STRICTLY ACCORDING TO SCTE&VT SYLLABUS

DEPARTMENT OF CIVIL ENGINEERING

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LAND SURVEYING-1

4TH SEMESTER CIVIL

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2	Chaining and Chain Surveying
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4	Map Reading Cadastral Maps & Nomenclature
5	Plane Table Surveying
6	Theodolite Surveying and Traversing:
7	Levelling and Contouring
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INTRODUCTION TO SURVEYING, LINEAR MEASUREMENTS:

Surveying is defined as "taking a general view of, by observation and measurement determining the boundaries, size, position, quantity, condition, value etc. of land, estates, building, farms mines etc. and finally presenting the survey data in a suitable form". This covers the work of the valuation surveyor, the quantity surveyor, the building surveyor, the mining surveyor and so forth, as well as the land surveyor.

The process of surveying is therefore in three stages namely:

- Taking a general view:
  This part of the definition is important as it indicates the need to obtain an overall picture of what is required before any type of survey work is undertaken. In land surveying, this is achieved during the reconnaissance study.

- Observation and Measurement:
  This part of the definition denotes the next stage of any survey, which in land surveying constitutes the measurement to determine the relative position and sizes of natural and artificial features on the land.

- Presentation of Data:
  The data collected in any survey must be presented in a form which allows the information to be clearly interpreted and understood by others. This presentation may take the form of written report, bills of quantities, datasheets, drawings and in land surveying maps and plan showing the features on the land.

Types of Surveying

On the basis of whether the curvature of the earth is taken into account or not, surveying can be divided into two main categories:

Plane surveying: is the type of surveying where the mean surface of the earth is considered as a plane. All angles are considered to be plane angles. For small areas less than 250 km^2 plane surveying can safely be used. For most engineering projects such as canal, railway, highway, building, pipeline, etc constructions, this type of surveying is used. It is worth noting that the difference between an arc distance of 18.5 km and the subtended chord lying in the earth's surface is 7mm. Also, the sum of the angles of a plane triangle and the sum of the angles in a spherical triangle differ by 1 second for a triangle on the earth's surface having an area of 196 km^2.

Geodetic surveying: is that branch of surveying, which takes into account the true shape of the earth (spheroid).

Classification of surveying:

For easy understanding of surveying and the various components of the subject, we need a deep understanding of the various ways of classifying it.

Surveying is classified based on various criteria including the instruments used, purpose, the area surveyed and the method used.

Classification on the Basis of Instruments Used. Based on the instrument used; surveys can be classified into;

i) Chain tape surveys
ii) Compass surveys
iii) Plane table surveys
iv) Theodolite surveys

Classification based on the surface and the area surveyed

1. Land survey:

Land surveys are done for objects on the surface of the earth. It can be subdivided into:

- Topographic survey: This is for depicting the (hills, valleys, mountains, rivers, etc) and manmade features (roads, houses, settlements…) on the surface of the earth.
- Cadastral survey is used to determining property boundaries including those of fields, houses, plots of land, etc.
- Engineering survey is used to acquire the required data for the planning, design and Execution of engineering projects like roads, bridges, canals, dams, railways, buildings, etc.
- City surveys: The surveys involving the construction and development of towns including roads, drainage, water supply, sewage street network, etc, are generally referred to as city survey.

2. Marine or Hydrographic Survey:

Those are surveys of large water bodies for navigation, tidal monitoring, the construction of harbours etc.

3. Astronomical Survey:

Astronomical survey uses the observations of the heavenly bodies (sun, moon, stars etc) to fix the absolute locations of places on the surface of the earth.

Classification on the basis of purpose:

4. Engineering survey

Control Survey: Control survey uses geodetic methods to establish widely spaced vertical and horizontal control points.

5. Geological Survey: Geological survey is used to determine the structure and arrangement of rock strata. Generally, it enables to know the composition of the earth.

6. Military or Defence Survey is carried out to map places of military and strategic importance.

7. Archeological survey is carried out to discover and map ancient/relies of antiquity.

Classification Based on Instrument Used:

8. Chain/Tape Survey: This is the simple method of taking the linear measurement using a chain or tape with no angular measurements made.

9. Compass Survey: Here horizontal angular measurements are made using magnetic compass with the linear measurements made using the chain or tape.

10. Plane table survey: This is a quick survey carried out in the field with the measurements and drawings made at the same time using a plane table.

11. Levelling: This is the measurement and mapping of the relative heights of points on the earth's surface showing them in maps, plane and charts as vertical sections or with conventional symbols.

12. Theodolite Survey: Theodolite survey takes vertical and horizontal angles in order to establish controls.

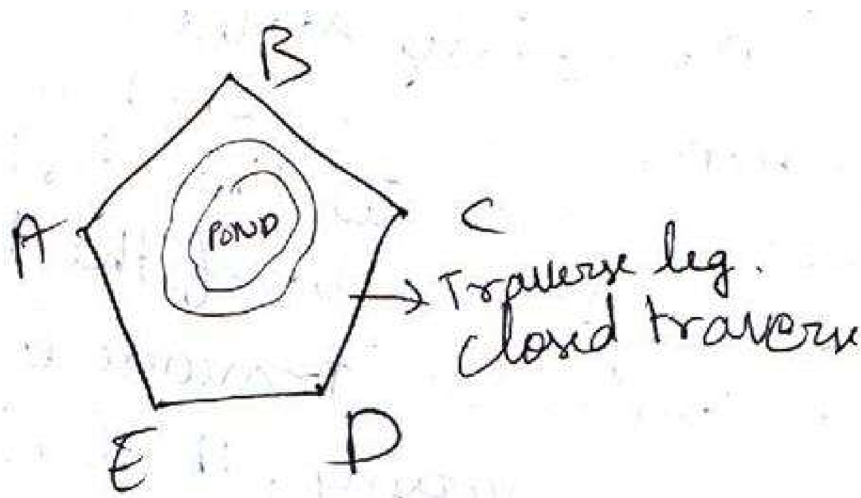
Classification based on the method used:

13. Triangulation Survey In order to make the survey, manageable, the area to be surveyed is first covered with series of triangles. Lines are first run round the perimeter of the plot, then the details fixed in relation to the established lines. This process is called triangulation. The triangle is preferred as it is the only shape that can completely over an irregularly shaped area with minimum space left.

14. Traverse survey: If the bearing and distance of a place of a known point is known: it is possible to establish the position of that point on the ground. From this point, the bearing and distances of other surrounding points may be established. In the process, positions of points linked with lines linking them emerge. The traversing is the process of establishing these lines, is called traversing, while the connecting lines joining two points on the ground. Joining two while bearing and distance is known as traverse. A traverse station is each of the points of the traverse, while the traverse leg is the straight line between consecutive stations. Traverses may either be open or closed.

Closed Traverse:

When a series of connected lines forms a closed circuit, i.e. when the finishing point coincides with the starting point of a survey, it is called as a 'closed traverse', here ABCDEA represents a closed traverse.



Open Traverse:

When a sequence of connected lines extends along a general direction and does not return to the starting point, it is known as 'open traverse' or (unclosed traverse).

BRANCHES OF SURVEYING:

- Aerial Surveying

Aerial surveys are undertaken by using photographs taken with special cameras mounted in an aircraft viewed in pairs. The photographs produce three-dimensional images of ground features from which maps or numerical data can be produced usually with the aid of stereo plotting machines and computers.

- Hydrographic Surveying (Hydro-Survey)

Hydro survey is undertaken to gather information in the marine environment such as mapping out the coast lines and sea bed in order to produce navigational charts.

- ❖ Geodetic Survey:

In geodetic survey, large areas of the earth surface are involved usually on national basis where survey stations are precisely located large distances apart. Account is taken of the curvature of the earth; hence it involves advanced mathematical theory and precise measurements are required to be made. Geodetic survey stations can be used to map out entire continent, measure the size and shape of the earth or in carrying out scientific studies such as determination of the Earth's magnetic field and direction of continental drifts.

- ❖ Plane Surveying:

In plane surveying relatively small areas are involved and the area under consideration is taken to be a horizontal plane. It is divided into three branches.

i) Cadastral surveying
ii) Topographical surveying
iii) Engineering surveying

Cadastral surveying

These are surveys undertaken to define and record the boundary of properties, legislative area and even countries. It may be almost entirely topographical where features define boundaries with the topographical details appearing on ordinance survey maps. In the other hand, markers define boundaries, corner or line points and little account may be taken of the topographical features.

Topographical Survey

These are surveys where the physical features on the earth are measured and maps/plans prepared to show their relative positions both horizontally and vertically. The relative positions and shape of natural and man –made features over an area are established usually for the purpose of producing a map of the area of for establishing geographical information system.

Engineering Survey

These are surveys undertaken to provide special information for construction of Civil Engineering and building projects. The survey supply details for a particular engineering schemes and could include setting out of the work on the ground and dimensional control on such schemes.

BASIC PRINCIPLES IN SURVEYING:

principle of working from whole to part:

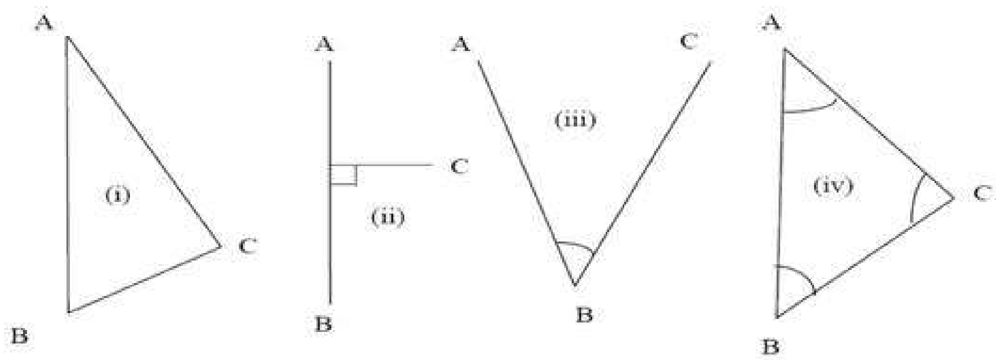
i) It is a fundamental rule to always work from the whole to the part. This implies a precise control surveying as the first consideration followed by subsidiary detail surveying.
ii) This surveying principle involves laying down an overall system of stations whose positions are fixed to a fairly high degree of accuracy as control, and then the survey of details between the control points may be added on the frame by less elaborate methods.
iii) Once the overall size has been determined, the smaller areas can be surveyed in the knowledge that they must (and will if care is taken) put into the confines of the main overall frame.
iv) Errors which may inevitably arise are then contained within the framework of the control points and can be adjusted to it.

Surveying is based on simple fundamental principles which should be taken into consideration to enable one get good results.

a) Working from the whole to the part is achieved by covering the area to be surveyed with a number of spaced out control point called primary control points called primary control points whose pointing have been determined with a high level of precision using sophisticated equipment. Based on these points as theoretic, a number of large triangles are drawn. Secondary control points are then established to fill the gaps with lesser precision than the primary control points. At a more detailed and less precise level, tertiary control points at closer intervals are finally established to fill in the smaller gaps. The main purpose of surveying from the whole to the part is to localize the errors as working the other way round would magnify the errors and introduce distortions in the survey. In partial terms, this principle involve covering the area to be surveyed with large triangles. These are further divided into smaller triangles and the process continues until the area has been sufficiently covered with small triangles to a level that allows detailed surveys to be made in a local level. Error is in the whole operation as the vertices of the large triangles are fixed using higher precision instruments.

b) Using measurements from two control parts to fix other points. Given two points whose length and bearings have been accurately determined, a line can be drawn to join them hence surveying has control reference points. The locations of various other points and the lines joining them can be fixed by measurements made from these two points and the lines joining them. For an example, if A and B are the control points, the following operations can be performed to fix other points.

i) Using points A and B as the centres, ascribe arcs and fix (where they intersect).
ii) Draw perpendicular from D along AB to a point C.
iii) To locate C, measure distance AB and use your protractor to equally measure angle ABC.
iv) To locate C the interior angles of triangle ABC can be measured. The lengths of the sides AC and BC can be calculated by solving the triangle.



The process of surveying:

The survey process passes through 3 main phases – the reconnaissance, field work and measurements, and, the office work.

(a) Reconnaissance survey

This is a pre-field work and measurement phase. It requires taking an overall inspection of the area to be surveyed to obtain a general picture before commencement of any serious survey. Walking through the site enables one to understand the terrain and helps in determining the survey method to be adopted, and the scale to be used. The initial information obtained in this stage helps in the successful planning and execution of the survey.

(b) Field work and measurement:

This is the actual measurements in the field and the recordings in the field notebook. To get the best results in the field, the surveyor must be acquainted with the functions of the equipment and take good care of them.

(c) Office work: This is the post field work stage in which data collected and recordings in the field notebooks are decoded and used to prepare the charts, planes and maps for presentation to the clients and the target audience.

HORIZONTAL DISTANCE MEASUREMENT:

One of the basic measurements in surveying is the determination of the distance between two points on the earth's surface for use in fixing position, set out and in scaling. Usually spatial distance is measured. In plane surveying, the distances measured are reduced to their equivalent horizontal distance either by the procedures used to make the measurement or by applying numerical corrections for the slope distance (spatial distance). The method to be employed in measuring distance depends on the required accuracy of the measurement, and this in turn depends on purpose for which the measurement is intended.

Pacing: – where approximate results are satisfactory, distance can be obtained by pacing (the number of paces can be counted by tally or pedometer registry attached to one leg). Average pace length has to be known by pacing a known distance several times and taking the average. It is used in reconnaissance surveys& in small scale mapping

Odometer of a vehicle: - based on diameter of tires (no of revolutions X wheel diameter); this method gives a fairly reliable result provided a check is done periodically on a known length. During each measurement a constant tyre pressure has to be maintained.

Tachometry: -distance can be can be measured indirectly by optical surveying instruments like theodolite. The method is quite rapid and sufficiently accurate for many types of surveying operations.

Taping (chaining): - this method involves direct measurement of distances with a tape or chain. Steel tapes are most commonly used. It is available in lengths varying from 15m to 100m. Formerly on surveys of ordinary precision, lengths of lines were measured with chains.

Electronic Distance Measurement (EDM): - are indirect distance measuring instruments that work using the invariant velocity of light or electromagnetic waves in vacuum. They have high degree of accuracy and are effectively used for long distances for modern surveying operations

CHAIN SURVEYING:

This is the simplest and oldest form of land surveying of an area using linear measurements only. It can be defined as the process of taking direct measurement, although not necessarily with a chain.

Equipment used in chain surveying

This equipment can be divided into three, namely

i) Those used for linear measurement. (Chain, steel band, linear tape)
ii) Those used for slope angle measurement and for measuring right angle (E.g. Abney level, clinometer, cross staff, optical squares)
iii) Other items (Ranging rods or poles, arrows, pegs etc).

Chain: -

The chain is usually made of steel wire, and consists of long links joined by shorter links. It is designed for hard usage, and is sufficiently accurate for measuring the chain lines and offsets of small surveys.

Chains are made up of links which measure 200mm from centre to centre of each middle connecting ring and surveying brass handless are fitted at each end. Tally markers made of plastic or brass are attached at every whole metre position or at each tenth link. To avoid confusion in reading, chains are marked similarly form both end (E.g. Tally for 2m and 18m is the same) so that measurements may be commenced with either end of the chain

There are three different types of chains used in taking measurement namely:

i) Engineers chain
ii) Gunter’s chain
iii) Steel bands

Steel Bands:

This may be 30m, 50m or 100m long and 13mm wide. It has handles similar to those on the chain and is wound on a steel cross. It is more accurate but less robust than the chain. The operating tension and temperature for which it was graduated should be indicated on the band.

Tapes:

Tapes are used where greater accuracy of measurements are required, such as the setting out of buildings and roads. They are 15m or 30m long marked in metres, centimetre and millimetres. Tapes are classified into three types;

i) Linen or Linen with steel wire woven into the fabric; These tapes are liable to stretch in use and should be frequently tested for length. They should never be used on work for which great accuracy is required.
ii) Fibre Glass Tapes: These are much stronger than lines and will not stretch in use.
iii) Steel tapes: These are much more accurate, and are usually used for setting out buildings and structural steel works. Steel tapes are available in various lengths up to 100m (20m and 30m being the most common) encased in steel or plastic boxes with a recessed winding lever or mounted on open frames with a folding winding lever.

Arrows: Arrow consists of a piece of steel wire about 0.5m long, and are used for marking temporary stations. A piece of coloured cloth, white or red ribbon is usually attached or tied to the end of the arrow to be clearly seen on the field.

Pegs: Pegs are made of wood 50mm x 50mm and some convenient length. They are used for points which are required to be permanently marked, such as intersection points of survey lines. Pegs are driven with a mallet and nails are set in the tops.

Ranging Rod:

These are poles of circular section 2m, 2.5m or 3m long, painted with characteristic red and white bands which are usually 0.5m long and tipped with a pointed steel shoe to enable them to be driven into the ground. They are used in the measurement of lines with the tape, and for marking any points which need to be seen.

Optical Square: This instrument is used for setting out lines at right angle to main chain line. It is used where greater accuracy is required. There are two types of optical square, one using two mirrors and the other a prism.

Cross Staff:

This consists of two pairs of vanes set at right angle to each other with a wide and narrow slit in each vane. The instrument is mounted upon a pole, so that when it is set up it is at normal eye level. It is also used for setting out lines at right angle to the main chain line.

Clinometer:

This instrument is used for measuring angles of ground slopes (slope angle). They are of several form, the common form is the WATKING'S CLINOMETER, which consist of a small disc of about 60mm diameter. A weighted ring inside the disc can be made to hang free and by sighting across this graduated ring angle of slopes can be read off. It is less accurate than abney level.

Abney Level:

This instrument is generally used to obtain roughly the slope angle of the ground. It consists of a rectangular, telescopic tube (without lenses) about 125mm long with a graduated arc attached. A small bubble is fixed to the Vernier arm, once the image of the bubble is seen reflected in the eyepiece the angle of the line of sight can be read off with the aid of the reading glass.

GENERAL PROCEDURE IN MAKING A CHAIN SURVEY

i) Reconnaissance: Walk over the area to be surveyed and note the general layout, the position of features and the shape of the area.
ii) Choice of Stations: Decide upon the framework to be used and drive in the station pegs to mark the stations selected.
iii) Station Marking: Station marks, where possible should be tied - in to a permanent object so that they may be easily replaced if moved or easily found during the survey. In soft ground wooden pegs may be used while rails may be used on roads or hard surfaces.
iv) Witnessing: This consists of making a sketch of the immediate area around the station showing existing permanent features, the position of the stations and its description and designation. Measurements are then made from at least three surrounding features to the station point and recorded on the sketch. The aim of witnessing is to re-locate a station again at much later date even by others after a long interval.
v) Offsetting: - Offsets are usually taken perpendicular to chain lines in order to dodge obstacles on the chain line.
vi) Sketching the layout on the last page of the chain book, together with the date and the name of the surveyor, the longest line of the survey is usually taken as the base line and is measured first.

CRITERIA FOR SELECTING A SURVEY LINES/OFFSET

During reconnaissance, the following points must be borne in mind as the criteria to provide the best arrangement of survey lines,

i) Few survey lines: the number of survey lines should be kept to a minimum but must be sufficient for the survey to be plotted and checked.
ii) Long base line: A long line should be positioned right across the site to form a base on which to build the triangles.
iii) Well-conditioned triangle with angles greater than 30^0 and not exceeding 150^0: It is preferable that the arcs used for plotting should intersect as close as 90^0 in order to provide sharp definition of the stations point.
iv) Check lines: Every part of the survey should be provided with check lines that are positioned in such a way that they can be used for off- setting too, in order to save any unnecessary duplication of lines.
v) Obstacles such as steep slopes and rough ground should be avoided as far as possible.
vi) Short offsets to survey lines (close feature preferably 2m) should be selected: So that measuring operated by one person can be used instead of tape which needs two people.
vii) Stations should be positioned on the extension of a check line or triangle. Such points can be plotted without the need for intersecting arcs.

Ranging:

Ranging involves placing ranging poles along the route to be measures so as to get a straight line. The poles are used to mark the stations and in between the stations.

ERRORS IN SURVEYING

- Surveying is a process that involves observations and measurements with a wide range of electronic, optical and mechanical equipment some of which are very sophisticated.

- Despite the best equipment and methods used, it is still impossible to take observations that are completely free of small variations caused by errors which must be guided against or their effects corrected.

Types of errors:

1. Gross Errors

i) These are referred to mistakes or blunders by either the surveyor or his assistants due to carelessness or incompetence.
ii) On construction sites, mistakes are frequently made by in – experienced Engineers or surveyors who are unfamiliar with the equipment and method they are using.
iii) These types of errors include miscounting the number of tapes length, wrong booking, sighting wrong target, measuring anticlockwise reading, turning instruments incorrectly, displacement of arrows or station marks etc.
iv) Gross errors can occur at any stage of survey when observing, booking, computing or plotting and they would have a damaging effect on the results if left uncorrected.
v) Gross errors can be eliminated only by careful methods of observing booking and constantly checking both operations.

2. Systematic or Cumulative Errors

i) These errors are cumulative in effect and are caused by badly adjusted instrument and the physical condition at the time of measurement must be considered in this respect. Expansion of steel, frequently changes in electromagnetic distance (EDM) measuring instrument, etc are just some of these errors.

ii) Systematic errors have the same magnitude and sign in a series of measurements that are repeated under the same condition, thus contributing negatively or positively to the reading hence, makes the readings shorter or longer.
iii) This type of error can be eliminated from a measurement using corrections (e.g. effect of tension and temperature on steel tape).
iv) Another method of removing systematic errors is to calibrate the observing equipment and quantify the error allowing corrections to be made to further observations.
v) Observational procedures by re-measuring the quantity with an entirely different method using different instrument can also be used to eliminate the effect of systematic errors.

3. Random or Compensating Errors

i) Although every precaution may be taken certain unavoidable errors always exist in any measurement caused usually by human limitation in reading/handling of instruments.
ii) Random errors cannot be removed from observation but methods can be adopted to ensure that they are kept within acceptable limits.
iii) In order to analyse random errors or variable, statistical principles must be used and in surveying their effects may be reduced by increasing the number of observations and finding their mean. It is therefore important to assume those random variables are normally distributed.

Corrections to Linear Measurement and their Application: -

The following corrections are to be applied to the linear measurements with a chain or a tape where such accuracy is required.

i) Pull correction,
ii) Temperature correction
iii) Standard length correction
iv) Sag correction
v) Slope correction

If length measured 'L' and the difference in the levels of first and last point 'h' are given then

i) correction for slope is, $C_{sl}=h^2/2L$

ii) temperature correction Ct is given by $Ct=L\alpha(Tm-To)$

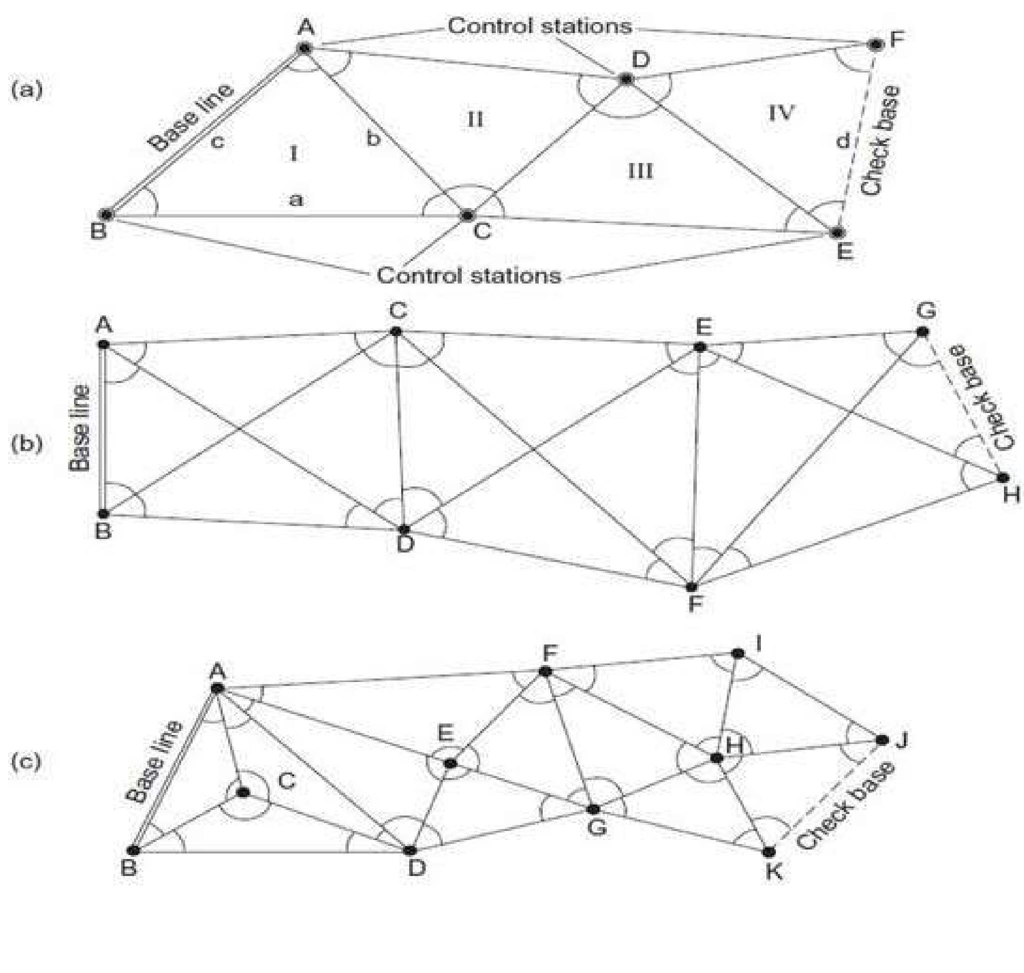
iii) correction for pull Cp is given by $Cp=(P-P_0)\ L/AE$

iv) Sag correction is given by $Cs=1/24(W/P)\ L$

TRIANGULATION:

It is easier to measure angles than it is distance, triangulation is the preferred method of establishing the position of control points. In this method the area to be surveyed is divided into number of well-conditioned triangles. The triangles should have angles greater than 30^0 but less than 90^0.

The principles of the method are illustrated by the typical basic figures shown in Figure. If all the angles are measured, then the scale of the network is obtained by the measurement of one side only, i.e. the base line. Any error, therefore, in the measurement of the base line will result in scale error throughout the network. Thus, in order to control this error, check base lines should be measured at intervals. The scale error is defined as the difference between the measured and computed check base. Using the base line and adjusted angles the remaining sides of the triangles may be found and subsequently the coordinates of the control stations. Triangulation is best suited to open, hilly country, affording long sights well clear of intervening terrain. In urban areas, roof-top triangulation is used, in which the control stations are situated on the roofs of accessible buildings.



Overcoming obstacles during chaining:

Agor (1993) classified the various types of obstacles encountered in the course of chaining into three cases:

- Obstacles which obstruct ranging but not chaining
- Obstacles which obstruct chaining but not ranging
- Obstacle which obstruct both ranging and chaining
- Obstacles that obstruct ranging but not chaining

Such a problem arises when a rising ground or a jungle area interrupts the chain line. Here the end stations are not intervisible.

There may be two cases: -

Case I:

The end stations may be visible from some intermediate points on the rising ground. In this case, reciprocal ranging is resorted to and the chaining is done by the stepping method.

Case II:

The end stations are not visible from intermediate points when a jungle area comes across the chain line.

COMPASS SURVEYING:

In compass survey, the direction of the survey line is measured by the use of a magnetic compass while the lengths are by chaining or taping. Where the area to be surveyed is comparatively large, the compass survey is preferred, whereas if the area is small in extent and a high degree of accuracy is desired, then chain survey is adopted. However, where the compass survey is used, care must be taken to make sure that magnetic disturbances are not present. The two major primary types of survey compass are: the prismatic compass and surveyors compass.

Prismatic Compass:

This is an instrument used for the measurement of magnetic bearings. It is small and portable usually carried on the hand. This Prismatic Compass is one of the two main kinds of magnetic compasses included in the collection for the purpose of measuring magnetic bearings, with the other being the Surveyor's Compass. The prismatic compass on the other hand is often a small instrument which is held in the hand for observing, and is therefore employed on the rougher classes of work. The graduations on this prismatic compass are situated on a light aluminium ring fastened to the needle, and the zero of the graduations coincides with the south point of the needle. The graduations therefore remain stationary with the needle, and the index turns with the sighting vanes. Since the circle is read at the observer's (rather than the target's) end, the graduations run clockwise from the south end of the needle (0º to 360º), whereas in the surveyor's compass, the graduations run anti-clockwise from north.

The prismatic attachment consists of a 45º reflecting prism with the eye and reading faces made slightly convex so as to magnify the image of the graduations. The prism is carried on a mounting which can be moved up and down between slides fixed on the outside of the case.

Temporary adjustment of prismatic compass:

The following procedure should be adopted after fixing the prismatic compass on the tripod for measuring the bearing of a line.

I. Centering: Centering is the operation in which compass is kept exactly over the station from where the bearing is to be determined. The Centering is checked by dropping a small pebble from the underside of the compass. If the pebble falls on the top of the peg then the Centering is correct, if not then the Centering is corrected by adjusting the legs of the tripod.

II. Levelling: Levelling of the compass is done with the aim to freely swing the graduated circular ring of the prismatic compass. The ball and socket arrangement on the tripod will help to achieve a proper level of the compass. This can be checked by rolling round pencil on glass cover.

III. Focusing: the prism is moved up or down in its slide till the graduations on the aluminium ring are seen clear, sharp and perfect focus. The position of the prism will depend upon the vision of the observer.

Magnetic Bearing:

The magnetic bearing of a survey line is the angle between the direction of the line and the direction of the magnetic meridian at the beginning of the line.

Magnetic Meridian:

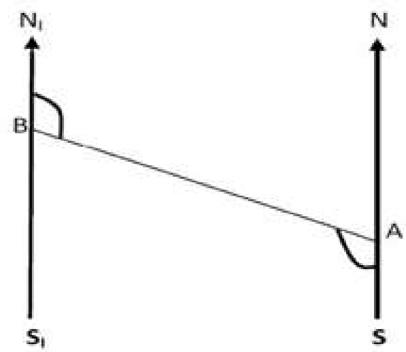
The magnetic meridian at any place is the direction obtained by observing the position of a freely supported magnetized needle when it comes to rest uninfluenced by local attracting forces. Magnetic meridians run roughly north –south and follow the varying trend of the earth's magnetic field. The direction of a magnetic meridian does not coincide with the true or geographical meridian which gives the direction of the true North pole except in certain places.

Angle of Declination:

It is defined as the angle between the direction of the magnetic meridian and the true meridian at any point.

Back and fore bearing:

Fore bearing is the compass bearing of a place taken from a status to the other in the direction that the survey is being carried out. The back bearing in the other hand is the bearing in the opposite direction i.e. the bearing taken backwards from the next station to its preceding station that the fore bearing was taken. The difference between BB and FB is always 180^0.



Here, BB=FB-180^0

- ❖ Whole circle bearing system (W.C.B.):

The bearing of a line measured with respect to magnetic meridian in clockwise direction is called magnetic bearing and its value varies between 0^O to 360^O.The quadrant start from north and progress in a clockwise direction as the first quadrant is 0^O to 90^O in clockwise direction , 2nd 90^O to 180^O , 3rd 180^O to 270^O, and up to 360^O is 4th one.

- ❖ Quadrantal bearing system (Q.B.):

In this system, the bearing of survey lines is measured with respect to north line or south line whichever is the nearest to the given survey line and either in clockwise direction or in anti-clockwise direction.

- ❖ Reduced bearing (R.B):

When the whole circle bearing is converted into Quadrantal bearing, it is termed as "REDUCED BEARING". Thus, the reduced bearing is similar to the Quadrantal bearing.

conversion of WCB to RB

ERROR IN COMPASS SURVEY:

There are two types of error which occur during compass surveying. The first error known as local attraction is an error which occurs in the compass due to the influence of any magnetic metal present near by while taking observation. The local attraction can also occur due to a source of magnetic flux nearby.

The other is the observational error which is human in nature. The error is basically additive and at the end of survey the errors can compensate into a larger value. Also sometimes this value results in closing error while making a closed traversal.

MAP READING AND NOMENCLATURE:

A map is a graphic representation of a portion of the earth's surface drawn to scale, as seen from above. It uses colours, symbols, and labels to represent features found on the ground. The ideal representation would be realized if every feature of the area being mapped could be shown in true shape. Obviously, this is impossible, and an attempt to plot each feature true to scale would result in a product impossible to read even with the aid of a magnifying glass.

a. Therefore, to be understandable, features must be represented by conventional signs and symbols. To be legible, many of these must be exaggerated in size, often far beyond the actual ground limits of the feature represented. On a 1:250,000 scale map, the prescribed symbol for a building covers an area about 500 feet square on the ground; a road symbol is equivalent to a road about 520 feet wide on the ground; the symbol for a single-track railroad (the length of a cross-tie) is equivalent to a railroad cross-tie about 1,000 feet on the ground.

b. The portrayal of many features requires similar exaggeration. A map provides information on the existence, the location of, and the distance between ground features, such as populated places and routes of travel and communication. It also indicates variations in terrain, heights of natural features, and the extent of vegetation cover. Because a map is a graphic representation of a portion of the earth's surface drawn to scale as seen from above, it is important to know what mathematical scale has been used. You must know this to determine ground distances between objects or locations on the map, the size of the area covered, and how the scale may affect the amount of detail being shown.

The mathematical scale of a map is the ratio or fraction between the distance on a map and the corresponding distance on the surface of the earth. Scale is reported as a representative fraction with the map distance as the numerator and the ground distance as the denominator.

$$\textit{Representative fraction (scale)} = \frac{\textit{map distance}}{\textit{ground distance}}$$

One of the oldest systematic methods of location is based upon the geographic coordinate system. By drawing a set of east-west rings around the globe (parallel to the equator), and a set of north-south rings crossing the equator at right angles and converging at the poles, a network of reference lines is formed from which any point on the earth's surface can be located.

a. The distance of a point north or south of the equator is known as its latitude. The rings around the earth parallel to the equator are called parallels of latitude or simply parallels. Lines of latitude run east-west but north-south distances are measured between them.

b. A second set of rings around the globe at right angles to lines of latitude and passing through the poles is known as meridians of longitude or simply meridians. One meridian is designated as the prime meridian. The prime meridian of the system we use runs through Greenwich, England and is known as the Greenwich meridian. The distance east or west of a prime meridian to a point is known as its longitude.

Grid Coordinates: We have now divided the earth's surface into 6° by 8° quadrangles, and covered these with 100,000-meter squares. The grid reference of a point consists of the numbers and letters indicating in which of these areas the point lies, plus the coordinates locating the point to the desired position within the 100,000-meter square. The next step is to tie in the coordinates of the point with the larger areas.

Grid Lines: The regularly spaced lines that make the UTM and the UPS grid on any large-scale maps are divisions of the 100,000-meter square; the lines are spaced at 10,000- or 1,000-meter intervals. Each of these lines is labelled at both ends of the map with its false easting or false northing value, showing its relation to the origin of the zone. Two digits of the values are printed in large type, and these same two digits appear at intervals along the grid lines on the face of the map. These are called the principal digits, and represent the 10,000 and 1,000 digits of the grid value. They are of major importance to the map reader because they are the numbers, he will use most often for referencing points. The smaller digits complete the UTM grid designation.

REPRESENTATIVE FRACTION

The numerical scale of a map indicates the relationship of distance measured on a map and the corresponding distance on the ground. This scale is usually written as a fraction and is called the representative fraction. The RF is always written with the map distance as 1 and is independent of any unit of measure. (It could be yards, meters, inches, and so forth.) An RF of 1/50,000 or 1:50,000 means that one unit of measure on the map is equal to 50,000 units of the same measure on the ground.

cadastral map content:

- Spatial information
- Property parcel boundaries
- Geodetic control monuments
- Easements and right-of-way (roads)
- Building footprints
- Administrative boundaries (general and cadastral)

Map preparation:

Method I: Pure Ground Method using ETS and DGPS.

Method II: Hybrid Method using Aerial Photographs supported by Ground Truthing using Differential Global Positioning System (DGPS) and / or Total Station.

Method III: Method using High Resolution satellite Imagery supported by Ground Truthing using Ground Truthing using Differential GPS and I or Total Station.

Location of ground control points:

The selected site should be open and clear to sky with a cut off angle of 15^0. High-tension power lines, transformers, electric substations, microwave towers, high-frequency dish antennas, radars, jammers, etc., which interfere with GPS signals, should be strictly avoided.

The co-ordinate list and description of the location of all the control points shall be maintained by State Land Records and Survey authorities. The locations and IDs of all the control points should be maintained in GlS form.

The co-ordinate list should be supplied both for geodetic system (Lat/Long) and Projected System - Universal Traverse Mercator, i.e., the UTM projection of the respective zone.

In case a village tri-junction has not been marked and monumented by a primary, secondary or tertiary control point, the same should be monumented as per prescribed specification.

Verification:

- After generation of ortho-image geo-referencing of 'Sabik' cadastral maps with the image: Georeferencing of individual parcels and the village as a whole for delineation/demarcation of village boundary.
- After plot vector generation and prior to ground truthing/verification: The geometry of parcels, the village boundary, matched and mismatched plots as seen on the image.
- Before submission of Draft Map to Tahasil for verification: The village in completeness, correctness of matched and mismatched parcels as identified by the vendor.
- Before final submission: Village map as a whole and the statistics after RoR linkage and 'Operation'.
- Some of the bund dimensions will be verified for ensuring correctness and quality of survey by the vendor

PLANE TABLE SURVEYING:

The plane table surveying is one of the fastest and easiest methods of surveying. Plotting of plans and field observations can be done at the same time in plane table surveying. It is useful for the following cases:

- It is best fitted for small-scale surveying i.e. any types of fields
- It is also used in surveying industrial areas where compass survey fails to perform
- It is often used to fill in details between stations fixed by triangulation method or theodolite traversing method.

Temporary Adjustments of The Plane Table:

1. Centering

This process is to ascertain that the point on the ground is represented accurately on the paper. It is carried out with the help of plumbing fork and plumbing bob. The pointed end (at the upper hand) of the plumbing fork is kept on paper and at the other end, a plumb bob is fixed. The board is shifted manually until the bob hangs exactly over the peg of the station. This work can be tiresome but a prerequisite for any further activities.

2. Levelling

Levelling is done so that the drawing board remains parallel to the ground. It is done in the following three methods:

- ordinary tilting the board
- by ball and socket arrangement or
- by adjusting the legs of the tripod.

3. Orientation

The process by which the position occupied by the board at various survey stations are kept parallel is known as the orientation. In the plane table surveying, the whole table needs to be moved at several stations to complete a survey. Every time the table is moved one has to make sure that the new station is parallel to the previous one otherwise the lines drawn on paper will not represent the same lines on the field. Methods of orientation are:-

Orientation by Magnetic Needle:

This method is used when it is not possible to bisect the previous station from the new station. This method is not much reliable and prone to errors due to variations of the magnetic field.

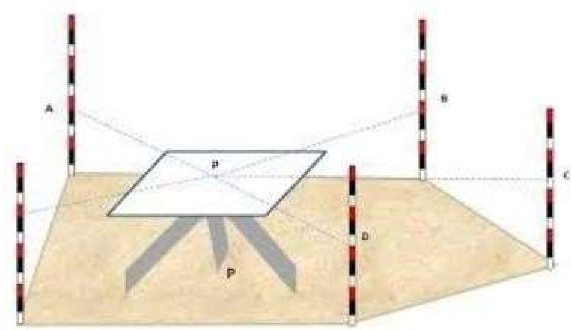
Orientation by Back Sighting:

This is a more reliable method. In this method, a particular line drawn from the previous station is drawn again from the new station. This process is called back-sighting. One does not necessarily have to draw the line the second time rather check if the new line superposes over the previous one or not.

Methods of Plane Table Surveying:

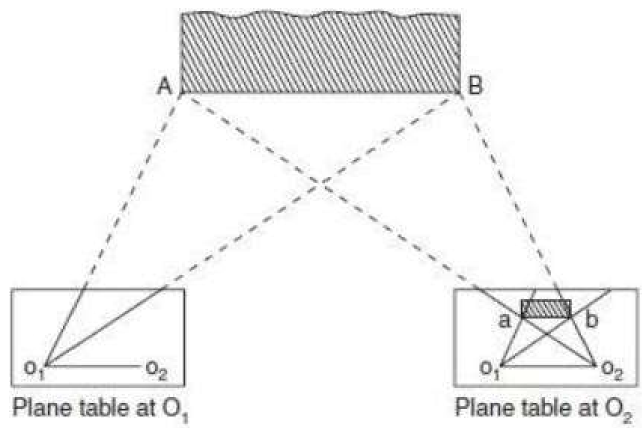
1. Radiation Method: It is the simplest method of plane table surveying. This method is only effective if the whole surveying is to be done from one single station i.e. the table will be in such a position from where all the other points of the field are easily visible. The procedure is as follows:

a) A point P is to be selected in such a fashion that all the other points (A B C D E) are seen easily from P.
b) Centering, levelling, and orientation must be done prior to surveying.
c) At first, by putting the alidade on point P a line of sight for station A is to be drawn.
d) After measuring the distance of PA on field, the measurement needs to be put on paper to a suitable scale.
e) Similarly, points b, c, d, and e are obtained on paper by drawing lines of sight for stations B, C and D and measuring the distances PB, PC, PD and PE on ground respectively.
f) Points a, b, c, d, and e are joined on paper, as shown in the figure.



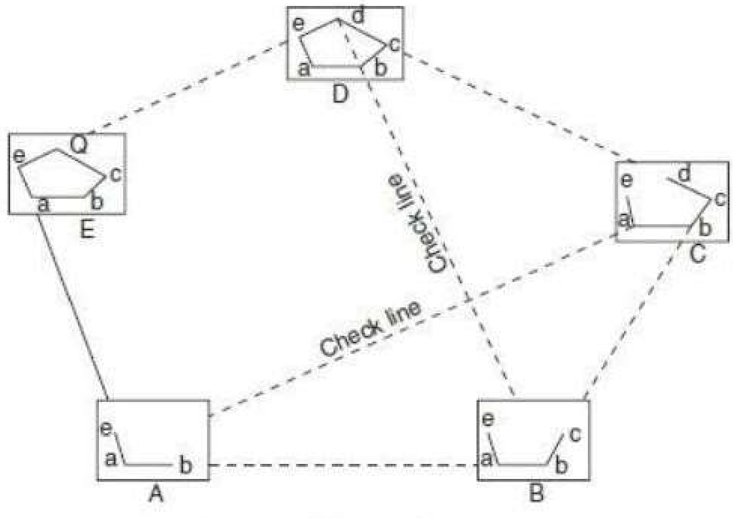
Intersection Method: In previous method it was possible to measure every distance on the field manually. In case of a mountainous terrain or rough surface where distances cannot be taken physically, it is best to use intersection method. The procedure is:

a) Two stations O_1 and O_2 are selected so that the points to be located on paper are easily seen from them.
b) The baseline (O_1, O_2) is plotted on the paper. This is done in the way below: The table can be cantered and levelled at station O_1 and then after orienting at station O_2, the distance O_1 O_2 can be accurately measured and put up to some scale on the paper. The line O_1O_2 can be drawn to some scale on the paper and then the board can be adjusted from station O_1 by back sighting at station O_2.
c) From station O_1, rays for stations A, B are drawn etc.
d) Now moving the table to the new station and orienting it again the rays of stations A, B are drawn etc.,
e) The intersection of rays from stations O_1 and O_2 will give points a, b etc. on paper, as shown in the figure.



Traversing Method: This is more or less like the compass survey. It is used for running survey lines between stations, which have been previously fixed by other methods of survey, to locate the topographic details.

a) The plane table is fixed at a location (say A)
b) From that point, a sight is taken toward B and the distance AB is measured.
c) The plane table is shifted to station B and sighted toward A (this is called back sighting). Distance BA was measured.
d) The average distance between AB and BA are plotted to suitable scale on the drawing paper.
e) Then the point C is sighted from B and the distance was measured. This process is repeated for all the stations.
f) Conduct some check at uniform intervals. Finally, plot the traverse lines on the drawing sheet. Notice that back sighting was done only for the first two stations.



Resection Method: This method is suitable for establishing new stations at a place in order to locate missing details. It is the process of determining the previously plotted position of any peg station, by means of sight taken towards known points, the location of which has been plotted.

Resection method involves two different procedures as follows:

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

THEODOLITE SURVEYING AND TRAVERSING:

Theodolite is a measurement instrument utilized in surveying to determine horizontal and vertical angles with the tiny low telescope that may move within the horizontal and vertical planes.

It is an electronic machine which looks sort of a tiny telescope. It is extensively used for the measurement of vertical and horizontal angles for scaling functions and within the housing industry. The accuracy with that these angles may be measured ranges from 5mins to 0.1 secs. It is utilized in triangulation networks.

Theodolite uses for many purposes, but mainly it is used for measuring angles, scaling points of constructional works. For example, to determine highway points, huge buildings' escalating edges theodolites are used. Depending on the job nature and the accuracy required, theodolite produces more curved of readings, using paradoxical faces and swings or different positions for perfect measuring survey.

Followings are the major uses of theodolite:

a) Measuring horizontal and vertical angles
b) Locating points on a line
c) Finding the difference in the level
d) Prolonging survey lines
e) Ranging curves
f) Setting out grades
g) Tachometric surveying

Theodolite is popular surveying instrument. It is a measurement tool with which we can find horizontal and vertical angles. It is an electronic device and has sophisticated parts. To learn theodolite surveying a surveyor must know the all the parts of theodolite machine. In the following article, major parts of a theodolite are discussed to make the device well familiar for the surveyor.

Parts of a Theodolite:

- Telescope
- Horizontal plate (Circle)
- Vertical Circle
- Index frame
- The standards
- The upper plate
- The lower plate
- Plate level
- The levelling head
- The shifting head
- Magnetic compass
- Tripod
- Plumb bob

- Telescope- It is used to see the object. It rotates about a horizontal axis in the vertical plane. It can be up to an accuracy of 20 degrees.

- Horizontal plate (Circle)- It is used for measuring the horizontal angle.

- Vertical Circle- It is used for measuring the vertical angle.

- Index frame- The frame consists of horizontal and vertical wings. This frame is additionally called t-frame or Vernier frame. The horizontal wing helps to require the measurement of vertical angles and vertical wing helps to grip the telescope at the wanted level.

- The standards- Standards look like 'A' shaped and for that, it is known as A-frame. The standards' frames support the telescope and allow it to spin about the vertical axis.

- The upper plate- It is the bottom on that standard and vertical settled. It also helps to rotate the standards and telescope in a regular manner for correct measurement. it is necessary that the upper plate should be horizontal to the alidade axis and coordinate to the trunnion axis. The instrument must be levelled and this levelled is achieved by adjustment of three-foot screws and perceptive an explicit tube bubble. The bubble is understood as plate bubble and located within the upper plate.

- The lower pale- The lower plate is that the base of the entire instrument. It homes the foot screws and the carrying for the vertical axis. it is strictly connected to the tripod-escalating assembly and does not modification or shift. Horizontal angles are measured with this plate.

- Plate level- Plate levels are lifting by the upper plate that is the proper angles to every different with one they are coordinate to trunnion axis. Plate levels facilitate the telescope to mend incorrect vertical point.

- The levelling head- The levelling head consists of two parallel triangular plates called tribrach plates. The upper one is called as upper tribrach plate and is used to level the upper plate and telescope with the help of equalizing screws provided at its three ends. The lower one is called a lower tribrach plate and is connected to the tripod stand.

- The shifting head-Shifting head conjointly consists of two parallel plates that are modified one over the opposite among a limited range. Shifting head lies below the lower plate. It is helpful to centralize the complete instrument over the positioning.

- Magnetic compass- A circular box compass or magnetic compass is mounted on the Vernier scale between the standards. It is provided for taking the magnetic bearing points.

- Tripod- The theodolite is mounted on a powerful tripod once getting used within the field. The tripod's legs are sturdy or framed. At the lower ends of the legs, pointed steel shoes are provided to urge them pushed into the bottom. The tripod head has male screws on that the trivet of the levelling head is screwed.

- Plumb bob- To centre the instrument precisely over a station mark, a plumb bob is suspended from the hook fitted to the rock bottom of the central vertical axis.

Types of Theodolite:

a) Repeating Theodolite
b) Directional Theodolite
c) Electrical Digital Theodolite
d) Total Station

Theodolite traverse:

A traverse is a series of connected lines whose lengths and directions measures in the field. In a theodolite traverse, to directions measured with a theodolite. A theodolite traverse in commonly used for providing a horizontal control system to determine the relative positions of the various points on the surface of the earth. It especially uses for providing control for site surveys in urban areas where the triangulation is not feasible.

The equipment required for conducting a theodolite traverse will include a theodolite, a steel tape, two ranging poles, stakes, tacks, plumb bobs, chain pins, tripods, crayons, makers, an ax and a hammer. The traverse may be an open traverse or a closed traverse. A closed traverse commonly uses in control survey, construction survey, property survey, and topographic survey.

Theodolite traversing:

In this type of traversing, traverse legs measure by direct chaining on the ground the traverse angles at every traverse station measures accurately with a theodolite.

The basic procedure for theodolite traversing is the same as that in any other method of traversing. First reconnaissance has to conducted with a sketch drawn the terrain using the approximate location of traverse station then the important details are to pick up, the intervisibility of station to check. Theodolite traversing required station marking tools such as pegs. arrows, etc., a theodolite with its stand and steel tape.

Measure with a theodolite:

The method of repetition used to measure traverse angles to a finer degree of accuracy than that achievable with the least count of the vernier fitted on the theodolite. In this method, an angle measure there or four times by keeping the vernier clamp when sighting at the back station. While swinging from froward station to back station, the upper plate is let loose and made free to rotate. Thus an angle reading mechanically adds as many times as the number of repetitions. The difference of the firest and the last reading five the integrate traverse angle and the average traverse angle then obtained by dividing the integrated angle by the number of repetitions.

Fieldwork during a theodolite traversing

- Reconnaissance
- Selection and marking of stations
- Measurement for traverse legs
- Measurement of traverse angles
- Booking of filed notes
- Computation.

❖ Reconnaissance

Reconnaissance is the preliminary inspection of the area to survey to have some idea of the terrain and the principal features of the ground. In reconnaissance, the surveyor thoroughly examines the ground and then decides upon the best possible arrangement of triangles.

In reconnaissance, the surveyor obtains the required information and data about the shape and extent of the area to survey. During reconnaissance, the surveyor generally makes an index sketch to show the principal features, such as buildings, roads, Dallas, boundaries. The positions of the stations and survey lines also mark. The direction in with the chain lines are to measure is mark by arrowheads.

❖ Selection and Marking of Stations

Every traverse station selected keeping in view that consecutive stations are intervisible without much clearance. The traverse legs, as far as possible, kept of the same length to have a systematic error in angular measurements. The closing error in angular measurement is, therefore divide equally to all traverse angles assuming all angles of equal weights.

As far as possible traverse stations mark on pakka points, i.e. distance stones, culverts, road crossing, etc. A precise description of each station should enter in the field book giving the exact distance of the marks on easily recognizable points close by. Description of traverse stations neatly written in the filed book enables the plane tables to find them at a later date.

❖ Measurement of Traverse Legs

Distances between traverse stations measures directly by chaining which is a more reliable method except in rough ground. Each distance must measure independently by a 30-meter chain. Both chains testes regularly against standard chains.

The measurement of traverse angles may make by one of the following methods-

- Repetition method
- Reiteration method
- Practical method
- Repetition method

❖ Repetition Method:

The method of repetition uses to measure traverse angles to a finer degree of accuracy than that achievable with the least count of the Vernier fitted on the theodolite. In this method, an angle measures there or four times by keeping the Vernier clamped when sighting at the back station. While swinging from forward station to back station, the upper plate lets loose and made free to rotate. Thus, an angle reading is mechanically adding as many times as the number of repetitions.

❖ Reiteration Method

This method is most suitable for the measurement of the horizontal angles having a common station. Several angles measure successively and a check makes by summing up them. The sum of all the angles at a point is equal to 360 degrees.

❖ Practical Method

This method employed by measuring a set of independent values of the traverse angles and then taking their average.

❖ Booking of Fieldnotes

It should be appreciated that the utmost care taken in marking filed observations will go waste unless observation is neatly and systematically recorded in the field books, to derive correct data during computation specimens field books depending upon the method of observation of traverse angles.

❖ Computation

For calculation of independent rectangular co-ordinate from the field observations, the following computations make in their order of sequence:-

a) Checking of means of field observations
b) Setting up traverse angles and distance of traverse legs.
c) Ascertaining the bearings of traverse leg.
d) Running down the bearings.
e) Computation of reduced bearings of each traverse leg.

f) Calculation of consecutive coordinates.
g) Calculation of the closing error.
h) Balance for consecutive coordinates.
i) Calculation of independent coordinates.

Errors in Traversing

The errors involved in closed traversing are two kinds:

a) Linear Error and
b) Angular Error

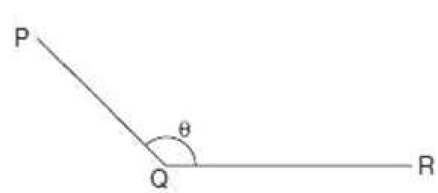
The most satisfactory method of checking the linear measurements consists in chaining each survey line a second time, preferably in the reverse direction on different dates and by different parties. The following are checks for the angular work:

Travers by included angles:

- The sum of measured interior angles should be equal to (2N-4), where N=number of sides of the traverse. If the exterior angles are measured, their sum should be equal to (2N=4)p/2
- Travers by deflection angles: The algebraic sum of the deflection angles should be equal to 360°, taking the right hand and deflection angles as a positive and left-hand angle as negative.
- Traversing by direct observation of bearings: The force bearing of the last line should be equal to its back bearing ±180° measured from the initial station.

Measurement of Horizontal Angle:

The procedure is explained for measuring horizontal angle θ = PQR at station Q



a) Set the theodolite at Q with vertical circle to the left of the line of sight and complete all temporary adjustments.

b) Release both upper and lower clamps and turn upper plate to get 0° on the main scale. Then clamp main screw and using tangent screw get exactly zero reading. At this stage Vernier A reads 0° and Vernier B reads 180°.

c) Through telescope take line of sight to signal at P and lock the lower clamp. Use tangent Screw for exact bisection.

d) Release the upper clamp and swing telescope to bisect signal at R. Lock upper clamp and use tangent screen to get exact bisection of R.

e) Read Vernier's A and B. The reading of Vernier A gives desired angle PQR directly, while 180° is to be subtracted from the reading of Vernier B to get the angle PQR.

f) Transit (move by 180° in vertical plane) the telescope to make vertical circle to the right of telescope. Repeat steps 2 to 5 to get two more values for the angle.

g) The average of 4 values found for θ, give the horizontal angle. Two values obtained with face left and two obtained with face right position of vertical circle are called one set of readings.

h) If more precision is required the angle may be measured repeatedly. i.e., after step 5, release lower clamp, sight signal at P, then lock lower clamp, release upper clamp and swing the telescope to signal at Q. The reading of Vernier A doubles. The angle measured by Vernier B is also doubled. Any number of repetitions may be made and average taken. Similar readings are then taken with face right also. Finally, average angle is found and is taken as desired angle 'Q'. This is called method of repetition.

i) There is another method of getting precise horizontal angles. It is called method of reiteration. If a number of angles are to be measured from a station this technique is used.

j) With zero reading of Vernier A signal at P is sighted exactly and lower clamp and its tangent screw are locked. Then θ1 is measured by sighting Q and noted. Then θ2, θ3 and θ4 are measured by unlocking upper clamp and bisecting signals at R, S and P. The angles are calculated and checked to see that sum is 360º. In each case both veneers are read and similar process is carried out by changing the face (face left and face right).

		Face left Swing right				Face right swing left				
Instrument at	Sighted to	A	B	Mean	Horizontal Angle	A	B	Mean	Horizontal Angle	Average Horizontal Angle

Measurement of Vertical Angle:

Horizontal sight is taken as zero vertical angle. Angle of elevations are noted as +ve angles and angle of depression as –ve angles.

To measure vertical angle the following procedure may be followed:

a) Complete all temporary adjustment at the required station.
b) Take up levelling of the instrument with respect to altitude level provided on the A – frame.
c) This levelling process is similar to that used for levelling dumpy level i.e., first altitude level is kept parallel to any two levelling screws and operating those two screws bubble is brought to centre. Then by rotating telescope, level tube is brought at right angles to the original position and is levelled with the third screw. The procedure is repeated till bubble is centred in both positions.
d) Then loosen the vertical circle clamp, bisect P and lock the clamp. Read veneers C and D to get vertical angle.

The observation recorded by the above process is then entered to the table in a specific format given below.

Station	Object	Face	Reading		Reading		Mean Vernier A	Mean Vernier B	Mean Face angle
			Vernier A		Vernier B				
			Initial	Final	Initial	Final			

Methods for closed traverse:

•Included angle method

•Magnetic bearing method

Included Angle method:

a) For running the traverse ABCDEFG Set up the theodolite at 1ST station A and observed the bearing of the line AB.
b) Then measure the angle GAB. Shift the instrument to each of the successive station B, C etc. and measure the angles ABC, BCD etc.

c) Measure the line AB, BC, CD etc. and take offset to locate the required detail after this check is applied for interiors angles it is (2n-4) x900,

d) And for exterior angles it is (2n+4) x900, n = number of sides of the traverse.

Magnetics Bearing Method:

a) Set up and level the theodolite at station P of the traverse PQRSTP, a closed traverse.

b) Using the upper clamp and upper tangent screw, set Vernier A to read zero.

c) Loosen the magnetic needle. Release the lower clamp and point the telescope in the direction of the magnetic meridian till the magnetic needle comes to rest at the zero-position using the lower tangent screw the north end of the magnetic needle to read exactly zero.

d) Release the upper plate and swing the instrument to bisect the signal at Q. With the upper tangent screw, bisect the station mark exactly. Read Vernier A, this gives the bearing of the line PQ.

e) Keeping both the clamps tight, shift the instrument to Q. Set up and level the instrument.

f) Check the reading on Vernier A. It should be the same as the magnetic bearing of the line PQ (if not, this can be corrected and the bearing value noted earlier be set on Vernier A).

g) Release the upper clamp. Swings the instrument clockwise to bisect the station mark at R. Using upper tangent screw bisect mark R exactly. Read the Vernier at A and note down the reading.

h) With both clamps tight, shift the instrument to R and repeat the procedure. The work is continued at all stations in a similar manner.

GALE'S TRAVERSE TABLE:

In the field usually lengths and inward angles of a closed traverse are measured.

In addition, bearing of a line is taken. For adjustment of the traverse, the field data and computations are systematically recorded in a table known as Gale's Traverse Table. The steps involved are:

a) Write the names of the traverse stations in column 1 of the table. "
b) Write the names of the traverse lines in column 2.
c) Write the lengths of the various lines in column 3.
d) Write the angles in column 4.
e) Sum up all the angles and see whether they satisfy the geometric conditions as applicable, i.e. Sum of nil interior angles = (2n - 4) right angles, sum of all exterior angles = (2n+4) right angles. If not, adjust the discrepancy.
f) Enter corrections in column 5.
g) Write the corrected angles in column 6.
h) Starting from the actual or assumed bearing of the initial line, calculate the whole circle bearings of all other lines from the corrected angles and enter in column 7.
i) Convert the whole circle bearings to reduced bearings and enter in column 8.
j) Enter the quadrants of the reduced bearings in column 9.
k) Compute the latitudes and departures of the measured' lines from lengths and bearings and put in proper columns la, 11, 12 and 13 as applicable. Sum up the latitudes and departures to find the closing error.
l) Calculate corrections by applying Transit rule or Bowditch's rule as desired.
m) Enter the corrections in appropriate columns 14 to 17.
n) Determine the corrected latitudes and departures and enter in appropriate columns 18 to 21. They will be corrected consecutive coordinates.
o) Calculate the independent coordinates of all other points from the known or assumed independent coordinates of the first station. As a check the independent coordinates of the first point should be computed. It should tally with the known or assumed value.

BALANCING THE CLOSING ERROR GRAPHICALLY:

For rough surveys or traverse of small area, adjustment can also be carried out graphically. In this method of balancing, the locations and thus the coordinates of the stations are adjusted directly. Thus, the amount of correction at any station is proportional to its distance from the initial station.

Let Po Qo Ro So To P' is the graphical plot of a closed-loop traverse PQRSTP. The observed length and direction of traverse sides are such that it fails to get balanced and is depicted in its graphical presentation by an amount Po P'.

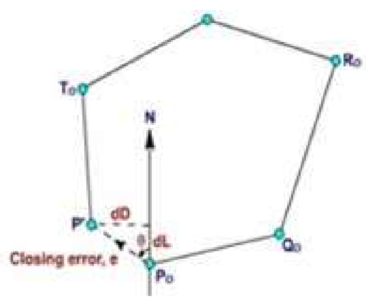
Thus, the closing error of the traverse is Po P' (Given in Figure below). The error Po P' is to be distributed to all the sides of the traverse in such a way that the traverse gets closed i.e., P' gets coincides with Po in its plot.

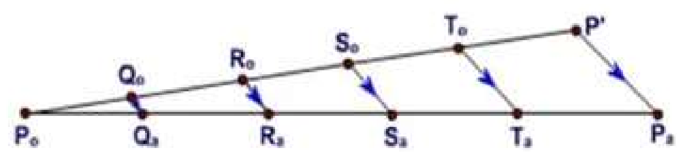
This is carried out by shifting the positions of the station graphically. In order to obtain the length and direction of shifting of the plotted position of stations, first a straight line is required to be drawn, at some scale, representing the perimeter of the plotted traverse.

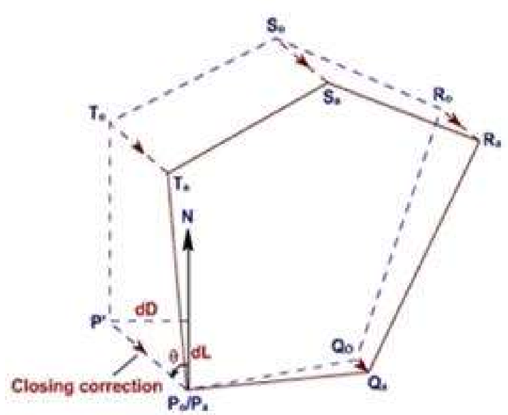
In this case, a horizontal line Po P' is drawn (Given in Figure below). Mark the traverse stations on this line such as Qo, Ro, So and To in such a way that distance between them represent the length of the traverse sides at the chosen scale.

At the terminating end of the line i.e., at P', a line P' P a is drawn parallel to the correction for closure and length equal to the amount of error as depicted in the plot of traverse. Now, join Po to Pa and draw lines parallel to P' Pa at points Qo, Ro, So and To.

The length and direction of Qo Qa, Ro Ra, So Sa and To Ta represent the length and direction of errors at Qo, Ro, So and To respectively. So, shifting equal to Qo Qa , Ro Ra, So Sa and To Ta and in the same direction are applied as correction to the positions of stations Qo, Ro, So and To respectively. These shifting provide the corrected positions of the stations as to Qa, Ra, Sa,Ta and Pa. Joining these corrected positions of the stations provide the adjusted traverse Pa Qa Ra, Sa Ta(Given in Figure below).







LEVELLING:

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

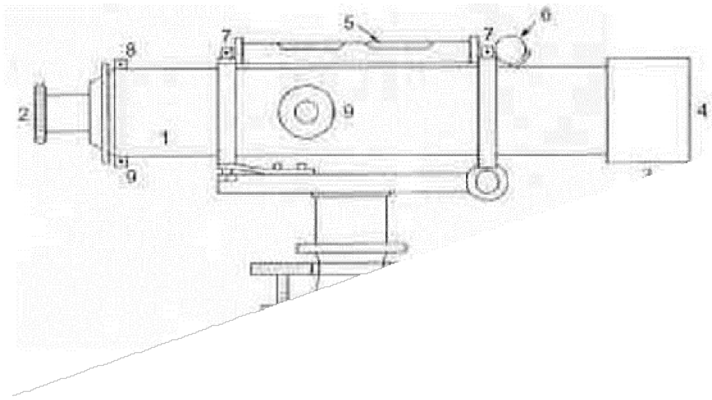
Definition of basic term’s used in levelling:

- 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 that 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 w.r.t some assumed datum is known. There are four types of bench mark.

Types of levels:

- Dumpy level
- wye level
- Cooke's – Reversible level
- Tilting level
- Auto level
- Cushing's level

Working principle of auto & dumpy level:



PARTS OF FIGURE

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.

Fundamental axis of a level:

- **Vertical axis:** It is the centre line of axis of notation of the level.
- **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.
- **Axis of telescope**: It is the line joining the optical centre of the object glass & the centre of eye piece.
- **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.

a) Loosen the clamp and turn the instrument until bubble axis is parallel to line joining any two screws.
b) Turn the two screws inward or outward equally till bubble is centred.
c) Turn the telescope through 90 degrees so that it lies over the third screw.

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 in which the focusing is done by the external movement of either objective or eye – piece is known as – External focusing telescope.

Telescope in which the focusing is done by the internally with a negative less is known as – internal focusing telescope

Sensitiveness of a bubble tube: When the difference in elevation between any two points is determined from a single set up by back sighting on one point and fore sighting on the other. The error is due to non-parallelism. When the bubble is not in the centre of run and sensitivity is lost, due to the error of curvature and refraction which is eliminated if lengths of 2 sides are made equal.

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.

$$C_C = d^2/2R$$

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,

$$C_R = 0.01121d^2$$

where d is in km.

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. The sight is also known as +ve sight (add)
5. Fore sight (F.S): This is the last reading – taken from instrument just before shifting the instrument. This is also – ve sight.
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 the readings from single setting of instruments. Each shifting 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

- **Crossectioning:** In many engineering projects to calculate earth work involved not only LS is involved but CS of ground is taken in regular intervals.

- **Reciprocal levelling:** When it is not possible to balance FS and BS due to non-parallelism of line of collimation and axis of bubble tube and also due curvature and refraction this is used.

$$H = [(h_a - h_b) + (h'_a - h'_b)]/2$$

PROFILE LEVELLING:

This type of levelling is known as – longitudinal section.

The reduced levels of various points at regular intervals are found along a line or a set of lines. Then the engineers draw the sectional view of the ground to get the profile. This type of levelling is commonly employed in deciding railways, highways, canal, sewage line routes.

After getting reduced level of various points along the line, profile of the ground is plotted on a drawing sheet. Normally vertical scale is much larger than the horizontal scale to clearly view the profile. Then when the engineers decide the formation level of the proposed project

The decision is mainly based on balancing, cutting & filling so that the transport of earth is minimum. However, the proposed gradient of formation level should not be more than as permitted. After deciding the formation level & the gradient the difference between two consecutive points is known. If RL of first point is known RL of other points are calculated.

STEPS TO TAKE OBSERVATION:

- Differential levelling is the method of direct levelling the object of which is. To determine Difference in elevations of two points regardless of horizontal position of point with respect to each Other, when points are apart it may be necessary to setup the instrument several times. This type of Levelling is also known as "FLY LEVELLING".
- Instrument level is setup at convenient positions near first point (say A).
- Temporary adjustments should be done, (setting up, levelling up, elimination of a par-allot) are Performed.
- First sight of B.M (point of known elevation) is taken and reading is entered in back Sight column.
- If distance is large instrument is shifted, the instrument becomes turning point (or) changing point.
- After setting up instrument at new position, performing temporary adjustment and Take back sight as turning point.
- Thus, turning point will have both back sight and fore sight readings.
- Link wise the process is repeated till last point (say B) is reached.

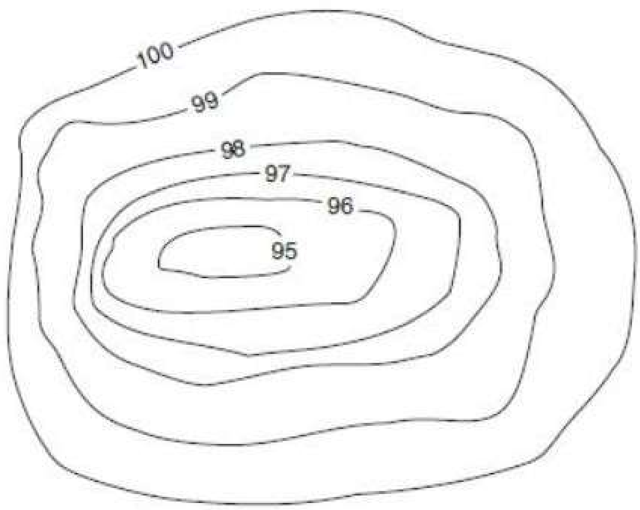
Readings are entered in a tabular form is given Below and Reduced levels are calculated either by height of instrument method (or) rise and fall method.

STATION POINT	BACK SIGHT	INTERMIDEATE SIGHT	FORESIGHT	HEIGHT OF INSTRUMENT	REDUCED LEVEL	REMARKS

ARITHMETIC CHECK: - Σ B.S - ΣF. S= ΣRISE - ΣFALL= LAST RL - FIRST R.L

CONTOURING:

A contour line is an imaginary line which connects 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. Figure shows contours in an area with contour interval of 1 m. On contour lines the level of lines is also written.



Characteristics of Contours:

The contours 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 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.

9. Contour lines with V-shaped with convexity towards higher ground indicate valley.

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.

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

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.

METHODS OF CONTOURING:

Contouring consists of finding elevations of various points in the area surveyed. At the same time the horizontal positions of those points should also be found. Thus, it needs vertical control and horizontal control in the work. For vertical control levels, theodolite or clinometers may be used while for horizontal controls chain, compass, plane table or theodolite are used Bases on the instruments used, there can be different methods of surveying.

However, broadly speaking there are two methods of surveying: i) Direct methods, ii) Indirect methods.

Direct method involves finding vertical and horizontal controls of the points which lie on the selected contour line. In indirect method, the levels are taken at some selected points, their levels are reduced and the horizontal controls also carried out. After locating these points in plan, reduced levels are marked and contour lines are interpolated between selected points.

COMPUTATION OF AREA & VOLUME:

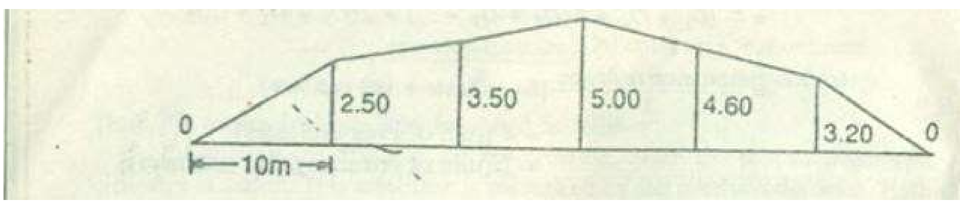
The main objective of the surveying is to compute the areas and volumes. Generally, the lands will be of irregular shaped polygons. There are formulae readily available for regular polygons like, triangle, rectangle, square and other polygons. But for determining the areas of irregular polygons, different 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:

- Mid-ordinate method
- Average ordinate method
- Trapezoidal rule
- Simpson's rule

The mid-ordinate rule:



Let $O_1, O_2, O_3, O_4 \ldots\ldots O_n$= ordinates at equal intervals

l=length of base line

d= common distance between ordinates

$h_1, h_2, \ldots \ldots h_n$=mid-ordinates

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

Average ordinate method:

Let O_1, O_2, …..O_n=ordinates or offsets at regular intervals

l= length of base line

n= number of divisions

n+1= number of ordinates

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

$$\text{Area}= \frac{\text{sum of the ordinates} * \text{length of base line}}{\text{no of ordinates}}$$

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 O_1, O_2, …. O_n=ordinate at equal intervals, and d= common distance between two ordinates.

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

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

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

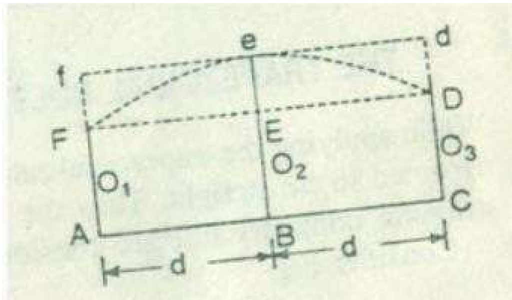
$$\text{Last area}= \frac{O_{n-1}+O_n}{2} *d$$

$$\text{Total area}=d/2\{ O_1+2O_2+2O_3+\ldots\ldots+2O_n-1+O_n\}$$

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

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 sometimes called as parabolic rule.



Let

O_1, O_2, O_3= 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 *{ O_2- O_1+O_3 /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(O_1+4O_2+O_3)

Similarly, the area of next two divisions

Δ_2 = d/3(O_1+4O_2+O_3) and so on

Total area = d/3[O_1+O_n+4(O_2+O_{4+}......) + 2(O_3+O_5)]

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

Formula for calculation of volume:

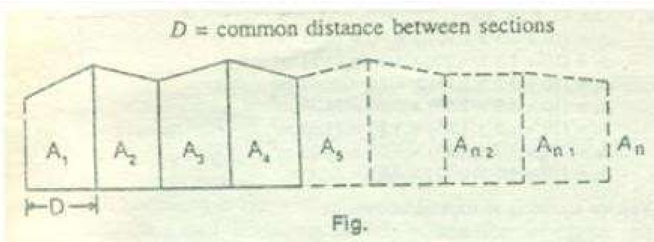


Fig.

D= common distance between the sections

A. trapezoidal rule

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

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

1. Prismoidal formula

Volume(cutting or filling), $V= D/3\{A_1+ A_n +4(A_2+ A_4+ A_{n-1})+ 2(A_3+ A_5+\ldots.+ An_{n-1})\}$

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

Note: The prismoidal formula is applicable when 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.