



FACULTY OF ENGINEERING AND
TECHNOLOGY (DEPARTMENT OF
CIVIL ENGINEERING)

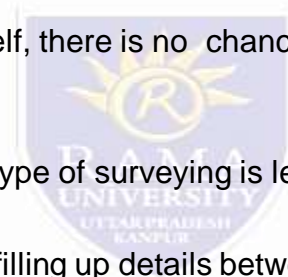
PLANE TABLE SURVEYING (INTRODUCTION)

- A plane table surveying is a graphical method of surveying. In this method of surveying, field observation and plotting are done simultaneously helping the surveyor to compare the plotted details with actual features of the ground.
- The plane tabling is generally adapted for surveys in which high precision is not required. It is mainly employed for small-scale or medium size mapping.
- Geometrical conditions of site are manuscript in the map sheet using plane table and alidade after that topographic details are arranged on the map.
- Surveying industrial areas where compass survey fails to perform.
- Used to fill in details between stations fixed by triangulation method or theodolite traversing method.
- It is simple and cheaper than theodolite survey. It is most suitable for small scale maps. •
- The plan is drawn by the surveyor in the field, while the area to be surveyed is before his eyes. Therefore, there is no possibility of omitting the necessary measurements.



PLANE TABLE SURVEYING (INTRODUCTION)

- **PLANE TABLE SURVEYING (INTRODUCTION)**
- 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 the table top, the observation are made to the objects, distance 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 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 others method.



Purpose of plane table surveying

In case of plane table survey, the measurements of survey lines of the traverse and their plotting to a suitable scale are done simultaneously on the field. Following are the purposes in which the plane table survey is found to be useful:

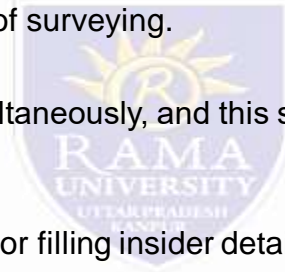
- I. Compass survey cannot be carried out with success in industrial areas of the town. Plane table survey will be the best alternative in such cases.
- II. For preparing plans on a small scale, plane table survey proves to be speedy, easy and accurate.
- III. The city or town has expanded within two or three decades and it is required to plot the developed area on the previously plotted plan of the existing area.
- IV. This type of surveying is used for filling up details between the survey stations previously fixed by others method.
- V. Field notes of the measurements are not required, and thus the errors in booking are eliminated.
- VI. The correctness of plotted work can be checked by check observations in the field.
- VII. The reduced levels of points other than the station points of known elevations may be found out with the help of a tangent clinometer.

PURPOSE OF PLANE TABLE SURVEYING

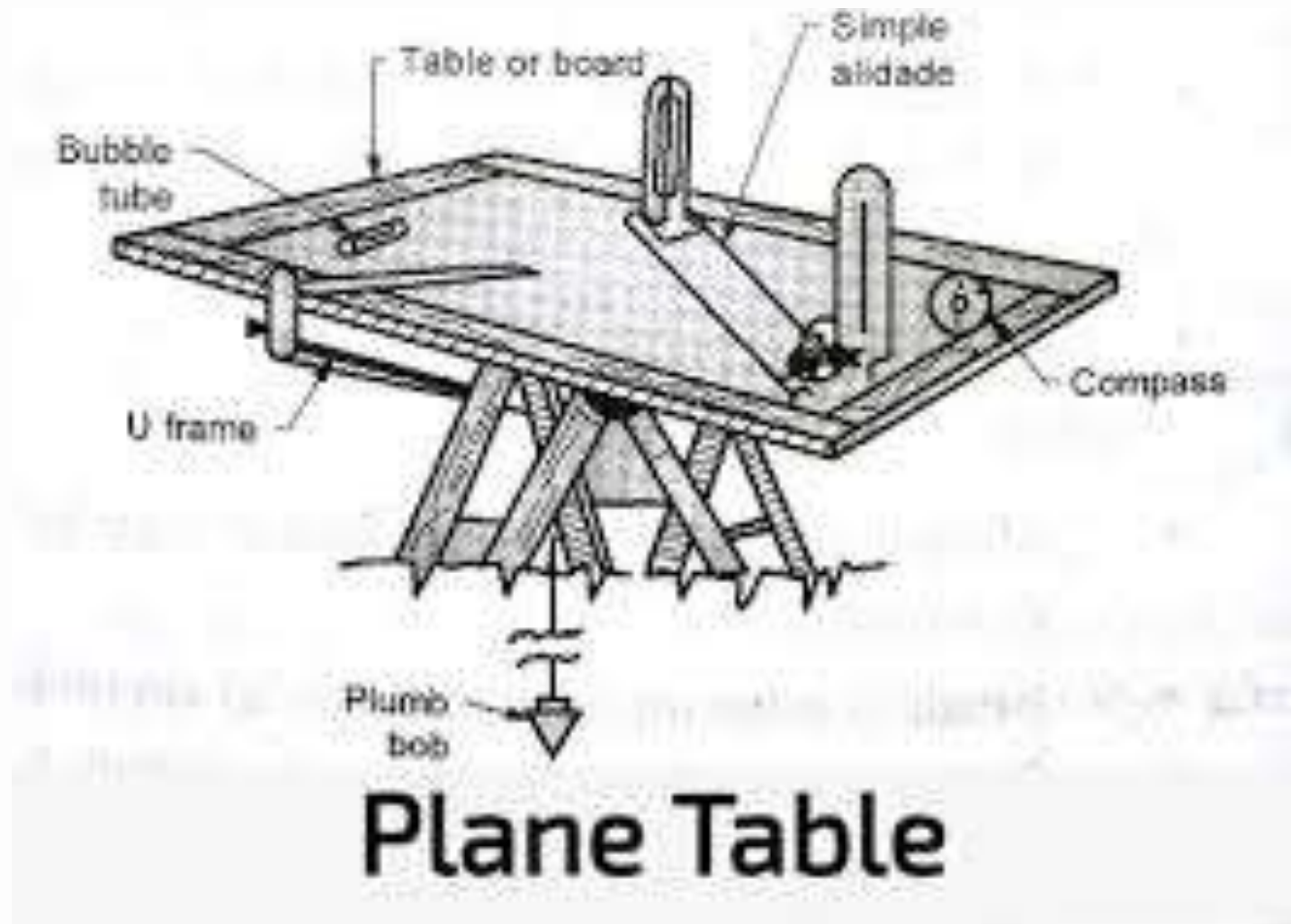


PRINCIPLE OF PLANE TABLE SURVEY

- Plane table surveying is based on the principle that lines drawn during plotting always lie parallel to the corresponding lines actually present on the ground.
- The law of plane tabling is parallelism, meaning the rays drawn from stations to items on the paper are parallel to the lines in the stations to the objects on the ground.
- The relative positions of these objects on the ground are represented with their own plotted positions about the paper and lie on the respective rays.
- The table is always placed at each of the successive stations parallel into the position it occupied in the starting station. Plane tabling is a graphical way of surveying.
- The fieldwork and plotting are done simultaneously, and this survey doesn't involve using a field book(measurement book).
- Plane table survey is mainly acceptable for filling insider details when traversing is done with the theodolite.
- Sometimes traversing with a plane table might also be done. However, this survey is recommended for the work where great accuracy isn't required.
- As the fixing and fitting arrangement of this instrument is not perfect, most accurate work cannot be expected.
- For example, let us consider four ground stations A, B, C and D which on joining provides a rectangle ABCD. This has been plotted on a sheet of paper at a scale by plane table surveying. Here, the sides AB, BC, CD and DA are plotted in such a way that they are parallel to the sides actually available on the ground.



PRINCIPLE OF PLANE TABLE SURVEY

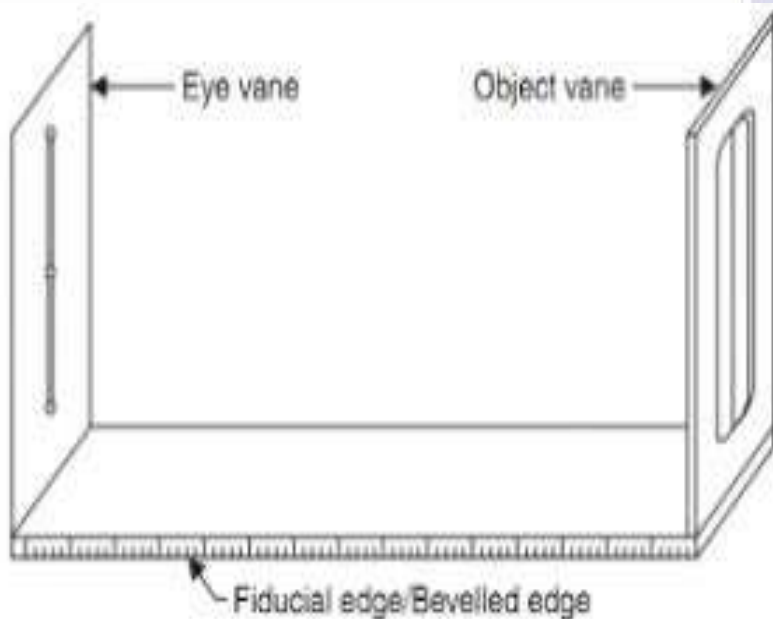


Drawing Board

- The board may be mounted on a tripod with a leveling head or a ballad-socket arrangement in such a fashion that it can be leveled and revolved about a vertical axis and may be clamped in any position.

Alidade

- The alidade is a ruler with a sight line attached and is used on the plane table for bisecting the object, drawing rays, direction lines, etc.
- One of the sight vanes is provided with a narrow rectangular slit. While other is provided with a central vertical hair or wire.



ALIDADE

- Depending on the type of line of sight there are two types of alidade:
 - a) Plain alidade
 - b) Telescope alidade

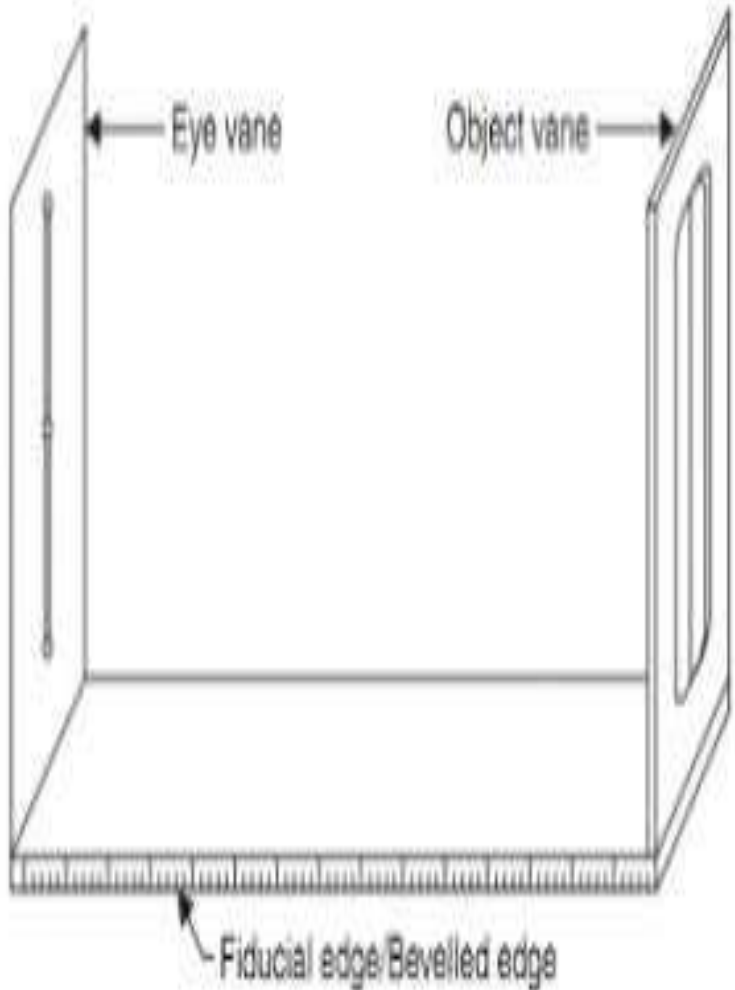
PLAIN ALIDADE

- A sight vane is provided at each end of the ruler. The vane with the narrow slit serves as eye vane and the other wide 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.
- Plane alidade is not suitable for the surveying in hilly areas as the inclination of the line of sight in this case is limited.

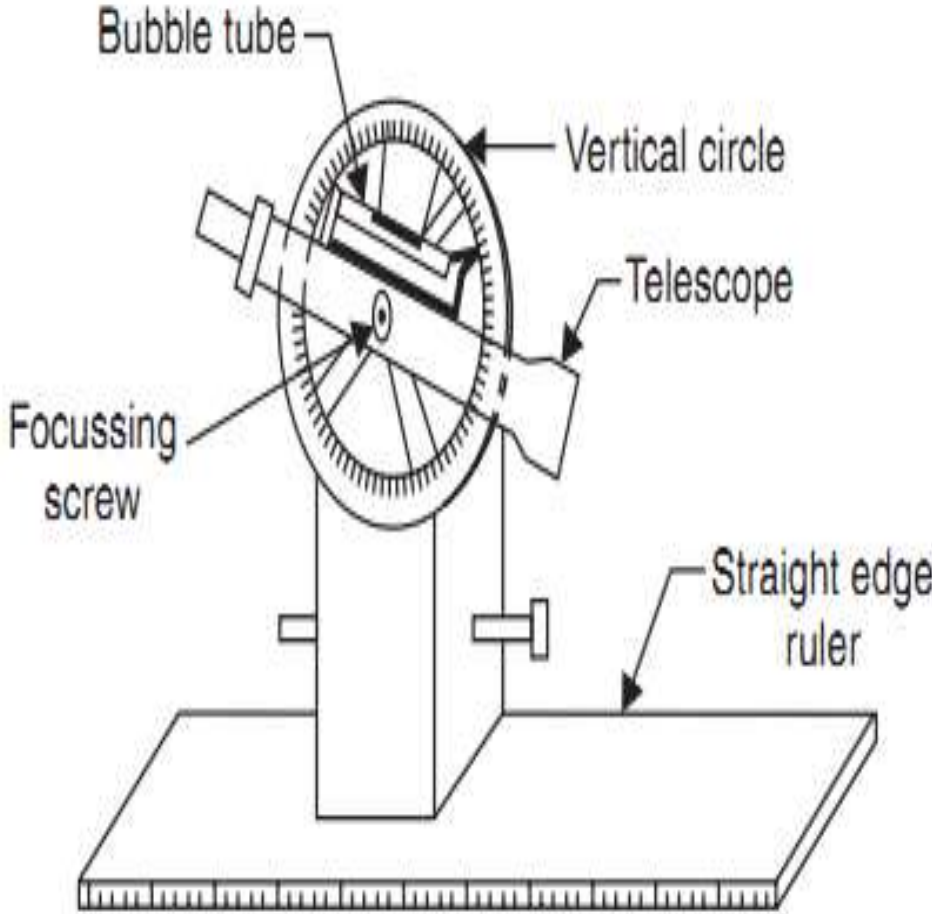
TELESCOPE ALIDADE

- It consist of telescope mounted on a column fixed to the ruler. The line of sight through the telescope is kept parallel to the beveled edge of the ruler .
- The telescope is provided with the level tube and vertical graduation arc. If horizontal sight is required bubble in the level tube is kept at the centre. If inclined sight are required vertical graduation helps in noting the inclination of the line site.
- By providing telescope the range and the accuracy of line of sight is increased

EQUIPMENT USED IN PLANE TABLE SURVEYING



Plain alidade

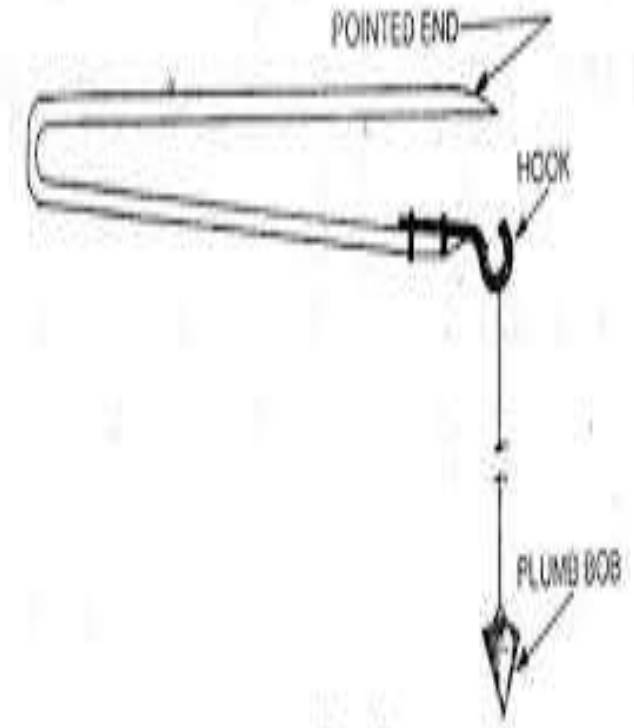
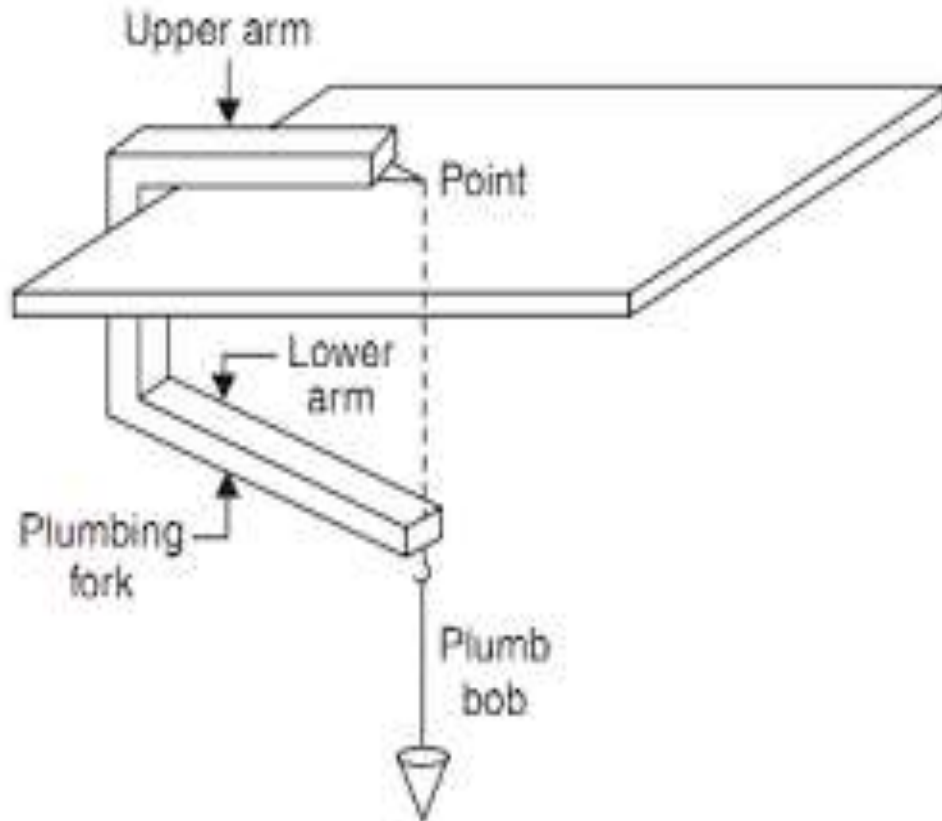


Telescope Alidade

PLUMBING FORK WITH PLUMB BOB

- Plumbing fork is a U-shaped metal frame with an upper horizontal arm and a lower inclined arm.
- The upper arm is provided with a pointer, whereas the lower arm is provided with a hook.
- When the plumbing fork is kept on a plane table along with a plumb bob is suspended by the hook, then the plumb line moves through the end of the pointer in the upper arm.
- At the start of the plane table survey, plumb bob helps in moving a ground station to the drawing sheet, & later on, it assists in transferring station positions on drawing sheets into the ground.
- The plumbing bob helps in transferring the ground point to the drawing and vice versa.

EQUIPMENT USED IN PLANE TABLE SURVEYING

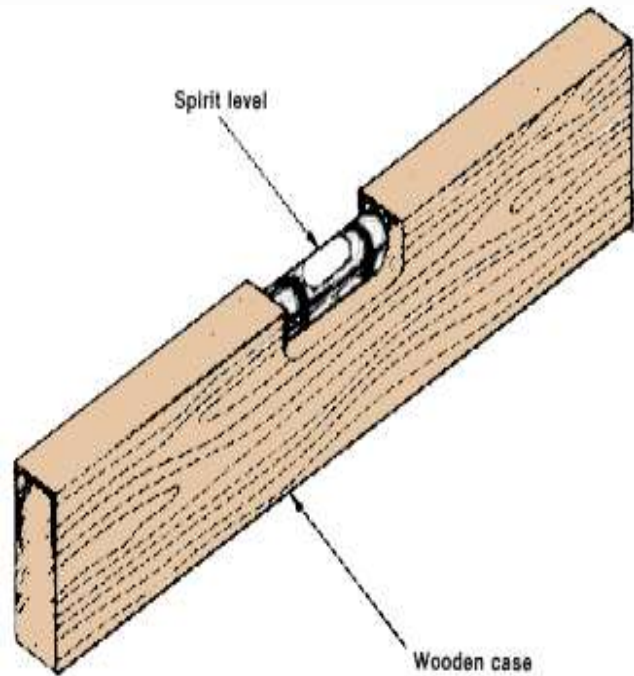


PLUMBING FORK WITH PLUMB BOB

EQUIPMENT USED IN PLANE TABLE SURVEYING

Spirit Level

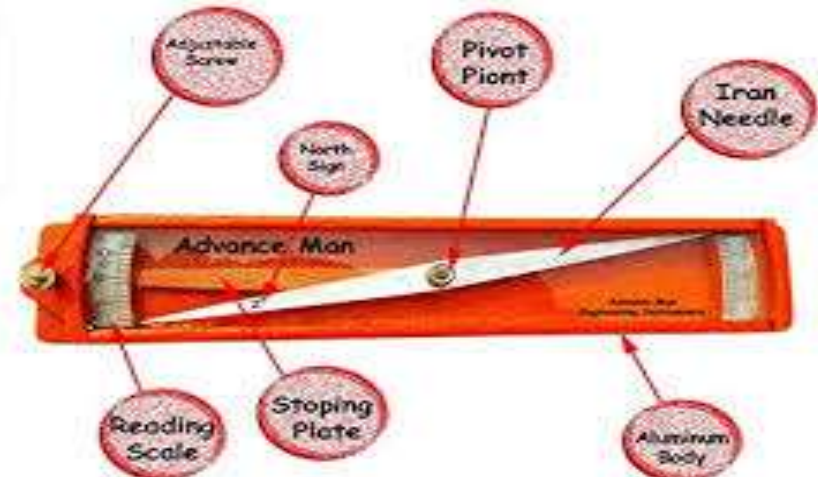
- A spirit level with a flat base is utilized for leveling plane table.
- To ensure proper leveling, spirit level needs to be used in two positions at right angles to one other, and leveling of the plane table ought to be ensured.
- The spirit level can be place in two perpendicular directions and leveled.



EQUIPMENT USED IN PLANE TABLE SURVEYING

TROUGH COMPASS

- Trough Compass A trough compass is made up of an 80 to 150 mm long and 30 mm wide box carrying out a freely suspended magnetic needle in its center. At the top of the box is provided with a glass cover.
- In the ends of the needle, graduations are marked out of zero to five degrees on each side of the center.
- When the needle ends to coincide with zero-zero, the line of needle ends is parallel to the long edge of the box.
- Hence, a marking on either side of a long edge indicates the north direction of the survey.
- Thus, the trough compass is useful for marking the north line on the drawing sheet.



DRAWING SHEET AND ACCESSORIES FOR DRAWING

- The drawing paper of superior quality ought to be used in a plane table survey.
- It ought to be well seasoned before use by exposing it alternatively to warm and moist atmosphere.
- By seasoning, shrinkage of sheets in the future is reduced considerably. The sheet ought to be in a position to withstand rubbing against alidade.
- The drawing sheet shouldn't be folded. Many times two sheets attached using their grains at right angles to one another and using a sheet of muslin between them are utilized.
- For works of importance, fiberglass sheets or paper backed with thin aluminum sheets are utilized.
- Clips, clamps and adhesive tapes /Chain might be used for fixing drawing sheet into the table. Sharp hard pencil (4 H), good quality eraser, pencil cutter and sandpaper to keep pencil point sharp are other accessories need for drawing work.
- A waterproof cover such as plastic sheet ought to be carried from the surveyor, to protect drawing sheet out of the rain, if required.

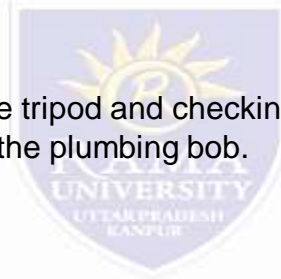
WORKING OPERATIONS OF PLAIN TABLE SURVEY

Once fixing the table into the stand and drawing sheet into the following operations are to be carried out :

- **Centering**
- **Leveling**
- **Orientation**

CENTERING

- Centering is the process of setting the plane table on the point so that its plotted position is exactly over the position on the ground.
- This is achieved by moving the legs of the tripod and checking the position of the point on the ground and on the paper with the help of plumbing fork and the plumbing bob.



LEVELING

- Spirit level is used to check the level of the table. The level ought to be ensured in two positions of spirit level that are at right angles to one another.
- The legs of the tripod are moved radially or along the circumference to correct the level of the table.

WORKING OPERATIONS OF PLAIN TABLE SURVEY

ORIENTATION

- Orientation is the process of placing a plane table in a station such that all the lines plotted are parallel to corresponding lines on the ground.
- This is a very important process in plane tabling. Accuracy of plane table survey mainly depends on how correctly at each station perfect orientation is achieved. It may be achieved by anyone of the following methods:
 - a) Using trough compass
 - b) By back sighting
 - c) By solving two-point or three-point problems.

ORIENTATION USING TROUGH COMPASS:

- After the survey work starts from the first station, the table is oriented in appropriate direction, and the north direction is marked near the right-hand top corner utilizing trough compass.
- This orientation is to be kept at all subsequent stations.
- To acquire exactly the same orientation, trough compass is placed along the north direction marked, and the table is rotated until the compass needle is along with zero-zero readings.
- Then it's clamped. Therefore, the necessary orientation of this table is obtained. This procedure of orientation is considered rough since the local attraction to compass can impact proper orientation.
- This way is used as a preliminary orientation, and finer orientation is obtained from other methods.

ORIENTATION BY BACK SIGHTING:

- It's a commonly employed way. Before shifting the table, point in Measurement book from station **A** to station **B**, line ab is attracted from a plotted position of station **A** (i.e., a) towards following station **B**. Distance **AB** is Plotted and measured position b of station **B** is located.
- Subsequently, plane table is shifted to station **B** and centered such that point 'it is exactly over station **B** keeping the alidade along with ba station A is sighted and clamped.
- This offers the required orientation. Checks could be applied by sighting already plotted objects from point ' b .'



METHODS OF PLANE TABLE SURVEYING

These four methods are available for carrying out a plane table survey as per below Plane Table Surveying Methods:

- Radiation
- Intersection
- Traversing, and
- Resection

The first two methods are usually employed for locating the details whereas Another two methods are used for testing and locating the positions of plane table stations onto the drawing sheet.

RADIATION

- To fill details of objects near station '0', a plane table is set on station '0' the plotted position '0' approximately over the ground station.
- Then using alidade pivoted at '0', the rays are drawn in the direction **OA, OB. OC** ... with soft pencil [As per below Figure] Then the distances **OA, OB. OC** ... is scaled and measured down to get the plotted positions **a, b, c** ... of field positions A, B,... Thus, these items are plotted by first drawing radial lines.



METHODS OF PLANE TABLE SURVEYING

- This method is acceptable for small areas, and it is convenient if the distances are small.
- This method has a wider scope if the telescopic alidade is used, where distances are measured tacheometrically.

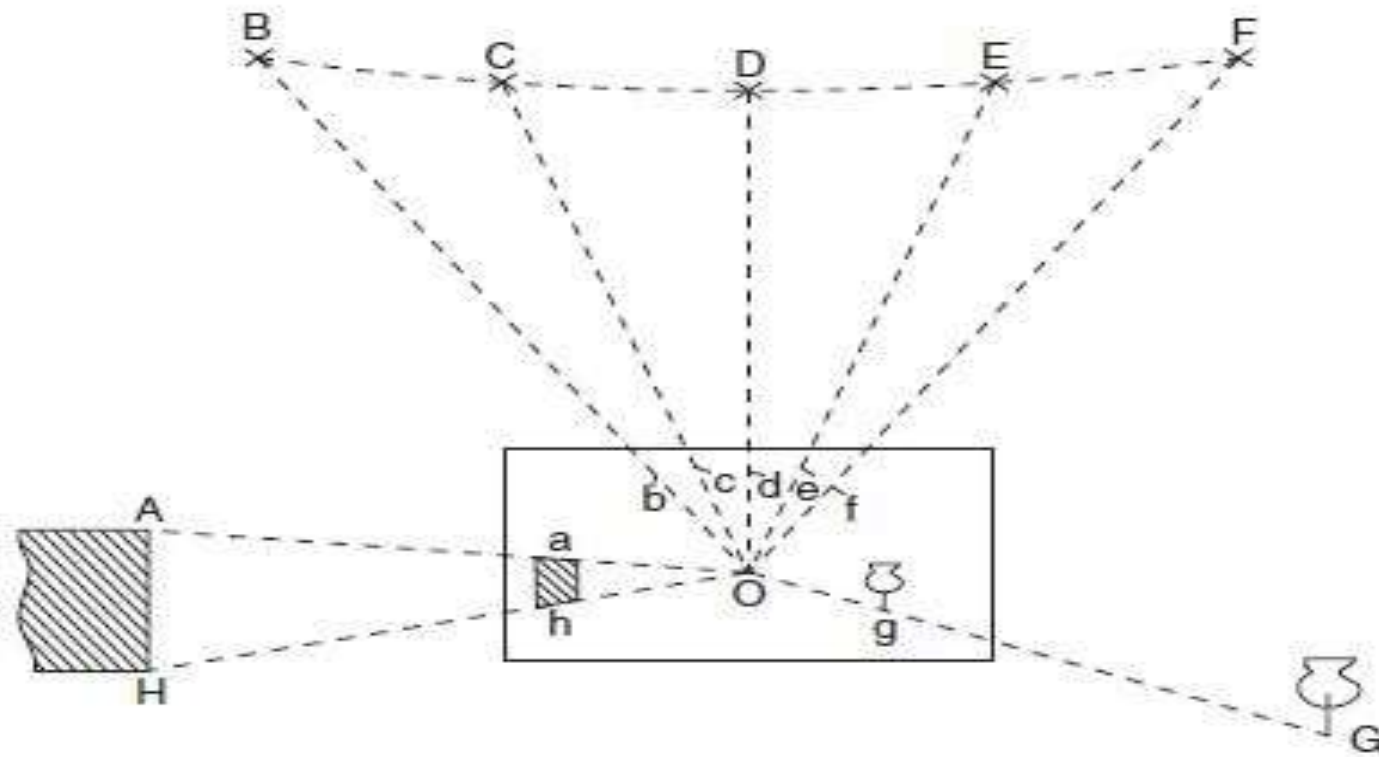


Fig. 14.7. Radiation method of plane tabling

METHODS OF PLANE TABLE SURVEYING

INTERSECTION

- Within this method, two stations are so chosen that all of the other stations to be plotted are observable from these. The line joining both of These stations is called the baseline. The length of the line is measured very accurately.
- Also, rays are drawn from these stations to the stations to be plotted.
- The intersection of the line from the two stations provides the position of the station to be plotted onto the drawing sheet. From time to time, this way is also termed as graphical triangulation.

PROCEDURE

- Let **A** and **B** be the two accessible stations (as per below figure), such that **A** and **B** can be suitably plotted. **C** is the station to be plotted by intersection.
- Place the plane table at **A**. Set it up. Plot the **NS** direction. Transfer ground station **A** as an onto the drawing sheet. With the alidade centered at a. sight station **B**.
- Draw a ray **aB** and cut ab to a suitable scale. With the alidade at a sight, **C** also and draw a ray **aC**. Shift the table to **B** and set it up. Place the alidade at **b** and sight **C**. Draw a ray **bC**. The intersection of the two-line gives the position of station **C** as **c** on the plane table.

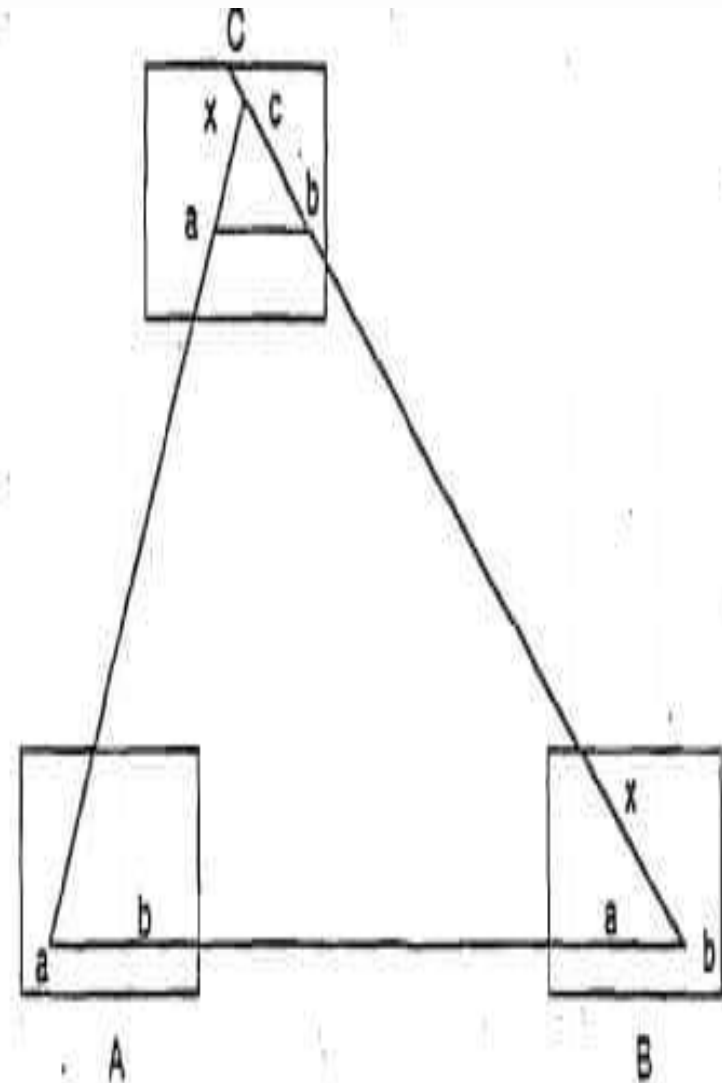


Lecture -04

METHODS OF PLANE TABLE SURVEYING

This method is commonly employed for locating:

- Details
- The distant and inaccessible points
- The station which may be used latter.



METHODS OF PLANE TABLE SURVEYING

TRAVERSING

- This method is like a compass or a theodolite traversing. The table is set in each of the stations in succession. A foresight is taken to another station, and the distance is cut into a suitably chosen scale.
- This method is used for locating plane table survey station.
- In this method, ray drawn to next station before shifting the table and distance between the station 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 check, rays are taken to other station also, whenever it is possible.

PROCEDURE

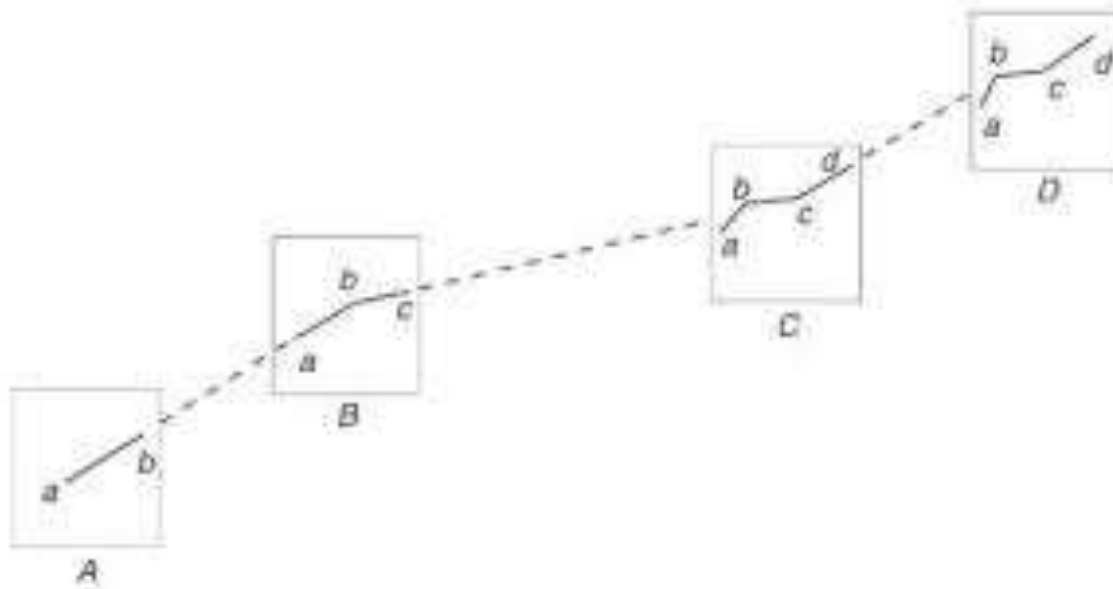
- Set up the plane table at the initial station **A** (as per below figure). Transfer ground station **A** as **a** on the drawing sheet.
- Draw a ray **aB** along the fiducial edge with the alidade pivoted against **a**.
- Cut the distance **ab** to the selected scale. Shift and set up the table at **B**. Orient the plane table.
- Place the alidade at **b** and sight station **C**. Draw a ray **bC** along the alidade and cut the distance **bc** to the selected scale. The procedure is carried out till all the stations are traversed.



METHODS OF PLANE TABLE SURVEYING

SUITABILITY

- It's most suited if a narrow strip of this terrain is will surveyed, e.g., a survey of streets, railways, etc.
- This method may be used for traversing the open in addition to close traverses.



Traversing with table survey

RESECTION

- This is an orientation technique that fixes the position of the plane table station in a plan.
- When a number of points already fixed by plane table or otherwise are available in plan, it is often convenient to set up the plane table at some arbitrary station and pick up detail from there.
- This adds to the flexibility of a plane table survey. Conspicuous points such as temple-tops, church spires, and hilltops already fixed by any method are not convenient points on which a plane table can be set, and from which low-lying detail can be fixed.
- If such points are visible from the area of the detail, the plane table can be set up to pick out the detail from an arbitrary location near it.
- The position of the plane table in plan is now fixed by the resection procedure. A point determined by resection is called a plane table fix.
- 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



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 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.

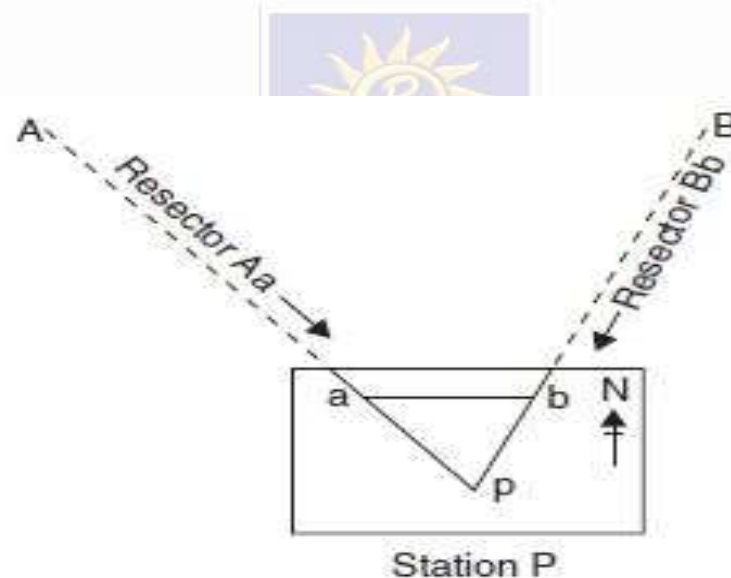


Fig. 14.10. Resection after orientation with compass

METHODS OF PLANE TABLE SURVEYING

Resection after Orientation by Back Sighting

- 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.

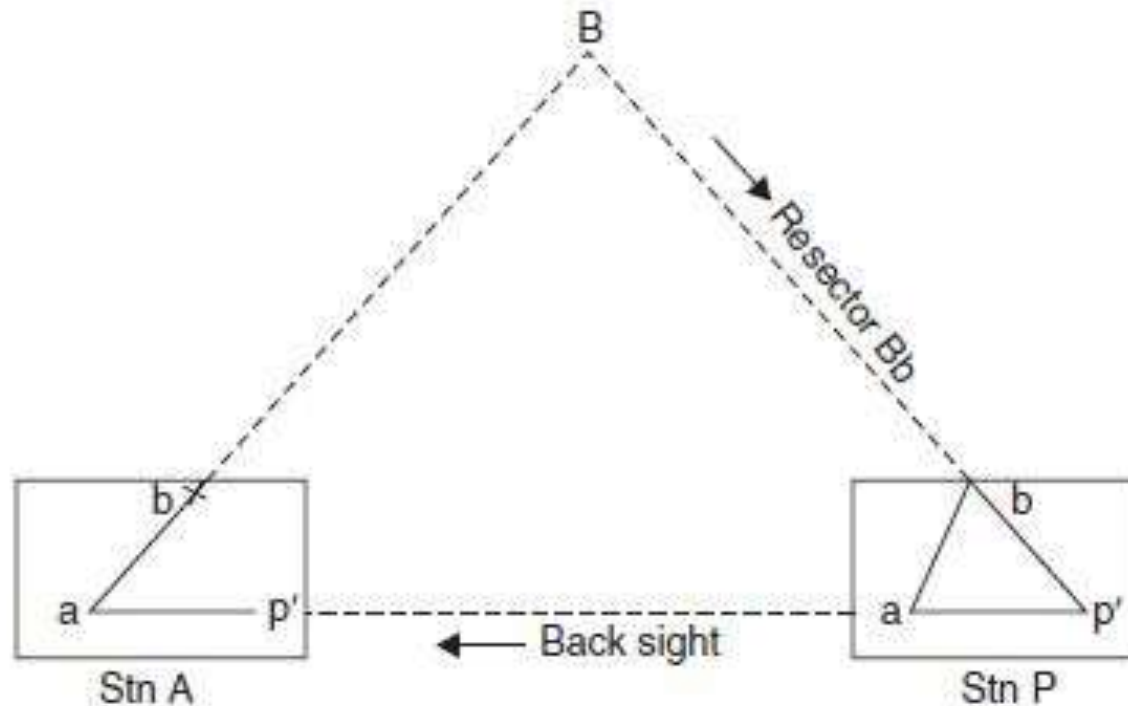


Fig. 14.11. Resection after back sighting

METHODS OF PLANE TABLE SURVEYING

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 defined points is known as solving two point problem.
- Let A and B be two well defined points like lightning 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 acute.
- 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 b_1 are not coinciding due to the angular error in the orientation of table. The angle bab_1 , 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 .

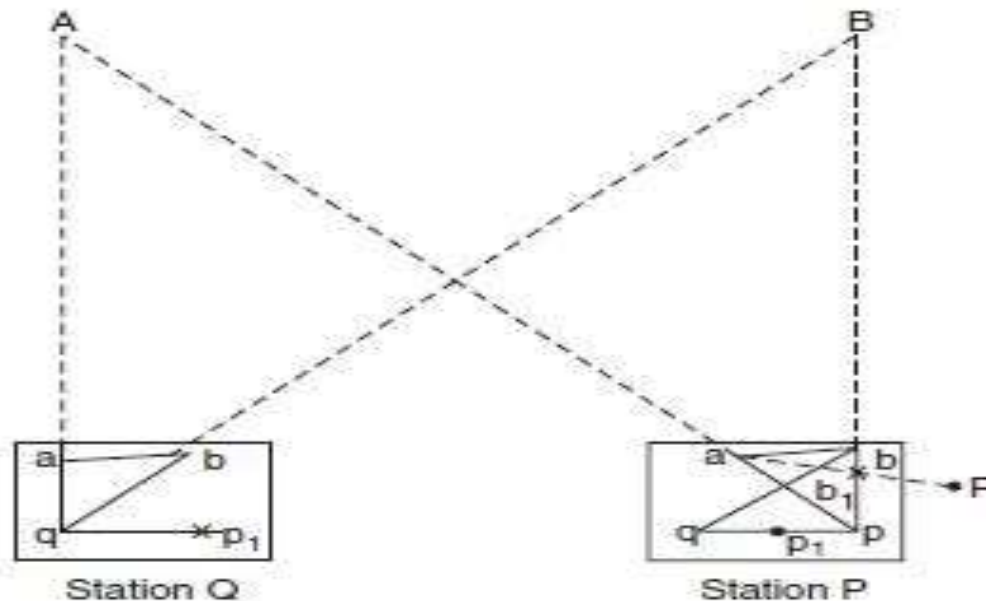


Fig. 14.12. Two-point problem

METHODS OF PLANE TABLE SURVEYING

- 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).

MECHANICAL METHOD

- This method is known as tracing paper method since it needs a tracing paper. The method involved the following steps
- 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.



METHODS OF PLANE TABLE SURVEYING

- 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.

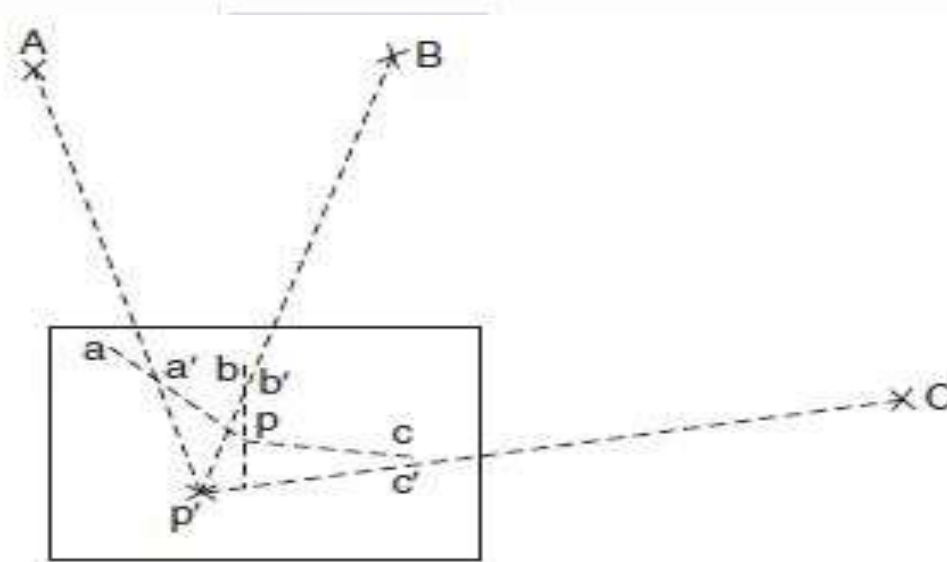


Fig. 14.13

GRAPHICAL METHOD

The following two graphical methods are available to solve three point problem:

- I. Bessel's solution
- II. Method of perpendiculars.

Bessel Solution:

- It involves the following steps:
 1. Keep the beveled 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 beveled 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'.



METHODS OF PLANE TABLE SURVEYING

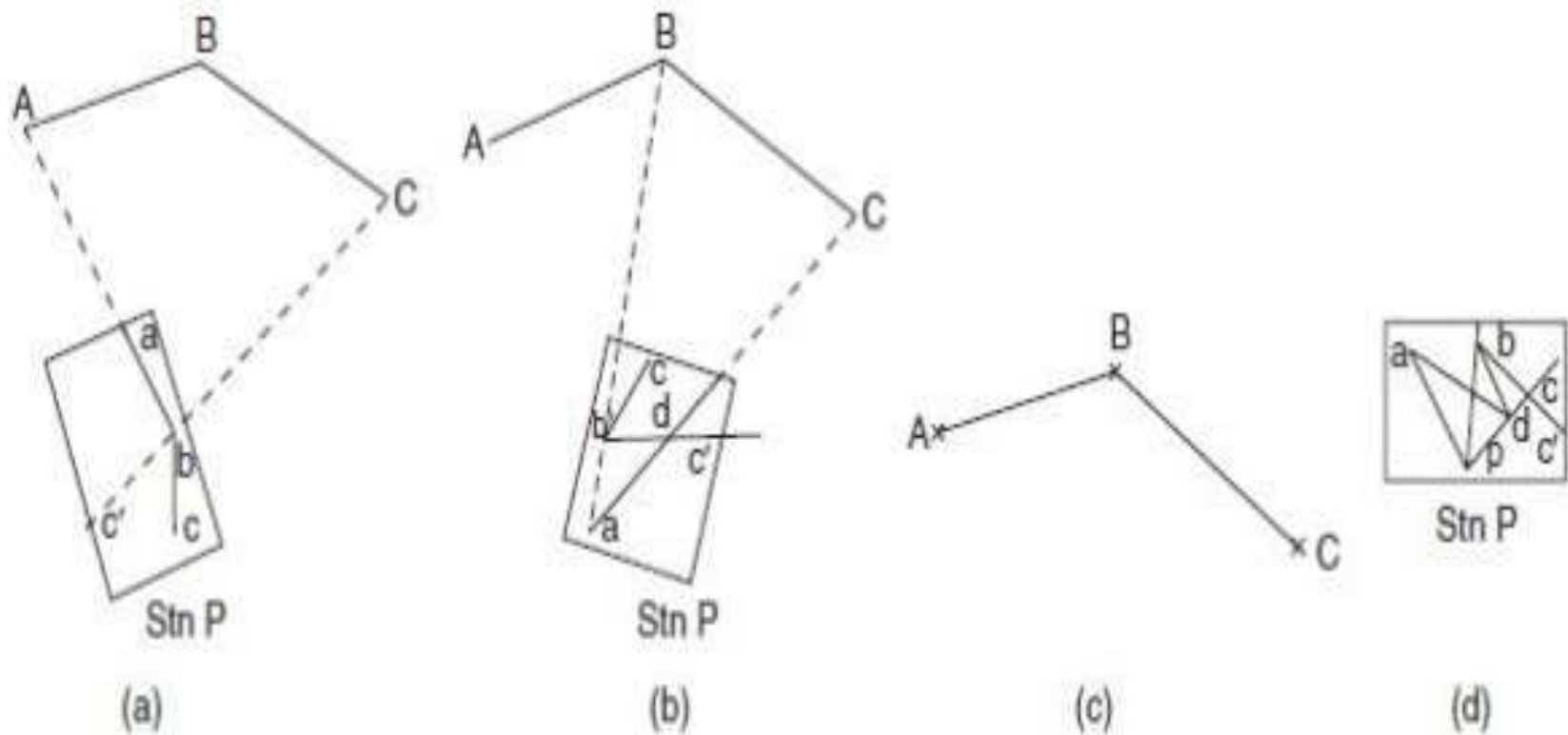


Fig. 14.14. Graphical solution (Bessel's method)

METHODS OF PLANE TABLE SURVEYING

METHOD OF PERPENDICULARS

- This is another graphical method. It involves the following steps
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
 2. Draw cf perpendicular to bc and clamp the table when fcC are in a line. Draw Bb to intersect Ccf at F
 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.

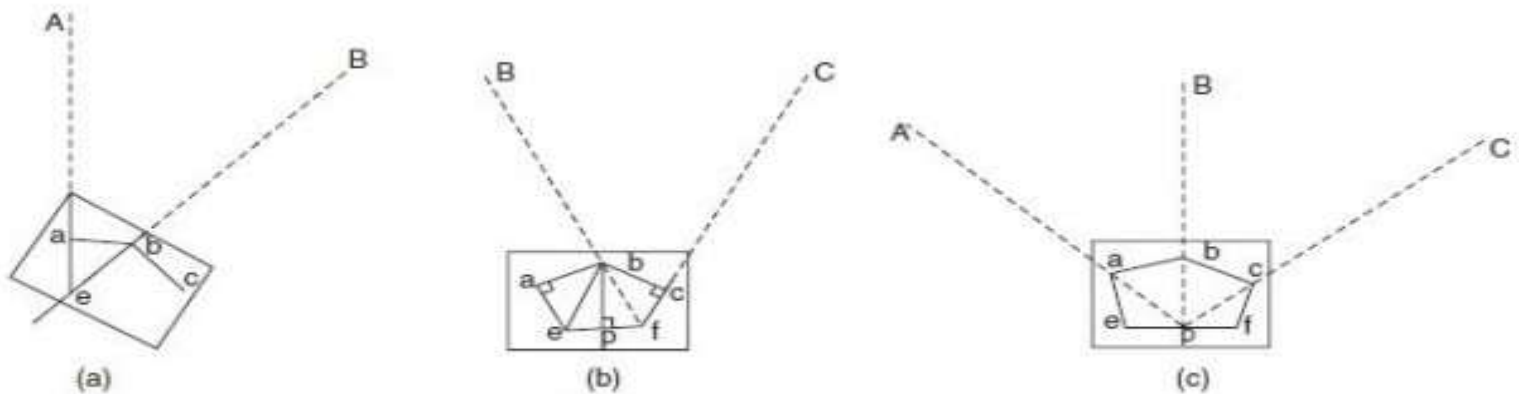


Fig. 14.15. Method of perpendiculars of solve three point problem

METHODS OF PLANE TABLE SURVEYING

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 . 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.

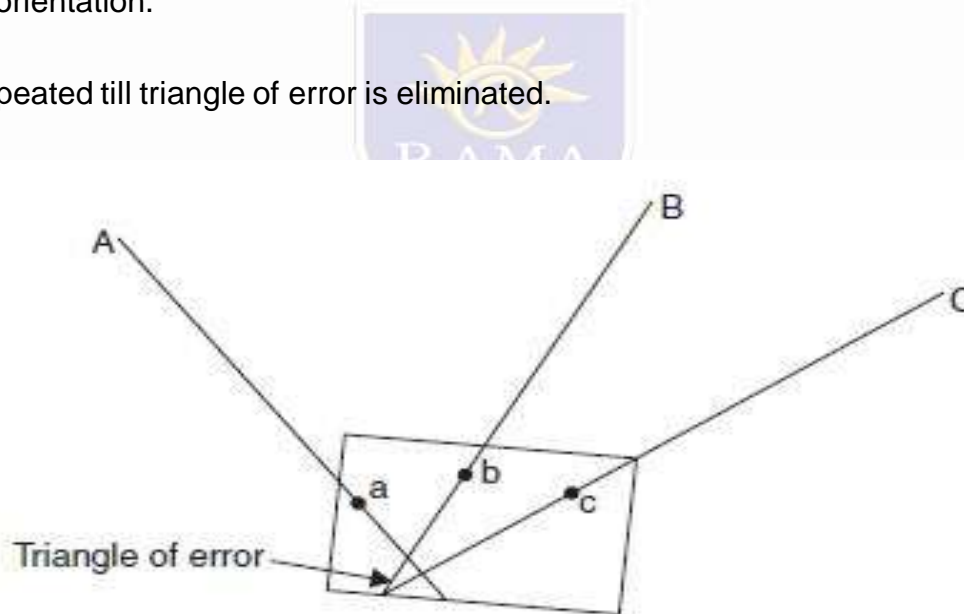


Fig. 14.16

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.
- 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

METHODS OF PLANE TABLE SURVEYING

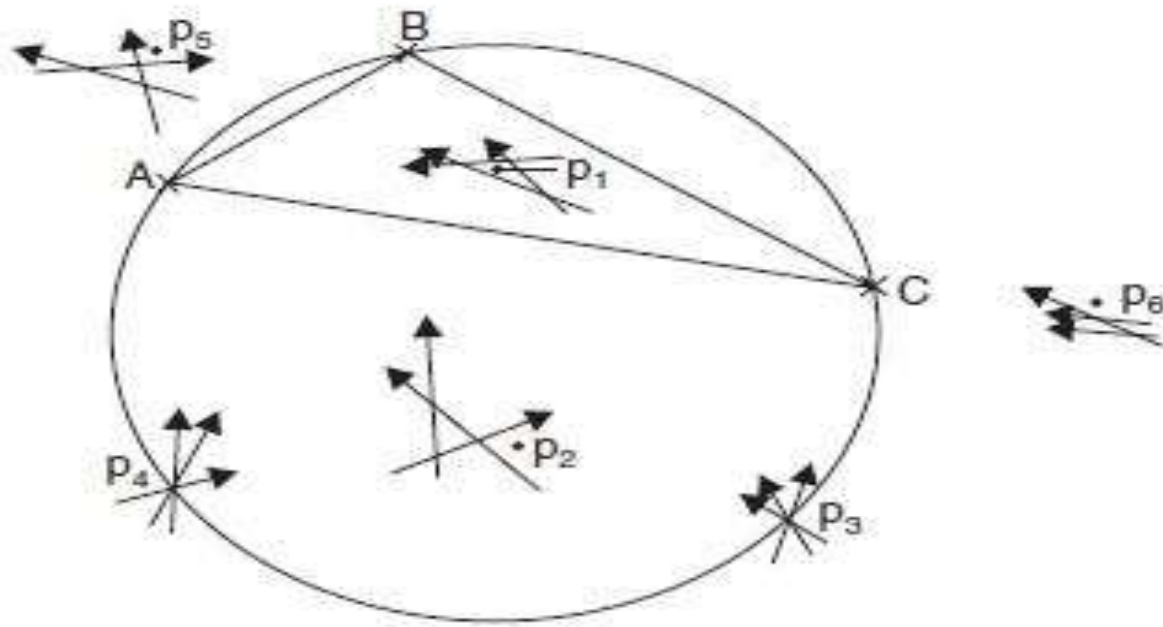


Fig. 14.17

Temporary adjustment of Plane Table

- It is necessary to check whether the accessories satisfies some basic conditions and if required, necessary adjustments are to be done before starting any plane table surveying work. The operations involved in this are known as temporary adjustment of plane table. The conditions needed to be tested and subsequent adjustments are as follows:
 1. **The surface of the board should be a perfectly plane.**
 - **Test :** It is tested by placing a straight edge on the top surface of the plane table in different directions. If there is no gap between the base of the straight edge and the surface of the plane table then the surface is perfectly plane. Otherwise, the surface is not perfectly plane.
 - **Adjustment :** If the gaps are minute, those are removed by rubbing with sand paper and for more gaps, the table should be replaced.
 2. **The fiducial edge of the alidade should be straight.**
 - **Test :** It is tested by drawing a fine line on the paper along the fiducial edge of the alidade. Then, by reversing the alidade, end for end, and placing against the line drawn, a line is to be drawn again along the fiducial edge. If the two lines coincide, the edge is straight. Otherwise, the edge is not straight.
 - **Adjustment :** The fiducial edge of the alidade is to be made straight by filing and then test is repeated till satisfactory outcome.



TEMPORARY ADJUSTMENT OF PLANE TABLE

3. **In fully opened condition, the sight vanes of the alidade should be perpendicular to its base.**
 - **Test :** Hang a plumb bob at a distance of about 5 to 10 m from the plane table. Bisect the string of the plumb bob through the alidade placed on properly leveled plane table. If the sighting slit, the object vane hair and the plumb bob string lie the same vertical line, the vanes of the alidade are perpendicular to the base of the alidade. Otherwise, it requires adjustment.
 - **Adjustment :** is being carried out by inserting packing under the base of the sight vanes or by filing the base, as required. The test and adjustment get repeated till satisfactory outcome is achieved.
4. **The telescopic alidade if used should be in perfect adjustment.**
 - The testing and adjustment of the telescopic alidade are to be carried as discussed in case of theodolite.



ERRORS IN PLANE TABLE SURVEYING

Errors in plane table surveying are of three types :

1. Instrumental errors
2. Errors in plotting
3. Errors due to manipulation and sighting

INSTRUMENTAL ERRORS

Instrumental errors are the primary source of errors in plane table surveying which can occur in the following ways :

- I. Errors will occur if the top surface of the plane table is not flat or contains undulations.
- II. The fittings of the tripod and plane table should be tightly fastened. Loose fittings can make the plane table unstable and cause errors while drawing.
- III. The magnetic compass used in plane table surveying should represent accurate direction otherwise an error may occur due to the wrong orientation of plane table.
- IV. When the beveled edge or fiducially edge of the alidade is not straight or curved, an error occurs in the drawing.
- V. Both sight vane and object vane of alidade should be perpendicular to the base of an alidade- if not, there will be an error in sighting.
- VI. Faulty Spirit level or level tube may not keep the plane table in horizontal position, therefore an error may occur.

ERRORS IN PLANE TABLE SURVEYING

Errors in Plotting

Errors may occur during plotting as well and they could be due to :

- I. Use of poor quality drawing sheet may affect the scale of the drawing. It is due to the expansion or contraction of drawing paper against temperature changes. Well-seasoned drawing sheet will not expand or contract due to weather fluctuations.
- II. The pencil used for plotting should contain thin and sharp nose. Usage of a thick pencil may alter the scale of drawing especially in the case of very small scale drawings.

Errors of Manipulation and Sighting:

Errors of manipulation and sighting come under personal errors or man-made errors. They may occur due to any of the following cases :

- I. The board not being horizontal.
- II. The table not being accurately centered.
- III. The table not being correctly oriented.
- IV. The table not being properly clamped.
- V. The objects not being correctly sighted.
- VI. The alidade not being correctly centered on the station-pointing the paper.
- VII. The rays not being accurately drawn through the station point.



TESTING AND ADJUSTING THE PLANE TABLE SURVEYING:

1. The Board:

- I. The upper surface of the board should be a perfect plane:
 - a. Test: Apply a straight edge in all directions.
 - b. Adjustment: If the surface is not perfectly plane, remove high parts by planning or sand papering.

- II. The upper surface of the board should be perpendicular to the vertical axis of the instrument:
 - a. Test set up and level the table: Place a spirit level on the table and bring the bubble in the central position. Turn the table through 180 and see if the bubble remains central or not. Then place the level at 90 to its previous position, and repeat, if the bubble remains central on reversal in both the above cases, the adjustment is correct.
 - b. Adjustment: If not correct half the apparent error by inserting a packing or washer between the underside of the board and its support. Repeat the whole process until the bubble remains central after reversal in each case.

2. The Alidade:

- I. The ruling edge of the alidade should be a straight line:
 - a. Test: Select two points on the sheet at a distance approximately equal in length to the length of the alidade. Join these points by drawing a fine line along the edge. Reverse the alidade end for end and place it against the end points, and again draw a line. If the two lines coincide, the alidade is correct.
 - b. Adjustment: If not, correct the edge by repeated filing and testing.

- II. The alidade spirit levels should have their axes parallel to the base of the alidade:
 - a. Test: Place the alidade on the table and bring the bubble of one of the levels of the alidade central by the foot-screws of the table. Mark the position of the alidade, lift and reverse it through 180 and replace it within the marks. If the bubble still remains in the centre of its run, the adjustment is correct.
 - b. Adjustment: If not, bring the bubble half way back by means of level tube adjusting screws and the remaining half by the foot-screws and repeat until the test is satisfied. Test and adjust the second level tube in the same way.

- III. The sight vanes of the plain alidade should be perpendicular to the base of the alidade:
 - a. Test: Suspend a plumb line at a short distance from the instrument. Place the alidade on the levelled table and observe whether the sighting slit and vertical hair of the object vane appear parallel to the plumb line.
 - b. Adjustment: If not, adjust by filing or packing the base of the sights.

In the case of telescopic alidade, the conditions of adjustments are:

- I. The line of collimation should be perpendicular to the horizontal axis of the telescope.

- II. The horizontal axis should be parallel to the base of the alidade.

- III. The telescope level should be parallel to the line of sight.

- IV. The vertical circle should read zero when the line of sight is horizontal.

ADVANTAGES & DISADVANTAGES OF PLANE TABLE SURVEYING

Advantages of Plane Table Surveying

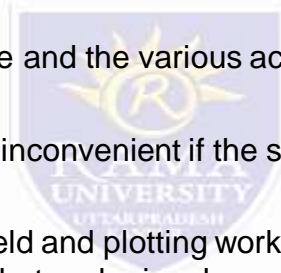
Some of the advantages of plane table surveying are:

- I. It is one of the most rapid method of surveying.
- II. Field-notes are not required, and thus the possibility of mistakes in booking is eliminated.
- III. Measuring of lines and angles is mostly dispensed with since they are obtained graphically.
- IV. Since the map is plotted in the field, there is no chance of omitting necessary measurement.
- V. The surveyor is fully confident about the true representation of the area since he can always compare his work with the actual features on the ground and cannot, therefore, over-look any essential detail.
- VI. The surveyor can check the accuracy of his work more frequently and from any position he may desire, thus eliminating all error at the spot.
- VII. It is particularly suitable for filling in details in hilly areas and in magnetic areas where chain and compass surveys are not suitable.
- VIII. Contours and other irregular objects may be accurately represented on the map since the tract is in view.
- IX. It is less costly than theodolite survey.
- X. No great skill is required in making a satisfactory map and the work can be entrusted even to a subordinate.

Disadvantages of Plane Table Surveying:

Some of the disadvantages of plane table surveying are:

- I. It is unsuitable for work in a wet climate, and is difficult in high wind.
- II. It is not useful for large scale surveys and accurate work.
- III. It is not suitable for surveying a densely wooded area.
- IV. The instrument is heavy and cumbersome and the various accessories, being loose, are likely to be lost.
- V. The absence of field-notes is sometimes inconvenient if the survey has to be replotted to a different scale.
- VI. Only day time can be availed of for the field and plotting work whereas in other methods of surveying, day time can be used for field- work and night or even hot and rainy days can be utilised for plotting.



INTRODUCTION

- A contour or a contour line may be defined as the line of intersection of a level surface with the surface of ground. This means every point on a contour line has the same altitude as that of the assumed intersecting surface.
- Supposing a depression is partly filled with water and R.L of the water surface is say 60 m, then the shore line of this water represents 60 m contour. And if the level of water is raised successively by 1 m, the successive shorelines represent 61, 62, 63 m contours and so on.
- The process of tracing contour lines on the surface of the earth is called contouring and the maps upon which these lines are drawn are called contour maps. A contour map therefore, gives an idea of the altitudes of the surface features as well as their relative positions in plan. Thus a contour map serves the purpose of both, a plan and a section.
- Contour An imaginary line on the ground surface joining the points of equal elevation is known as contour.
- It facilitates depiction of the relief of terrain in a two dimensional plan or map. In other words, contour is a line in which the ground surface is intersected by a level surface obtained by joining points of equal elevation. This line on the map represents a contour and is called contour line.
- Contouring is the science of representing the vertical dimension of the terrain on a two dimensional map.

CONTOURING(INTRODUCTION)

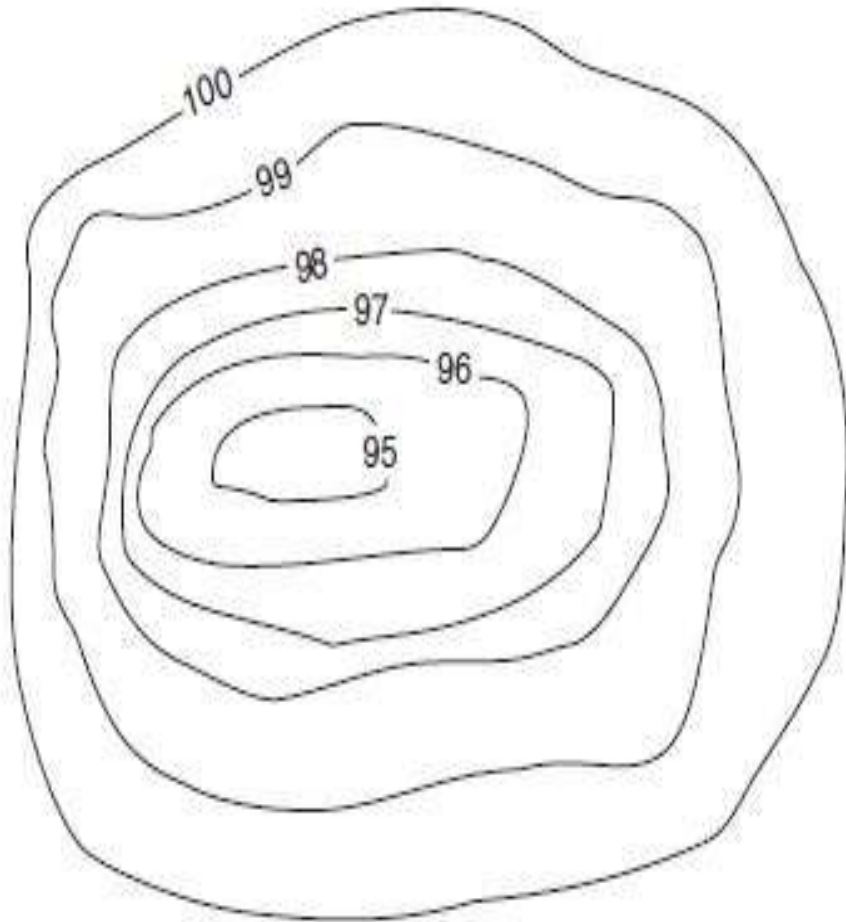
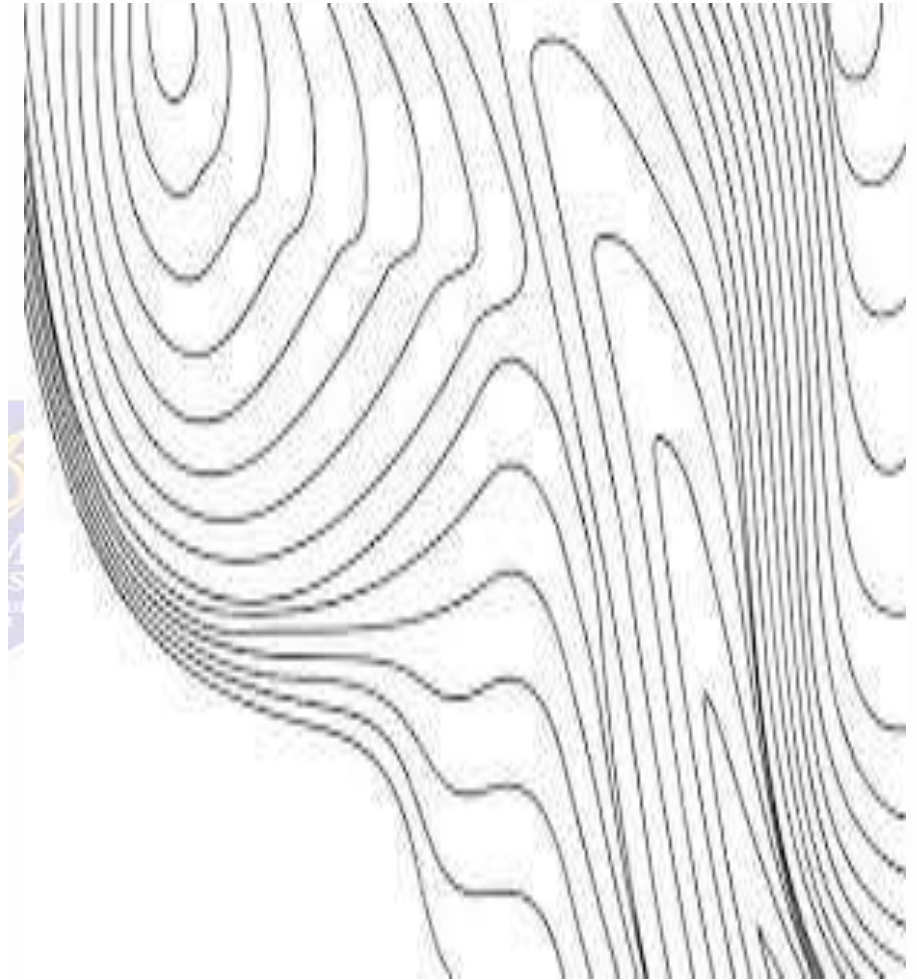


Fig. 17.1. Contours



TERMS USED IN CONTOURING

CONTOUR MAP

- A map showing contour lines is known as Contour map.
- A contour map gives an idea of the altitudes of the surface features as well as their relative positions in plan serves the purpose of both, a plan and a section and a section.

CONTOURING

- The process of tracing contour lines on the surface of the earth is called Contouring.

CONTOUR LINE

- A Contour line is an imaginary outline of the terrain obtained by joining its points of equal elevation.

CONTOUR INTERVAL (CI)

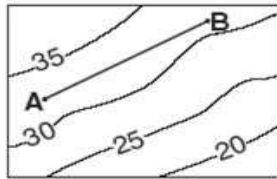
- It is the vertical distance between any two consecutive contours. Suppose a map includes contour lines of 100m, 98m ,96 m and so on .The contour interval here is 2 m. \
- This interval depends upon
 - I. the nature of the ground (i.e. whether flat or sleep).
 - II. the scale of the map
 - III. the purpose of the survey.



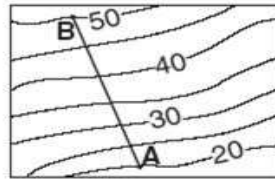
TERMS USED IN CONTOURING

- Contour intervals for flat country are generally small, e.g. 0.25 m, 0.5 m, 0.75m. etc. Contour interval for a steep slope in a hilly area is generally greater. e.g. 5m, 10 m, 15 m etc.
- It should be remembered that the contour interval for a particular map is Constant.

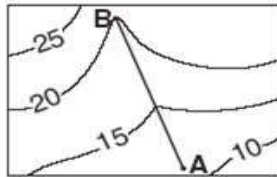
Contour Interval



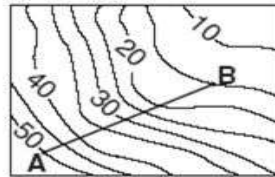
(1)



(3)



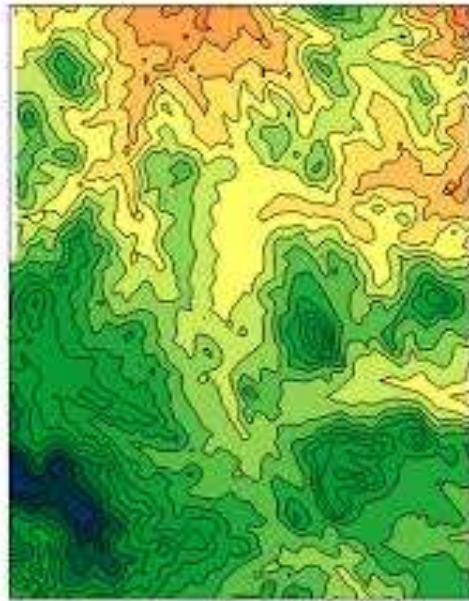
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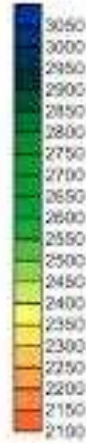
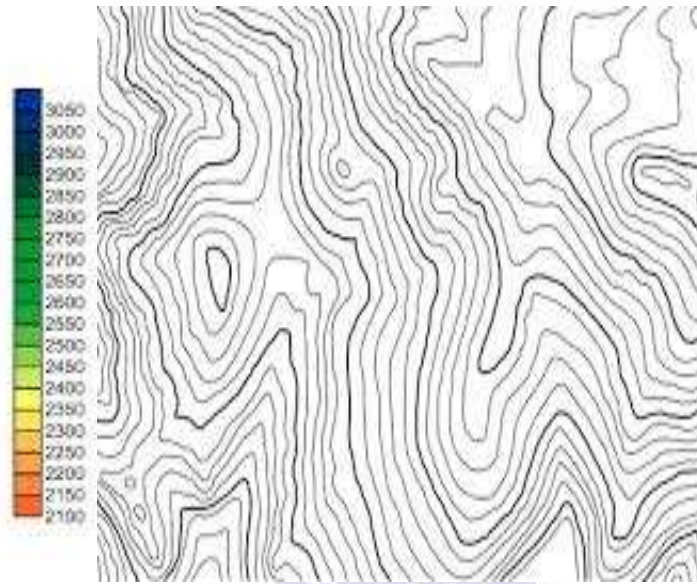
(4)

- What does “contour interval “ mean?
 - The value between two consecutive lines
- What is the contour interval for:
 - Map (1)
 - 5 (units)
 - Map (2)
 - 5 (units)
 - Map (3)
 - 5 (units)
 - Map (4)
 - 5 (units)

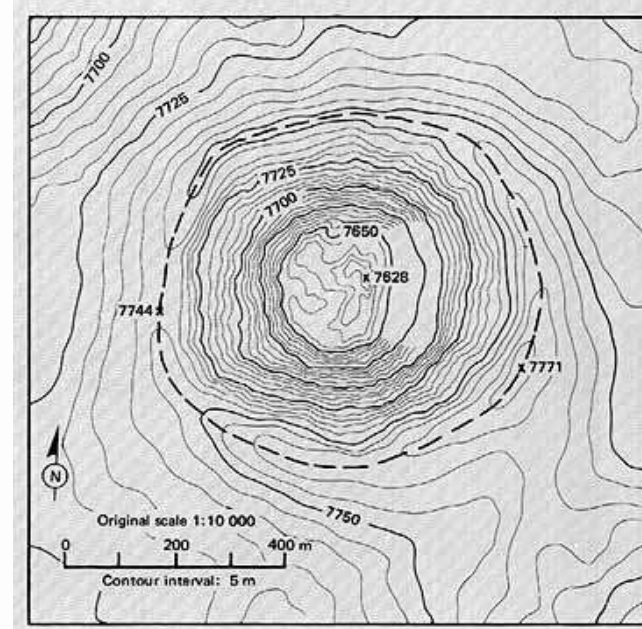
TERMS USED IN CONTOURING



CONTOUR MAP



CONTOUR LINES

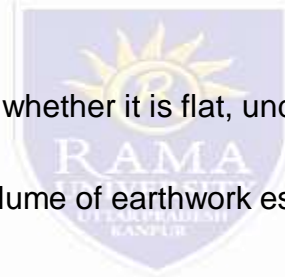


CONTOUR MAP

PURPOSE OF CONTOURING

Contour survey is carried out at the starting of any engineering project such as a road, a railway, a canal, a dam, a building etc.

- I. For preparing contour maps in order to select the most economical or suitable site.
- II. To locate the alignment of a canal so that it should follow a ridge line.
- III. To mark the alignment of roads and railways so that the quantity of earthwork both in cutting and filling should be minimum.
- IV. For getting information about the ground whether it is flat, undulating or mountainous.
- V. To find the capacity of a reservoir and volume of earthwork especially in a mountainous region.
- VI. To trace out the given grade of a particular route.
- VII. To locate the physical features of the ground such as a pond depression, hill, steep or small slopes.



CONTOUR INTERVAL AND HORIZONTAL EQUIVALENT

Contour Interval and Horizontal Equivalent:

Contour Interval -The constant vertical distance between two consecutive contours is called the Contour Interval

Horizontal Equivalent - the horizontal distance between any two adjacent contours is termed as the horizontal equivalent. The horizontal equivalent depends upon the slope of the ground.

The contour interval depends upon the following factors:

- I. **The nature of the ground:** In flat and uniformly sloping country, the contour interval is small, but in broken and mountainous region, the contour interval should be large otherwise the contours will come too close to each other.
- II. **The purpose and extent of the survey:** Contours interval is small if the area to be surveyed is small and the maps are required to be used for the design work or for determining the quantities of earth work etc., while wider interval shall have to be kept for large areas and comparatively less important works.
- III. **The scale of the map:** The contour interval should be in the inverse ratio to the scale of i.e. the smaller the scale, the greater the contour interval.
- IV. **Time and expense of field and office work:** The smaller the interval, the greater is the amount of field -work and plotting-work.

The following are the common values of the contour interval adopted for various purposes:

- a. For large scale maps of flat country, for building sites for detailed design work and for calculation of quantities of earth work: 0.2 to 0.5 m.
- b. For reservoirs and town planning schemes: 0.5 to 2 m.
- c. For location surveys: 2 to 3 m.
- d. For small scale maps of broken country and General topographical work : 3 m, 5 m, 10 m or 25 m.



FACTORS GOVERNING SELECTION OF CONTOUR INTERVALS

The survey leader has to decide an appropriate contour interval for his project before start of survey work. The following factors govern the selection of contour interval for a project:

S.No	Factor	Select High CI like 1m, 2m, 5m or more	Select Low CI like 0.5m, 0.25m, 0.1m or less
1	Nature of ground	If the ground has large variation in levels, for instance, hills and ponds	If the terrain is fairly level
2	Scale of the map	For small scale maps covering a wide area of varying terrain	For large scale maps showing details of a small area
3	Extent of survey	For rough topographical map meant for initial assessment only	For preparation of detailed map for execution of work
4	Time and resources available	If less time and resources are available	If more time and resources are available

CHARACTERISTIC OF CONTOURS

Contours show distinct characteristic features of the terrain as follows:

- I. All points in a contour line have the same elevation.
- II. Flat ground is indicated where the contour are widely separated and the steep ground where they run close together.
- III. A uniform slope is indicated when the contour lines are uniformly spaced and a plane surface when they are straight, parallel and equally spaced.
- IV. A series of closed contour lines on the map represent a hill, if the higher values are inside

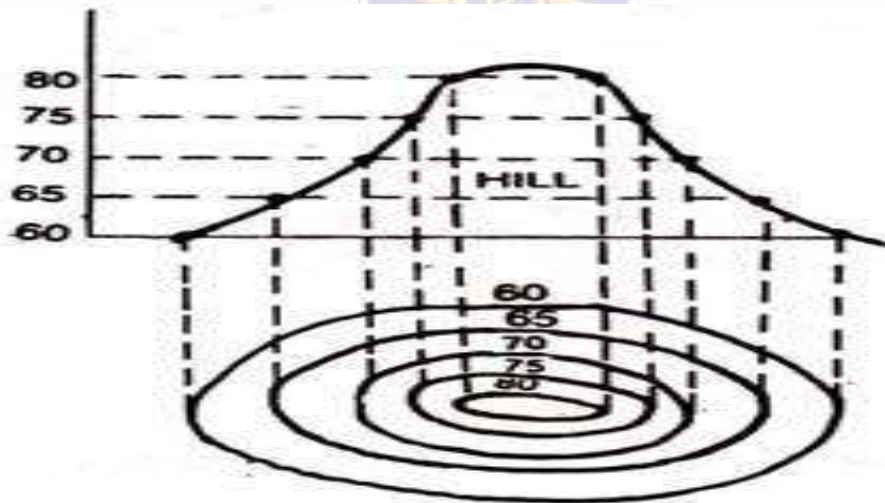


Fig. 8.1

CHARACTERISTIC OF CONTOURS

- V. A series of closed contours on the map indicate a depression, if the higher values are outside.
- VI. Contour lines across ridge or valley lines at right angles. If the higher values are inside the bend or loop in the contour, it indicates a "Ridge". And if the higher values are outside the bend, it represents a "Valley".

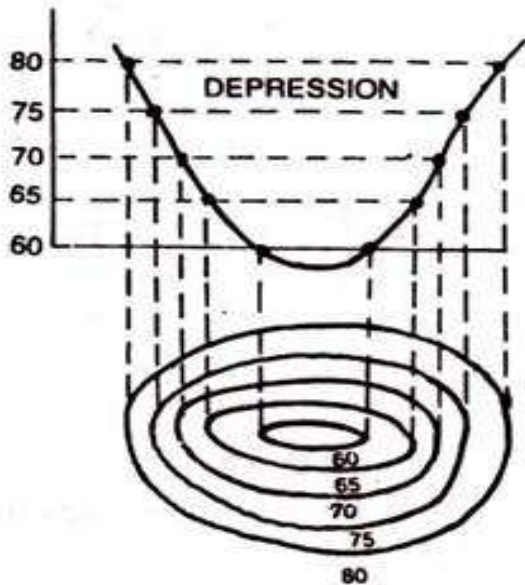


Fig. 8.2

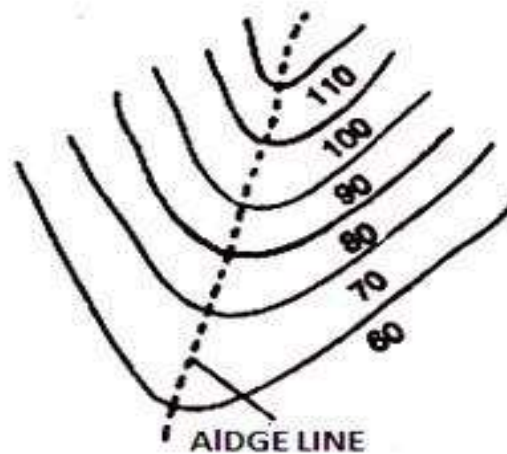


Fig. 8.3

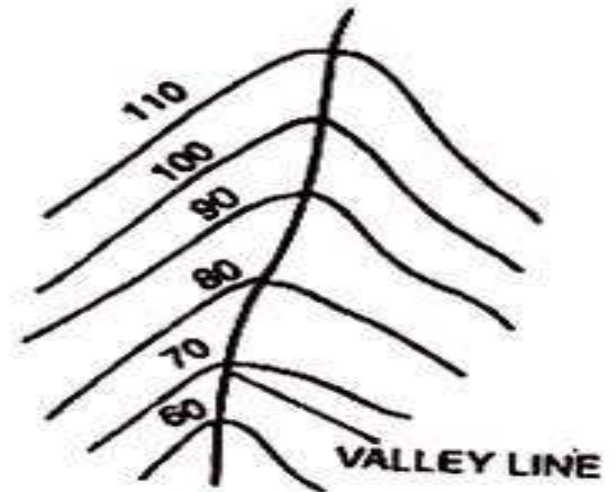


Fig. 8.4

CHARACTERISTIC OF CONTOURS

- VII. Contour lines cannot end anywhere but close on themselves either within or outside the limits of the map.
- VIII. Contour lines cannot merge or cross one another on map except in the case of an overhanging cliff.
- IX. Contours never run into one another except in the case of a vertical cliff. In this case, several contours coincide and the horizontal equivalent becomes zero.
- X. Depression between summits is called a saddle. It is represented by four sets of contours. It represents a dip in a ridge or the junction of two ridges. And in the case of a mountain range, it takes the form of a pass. Line passing through the saddles and summits gives water shed line.

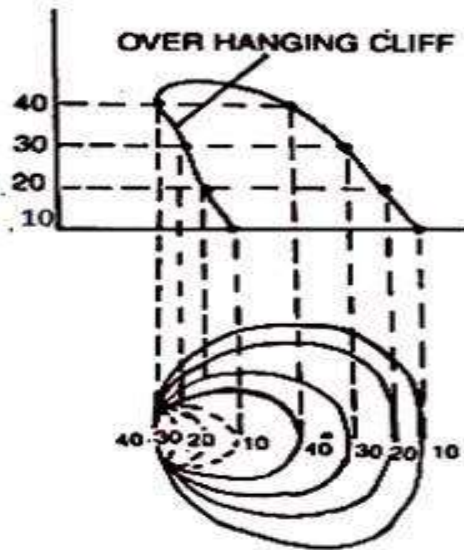


Fig. 8.5

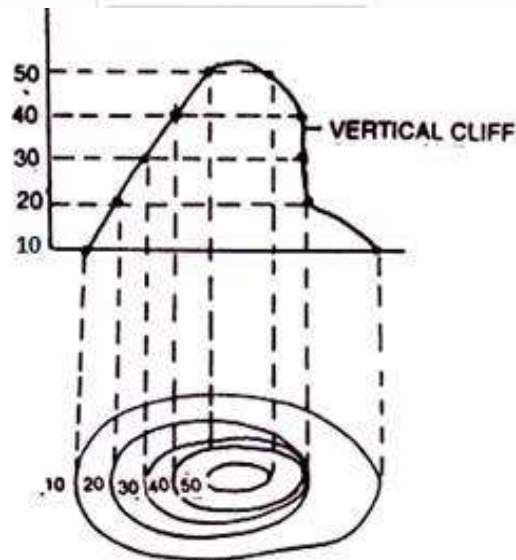


Fig. 8.6

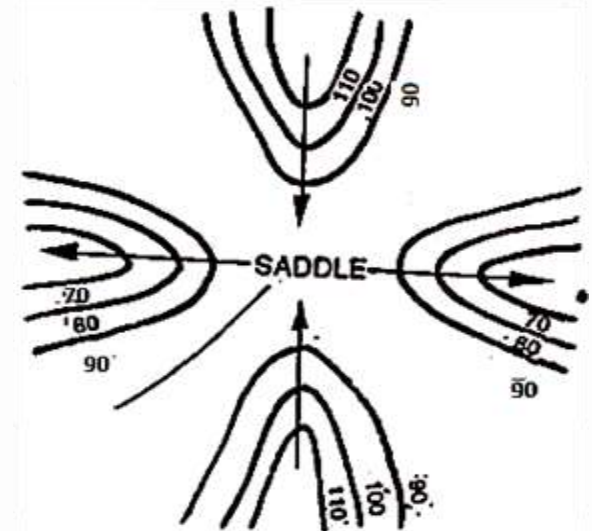


Fig. 8.7

- 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 leveling work is carried out and simultaneously to exercise horizontal control chain survey or compass survey or plane table survey is to be carried out. If the theodolite is used both horizontal and vertical controls can be achieved from the same instrument.
- Based on the instruments used one can classify the contouring in different groups:
 - I. Direct method, and
 - II. Indirect method.

DIRECT METHOD

- In this method, the contours to be located are directly traced out in the field by locating and making a number of points on each contour.
- These points are then surveyed and plotted on plan and the contours drawn through them.
- This method is the most accurate but very slow and tedious as a lot of time is wasted in searching points of the same elevation for a contour.
- This is suitable for small areas and where great accuracy is required.



METHODS OF CONTOUR

a. Vertical Control:

- The points on the contours are traced either with the help of a level and staff or hand level.
- The level is set at a point to command as much area as is possible and is leveled.
- The staff is kept on BM and the height of the instrument is determined. If BM is not nearby, fly leveling may be carried out to establish a temporary bench mark in that area.
- Having known the height of the instrument, the staff reading is calculated so that the bottom of the staff is at an elevation equal to the value of contour. \
- Eg. If height of instrument is 800.250 meters the staff reading to plot a contour of 800 meters will be 0.250 meters. Taking one contour at a time(for 800m contour) the staff man is directed to keep the staff on those points where staff reading of 0.250 m is obtained every time.

b. Horizontal Control:

- c. After having located the points for various contours vertically they are to be surveyed with a suitable control system for horizontally located.
- d. For this, the location of points are traced by the method of plane tabling, chain survey or theodolite.
- e. Then the contour are drawn through these points.
- f. For accurate contouring sufficient number of the points at close interval are required.
- g. The plotted positions of the consecutive points of any contour are simply joined by straight lines to form contour lines

PROCEDURE

- To start with, a temporary B.M. is established near the area to be surveyed with reference to a permanent B.M. by taking flying levels. The level is then set up in such a position so that the maximum number of points can be commanded from the instrument station. The height of instrument is determined by taking a back sight on the B.M. and adding it to the R.L of the bench mark.
- The staff readings required to fix points on the various contours from the height of instrument. As an example, if the height of instrument is 72.58 m, then the staff readings required to locate the 72, 71 and 70m contours are 0.58, 1.58 and 2.58 m respectively. The staff is held on an approximate position of point and then moved up or down the slope until the desired reading is obtained.
- The point is marked with a peg. Similarly various other points are marked on each contour. The line joining all these points gives the required contour. It may be noted that one contour is located at a time. Having fixed the contours within the range of the instrument, the level is shifted and set up in a new position. The new height of instrument and the required staff readings are then calculated in a similar manner and the process repeated till all the contours are located.
- The position of the contour points are located suitably either simultaneously with levelling or afterwards. A theodolite or a compass or a plane table traversing is usually adopted for locating these points. The points are then plotted on the plan and the contours drawn by joining the corresponding points by dotted curved lines.

Direct Method by Radial Lines:

- This method is suitable for small areas where a single point in the centre can command the whole area. Radial lines are laid out from the common centre by theodolite or compass and their positions are fixed up by horizontal angles and bearings. Temporary bench marks are first established at the centre and near the ends of the radial lines.
- The contour points are then located and marked on these lines as explained above and their positions are determined by measuring their distances along the radial lines. They are then plotted on the plan and the contours drawn by joining all the corresponding points.

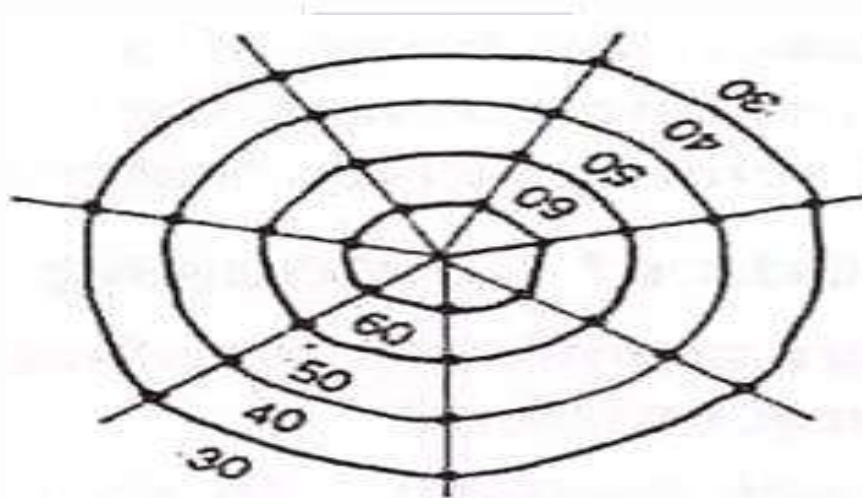
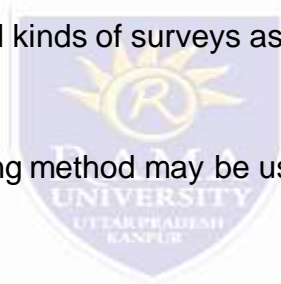


Fig. 8.8

Indirect Method

- In this method, the points located and surveyed are not necessarily on the contour lines but the spot levels (spot level means the R.L. of a point on the surface of the ground) are taken along the series of lines laid out over the area.
- The spot levels of the several representative points representing hills, depression, ridge and valley lines, and the changes in the slope all over the area to be contoured are also observed. Their positions are then plotted on the plan and the contours drawn by interpolation. This method of contouring is also known as contouring by spot levels.
- This method is commonly employed in all kinds of surveys as this is cheaper, quicker and less tedious as compared with the direct method.
- for selecting points anyone of the following method may be used:
 - a. Method of square
 - b. Method of cross-section
 - c. Radial line method



BY SQUARES

- In this method, the whole area is divided into a number of squares, the sides of which may vary from 5m to 30m depending upon the nature of the ground and the contour interval. The squares need not be of the same size throughout, the corners of the squares are pegged out and the reduced levels of these points are determined with a level.
- The important points within the squares may be taken when required and located by measurements from the corners. The squares are plotted and the reduced levels of the corners are written on the plan. The contour lines are then interpolated

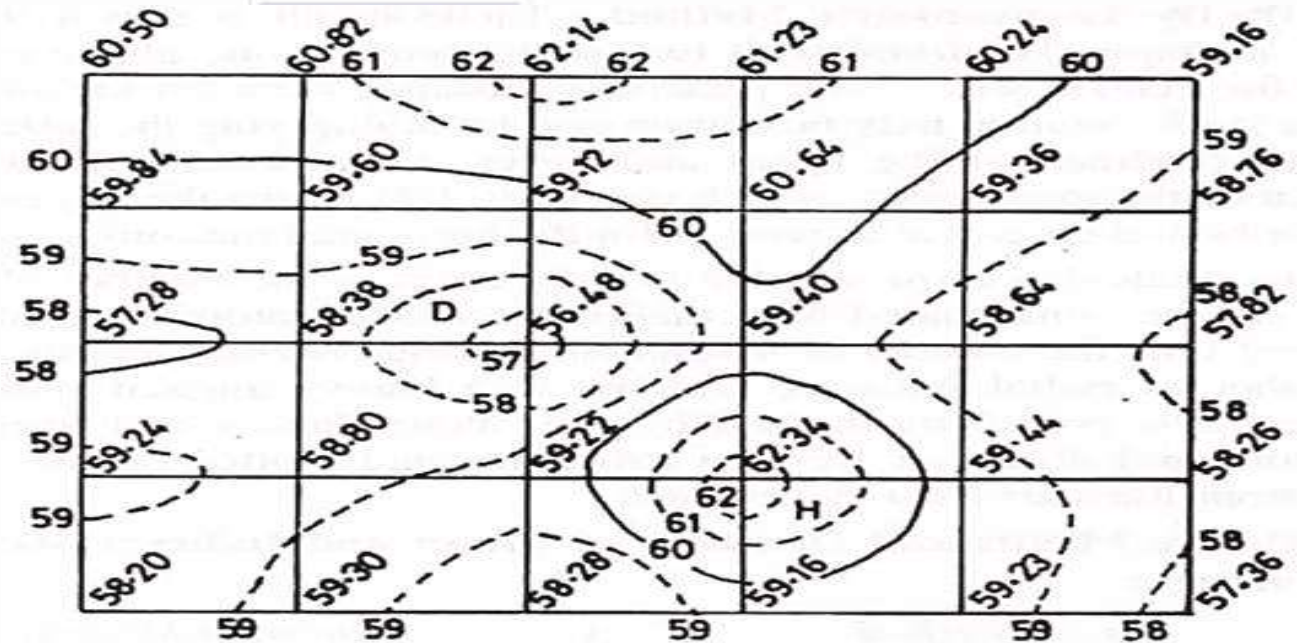


Fig. 8.9

By Cross-Sections

- This method is most suitable for survey of long narrow strips such as a road, railway canal etc. Cross-sections are run transverse to the centre line of the work and representative points are marked along the lines of cross-section. The cross-section lines need not necessarily be at right angles to the centre line of the work.
- This may be inclined at any angle to the centre line if necessary. The spacing of the cross-sections depends upon the topography of the country and the nature of the survey, the common value is 20 to 30m in hilly country and 100m in flat country. The levels of the points along the section line are plotted on the plan and the contours are then interpolated as usual.

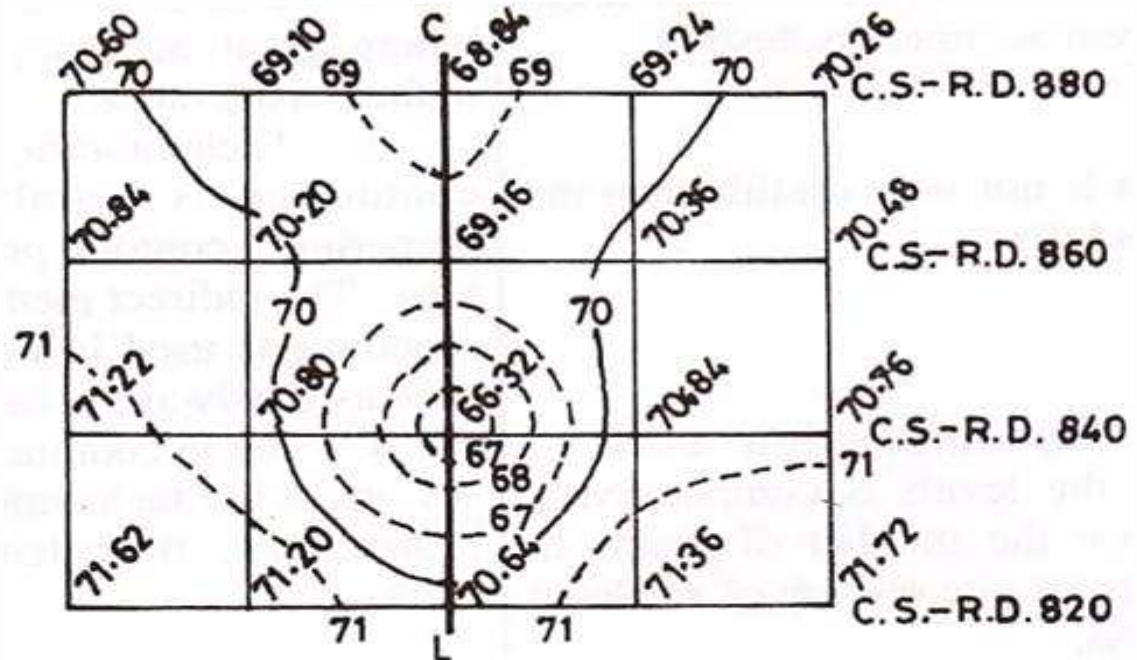


Fig. 8.10

Lecture -09

METHODS OF CONTOUR

By Tacheometric Method

- Tacheometer is transit theodolite having a diagram fitted with two stadia wires, one above and other below the central wire. The horizontal distance between the instrument and the staff -station may be determined by multiplying the difference of the staff readings of the upper and lower stadia wires with the stadia constant of the instrument, which is usually 100. Thus the tacheometer is used for both the vertical as well as for the horizontal measurements.
- This method is most suitable in hilly areas as the number of stations which can be commanded by a tacheometer is far more than those by a level and thus the number of instrument-settings is considerably reduced.
- A number of radial lines are laid out at a known angular interval and representative points are marked by pegs along these radial lines. Their elevations and distances are then calculated and plotted on the plan and the contour lines are then interpolated.

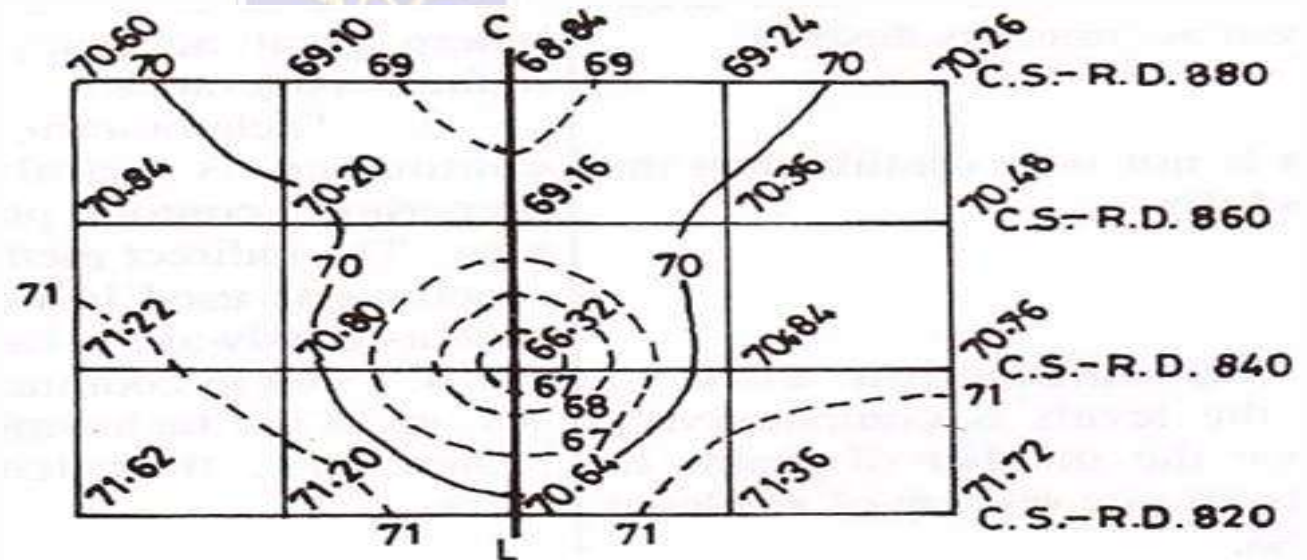


Fig. 8.10

Relative Merits and Demerits of Direct and Indirect Methods of Contouring:

Direct Method:

- I. The method is most accurate but is very slow and tedious.
- II. It is used for small areas where great accuracy is desired.
- III. It is not very useful when the ground is hilly.
- IV. The calculation work of reducing the levels is comparatively more since the number of points in command from one set-up of the level is very less.

Indirect Method:

- I. The method is not very accurate but is cheaper, quicker and less laborious.
- II. It is used for large areas where great accuracy is not the main consideration.
- III. Tacheometric method of contouring is mainly used for preparing contour plans of hilly area. The indirect method by cross-sections is used in route surveys such as a railway, a canal etc.
- IV. Area in command from one set-up of the tacheometer is more, therefore, the calculation work is less.



Interpolation of Contours

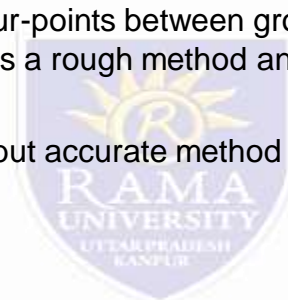
- The process of spacing the contours proportionally between the plotted ground points is termed as interpolation of contours. This becomes necessary in the case of indirect contouring as only the spot levels are taken in this method. The intermediate contours may also be interpolated in direct contouring if the interval is large. While interpolation of contours the ground between any two points is assumed to be uniformly sloping.

There are three methods of interpolation:

- I. **By estimation:** The positions of the contour-points between ground -points are estimated roughly, and the contours are then drawn through these points. This is a rough method and is suitable for small scale maps.
- II. **By arithmetical calculation:** This is very but accurate method and is used for small areas where accurate results are necessary.

The contours are interpolated as under:

- Suppose A and B are two points at a distance of 30m and the reduced levels A and B are 24.32m and 26.90m respectively. Taking the contour interval as 1m, 25 and 26m contours may be interpolated in between A and B. The difference of level between A and B is 2.58m. The difference of level between A and 25 and A and 26m contours is 0.68m and 1.68m respectively.
- Therefore the horizontal distance between A and 25 m contour $= (0.68/2.58) * 30$ and that between A and 26 m contour $= (1.68/2.58) * 30$
- These distances are then plotted to scale on the map.



INTERPOLATION OF CONTOURS

III. Graphical method: Graphical method of interpolation are simpler as compared to arithmetical methods and also the results obtained are accurate.

Out of several graphical methods, the one in common use is explained below:

- Suppose the contour interval is 5m , then on a piece of tracing cloth, a number of parallel lines spaced at 0.5 m (usually one tenth of the contour interval) are drawn, every tenth line being made thick (Fig. 8.11). Suppose it is required to interpolate contours between two points A and B of elevations 61.5 m and 72.5m respectively.
- If the bottom line represent an elevation of 60m, then the successive thick lines will represent 65m, 70m and 75 m etc. Place the tracing cloth so that the point A is on the third line from the bottom. Now, move the tracing cloth until B is on the fifth line above the 70m thick line.
- The intersections of the thick lines 1 and 2 representing elevations of 65m and 70m and the line AB give the position of the points on the 65m and 70m contours respectively and are pricked through on the plan with a pin.



INTERPOLATION OF CONTOURS

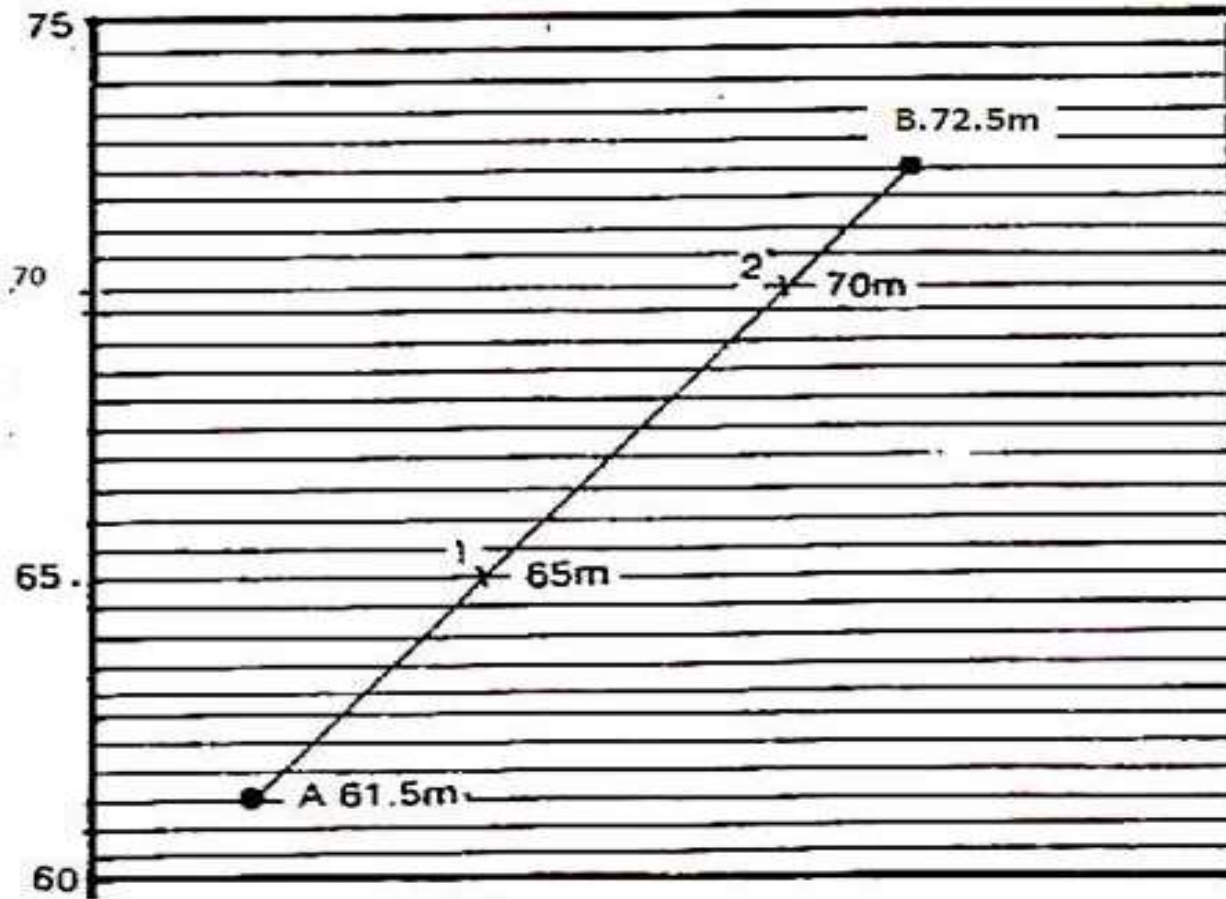


Fig. 8.11

DIFFERENCES BETWEEN DIRECT AND INDIRECT METHOD OF CONTOURING

S No	Direct Method	Indirect Method
1	Very tedious	Not tedious
2	Accurate	Less accurate
3	Slow	Fast
4	Requires more resources	Requires less resources
5	Suitable for contouring of small area.	Suitable for large areas
6	Points are physically located on the ground	Points are interpolated in the office

USE OF CONTOUR MAP

Contour maps are very useful since they provide valuable information about the terrain. Some of the uses are as follows:

- I. The nature of the ground and its slope can be estimated
- II. Earth work can be estimated for civil engineering projects like road works, railway, canals, dams etc.
- III. It is possible to identify suitable site for any project from the contour map of the region.
- IV. Inter-visibility of points can be ascertained using contour maps. This is most useful for locating communication towers.
- V. To Determine Catchment Area or Drainage Area
The catchment area of a river is determined by using contour map. The watershed line which indicates the drainage basin of a river passes through the ridges and saddles of the terrain around the river. Thus, it is always perpendicular to the contour lines. The catchment area contained between the watershed line and the river outlet is then measured with a planimeter
- VI. Storage capacity of a Reservoir
The storage capacity of a reservoir is determined from contour map. The contour line indicating the full reservoir level (F.R.L) is drawn on the contour map. The area enclosed between successive contours are measured by planimeter. The volume of water between F.R.L and the river bed is finally estimated by using either Trapezoidal formula or Prismoidal formula.

Tracing the Contour Gradient for Alignment of Roads, Railways and Canals etc.:

- A contour gradient may be defined as a line joining the points on different contours along the same gradient.
- Fig. 8.17 show a contour map on which the contour lines are at 2m intervals. The ground is sloping in an upward direction from A to B. Supposing it is required to trace the path of a road with a ruling gradient of 1 in 30 from the starting point A on the 80 m contour line. Since the contour interval is 2m and the gradient 1 in 30, the horizontal distance between successive points on consecutive contours is 60m (2×30).
- With A as centre and radius equal to 60m draw an arc cutting the 82m contour at 1. With 1 as centre and the same radius, draw an arc intersecting the 84m contour at 2 and so on for successive contours. Join these points which lie on the desired gradient. It may be noted that each of the arcs described will intersect the next contour at two points viz 1 and i, 2 and ii, 3 and iii etc. at 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116, 118, 120, 122, 124, 126, 128, 130, 132, 134, 136, 138, 140, 142, 144, 146, 148, 150, 152, 154, 156, 158, 160, 162, 164, 166, 168, 170, 172, 174, 176, 178, 180, 182, 184, 186, 188, 190, 192, 194, 196, 198, 200, 202, 204, 206, 208, 210, 212, 214, 216, 218, 220, 222, 224, 226, 228, 230, 232, 234, 236, 238, 240, 242, 244, 246, 248, 250, 252, 254, 256, 258, 260, 262, 264, 266, 268, 270, 272, 274, 276, 278, 280, 282, 284, 286, 288, 290, 292, 294, 296, 298, 300, 302, 304, 306, 308, 310, 312, 314, 316, 318, 320, 322, 324, 326, 328, 330, 332, 334, 336, 338, 340, 342, 344, 346, 348, 350, 352, 354, 356, 358, 360, 362, 364, 366, 368, 370, 372, 374, 376, 378, 380, 382, 384, 386, 388, 390, 392, 394, 396, 398, 400, 402, 404, 406, 408, 410, 412, 414, 416, 418, 420, 422, 424, 426, 428, 430, 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4180, 4182, 4184, 4186, 4188, 4190, 4192, 4194, 4196, 4198, 4200, 4202, 4204, 4206, 4208, 4210, 4212, 4214, 4216, 4218, 4220, 4222, 4224, 4226, 4228, 4230, 4232, 4234, 4236,

Finding Volume of Earth and Capacity of a Reservoir from Contour Lines:

- The volume of earth work and capacity of a reservoir may be calculated by treatment of contour lines. This method is only approximate as in dealing with contour lines we have to assume that the surface of the ground slopes uniformly from one contour to the next and in most cases this assumption is incorrect. However sufficient accuracy can be attained if the contours are located with an interval small enough to record mirror features of the ground.
- After preparation of the contoured plan of the particular site, the area enclosed by each contour line is measured by a planimeter, knowing the vertical distance between the first and the second contour lines (the contour interval) and their areas, Volume of earth work or water between them may be calculated wither by trapezoidal formula or by some other formula.

- Let A_1, A_2, A_3 etc. = The areas within successive contour in sq. metres.

- d = the contour interval in metres

- **Then volume of the earth work or water between two adjacent contours:**

$$\text{By trapezoid formula} = \frac{d}{3}(A_1 + A_2)\text{Cu.metres}$$

$$\text{And more accurately} = \left(\frac{d}{3} A_1 + A_2 + \sqrt{A_1 A_2}\right) \text{cu. metres}$$

- Similarly cubic contents between successive contours may be found out, which when added together gives the required total cubical contents. This may be well understood by the following example.

