UNIT-I

Surveying It is the art of determination of horizontal distances, differences in elevation, directions, angles, locations, areas and volumes on or near the surface of the earth. It involves the measurement and recording of the size and s hap e (including the vertical shape) of an area on the earths surface.

The process of survey divided into two parts:

(a) **Field work**- taking measurements

(b) **Office work**- computing and drawing

1.1 Object of survey The primary object of survey is the preparation of plan or map. The results of surveys when plotted and drawn on paper constitute a plan. A plan is , the representation to some scale, of the ground and the objects upon it as projected on a horizontal plane, which is represented by the plane of the paper on which the plan is drawn. The representation is called a map, if the scale is small. If the scale is large, it is called a plan. On plan, only horizontal distances are shown. The scale of a map is the fixed relation that, every distance on the map bears to the corresponding distance on the ground. Suppose, if one cm on a map represents 5 m on the ground, the scale of a map is 5m to 1 cm.

1.2 Primary division of surveying: Surveying may be divided into two general classes:

(a) Geodetic surveying

(b) Plane surveying

1.2.1 Geodetic surveying It is also called **trigonometrical surveying.** The object of a geodetic surveying is to determine the precise positions on the surface of the earth of a system of widely distant points and the dimensions of areas. In this survey, the curvature of the earth is taken into account, since large distances and areas are covered. Artificial earth satellites have come into wide use in this survey.

1.2.2 Plane surveying In this survey, t h e earth h s surface is considered as a p l an e. The curvature of the earth is not taken into account, as the surveys extend only to small areas. The line joining any two points as a straight line, and all angles are plane angles. Surveys normally carried out for the location and construction of roads, canals and, buildings. In general, the surveys necessary for the works of man are plane surveys.

1.3 Classification: Surveys may be classified in a variety of ways.

I. Classification based upon the nature of the field of survey:

(a) Land Surveys.
(b) Marine or Navigation Surveys.
(c) Astronomical Surveys.

II. Classification upon the object of survey:

(i) Archaeological surveys.
(ii) Geological Surveys -for determining different strata in the earths crust.
(iii) Mine Surveys- for exploring mineral wealth such as gold, coal, etc.
(iv) Military Surveys- for determining points of strategic importance both offensive and defensive.

III. Classification based upon the methods employed in survey

(a) Triangulation Surveys.

(b) Traverse Surveys.

IV. Classification based upon the instrument employed:

(i) Chain Surveys.
(ii) Theodolite Surveys.
(iii) Tacheometric Surveys.
(iv) Compass Surveys.
(v) Plane Table Surveys.
(vi) Photographic and Aerial Surveys.

Principles of surveying:

There are two fundamental principles.

1. To work from the whole to the part.
    - Control points: - triangulation of traversing.
    - Triangulation divided into large triangle.
    - Triangles- subdivided in to small triangles
    - To control and localize minor errors.
    - On the other hand –It we work from the part of the whole; small errors are magnified & uncontrollable at the end.

2. To fix the position of new stations by at least two independent process. The stations are fixed from points already fixed by
    - Linear measurement or
    - Angular measurements or B
    - Both the linear and angular measurements.

    E.g. Chain surveying- main lines & stations points are checked by means of check or tie lines.

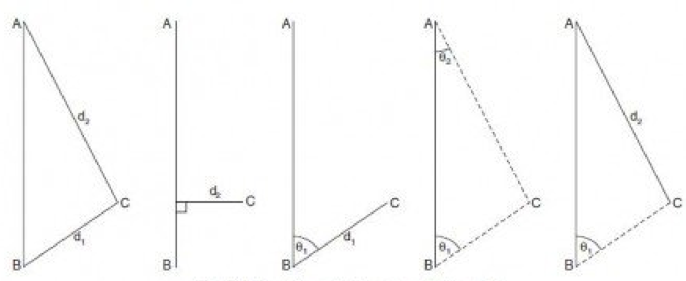


Fig. 11.3. Locating point C w.r.t. points A and B

2.0 Chaining: It is the method of measuring distance with a chain or tape. Of the various methods of determining distance, chaining is the most accurate and common method. For work of ordinary precision, a chain is used. But, where great accuracy is required, a steel tape is invariably used.

2.1 Instruments used in Chain survey
Instruments used for measuring distances

1. Chain

2. Tape

Instruments used for marking survey stations.
1.Ranging rod

2. Offset rod

3. Laths and whites

4. Pegs

Instruments used for setting right angles

1. Cross staff

2. Optical square

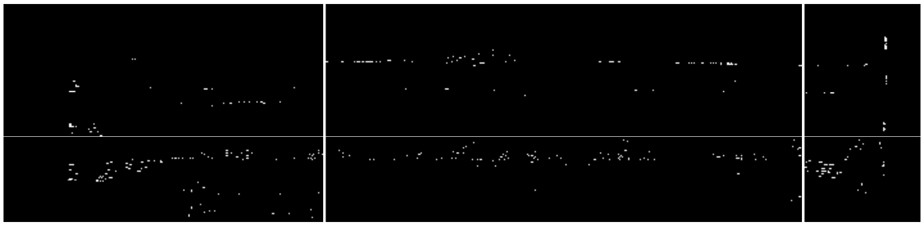
Other instruments:

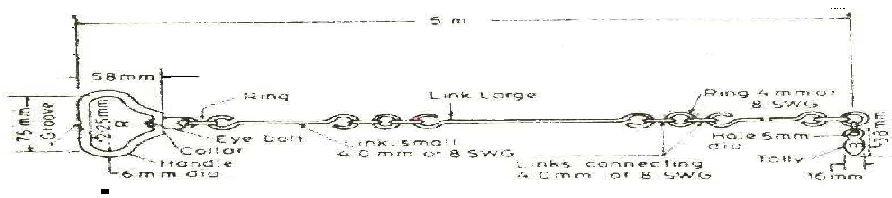
1. Arrow

2. Plumb bob

Chain :
The chain is composed of 100 or 150 pieces of links, made up of 4 mm diameter galvanized mild steel wire. The ends of each link bent into a loop and connected together by means of three oval rings which offered flexibility to the chain and make less liable to become **kinked**. The joints of the links are usually open, but in the best chains they are welded so as to render the chain less liable to stretching. The ends of the chain provided with brass handles for dragging the chain on the ground, each with a swivel joint, so that the chain can be turned round without twisting. The length of a link is the distance between the centers of the two consecutive middle rings. The end links include the handles. Metallic tags or indicators of distinctive pattern are fixed at various distinctive points of the chain to felicitate quick reading of fraction of a chain in surveying measurements.

(ii) it can be easily repaired in**Metric chain** IS 1492-1956 covers requirement of chains in metric units. The chains are made in length of 5, 10, 15,20 and 30 meters .To enable the reading of fractions of a chain without much difficulty, tallies are fixed at every five-meter length and small brass rings are provided at every meter length, except where tallies are attached. Connecting links between two large links are oval in shape, the central one being a circular ring. The length of the chain is marked over tm he handle to indicate the length and also to distinguish from non-metallic chains. The length of each link is 0.2 m (20cm) in 20m chain is provided with 100 links and 30 m chain divided into 150 links (Fig. 1).
The advantages of the chain are :
(i) it is very suitable for rough usage the field
(iii) it can be easily read.





Types of chains

(1) Gunter's Chain: It i s also call ed su rveyo r‟s ch ain **.** The Gun t er‟s chain is 66 ft. long and is divided into 100 links. Therefore, each end link is equal to 0.66 ft. long. It is very convenient for measuring distances in miles and furlongs and for measuring land when the unit of area is an **acre**, on account of its simple relation to the mile and the acre. 1 0 Gu nt urs chain s – 1 furlong 8 0 Gunturs chain s - 1 mile 1 0 square Gunturs chains – 1 acre

(2) Revenue Chain: The revenue chain is commonly used for measuring fields in cadastral survey. It is **33 ft. long and divided into 16 links**.

(3) Engi neers ' Chain: Th e en gi neers chain is **100 ft.** long and is divided into 100 links each link is equal to 1 ft. The construction details are same as that of a Gunters chain . It is used on all engineering surveys . The distances measured with the engineers chain are recorded i n feet and decimal s .

(4)Steel Band: The steel band, also called the band chain, consists of a ribbon of steel with a brass swivel handle at each end. It is 20 or 30 m long and 16 mm wide. It is wound on open steel cross, or on a metal reel in a closed case. The graduations are marked in two ways: (a) The band is divided by brass studs at every 0.2 m and numbered at every l m, the first and the last link being subdivided into cm and mm, (b) The graduations are etched as metres, decimeters, centimeters on one side and 0.2 m links on the other. Brass tallies are fixed at every 5 m length of the band. It is best adapted to general field work and rough usage. For accurate work, the steel band is now preferred. It is lighter and easier to handle than the chain. It is practically unalterable in length. It must be protected from rust by frequent cleaning and oiling.

Tapes: When greater accuracy is required in measurement and the ground to be surveyed is not very rough, the tapes can be used. Tapes are available both in ft. and

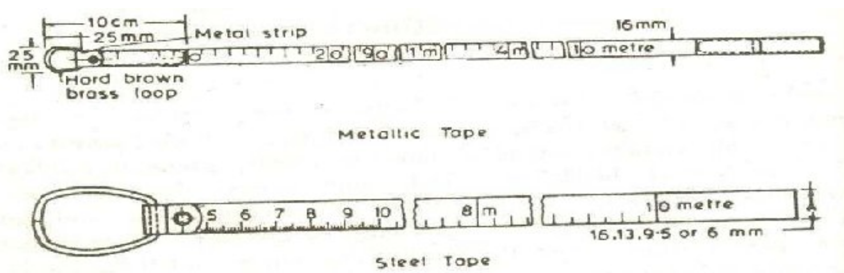
(1) **Cloth or linen Tape**: It is made of varnished strip of woven linen 12 to 16 mm wide with a brass handle at zero ends, whose length is also included in the length of the tape. The tape is attached to a spindle and is wound in a leather case. It is very light and handy, but not so accurate. For very precise measurements, it is not used. The linen tape may be used for taking subsidiary measurements such as offsets. It is easily affected by damp. When the tape gets wet, it shrinks and care should be taken that it is not wound up until is cleaned and dried. It stretches easily and is likely to twist and tangle. It is therefore little used in surveying.

(2) **Metallic Tape**: It is made from good quality cotton or linen and is reinforced with fine brass or copper wires. This prevents stretching of fibres and is therefore, better than simple linen tapes. They are also not suited for very precise measurements. It is made in lengths of 2, 5, 10, 20, 30 and 50 metres.

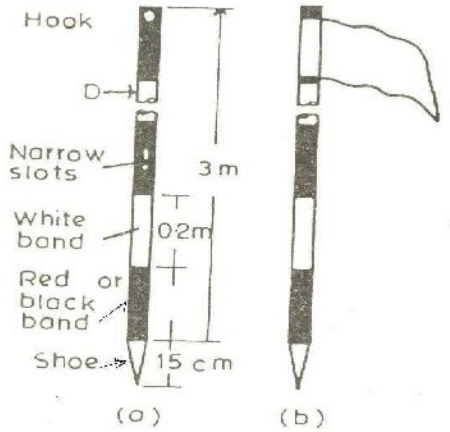
(3) **Steel Tape**: It is made of steel ribbon or stainless steel, or may be provided with vinyl coating and is very accurate. It is used for very precise measurements and for checking the accuracy of chain lengths. The denominations of the tape measures are 1, 2, 10, 30, and 50 m. The outer end of the tape is provided with a ring or other device facilitating withdrawal. The ring or the device is fastened to the tape by a metal strip of the same width as the tape. The length of the tape includes the metal ring when provided Steel tape.

(4) **Invar Tape**: For work of the highest precision, the invar tape is generally used as in measurement of base lines in triangulation and in city work. It is made of an alloy of steel (64%) and nickel (36%) and possesses a very low coefficient of thermal expansion ($0.6 \times 10_2$ for 1°C). It is 6 mm wide and may be obtained in lengths of 30 m, 50 m and 100 m.

(5) **Synthetic Tape**: The tapes are manufactured of glass fibre having a PVC coating. They are graduated every 10 mm and figured every 100 mm whose metric figures are shown in red at every metre. The tapes maintain their lengths well and are convenient for measuring short lengths.

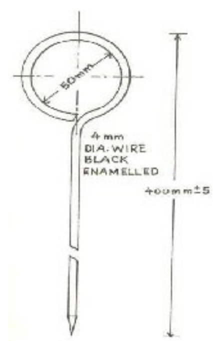


Ranging Rods: The ranging rods are used for ranging lines and to mark stations which are at greater distance (Fig.3). They are made of well seasoned straight grained timber of teak, blue pine, sisso or deodar. They are circular or octagonal in cross section of 3 cm nominal diameter and pointed metal shoe of 15 cm long is provided at the lower end to facilitate fixing in the ground. They are made of two sizes namely one of 2 m and the other of 3 m and are divided into equal parts each 0.2 m long. In order to make them visible at a distance, they are painted alternately black and white, or red and white or red, white, and black successively. When they are at a considerable distance, red and white and yellow flags about 25 cm square be fastened at the top to improve the visibility.



Off-set rod (a) and Ranging rod (b)

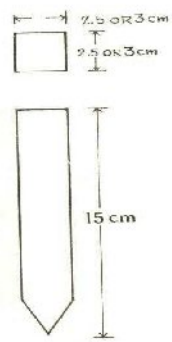
Arrows (Chain pins): Accompanying each chain are 10 arrows. They are also called marking or chaining pins, and are used to mark the end of each chain during the process of chaining. They are made of good quality metallic wires of 4 mm (8 s. w. g.) in diameter and of a minimum tensile strength of 700N/ mm. The wire is black enameled. The arrows are made 400 mm in length, are pointed at one end for inserting into the ground and bent into a ring at the other end for facility of carrying. They should have a piece of white or red tape tied to the ring so that they can be made easily visible at a distance. To mark the end of each chain length, the arrow is inserted in the ground, but when the ground is hard, a scratch may be made with the pointed end .

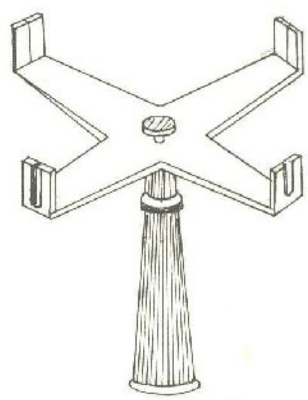


Off-set rod: The off-set rod is similar to the ranging rod but is usually 3 m long and is divided into parts each 0.2 m in length. It is chiefly used for aligning the off-set line and measuring short off-sets.

Plumb bob: A plumb bob consists of a metal weight made of brass with a pointed end (Fig.5). It is suspended by a string and is used to locate points directly below or above another point. It is also used for accurately centering of compass or level or theodolite over a station mark, and for testing the verticality of ranging poles.

Pegs: Wooden pegs are used to mark the positions of stations. They are made of hard timber and are tapered at one end (Fig.6). They are usually, 2.5 cm square and 15 cm long, but in soft ground, pegs 40 to 60 cm long and 4 to 5 cm square suitable.





Open cross-staff

Cross-Staff Cross-staff is used for (i) finding the foot of the perpendicular from a given point to a line, and (ii) setting out a right angle at a given point on a line. There are two types of cross-staff, namely,

(1) **Open cross-staff**

(2) **French cross -staff**,

The first one being in common use.

Open cross-staff: The simplest form of cross staff is the open cross staff**.** It consists of two parts (1) the head and (2) the leg. The head consists of four metal arms with vertical slits. The arms are rigidly fixed in such a manner so that the center of one pair of arms forming a straight line makes right angle with the other pair of arms. In one line, one of the slits is narrower than the other. One horse hair is fixed at the center of the wider slit. The object is sighted from the narrow slit in line with the hair. The cross staff is mounted on 25 mm diameter, about 1.5 meter long pole for fixing on the ground .

For laying out a right angle at a point on the chain line, the cross staff is held vertically on the supporting pole at the given point. Ranging rod is fixed on the chain line on either side of the cross staff and sighted through the slit and horse hair. The cross staff is turned till the ranging rod is visible. At this time, one sight through the other pair of slits and another person fixes a ranging rod in this line of sight. Foot of the cross staff joined with the ranging rod gives perpendicular line with the chain line.

Optical Square It is more accurate than the cross staff and it can be used for locating objects situated at larger distances. It is small and compact hand instrument (Fig.8) and works on the principle of reflection. Generally it is a round brass box about 5 cm in diameter and 1.25 cm deep. There is also a metal cover to protect it from dust, moisture etc. As shown in fig. 8, it consists of horizontal mirror (H) and index mirror (1) placed at an angle of 45 to each other. The mirror H is half silvered and the upper half is plain while the mirror I is fully silvered. There are three openings a, b and c on the sides. Let AB is the chain line and it is required to locate an object O during the process of surveying. The optical square is held in such a manner that a ray of light from object O passes through slot c, strikes the mirror, gets reflected and strikes the silvered portion of the mirror H. After being reflected from H, the ray passes through the pin hole and becomes visible to the eye. The observer looking through the hole a can directly see the ranging rod at B through the un-silvered portion of the mirror H and he image of the ranging rod placed at O. Thus when both the ranging rods coincide, the line OD becomes perpendicular to the chain line. If they do not coincide, the optical square has to move back and forth to get the correct position of D.

Chaining a line In all chaining operations two men, called chainmen, are required. The chainman at the forward end of the chain is called the leader or head chainman, while the chainman at the rear end the chain is known as the follower or rear chainman. The duties of the leader are ; (i) to drag the chain forward, (ii) to insert arrows at the end of every chain, and (iii) to obey instructions of the follower, while the duties of the follower are; (i) to place the leader in line with the ranging rod or pole at the forward station, (ii) to call out instructions to the leader, (iii) always to carry the rear handle in his hand and not to allow it to drag on the ground, and (iv) to pick up the arrows inserted by the leader. The chainman who is more intelligent and experienced be selected as the follower, as upon his care and judgment depends the accuracy of measurements.

Unfolding the Chain To lay out the chain on the ground, remove the leather strap, take both the handles in the left hand and throw the chain well forward with the right hand. The leader, taking one handle of the chain may then be examined to see if there are any kinks or bent links. This operation is also called unfolding the chain.

Testing of a chain It is always necessary to check the length of chain before commencing each day's work and at frequent intervals; otherwise the measurement will become unreliable. Before testing the chain, the surveyor should see that the links and rings are free from mud that there are no links or bent links. The chain is tested by comparing it with (i) the chain standard (standard chain length) (i i) wit h the steel t ape which should be kept in the surveyors office for this sole purpose.

If these are not available at hand, a test gauge may be established by driving two stout pegs in the required distance apart (20 m or 30m) and inserting nails into their tops to mark exact distance. It is advisable to have a permanent test gauge established in close proximity to the surveyor's office.

During the first use, the links become bent and, consequently the chain is shortened. It is also shortened by mud clogging the links when working over muddy ground. On the other hand, it gets elongated due to wear of many wearing surfaces, stretching of the links and joints, and opening out of the small rings and rough handling in pulling it through hedges and fences.

Adjusting the chain If the chain is found to be too long, it may be adjusted by

i) Closing up the joints of the connecting rings (that may be opened out)

ii) Hammering back to the shape of the elongated rings

iii) Replacing some of the worn out rings with new ones

iv) Removing one or more of the small rings.

If the chain is found to be too short, it may be adjusted by

i) Straightening any bent links

ii) Flattening some of the small connecting rings

iii) Replacing some of the worn out rings with new ones

iv) Replacing a few of the rings by those of the larger size

v) Inserting new rings as required

Errors in chaining

The errors that occur in chaining are classified as

i)compensating and

ii) cumulative.

These errors may be due to variation in temperature, defects in construction and personal defects in vision.
Compensating errors: are those which are liable to occur in either direction and hence tend to compensate i.e. they are not likely to make the apparent result too large or too small. Compensating errors are caused due to incorrect holding of the chain, fractional part of the chain may not be correct and during stepping operation, crude method of plumbing is adopted

Cumulative errors: are those which occur in the same direction and tend to add up or accumulate i. e., either to make the apparent measurement always too long or too short. (i) Positive errors - These errors makes the measured length more than actual length. (ii) Negative errors - making the measured length less than the actual.
Errors in measurement due to incorrect length of chain The length of a chain may be correct at the beginning, but it may change with time as more and more used. Due to continuous use of the chain over rough ground, the oval shaped rings get elongated and thus the length of the chain increases. On the other hand some of the links may get bent for there may be kinks. As a result the chain length reduces. In a very old chain, some ring or links may be missing. Therefore, before the start of the work the correctness of the chain length should be tested with a steel or invar tape. If the chain is too long, measured distance will be less and if the chain is short, the measured distance will be more than the actual distance. However, the measured distance can be corrected by using the formula:

Where L' = in correct leng th o f a ch ain ,
L= normal correct length of a chain which may be 20m, 30m,etc.

Therefore, correct distance ×corr[redacted]t [redacted]ngth of chain= Incorrect distance ×

incorrect length of chain . If e is elongation or shortening of chain length, L‟=(L+ e) , plus sign is used when the chain is too long and minus sign is used when the chain is too short.

RANGING:
When a survey line is longer than a chain length, it is necessary to align intermediate points on chain line so that the measurements are along the line. The process of locating intermediate points on survey line is known as ranging

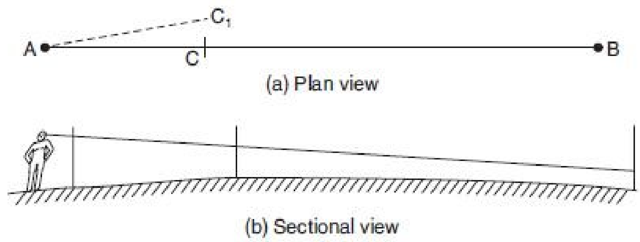


Fig. 12.18. Direct ranging

INDIRECT OR RECIPROCAL RANGING:

Due to intervening ground, if the ranging rod at B is not visible from station A, reciprocal ranging may be resorted. Figure 12.19 shows this scheme of ranging. It needs two assistants one at point M and another at point N, where from those points both station A and station B are visible. It needs one surveyor at A and another at B. To start with M and N are approximately selected, say M1 and N1. Then surveyor near end A ranges person near M to position M2 such that AM2N1 are in a line. Then surveyor at B directs person at N, to move to N2 such that BN2M2 are in a line. The process is repeated till AMNB are in a line.

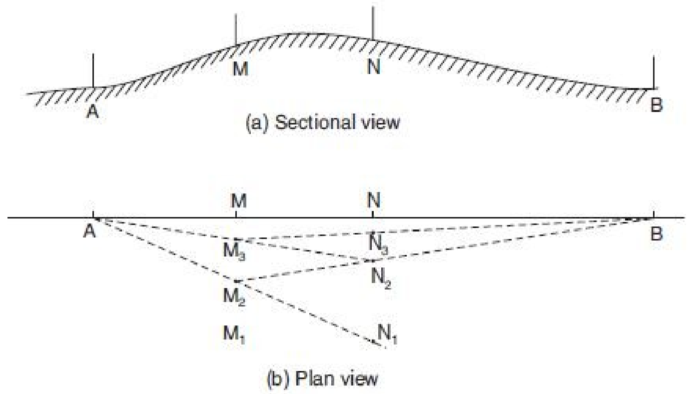


Fig. 12.19. Reciprocal ranging

SCALES:

It is not possible and also not desirable to make maps to one to one scale. While making maps all distances are reduced by a fixed proportion. That fixed proportion is called scale of the map. Thus, if 1 mm on the paper represents 1 metre on the ground, then the scale of the map is 1 mm = 1 m or 1 mm = 1000 mm or 1 : 1000. To make scale independent of the units it is preferable to use representative factor which may be defined as the ratio of one unit on paper to the number of units it represent on the ground.
Thus 1 mm = 1 m is equivalent to
RF = 1 /1000
Apart from writing scale on map, it is desirable to show it graphically on it. The reason is, over the time, the paper may shrink and the scaling down the distances from map may mislead. The graphical scale should be sufficiently long (180 mm to 270 mm) and the main scale divisions should represent one, ten or hundred units so that it can be easily read.
The scale of a map is considered as
(i) large if it is greater than 1 cm = 10 m i.e.,
RF > 1 / 1000
(ii) intermediate if it is between
RF = 1 / 1000 and 1 / 10,000
(iii) small if RF < 1 /10,000
In general, scale selected should be as large as possible, since it is not possible for human eye to distinguish between two point if distance between them is less than 0.25 mm. The recommended scales for various types of surveys are as shown in Table 11.1.

Table 11.1. Recommended scales for various types of surveys

Type of Survey	*Scale*	*RF*
1. Building sites	1 cm = 10 m or less (1 : 1000 or less)	$\frac{1}{1000}$ or less
2. Town planning schemes and reservoirs	1 cm = 50 m to 100 m (1 : 5000 to 1 : 10000)	$\frac{1}{5000}$ to $\frac{1}{10000}$
3. Cadastral maps	1 cm = 5 m to 500 m (1 : 5000 to 1 : 50000)	$\frac{1}{500}$ to $\frac{1}{50000}$
4. Location surveys	1 cm = 50 m to 200 m (1 : 5000 to 1 : 20000)	$\frac{1}{5000}$ to $\frac{1}{20000}$
5. Topographic surveys	1 cm = 250 m to 2500 m (1 : 25000 to 1 : 250000)	$\frac{1}{25000}$ to $\frac{1}{250000}$
6. Geographic maps	1 cm = 5000 m to 160000 m (1 : 500000 to 1 : 16000000)	$\frac{1}{500000}$ to $\frac{1}{16000000}$
7. Route surveys	1 cm = 100 m (1 : 10000)	$\frac{1}{10000}$
8. Longitudinal sections		
(*i*) Horizontal scale	1 cm = 10 m to 200 m (1 : 1000 to 1 : 20000)	$\frac{1}{1000}$ to $\frac{1}{20000}$
(*ii*) Vertical scale	1 cm = 1 m to 2 m (1 : 100 to 1 : 200)	$\frac{1}{100}$ to $\frac{1}{200}$
9. Cross-sections (Both horizontal and vertical scales same)	1 cm = 1 m to 2 m (1 : 100 to 1 : 200)	$\frac{1}{100}$ to $\frac{1}{200}$

The following two types of scales are used in surveying:
1.Plain Scales
2.Diagonal Scale

PLAIN SCALE::On a plain scale it is possible to read two dimensions directly such as unit and tenths. This scale is not drawn like ordinary foot rule (30 cm scale). If a scale of 1 : 40 is to be drawn, the markings are not like 4 m, 8 m, 12 m etc. at every 1 cm distance.

Example 11.1: Construct a plain scale of RF = 1 /500 and indicate 66 m on it.

Solution. If the total length of the scale is selected as 20 cm, it represents a total length of 500 × 20 = 10000 cm = 100 m. Hence, draw a line of 20 cm and divide it into 10 equal parts. Hence, each part correspond to 10 m on the ground. First part on extreme left is subdivided into 10 parts, each subdivision representing 1 m on the field. Then they are numbered as 1 to 10 from right to left as shown in Fig. 11.6. If a distance on the ground is between 60 and 70 m, it is picked up with a divider by placing one leg on 60 m marking and the other leg on subdivision in the first part. Thus field distance is easily converted to map distance.

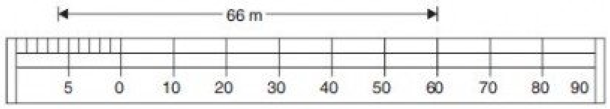


Fig. 11.6

IS 1491—1959 recommends requirements of metric plain scales designated as A, B, C, D, E and F as shown in Table 11.2. Such scales are commonly available in the market. They are made of either varnished cardboard or of plastic materials. Such scales are commonly used by surveyors and architects.

Table 11.2. Recommended plain scales

Designation	*Scale*	*RF*
A	Full size	1/1 (1:1)
	50 cm to a metre	1/2 (1:2)
B	40 cm to a metre	1/2.5 (1:25)
	20 cm to a metre	1/5 (1:5)
C	10 cm to a metre	1/10 (1:10)
	5 cm to a metre	1/20 (1:20)
D	2 cm to a metre	1/50 (1:50)
	1 cm to a metre	1/100 (1:100)
E	5 mm to a metre	1/200 (1:200)
	2 mm to a metre	1/500 (1:500)
F	1 mm to a metre	1/1000 (1:1000)
	0.5 mm to a metre	1/2000 (1:2000)

DIAGONAL SCALE:In plain scale only unit and tenths can be shown whereas in diagonal scales it is possible to show units, tenths and hundredths. Units and tenths are shown in the same manner as in plain scale. To show hundredths, principle of similar triangle is used. If AB is a small length and its tenths are to be shown, it can be shown as explained with Fig. 11.7 below.

Draw the line AC of convenient length at right angles to plain scale AB. Divide it into 10 equal parts. Join BC. From each tenth point on line AC draw lines parallel to AB till they meet line BC. Then line 1–1 represent 1 / 10 th of AB, 6–6 represent 6 / 100 th of AB and so on. Figure 11.8 shows the construction of diagonal scale with RF = 1 / 500 and indicates 62.6 m.

Draw the line AC of convenient length at right angles to plain scale AB. Divide it into 10 equal parts. Join BC. From each tenth point on line AC draw lines parallel to AB till they meet line BC. Then line 1–1 represent $\frac{1}{10}$ th of AB, 6–6 represent $\frac{6}{10}$ th of AB and so on. Figure 11.8 shows the construction of diagonal scale with RF = $\frac{1}{500}$ and indicates 62.6 m.

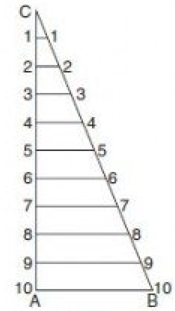


Fig. 11.7

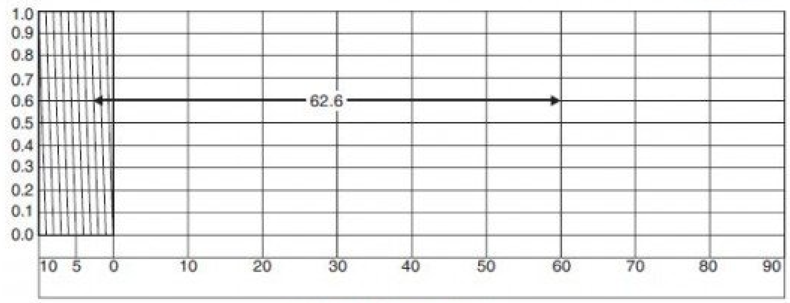


Fig. 11.8. Diagonal scale

IS 1562—1962 recommends diagonal scales *A. B. C.* and *D* as shown in Table 11.3.

Table 11.3. Indian standard diagonal scales (recommended)

Designation	*RF*	*Total Graduated Length*
A	$\frac{1}{1}$	150 cm
B	$\frac{1}{100000}$, $\frac{1}{50000}$, $\frac{1}{25000}$	100 cm
C	$\frac{1}{100000}$, $\frac{1}{50000}$, $\frac{1}{25000}$	50 cm
D	$\frac{1}{100000}$, $\frac{1}{8000}$, $\frac{1}{4000}$	150 cm

<u>OBSTECLES:</u>

Though it is desirable to select stations so as to avoid obstacles, occasionally the obstacles are unavoidable.Various obstacles to chaining may be grouped into:

(i) Obstacles to ranging (chaining free-vision obstructed)

(ii) Obstacles to chaining (chaining obstructed-vision free)

(iii) Obstacles to both ranging and chaining.

<u>Obstacles to Ranging:</u>

These obstacles can be further classified into the following categories:

(a) Both ends of the line are visible from some intermediate points. Intervening ground is an example of such obstacle. By resorting to reciprocal ranging this difficulty can be overcome.

(b) Both ends of the line may not be visible from intermediate points on the line, but may be visible from a point slightly away from the line. Intervening trees and bushes are the examples of such obstacles. This obstacle to chaining may be overcome by measuring along a random line as shown in Fig. 12.20. In this case required length

$$EB = \sqrt{EC^2 + CB^2}$$

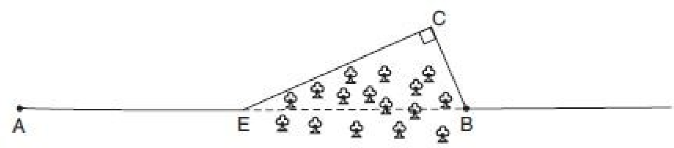


Fig. 12.20. Obstacle to ranging

Obstacles to Chaining:

In this type the ends of lines are visible but chaining is obstructed. Examples of such obstructions are ponds, lakes, marshy land etc. Various geometric properties may be used to find obstructed length CB as shown in Fig. 12.21.

(*a*) Set CD and BE perpendiculars to AB, such that CD = BE. Then

$$CB = DE \qquad \text{[Fig. 12.22 (a)]}$$

(*b*) Set perpendicular CD to AB. Measure CD and DB. Then

$$CB = \sqrt{BD^2 - CD^2} \qquad \text{[Fig. 12.22 (b)]}$$

(*c*) Set CD and DB such that DB ⊥ CD. Measure them. Then

$$CB = \sqrt{CD^2 + BD^2} \qquad \text{[Fig. 12.22 (c)]}$$

(*d*) Select a convenient point F. Set FE = CF and FD = BF. Then

$$CB = DE \qquad \text{[Fig. 12.22 (d)]}$$

(*e*) Select a convenient point F. Locate D and E such that CF = *n* DF and BF = *n* EF. Measure DE. Then,

$$\frac{CF}{DF} = \frac{BF}{EF} = n = \frac{CB}{DE}$$

$$\therefore \quad CB = n\,DE \qquad \text{[Fig. 12.22 (e)]}$$

(*f*) Select points D and E on line passing through C [Fig. 12.22 (*b*)]. Measure CD, CE, DB and EB.

Then, from ΔBDE,

$$\cos\theta = \frac{BD^2 + DE^2 - EB^2}{2BD \cdot DE} \qquad ...(a)$$

and from ΔBDC,

$$\cos\theta = \frac{CD^2 + BD^2 - CB^2}{2CD \cdot BD} \qquad ...(b)$$

Obstacles to Both Chaining and Ranging :

Building is a typical example of this obstacle. Referring to Fig. 12.22, line AB is to be continued beyond the obstacle,

say as GH. Four possible methods are presented below:
(a) Set perpendiculars AC, BD such that AC = BD [Fig. 12.22 (a)]. Extend line CD to F. Drop perpendiculars EG and FH to line CF such that EG = FH = AC. GH is the continuation of line AB and DE = BG.
(b) Referring to Fig. 12.22 (b), set BC ⊥ to AB. Select D on extended line of AC. Set perpendicular DH such that AD = DH. Select point E on DH such that DE = DC. Then arcs of length EG = BC and arc of length HG = AB are drawn from E and H respectively and G is located. GH is continuation of AB and BG = CE. (c) Referring to Fig. 12.22 (c), C is located such that AC = BC = AB. Extend AC to D and construct equilateral triangle DEF. Extend DF to H such that DH = DA. Locate convenient point I on HD and construct equilateral triangle to locate G. Then GH is the continuation of line AB and length BG
is given by
BG = AH – AB – GH = AD – AB – GH

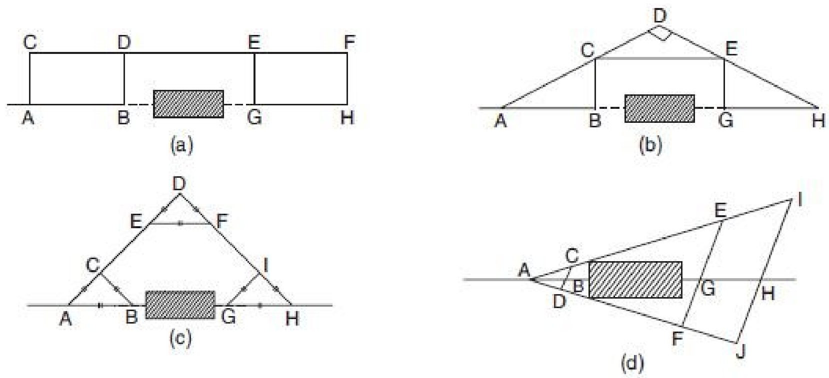


Fig. 12.22. Obstacles to both ranging and chaining

$$CD = 220 \text{ m} \qquad CE = 280 \text{ m}$$
$$DB = 500 \text{ m} \qquad EB = 600 \text{ m}$$
$$\therefore \quad DE = DC + CE = 220 + 280 = 500 \text{ m}$$

From ΔBDE,

$$\cos\theta = \frac{DE^2 + BD^2 - EB^2}{2\, DE \cdot BD} = \frac{500^2 + 500^2 - 600^2}{2 \times 500 \times 500} = 0.28$$

From ΔBDC,

$$\cos\theta = \frac{CD^2 + BD^2 - BC^2}{2\, CD \cdot BD}$$

$$0.28 = \frac{220^2 + 500^2 - BC^2}{2 \times 220 \times 500}$$

$$61600 = 220^2 + 500^2 - BC^2$$

$$\mathbf{BC = 486.62 \text{ m}} \quad \textbf{Ans.}$$

Errors in chaining may be classified as:
(i) Personal errors
(ii) Compensating errors, and
(iii) Cumulating errors.

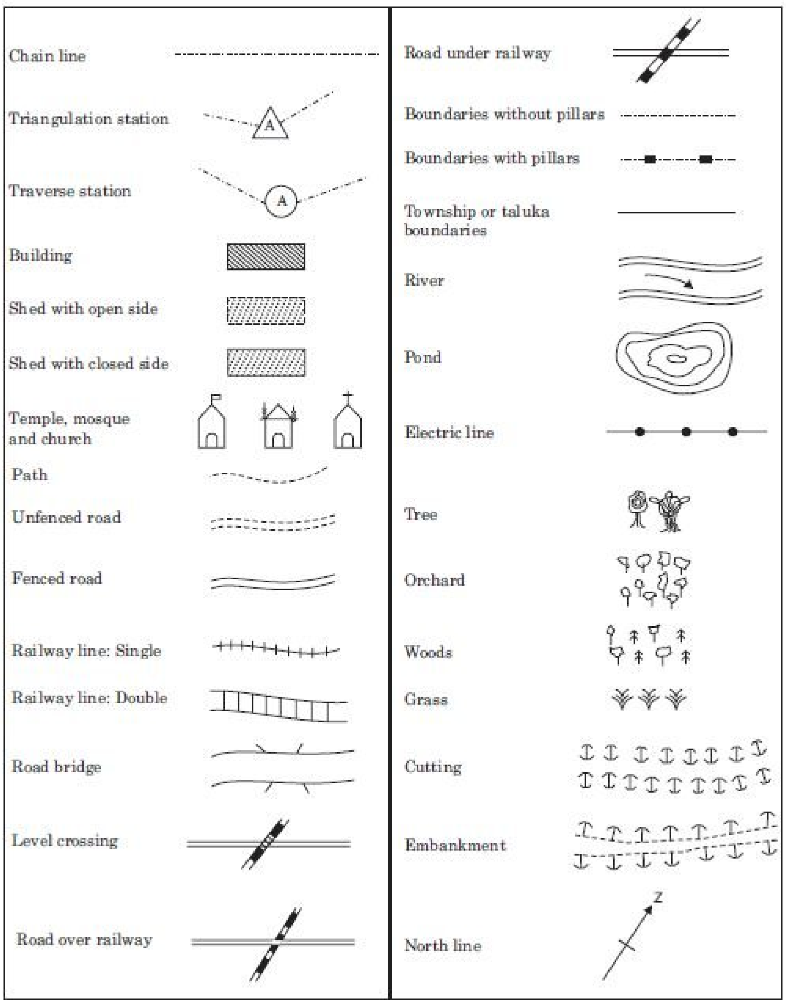
Personal Errors
Wrong reading, wrong recording, reading from wrong end of chain etc., are personal errors. These errors are serious errors and cannot be detected easily. Care should be taken to avoid such errors.

Compensating Errors
These errors may be sometimes positive and sometimes negative. Hence they are likely to get compensated when large number of readings are taken. The magnitude of such errors can be estimated by theory of probability. The following are the examples of such errors:
(i) Incorrect marking of the end of a chain.
(ii) Fractional part of chain may not be correct though total length is corrected.

(iii) Graduations in tape may not be exactly same throughout.
(iv) In the method of stepping while measuring sloping ground, plumbing may be crude.

Cumulative Errors
The errors, that occur always in the same direction are called cumulative errors. In each reading the error may be small, but when large number of measurements are made they may be considerable, since the error is always on one side. Examples of such errors are:

(i) Bad ranging
(ii) Bad straightening
(iii) Erroneous length of chain
(iv) Temperature variation
(v) Variation in applied pull
(vi) Non-horizontality
(vii) Sag in the chain, if suspended for measuring horizontal distance on a sloping ground.
Errors (i), (ii), (vi) and (vii) are always +ve since they make measured length more than actual.
Errors (iii), (iv) and (v) may be +ve or –ve.



Chain triangulation and Cross-staff survey

Measurement of areas One of the main purpose of surveying is to measure the area of an agricultural farm, area of plots to be used for construction purposes, command area of tube wells, canals etc. Two general methods for measuring areas are: i) Triangulation, and ii) Traversing. In traversing, the length of connected lines as well as their directions are measured by chain and compass respectively.

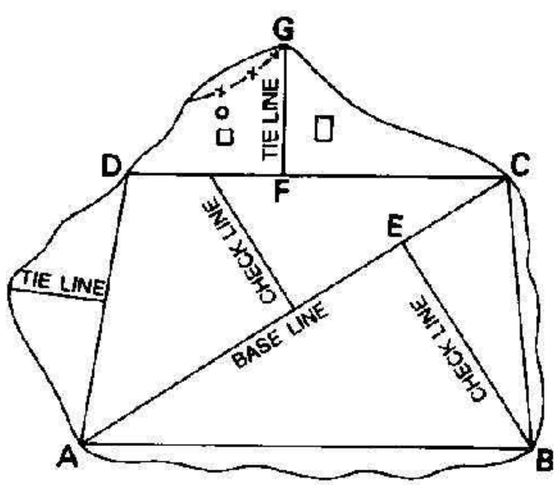
Triangulation survey Triangulation is the basis of trigonometrical or geometric surveys. As such triangulation refers to a system of surveying in which one line is measured with a chain and all the three angles are measured correctly by compass or theodolite. In case, only the sides of the triangles are directly measured in the field and no angular measurement is taken, it is called triangulation (or) chain surveying. The whole area is suitably divided into number of triangles and computes the area of individual triangles and added to get total area. In dividing the total area into triangles, care should be taken to see that the triangles are almost equilateral as far as possible to minimum the errors. Although, the chain triangulation is very simple, but it is suitable only for small plane areas without much obstruction.

Survey stations A survey station is a point of reference at the beginning and end of a chain line. Stations are of two types, they are:

i)Main stations

ii) Subsidiary on tie stations.

Main stations :Main stations are the ends of the lines which connect the boundaries of the survey, and the lines joining the main stations are called the main survey or chain lines. Subsidiary or tie stations are the points selected on main survey lines to run auxiliary lines to locate the interior details such as fences, hedges, buildings etc. when they are distant from the main lines. The symbol "O" is used to denote stations. Capital and small letters are used to represent main and tie stations respectively.



Selection of stations :While arranging the frame work of survey by selecting different stations, the following points should be kept in mind:
1) All the main stations should be inter-visible.
2) The first principle in surveying is the working from whole to part and not from part to whole. This should be strictly followed.
3) Generally, a long line (base line) should be run approximately through the centre and the whole length of the area.
4) All triangles should be well conditioned to make their sides almost equal.
5) Long offsets should be avoided.
6) As far as possible, the no. of survey lines should be minimized.

Base Line: The longest chain line in chain surveying is called the base line. This is the most important line and the whole framework of triangles is based on this line and therefore, the baseline should be very accurately measured It should be passing through the centre of the area.

Subsidiary or tie lines: When numbers of features are to be located and they are far away from the main chain lines, then subsidiary or tie lines are used to locate such details. Tie line FG is used to locate number of features. Tie line is obtained by joining two fixed points on the main survey line. Tie lines can also be used as check lines to check the accuracy of measurements and plotting.

Check lines: Check lines are also called as proof lines. The mistakes of the measurement and plotting can be easily checked with the help of check lines. The check line is a line joining the apex of a triangle to some fixed points on the opposite side, a line joining some fixed points on any two sides of a triangle. Every triangle should be provided with a check line.

A chain survey may be executed in the following steps:

Reconnaissance: The preliminary instruction of the area to be surveyed is called reconnaissance. It is essential that the surveyor should have a thorough knowledge of the ground to be surveyed and its principle features. On arriving at the ground, the surveyor should therefore, walk over the whole area and thoroughly examine the ground, so as to decide upon the best possible arriving of the work. The surveyor should note the various boundaries, the positions of buildings, roads, streams etc., various difficulties that may intervene the proposed chain lines and the suitable positions of the stations. During the reconnaissance, the surveyor should prepare a neat hand sketch called an index sketch or key plan fairly resembling the plan of the ground, showing the boundaries, the principles features such as buildings, roads, tanks, etc., the positions of the stations and chain lines. The sketch is drawn in the field.

Marketing stations: Having completed the reconnaissance and the index sketch, survey stations should be marked on the ground by fixing vertically a ranging rod or a pole at each station if the survey is only of a temporary character.

Reference sketches: After the stations are marked, they should be referred i.e., located the measurements called ties, taken from three permanent points which are definite and easily recognized i.e., corners of buildings, gate pillars, boundary stones, fence posts. Reference sketches in case the station marks are displaced or lost or required at a future data.

Running survey lines: Having finished the preliminary work, chaining may be commenced from the base line and carried through all the lines of the frame work as continuously as possible

Plotting procedure of chain survey After the survey is completed, the recorded information is taken to the office and they are plotted on a drawing sheet using a suitable scale. While plotting a chain survey, the following steps are to be followed:

(i) Depending upon the area covered in the survey and its importance, a suitable scale is chosen. Boundary lines are drawn leaving a suitable margin all around. (ii) The base line which is the mainline in the survey should be suitably located in the map to accommodate the whole plotting easily in the drawing sheet. The base line should be most accurately plotted.

(iii) The intermediate stations are marked on the base line and the frame work of triangles is completed.

(iv) Chainage lengths are measured along the chain lines for various offsets and points are marked. From these points perpendiculars of suitable lengths are drawn to locate the offsets. (

v) The accuracy of plotted frame work may be checked by means of check and tie lines.

(vi) The field book should be kept side by side in the same direction as the survey proceeded in the field parallel to the chain line to be plotted.

(vii) For drawing different objects, conventional symbols should be used.

(viii) The title of the survey, name of the surveyor, date etc., should be written at the right hand bottom corner. The scale is drawn below the map.

Compass Survey

In compass survey chain or tape is used for linear measurement. If the surveying starts from a station, goes round an area and ends at the starting station it is called closed traverse. If survey starts from a point, goes along a number of interconnected lines and ends at some other point it is called as open traverse. Closed traverse is used for preparing plan of an area while open traverse is useful in the road, rail or canal projects. The following are required for chain and compass survey:

(i) Compass and stand
(ii) Chain and tape
(iii) 10 arrows
(iv) 5 to 6 ranging rods
(v) Ranging poles
(vi) Pegs and hammer
(vii) Plumb bobs
(viii) Line ranger, cross staff etc.

Field Work
Field work involves:
(i) reconnaissance survey
(ii) preparation of location sketches of stations
(iii) measurement of directions
(iv) measurement of lengths and offsets, and
(v) recording measurements.
(i) Reconnaissance Survey: The entire area to be surveyed is inspected to select survey stations.
Important points to be considered in selecting stations are:
(a) Adjacent stations should be intervisible.
(b) Lines to be chained should be free of obstacles.
(c) Number of survey lines should be minimum.

(d) Survey lines should run close to the important objects, so that offset lengths are small.
An index map is prepared with pencil and stations are marked. If necessary, changes may be made in survey lines and corresponding changes in the index plan.
Location Sketches
Before commencing surveying a line, the location sketches of the stations of that line should be prepared.
At the beginning of the field book few pages should be reserved for drawing location sketches.

Direction Measurement
The following precautions should be taken in measuring the direction of a survey line with compass.
(a) Centre the compass on the station correctly.
(b) Level the compass and ensure needle is free to move.
(c) Take the reading only after vibration of graduation circle/needle is stopped. Use the knob, if necessary.
(d) Gently tap the top of the glass of compass to remove sluggishness of the needle and take the reading after vibration stops.
(e) While taking reading parallax should be avoided.
(f) Care should be taken to keep away steel and iron objects like key bunch, metal framed spectacles, iron buttons, chain, arrows etc.
(g) If handkerchief is used to clean top of glass of campass, the glass is charged with electricity. As a result of it local attraction is induced. To avoid this problem apply moist fingers to clean the glass.
(h) If the compass is not in use, fold the prism and object vane on the top of glass plate, so that needle is lifted from the pivot to avoid unnecessary wear of the pivot.
(i) For all survey lines fore bearings and back bearings should be taken. If any other survey station is visible, bearing should be taken to that station also, which helps in checking survey work.

BEARINGS: Bearing of a line is the angle made by the line with respect to a reference direction, the reference direction being known as meridian. The direction shown by a freely suspended and properly balanced magnetic needle is called magnetic meridian and the horizontal angle made by a line with this meridian is known as magnetic bearing.
The points of intersection of earth's axis with surface of the earth are known as geographic north and south pole. The line passing through geographic north, south and the point on earth is called true meridian at that point and the angle made by a line passing through that point is called true bearing.
In whole circle bearing (WCB) the bearing of a line at any point is measured with respect to a meridian. Its value varies from zero to 360°, increasing in clockwise direction. Zero is north direction, 90° is east, 180° is south and 270° is west (Ref. Fig. 13.2). This type of bearing is used in prismatic compass.

In reduced bearing (RB) system, bearings are measured from north or south direction towards east or west. Hence, angles are from 0 to 90° as shown in Fig. 13.3. This system of measuring bearings is used in Surveyor's compass and it is also known as Quadrantal Bearing (QB). The bearing measured is designated with letter N or S in the beginning to indicate whether it is from north or south. The letter E or W written after the angle indicates whether the bearing read is towards east or west, respectively.
The conversion of the bearing from one system to the other system can be easily carried out

by drawing a sketch to indicate WCB o

Quadrant in which bearing lies	*Conversion relation*
NE	$\alpha = \theta$
SE	$\alpha = 180° - \theta$
SW	$\alpha = \theta - 180°$
NW	$\alpha = 360° - \theta$

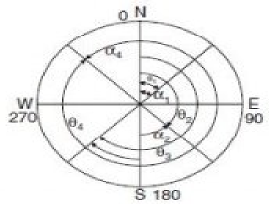


Fig. 13.4

r

RB as shown in Fig. 13.4. It may be observed that conversion table is as given below:

To take a reading from a compass, the following temporary adjustments are required:
(i) Centring: The compass should be fixed to the stand and set over the station. To centre the compass legs of the tripod stand should be moved inward-outward or in a circumferential direction. To check centring plumb may be used or a pebble dropped from the centre of the compass.
(ii) Levelling: In compass survey perfect levelling is not necessary, but it should be sufficient to permit free suspension of magnetic needle. For checking levelling a bubble level is provided in many compasses. After centring bubble should be ensured in the middle of the circle provided for it in the level. If it is not within that circle, circumferential movements may be provided to the legs of tripod so that without disturbing centring the levelling is achieved.
(iii) Focussing the prism: In prismatic compass, to focus the prism on graduated circle, its attachment is slided up or down till the readings are clearly visible. There is no such requirement in surveyors compass.
The following steps are required for observing bearing of a line, say, AB:
(i) Centre the compass over A.
(ii) Level the compass.
(iii) Focus the prism, if prismatic compass is used.
(iv) Rotate the box till ranging rod at B is sighted through the line of sight.
(v) Bring the needle to rest using knob.
(vi) Take the reading and note it in the field book.
Care should be taken to see that the line of sight is not disturbed between the line of sighting the object and the time of reading the bearing.

A freely suspended and properly balanced magnetic needle is expected to show magnetic meridian.
However, local objects like electric wires and objects of steel attract magnetic needle towards themselves.
Thus, needle is forced to show slightly different direction. This disturbance is called local attraction.
The list of materials which cause local attraction are:
(i) magnetic rock or iron ore,
(ii) steel structures, iron poles, rails, electric poles and wires,
(iii) key bunch, knife, iron buttons, steel rimmed spectacles, and
(iv) chain, arrows, hammer, clearing axe etc.
Surveyor is expected to take care to avoid local attractions listed in (iii) and (iv) above.

Detecting Local Attraction
For detecting local attraction it is necessary to take both fore bearing and back bearing for each line. If the difference is exactly 180°, the two stations may be considered as not affected by local attraction. If difference is not 180°, better to go back to the previous station and check the fore bearing. If that reading is same as earlier, it may be concluded that there is local attraction at one or both stations.

Correcting Observed Bearings

If local attraction is detected in a compass survey observed bearings may be corrected by any one of the following two methods:

Method I: It may be noted that the included angle is not influenced by local attraction as both readings are equally affected. Hence, first calculate included angles at each station, commencing from the unaffected line and using included angles, the corrected bearings of all lines may be calculated.

Method II: In this method, errors due to local attraction at each of the affected station is found starting from the bearing of a unaffected local attraction, the bearing of the successive lines are adjusted.

The magnetic meridian and the true meridian may not coincide with each other in a place. The horizontal angle between these two meridians is known as magnetic declination. The magnetic north at a place may be towards east or west of true north (Fig. 13.7). If it is towards east, it is known as eastern or +ve declination. Western declination is known as –ve declination. Eastern declination is to be added to observed magnetic bearings to get true meridian. To find magnetic declination at a point true meridian should be established from astronomical observations and magnetic meridian by a compass. Maps are made with respect to true meridian.

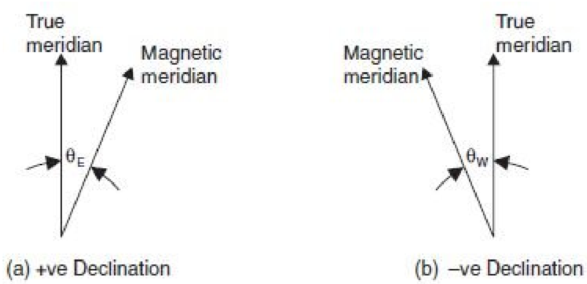


Fig. 13.7. Magnetic declination

Magnetic declination varies from time to time and also from place to place. In the noon sun is exactly on the geographical meridian. In India, 'Survey of India' department conducts astronomical survey and publishes Isogonic Charts from which magnetic declinations at any point can be found.

The lines joining the points at which declination is the same at the given time are called 'Isogonic Lines'. Lines joining points of zero declinations are called 'Agonic Lines'. The isogonic lines are quite irregular near geographic poles. The isogonic charts show lines of equal annual change in declination.

The following type of variations are observed in declination:

(i) Secular variation,
(ii) Annual variation,
(iii) Daily variations, and
(iv) Irregular variations.

13.6.1 Secular Variation

The magnetic meridian swings like a pendulum to the left and to the right of true meridian. Its period of variation is approximately 250 years.

13.6.2 **Annual Variation**

It is observed that in a year declination varies from 1′ to 2′.

13.6.3 **Daily Variation**

The daily variation of magnetic declination is as much as 10′. This variation is also known as 'Dirunal Variation'. The following factors influence its magnitude:

(a) It is more in day and less in night.
(b) It is more in summer and less in winter.
(c) The amount of variation changes from year to year.
(d) It is more near magnetic poles and less near equator.

13.6.4 **Irregular Variation**
Due to earthquakes and volcanic eruptions, magnetic storms occur, resulting into changes in magnetic meridian. Such changes are from 1° to 2°.

Magnetic Dip

A perfectly balanced, freely suspended magnetic needle dips towards its northern end in northern hemisphere and towards its southern end in southern hemisphere. If it is at north pole, the needle takes vertical position. The vertical angle between the horizontal and the direction shown by a perfectly balanced and freely suspended needle is known as the magnetic dip at that place. Its value is 0° at equator and 90° at magnetic poles. To counteract the dip, a sliding rider (weight) is provided on the needle.

PLANE TABLE SURVEYING

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

ACCESSORIES USED IN PLANE TABLE:

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

1.Plane table
2. Alidade
3. Plumbing fork with plumb bob.

4. Spirit level
5. Trough compass
6. Drawing sheets and accessories for drawing

1.Plane table

The most commonly used plane table is shown in Fig. 14.1. It consists of a well seasoned wooden table top mounted on a tripod. The table top can rotate about vertical axis freely. Whenever necessary table can be clamped in the desired orientation. The table can be levelled by adjusting tripod legs.

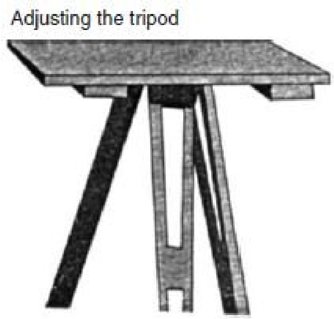


Fig. 14.1. Plane table with stand

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Alidade

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

Plain Alidade: Figure 14.2 shows a typical plain adidate. A sight vane is provided at each end of the ruler. The vane with narrow slit serves as eye vane and the other with wide slit and having a thin wire at its centre serves as object vane. The two vanes are provided with hinges at the ends of ruler so that when not in use they can be folded on the ruler. Plain alidade is not suitable in surveying hilly areas as the inclination of line of sight in this case is limited.

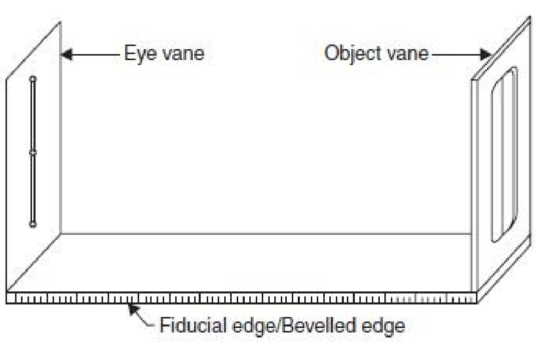


Fig. 14.2. Plane alidade

Telescopic Alidade: It consists of a telescope mounted on a column fixed to the ruler [Fig. 14.3]. The line of sight through the telescope is kept parallel to the bevelled edge of the ruler. The telescope is provided with a level tube and vertical graduation arc. If horizontal sight is required bubble in the level tube is kept at the centre. If inclined sights are required vertical graduation helps in noting the inclination of the line of sight. By providing telescope the range and the accuracy of line of sight is increased.

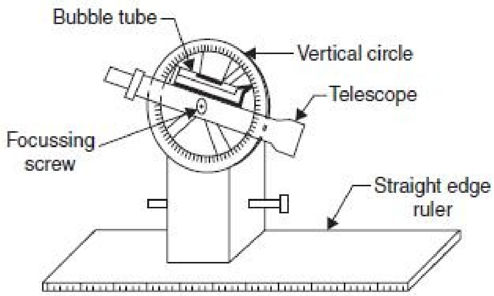


Fig. 14.3. Telescopic alidade

Plumbing Fork and Plumb Bob

Figure 14.4 shows a typical plumbing fork with a plum bob. Plumbing fork is a U-shaped metal frame with a upper horizontal arm and a lower inclined arm. The upper arm is provided with a pointer at the end while the lower arm is provided with a hook to suspend plumb bob. When the plumbing fork is kept on the plane table the vertical line (line of plumb bob) passes through the pointed edge of upper arm. The plumb bob helps in transferring the ground point to the drawing sheet and vice versa also.

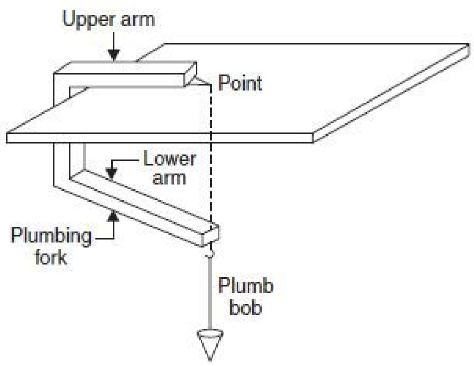


Fig. 14.4. Plumbing fork and plumb bob.

Spirit Level

A flat based spirit level is used to level the plane table during surveying (Fig. 14.5). To get perfect level, spirit level should show central position for bubble tube when checked with its positions in any two mutually perpendicular direction.

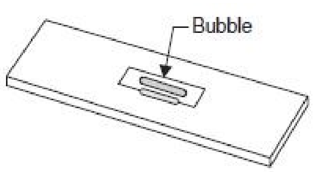


Fig. 14.5. Spirit level

Trough Compass

It consists of a 80 to 150 mm long and 30 mm wide box carrying a freely suspended needle at its centre (Ref. Fig. 14.6). At the ends of the needle graduations are marked on the box to indicate zero to five degrees on either side of the centre. The box is provided with glass top to prevent oscillation of the needle by wind. When needle is centred (reading 0–0), the line of needle is parallel to the edge of the box. Hence marking on the edges in this state indicates magnetic north–south direction.

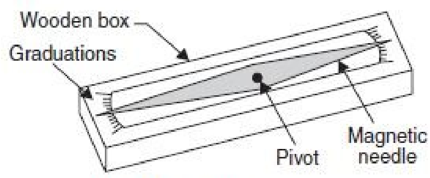


Fig. 14.6. Trough compass

Drawing Sheet and Accessories for Drawing

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

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

The following four methods are available for carrying out plane table survey:

1. Radiation
2. Intersection
3. Traversing
4. Resection.

The first two methods are employed for locating details while the other two methods are used for locating position of plane table station on drawing sheet.

Radiation

After setting the plane table on a station, say O, it is required to find the plotted position of various objects A, B, C, D ….. . To get these positions, the rays OA, OB, OC ….. are drawn with soft pencil (Ref. Fig. 14.7). Then the distances OA, OB, OC ….., are measured scaled down and the positions of A, B, C ….., are found on the drawing sheets.

This method is suitable for surveying small areas and is convenient if the distances to be measured are small. For larger areas this method has wider scope, if telescopic alidade is used, in which the distances are measured technometrically.

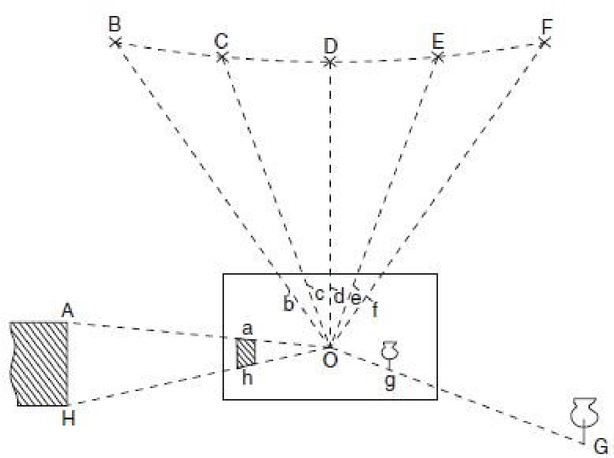


Fig. 14.7. Radiation method of plane tabling

Intersection

In this method the plotted position of an object is obtained by plotting rays to the object from two stations. The intersection gives the plotted position. Thus it needs the linear measurements only between the station points and do not need the measurements to the objects. Figure 14.8 shows the method for locating objects A and B from plane table positions O1 and O2.

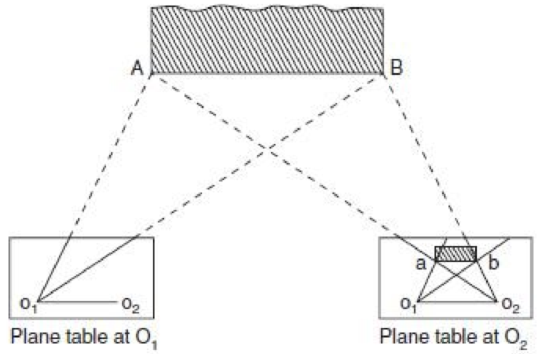


Fig. 14.8. Intersection method of plane tabling

This method is commonly employed for locating:
(a) details
(b) the distant and inaccessible points
(c) the stations which may be used latter.

Traversing

This is the method used for locating plane table survey stations. In this method, ray is drawn to next station before shifting the table and distance between the stations measured. The distance is scaled down and next station is located. After setting the plane table at new station orientation is achieved by back sighting. To ensure additional checks, rays are taken to other stations also, whenever it is possible. Figure 14.9 shows a scheme of plane table survey of closed area. This method can be used for open traverses also.

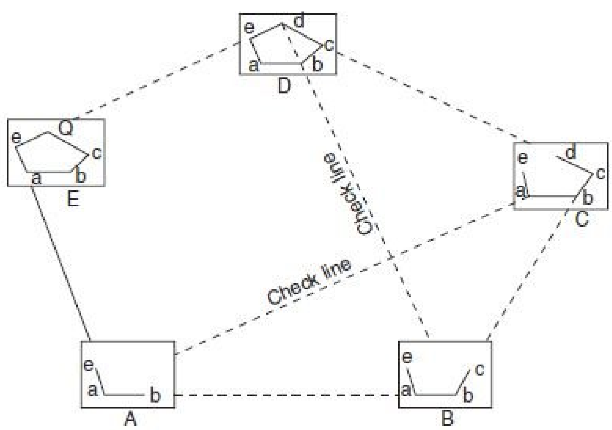


Fig. 14.9. Plane table traversing

Resection

This method is just opposite to the method of intersection. In the method of intersection, the plotted position of stations are known and the plotted position of objects are obtained by intersection. In this method the plotted position of objects are known and the plotted position of station is obtained. If a, b and c are the plotted positions of objects A, B and C respectively, to locate instrument station P on the paper, the orientation of table is achieved with the help of a, b, c and then resectors Aa, Bb, Cc are drawn to get the 'p' , the plotted position of P. Hence in the resection method major work is to ensure suitable orientation by any one of the methods. The following methods are employed in the method of resection:

(a) by compass
(b) by back sighting
(c) by solving two point problem
(d) by solving three point problem.

(a) Resection after Orientation by Compass: Let a and b be the plotted positions of A and B of two well defined points in the field. Keeping the through compass along north direction marked on the drawing sheet table is oriented on station P, the position of which is to be found on paper. The resectors Aa and Bb [Fig. 14.10] are drawn to locate 'p' the plotted position of station point P. This method gives satisfactory results, if the area is not influenced by local attractions. It is used for small scale mapping only.

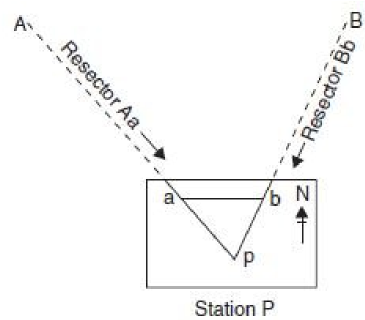


Fig. 14.10. Resection after orientation with compass

(b) Resection after Orientation by Back Sighting: Figure 14.11 shows the scheme of resection after orientation by back sighting. From station A, the position of B is plotted as 'b' and ray has been taken to station P as ap'. Then plane table is set at P and oriented by back sighting A, line AP is not measured but the position of P is obtained on the paper by taking resection Bb.

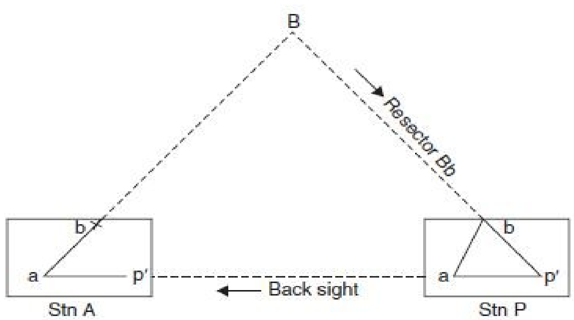


Fig. 14.11. Resection after back sighting

(c) Resection after Solving Two Point Problem: The problem of finding plotted position of the station point occupied by the plane table with the help of plotted positions of two well

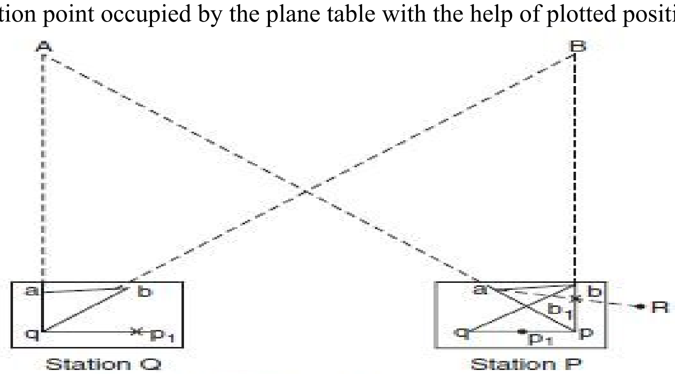


Fig. 14.12. Two-point problem

defined points is known as solving two point problem. Figure 14.12 shows the scheme of solving this.

Procedure: Let A and B be two well defined points like lightening conductor or spire of church, the plotted positions a and b already known. Now the problem is to orient the table at P so that by resection its plotted position p can be obtained. The following steps may be followed to solve this problems:
(i) Select a suitable point Q near P such that the angles PAQ and PBQ are not accute.
(ii) Roughly orient the table at Q and draw the resectors Aa and Bb to get the point 'q'.
(iii) Draw the ray qp and locate p1 with estimated distance QP.
(iv) Shift the plane table to P and orient the table by back sighting to Q.
(v) Draw the resector Aa to get 'p'.
(vi) Draw the ray pB. Let it intersect line bq at b1.
(vii) The points b and b1 are not coinciding due to the angular error in the orientation of table. The angle bab, is the angular error in orientation. To correct it,
* Fix a ranging rod at R along ab, * Unclamp the table and rotate it till line ab sights ranging rod at R. Then clamp the table. This gives the correct orientation of the table which was used in plotting the points A and B. (viii) The resectors Aa and Bb are drawn to get the correct plotted position 'p' of the station P.
(d) Resection after Solving Three Point Problem: Locating the plotted position of a station point using observations to three well defined points whose plotted positions are known, is called solving three point problem.
Let A, B, C be three well defined objects on the field whose plotted positions a, b and c are known. Now the problem is to locate plotted position of the station point P. Any one of the following methods can be used.
(i) Mechanical (Tracing paper) method,
(ii) Graphical method, or
(iii) Trial and error method (Lehman's method).
(i) Mechanical Method: This method is known as tracing paper method since it needs a tracing paper. The method involved the following steps [Ref. Fig. 14.13.]

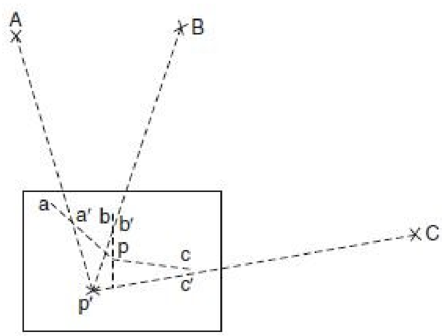


Fig. 14.13

* Set the table over station P and by observation approximately orient the table.
* Fix the tracing paper on the plane table and select P approximately, say as p′. From p′, draw p′ A, p′ B and p′ C. These lines may not pass through the plotted positions a, b and c since the orientation is not exact.
* Loosen the tracing paper and rotate it so that the rays pass through respective points a, b and c. Now prick the point p′ to get the plotted position 'p' of the station P.
* Keep the alidade along pa and sight A. Then clamp the table. This is correct orientation. Check the orientation by observing along pb and pc.
(ii) Graphical Method: The following two graphical methods are available to solve three point problem:
* Bessel's solution
* Method of perpendiculars.
Bessels Solution: It involves the following steps:
1. Keep the bevelled edge of alidade along ba and sight object at A. Clamp the table and draw

bc′ along the line bc [Fig. 14.14 (a)].
2. Keep bevelled edge of alidade along ab, unclamp the table and sight B. Clamp the table. Draw line ac intersecting bc′ at d [Fig. 14.14(b)].
3. Keep the alidade along dc and bisect C. Clamp the table [Fig. 14.14(c)]. This gives the correct orientation.
4. Draw resectors to get ‘p’.

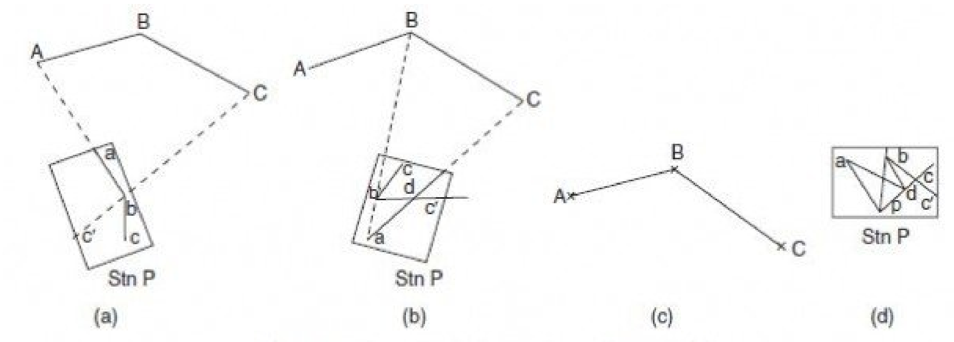


Fig. 14.14. Graphical solution (Bessel’s method)

Method of Perpendiculars
This is another graphical method. It involves the following steps [Ref. Fig. 14.15].
1. Draw line ae perpendicular to ab. Keep alidade along ea and turn the table till A is sighted. Clamp the table and draw the ray Bb to intersect the ray Aac at e [Fig. 14.15(a)].
2. Draw cf perpendicular to bc and clamp the table when fcC are in a line. Draw Bb to intersect Ccf at F [Fig. 14.15(b)].

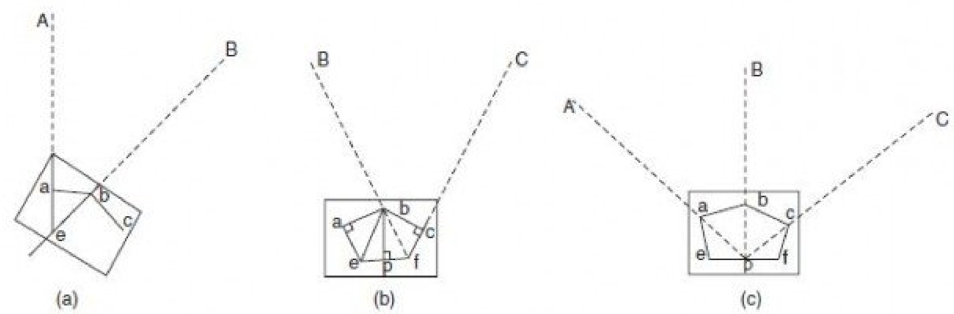


Fig. 14.15. Method of perpendiculars of solve three point problem

3. Join cf drop bp perpendicular to ef to get the plotted position ‘p’.
4. Orient the table such that pbB are in a line. Clamp the table to place it in correct orientation. Resections Aa and Cc may be used to check the orientation.

Trial and Error Method
This method is also known as ‘triangle of error method’ and ‘Lehman’s Method’. It involves the following steps:
1. Set the table over point P and orient the table approximately, just by observation.
2. Draw the rays aA, bB and cC [Fig. 14.16]. If the orientation was perfect, the three rays would have intersected at a single point, i.e. at point ‘p’. Otherwise a triangle of error is formed.
3. To eliminate the triangle of error an approximate position, ray p′, is selected near the triangle of error. Then keeping alidade along p′a object A is sighted and the table is clamped. Draw the resectors cC and bB to check the orientation.
4. Above step is repeated till triangle of error is eliminated.

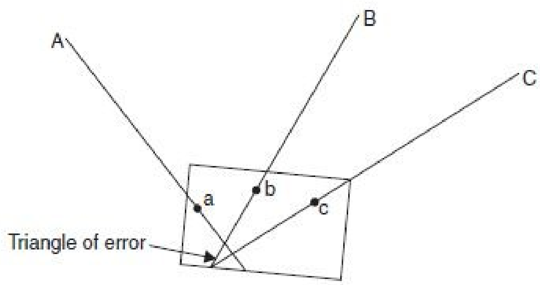


Fig. 14.16

Lehman presented the following guidelines to select ‘p′’ so that triangle of error is eliminated quickly.
Rule 1: The distance of point sought ‘p’ is in the same proportion from the corresponding rays as the distance of those from the plane table station.

Rule 2: The point sought ‘p’ is on the same side of all the three resectors.
Defining the triangle ABC on the field as great triangle and the circle passing through them as great circle, from the above two rules of Lehman, the following sub-rules may be drawn [Ref. Fig. 14.17].

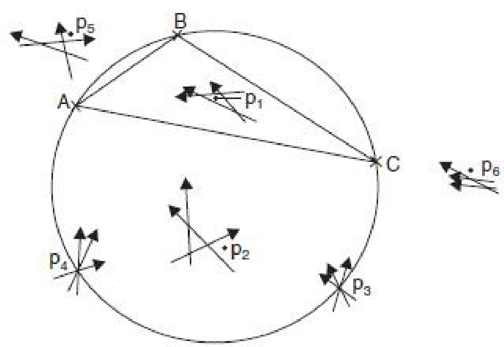


Fig. 14.17

* If ‘P’ lies within the great triangle, the point ‘p’ is within the triangle of error (p1 in the Fig. 14.17).
* If the plane table station P lies outside the great triangle the point sought ‘p’ is outside the triangle of errors (p2).
* If the ‘P’ is on the great circle, the correct solution is impossible (p3 and p4).
* If ‘P’ is outside the great circle, ‘p’ is nearer to the intersection of rays to the nearest two points (P5).
* If point P is outside the great circle and the two rays drawn are parallel to each other the point sought is outside the parallel lines and on the same side of the three rays (P6).

Advantages are
1. Possibility of omitting measurement is eliminated.
2. The surveyor can compare the plotted work in the field then and there only.
3. Irregular objects are plotted more accurately, since they are seen while plotting.
4. Booking errors are eliminated.
5. Local attractions do not influence the plotting.
6. No great skill is required to produce satisfactory maps.
7. Method is fast.
8. No costly instruments are required.

Limitations are

1. Survey cannot be conducted in wet weather and rainy days.
2. Plane table is cumbersome and heavy to carry.
3. It needs many accessories.
4. It is less accurate.
5. Reproduction of map to different scale is difficult.

The errors may be grouped into the instrumental and personal errors.

Instrumental Errors

1. The surface of plane table not perfectly plane.
2. Bevelled edge of alidade not straight.
3. Sight vanes of alidade not perfectly perpendicular to the base.
4. Plane table clamp being loose.
5. Magnetic compass being sluggish.
6. Drawing sheet being of poor quality.

Personal Errors

1. Centering errors
2. Levelling errors
3. Orientation errors
4. Sighting errors
5. Errors in measurement
6. Plotting errors
7. Errors due to instability of tripod.

LEVELLING

DEFINITION: Levelling is the branch of surveying which is used to determine the elevations of given points with respect to a datum.Levelling deals with veticle distences of the point.
The following methods are used to determine the difference in elevation of various points:
(i) Barometric levelling (ii) Hypsometric levelling
(iii) Direct levelling and (iv) Indirect levelling.

Barometric Levelling
This method depends on the principle that atmospheric pressure depends upon the elevation of place. Barometer is used to measure the atmospheric pressure and hence elevation is computed. However it is not accurate method since the atmospheric pressure depends upon season and temperature also. It may be used in exploratory surveys.

Direct Levelling
It is common form of levelling in all engineering projects. In this method horizontal sight is taken on a graduated staff and the difference in the elevation of line of sight and ground at which staff is held are found. Knowing the height of line of sight from the instrument station the difference in the elevations of instrument station and the ground on which staff is held can be found. This method is thoroughly explained in next article.

Indirect Methods
In this method instruments are used to measure the vertical angles. Distance between the instrument and staff is measured by various methods. Then using trigonometric relations, the difference in elevation can be computed. This is considered beyond the scope of this book. One can find details of such methods in books on surveying and levelling.

Levelling instruments

Two instruments are required to determine the reduced levels of points. They are:

(i) level and

(ii) a levelling staff.

The level is used to provide a horizontal line of sight and the levelling staff which is a graduated rod is used to read the vertical height of the line of sight above the selected station. g may be defined as the art of determining the relative heights or elevations of points or objects on the surface of the earth. Therefore, it deals with measurements in vertical plane. Levelling has wide applications in the field of agriculture. Construction of irrigation and drainage channels, terraces, bunds, reservoirs, outlet structures, etc, require the knowledge of surveying. For any soil conservation and land levelling work, levelling is the first job to be taken up.

The level

Various types of levels are used for surveying *v*iz

(i)Wey level,

(ii)Tilting level and

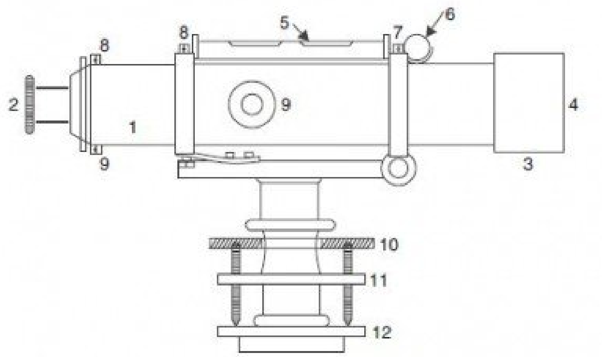
(iii)Dumpy level.

(iv)Reversible level

The dumpy level is widely used for levelling works. For small and rough levelling works, the hand levels and farm levels are used. The dumpy level is very sturdy, compact and stable equipment. The telescope is rigidly fixed to the frame. Therefore, the telescope cannot be rotated about the longitudinal axis and also cannot be removed from the support. Because of its simple features and versatile usefulness, it is widely used.

Dumpy level The dumpy level is simple, compact and stable. Main parts of a dumpy level are shown in fig. A levelling instrument essentially consists of tripod or three legged stand, levelling head mounted on the tripod, the limb, telescope and the bubble tube. The most important part is the telescope which may be either internal focusing or external focusing type. A levelling head is mounted on the tripod stand having two parallel plates and three or four foot screws. The limb, consists of the vertical axis and a horizontal plate, connects the levelling head with the above telescope.It is a short and stout instrument with telescope tube rigidly connected to the vertical spindle. Hence the level tube cannot move in vertical plane. It cannot be removed from its support. Hence it is named as dumpy level. The telescope rotates in horizontal plane in the socket of the levelling head. A bubble tube is attached to the top of the telescope.

Plate 15.1 Dumpy level



1. Telescope
2. Eyepiece
3. Shade
4. Objective end
5. Longitudinal bubble tube
6. Transverse bubble tube
7. Bubble tube adjusting screws
8. Diaphragm adjusting screws
9. Focusing screws
10. Foot screws
11. Upper parallel plate (tribrach)
12. Foot plate (Trivet stage)

Wye or Y-Level

In this type of level, the telescope is supported in two Y-shaped supports and can be fixed with the help of curved clips. Clips can be opened and telescope can be reversed end to end and fitted. The advantage of this level is some of the errors eliminated, if the readings are taken in both the direction of telescope.

Reversible Level

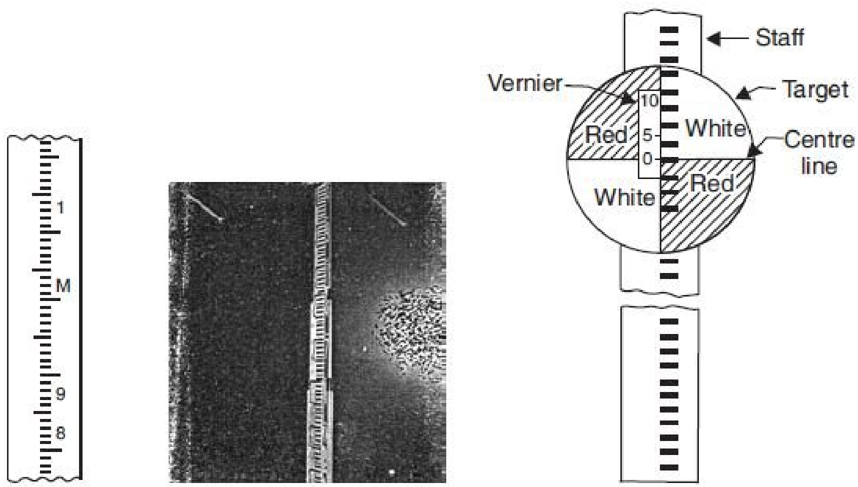
In this instrument the telescope is supported by two rigid sockets into which telescope can be introduced from either end and then screwed. For taking the readings in the reversed position of telescope, the screw is slackened and then the telescope is taken out and reversed end for end. Thus it combines the rigidity of dumpy level and reversibility of Y-level.

Tilting Level

In this, telescope can be tilted through about four degrees with the help of a tilting screw. Hence bubble can be easily centered. But it needs centering of the bubble before taking every reading. Hence it is useful, if at every setting of the instrument number of readings to be taken are few.

Along with a level, a levelling staff is also required for levelling. The levelling staff is a rectangular rod having graduations. The staff is provided with a metal shoes at its bottom to resist wear and tear. The foot of the shoe represents zero reading. Levelling staff may be divided into two groups:

(i) Self reading staff (ii) Target staff.
(i) Self reading staff: This staff reading is directly read by the instrument man through telescope. In a metric system staff, one metre length is divided into 200 subdivisions, each of uniform thickness of 5 mm. All divisions are marked with black in a white background. Metres and decimetres are written in red colour [Fig 15.4 (a)]. The following three types of self reading staffs are available:
(a) Solid staff: It is a single piece of 3 m.
(b) Folding staff: A staff of two pieces each of 2 m which can be folded one over the other.
(c) Telescopic staff: A staff of 3 pieces with upper one solid and lower two hollow. The upper part can slide into the central one and the central part can go into the lower part.
Each length can be pulled up and held in position by means of brass spring. The total length may be 4 m or 5 m [Fig. 15.4 (b)].



(a) Self-reading staff (b) Telescopic staff (c) Target staff

Fig. 15.4

(ii) Target staff: If the sighting distance is more, instrument man finds it difficult to read self reading staff. In such case a target staff shown in [Fig. 15.4 (c)] may be used. Target staff is similar to self reading staff, but provided with a movable target. Target is a circular or oval shape, painted red and white in alternate quadrant. It is fitted with a vernier at the centre. The instrument man directs the person holding target staff to move the target, till its centre is in the horizontal line of sight. Then target man reads the target and is recorded.

The following terms are used in direct method of levelling:

(i) Plane of Collimation: It is the reduced level of plane of sight with respect to the datum selected. It is also known as 'height of instrument'. It should not be confused with the height of telescope from the ground where the instrument is set.
(ii) Back Sight (BS): It is the sight taken on a level staff held on the point of known elevation with an intension of determining the plane of collimation. It is always the first reading after the instrument is set in a place. It is also known as plus sight, since this reading is to be added to RL of the point (Benchmark or change point) to get plane of collimation.
(iii) Intermediate Sight (IS): Sights taken on staff after back sight (first sight) and before the last sight (fore sight) are known as intermediate sights. The intension of taking these readings is to find the reduced levels of the points where staff is held. These sights are known as 'minus sights' since the IS reading is to be subtracted from plane of collimation to get RL of the point where staff is held.
(iv) Fore Sight (FS): This is the last reading taken from the instrument station before shifting it or just before ending the work. This is also a minus sight.
(v) Change Point (CP): This is also known as turning point (TP). This is a point on which both fore sights andback sights are taken. After taking fore sight on this point instrument is set at some other convenient point and back sight is taken on the staff held at the same point. The two readings help in establishing the new plane of collimation with respect to the earlier datum. Since there is time gap between taking the two sights on the change point, it is advisable to select change point on a well defined point.

TEMPORARY ADJUSTMENTS: The adjustments to be made at every setting of the instrument are called temporary adjustments. The following three adjustments are required for the instrument whenever set over a new point before taking a reading:

(i) Setting (ii) Levelling and
(iii) Focussing.

Setting

Tripod stand is set on the ground firmly so that its top is at a convenient height. Then the level is fixed on its top. By turning tripod legs radially or circumferentially, the instrument is approximately levelled.
Some instruments are provided with a less sensitive circular bubble on tribrach for this purpose.

evelling The procedure of accurate levelling with three levelling screw is as given below:
(i) Loosen the clamp and turn the telescope until the bubble axis is parallel to the line joining any two screws [Ref. Fig. 15.5 (a)].

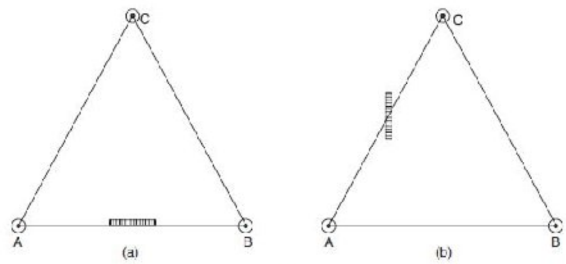


Fig. 15.5

(ii) Turn the two screws inward or outward equally and simultaneously till bubble is centred.
(iii) Turn the telescope by 90° so that it lies over the third screw [Fig. 15.4 (b)] and level the instrument by operating the third screw.
(iv) Turn back the telescope to its original position [Fig. 15.5 (a)] and check the bubble. Repeat steps (ii) to (iv) till bubble is centred for both positions of the telescope.
(v) Rotate the instrument by 180°. Check the levelling.

Focussing or elimination of parallax:
Focussing is necessary to eliminate parallax while taking reading on the staff. The following two stepsare required in focussing:
(i) Focussing the eyepiece: For this, hold a sheet of white paper in front of telescope and rotate eyepiece in or out till the cross hairs are seen sharp and distinct.
(ii) Focussing the objective: For this telescope is directed towards the staff and the focussing screw is turned till the reading appears clear and sharp.

Types of leveling

The following are the different types of direct levelling:
(i) Simple levelling (ii) Differential levelling
(iii) Fly levelling (iv) Profile levelling
(v) Cross sectioning and (vi) Reciprocal levelling.

Simple Levelling
It is the method used for finding difference between the levels of two nearby points. Figure 15.6 shows one such case in which level of A is assumed, say 200.00 m. RL of B is required.

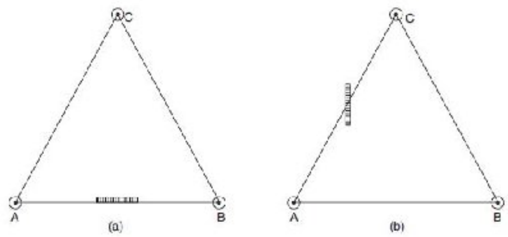


Fig. 15.5

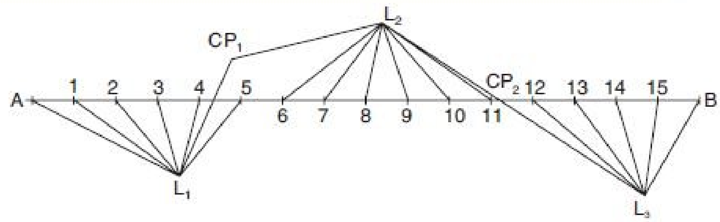
RL of A = 200.00 m
Back sight on A = 2.7 m.
∴ Plane of collimation for setting at station = 200 + 2.7 = 202.7 m
Fore sight on B = 0.80 m
∴ RL of B = 202.7 – 0.80 = 201.9 m
It may be noted that the instrument station L1 need not be along the line AB (in plan) and RL of L1 do not appear in the calculations.

Differential Levelling
If the distance between two points A and B is large, it may not be possible to take the readings on A and B from a single setting.
In such situation differential levelling is used. In differential levelling the instrument is set at more than one position, each shifting facilitated by a change point.

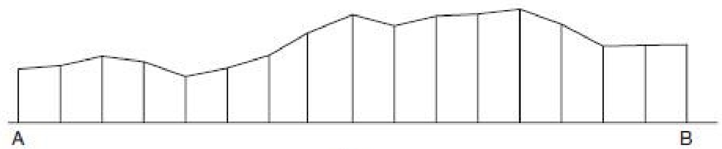
Fly Levelling
If the work site is away from the benchmark, surveyor starts the work with a back sight on the benchmark by setting instrument at a convenient point. Then he proceeds towards the site by taking fore sights and back sights on a number of change points till he establishes a temporary benchmark in the site. Rest of the levelling work is carried out in the site. At the end of the work again levelling is carried out by taking a set of convenient change points till the bench work is reached. This type of levelling in which only back sight and fore sights are taken, is called fly levelling, the purpose being to connect a benchmark with a temporary benchmark or vice versa. Thus the difference between fly levelling and differential levelling is only in the purpose of levelling.

Profile Levelling

This type of levelling is known as longitudinal sectioning. In high way, railway, canal or sewage line projects profile of the ground along selected routes are required. In such cases, along the route, at regular interval readings are taken and RL of various points are found. Then the section of the route is drawn to get the profile. Figure 15.8 (a) shows the plan view of the scheme of levelling and Fig. 15.8 (b)
shows the profile of the route. For drawing profile of the route, vertical scale is usually larger compared to scale for horizontal distances. It gives clear picture of the profile of the route.



(a)



(b)

Fig. 15.8

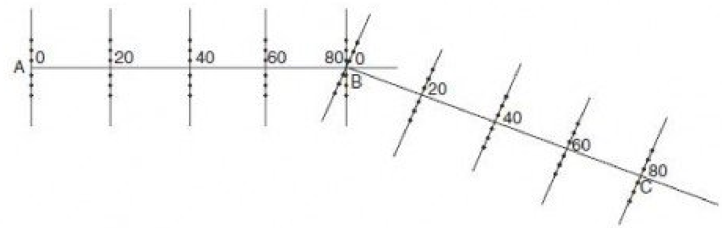


Fig. 15.9

Table 15.4 shows a page of level book required for this type of levelling.

Table 15.4. A typical page book for cross-section levelling

Station	*Distance in m*			*Readings*			*Plane of Collimation*	*RL*	*Remarks*
	L	*C*	*R*	*BS*	*IS*	*FS*			
BM									
		0							
L_1	3								
L_2	6								
L_3	9								
R_1			3						
R_2			6						
R_3			9						
		20							
L_1	3								
L_2	6								
L_3	9								
R_1			3						
R_2			6						
R_3			9						
									Checked.

Reciprocal Levelling

In levelling, it is better to keep distance of back sight and fore sight equal. By doing so the following errors are eliminated:

(i) Error due to non-parallelism of line of collimation and axis of bubble tube.

(ii) Errors due to curvature and refraction.
But in levelling across obstacles like river and ravine, it is not possible to maintain equal distances for fore sight and back sight. In such situations reciprocal levelling as described below is used:

OBJECTIVES OF LEVELLING:

As stated in the definition of levelling, the object is
(i) to determine the elevations of given points with respect to a datum
(ii) to establish the points of required height above or below the datum line.

Uses of levelling are

(i) to determine or to set the plinth level of a building.
(ii) to decide or set the road, railway, canal or sewage line alignment.
(iii) to determine or to set various levels of dams, towers, etc.
(iv) to determine the capacity of a reservoir.

CONTOURING

A contour line is a 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. For example, Fig. 17.1 shows contours in an area with contour interval of 1 m. On contour lines the level of lines is also written.

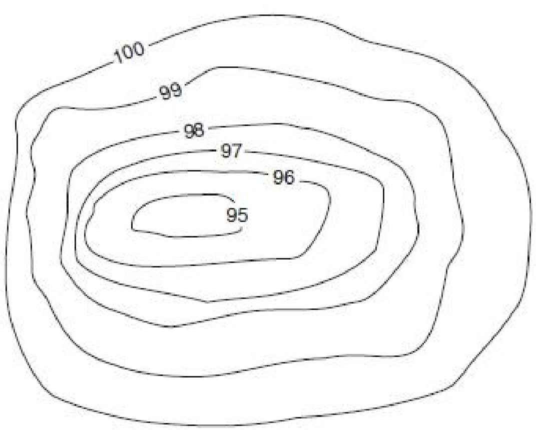


Fig. 17.1. Contours

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 (Fig. 17.1) indicate a pond.
7. Approximately concentric closed contours with increasing values towards centre indicate hills.
8. Contour lines with U-shape with convexity towards lower ground indicate ridge (Fig. 17.2).

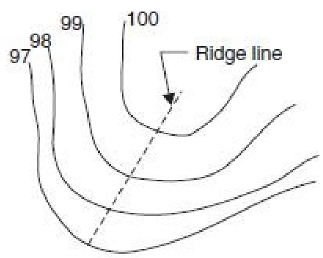


Fig. 17.2

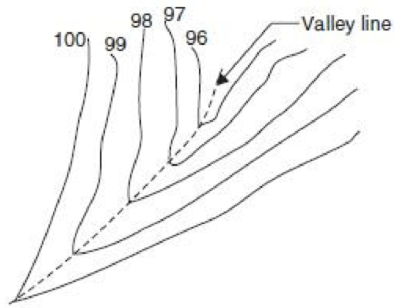


Fig. 17.3

9. Contour lines with V-shaped with convexity towards higher ground indicate valley (Fig. 17.3).
10. Contour lines generally do not meet or intersect each other.
11. If contour lines are meeting in some portion, it shows existence of a vertical cliff (Fig. 17.4).

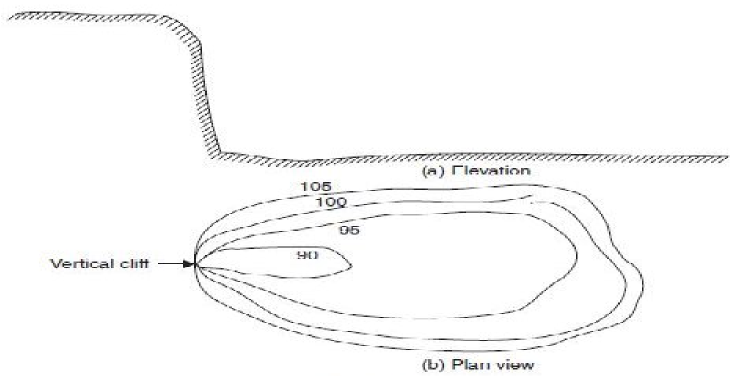


Fig. 17.4

12. If contour lines cross each other, it shows existence of overhanging cliffs or a cave (Fig. 17.5).

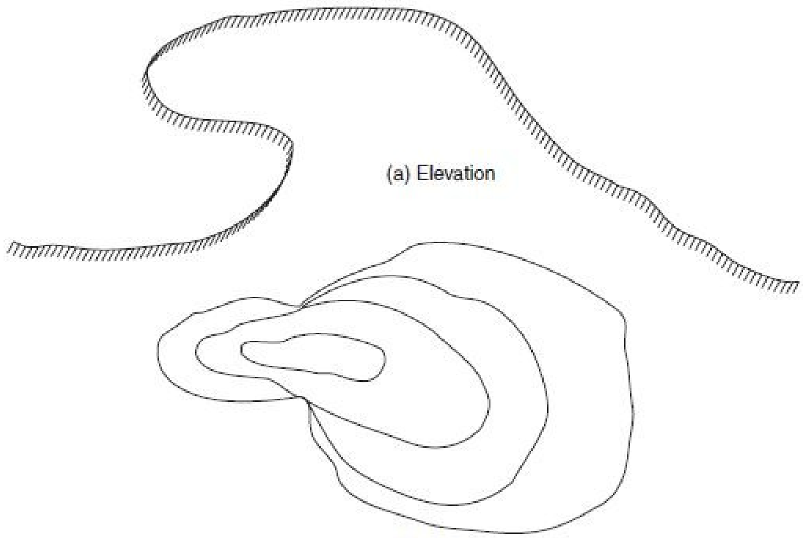


Fig. 17.5

Uses of Contour Maps

Contour maps are extremely useful for various engineering works:

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

Contouring needs the determination of elevation of various points on the ground and at the same the horizontal positions of those points should be fixed. To exercise vertical control levelling work is carried out and simultaneously to exercise horizontal control chain survey or compass survey or plane table survey is to be carried out. If the theodolite is used both horizontal and vertical controls can be achieved from the same instrument. Based on the instruments used one can classify the contouring in different groups.

However, broadly speaking there are two methods of surveying:
1. Direct methods
2. Indirect methods.

Direct Methods

It consists in finding vertical and horizontal controls of the points which lie on the selected contour line.
For vertical control levelling instrument is commonly used. A level is set on a commanding position in the area after taking fly levels from the nearby bench mark. The plane of collimation/height of instrument is found and the required staff reading for a contour line is calculated. The instrument man asks staff man to move up and down in the area till the required staff reading is found. A surveyor establishes the horizontal control of that point using his instruments. After that instrument man directs the staff man to another point where the same staff reading can be found. It is followed by establishing horizontal control. Thus several points are established on a contour line on one or two contour lines and suitably noted down. Plane table survey is ideally suited for this work. After required points are established from the instrument setting, the instrument is shifted to another point to cover more area. The level and survey instrument need not be shifted at the same time. It is better if both are nearby so as to communicate easily. For getting speed in levelling some times hand level and Abney levels are also used. This method is slow, tedious but accurate. It is suitable for small areas.

Indirect Methods

In this method, levels are taken at some selected points and their levels are reduced. Thus in this method horizontal control is established first and then the levels of those points found. After locating the points on the plan, reduced levels are marked and contour lines are interpolated between the selected points.
For selecting points anyone of the following methods may be used:
(a) Method of squares,
(b) Method of cross-section, or
(c) Radial line method.
Method of Squares: In this method area is divided into a number of squares and all grid points are marked (Ref. Fig. 17.6). Commonly used size of square varies from 5 m × 5 m to

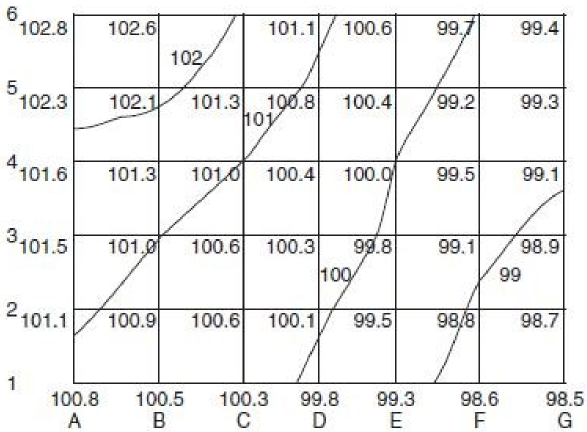


Fig. 17.6

20 m × 20 m. Levels of all grid points are established by levelling. Then grid square is plotted on the drawing sheet. Reduced levels of grid points marked and contour lines are drawn by interpolion [Ref. Fig. 17.6].

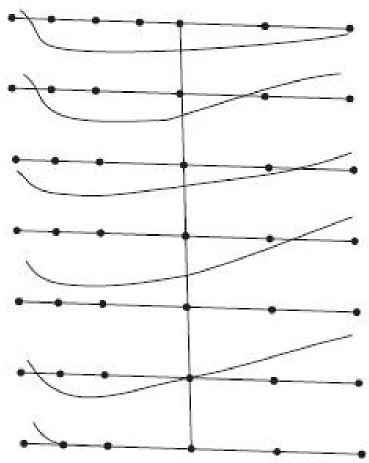


Fig. 17.7

Method of Cross-section: In this method cross-sectional points are taken at regular interval. By levelling the reduced level of all those points are established. The points are marked on the drawing sheets, their reduced levels (RL) are marked and contour lines interpolated.
Figure 17.7 shows a typical planning of this work. The spacing of cross-section depends upon the nature of the ground, scale of the map and the contour interval required. It varies from 20 m

to 100 m. Closer intervals are required if ground level varies abruptly. The crosssectional line need not be always be at right angles to the main line. This method is ideally suited for road and railway projects.

Radial Line Method: [Fig. 17.8]. In this method several radial lines are taken from a point in the area. The of each line is noted. On these lines at selected distances points are marked and levels determined. This method is ideally suited for hilly areas. In this survey theodolite with tacheometry facility is commonly used.

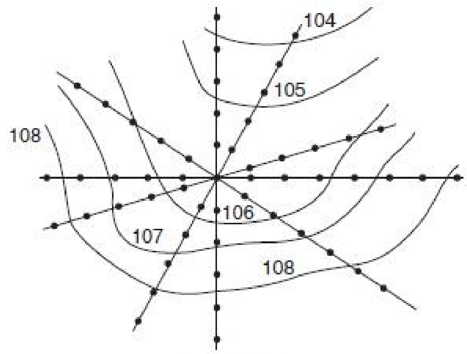


Fig. 17.8

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

(a) Estimation (b) Arithmetic calculation

(c) Mechanical or graphical method.

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

On a tracing sheet several parallel lines are drawn at regular interval. Every 10th or 5th line is made darker for easy counting. If RL of A is 97.4 and that of B is 99.2 m. Assume the bottom most dark line represents. 97 m RL and every parallel line is at 0.2 m intervals. Then hold the second parallel line on A. Rotate the tracing sheet so that 100.2 the parallel line passes through point B. Then the intersection of dark lines on AB represent the points on 98 m and 99 m contours [Ref. Fig. 17.9]. Similarly the contour points along any line connecting two neighbouring points may be obtained and the points pricked. This method maintains the accuracy of arithmetic calculations at the same time it is fast.

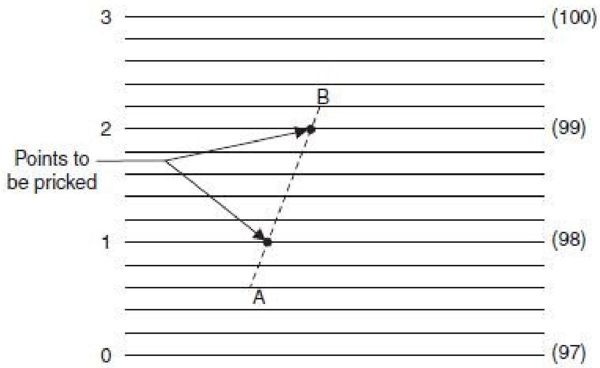


Fig. 17.9

Drawing Contours

After locating contour points smooth contour lines are drawn connecting corresponding points on a contour line. French curves may be used for drawing smooth lines. A surveyor should not lose the sight of the characteristic feature on the ground. Every fifth contour line is made thicker for easy readibility.

On every contour line its elevation is written. If the map size is large, it is written at the ends also.