MODULE - I
INDRODUCTION AND CHAIN SURVEYING

Surveying:

Surveying is an art of determining the relative positions of various points on, above or below the surface of the earth by means of direct or indirect measurement of distance, direction and elevation.

Purpose of surveying:

The primary object of surveying is to prepare a plan or map to show the relative position of the objects on the surface of the earth. It is also used to determine the areas, volumes and other related quantities.

Types Of Survey:

1. classification based on accuracy desired:

a) Plane surveying:

i) The curvature of the earth is neglected
ii) A line joining any two points is considered straight.
iii) The triangle formed by any three points is considered as plane triangle.
iv) It is done on a area less than 250 sqKm.

b) Geoditic surveying:

i) The curvature of the earth is taken.
ii) A line joining any two points is considered as curved line.
iii) The triangle formed by any three points is considered as spherical triangle.
iv) It is done on a area greater than 250sqKm

2. classification based on place of survey:

a. land survey
b. hydrographic survey
c. underground survey
d. aerial survey

3. **classification based on instrument used:**

a. chain survey
b. traverse survey
c. levelling
d. tacheometry
e. plane table surveying
f. total station survey
g. theodolite syrveying

4. **Classification of survey based on purpose:**

a. Geological Survey
b. Geographical Survey
c. Engineering Survey
d. Cadastrial survey

e. Defence Survey
f. Mine Survey
g. Route Survey
h. Archaeological Survey

Principles Of Surveying:

(i) Working from whole to part.
(ii) To locate a new station by at least two measurements (angular, linear) from fixed reference points

Various Measurements in Surveying:

a) **Horizontal Distance:** distance measured in horizontal plane
b) **Horizontal Angle:** angle is measured between two points in horizontal plane.
c) **Vertical distance:** vertical distances are measured in the direction of gravity.
d) **Vertical Angle:** vertical angle is measured between two lines in vertical plane.

Plan and Map:

Plan: it is the graphical representation of various features on or near to the earth's surface such as projected on a Horizontal plane. Plan represents a area on horizontal plane.

Map: In this, the scale of graphical projection or horizontal plane is small. Due to small scales a map depicts a large number of details as compared to plan.

Scale of Map:

A map is made on a sheet of paper which has limited dimensions. On this restricted area, a large number of details have to be shown.

The ratio of distance between two points on map to corresponding distance on ground is called **Scale of Map.**

Representation of Scale:

a) **Engineer's Scale:** This scale is represented by a statement like 1 cm= 50 m or 1cm= 180 m etc. A scale of 1 cm= 50 m represents 50m on ground is represented by 1 cm on Map.
b) **Representative fraction:** this scale is expressed in same units. 1 cm= 50 m is represented in RF as 1/5000. Here 5m is converted into 5000cm.
c) **Graphical Scale:** it is the line drawn on a map such that its map distance corresponds to a convenient unit of length on ground.

MODULE I
CHAIN SURVEYING

Methods of linear Measurements:

a) **Direct method:** the direct methods are employed in field using tape or a chain.
b) **Optical Method:** un optical methods, the distances are measured indirectly using the principles of optics.
c) **Electronic Distance Measurement method:** EDM is the most recent development in this field.

Approximate Linear Measurement methods:

i. **Pacing**
ii. **Passometer**
iii. **Pedometer**
iv. **Odometer**
v. **Measuring wheel**
vi. **Speedometer**

Chain Surveying:

Chain surveying is the type of surveying in which only linear measurements are made in the field.

Fundamental principle of chain surveying:

The main principle of chain surveying or chain triangulation is to provide a framework consist of number of well-conditioned triangles or nearly equilateral triangles. It is used to find the areaof the field.

W**ell-conditioned triangle:**

A triangle is said to be well- conditioned or well proportioned when it contains no anglesmaller than 30^0 and no angle greater than 120^0.The main principle of chain surveying is chaintriangulation. It consists of frame work of triangles. To plot the network of triangles accurately, thetriangles must be nearly equal to equilateral or well-conditioned. The distortion due to errors inmeasurement and plotting should be minimum.

DESCRIPTION OF INSTRUMENTS:-

1 a) Chain:-

The chain is composed of 100 or 150 pieces of galvanized mild steel wire, 4mm in diameter called links .The ends of each link are bent into a loop and connected together by means of three oval rings. The ends of the chain are provided with handles for dragging the chain on the ground, each wire with a swivel joint so that the chain can be turned without twisting. The length of the chain is measured from the outside of one handle to the outside of another handle.

Following are the various types of chain in common use:

1) Metric chains

2) Gunter` s chain or surveyors chain

3) Engineers chain

4) Revenue chain

5) Steel band or Band chain

Metric chain:

Metric chains are made in lengths 20m and 30m. Tallies are fixed at every five-meter length and brass rings are provided at every meter length except where tallies are attached

b) Tapes:

The following are the various types of tapes

i) Cloth tape

ii) Metallic tape

iii) Steel tape

iv) Invar tape

Different Tape corrections:

a. Correction for absolute length or standardisation.
b. Correction for temperature.
c. Correction for pull or tension.
d. Correction for sag. (- ve)
e. Correction for slope. (- ve)

Among the above, metallic tapes are widely used in surveying. A metallic tape is made of varnished strip of waterproof line interwoven with small brass, copper or bronze wires. These are light in weight and flexible and are made 2m, 5m 10m, 20m, 30m, and 50m.

2. Arrows:

Arrows are made of good quality hardened steel wire of 4 mm diameter. The arrows are made 400 mm in length, are pointed at one and the other end is bent into a loop or circle

3. Ranging rods:

Ranging rods are used to range some intermediate points in the survey line The length of the ranging rod is either 2m or 3m. They are shod at bottom with a heavy iron point. Ranging rods are divided into equal parts 0.2m long and they are painted alternately black and white or red and white or red, white and black. When they are at considerable distance, red and white or white and yellow flags about 25 cm square should be fastened at the top.

4. Cross staff:

The simplest instrument used for setting out a right angle. The common forms of cross staff are:

1. Wooden cross staff
2. French cross staff
3. Adjustable cross staff
4. Open cross staff

5. Offset Rod:

The offset rod is used for measuring the off set of short lengths. It is similar to a ranging rod and is usually of 3m lengths.

6. Pegs:

These are rods made from hard timber and tapered at one end, generally 25mm or 30mm square and 150mm long wooden pegs are used to mark the position of the station on.

PRACTICING UNFOLDING AND FOLDING OF A CHAIN:

UNFOLDING:

- Remove the strap of the folded chain and take both the handles in the left hand and hold the remaining portion of the chain in the right hand.
- Holding both the handles in the left hand, throw the remaining portion o f the chain in the forward direction on the ground.
- Now the follower stands at the starting station by holding one handle and directs the leaderto move forward by holding the other handle until the chain is fully stretched.

FOLDING:

- Bring the two handles together on the ground by pulling the chain at the center.
- Commencing from the center two pairs of links are taken at a time with the right hand and placed alternatively in both directions in the left hand.
- When the chain is completely folded the two brass handles will appear at the top.
- Now tie the chain with leather strap.

Operations involved in chain survey:

(i). Ranging: The process of locating intermediate points on a straight line between two endpoints in a straight line.

(ii). Chaining: The process of measuring the distance with a chain or tape.

(iii). Offsetting: The process of measuring the lateral distance of the object from the survey line to the left or right according to their positions**.**

Terminology:

(a).Main stations: Main station is a prominent point on the chain line and can be either at the beginning of the chain line or at the end or along the boundary.

(b). Main Survey Lines: the line joining the main survey stations are called as survey lines also known as main survey lines.

(c). Subsidiary stations: The stations located on the main survey lines are known as Subsidiary stations.

(c). Tie stations: These are also subsidiary stations taken on the main survey lines to locate the detailsof the object

.

(d) Check lines: These lines are run to check the accuracy of the traverse consisting of a frame work of tringles. Check lines are measured in the field during the survey process of the land.

Offset:

An offset is the lateral distance of an object or ground feature measured from a survey line. The two types of offsets are,

(i). Perpendicular offset: The angle of offset from a point on a chain line is 90^0

(ii). Oblique offset: When the angle of offset is other than 90^0.

Line Ranger:

The line Ranger is a small reflecting instrument used for fixing intermediate points on thechain lines. Without going to either end, we can fix the intermediate points.

Cross Staff Survey:

This type of survey is used for locating the boundaries of a field which are usually not of regular shape, for the purpose of finding the area of the field.

A base line is selected in the middle of the field and the field area is divided into simple regular figures.

Cross staff is used for setting out the perpendicular/normal to the base line.

The length of the base line and the perpendicular distances are measured with the help of chain/tape.

Cross staff(and also the optical Square) is used for setting out the off sets.

The base line should be so selected that offsets on either side of the base line should nearly be equal. the calculation of areas is usually done in tabular form.

Errors in Chain Surveying:

a. **Compensating Errors**: Which are liable to occur in either direction and tend tocompensate.

b. **Cumulative Errors:** Which occur in the same direction and tend to add or subtract. It may be positive (measured lengths more than the actual length) or negative (measured lengths less than the actual length).

c. **Personal error**: Bad ranging (Cumulative Errors). Careless holding (CompensatingErrors). Bad straightening (Cumulative Errors). Non- horizontality (Cumulative Errors). Sag in chain

d. Natural Errors: Variation in temperature

MODULE II
COMPASS SURVEYING

Compass surveying:

Compass surveying is the type of surveying in which the direction of the survey lines are measured with a compass and the length of the survey lines are measured with a tape or chain in the field.

Meridians:

The direction of a line is expressed in terms of horizontal angle which the line makes with a reference line. The direction of line is generally measured in clock wise direction. The fixed reference line is called as meridian.

Four types of meridians are used in surveying are:

a. True meridian
b. Magnetic meridian
c. Grid meridian
d. Arbitrary meridian

Bearing:

The bearing of a horizontal line is the angle which it makes with reference line or meridian. These are the four types of bearings and meridians as described below.

(a). True meridian and bearing:

True meridian:

The line or plane passing through the geographical North Pole, South Pole and any point on the surface of the earth, is known as true meridian or geographical meridian. True meridian at a point is constant.

True bearing:

The angle between the true meridian and a survey line is known as true bearing or Azimuth of the line.

(b). Magnetic meridian and Bearing:

Magnetic meridian:

Magnetic meridian at a point is the direction indicated by freely suspended, properlybalanced and unaffected magnetic needle at that point.

Magnetic Bearing:

The angle between the magnetic meridian and a survey line is known as magnetic bearing or bearing of the line. It changes with time.

Bearings designation:

1.Whole circle bearing system(WCB):

The magnetic bearing of a line measured clockwise from the north pole towards the line, is known as ‘ whole circle bearing’, of that line.Such a bearing may have any value between 0◦to 360◦ . The whole circle bearing of a line is obtained by a prismatic compass.

2.Quadrantal bearing(QB):

The magnetic bearing of a line measured clock wise or counter clock wise either from north pole or south pole (Whichever is nearer the line) towards east or west ,is known as the ‘quadrantal bearing’ of the line . This system consists of four quadrants NE, SE, SW and NW. The value of a quadrantal bearings lies between 0◦to 90◦, but the quadrants should always be mentioned. Quadrantal bearings are obtained by the surveyor’s compass.

Fore Bearing and Back Bearing:

Fore bearing is the bearing of the line in the direction of progress of survey while **Back bearing** is the bearing of a line opposite to the direction of progress of survey.

The difference of FB and Bb of a line is always 180^0 if both the stations are perfectly free from local attractions.

Magnetic Needle:

It is a magnetized iron in the form of long, narrow strip. It is freely suspended at its centre of gravity and takes turn in the horizontal plane and aligns itself parallel to lines of magnetic force of earth at that location of magnetic needle.

COMPASS - TYPES

There are two types of compasses:

1) Prismatic compass

2) Surveyor’s compass.

3) Tubular compass.

4) Trough compass.

Prismatic Compass:

Prismatic compass is very valuable instrument. It is usually used for rough survey for measuring bearing and survey lines. The least count of prismatic compass is 30 min. It consists of circular box of 10cm-12 cm dia. of non magnetic material. pivot is fixed at the centre of box and is made up of hard steel with a Sharp pivot. Graduated aluminium is attached to the needle. It is graduated in clockwise direction from 0^0 to 360^0.the figures are written in inverted. Zero Is written at south end and 180 at north end and 270 at the east. Diametrically opposite are fixed to the box. The sighting vane consists of a hinged metal frame in the centre of which is stretched a vertical Horse hair fine silk thread of which is stretched a vertical hair. it presses against a lifting pin which lift the needle of the pivot and holds it against the glass lid. Thus preventing the wear of the pivot point to damp the oscillations of the needle when about to take reading and to bring to rest quickly, a light spring is brought lifted Inside the box. The face of the prism can be folded out the edge of the box when North end is used Sometime the sighting vanes is provided with a hinge mirror Which can be placed upward or downwards on the frame and can be also Slide along it is required. The mirror can be made inclined at any angle so that Objects which are too high or too low can be sighted directly by reflecting.

Temporary Adjustments of a Prismatic Compass

1. **Fixing the compass to tripod**:

   The tripod is placed at the required station with its legs well apart. Then the prismatic compass is held by the left hand and placed over the threaded top of the stand. After this, the compass box is turned by clockwise by the right hand. Thus the threaded base of the compass box is fixed with threaded top of the stand.

2. **Centering:**

   Normally, the compass is centered by dropping a piece of stone from the bottom of the compass box. Centering may also be done with the aid of plumb bob held centrally the compass box.

3. **Levelling:**

Levelling is done with the help of a ball and socket arrangement provided on top of the tripod stand. This arrangement is loosened and the box is placed in such a way the graduated ring rotates freely without touching either the bottom of the box or the glass cover top.

4. **Adjustment of prism**:

The prism is moved up and down till the figures on the graduated ring are seen sharp and clear.

5. **Observation of bearing:**

After centering and levelling the compass box over the station the ranging rod at the required station is bisected perfectly by sighting through the slit of the prism and horse hair at the sight vane

Prismatic compass versus the surveyor's compass:

S.No	Characteristic	Surveyor,s compass	Prismatic Compass
1.	Magnetic Needle	Edge bar needle is used and it acts as an index	Board needle is used which is hidden below the aluminum ring. It does not acts as an index.
2	Graduation	Graduated ring is attached to the box and ring rotates with the box.	Graduated ring is attached to the needle and remains stationary when the box is rotated.
3	Sighting vanes	Object vane consists of a metal frame with vertical hair. Eye vane also consists of a metal frame with a fine silt	Object vane consists of a metal frame with a vertical hair. Eye vane also consists of a small frame with a fine silt near the prism.
4	Reading	Sighting and reading are done separately and that too from different positions. After sighting the object, the observer moves around and takes the reading at the north end of the needle.	Sighting and reading are done simultaneously from the same position of the observer.
5	Support	This cannot be used without a	This can be held in hand while

	requirement	support like tripod etc	taking the observation but it is better to use tripod with it.

Magnetic declination:

The horizontal angle which the magnetic meridian makes with the true meridian is called as **magnetic declination.**

When magnetic north lies towards the west of north, then the declination is said to be **negative.**

If the magnetic north lies towards the east of true north, then the declination is said to be **positive.**

Declination varies from place to place and also from time to time at the same place. This variation of declination at different places is studied with the help of **isogonic lines** which are the lines passing through the points on the earth's surface having the same declination at a particular time. A special case of isogonic lines is the **agonic lines** which represents the isogonic lines with zero declination. Thus all the points on agonic lines, the true meridian and the magnetic meridian coincide.

Variations in magnetic Declination:

Magnetic meridian at a place does not remain constant and also does not remain same at all the points on the earth. At a place there are four types of variations in magnetic declination.

Secular Variations:

- The secular variation of declination at a place occurs continuously over a long period of time.
- The lines of equal changes are called as **isopars.**
- There exists no reliable method of measuring this secular variation.

Annular Variation:

The variation of declination from year to year at a place from the mean position of the year is called as annual variation in declination. The annular variation is independent of secular variation at a place.

Diurnal Variation:

The variation of declination in one day from mean position is called as diurnal variation. This variation depends on locality, season, time and year.

Irregular Variation:

Occurrence of magnetic storms and also the magnetic disturbances cause a change in the earth's magnetic field, in an irregular manner. Such variations in declinations are quite unpredictable and random. Some of the causes of irregular variation in declination are the earth quakes, volcanic disturbances etc.

True Bearing from the Magnetic Bearing:

If the declination at a place is known, then the true bearing of the survey line can be computed from the magnetic bearing.

When declination is towards east, then

True bearing = Magnetic bearing + Declination

When declination is toward west, then

True bearing = Magnetic bearing - Declination

DIP:

A freely suspended magnetic needle aligns itself parallel to earth's magnetic field lines i.e., the longitudinal axis of the magnetic needle lies in the plane of magnetic material. The vertical angle which the magnetic needle makes with horizontal is referred to as dip. This dip is zero at equatorand90^0 at magnetic poles at earth.

Isoclinic lines: these are the lines which join points on earth with same value of dip.
Aclinic lines: these are the special case of isoclinic lines which join points of zero dip.

LOCAL ATTRACTION:

Ideally, the magnetic needle of a compass should again itself along the earth's magnetic field lines only i.e., magnetic field developed due to earth only.

However, many a times, there are certain magnetic materials present which influence the earth's magnetic field and magnetic needle aligns itself along the direction of resultant magnetic field and thus needle does not give the direction of earth's magnetic lines. Some of the magnetic materials are iron articles like rails, chains, arrows etc. and current carrying conductor.

The amount of deviation of magnetic needle is proportional to the amoumt of local attraction present.

Detection of Local Attraction:

The local attraction at a place can be detected by measuring the fore bearing and back bearing of a line at that place. Ideally, the difference of fore and back bearing of a line should be 180^o but if it is not, then the place is definitely affected by local attraction.

Plotting a Compass Traverse:

A compass traverse must be plotted only after proper checking of bearings of the traverse lines and after suitable corrections has already been applied. Before commencing the actual plotting work, a rough plot of the traverse to some suitable scale must be plotted to have an idea about the size and the shape of the compass traverse.

The following methods are generally used for plotting a compass traverse:
a) Parallel meridian method
b) Included angles method
c) Method of tangents
d) Method of chords
e) Rectangular coordinate method
f) Paper protractor method

Errors in Compass Surveying:

1. Instrumental Errors:

These are the errors are associated with the defects in the instrument itself like:
a. The magnetic needle is sluggish
b. The needle is not absolutely straight
c. The pivot is not at the center of graduated circle
d. The pivot is blunt
e. The plane of sight is not vertical
f. The line of sight does not pass through the center of graduated ring in the prismatic compass
g. The graduated ring of the prismatic compass i9s not truly horizontal.

2. Sighting errors:

These errors occurs due to sighting and due to wrong manipulations:
a. Compass not properly centered on the station
b. Compass not properly levelled
c. Ranging rod properly bisected at the station
d. Ranging rod not properly bisected at the station
e. Reading the graduated ring from the wrong direction in the prismatic compass

3. Errors due to external errors:

These errors occurs due to external factors like
a. Change in the atmospheric magnetism due to storms
b. Variation in magnetic declination
c. Local attraction due to magnetic items made of iron, nickel or cobalt.

Limits of accuracy:

1. The angular error of closure should not be greater than 15 $\sqrt{N}$minutes where N is the number of sides of the traverse. Also the error per bearing should not be greater than 15 minutes.
2. The degree of accuracy is defined as
   Degree of accuracy =$\frac{linear\ error\ of\ closure}{perimeter\ of\ the\ traverse}$

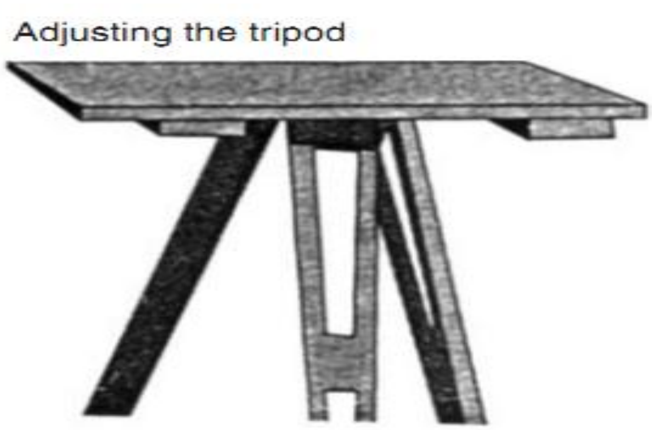
MODULE III

PLANE TABLE SURVEYING

In plane table surveying a table top, similar to drawing board fitted on to a tripod is the main instrument. A drawing sheet is fixed on to the table top, the observations are made to the objects, distances are scaled down and the objects are plotted in the field itself. Since the plotting is made in the field itself, there is no chance of omitting any necessary measurement in this surveying. However the accuracy achieved in this type of surveying is less. Hence this type of surveying is used for filling up details between the survey stations previously fixed by other methods.

- **Plane Table Surveying is a graphical method of survey** in which the field observations and plotting are done simultaneously.
- It is **simple and cheaper than Theodolite survey**. It is most suitable for small scale maps.
- The plan is drawn by the surveyor in the field, while the area to be surveyed is before his eyes. Therefore, there is no possibility of omitting the necessary measurements.
- **The principle of plane tabling is parallelism means,**
- **Principle:** "**All the rays drawn through various details should pass through the survey station**."
- The Position of plane table at each station must be identical, i.e. at each survey station the table must be oriented in the direction of magnetic north.

The most commonly used **plane table** is shown in Fig. 1. It consists of a well seasoned wooden table top mounted on a tripod. The table top can rotate about vertical axis freely. Whenever necessary table can be clamped in the desired orientation. The table can be levelled by adjusting tripod legs.



The following accessories are required to carry out plane table survey:

1. Alidade

2. Plumbing fork with plumb bob.

3. Spirit level

4. Trough compass

5. Drawing sheets and accessories for drawing.

1. Alidade

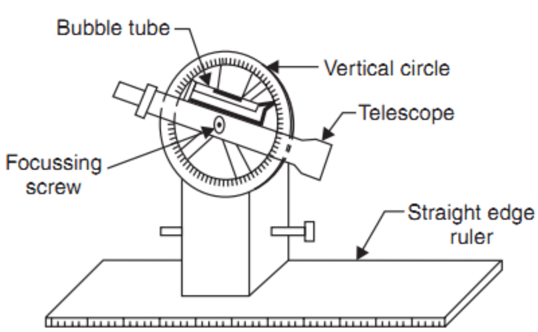
It is a straight edge ruler having some form of sighting device. One edge of the ruler is bevelled and is graduated. Always this edge is used for drawing line of sight. Depending on the type of line of sight there are two types of alidade:

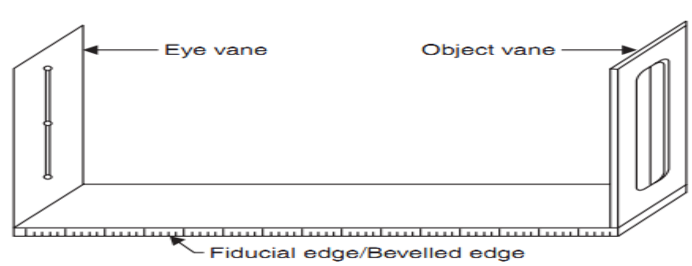
(a) Plain alidade

(b) Telescopic alidade

Plain Alidade: Figure 2 shows a typical plain alidade. A sight vane is provided at each end of the ruler. The vane with narrow slit serves as eye vane and the other with wide slit and having a thin wire at its centre serves as object vane. The two vanes are provided with hinges at the ends of ruler so that when not in use they can be folded on the ruler. Plain alidade is not suitable in surveying hilly areas as the inclination of line of sight in this case is limited.

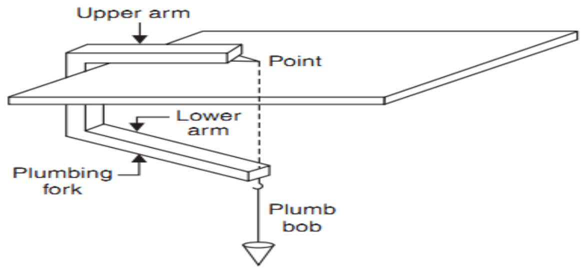
Telescopic Alidade: It consists of a telescope mounted on a column fixed to the ruler [Fig. 3]. The line of sight through the telescope is kept parallel to the bevelled edge of the ruler. The telescope is provided with a level tube and vertical graduation arc. If horizontal sight is required bubble in the level tube is kept at the centre. If inclined sights are required vertical graduation helps in noting the inclination of the line of sight. By providing telescope the range and the accuracy of line of sight is increased.





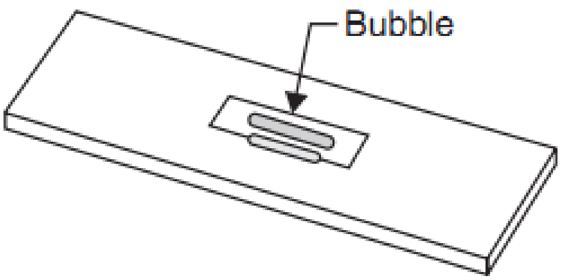
2. Plumbing Fork and Plumb Bob

Figure 4 shows a typical plumbing fork with a plum bob. Plumbing fork is a U-shaped metal frame with a upper horizontal arm and a lower inclined arm. The upper arm is provided with a pointer at the end while the lower arm is provided with a hook to suspend plumb bob. When the plumbing fork is kept on the plane table the vertical line (line of plumb bob) passes through the pointed edge of upper arm. The plumb bob helps in transferring the ground point to the drawing sheet and vice versa also.



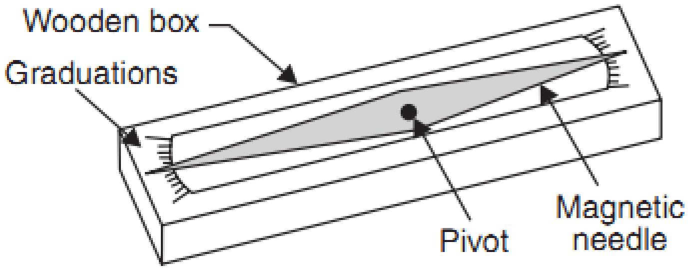
3. Spirit Level

A flat based spirit level is used to level the plane table during surveying (Fig.5). To get perfect level, spirit level should show central position for bubble tube when checked with its positions in any two mutually perpendicular directions.



4. Trough Compass

It consists of a 80 to 150 mm long and 30 mm wide box carrying a freely suspended needle at its centre (Ref. Fig. 6). At the ends of the needle graduations are marked on the box to indicate zero to five degrees on either side of the centre. The box is provided with glass top to prevent oscillation of the needle by wind. When needle is centred (reading 0–0), the line of needle is parallel to the edge of the box. Hence marking on the edges in this state indicates magnetic north–south direction.



5. Drawing Sheet and Accessories for Drawing

A good quality, seasoned drawing sheet should be used for plane table surveying. The drawing sheet may be rolled when not in use, but should never is folded. For important works fibre glass sheets or paper backed with thin aluminium sheets are used.

Clips clamps, adhesive tapes may be used for fixing drawing sheet to the plane table. Sharp hard pencil, good quality eraser, pencil cutter and sand paper to keep pencil point sharp are other accessories required for the drawing work. If necessary, plastic sheet should be carried to cover the drawing sheet from rain and dust.

Advantages and Disadvantages of Plane Table Surveying

Advantages

- It is **simple and cheaper than the theodolite survey.**
- It is most **suitable for small scale maps.**
- No **great skill is required** to produce a satisfactory map and work may be entrusted to a subordinate.

- It is **useful in magnetic areas** where compass may not be used.
- The **mistakes in writing field books are eliminated.**
- The **plan is drawn by the surveyor himself** while the area to be surveyed is before his eyes. **Therefore, there is no possibility of omitting the necessary measurements**.
- The **surveyor Can compare the plotted work** with the actual features of the area.

Orientation

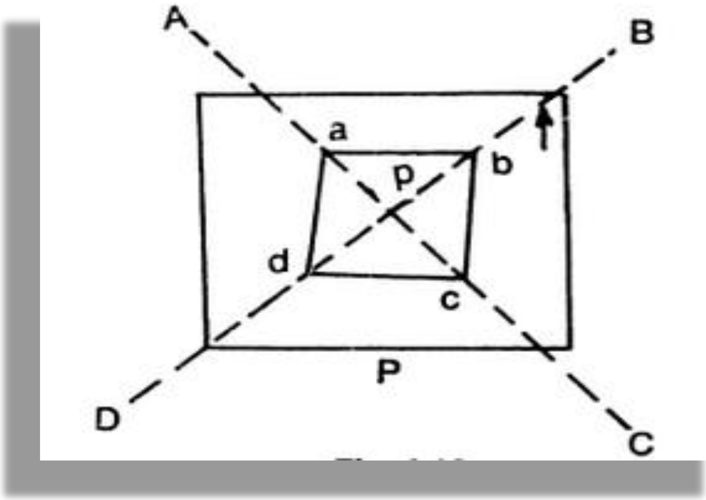
- The **Process by which the positions occupied by the board at various survey stations are kept parallel** is known **as the orientation**. Thus, when a plane table is properly oriented, the lines on the board are parallel to the lines on ground which they represent.
- There are two methods of orientation:
- By magnetic needle
- By back sighting
- **By Magnetic Needle**
- In this method, **the magnetic north is drawn on paper at a particular station.** At the next station, the trough compass is placed along the line of magnetic north and the table is turned in such a way that the ends of magnetic needle are opposite to zeros of the scale. The board is then fixed in position by clamps. This method is inaccurate in the since that the results are likely to be affected by the local attraction.

Methods Of Plane Tabling

- There are four distinct methods of plane tabling:
- Method of Radiation
- Method of Intersection
- Method of Traversing
- Method of Resection
- Suppose P is a station on the ground from where the object A, B, C and D are visible.

Radiation Method

- The plane table is set up over the station P. A drawing is fixed on the table, which is then leveled and centered. A point p is selected on the sheet to represent the station P.

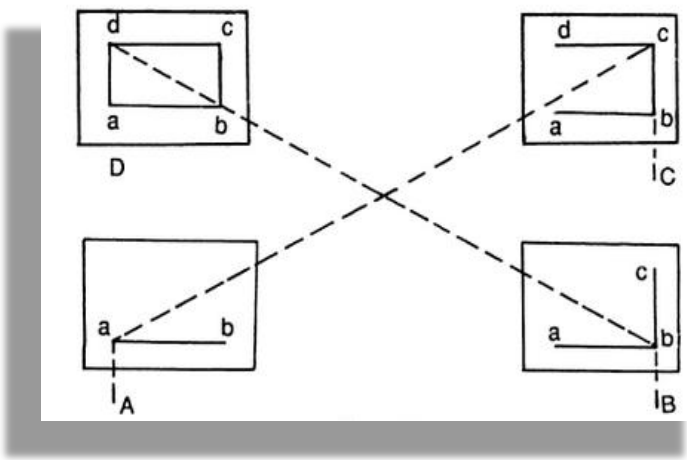
- The north line is marked on the right-hand top corner of the sheet with trough compass or circular box compass.
- With the alidade touching p, the ranging rod at A,B, C and D are bisected and the rays are drawn.
- The distances PA, PB, PC and PD are measured and plotted to any suitable scale to obtain the points a, b, c and d representing A,B,C,D on paper.
- 

Method Of Intersection

- In intersection method of plane table surveying, the objects or points to be located are obtained at the point of intersection of radial lines drawn from two different stations.
- In this method, the plotting of plane table stations are to be carried out accurately. Checking is important and thus done by taking third sight from another station.
- The intersection method is suitable when distances of objects are large or cannot be measured properly. Thus, this method is preferred in small scale survey and for mountainous regions.

Method Of Traversing

- This method of plane table surveying is used to plot a traverse in cases stations have not been previously plotted by some other methods. In this method, traverse stations are first selected. The stations are plotted by method of radiation by taking back sight on the preceding station and a fore sight to the following station. Here distances are generally measured by tachometric method and surveying work has to be performed with great care.
- Suppose A,B,C,D are the traverse stations,
- The table is set up at the station A, a suitable point a is selected on the sheet in such a way that the whole area may be plotted in the sheet. The table is centered, leveled and clamped. The north line is marked on the right-hand top corner of the sheet.
- With the alidade touching point a the ranging rod at B is bisected and a ray is drawn. The distance AB is measured and plotted to any suitable scale.



- The table is shifted touching point a the ranging rod at B is bisected and a ray is drawn. The distance is measured and plotted to any suitable scale.
- The table is shifted and centered over B. It is then leveled, oriented by back sighting and clamped.
- With the alidade touching point b, the ranging rod at C is bisected and ray is drawn. The distance BC is measured and plotted to the same scale.
- The table is shifted and set up at C and the same procedure is repeated.
- In this manner, all stations of the traverse are connected.
- **Check lines.** To check the accuracy of the plane table traverse, a few check lines are taken by sighting back to some preceding station.

- **Error of closure** . If the traverse to be plotted is a closed traverse, the foresight from the terminating station should pass through the first station. Otherwise the amount by which plotted position of the first station on the foresight fails to close is designated as the error of closure. It is adjusted graphically, if the error is within permissible limits, before any further plotting works are done.

Method of Resection

- Resection is the process of determining the plotted position of the station occupied by the plane table, by means of sights taken towards known points, locations of which have been plotted.
- There are four methods of resection.
- By Compass
- By back sighting
- By two point problem
- By three point problem
- Suppose It is required to establish a station at position P. Let us select two points A and B on the ground. The distance AB is measured and plotted to any suitable scale. The line AB is known as the "base line"
- The table is set up at A. It is leveled, centered and oriented by bisecting the ranging rod at B. The table is then clamped.
- With the alidade touching point a, the ranging rod at P is bisected and a ray is drawn. Then a point P_1 is marked on this way by estimating with the eye.

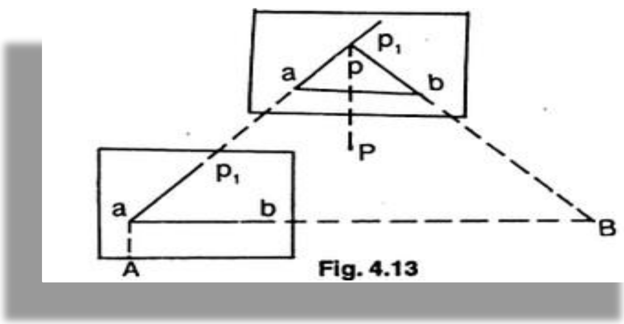


Fig. 4.13

- The table is shifted and centered in such a way that P_1 is just over P. It is then oriented by back-sighting the ranging rod at A.
- With the alidade touching point b, the ranging rod at B is bisected and a ray is drawn. Suppose this ray intersects the previous ray at a point P. This point represents the position of the station

P on the sheet. Then the actual position of the station is marked on the ground by U-fork and plumb-bob

By Compass

- This method is used only for small scale or rough mapping.
- Let A and B be two visible stations which have been plotted on the sheet as a and b. Let C be the instrument station to be located on the plan.
- Set the table at C and orient it with compass. Clamp the table.
- Pivoting the alidade about a, draw a ray towards A, as Similarly, pivoting the alidade about b, draw a ray towards B, as bb’, The intersection of aa’ and bb’ will give point c on the paper.

Resection

Resection is a method of plane table surveying in which location of plane table is unknown and it is determined by sighting it to known points or plotted points. It is also called method of orientation and it can be conducted by two field conditions as follows.

- The three-point problem
- The two-point problem

The Three Point Problem

In this condition, three points and their positions in the field are known. Plane table is placed at apposition from where all the three points are visible. So, by sighting those three points we can locate the point where equipment is located. This can be achieved by many methods as follows.

- Tracing method
- Lehmann method
- Analytical methods
- Graphical method

Tracing Method in Plane Table Surveying

In tracing method, plane table is located at a point from where three points are visible. The table is oriented with respect to the plotted lines of those three points. Place the tracing paper on the drawing sheet and again sight the three points and plot the radiating lines. The tracing paper is then moved above the drawing sheet until the three radiating lines pass through corresponding points previously plotted on the map. Finally, the position of plane table is marked.

Lehmann Method

In this method, Plane table is located at a point P and sight the station A, B and C and plot the rays Aa, Bb, and Cc. The rays form small triangle which is called triangle of error. Another point P1 is chosen to reduce the error and sight the point A from P1 similarly to B and C. which will give another triangle of error. Repeat this procedure until error becomes zero.

Analytical Methods

There are many analytical methods are developed in three-point problem condition. In this method, from station P A, B and C are sighted and note the values of angles and lengths. From these values determine the position of unknown points by using analytical formulae.

Graphical Method

In graphical method also, angles and lengths are determined and represented it on a graph and determines the location of plane table.

The Two-Point Problem

In the two-point problem, two points are sighted from other point corresponding to the points given in plane table sheet. Here two cases are to be discussed.

Case 1: when the points can be occupied by the plane table

As shown in fig. A and B are the two points corresponding to the points a and b. Now, plane table is located at B and oriented by sighting A. sight C from B and bx is plotted on the sheet. Then shift the plane table to C, oriented by backsighting B along xb. Then alidade is placed over a and sight station A, then line Aa cuts the line bx at somewhere which is located as point c at station C.

Case2: When the plane table cannot occupy the controlling stations

In this case, an auxiliary point D is considered nearer to C. Locate the plane table at D according to the line ab parallel to AB. Then sight the station A and B corresponding to a and b. the rays drawn are intersected at some point which is marked as d. then sight towards C by placing alidade at d. mark the distance Dc as c1. Shift the table to C and backsight to D with reference to c1.

Then sight A corresponding to a, the ray drawn is intersects the previously drawn ray from D in c2. From c2 sight B draw a ray which intersects db and marked the intersection as b1. The table is oriented till ab comes in line with P. From P sight and draw rays Aa and Ba. The intersection of these two rays will give the Location of Point C

Sources of errors in plane table surveying

1.Instrumental errors

The primary source of instrumental errors in plane table surveying arise from the lack in temporary adjustment. Thus, the causes for instrumental errors are as follows :

(i) Undulated plane table surface : Error in observation as well as plotting will occur if the top surface of the plane table is not perfectly plane.

(ii) Curved or inclined fiducial edge : If the fiducial edge of the alidade is not straight, the rays drawn would not be straight and an error in relative location of object will occur.

(iii) Loose fittings in plane table : If the fittings of the plane table and that of tripod are loose, the plane table will not remain stable and error in surveying will occur.

(iv) Improper magnetic compass: If the magnetic compass is sluggish or does not represent proper magnetic direction, an error in orientation of the plane table will occur, (if it is done with the magnetic compass) and thus basic principle of plane table surveying will get violated.

(v) Non-perpendicularity of the sight vanes : If the sight vanes are not perpendicular to the base of the alidade, there would be an error in sighting.

(vi) Defect in level tube: If the level tube is defective, the plane table will not be horizontal when the bubble is central. The plot thus obtained will be inaccurate.

(vii) Unseasoned, poor quality drawing paper : Poor quality drawing paper gets affected by the weather changes and thus it may expand or contract and changes the scale of plotting. The plot thus obtained will be incorrect

2.Man made errors

(i) Improper leveling of plane table : If the plane table is not properly leveled and made horizontal, the sight vanes will be inclined to the vertical. There would be an error and the points located will not be correct.

(ii) Inaccurate Centring : If the plane table is not accurately centred, the error in plotted position of station will cause error in plotting of all other details from that station.

(iii) Improper orientation : If the plane table is not oriented properly, the fundamental principle of plane table surveying will get violated and thus plotting in general will be inaccurate.

(iv) Improper clamping of plane table : Improperly clamped plane table will disturb its orientation, and thus error due improper orientation will creep into.

(v) Inexact bisection of object : If the object is not sighted accurately or not bisected properly, error in direction of object will occur and thus its plotted position.

(VI) Improper plotting : This may be caused due to any error in measurement of distance or direction of ray, due to error in instruments or error in manipulation or sighting. This will lead to inaccurate map of the survey and thus the objective of surveying will be poorly achieved.

(vii) Instability of tripod stand : If the tripod stand is not set in stable, the whole of surveying and plotting will get disturbed and thus error in surveying and making map.

Practical hints in plane tabling

For GOOD location of details through plane table surveying, following practical hints may be followed:

- The drawing board should be well seasoned and good quality but should be free from glare.
- The tripod stand should be placed in stable condition before fixing the drawing board.
- The level of the plane table should be set up at a height slightly lower than the height of the elbow of the surveyor.
- Time should be spent for centring to achieve accuracy within plotting error or better but not very accurate is required.
- The plotted positions of the stations should be checked before starting any location of details. This is to be done by method of resection to some prominent objects present in the area.
- Orientation of the table better be checked intermittently and verify by method of back sighting.
- To plot the plane table location through three point problem, occupy a position inside the great triangle.
- Sliding of alidade on drawing paper should be avoided. Alidade better be used by lifting its object vane side getting its sight vane side pivoted.
- The portion of the sheet which is not being used at any time may better be kept covered with a waterproof cloth .
- The fiducial edge of the alidade in use should be cleaned intermittently to remove graphite.
- Use hard pencil (such as 4H) to avoid smudging.
- During storage, the plane table board should be stored on edges, This helps in minimizing warp

MODULE IV

LEVELLING

Levelling (*or Leveling*) is a branch of surveying, the object of which is: i) to find the elevations of given points with respect to a given or assumed datum, and ii) to establish points at a given or assumed datum. The first operation is required to enable the works to be designed while the second operation is required in the setting out of all kinds of engineering works. Levelling deals with measurements in a vertical plane.

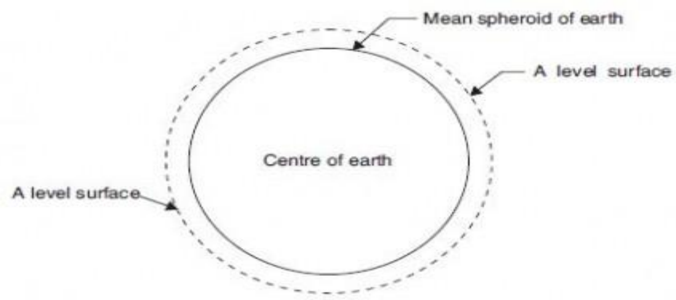


Fig. 15.1. A level surface

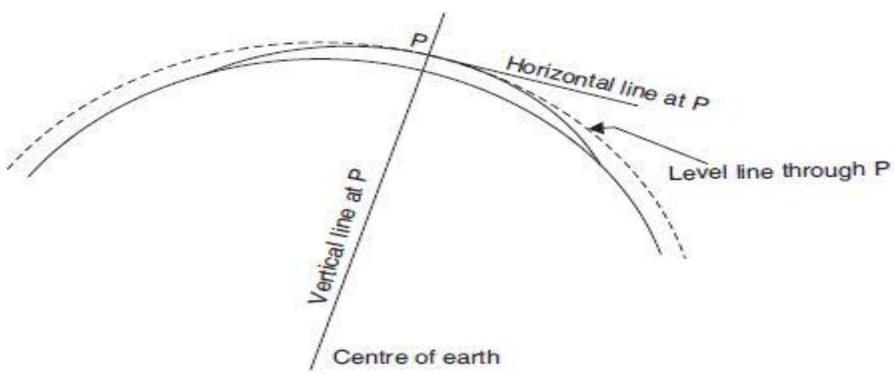


Fig. 15.2. Vertical and horizontal lines

TERMINOLOGY

Level surface: A level surface is defined as a curved surface which at each point is perpendicular to the direction of gravity at the point. The surface of a still water is a truly level surface. Any surface parallel to the mean spheroidal surface of the earth is, therefore, a level surface.

Level line: A level line is a line lying in a level surface. It is, therefore, normal to the plumb line at all points.

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 commonly considered to be the line defined by a plumb line.

Datum: Datum is any surface to which elevation are referred. The mean sea level affords a convenient datum world over, and elevations are commonly given as so much above or below sea level. It is often more convenient, however, to assume some other datum, specially, if only the relative elevation of points are required.

Elevation: The elevation of a point on or near the surface of the earth is its vertical distance above or below an arbitrarily assumed level surface or datum. The difference in elevation between two points is the vertical distance between the two level surface in which the two points lie.

Vertical angle: Vertical angle is an angle between two intersecting lines in a vertical plane. Generally, one of these lines is horizontal.

Mean sea level: MSL is the average height of the sea for all stages of the tides. At any particular place MSL is established by finding the mean sea level (free of tides) after averaging tide heights over a long period of at least 19 years. In India MSL used is that established at Karachi, presently, in Pakistan. In all important surveys this is used as datum.

Reduced Levels (RL): The level of a point taken as height above the datum surface is known as RL of that point.

Bench Mark: It is a relatively permanent point of reference whose elevation with respect to some assumed datum is known. It is used either as a starting point for levelling or as a point upon which to close as a check.

(a)GTSbenchmarks

(b)Permanentbenchmarks
(c) Arbitrary benchmarks and

(d) Temporary benchmarks.

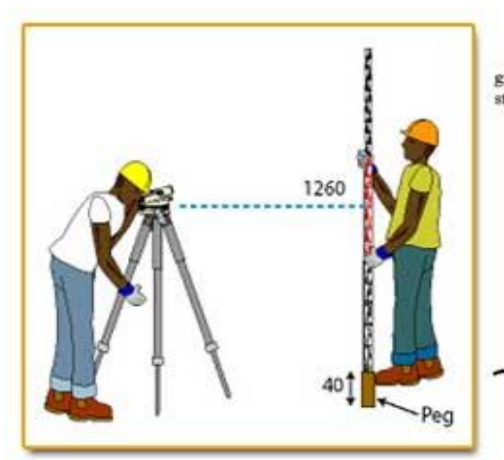
(a) GTS Benchmark: The long form of GTS benchmark is Great Trigonometrical Survey benchmark. These benchmarks are established by national agency. In India, the department of Survey of India is entrusted with such works. GTS benchmarks are established all over the country with highest precision survey, the datum being mean sea level. A bronze plate provided on the top of a concrete pedastal with elevation engraved on it serves as benchmark. It is well protected with masonry structure built around it so that its position is not disturbed by animals or by any unauthorised person.ThepositionofGTS benchmarks are shown in the topo sheets published.

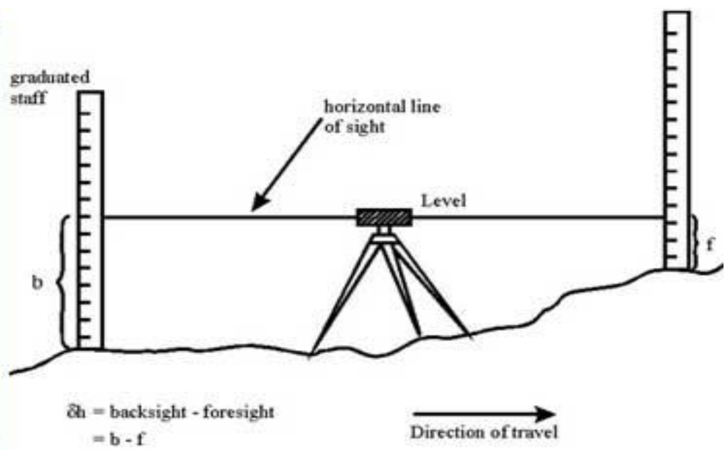
(b) Permanent Benchmark: These are the benchmarks established by state government agencies like PWD.

They are established with reference to GTS benchmarks. They are usually on the corner of plinth of public buildings.

(c) Arbitrary Benchmark: In many engineering projects the difference in elevations of neighbouring points is more important than their reduced level with respect to mean sea level. In such cases a relatively permanent point, like plinth of a building or corner of a culvert, are taken as benchmarks, their level assumed arbitrarily such as 100.0 m, 300.0 m, etc.

(d) Temporary Benchmark: This type of benchmark is established at the end of the day's work, so that the next day work may be continued from that point. Such point should be on a permanent object so that next day it is easily identified.





Methods of levelling

Three principle methods are used for determining differences in elevation, namely, barometric levelling, trigonometric levelling and spirit levelling.

Barometric levelling

Barometric levelling makes use of the phenomenon that difference in elevation between two points is proportional to the difference in atmospheric pressures at these points. A barometer, therefore, may be used and the readings observed at different points would yield a measure of the relative elevation of those points.

At a given point, the atmospheric pressure doesn't remain constant in the course of the day, even in the course of an hour. The method is, therefore, relatively inaccurate and is little used in surveying work except on reconnaissance or exploratory survey.

Trigonometric Levelling (Indirect Levelling)

Trigonometric or Indirect levelling is the process of levelling in which the elevations of points are computed from the vertical angles and horizontal distances measured in the field, just as the length of any side in any triangle can be computed from proper trigonometric relations. In a modified form called stadia levelling, commonly used in mapping, both the difference in elevation and the horizontal distance between the points are directly computed from the measured vertical angles and staff readings.

Spirit Levelling (Direct Levelling)

It is that branch of levelling in which the vertical distances with respect to a horizontal line (perpendicular to the direction of gravity) may be used to determine the relative difference in elevation between two adjacent points. A horizontal plane of sight tangent to level surface at any point is readily established by means of a spirit level or a level vial. In spirit levelling, a spirit level and a sighting device (telescope) are combined and vertical distances are measured by observing on graduated rods placed on the points. The method is also known as direct levelling. It is the most precise method of determining elevations and the one most commonly used by engineers.

Levelling Instruments

The instruments commonly used in direct levelling are:

1. A level
2. A levelling staff

An engineer's level primarily consists of a telescope mounted upon a level bar which is rigidly fastened to the spindle. Inside the tube of the telescope, there are objective and eye piece lens at the either end of the tube. A diaphragm fitted with cross hairs is present near the eye piece end. A focussing screw is attached with the telescope. A level tube housing a sensitive plate bubble is attached to the telescope (or to the level bar) and parallel to it. The spindle fits into a cone-shaped bearing of the leveling head. The leveling head consists of tribrach and trivet with three foot screws known as leveling screws in between. The trivet is attached to a tripod stand.

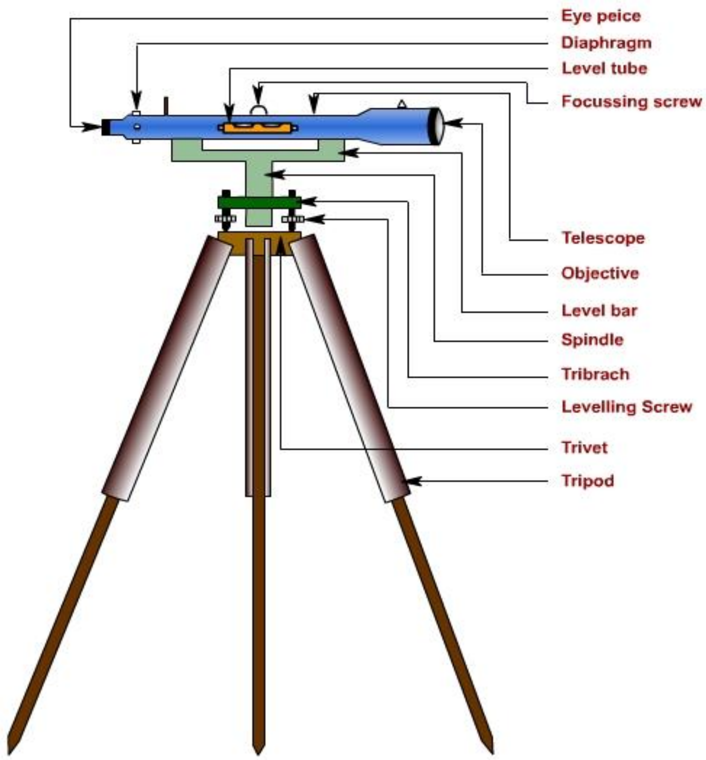


Figure 11.1 Schematic Diagram of an Engineer's Level

Telescope : used to sight a staff placed at desired station and to read staff reading distinctly.

Diaphragm : holds the cross hairs (fitted with it).

Eye piece : magnifies the image formed in the plane of the diaphragm and thus to read staff during leveling.

Level Tube : used to make the axis of the telescope horizontal and thus the line of sight.

Leveling screws : to adjust instrument (level) so that the line of sight is horizontal for any orientation of the telescope.

Tripod stand : to fix the instrument (level) at a convenient height of an observer

Temporary adjustments

The temporary adjustment of a dumpy level consists of Setting , Leveling and Focusing .

During Setting, the tripod stand is set up at a convenient height having its head horizontal (through eye estimation). The instrument is then fixed on the head by rotating the lower part of the instrument with right hand and holding firmly the upper part with left hand. Before fixing, the leveling screws are required to be brought in between the tribrach and trivet. The bull's eye bubble (circular bubble), if present, is then brought to the centre by adjusting the tripod legs.

Next, Leveling of the instrument is done to make the vertical axis of the instrument truly vertical. It is achieved by carrying out the following steps:

Step 1: The level tube is brought parallel to any two of the foot screws, by rotating the upper part of the instrument.

Step 2: The bubble is brought to the centre of the level tube by rotating both the foot screws either inward or outward. (The bubble moves in the same direction as the left thumb.)

Step 3: The level tube is then brought over the third foot screw again by rotating the upper part of the instrument.

Step 4: The bubble is then again brought to the centre of the level tube by rotating the third foot screw either inward or outward.

Step 5: Repeat Step 1 by rotating the upper part of the instrument in the same quadrant of the circle and then Step 2.

Step 6: Repeat Step 3 by rotating the upper part of the instrument in the same quadrant of the circle and then Step 4.

Step 7: Repeat Steps 5 and 6, till the bubble remains central in both the positions.

Step 8: By rotating the upper part of the instrument through 180 ° , the level tube is brought parallel to first two foot screws in reverse order. The bubble will remain in the centre if the instrument is in

Permanent adjustment.

Focusing is required to be done in order to form image through objective lens at the plane of the diaphragm and to view the clear image of the object through eye-piece. This is being carried out by removing parallax by proper focusing of objective and eye-piece. For focusing the eye-piece, the telescope is first pointed towards the sky. Then the ring of eye-piece is turned either in or out until the cross-hairs are seen sharp and distinct. Focusing of eye-piece depends on the vision of observer and thus required whenever there is a change in observer. For focusing the objective, the telescope is first pointed towards the object. Then, the focusing screw is turned until the image of the object appears clear and sharp and there is no relative movement between the image and the cross-hairs. This is required to be done before taking any observation.

There are three fundamental lines in a level instrument These are

Vertical axis

Axis of the level tube

Line of sight

In a properly adjusted dumpy level, desired relations among fundamental lines are

Axis of the level tube is perpendicular to the Vertical axis

Horizontal cross hair should lie in a plane perpendicular to the Vertical axis, so that it will lie in a Horizontal plane when the instrument is properly leveled.

The Line of sight is parallel to the axis of the level tube.

Also, the optical axis, the axis of the objective lens and the line of sight should coincide.

The fundamental principle of leveling lies in finding out the separation of level lines passing through a point of known elevation (B.M.) and that through an unknown point (whose elevation is required to be determined).

With reference to let X represents a point of known elevation (Hx) or a B.M. and Y be a point whose elevation is required to be determined. To find out the unknown elevation of Y, a level is set up at L in between X and Y. A leveling staff is first held at X and a reading hx is observed, by sighting the staff (held vertical to the line of sight of the level). The staff reading at Y, say hy is then observed. The elevation of the point Y (say Hy) is thus given by Hx + (hx ~ hy) i.e., known elevation (Hx) added to the separation of level lines (hx ~ hy) passing through the points.

Direct Leveling : Direct measurement, precise, most commonly used; types:

Simple leveling : One set up of level. To find elevation of points.

Differential leveling : Numbers of set-ups of level. To find elevation of non-intervisible points.

Fly leveling : Low precision, to find/check approximate level, generally used during reconnaissance survey.

Precise leveling : Precise form of differential leveling.

Profile leveling : finding of elevation along a line and its cross section.

Reciprocal leveling : Along a river or pond. Two level simultaneously used, one at either end.

Indirect or Trigonometric Leveling : By measuring vertical angles and horizontal distance; Less precise.

Stadia Leveling : Using tacheometric principles.

Barometric Leveling : Based on atmospheric pressure difference; Using altimeter; Very rough estimation.

Principle of levelling

Applied to determine the elevation of point which is some distant apart from B.M i.e., the unknown elevation of a point cannot be determined in a single set up of an instrument. Thus, in this method, instrument gets setup number of times to observe reading along a route in between observed points. For each set up, staff readings are taken back to a point of known elevation (first sight from the B.M and forward to a point of unknown elevation) final sight to the terminal station

Differential Leveling

Applied to determine the elevation of point which is some distant apart from B.M i.e., the unknown elevation of a point cannot be determined in a single set up of an instrument. Thus, in this method, instrument gets setup number of times to observe reading along a route in between observed points. For each set up, staff readings are taken back to a point of known elevation (first sight from the B.M and forward to a point of unknown elevation) final sight to the terminal station.

Reduction of Level

The observed staff readings as noted in a level book are further required to be manipulated to find out the elevation of points. The operation is known as reduction of level. There are two methods for reduction of levels:

Rise and Fall method and

Height of instrument method.

Rise and Fall Method

For the same set up of an instrument, Staff reading is more at a lower point and less for a higher point. Thus, staff readings provide information regarding relative rise and fall of terrain points. This provides the basics behind rise and fall method for finding out elevation of unknown points.

With reference to when the instrument is at I1, the staff reading at A (2.365m) is more than that at S1 which indicates that there is a rise from station A to S1 and accordingly the difference between them (1.130m) is entered under the rise column in . To find the elevation of S1 (101.130m), the rise (1.130m) has been added to the elevation of A (100.0m). For instrument set up at I2 , S1 has been treated as a point of known elevation and considered for backsight (having reading 0.685m) . Foresight is taken at S2 and read as 3.570m i.e, S2 is at lower than S1 . Thus, there is a fall from S1 a nd S2 and there difference (2.885m) is entered under the fall column in Table 13.1. To find the elevation of S2 (98.245m), the fall (2.885m) has been subtracted from the elevation of S1 (101.130m). In this way, elevation of points are calculated by Rise and Fall method.

Level book note for Rise and Fall method

	Staff Reading		Difference in Elevation		Elevation	
Points	B.S (m)	F.S.(m)	Rise (m)	Fall (m)	R.L (m)	Remark
A	2.365				100.000	B.M.
S 1	0.685	1.235	1.130		101.130	T.P.1
S2	1.745	3.570		2.885	98.245	T.P. 2
B		2.340		0.595	97.650	

Height of Instrument Method

In any particular set up of an instrument height of instrument, which is the elevation of the line of sight, is constant. The elevation of unknown points can be obtained by subtracting the staff readings at the desired points from the height of instrument. This is the basic behind the height of instrument method for reduction of level.

With reference to and when the instrument is at, the staff reading observed at A is 2.365m. The elevation of the line of sight i.e., the height of instrument is 102.365m obtained by adding the elevation of A (100.0m) with the staff reading observed at A (2.365m). The elevation of S1 (101.130m) is determined by subtracting its foresight reading (1.235m) from the the height of instrument (102.365m) when the instrument is at I1 . Next, the instrument is set up at I2. S1 is considered as a point of known elevation and backsight reading (0.685m) is taken . The height of the instrument (101.815 m) is then calculated by adding backsight reading (0.685m) with the elevation (R.L.) of point S1(101.130m). Foresight is taken at S2 and its elevation (98.245m) is determined by subtracting the foresight (3.570m) from the height of the instrument (101.815 m). In this way, elevation of points are calculated by Height of instrument method.

Table 13.2 Level book note for Height of instrument method

	Staff Reading		Height of Instrument (m)	R.L. (m)	Remarks
Points	B.S (m)	F.S.(m)			
A	2.365		102.365	100.000	B.M.
S 1	0.685	1.235	101.815	101.130	T.P.1
S2		3.570		98.245	T.P.2

B		2.340		97.650	

Example

Ex13-1 Data from a differential leveling have been found in the order of B.S., F.S..... etc. starting with the initial reading on B.M. (elevation 150.485 m) are as follows : 1.205, 1.860, 0.125, 1.915, 0.395, 2.615, 0.880, 1.760, 1.960, 0.920, 2.595, 0.915, 2.255, 0.515, 2.305, 1.170. The final reading closes on B.M.. Put the data in a complete field note form and carry out reduction of level by Rise and Fall method. All units are in meters.

Solution :

B.S. (m)	F.S. (m)	Rise (m)	Fall (m)	Elevation (m)	Remark
1.205				150.485	B.M.
0.125	1.860		0.655	149.830	
0.395	1.915		1.7290	148.040	
0.880	2.615		2.220	145.820	
1.960	1.760		0.880	144.940	
2.595	0.920	1.040		145.980	
2.255	0.915	1.680		147.660	
2.305	0.515	1.740		149.450	
	1.170	1.135		150.535	B.M.

Arithmetic Check for Reduction of Level

In case of Rise and Fall method for Reduction of level, following arithmetic checks are applied to verify calculations.

 B.S. - F.S. = Rise - Fall = Last R.L. - First R.L.

With reference to Table 13.3:

□ B.S. - □ F.S. = 4.795 - 7.145 = - 2.350

□ Rise - □ Fall. = 1.130 - 3.480 = - 2.350

Last R.L. - First R.L.= 97.650 - 100.000 = -2.350

Table 13.3 Field book for Reduction of level

	Staff Reading (m)			Difference in elevation (m)		H.I (m)	R.L. (m)	Remarks
Points	B.S.	I.S.	F.S.	Rise	Fall			
A	2.365					102.365	100.000	B.M.
S 1	0.685		1.235	1.130		101.815	101.130	T.P.1
S2	1.745		3.570		2.885	99.990	98.245	T.P.2
B			2.340		0.595	102.365	97.650	
□	4.795		7.145		3.480	101.815		

Example

Ex13-2 Carry out the arithmetic checks for Reduction of level of Ex13-1.

Solution :

B.S. = 11.720 m;

F.S. = 11.670 m

Therefore B.S - F.S. = 0.050 m

Rise = 5.595 m; Fall = 5.545 m

Therefore Rise - Fall = 0.050 m

Last R.L. - First R.L. = 150.535 - 150.485 = 0.050 m.

B.S - F.S. = Rise - Fall = Last R.L. - First R.L.

Level Net

To establish a set of bench marks, each B.M. is also used as a turning point. Elevation of B.Ms are checked by terminating to a previously established bench mark or by returning to the initial bench mark. A line of levels that ends at the point of beginning is known as level net. The final observation in a level net is thus a foresight on the initial B.M. The elevation of each B.M. is to be kept checked within the prescribed limit of error.

Tale 13.4 Permissible limit of error in level net

Order	Class	Limit (mm)	Remark
First	I	$\pm 4\sqrt{K}$	K is the distance in km
	II	$\pm 5\sqrt{K}$	
Second	I	$\pm 6\sqrt{K}$	
	II	$\pm 8\sqrt{K}$	
Third		$\pm 12\sqrt{K}$	

Profile Leveling

Profile leveling is a method of surveying that has been carried out along the central line of a track of land on which a linear engineering work is to be constructed/ laid. The operations involved in determining the elevation of ground surface at small spatial interval along a line is called profile leveling. The route along which a profile is run may be single straight line, as in case of a short sidewalk; a broken line, as in the case of a transmission line or sewer; or a series of straight lines connected by curves, as in case of a railroad, highway or canal.

Stations

The line along which the profile is to be run is to be marked on the ground before taking any observation. Stakes are usually set at some regular interval which depends on the topography, accuracy required, nature of work, scale of plotting etc. It is usually taken to be 10 meter. In addition, stakes are placed at locations where marked changes in slope occur; a change in direction occur; at critical points like culverts, bridges and other features crossing the alignment. The beginning station of profile leveling is termed as 0+00. Points at multiples of 100m from this point are termed as full stations. Intermediate points are designated as pluses. For example, a point that is 153.25m from the beginning point of the survey is station 1+53.25 i.e., the point is 53.25m beyond the first full station.

Procedure

In carrying out profile leveling, a level is placed at a convenient location (say I1) not necessarily along the line of observation (Figure 14.1). The instrument is to be positioned in such a way that first backsight can be taken clearly on a B.M. Then, observations are taken at regular intervals (say at 1, 2, 3, 4) along the central line and foresight to a properly selected turning point (say TP1). The instrument is then re-positioned to some other convenient location (say I2). After proper adjustment of the instrument, observations are started from TP1 and then at regular intervals (say at 5, 6 etc) terminating at another turning point, say TP2 . Staff readings are also taken at salient points where marked changes in slope occur, such as that at X.

The distance as well as direction of lines are also measured.

Curvature of the earth:

The earth appears to "fall away" with distance. The curved shape of the earth means that the level surface through the telescope will depart from the horizontal plane through the telescope as the line of sight proceeds to the horizon.

This effect makes actual level rod readings too large by:

$C=0.239D^2$

where D is the sight distance in thousands of feet.

Effects of Curvature are:

Staff reading is too high

Error increases exponentially with distance

Curvature and Refraction

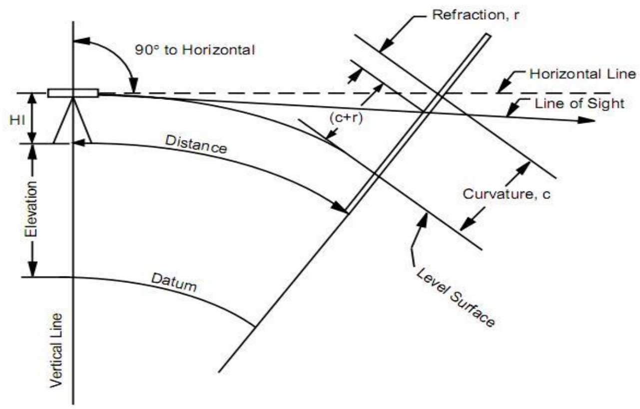


Figure 6-2. *Curvature and refraction.*

Atmospheric Refraction:

Refraction is largely a function of atmospheric pressure and temperature gradients, which may cause:

the bending to be up or down by extremely variable amounts.

There are basically three types of temperature gradient (dT/dh):

Absorption: occurs mainly at night when the colder ground absorbs heat from the atmosphere.

This causes the atmospheric temperature to increase with distance from the ground and $dT/dh > 0$.

Emission: occurs mainly during the day when the warmer ground emits heat into the atmosphere, resulting in a negative temperature gradient, i.e. $dT/dh < 0$.

Equilibrium: no heat transfer takes place ($dT/dh = 0$) and occurs only briefly in the evening and morning.

The result of $dT/dh < 0$ is to cause the light ray to be convex to the ground rather than concave as generally shown.

This effect increases the closer to the ground the light ray gets and errors in the region of 5 mm/km have resulted.

The atmosphere refracts the horizontal line of sight downward, making the level rod reading smaller. The typical effect of refraction is equal to about 14% of the effect of earth curvature.

Top of Form

Bottom of Form

Correlations for various distances

Distance	Correction
100'	0.00021'
200'	0.00082'
500'	0.0052'
700'	0.01'
1 mile	0.574'

How to eliminate error due to Curvature and Refraction

Proper field procedures (taking shorter shots and balancing shots) can practically reduce errors

Wherever possible, staff readings should be kept at least 0.5 m above the ground,

Using short observation distances (25 m) equalized for backsight and foresight

Air below is denser than air above Air below is denser than air above, Line of sight is bent downward which Negates earth curvature error by 14%.

Simultaneous Reciprocal Trigonometrical Heighting

Observations made at each station at exactly the same time, cancels the effects of curvature and refraction

MODULE V

CONTOURING

Contouring in surveying is the determination of elevation of various points on the ground and fixing these points of same horizontal positions in the contour map.

To exercise vertical control leveling work is carried out and simultaneously to exercise horizontal control chain survey or compass survey or plane table survey is to be carried out.

If the theodolite is used, both horizontal and vertical controls can be achieved from the same instrument. Based on the instruments used one can classify the contouring in different groups.

Methods of Contour Surveying

There are two methods of contour surveying:

1. Direct method
2. Indirect method

Direct Method of Contouring

It consists in finding vertical and horizontal controls of the points which lie on the selected contour line.

For vertical control levelling instrument is commonly used. A level is set on a commanding position in the area after taking fly levels from the nearby bench mark. The plane of collimation/height of instrument is found and the required staff reading for a contour line is calculated.

The instrument man asks staff man to move up and down in the area till the required staff reading is found. A surveyor establishes the horizontal control of that point using his instruments.

After that instrument man directs the staff man to another point where the same staff reading can be found. It is followed by establishing horizontal control.

Thus, several points are established on a contour line on one or two contour lines and suitably noted down. Plane table survey is ideally suited for this work.

After required points are established from the instrument setting, the instrument is shifted to another point to cover more area. The level and survey instrument need not be shifted at the same time. It is better if both are nearby to communicate easily.

For getting speed in levelling some times hand level and Abney levels are also used. This method is slow, tedious but accurate. It is suitable for small areas.

Indirect Method of Contouring

In this method, levels are taken at some selected points and their levels are reduced.

Thus in this method horizontal control is established first and then the levels of those points found.

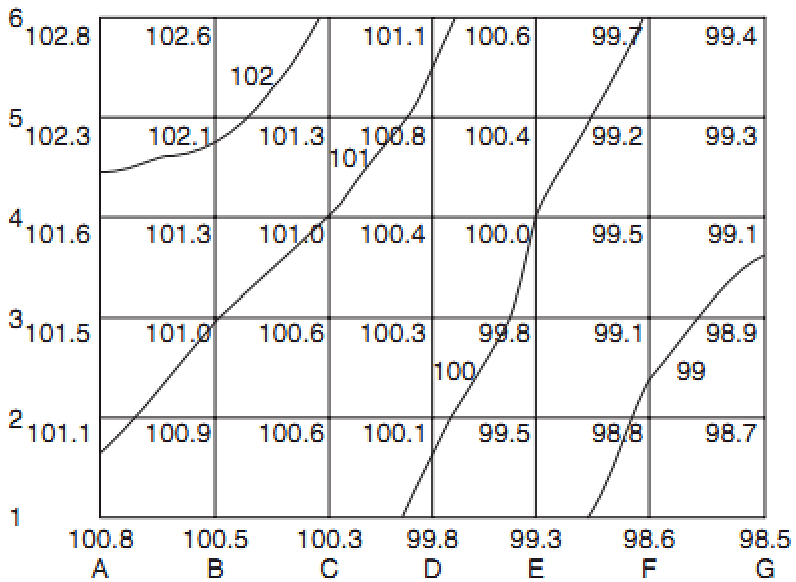
After locating the points on the plan, reduced levels are marked and contour lines are interpolated between the selected points.

For selecting points any of the following methods can be used:

1. Method of squares
2. Method of cross-section
3. Radial line method

Method of Squares

In this method area is divided into a number of squares and all grid points are marked



Commonly used size of square varies from 5 m × 5 m to 20 m × 20 m. Levels of all grid points are established by levelling. Then grid square is plotted on the drawing sheet. Reduced levels of grid points marked and contour lines are drawn by interpolation [Ref. Fig. 1].

Method of Cross-Section

In this method cross-sectional points are taken at regular interval. By levelling the reduced level of all those points are established. The points are marked on the drawing sheets, their reduced levels (RL) are marked and contour lines interpolated.

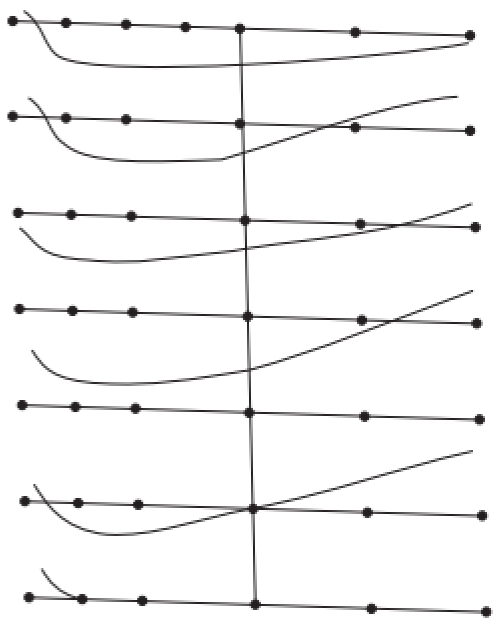


Fig. 2

Figure 2 shows a typical planning of this work. The spacing of cross-section depends upon the nature of the ground, scale of the map and the contour interval required. It varies from 20 m to 100 m. Closer intervals are required if ground level varies abruptly.

The cross- sectional line need not be always be at right angles to the main line. This method is ideally suited for road and railway projects.

Radial Line Method

[Fig. 3]. In this method several radial lines are taken from a point in the area. The direction of each line is noted. On these lines at selected distances points are marked and levels determined. This method is ideally suited for hilly areas. In this survey theodolite with tacheometry facility is commonly used.

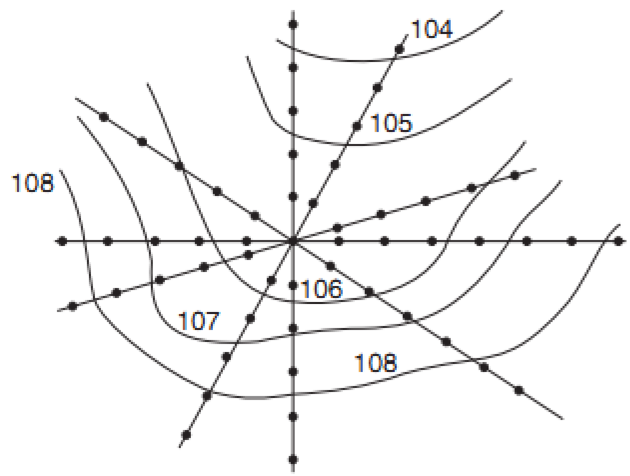


Fig. 3

For **interpolating contour points** between the two points any one of the following method may be used:

(a) Estimation

(b) Arithmetic calculation

(c) Mechanical or graphical method.

Mechanical or graphical method of interpolation consist in linearly interpolating contour points using tracing sheet:

On a tracing sheet several parallel lines are drawn at regular interval. Every 10th or 5th line is made darker for easy counting. If RL of A is 97.4 and that of B is 99.2 m. Assume the bottom most dark line represents 97 m RL and every parallel line is at 0.2 m intervals. Then hold the second parallel line on A.

Rotate the tracing sheet so that 100.2 the parallel line passes through point B. Then the intersection of dark lines on AB represents the points on 98 m and 99 m contours [Ref. Fig. 4].

Similarly the contour points along any line connecting two neighbouring points may be obtained and the points pricked. This method maintains the accuracy of arithmetic calculations at the same time it is fast.

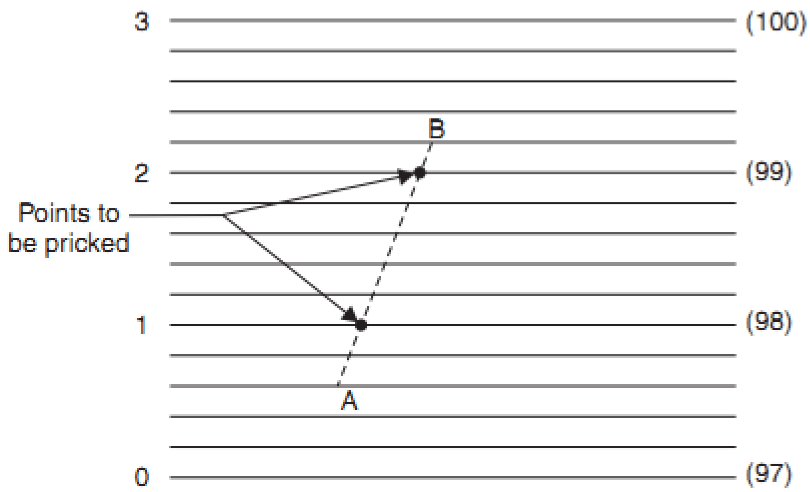


Fig. 4

Drawing Contours

After locating contour points smooth contour lines are drawn connecting corresponding points on a contour line. French curves may be used for drawing smooth lines. A surveyor should not lose the sight of the characteristic feature on the ground. Every fifth contour line is made thicker for easy readability. On every contour line its elevation is written. If the map size is large, it is written at the ends also.

Contour Maps and Its Uses

A contour maps consists of contour lines which are imaginary lines connecting points of equal elevation. Such lines are drawn on the plan of an area after establishing reduced levels of several points in the area.

The contour lines in an area are drawn keeping difference in elevation of between two consecutive lines constant. For example, the contour map in fig. 1 shows contours in an area with contour interval of 1 m. On contour lines the level of lines is also written.

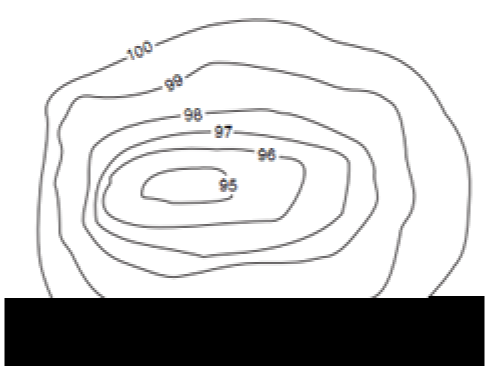


Fig. 1: Contours

Characteristics of Contour Maps

The contours maps have the following characteristics:

1. Contour lines must close, not necessarily in the limits of the plan.
2. Widely spaced contour indicates flat surface.
3. Closely spaced contour indicates steep ground.
4. Equally spaced contour indicates uniform slope.
5. Irregular contours indicate uneven surface.
6. Approximately concentric closed contours with decreasing values towards centre (Fig. 1) indicate a pond.
7. Approximately concentric closed contours with increasing values towards centre indicate hills.
8. Contour lines with U-shape with convexity towards lower ground indicate ridge (Fig. 2).

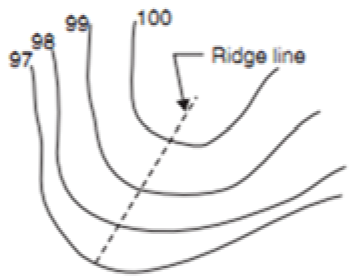


Fig. 2

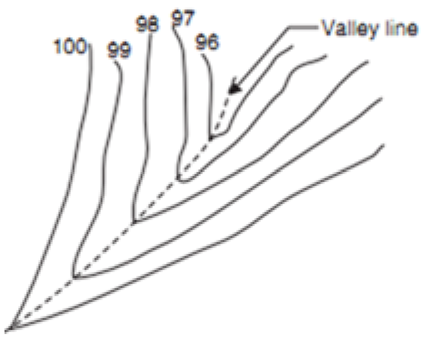


Fig. 3

9. Contour lines with V-shaped with convexity towards higher ground indicate valley (Fig.3).

10. Contour lines generally do not meet or intersect each other.

11. If contour lines are meeting in some portion, it shows existence of a vertical cliff (Fig. 4).

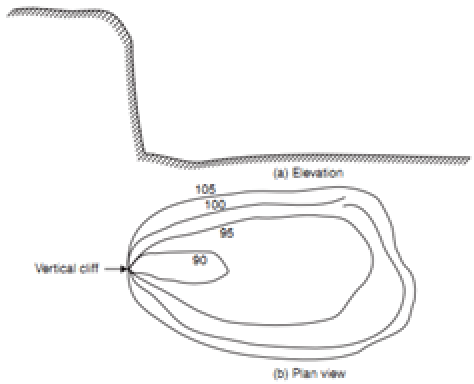


Fig. 4

12. If contour lines cross each other, it shows existence of overhanging cliffs or a cave (Fig. 5).

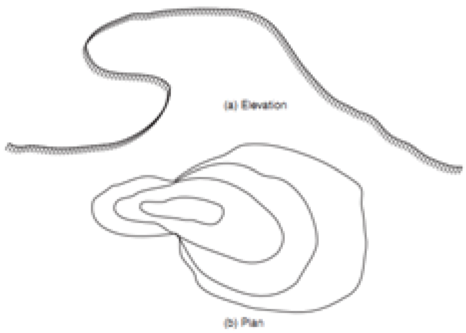


Fig. 5

Uses of Contour Maps

Contour maps are extremely useful for various engineering works:

1. A civil engineer studies the contours and finds out the nature of the ground to identify. Suitable site for the project works to be taken up.
2. By drawing the section in the plan, it is possible to find out profile of the ground along that line. It helps in finding out depth of cutting and filling, if formation level of road/railway is decided.
3. Intervisibility of any two points can be found by drawing profile of the ground along that line.
4. The routes of the railway, road, canal or sewer lines can be decided so as to minimize and balance earthworks.
5. Catchment area and hence quantity of water flow at any point of nalla or river can be found. This study is very important in locating bunds, dams and also to find out flood levels.
6. From the contours, it is possible to determine the capacity of a reservoir.

MODULE VI

AREA'S & VOLUMES'S

Introduction

Areas and Volumes are often required in the context of design, eg. we might need the surface area of a lake, the area of crops, of a car park or a roof, the volume of a dam embankment, or of a road cutting. Volumes are often calculated by integrating the area at regular intervals eg. along a road centreline, or by using regularly spaced contours. We simply use what you already know about numerical integration from numerical methods).

Objectives

After completing this topic you should be able to
calculate the areas of polygons and irregular figures and the volumes of irregular and curved solids.

COMPUTATION OF VOLUMES

The computation of volumes of various quantities from the measurements done in the field is required in the design and planning on many engineering works. The volume of earth work is required for suitable alignment of road works, canal and sewer lines, soil and water conservation works, farm pond and percolation pond consent.

The computation of volume of various materials such as coal, gravel and is required to check the stock files, volume computations are also required for estimation of capacities of bins tanks etc.

For estimation of volume of earth work cross sections are taken at right angles to a fixed line, which runs continuously through the earth work. The spacing of the cross sections will depend upon the accuracy required. The volume of earth work is computed once the various cross-sections are known, adopting Prismoidal rule and trapezoidal rule.

- The main objective of the surveying is to compute the areas and volumes.

Generally, the lands will be of irregular shaped polygons.

There are formulae readily available for regular polygons like, triangle, rectangle, square and other polygons.

But for determining the areas of irregular polygons, different methods are used.

Earthwork computation is involved in the excavation of channels, digging of trenches for laying underground pipelines, formation of bunds, earthen embankments, digging farm ponds, land levelling and smoothening. In most of the computation the cross sectional areas at different interval along the length of the channels and embankments are first calculated and the volume of the prismoids are obtained between successive cross section either by trapezoidal or prismoidal formula.

Calculation of area is carried out by any one of the following methods:

a) Mid-ordinate method

b) Average ordinate method

c) Trapezoidal rule

d) Simpson's rule

A) MID-ORDINATE METHOD

Let O1, O2, O3, O4……….On= ordinates at equal intervals

l=length of base line

d= common distance between ordinates

h1,h2,……..hn=mid-ordinates

Area = common distance* sum of mid-ordinates

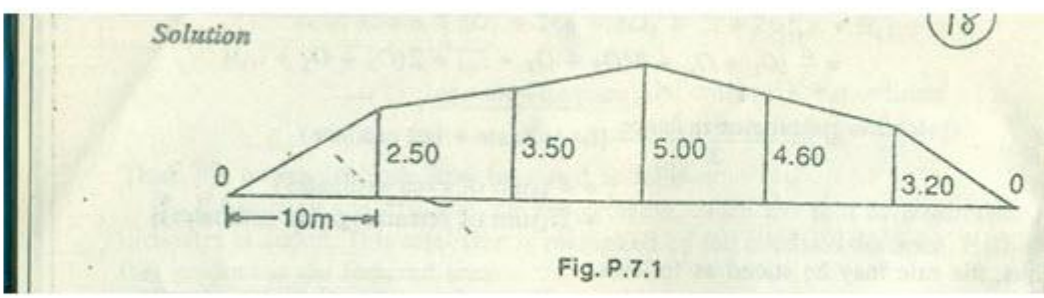


Fig. P.7.1

$$\text{Area} = \frac{O_1+O_2+\ldots}{n+1}$$

Area= sum of the ordinat… / no of ord…

Let O1, O2, …..On=ordinates or offsets at regular intervals

l= length of base line

n= number of divisions

n+1= number of ordinates

$$\text{Area of plot} = h_1 * d + h_2 * d + \ldots\ldots + h_n * d$$
$$= d\,(h_1+h_2+\ldots+h_n)$$

b.THE TRAPEZOIDAL RULE

While applying the trapezoidal rule, boundaries between the ends of ordinates are assumed to be straight. Thus the areas enclosed between the base line and the irregular boundary line are considered as trapezoids.

Let O1, O2, …..On=ordinate at equal intervals, and d= common distance between two ordinates

$$1^{st}\text{ area} = \frac{O_1+O_2}{2} * d$$

$$2^{nd}\text{ area} = \frac{O_2+O_3}{2} * d$$

$$3^{rd}\text{ area} = = \frac{O_2+O_3}{2} * d$$

$$\text{Last area} = \frac{O_{n-1}+O_n}{2} * d$$

Total area=d/2{ O1+2O2+2O3+…….+2On-1+On}

$$\text{AREA} = \frac{\text{common distance } ((1^{st}\text{ ordinate} + \text{last ordinate}) + 2(\text{sum of other ordinates})}{2}$$

Thus the trapezoidal rule may be stated as follows:

To the sum of the first and last ordinate, twice the sum of intermediate ordinates is added. This total sum is multiplied by the common distance. Half of this product is the required area.

Limitation: There is no limitation for this rule. This rule can be applied for any number of ordinates

c.SIMPSON’S RULE

In this rule, the boundaries between the ends of ordinates are assumed to form an arc of parabola. Hence simpson’s rule is some times called as parabolic rule. Refer to figure:

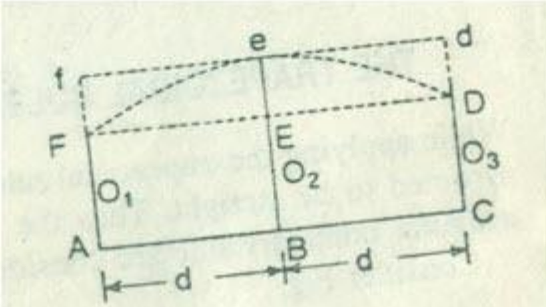


Fig.

Let

O1, O2, O3= three consecutive ordinates

d= common distance between the ordinates

area AFeDC= area of trapezium AFDC+ area of segment FeDEF

Here,

$$\text{Area of trapezium} = \frac{O_1+O_3}{2} * 2d$$

Area of segment= 2/3* area of parallelogram FfdD

= 2/3* eE*2d

= 2/3 *{ O2- O1+O3 /2 }*2d

So, the area between the first two divisions,

$$\Delta_1 = \frac{O_1+O_3}{2} * 2d + 2/3 * \{ O_2 - O_1+O_3 /2 \} * 2d$$

= d/3(O1+4O2+O3)

Similarly, the area of next two divisions

Δ2 = d/3(O1+4O2+O3) and so on

Total area = d/3[O1+On+4(O2+O4+……) + 2(O3+O5)]

$$= \frac{\text{Common distance}}{3} \{\text{1st ordinate} + \text{last ordinate}) + 4(\text{sum of even ordinates}) + 2(\text{sum of remaining odd ordinate})\}$$

Thus the rule may be stated as the follows

To the sum of the first and the last ordinate, four times the sum of even ordinates and twice the sum of the remaining odd ordinates are added. This total sum is multiplied by the common distance. One third of this product is the required area.

Limitation: This rule is applicable only when the number divisions is even i.e. the number of ordinates is odd.

The trapezoidal rule may be compared in the following manner:

Trapezoidal rule	Simpson's rule
The boundary between the ordinates is considered to be straight	The boundary between the ordinates is considered to be an arc of a parabola
There is no limitation. It can be applied for any number of ordinates	To apply this rule, the number of ordinates must be odd
It gives an approximate result	It gives a more accurate result.

Note: sometimes one or both the end of the ordinates may be zero. However they must be taken into account while applying these rules.

Worked- out problems

Problem 1: The following offsets were taken from a chain line to an irregular boundary line at an interval of 10 m:

0, 2.50, 3.50, 5.00, 4.60, 3.20, 0 m

Compute the area between the chain line, the irregular boundary line and the end of offsets by:

a) mid ordinate rule

b) the average –ordinate rule

c) the trapezoidal rule

d) Simpson's rule

Solution: (Refer fig)

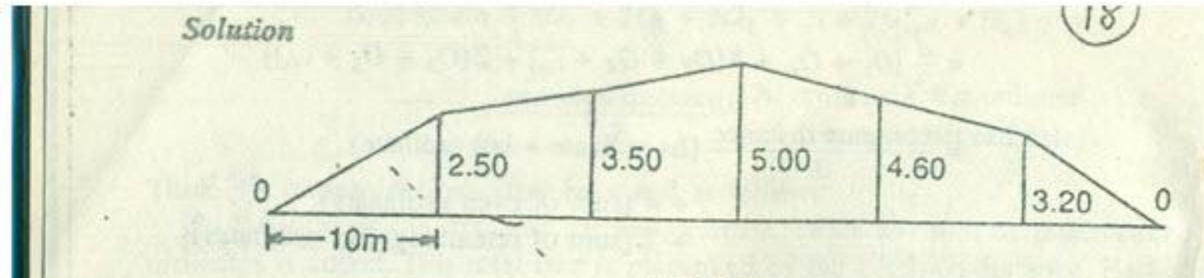


Fig. P.7.1

Mid-ordinate rule:

$$h_1 = \frac{0+2.50}{2} = 1.25 \text{ m}$$

$$h_2 = \frac{2.50+3.50}{2} = 3.00 \text{ m}$$

$$h_3 = \frac{3.50+5.00}{2} = 4.25 \text{ m}$$

$$h_4 = \frac{5.00+4.60}{2} = 4.80 \text{ m}$$

$$h_5 = \frac{4.60+3.20}{2} = 3.90 \text{ m}$$

$$h_6 = \frac{3.20+0}{2} = 1.60 \text{ m}$$

Required area= 10(1.25+3.00+4.25+3.90+1.60)

= 10*18.80=188 m2

By average-ordinate rule:

Here d=10 m and n=6(no of devices)

Base length= 10*6=60 m

Number of ordinates= 7

Required area=10((1.25+3.00+5.00+4.60+3.20+0)/7)

$$= \frac{16*18.80}{7} = 161.14m^2$$

By trapezoidal rule:

Here d=10m

Required area=10/2{0+0+2(2.50+3.50+5.00+4.60+3.20+)}

= 5*37.60=188 m2

By Simpson's rule:

d=10m

required area=10/3{0+0+4(2.50+5.00+3.20)+2(3.50+4.60)}

= 10/3{ 42.80+16.20}=10/3*59.00

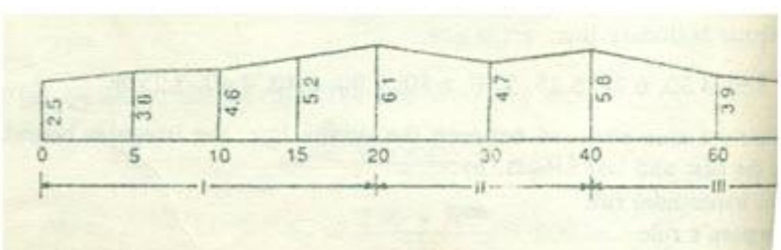
10/3*59= 196.66m2

Problem 2: the following offsets are taken from a survey line to a curves boundary line, and the first and the last offsets by:

a) the trapezoidal rule

b) simpson's rule

solution:



Solution Here. the intervals between the offsets are not regular thr here the intervals between the offsets are not reglar through out the length.

So, the section is divided into three compartments

Let

ΔI= area of the first section

ΔII= area of 2nd section

ΔIII= area of 3rd section

Here

$d1= 5$ m

$d2=10$ m

$d3=20$ m

a) by trapezoidal rule

$\Delta I= 5/2\{2.50+6.10+2(3.80+4.60+5.20)\} = 89.50$ m2

$\Delta II= 10/2\{6.10+5.80+2(4.70)\} =106.50$ m2

$\Delta III= 20/2\{5.80+2.20+2(3.90)\} = 158.00$ m2

Total area = 89.50+106.50+158.00 = 354.00 m2

b) by simpson's rule

$\Delta I= 5/3\{2.50+6.10+4(3.8+5.20) + 2(4.60)\} = 89.66$ m2

$\Delta II= 10/3\{6.10+5.80+4(4.70)\} =102.33$ m2

$\Delta III= 20/3\{5.80+2.20+4(3.90)\} = 157.33$ m2

Total area= 89.66+102.33+157.33 = 349.32 m2

FORMULA FOR CALCULATION OF VOLUME:

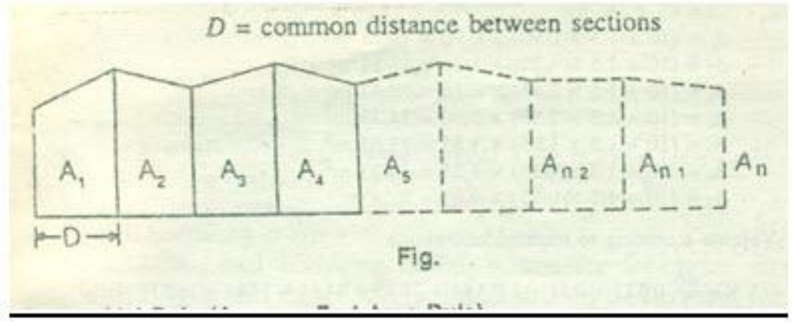


Fig.

D= common distance between the sections

A. trapezoidal rule

volume (cutting or filling), V=D/2(A1+An+2(A2+A3+….+An-1))

i.e. volume = $\frac{\text{common distance}}{2}$ {area of first section+ area of last section +2(sum of area of other sections)}

Prismoidal formula

Volume(cutting or filling), V= D/3{A1+ An +4(A2+ A4+ An-1)+ 2(A3+ A5+….+ Ann-1)}

i.e. V=$\frac{\text{common distance}}{3}$ {area of 1st section+ area of last section+ 4(sum of areas of even sections) +2(sum of areas of odd sections)

Note: the prismoidal formula is applicable whrn there is an odd number of sections. If the number of sections is even, the end strip is treated separately and the area is calculated according to the trapezoidal rule. The volume of the remaining strips is calculated in the usual manner by the prismoidal formula. Then both the results are added to obtain the total volume.

Works out problems

Problem 1: an embankment of width 10 m and side slopes 1 ½:1 is required to be made on a ground which is level in a direction transverseto the centre line. The central heights at 40 m intervals are as follows:

0.90,1.25,2.15,2.50,1.85,1.35, and 0.85

Calculate the volume of earth work according to

i) Trapezoidal formula

ii) Prismoidal formula

Solution: the c/s areas are calculated by

Δ= (b+sh)*h

Δ1= (10+1.5*0.90)*0.90 = 10.22 m2

Δ2= (10+1.5*1.25)*0.90 = 14.84 m2

Δ3= (10+1.5*1.25)*2.15 = 28.43 m2

Δ4= (10+1.5*2.50)*2.50 = 34.38 m2

Δ5= (10+1.5*1.85)*1.85 = 23.63 m2

Δ6=(10+1.5*1.35)*1.35 = 16.23 m2

Δ7=(10+1.5*0.85)*0.85= 9.58 m2

(a) Volume according to trapezoidal formula

V= 40/2{10.22+ 9.58+2(14.84+28.43+34.38+23.63+16.23)}

= 20{19.80+235.02} = 5096.4 m2

(b) Volume calculated in prismoidal formula:

V = 40/3 {10.22+9.58+4(14.84+34.38+16.23)+2(28.43+23.63)}

= 40/3 (19.80+ 261.80+104.12) = 5142.9 m2

Problem the areas enclosed by the contours in the lake are as follows:

Contour (m)	270	275	280	285	290
Area (m2)	2050	8400	16300	24600	31500

Calculate the volume of water between the contours 270 m and 290 m by:

i) Trapezoidal formula

ii) Prismoidal formula

Volume according to trapezoidal formula:

=5/2{2050+31500+2(8400+16300+24600)}

=330,250 m3