprocal Levelling) is used to obtain the exact level differences.

Let A and B the two stations. The level is set at a point near to the station A and after levelling the Instrument reading are taken for A and B.

Since A is very near to Instrument station no error will be introduced due to curvature, Refraction and Collimation. But there will be an error's' is the staff reading at B. The level is then shifted to the other bank on a point very near to B and the readings are taken on a staff held at A and B. Since B is very near no error will be introduced but there will be an error of 'e' is staff reading of 'A'.

For first set of level correct staff reading will be,

On A = ha On B = h_b-e

True difference in elevation = H = ha- (h_b-e)

For second set, correct reading is

On A = h'a-e. On B = h'b

The true difference in elevation is equal to the mean of the two apparent difference in elevation obtained by reciprocal observation.

H=[(ha-hb)+(h'a-h'b)]/2

Barometric Levelling:

It is based on the fact that the atmospheric pressure varies inversely with the height. The higher the place of observation, the lesser will be the atmospheric pressure.

A Barometer is used for the determination of the difference in pressure between two stations and their relative altitudes can be approximately deduced.

Hypsometry:

The working of Hypsometry to determine the altitudes of stations depends on the fact that the temperature at which water boils varies with the atmospheric pressure. A liquid boils when its pressure is equal to atmospheric pressure. The boiling point of vapor water is lowered at higher attitudes since the atmospheric pressure decreases.

A Hypsometer consists of a sensitive Thermometer, a small boiler and spirit lamp. Knowing the boiling temperature, atmospheric pressure can be found out from the relation.

Pressure in inches of Mercury = 29.92 ± 0.586 T_1

Errors in levelling:

1.Instrumentrumental:

1. Error due to imperfect adjustment.
2. Error due to sluggers bubble
3. Error due to movement of objective slide
4. Rod not of standard length
5. Error due to defective joint.

2. Natural:

    1. Earth's curvature
    2. Atmospheric refraction
    3. Variation in temperature
    4. Settlement of tripod
    5. Wind vibrations.

3. Personal:

    a) Mistakes in manipulation
    b) Rod handling
    c) Mistake in reading the rod
    d) Mistake in recording
    e) Errors in sighting

BOOKING AND REDUCING LEVELS:

There are two methods: i) Collimation or HI method

ii) Rise and fall method.

1.HI or PC method:

a) HI is calculated by adding BS to the BM
b) Elevations are calculated by deducting FS or IS from HI
   Check ΣBS- ΣFS= Last RL - First RL

2. RISE and FALL METHOD:

a) In this method comparing the readings for same setting of Instrument level difference between two consecutive points is found out.
b) The difference between staff readings indicates 'Rise' or 'fall'.
c) R.L of station is found out by adding Rise or subtracting fall.
   Check: ΣBS-ΣFS= ΣRise- Σ fall= Last RL – First R.L

CONTOURING

Contour: It is an imaginary line on the ground joining the points of equal elevation.

The value of a plan or map is highly useful if the relative positions of points are represented by both horizontally and vertically. Such maps are known as topographic maps. A topographic map gives clear picture of surface of ground.

Contour Interval (C.I): The vertical distance between any two consecutive contours is called contour Interval. The Contour Interval is kept constant for a contour plan.

The Horizontal distance between two points on two consecutive contours is known as Horizontal equivalent and it depends upon the steepness of the ground.

Factors to be considered for selecting proper contour Interval: -

1) **Nature of ground**: - Flat terrain- Smaller Contour Interval
   Hilly or Rolling terrain – Greater Contour Interval (otherwise contours will be very close)

2) **Scale of map**: - Contour Interval is inversely proportional to scale.
   1. If scale is small – Contour Interval should be large.
   2. Scale is large – Contour Interval should be small.

3) **Purpose and Extent of surveying: -**
   If survey is required for detailed design work or for accurate earthwork, smaller contour interval is used.

4) **Time and expense of field office work: -**
   If time available is less- Greater Contour Interval is used.

Characteristics of Contour: -

1. Two contour lines of different elevations cannot cross each other except incase of an overhanging cliff.
2. Contour lines close together indicate steep slope. If they are far apart indicates gentle slope. If they are equally spaced indicates uniform slope.
3. A closed contour line with one or more ones inside indicates a hill, similarly with one or more lower ones indicates a depression.
4. A single contour cannot split in to two lines.
5. A contour line must be a closed one, though not necessarily with in the limits of map.

6. Contour lines cross a watershed or Ridge line at right angles forming curves of U shape round it with concave side of curve towards higher ground.
7. Contour lines cross a valley line at right angles forming sharp curves of V shape across it with convex side towards higher ground

Methods of Locating Contours: -

1) **Direct Method:** - In this contour is located by determining the positions of series of points through which contour pass.
   A Dumpy level or a hand level is used for this method.

2) **Indirect method: -** In this method some guide points are selected along a system of straight lines and their elevations are found. The points are then plotted and contours are then drawn by interpolation. While interpolating it is assumed that the slope between any two adjacent guide points is uniform.

Some indirect methods: -

1) **By squares or spot levelling**: - When the area to be surveyed is small and ground is not much undulating this method is used with squares of size 5 to 20m, depending upon the nature of ground. The elevations of corners are determined by level. The contour lines may be drawn by interpolation.
2) **By cross sections**: - In this method cross sections are run traverse to the centre line of road, railway or canal. Usually the cross sections are taken to the main line.
3) **Tacheometric method:** - Tacheometer is a Theodolite fitted with stadia diaphragm so that from the staff readings the elevation and horizontal distance of a station can be ascertained.

Interpolation of Contours: -

It is the process of spacing the contours proportionately between plotted ground points established by indirect method.

1) **By estimation: -**
   The position of contour points between the guide points is located by estimation.

2) **By Arithmetic Calculation:** - The position of contour points between guide points is located by Arithmetic calculation. This method is time consuming.
3) **By Graphical method:** The position of contour points between guide points is located by Graphical method.

Contour Gradient: -

It is a line lying throughout on the surface of the ground and maintaining a constant inclination to the horizontal. To locate the contour gradient in the field a clinometer, Theodolite, a level can be used.

Uses of contour maps:

1) To draw the section of the ground.
2) To determine the inter-visibility between two stations.
3) To race the contour gradient.
4) To measure the drainage area (catchment's area).
5) To calculate the reservoir capacity.

MODULE 4

THEODOLITE SURVEY

INTRODUCTION

A "theodolite" is an instrument used to measure the horizontal & vertical angles.

Uses:-

1. Measurement of horizontal & vertical angles.
2. Prolonging a straight line.
3. Measurement of bearing.
4. Measurement of horizontal & vertical distance.
5. Determination of direction of true north.
6. Determining the difference in elevation.
7. Setting out curves.

CLASSIFICATION

1. Transit Theodolite 2. Non-Transit Theodolite

"Transit Theodolite" is one in which the line of sight can be reversed by revolving the telescope by 180^0 in the vertical plane. Transit Theodolite is in use now & the "non transit" is obsolete.

Parts of the Theodolite:-

1. **Telescope** :- It is an integral part of a theodolite rested on a horizontal axis called the "trunnion axis".

2. **Vertical circle** :- It is a circular graduated arc attached to the trunnion axis of the telescope. When the telescope rotates about the trunnion axis, the vertical circle also rotates. By means of vertical circle clamp & its corresponding slow motion or tangent screws, the telescope can be set accurately. The circle is graduated continuously from 0 degree to 360 degree in clock wise direction.

3. **Index frame or vernier frame** :- Two verniers are fitted on the index frame to measure the vertical angle.

When the telescope is moved in the vertical circle, the vertical circle moves relative to the verniers

4. **Standars or "A" frame :-**

Two standards resembling the form of letter "A" are mounted on the upper plate. The trunnion axis of the telescope is supported on "A" frame .

5. **Levelling head :-** It consists of two triangular parallel plates known as "tribrach plate". The upper tribrach has three arms carrying levelling screws. the lower tribrach has a circular hole through which a plumb bob may be suspended in some instument , the levelling screws are provided b/etween parallel plates

Function of levelling head :-

a) To support the main part of the instrument

b) To attach the theodolite to the tripod

c) To provide a means for levelling the theodolite

6. **Lower plate** "Lower plate" is also called as a "scale plate". The lower plate carries a horizental circle & hence known as a "scale plate".The lower plate carries a lower clamped screw & a corresponding slow motion or a tangent screw with the help of which it can be fixed accurately in any designed position. Usually, the size of theodolite is represented by the size of the scale plate. ex :-10cm, 12cm,theodolite etc.

7. Upper plate (vernier plate) :- it is attached to the inner axis & carries 2 verniers. The upper plate supports the standards it carries an upper clamp screw & a corresponding tangent screw for the Purpose of accurately fixing the position

Note :-

1. On clamping the upper & unclamping the lower clamp , the instrument can rotate on its outer axis without any
   relative motion b/w the plates (instrument rotates but no change in angle)
2. If the lower clamp is clamped & the upper clamp is unclamped , the upper plate & the instrument can rotate on
   the inner axis with a relative motion b/w the vernier & the scale (instrument rotates & the angle changes)
3. On releasing both the plates, the instrument rotates about the inner & outer axis (instrument rotates angle changes)
4. For using tangent screws, the corresponding clamp screw must be tightened

Some basic definition :-

Vertical axis :- It is an imaginary axis about which the instrument can be rotated in a horizontal plane

Horizontal axis :- It is the axis about which the telescope & the vertical circle rotate in a vertical plane. It is also called as "trunnion axis"

Line of sight or line of collimation :- It is an imaginary line joining the centre of cross hairs to the centre of the objective.

Centering :-The process of setting the theodolite exactly over the station mark is known as "centering"

Transiting :- Rotating the telescope about 180 degree above the trunnion axis or it is the process of turning the telescope in vertical plane through 180 deggre about the trunnion axis. It is the process of turning the telescope in vertical plane through 180 deggre about the trunnion axis. Since, the line of sight is reversed in this position it is also known as "plunging or reversing"

Swinging the telescope :-

It is the process turning the telescope in a horizontal plane. if the telescope is rotated in clockwise direction , it is called "right swing" & if the telescope is rotated in anti clockwise direction , it is called "left swing"

Face left observation :-

If the face of the vertical circle is to the left of the observer, the observation of the angle is known as "face left Observation. Similarly, if the face of the vertical circle is to the right of the observer, the observation of the angle is known as "face right observation"

Telescope normal :-A telescope is said to be normal or direct when the face of the vertical circle is to the left of the observer & the bubble of the telescope is up.

Telescope inverted :-A telescope is said to inverted when the face of the vertical circle is to the right & the bubble of the telescope is down

Temporary Adjusting or station adjustment

i. Setting over the station
ii. Leveling up
iii. Eliminating or elimination of parallax
iv. Focusing the eye piece
v. Focusing the objective

Measurement of horizontal angles :- (Please refer the text book for tabular column)

1. Set up the instrument at "A" & level it accurately
2. Release all the clamps , turn the upper & lower plates in opposite direction till the zero of the vernier is against zero of the scale & the vertical circle is to the left
3. Clam both the plates together by upper clamp & the lower clamp. Operative the upper tangent screw & bring the two zero's to coincide.

4. Loose the lower clamp , the signal at point 'p' (since both the plates are clamped together instrument will rotate about outer axis & the reading will not change)
5. Bisect point 'p' accurately by using lower tangent screw check the reading of vernier "A&B"
6. Unclamp the upper plate (lower clamp is tightened) & rotate the instrument clock wise about the inner axis to bisect the point 'R' clamp the upper plate & bisect the point 'R' accurately using the upper tangent screw
7. Take the reading on both the verniers

Method of repetition :-(Pl refer the text book for tabular column)

Measuring an angle two or more times allowing the vernier to remain clamped each time at the end of each measurement instead of setting it back to zero when sighting at the back sight.

Advantages of measurement of repetition method:-

1. The errors of graduation are minimized by reading the angles on different parts of graduated circle
2. Personal errors of bisection are eliminated
3. The errors due to eccentricity of centers & that of vernier are eliminated by reading both the verniers
4. Errors due to line of collimation not being perpendicular to the transverse axis of the telescope is eliminated by taking face left & face right reading

Reiteration (Direction method)

This method of measuring the angle is preferred when several angular measurement are to be taken at a station. All the angle are measured successively & finally the horizon is closed.

Note 1 :- The final reading on vernier should be same as the intial reading if not , the descripancy or the error is equally distributed among all the angles.

Note 2 :- The method of reiteration is most commonly used in triangulation survey.

Note 3 :- For the face left, the observation should be made in clockwise direction where as for face right the observation should be made in the anti clockwise direction

Comparison of method of repetition & reiteration

1. Method of repetition is preferred for the measurement of a single angle where as the method of reiteration is preferred in triangulation where number of angle are required at one point.
2. By exercising appropriate precautions, instrumental error can be eliminated in either of the cases
3. Through method of repetition appears to be better it is more time consuming & chances of personal error are more.

Sources of Errors in theodolite works

1. Instrumental errors 2. Personal errors 3. Natural errors

1. **Instrumental error** :-
   a) Error due to eccentricity of inner & outer arm
   b) Error due to line of collimation not being perpendicular to the trunnion axis
   c) Trunnion axis not perpendicular to vertical axis
   d) Vertical axis not truly vertical
   e) Vertical circle index error
   f) Error due to imperfect graduation on horizontal scale

2. **Personal errors** :-
   a) In accurate centering
   b) Error of pointing
   c) Improper focusing

d) Level bubble not centered

e) Misreading verniers

f) Displacement of tripod

3. **Natural error :-**

a) Poor visibility (rain, snow fall , blowing dust)

b) Sudden temperature change

c) Settlement of tripod leg on hot pavement or saggy ground

d) High velocity wind

Tacheometry

It is a method of surveying in which horizontal distances and vertical elevations are determined from subtended intervals and vertical angles observed with an instrument.

Uses of Tacheometry

1. Preparation of topographic map where both horizontal and vertical distances are required to be measured;
2. Survey work in difficult terrain where direct methods of measurements are inconvenient;
3. Reconnaissance survey for highways and railways etc;
4. Establishment of secondary control points.

Instrument:

The instruments employed in Tacheometry are the engineer's transit and the leveling rod or stadia rod, the theodolite and the subtense bar

Systems of Tachometric Measurement

Depending on the type of instrument and methods/types of observations, tacheometric measurement systems can be divided into two basic types:

(i) Stadia systems and

(ii) Non-stadia systems

Stadia Systems

In this system, staff intercepts at a pair of stadia hairs present at diaphragm, are considered. The stadia system consists of two methods:

- Fixed-hair method

- Movable-hair method

Non - stadia systems

This method of surveying is primarily based on principles of trigonometry and thus telescopes without stadia diaphragm are used. This system comprises of two methods:

(i) Tangential method (ii) Subtense bar method.

Fixed-hair method or Stadia method

It is the most prevalent method for tacheometric surveying. In this method, the telescope of the theodolite is equipped with two additional cross hairs, one above and the other below the main horizontal hair at equal distance. These additional cross hairs are known as stadia hairs. This is also known as tacheometer.

Principle of Stadia method

A tacheometer is temporarily adjusted on the station P with horizontal line of sight. Let a and b be the lower and the upper stadia hairs of the instrument and their actual vertical separation be designated as i. Let f be the focal length of the objective lens of the tacheometer and c be horizontal distance between the optical centre of the objective lens and the vertical axis of the instrument. Let the objective lens is focused to a staff held vertically at Q, say at horizontal distance D from the instrument station.

Determination of Tacheometric Constants

The stadia interval factor (K) and the stadia constant (C) are known as tacheometric constants. Before using a tacheometer for surveying work, it is required to determine these constants. These can be computed from field observation by adopting following procedure.

Step 1 : Set up the tacheometer at any station say P on a flat ground.

Step 2 : Select another point say Q about 200 m away. Measure the distance between P and Q accurately with a precise tape. Then, drive pegs at a uniform interval, say 50 m, along PQ. Mark the peg points as 1, 2, 3 and last peg -4 at station Q.

Step 3 : Keep the staff on the peg-1, and obtain the staff intercept say s_1 .

Step 4 : Likewise, obtain the staff intercepts say s_2, when the staff is kept at the peg-2,

Step 5 : Form the simultaneous equations, using Equation (23-2)

$D_1 = K. s_1 + C$ --------------(i)

and $D_2 = K. s_2 + C$ -------------(ii)

Solving Equations (i) and (ii), determine the values of K and C say K_1 and C_1 .

Step 6 : Form another set of observations to the pegs 3 & 4, Simultaneous equations can be obtained from the staff intercepts s_3 and s_4 at the peg-3 and point Q respectively. Solving those equations, determine the values of K and C again say K_2 and C_2.

Step 7 : The average of the values obtained in steps (5) and (6), provide the tacheometric constants K and C of the instrument.

Anallactic Lens

It is a special convex lens, fitted in between the object glass and eyepiece, at a fixed distance from the object glass, inside the telescope of a tacheometer. The function of the anallactic lens is to reduce the stadia constant to zero. Thus, when tacheometer is fitted with anallactic lens, the distance measured between instrument station and staff position (for line of sight perpendicular to the staff intercept) becomes directly proportional to the staff intercept. Anallactic lens is provided in external focusing type of telescopes only.

Uses of Stadia Method

The stadia method of surveying is particularly useful for following cases:

1. In differential leveling, the backsight and foresight distances are balanced conveniently if the level is equipped with stadia hairs.
2. In profile leveling and cross sectioning, stadia is a convenient means of finding distances from level to points on which rod readings are taken.
3. In rough trigonometric, or indirect, leveling with the transit, the stadia method is more rapid than any other method.
4. For traverse surveying of low relative accuracy, where only horizontal angles and distances are required, the stadia method is a useful rapid method.

On surveys of low relative accuracy - particularly topographic surveys-where both the relative location of points in a horizontal plane and the elevation of these points are desired, stadia is useful. The horizontal angles, vertical angles, and the stadia interval are observed, as each point is sighted; these three observations define the location of the point sighted.

Errors in Stadia Measurement

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

1. Error in Stadia Interval factor

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

2. Error in staff graduations

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

3. Incorrect stadia Interval

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

4. Error in verticality of staff

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

5. Error due to refraction

This causes random error in staff reading.

6. Error in vertical angle

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

Tangential Method

The tangential method of Tacheometry is being used when stadia hairs are not present in the diaphragm of the instrument or when the staff is too far to read.

In this method, the staff sighted is fitted with two big targets (or vanes) spaced at a fixed vertical distances. Vertical angles corresponding to the vanes, say q_1 and q_2 are measured. The horizontal distance, say D and vertical intercept, say V are computed from the values s (pre-defined/known) q_1 and q_2 . This method is less accurate than the stadia method.

Depending on the nature of vertical angles i.e, elevation or depression, three cases of tangential methods are there.

When Both vertical Angles are Angles of Elevation

Subtense bar Instrument

Subtense bar is a graduated bar of fixed length mounted horizontally on a tripod stand. The bar is centrally supported on a leveling head and is fitted with a sighting device at the centre. At its ends, there are targets and these are at fixed distance apart. The bar can rotate about the vertical axis in a horizontal plane. It can be fixed at any position using a clamping and its tangent screw. It is used to measure horizontal distance and difference in elevation indirectly where the terrain is rough and requirement of accuracy is not high.