MINE SURVEYING-1

Lect. Note

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MINE SURVEYING-1

Definition of surveying:

Surveying is the art of determining the relative positions of different objects on the surface of the earth by measuring the horizontal distances between them, and by preparing a map to any suitable scale.

Object of surveying:

The primary object of a survey is the preparation of a plan or map to show the relative positions of the objects on the earth surface. The map is drawn to some suitable scale.

Uses of surveying:

1. To prepare a topographical map which shows the hills,valleys,rivers,village towns,forests etc. Of a country.
2. To prepare a contour map to determine the capacity of a reservoir and to find the best routes for roads, railways etc.
3. To prepare a geological map showing areas including under ground resources.
4. To prepare an engineering map showing the details of engineering works such as roads, railways, irrigation canals etc.
5. To prepare a cadastral map showing the boundaries of houses, fields, and other properties.

Primary classification of surveying:

a) Geodetic surveying: In geodetic surveying also called the trigonometrical surveying the curvature of the earth if taken into consideration, since the large distances and areas are covered.
b) Plane surveying: In plane surveying the curvature of the earth is not taken into consideration, as the area and distance covered is small.

Secondary claissification

1.Based on Instruments used:

a) Chain surveying

b)Compass surveying

c) Plane table surveying

d) Theodolite surveying

e) Tacheometric surveying

f) Photographic surveying

2. Based on methods:

a) Triangulation surveying

b) Traverse surveying

3. Based on objects:

a) Geological surveying

b) Mine surveying

c) Archaeological surveying

d) Military surveying

4. Based on nature of field:

a) Land surveying

b) Marine surveying

c) Astronomical surveying

Land surveying is further classified into

i) Topographical surveying
ii) Cadastral surveying

iii) City surveying
iv) Engineering surveying

General principle of surveying:

The general principle of surveying are given below :

1. To work from whole to part
2. To locate a new station by at least two measurements (linear or angular) from fixed reference point.

METHODS OF LINEAR MEASUREMENTS:

The following methods are generally used for linear measurements :

1. BY pacing or stepping
2. By passometer
3. By speedometer
4. By perambulator
5. By chaining

Out of the above methods chaining method is an accurate and common method. In this method the distances are directly measured in the field by chain or tape.

ACCESSORIES FOR LINEAR MEASUREMENTS :

1. **Ranging rods:** The ranging rods are used for marking the positions of stations and for ranging the line. They are made of well seasoned straight grained timber of teak, blue pines, sisso or deodar and in order to make them visible they painted with alternate black and white.
2. **Chains:** A chain is prepared with 100 or 150 pieces of galvanised mild steel wire of 4mm diameter called links. The end of each link are bent into a loop and connected together by means of three oval shaped rings to provide flexibility and make it less liable to kink.

Fig 1.3

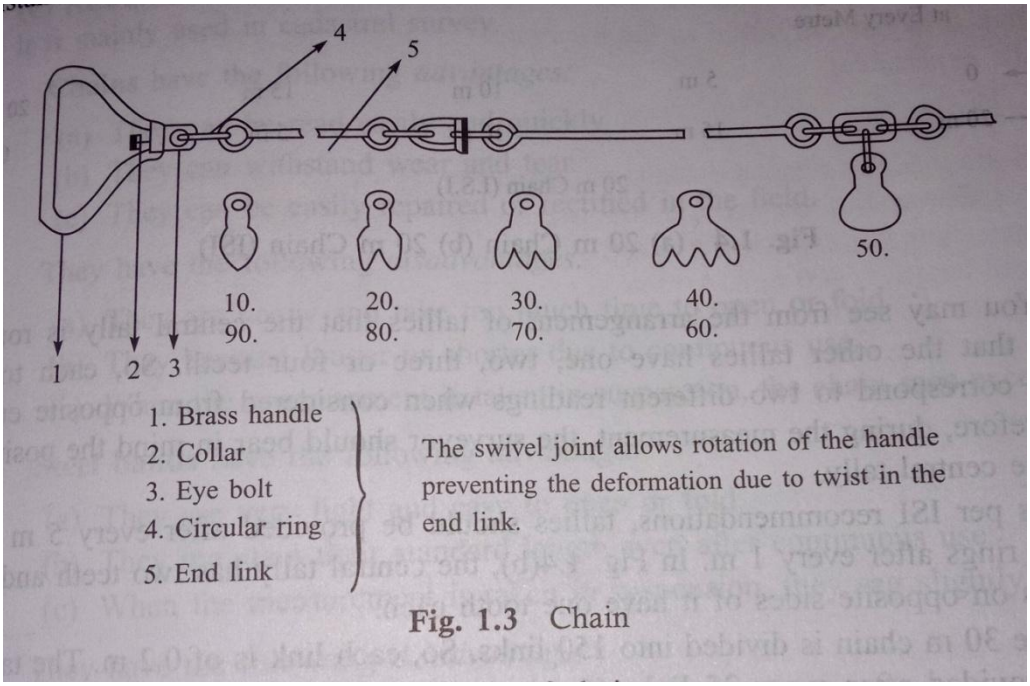


Fig. 1.3 Chain

Types of chain:

a) Metric chain:- Metric chains are available in lengths of 20M and 30M .The 20m chain is divided into 100 links each of 0.2m.Tallies are provided at every 10 links. This chain is suitable for measuring distances along fairly level ground.
b) Steel band chain:- It consists of a ribbon of steel of 16mm width and of 20m or 30m length. It has a brass handle at each end. It is graduated in metres, decemetres and in centimetres on one side and has 0.2m link on the other. It is used in projects where more accuracy is required.
c) Engineers' chain:- It is 100 feet long and is divided into 100 links each 1ft long. It was previously used for all engineering works.
d) Gunters' chain:- It is 66ft long and divided into 100 links each 0.66ft long. It is very convenient for measuring distances in miles and furlongs.
e) Revenue chain:- The revenue chain is commonly used for measuring fields in cadastral survey. It is 33ft long and divided into 16 links.

3. Tapes: Tapes are made of various materials and therefore divided into five classes: 1) cloth or linen 2) Metallic 3) steel 4) Invar 5) Synthetic materials.

Tapes of denominations 10,20,30 and 50 metres are supplied in a case made of leather or corrosion resisting metals or a metal with a corrosion resisting finish fitted with a winding device.

4. **Arrows** : Arrows are made of tampered steel wire of 4mm dia. One end of the arrow is bent into a ring of 50mm dia. And the other end is pointed. Its overall length is 400mm. Arrows are used for counting the nos of chains while measuring a chain line.

RANGING: The process of establishing intermediate points on the chain line is called ranging. Ranging must be done before a survey line is chained.

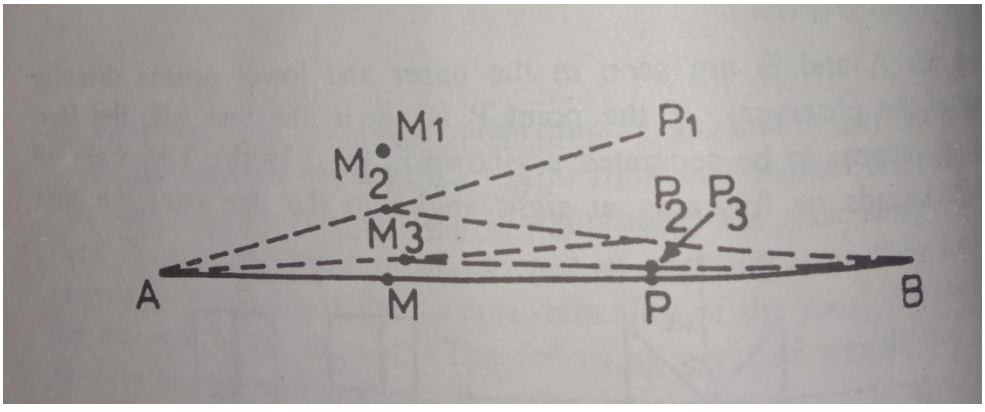
Ranging is of two types:

1) Direct ranging
2) Indirect ranging or reciprocal ranging

INDIRECT OR RECIPROCAL RANGING :

When the end stations are not intervisible due to high ground or hill intevening and also when the ends of a line are not distinctly visible from one another due to the distance being too great, in such a case intermediate points can be fixed on the line by process known as reciprocal ranging.

Fig.



Let A and B be the two stations with rising ground or a hill between them as shown in the figure. Let two chainmen with ranging rods take up the positions M1 and P1 as nearly in the line as possible such that the chainman at M1 can see both the ranging rods at P1 and B and also the

chainman at P1 can see both the ranging rods at M1 and A. The chainmen then proceed to the line in each other alternately. The chainman at p1 directs the chainman at M1 to come to M2 in line with A and then the chainman at M2 directs the chainman at p1 to p2 in line with B. By successively directing each other into line their positions will be changed until finally they are both in the line AB i.e the four ranging rods A, M, P and B are in the same straight line.

TESTING OF A CHAIN:

Due to continuous use , a chain may be elongated or shortened . So the chain should be tested and adjusted accordingly. The chain is tested by comparing it with

i) a standard chain
ii) with the steel tape which should be kept in the surveyor's office

ADJUSTMENT OF CHAIN:

Chains are adjusted in the following ways:

1. When the chain is too long, it is adjusted by
a) Closing up the joints of the rings
b) Hammering the elongated rings
c) Replacing some old rings by new rings, and
d) Removing some of the rings.
2. When the chain is too short, it is adjusted by
a) Straightening the bent links
b) Opening the joints of the rings
c) Replacing the old rings by some large rings, and
d) Inserting new rings where necessary.

CHAIN SURVEYING :

Chain surveying is also known as chain triangulation in which the sides of the various triangles are measured directly in the field by chain or tape and no angular measurements are taken.

Chain surveying is recommended when

a) The ground surface is more or less level
b) A small area is to be surveyed
c) A small scale map is to be prepared , and
d) The formation of well- conditioned triangles is easy.

Principle of chain surveying : The principle of chain surveying is triangulation. This means that the area to be surveyed is divided into a nos. of small triangles which should be well conditioned and the sides of the triangles are measured with a chain or tape and no angular measurements are taken.

Well conditioned triangle: A triangle is said to be well conditioned when no angle in it is less than 30^0 or greater than 120^0 . An equilateral triangle considered to be the best condition or ideal triangle.

DEFINATION OF TERMS ASSOCIATED WITH CHAIN SURVEYING:

A. Survey stations : Survey stations are the points at the beginning and the end of a chain line. They may also occur at any convenient points on the chain line. Such stations may be
   a) Main station
   b) Subsidiary or tie station

B. **Base line**: It is the longest of the main survey line on which the frame work of the survey is built.

C. **Check line**: The line joining the apex point of a triangle to some fixed point on its base is known as the base line. It is taken to check the accuracy of the triangle.

D. Offset: The lateral measurements taken from an object to the chain line is known as offset. Offsets are taken to locate the interiors details with reference to the chain line.

FIELD WORK IN CHAIN SURVEYING:

Equipments Required:

i) A chain and 10 arrow pins ii) a 20m metallic tape iii) ranging rods 12nos iv) an offset rod v) an optical square vi) pegs,hammer vii) survey field book, pencils etc.

A chain survey is carried out in the field in the following steps;

1. Reconnaissance: The preliminary inspection of the land to be surveyed is called reconnaissance. i.e the surveyor is to go around the land and see whether that land is suitable for the chain surveyinf or not.
2. Marking survey stations: after getting the complete informations then the survey stations should be marked on the ground by wooden pegs. The pegs are driven into the ground firmly and these should be a height of 2.5cm above the ground.
3. Reference sketches: For precautions against station pegs being missed or removed a reference sketch should be made for all main stations. This is made by taking measurements from three permanent points which are definite and easily recognised.
4. Running chain lines and taking offsets: after the main stations are marked then the survey lines are measured by a chain and side by side the offsets are taken for locating interiors details with a optical square.
5. Booking data and making maps; The data are recorded in the field book and then the surveyor will prepare a map or plan as per the data.

OBSTACLES IN CHAINING

While chaining various obstacles such as river, pond, building woods etc are sometimes met with in chaining. Special methods are therefore used in measuring distances across the obstructions .

The various obstacles may be classed as

i) Those which can be chained across but cannot be seen across i.e chaining free , vision obstructed. Ex; rising ground, hill intervening
ii) Those which can be seen across but cannot be chained across i.e chaining obstructed, vision free. Ex river, pond
iii) Those which can neither be seen across nor can be chained across i.e both chaining and vision are obstructed. Ex building.

ERRORS IN CHAINING: The errors that occur in chaining are classified as

1. Compensating error

2. Cumulative errors

Compensating error:

a) Incorrect holding of the chain
b) Fractional parts of the chain or tape may not be correct
c) Inaccurate measurements of right angles with chain and tape
d) Horizontality and verticality of steps not being properly maintained during the stepping operations.

Cumulative errors: The cumulative error are those which occur in the same directions and tend to add up . In chaining these may be caused due to the followings

a) The length of the chain or tape being shorter than the actual length.
b) Slope correction not being applied.
c) Correction of sag not being made
d) Measurements being taken with faulty alignment
e) Measurements being taken in high winds with the tape in suspensions.

CHAIN AND TAPE CORRECTIONS:

A) Tape corrections

1. Temperature corrections(C_t): This correction is necessary because the length of the tape or chain may increase or decrease due to rise or fall of temp. The correction is given by the expression

   $C_t = a(T_m - T_0)XL$, where

   a = coefficient of thermal expansion

   T_M = temp. During measured in degree

   T_0 = temp. At which the tape was standardised

   L = length of tape in m.

2. Pull corrections(C_P): The correction is necessary when the pull used during measurements is different from that at which the tape is standardised. It is given by the formula

   $C_P = (P - P_0) X L/AE$ where,

   P = The pull applied during measurement in Newton

   P_0 = The pull under which the tape is standardised in N.

A =Area of cross-section of tape in sq.cm

E = the modulus of elasticity of steel(19.3 to 20.7x 10^{10} N/m^2)

The sign of correction is plus.

3. Correction for absolute length:

   C_a = Lc/l where

   C_a = the correction for absolute length

   L = the measured length of the line

   l= the nominal length of the tape

   c= the correction to a tape

   The sign of the correction will be same as that of c.

4. Slope correction(C_h):

   C_h = l(1-cosα) ,this correction is always negative.

5. Sag correction (C_S): This correction is necessary when the measurement is taken with the tape in suspension. It is given by the expression, $C_s = Lw^2 / 24n^2P_m^2$ where,

   C_S = Sag correction in metres

   L = length of tape in m

   w= weight of tape per unit length, in kg/m

   n= nos of span

   P_m = pull applied during measurement in kg.

   The sign of correction is always negative

B. Chain correction:

1. Correction applied to incorrect length;

It is given by the expression

True length of the line= L^l/L X Measured length , where

L^l = True length of the chain

L= True length ± error

2 .Correction of incorrect area;

True area=($L^l/L)^2$ x measured area

COMPASS TRAVERSING

Introduction:

When the area is large, undulating and crowded with many details triangulation is not possible. In such an area the method of traversing is adopted.

In traversing the frame work consists of a number of connected lines the length and directions of which are measured with a chain or tape, and with an angular instrument respectively. In one of the method the angle measuring instrument used is the compass. Hence the process is known as compass traversing.

PRINCIPLE OF COMPASS SURVEYING:

The principle of compass surveying is traversing, which involves a series of survey lines . The magnetic bearing of the lines are measured by prismatic compass and the distances of the lines are measured with a chain.

Interior details are located by taking offsets from main survey lines. Sometimes tie lines are taken for locating the details.

Bearing of a line: The bearing of a line is the horizontal angle which the line makes with some reference directions or meridian.

Figure:

The reference directions used in surveying may be

i) True meridian
ii) Magnetic meridian
iii) Arbitrary or assumed meridian

True meridian: The line or plane passing through the geographical north pole or geographical south pole and any point on the surface of the earth is known as true meridian.

The angle between the true meridian and a line is known as true bearing.

Magnetic meridian: The direction indicated by a freely suspended and properly balanced magnetic needle unaffected by local attractive forces if called the magnetic meridian.

The angle which a line makes with the magnetic meridian is known as magnetic bearing.

Arbitrary meridian: Sometimes for the survey of a small area , a convenient direction is assumed as a meridian known as the arbitrary meridian.

The angle between the arbitrary meridian and a line is known as arbitrary bearing or assumed bearing.

Designation of magnetic bearing: There are two systems of notations commonly used to express the bearing;

1. Whole circle system
2. Quadrantal system

1. Whole circle bearing (WCB): In this system the bearing of a line is always measured clockwise from the north point of the reference meridian toward the line right round the circle. The angle thus measured is called WCB. It may have any value between 0^0 to 360^0 . The bearing observed with a prismatic compass or a theodolite are the WCB.
2. Quadrantal system: In this system the bearing of a line is measured clockwise or counter clockwise from the north point or south point whichever is nearer the line, towards the east or west. It has value between 0^0 to 90^0 . The bearing observed with a surveyor compass is quadrantal bearing.

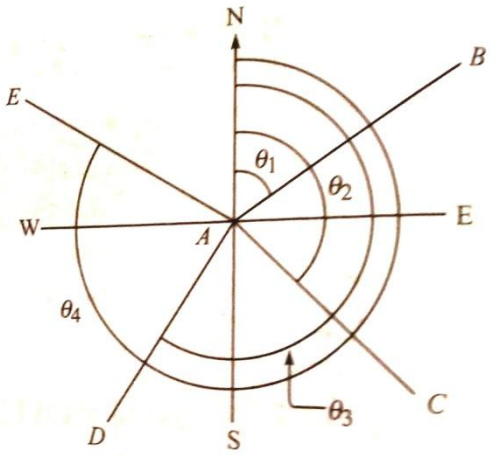


Fig:

Reduced bearing: When the whole circle bearing of a line exceeds 90^0 , it must be reduced to the corresponding angle less than 90^0 , which has the same numerical values of the trigonometrical function. This angle is known as reduced bearing (R.B).

The following table should be remembered for conversion of WCB to RB:

WCB between	**Corresponding RB**	**Quadrant**
0^0 to 90^0	RB=WCB	NE
90^0 and 180^0	RB= 180^0- WCB	SE
180^0 and 270^0	RB= WCB- 180^0	SW
270^0 and 360^0	RB= 360^0- WCB	NW

Fore and back bearing: Every line has two bearings, one is observed along the progress of survey or forward direction, and is called fore bearing (F.B) , and the second is observed in the opposite direction and is called back bearing(B.B).

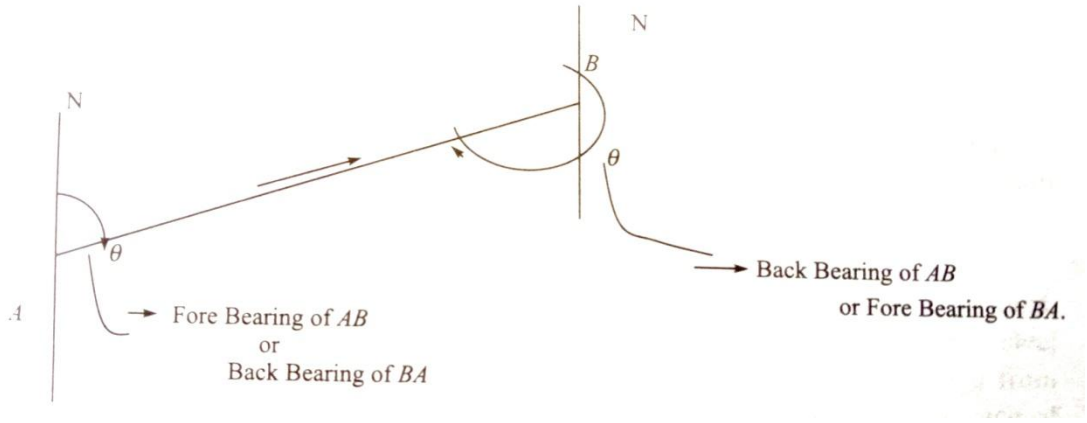


Fig:

In the whole circle bearing system the back bearing of a line may be obtained from the fore bearing by the following rules:

Back bearing = Fore bearing ± 180^0

Use plus sign if the given FB is less than 180^0 , and minus sign if it exceeds 180^0.

Calculation of angles from bearing:

Case-1: Given the whole circle bearings of the lines:

a) When the bearing of two lines as measured from the point of intersection of the lines are given:-

Rule: Subtract the smaller from the grater. The difference will give the interior angle , if it is less than 180^0 . If the difference exceeds 180^0 , it will be the exterior angle. Obtain the interior angle by subtracting the difference from 360^0.

b) When the bearing of two lines are given: Express both bearings as if measured from the points where the lines meet and then apply the above rule.

Case-2: Given the reduced bearings of the lines:

Rule (a): If the lines are in the same side of the same meridian then

Included angle= difference of two reduced bearings.

Rule (b): If the lines are on the same side of different meridian then

Included angle= difference of two reduced bearings.

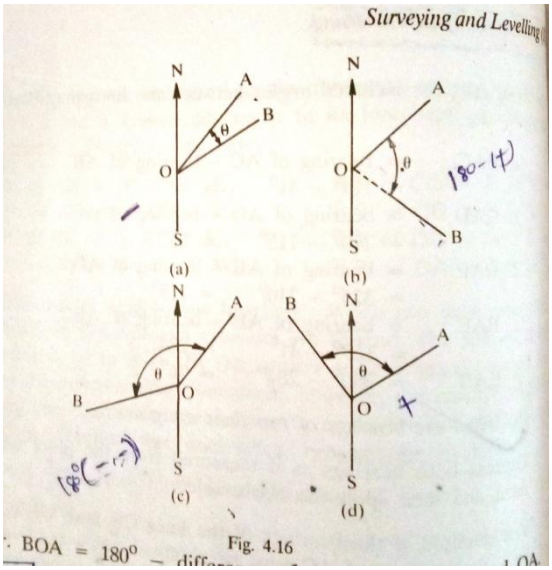
Rule (c): If the lines are on the different sides of the different meridians

Included angle= 180^0 – difference of two reduced bearings.

Rule (d): If the lines are on opposite sides of the same meridians

Included angle= Sum of two reduced bearings.

Figs:



Calculated bearing:

Bearing of a line = Given bearing+ included angle

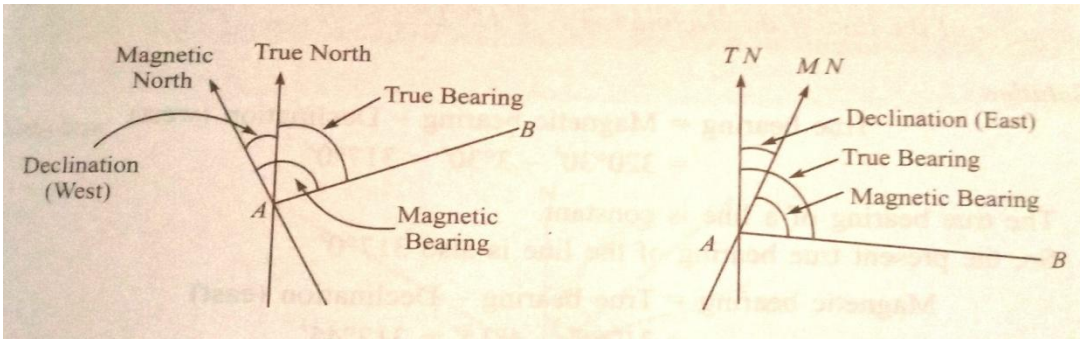
Local Attraction: A magnetic needle indicates the north direction when freely suspended or pivoted. But if the needle comes near some magnetic substances , such as iron ore, steel structures, electric cable conveying current etc. It is found to be deflected from its true positions and does not show the true north. This disturbing influence of magnetic substances is known as local attraction.

Detection of local attraction: To detect the presence of local attraction , the fore and back bearing of a line is taken. If the fore and back bearing of a line is exactly differ by 180^0 then there is no local attraction.

Note: If the fore and back bearing of no lines differ within the value of the permissible error of reading , the mean value of the bearing of that line in which there is least disagreement between the fore and back bearing should be found and the corrections made therefrom.

Magnetic declination: The horizontal angle which the magnetic meridian makes with the true or geographical meridian is known as magnetic declination.

Fig:



When the north end of the magnetic needle is pointed towards the west side of true meridian the position is termed declination of west and similarly when pointed towards the east of the true meridian is termed as declination of east.

Determination of true bearing: If a survey is made with a compass the rea ding observed are magnetic bearing. Knowing the magnetic declination at a place, the true bearing may be deducted by the following,

Rule 1: True bearing of a line = Magnetic bearing of the line ± declination

Use plus sign , when the declination is east, and minus sign ,when it is west.

Rule 2: Magnetic bearing of a line = true bearing of the line ± magnetic declination.

Use plus sign when the declination is west, and minus sign when it is east.

Note : These rules are applied in the case of WCB only.

Variation of magnetic declination: Since the magnetic needle does not constantly point in the same direction, the declination at any place is not constant but is subjected to changes in the value of the declinations which are known as variations of the declination. They are

i) Secular variations
ii) Annual variations
iii) Diurnal variations
iv) Irregular variations.

Sources of error in compass observations:

The errors may be classified as i) instrumental error ii) errors of manipulations and sighting iii) errors due to external influence.

1) Instrumental Errors:
    a) The needle not being perfectly straight
    b) The pivot being bent
    c) The needle being sluggish
    d) The graduated circle not being horizontal
    e) The line of sight not passing through the centre of the graduated ring
    f) The vertical hair being too thick or loose.
2) Error of manipulation and sighting:
    a) Inaccurate centring of the compass over the station occupied.
    b) Inaccurate levelling of the compass box.
    c) Imperfect bisections of the ranging rods at stations or other objects.
    d) Carelessness in reading the graduated circle or the needle.
    e) Carelessness in recording the observe readings.
3) Error due to external influences:
    a) Magnetic changes in the atmosphere on a cloudy or stormy day.
    b) Irregular variations due to magnetic storms, earthquakes, sun spots etc.
    c) Variations in declinations.
    d) Local attractions due to proximity of steel structures, electric lines

COMPARISION BETWEEN PRISMATIC COMPASS AND MINER'S DIAL

Sl. No.	Prismatic compass	Miner' dial
1.	It can be used with hand and without a stand.	It cannot be used without a stand.
2.	The needle is of broad form.	The needle is of edge-bar form.
3.	The sighting of an object and reading of the bearing are done simultaneously.	The observer has to sight first and then go round and read the bearing.
4.	Graduations are written upside down.	Graduations are written ordinarily and not upside down.
5.	Graduations are from 0^0 to 360^0 clockwise.	Graduations are made anti-clockwise. East and West points are transposed.
6.	Least value that can be estimated is 15 minutes.	Modern dials are microptic type and can read upto 1 minute.
7.	It is lighter and used for filling up small details and making rough traverse survey.	It is heavier and is used for more precise work.

THEODOLITE SURVEY :-

Theodolite:- It is the most intricate and accurate instrument used for measurement of horizontal and vertical angles. It consists of a telescope by which distant objects can be sighted.

Uses of theodolite:- The followings are the different purposes for which the theodolite can be used:

1. Measuring horizontal and vertical angles
2. Measuring deflection angle
3. Measuring magnetic bearing
4. Measuring the horizontal distance between two points
5. Finding the vertical height of an object
6. Finding the difference of elevations between various points

7. Ranging a survey line.

Temporary adjustment of theodolite:-

There are three temporary adjustment of a theodolite

1. Setting up of the thedolite over a station
2. Levelling up
3. Elimination of parallax

Setting up:- This includes two operations

a) Centering a theodolite over a station: By centering of a theodolite over a station is meant setting of the centre over a station mark hook the chain beneath the centre of the instrument.
b) Approximately levelling by tripod legs only.

Levelling up:- Having centered and approximate levelling the instrument , it is accurately levelled with reference to the plate levels by means of levelling screws so that the vertical axis shall be truly vertical.

Elimination of parallax:- Accurate work is impossible if parallax is not eliminated . To eliminate it, the image formed by the objects must lie in the plane of the cross-hairs. It is done by two steps i) by focussing the eye piece and ii) by focussing the object glass.

Measurement of horizontal angles:- There are two methods of measuring horizontal angles 1) repetition method 2) reiteration method

Repetition method:- In this method the angle is added a number of times. The total is divided by the number of readings to get the angle. The angle should be measured clockwise in the face left and face right positions with three repetition at each face. The final reading of the first observation will be the initial reading of the second observation, and so on .

Fig.

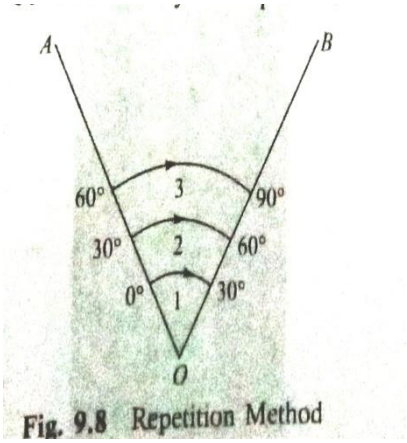


Fig. 9.8 Repetition Method

1. Suppose the angle AOB as shown in the figure is to be measured by repetition method. The theodolite is set up at o. The instrument is centered and levelled properly. Vernier A set to 0^0 and vernier B to 180^0.
2. The upper clamp is fixed, and the lower one loosened. By turning the telescope the ranging rod at A is perfectly bisected with the help of the lower clamp screw and lower tangent screw. Here the initial reading of vernier A is 0^0.
3. The upper clamp is loosened and the telescope is turned clockwise to bisect the ranging rod which is held at B. The upper clamp is clamped. Suppose the reading of vernier A is 30^0.
4. The lower clamp is loosened and the telescope turned clockwise to bisect the ranging rod at A. Here the initial reading is 30^0 for the second observation.
5. The lower clamp is tightened. The upper one is loosened and the telescope is turned clockwise to bisect the ranging rod at B . Let the reading of vernier u
6. The initial reading for the third observation is set at 60^0 . Angle AOB is again measured. Let final reading on the vernier A be 90^0, which is the accumulated reading

   Angle AOB = accumulated angle/ no. Of observations=$90^0/3=30^0$.
7. The face of the instrument is changed and the previous procedure is followed.
8. The mean of the two observations gives the actual angle AOB.

Traverse survey with theodolite:-

In theodolite traversing the field work consists of

a) Reconnaissance
b) Selection, marking and referencing of stations
c) Running of survey lines
d) Picking up of the details
e) Booking of field notes

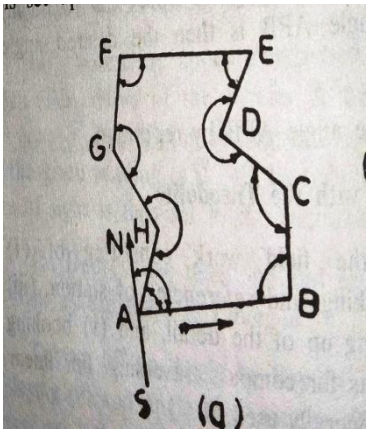
The methods by which the relative directions of the lines of a traverse may be determined are :

1. By the measurement of angle between successive lines
2. By the direct observations of bearing of the lines.

Traversing by the method of included angles:

This method is chiefly used in land surveying. Where great accuracy is required , it is invariably used as the angle can be measured by the method of repetition in any desired precision.

In this method the bearing of the initial line and the included angles of a traverse are measured. In a closed traverse the angles measured are either interior or exterior according as the traverse is run in counter clockwise or in clockwise direction. It is , however customary to run a closed traverse in a counter- clockwise direction.

Fig. 

Procedure:-

a) In running a traverse ABCDEFGH the theodolite is set up over the first station A, and the bearing of the line AB is observed.
b) The angle HAB is then measured by taking a backsight on the preceding station H and a foresight on the forward station B turning the telescope clockwise.
c) Both the verniers then read.The mean of the two vernier readings gives the required angle HAB.
d) Face left and face right observations should be made to eliminate the instrumental error.
e) The theodolite is then moved to each of the successive stations B,C etc. and the angle ABC, BCD,etc. are measured in a similar manner.
f) The lines AB, BC, etc. are measured with a tape or a chain, and the offset necessary to locate the boundary and other details are taken in the usual way and recorded in the field book.

LEVELLING

Levelling:- The art of determining the relative heights or elevations of points or objects on the earth surface is known as levelling. It deals with measurements in a vertical plane.

Uses:- Levelling is done for the following purposes:

1. To prepare a contour map for fixing sites for reservoirs, Dam etc. And to fix the alignment of roads, railway, irrigation canals and so on.
2. To determine the altitudes of different important points on a hill or to know the RL of different points on or below the earth surface.
3. To prepare a longitudinal section and cross- sections of a project.
4. To prepare a layout map for water supply sanitary or drainage schemes.

Definitions of terms used in levelling:-

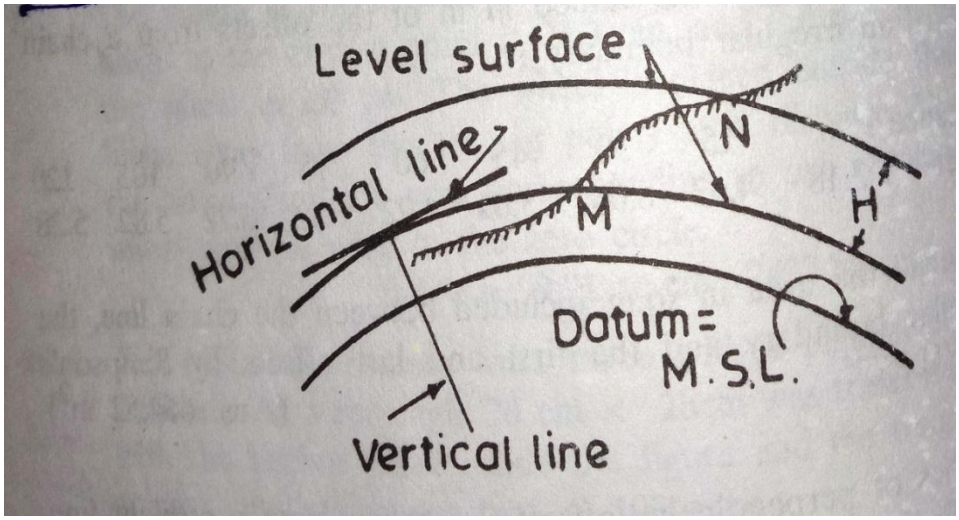


Fig:

Level surface: - Any surface parallel to the mean spheroidal surface of the earth is said to be a level surface. It may be regarded as a curved surface, every point on it is equidistance from the centre of the earth.

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

Horizontal plane:- Any plane tangential to the level surface at any point is known as the horizontal plane. It is perpendicular to the direction of gravity (plumb line).

Datum surface or line:- A datum surface or line is any arbitrarily assumed level surface or line from which vertical distances are measured.

Elevation:- The elevation of a point is its vertical distance above or below the datum. It is also known as the reduced level (R.L) . The elevation of a point is plus or minus according as the point is above or below the datum.

Bench mark:- A bench mark (B.M) is a fixed reference point of known elevation.

Line of collimation:- The line of collimation is an imaginary line joining the intersection of the cross hairs to the optical centre of the object glass and its continuation. It is also called the line of sight.

Backsight reading (B.S):- This is the staff reading taken on a point of known elevation as on bench mark or a change point. It is also called a plus sight. It is the staff reading taken after the level is set up and levelled.

Foresight reading(F.S):- It is a staff reading on a point whose RL is to be determined as on a change point. It is also termed as a minus sight. It is the last staff reading denoting the shifting of the instrument.

Intermediate reading(I.S): It is any other staff reading between the BS and FS in the same set up of the instrument.

Change point :- A change point (C.P) is a point denoting the shifting of the instrument. It is a point on which the fore and back sight readings are taken. It is also called a turning point(T.P) .

Height of the Instrument (H.I):- It is the RL of the plane of collimation when the instrument is correctly levelled.

Parallax:- The apparent movement of the image relative to the cross-hair is known as parallax. This occurs due to imperfect focussing, when the image does not fall in the plane of the diaphragm.

INSTRUMENTS USED IN LEVELLING:-

To determine the elevation of points two instruments are required.

1. Level 2. a levelling staff

The level furnishes a horizontal line of sight , and the levelling staff is used to determine vertical distance of the points below the horizontal line of sight.

Adjustment of the level:- The adjustment of the level are of two kinds ,

1. Temporary 2. Permanent

Temporary adjustments:- The temporary adjustments are those which have to be performed at each set up of the level. They are necessary preparatory for taking readings. They are two in number, (1) Setting up the level, which includes (a) Planting the tripod (b) levelling up (2) Focussing the eye and object glass to eliminate the parallax .

Steps in levelling:- There are two essential steps in levelling,

1. The first step is to find the RL of the plane of collimation(H.I) of the level by taking a backsight on a bench mark.
2. The second step if to find the RL of any other point by taking a reading on the staff held at that point.

Height of the instrument (H.I) = RL of bench mark+ BS

RL of any other point = H.I – I.S

Reduction of levels :- There are two methods of working out the reduced levels of the points from the staff reading taken in the field:-

1. Height of the instrument (H.I) or collimation method
2. Rise and Fall method

Collimation system:- It consists in finding the elevation of plane of collimation(H.I) for every set up of the instrument and then obtaining the RL of points with reference to the respective plane of collimation.

Arithmetical check: $\sum BS - \sum FS$ = First RL- Last RL

Rise and fall system: It consists in determining the difference of the level between consecutive points by comparing each point after the first with that immediately preceding it. The difference between their staff readings indicates a rise or a fall according as the staff reading at the point is smaller or greater than that at the preceding point.

Arithmetical check: ∑ BS- ∑ FS = ∑ rise - ∑ fall = last RL – first RL

Curvature and refraction:- In precise levelling work or when the sights are long, the effects of curvature and refraction have to be taken into account. The effect of curvature is to cause the objects sighted to appear lower than they really are, while that of refraction is to make them appear higher than they really are. The combined effect of curvature and refraction is that the objects appear lower than they really are.

Fig:-

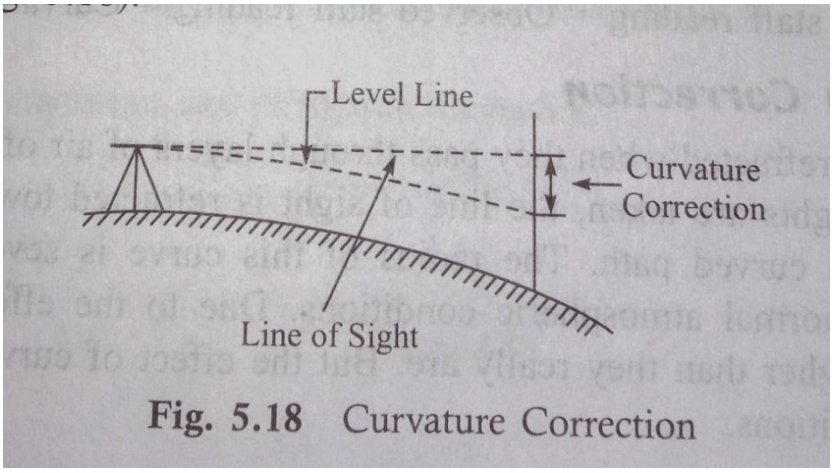
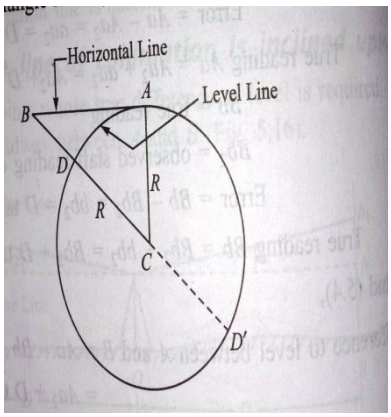


Fig. 5.18 Curvature Correction

Corrections to be applied:-

1. Curvature correction:- For long sights, the curvature of the earth affects staff reading. The line of sight is horizontal, but the level line is curved and parallel to the mean spheroidal surface of the earth. The vertical distance between the line of sight and the level line at a particular place is called the curvature correction. Due to curvature, objects appear lower than they really are.
   Curvature correction is always subtractive.

DERIVATION OF FORMULA:

Fig: 

The formula for curvature correction is derived as follows.

Let AB= D= horizontal distance in kms.

BD= C = curvature correction

DC= AC= R= radius of earth

DD'= diameter, considered , 12742km

From right angled triangle ABC

$BC^2 = AC^2 + AB^2$

or $(R+C_C)^2 = R^2 + D^2$

Or $C_C \times 2R = D^2$

Curvature correction= $C_C = D^2 / 2R$

C_C^2 is neglected as it is very small as comparison to the diameter of the earth.

$$C_C = (\underline{D^2 \times 1000}) / 12742 = 0.0785D^2 \text{ m}$$

2.Refraction correction:- Due to the effect of refraction , objects appear higher than they really are. So, when long sights are taken the line of sight is refracted towards the surface of the earth in a curved path. The radius of this curve is seven times that of the earth under normal atmospheric conditions.

Refraction correction $C_r = 1/7 \times 0.0785D^2 = 0.0112D^2$ m

Refraction correction is always additive.

3 .Combined correction:-

Combined correction= curvature correction + refraction correction

$= -0.0785D^2 + 0.0112D^2$

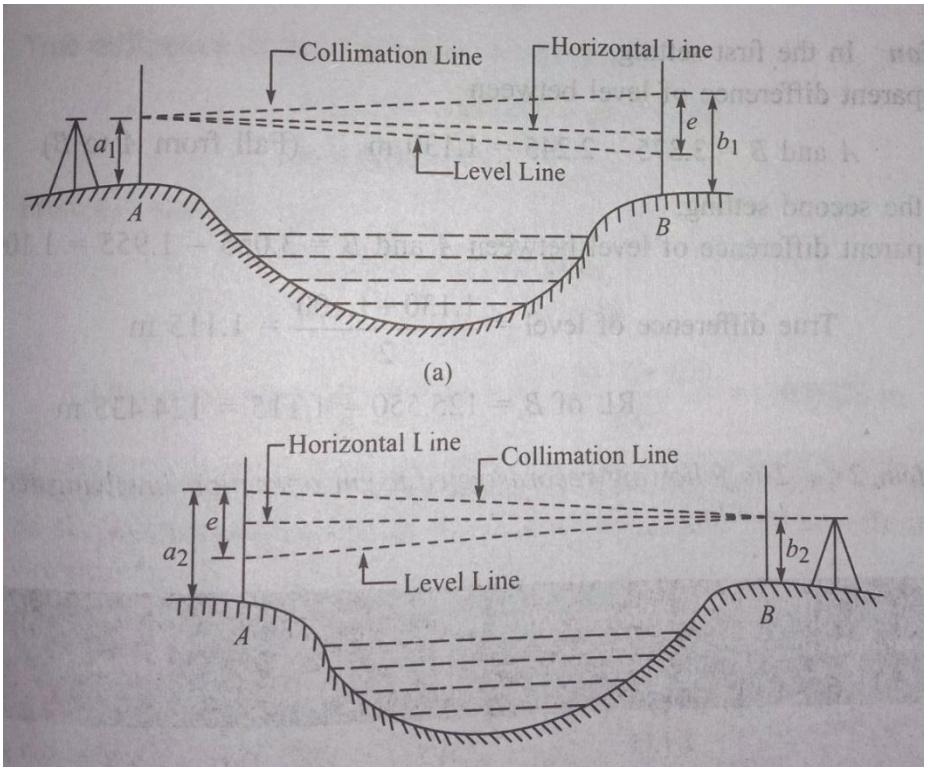
$= -0.0673D^2 m$

So, combined correction is always subtractive.

RECIPROCAL LEVELLING:- Reciprocal levelling is a method of levelling adopted to determine the difference of level between two points at a considerable apart with great precision.

In reciprocal levelling the level is set up on both banks of the river or valley and two set of staff readings are taken by holding the staff on both banks. In this case it is found that the errors(error due to curvature and refraction, and collimation error) are completely eliminated and the true level difference is equal to the mean of the two apparent difference of level.

Fig:-



Procedure:-

1. Suppose A and B are two points on opposite banks of a river. The level is set up very near A and after proper temporary adjustments , staff readings are taken at A and B. Suppose the staff readings are a_1 and b_1 .
2. The level is shifted and set up very near B and after proper adjustment staff readings are taken at A and B. Let the readings be a_2 and b_2 .

Let h= true difference of level between A and B

e = combined error due to curvature, refraction and collimation

In the first case,

Correct staff reading at A =a_1 (as the level is very near A)

Correct staff reading at B= b1—e

True difference of level between A and B,

$h = a_1 – (b_1-e)$ (fall from B to A) (i)

In the second case,

Correct staff reading at B = b_2 (as level is near B)

Correct staff reading at A = a_2-e

So, true level difference,

$h =(a_2 –e)- b_2$ (ii)

From i and ii

$2h = a_1 – (b_1 – e) +(a_2 –e) – b_2 =(a_1 – b_{1)} +(a_2 – b_2)$

$h = (a_1 – b_{1)} +(a_2 – b_2)/2$

It may be observed that the error is eliminated and that the true difference is equal to the mean of the two, apparent differences of level between A and B.

SOURCES OF ERROR IN LEVELLING:-

The following are the different sources of error in levelling.

1. Instrumental errors
   a) The permanent adjustment of the instrument may not be perfect.
   b) The internal arrangement of the focussing tube is not perfect.
   c) The graduation of the levelling staff may not be perfect.
2. Personal error:-
   a) The instrument may not be levelled perfectly.
   b) The parallax may not be eliminated entirely.
   c) The position of the staff may be displaced at the change point at the time of taking FS and BS.
   d) A wrong entry may be made in the level book.
   e) The staff may not be properly and fully extended
3. Error due to natural causes:-
   a) When the distance of the sight is long , the curvature of the earth may affect the staff reading.
   b) The effect of refraction may cause a wrong staff reading to be taken.
   c) The effect of high wind and a shining sun may result in a wrong staff reading.

SENSITIVENESS OF THE BUBBLE :-

The term sensitiveness of a bubble means the effect caused by the deviation of the bubble per division of the graduation of the bubble tube.

Sensitiveness is expressed in terms of the radius of the curvature of the upper surface of the tube or by an angle through which the axis is tilted for the deflection of one division of the graduation.

Fig:-

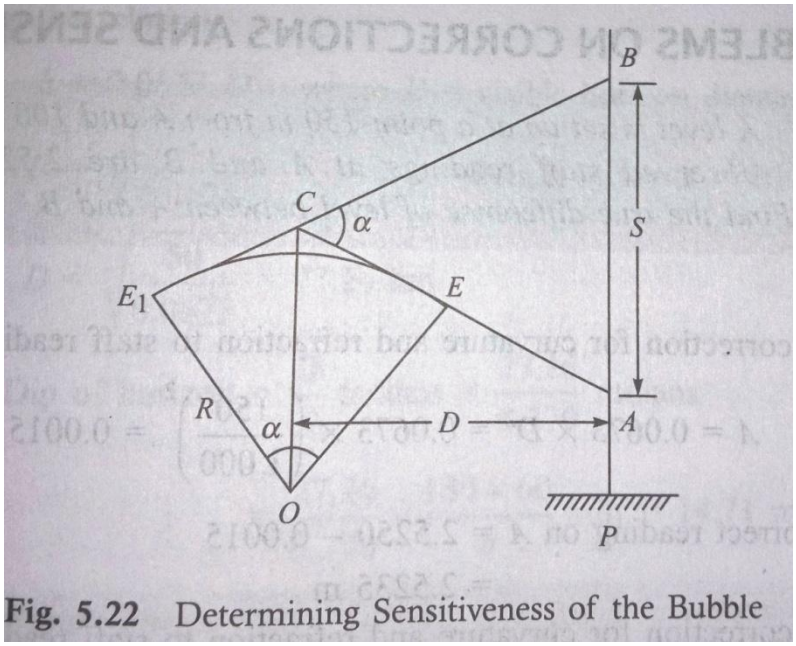


Fig. 5.22 Determining Sensitiveness of the Bubble

Determining sensitiveness:- Considering the figure suppose the level was set up at o at a distance D from the staff P . The staff reading is taken with the bubble at the extreme right end (i.e at E) ,say it is PA . Another staff reading is taken with the bubble at the extreme left end (i.e at E_1). Let it be PB.

Let D = distance between the level and the staff

S= Intercept between the upper and lower sight.

n= number of divisions through which the bubble is deflected.

R= radius of curvature of the tube.

α= angle subtended by arc EE_1 , and

d= length of one division of the graduation, expressed in the same unit as D and S.

Movement of centre of bubble = EE_1= nd

Triangles OEE_1 and ACB are similar.

Here Rα= arc EE_1, or α= EE_1/R = nd/R (as arc EE_1= chord EE_1) (1.1)

Again, EE_1/R= S/D (1.2)

From (1.1) and (1.2) $\alpha = nd/R = S/D$

Or $R = (ndxD)/S$

Let α' = angular value for one division in radians.

$\alpha' = \alpha/n = S/DX\ 1/n$ radians

or, $\alpha = S/Dn \times 206{,}265$ seconds (1 radian= 206,265 seconds)

CONTOURING

Introduction:- contouring is basically a levelling operation. The main objective of contouring is to determine the points on the ground having the same RL .It gives the topographical features of the ground, comparing different contours lines of different elevations for a closed area.

DEFINITIONS:-

1. Contour line:- The line of intersection of a level surface with the ground surface is known as the contour lines or simply the contours. It can also be defined as the line passing through points of equal reduced levels.
2. Contour interval:- The vertical distance between any two consecutive contours is known as a contour interval.
3. Horizontal equivalent:- The horizontal distance between any two consecutive contours is known horizontal equivalent. It varies according to the steepness of the ground.

OBJECT OF PREPARING CONTOUR MAP:-

For all engineering projects involving roads, railways and so on, a knowledge of the nature of the ground surface is required for locating suitable alignments and estimating the volume of the earth work. Therefore the contour map is essential for all engineering projects. This is why contour maps are prepared.

USES OF CONTOUR MAP:-

a) The nature of the ground surface of a country can be understood by studying the contour map. Hence, possible route of communication between different places can be demarcated.
b) A suitable site, or an economical alignment can be selected for any engineering projects.
c) The capacity of a reservoir can be approximately computed.
d) The inter visibility or otherwise of different points can be established.
e) A suitable route for a given gradient can be marked on the map.
f) Quantities of earth work can be approximately computed.

CHARACTERISTICS OF CONTOURS:-

a) The contour lines are closer near the top of a hill or high ground and wide apart at the foot.
b) The contour lines are closer near the bank of a pond or depression and wide apart toward the centre.
c) All points on the contour line have the same reduced levels.
d) Every contour line closes on itself, either within or beyond the limit of the map.
e) Contour never split, nor do two contours run into one, nor cross each other, except in the rare instance of an overhanging cliff.
f) The direction of the steepest slope at a point on contour is at right angles to the contour.

METHODS OF CONTOURING:-

In general , there are two field methods of determining contours.

a) Direct method
b) Indirect method

Direct method:- The method in which contouring of the points of required elevations are directly located on the ground with the help of levelling instrument is called direct method of contouring. The position of these points are surveyed by chain and offset method or by a plane table. The contour of required elevations are drawn by joining the respective points. The method is accurate , but it is slow and tedious.

Contouring by direct method is done by any of the following methods:

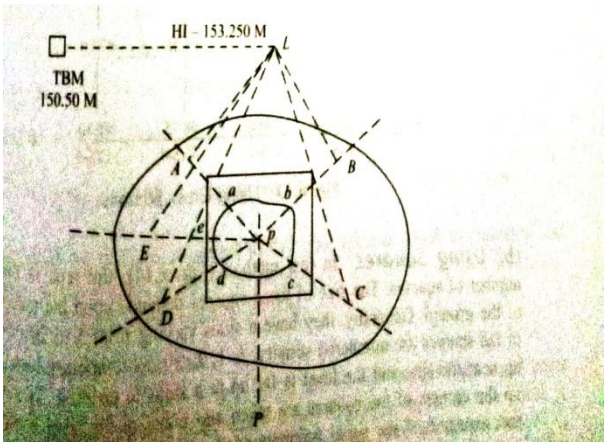
a) By selecting a long main line and then taking cross-section at suitable interval.
b) By radial line method
c) By use of plane table in conjunction with levelling operation.

RADIAL LINE METHOD:-

When the area is small and can be controlled from a single station, the method of radial line is adopted to obtain the contour map.

Procedure:-

Fig:-



1. The plane table is set up at a suitable station P from where the whole area can be commanded.
2. A point p is suitably selected on the sheet to represent the station P. Radial lines are then drawn in different directions.
3. A temporary bench mark is established near the site. The level is set up at a suitable position L and a BS reading is taken on TBM. Let the HI of this setting be 153.250m.
4. To find the contour of 152m RL , a staff reading of 1.250m is required at a particular point. , so that the RL of contour of that point comes to 152.000m. RL = HI – Staff reading
5. The staff man holds the staff along the rays drawn from the plane table stations in such a way that the staff reading on that point is exactly 1.250.
6. In this manner , points A, B, C, D and E are located on the ground, where the staff readings are exactly 1.250.
7. The distances PA, PB, PC, PD, and PE are measured and plotted to any suitable scale. Thus the points a, b, c, d, and e are obtained which are joined in order to obtain a contour of 152.000m.
8. The other contours may be located in similar fashion.

INDIRECT METHODS:-

The method in which spot levels taken on already fixed points over the entire area , their respective RLs written against each point on the plan drawn to

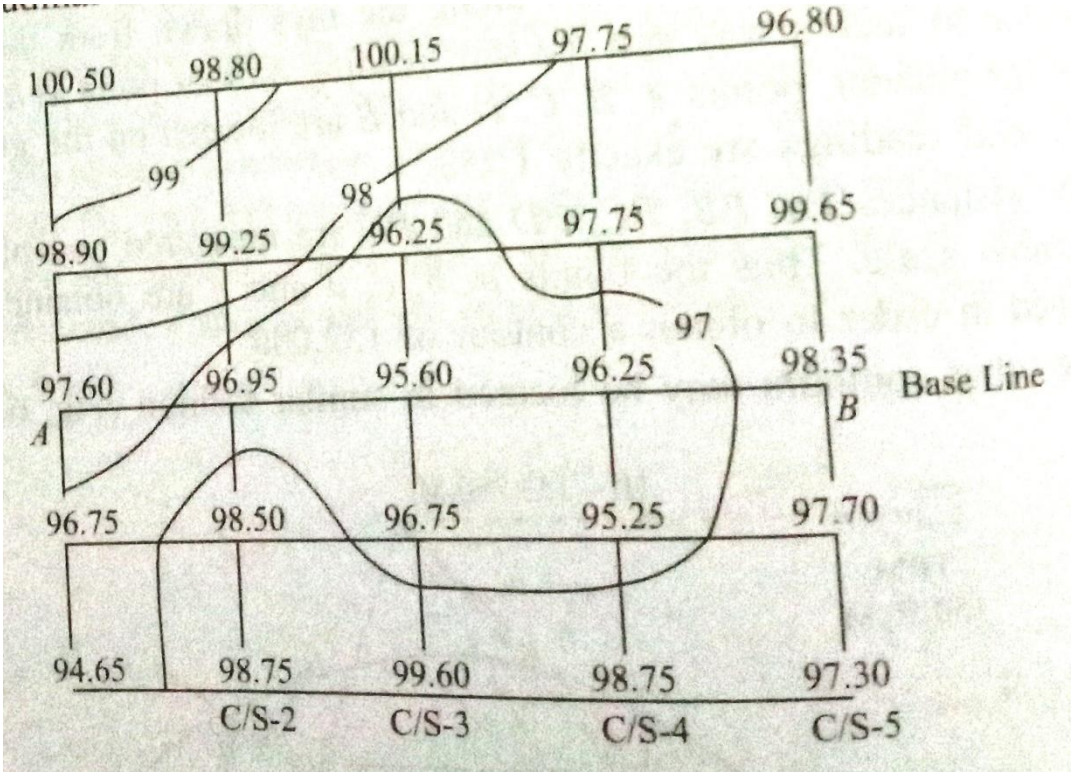
scale and contour lines are drawn by interpolation is known as indirect method of contouring.

Contouring by indirect method is done by any of the following methods:

a) By square method
b) By cross-section method
c) By tacheometric method

By cross-section method:-

Fig:-



Procedure:-

a) In this method , a base line, centre line or profile line is considered. cross-sections are taken perpendicular to this line at regular interval(say 50m 100m etc.) .
b) The points are marked along cross-section at regular intervals (say 5m, 10m etc.) .
c) A temporary bench mark is set up near the site. Staff readings are taken along the base line and the cross-sections. The readings are entered in

the level book, the base line and the cross-section should also be mentioned.

d) The RL of each of the points calculated. Then the base line and the cross-sections are plotted to a suitable scale .
e) The RL of the respective points are noted on the map , after which the required contour line is drawn by interpolation.

METHOD OF INTERPOLATION OF CONTOURS:-

The process of locating the contours proportionately between the plotted points is termed as interpolation. Interpolation may be done by

1. By estimation
2. By arithmetical calculations
3. By graphical method

In all these methods it is assumed that the slope of the ground between any two random points is uniform.

By arithmetical calculation:-

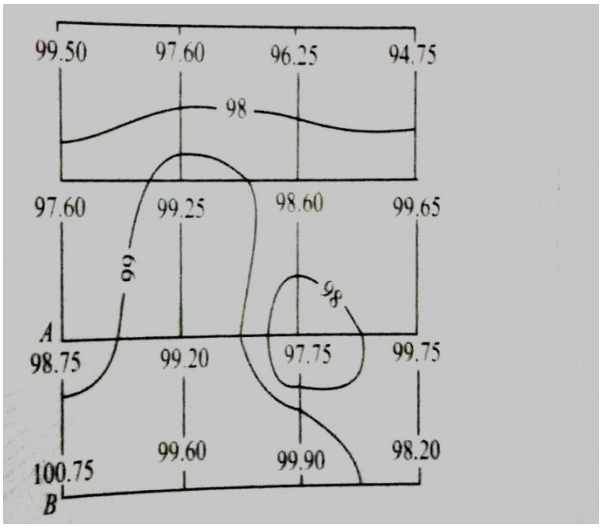


Fig:-

Let A and B be two corners of the square. The RL of A is 98.75m and that of B 100.75m. The horizontal distance between A and B is 10m.

Horizontal distance between A and B is 10m.

Vertical distance between A and B = 100.75m -98.75m = 2m

Let a contour of 99m be required. Then difference of level between A and 99m contour = 99.00 – 98.75 = 0.25m

Therefore, distance of 99m contour line from A = (10/2)x0.25 = 1.25m.

This calculated distance is plotted to the same scale in which the skeleton was plotted, to obtain a point of RL of 99.00m. Similarly the other points can be located.

COMPUTATION OF AREA AND VOLUME

Computation of area:- The term area in the context of surveying refers to the area of a tract of land projected upon the horizontal plane, and not to the actual area of the land surface.

Computation of area from field notes is done in two steps:

Step-1: - In cross staff survey the area of the field can be directly calculated from field notes. During survey work the whole area is divided into some geometrical figures such as triangles, rectangles, square and trapezium and the area is calculated.

Step-2:- Consider the fig. The area along the boundary is calculated as follows:

O_1 , O_2 = Ordinates

X_1, x_2 = chainages

Area of the shaded portion =(O_1 + O_2)/2x(X_1- x_2)

Similarly areas between all points of ordinates are calculated and added to the total boundary area.

The boundary are is calculated according to the one of the following rules:-

a) The mid- ordinate rule
b) The average ordinate rule
c) The trapezoidal rule

d) Simpson' rule

Mid- ordinate rule:

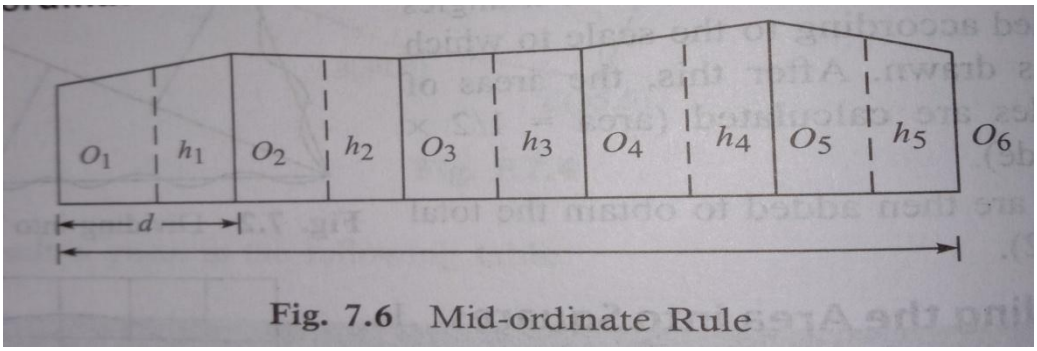


Fig. 7.6 Mid-ordinate Rule

Let O_1, O_2, O_3---- O_n = Ordinate at equal interval

L= length of base line

d= common distance between ordinates

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

Area of plot = $h_1$xd+ $h_2$xd+ ----------$h_n$xd

= d(h_1+ h_2+ ----------h_n)

I.e. Area= common distance sum of mid ordinates

Average ordinate rule:-

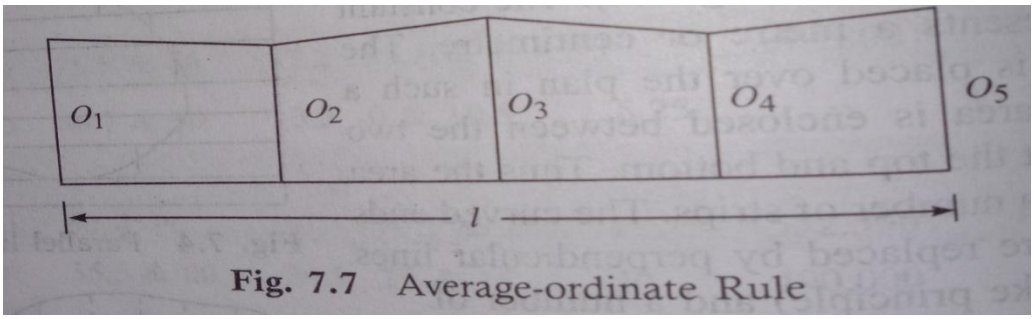


Fig. 7.7 Average-ordinate Rule

Let O_1, O_2, O_3---- O_n = ordinates or offsets at regular intervals .

L= length of base line

n= number of divisions

n+1= number of ordinates

Area =(O_{1+} O_2+ O_{3+}---- O_n)/O_{n+1} x l

i.e area= sum of ordinates/no. of ordinates x length of base line

Trapezoidal rule:- While applying the Trapezoidal rule , the boundaries between the end of ordinates are assumed to be straight. Thus the area enclosed between the base line and irregular boundary lines are considered as trapezoids.

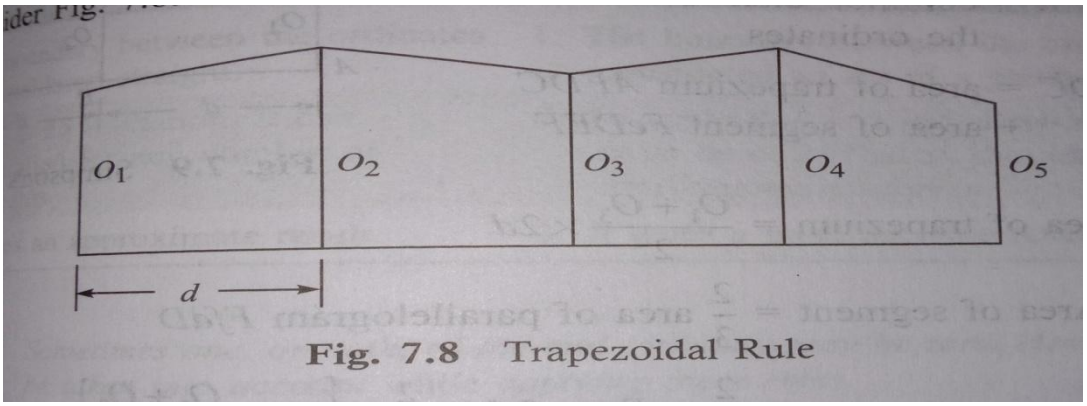


Fig. 7.8 Trapezoidal Rule

Let $O_{1,}$ O_2, O_3---- O_n = ordinates at equal intervals

d= common distance

First area= (O_{1+} O_2)/2 x d

Second area= (O_{2+} O_3)/2 x d

Third area= (O_{3+} O_4)/2 x d

Last are=(O_{n-1}+ O_n)/2 xd

Total area = d/2(O_1+2O_2+------2O_{n-1}+O_n)

Simpson's rule:- In this rule the boundaries between the end of ordinates are assumed to form arc of a parabola. Hence Simpson's rule is sometimes called the parabolic rule.

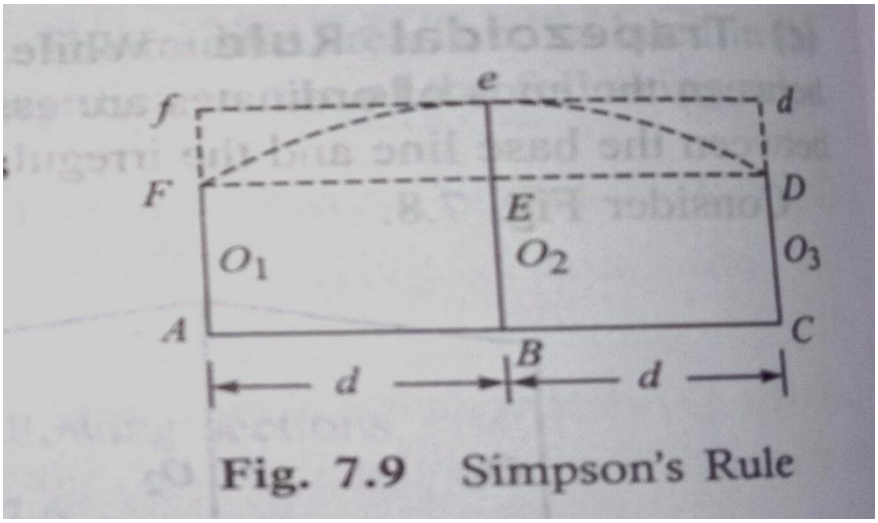


Fig. 7.9 Simpson's Rule

Referring to figure

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, area of trapezium = $(O_{1+} O_3)/2 \times 2d$

Area of the segment= $2/3 \times Eex2d$

$= 2/3 \times (O_2 –(O_{1+} O_3)/2) X2d$

So, the area between first two division = $d/3(O_1+4O_2 +O_3)$

Similarly the area between the next two division= $d/3(O_3+4O_4 +O_5)$

So, total area = $d/3(O_1 +4O_2+2 O_3+4O_4 + \text{-------} + O_n)$

$= d/3((O_1+O_n + 4(O_2+O_4+\text{-----}) + 2(O_3+ O_5+ \text{---}))$

COMPUTATION OF VOLUME:

For computation of the volume of the earth work, the sectional areas of the cross-section which are taken transverse to the longitudinal section during profile levelling are first calculated. Again the cross-sections may be of different types namely i) level ii) two-level iii) three-level iv) side-hill-two-level v) multi-level.

After calculation of cross-sectional areas the vol. of earth work is calculated by i) trapezoidal rule, ii) prismoidal rule

A) Trapezoidal Rule(Average –end-area rule)
   Volume(cutting or filling), $V = D/2((A_1 + A_n + 2(A_2+A_3+\text{-----}+A_{n-1}))$
   i.e volume= common distance/2((area of first section+ area of last section + 2(sum of area of other section))

B) Prismoidal formula:-

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

volume= common distance/2((area of first section+ area of last+4(sum of areas of even section)+2(sum of areas of other sections))

By: S. N Das,

Asst. Professor (Mining Engg.), GCE Keonjhar

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