Civil Engineering

Engineering Surveying

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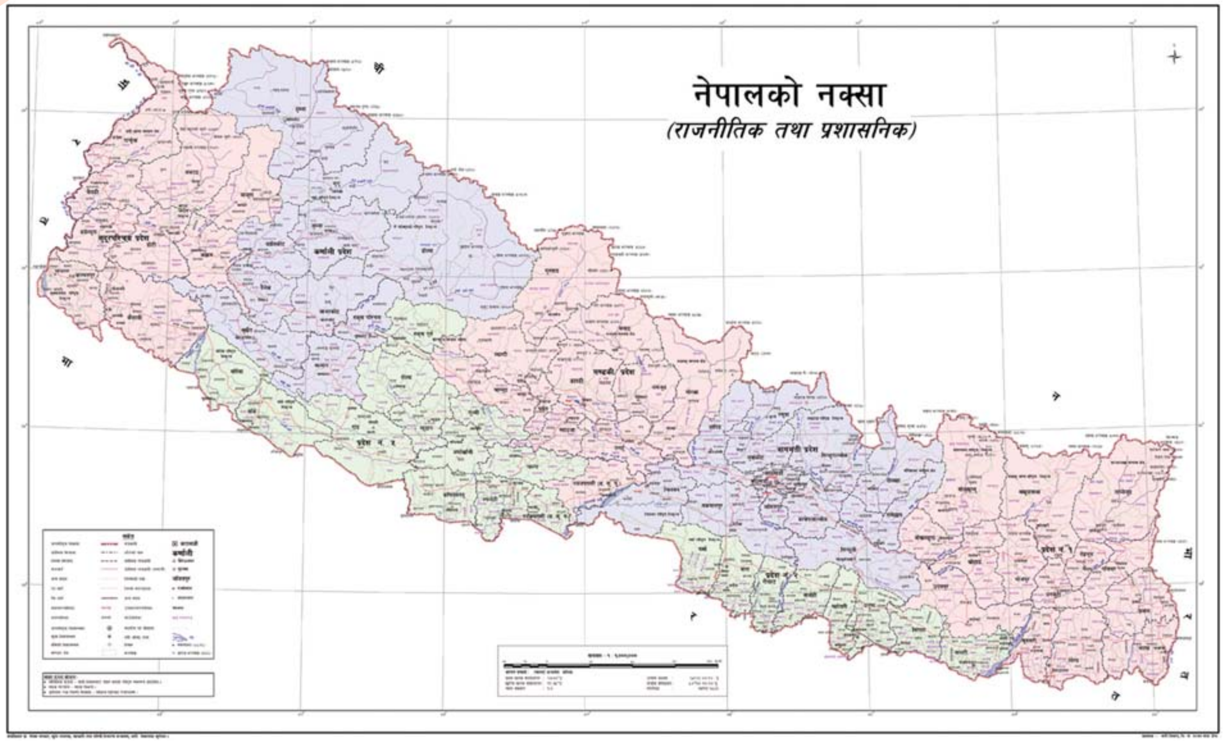

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Ministry of Education, Science and Technology
Curriculum Development Centre
Sanothimi, Bhaktapur

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Technical and Vocational Stream
Learning Resource Material

Engineering Surveying

(Grade 9)

Secondary Level

Civil Engineering

Government of Nepal

Ministry of Education, Science and Technology

Curriculum Development Centre

Sanothimi, Bhaktapur

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Preface

The curriculum and curricular materials have been developed and revised on a regular basis with the aim of making education objective-oriented, practical, relevant and job oriented. It is necessary to instill the feelings of nationalism, national integrity and democratic spirit in students and equip them with morality, discipline and self-reliance, creativity and thoughtfulness. It is essential to develop in them the linguistic and mathematical skills, knowledge of science, information and communication technology, environment, health and population and life skills. it is also necessary to bring in them the feeling of preserving and promoting arts and aesthetics, humanistic norms, values and ideals. It has become the need of the present time to make them aware of respect for ethnicity, gender, disabilities, languages, religions, cultures, regional diversity, human rights and social values so as to make them capable of playing the role of responsible citizens with applied technical and vocational knowledge and skills. This Learning Resource Material for Civil Engineering has been developed in line with the Secondary Level Civil Engineering Curriculum with an aim to facilitate the students in their study and learning on the subject by incorporating the recommendations and feedback obtained from various schools, workshops and seminars, interaction programs attended by teachers, students and parents.

In bringing out the learning resource material in this form, the contribution of the Director General of CDC Dr. Lekhnath Poudel, Dr. Tankanath Sharma, Khushiram Adhikari, Shubas Gurung, Sharmik Dhungana, Achyut Neupane is highly acknowledged. The book is written by Kedar Dahal, Jagadishchandra Karki and the subject matter of the book was edited by Badrinath Timalsina and Khilanath Dhamala. CDC extends sincere thanks to all those who have contributed in developing this book in this form.

This book is a supplimentary learning resource material for students and teachrs. In addition they have to make use of other relevnt materials to ensure all the learning outcomes set in the curriculum. The teachers, students and all other stakeholders are expected to make constructive comments and suggestions to make it a more useful learning resource material.

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Table of Contents

Unit 1
Plane table Surveying

1. Learning outcomes

Following are the learning outcomes of this unit:

a) To prepare plan or map by using plane table surveying.

b) Can prepare map in site simultaneously surveying.

c) Well known about principle of surveying.

d) Working principle of plane table surveying.

e) Methods of plane table surveying.

2. Lesson

1.1 Principle of Plane Table Surveying

1.2 Accessories Required for Plane Table Surveying – Plane Table, Alidade, Spirit Level, Magnetic Compass, Plumbing Fork, and Drawing Paper

1.3 Working Operations of Plane Table Surveying – Fixing the Table on the Tripod, Setting up the Plane Table (Leveling the Plane Table, Centering the Plane Table, Orienting the Plane Table), Sighting the Ground Stations

1.4 Orientation – Orientation by Magnetic Compass, Orientation by Back sighting

1.5 Methods of Plane Table Surveying – Radiation Method, Intersection Method

1.6 Errors in Plane Tabling – Instrumental Error, Personal Error (Non-horizontality of table, Inaccurate Centering, Defective Orientation, Defective sighting), Plotting Error

1.7 Advantages and Disadvantages of Plane Tabling

1.8 Numerical Practice

Instruments Required

- Tripod
- Plane Table
- Plumbing Fork

- Level
- Magnetic needle compass
- Alidade
- Measuring Tape
- Ranging Rods (For demonstration purpose)
- Other accessories
    - 28in x 22in drawing sheet
    - Scotch Tape
    - Chisel pointed Pencil
    - Eraser

3. Contents

1.1 Principle of Plane Table Surveying

(Source: https://www.google.com.np/search?q=plane+table+surveying)

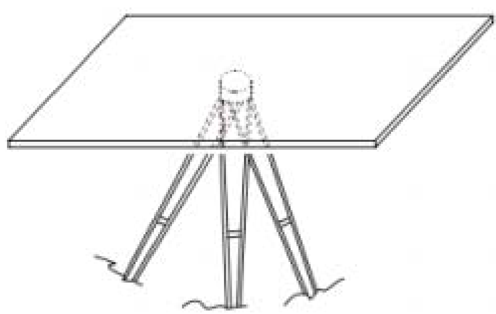
For quick and approximate surveying, when great precision and accuracy is not needed, plane table surveying techniques is very suitable. It is particularly convenient for filling the details between the stations already fixed and surveyed by more precise method of triangulation or Theodolite traversing. For small area surveys, plane table is recommended. The great advantage of this technique is that field work and map plotting is achieved simultaneously by use of graphical surveying.

The principle used in plane table surveying is that an unknown point of intersect can be established by measuring its directions from known points.

1.2 Accessories Required for Plane Table Surveying – Plane Table, Alidade, Spirit Level, Magnetic Compass, Plumbing Fork, and Drawing Paper

THE DRAWING BOARD

- Made of well-seasoned wood such as teak or pine.
- Size varies from 40cm x 30cm x 75cm x 60cm or 50cm to 60 m square.
- It is mounted on a tripod in such a manner that it can be leveled, and revolved about a vertical axis and clamped in any position.



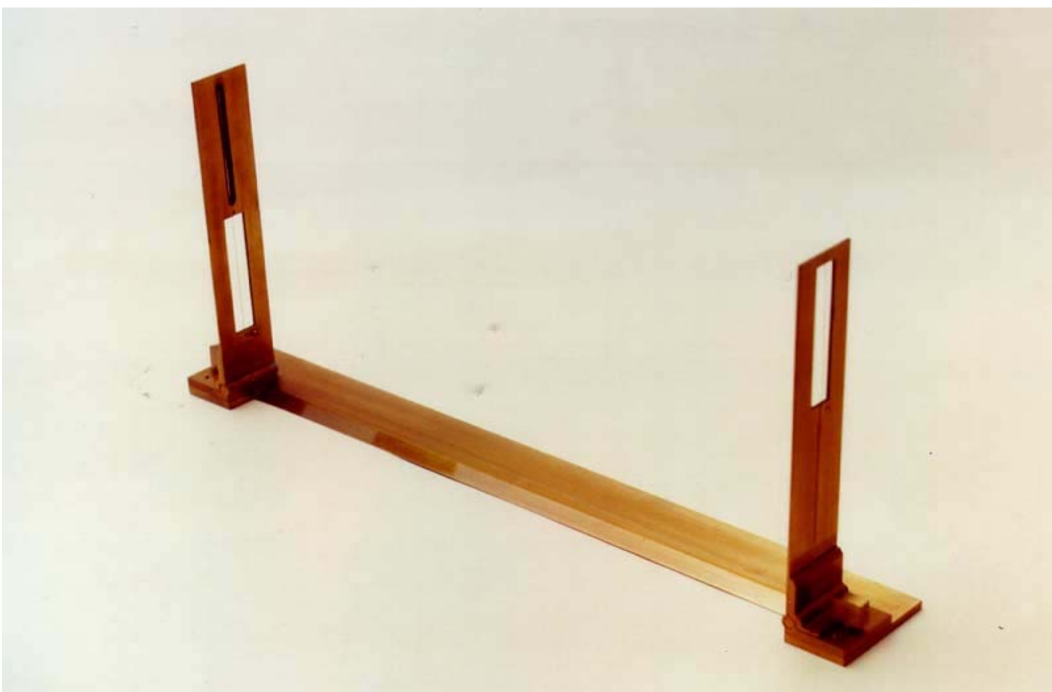
Drawing Board

PLAIN ALIDADE

- Consists of a metal (brass or gunmetal) or boxwood straight edge or ruler about 50 cm long.
- The beveled (ruling or working) edge of the alidade is called the ***fiducial edge***.
- It consists of two vanes at the ends, the vanes are hinged and can be folded

when the alidade is not in use.

- One of the sight vanes is provided with a narrow slit and the other with a central vertical wire or hair.
- One of the vanes known as ***sight vane*** is provided with a narrow slit with three holes, one at the top, one at the bottom and one in the middle.
- The other vane which is known as ***object vane***, is open and carried a hair or a fine thread or a thin wire stretched between the top and bottom of the slit.
- With the help of the slit, a definite line of sight may be established parallel to the ruling edge of the alidade.
- The length of the ruling edge should be equal to the smaller side of the plane table.
- A plane alidade can be used only when the elevations of the objects are low.



Alidade

(Source:http://image.slidesharecdn.com/surveying-150217010933-conversion-gate01/95/plane-table-surveying-ppt-7-638.jpg?cb=1424157731)

Plain Alidade

(Source:https://www.google.com.np/search?q=plane+table+surveying&biw=1517&bih=741&source=lnms&tbm=isch&sa=X&sqi=2&ved=0ahUKEwiYt7SQ7KLNAhWHM48KHU33CMgQ_AUIBigB&dpr=0.9#imgrc=IQlihRyQ0UuPVM%3A)

Telescopic Alidade

- The alidade which is fitted with a telescope is known as a ***telescopic alidade***.
- It is used to take inclined sights.
- It increases the range and accuracy of the sights.
- It consists of a small telescope with a level tube.
- A graduated scale is mounted on the horizontal axis.
- One side of the metal ruler is used as the working edge along which lines are drawn.
- The angles of elevation or depression can be read on the vertical circle.

Telescopic Alidade

(Source:https://www.google.com.np/search?q=plane+table+surveying&biw=1517&bih=741&source=lnms&tbm=isch&sa=X&sqi=2&ved=0ahUKEwiYt7SQ7KLNAhWHM48KHU33CMgQ_AUIBigB&dpr=0.9#imgrc=_)

Spirit Level

- It consists of a small metal tube which contains a small bubble.
- The spirit level may also be circular but its base must be flat so that it can be laid on the table.
- The table is truly level when the bubble remains central all over the table.

Sprit Level

(Source:https://www.google.com.np/search?q=plane+table+surveying&biw=1517&bih=741&source=lnms&tbm=isch&sa=X&sqi=2&ved=0ahUKEwiYt7SQ7KLNAhWHM48KHU33CMgQ_AUIBigB&dpr=0.9#imgrc=w2mM_AoRoTLltM%3A)

The Magnetic Compass

- A box compass consists of a magnetic needle pivoted at its centre freely.
- It is used for orienting the plane table to magnetic north.
- The edges of the box compass are straight and the bottom is perfectly flat.

Magnetic Compass

Plumbing Fork

The plumbing fork consists of a hair pin-shaped brass frame, having two equal arms.

One end has a pointer while a plumb bob is attached the other end.

It is used in large scale survey for accurate centering of the station location on the table over its ground position.

It is also used for transferring the location of the instrument station on the sheet on to the ground.

The fork is placed with its upper arm lying on the top of the table and the lower arm below it. The table is said to be centered when the plumb bob hangs freely over ground mark.

Plumbing Fork

Drawing Sheet

- Drawing paper should be of best quality and well seasoned to minimize the effect of climatic variations..
- The paper should be tinted green or grey for reducing glaring in sun and eye strains.
- Drawing paper is fixed on board with drawing pins, clamps, etc.
- For drawing rays and other detail quality pencils, dustless rubber and precision scales are used.
- A water-proof cover (Surveyor’s umbrella) is also an essential accessory to protect drawing paper from dampness and rain.

1.3 Working Operations of Plane Table Surveying – Fixing the Table on the Tripod, Setting up the Plane Table (Leveling the Plane Table, Centering the Plane Table, Orienting the Plane Table), Sighting the Ground Stations

Setting up the Plane Table

- The table should be set up at a convenient height. (say about 1m). The legs of the tripod should be spread well apart, and firmly fixed into the ground.
- The table should be so placed over the station on the ground that the point plotted on the sheet corresponding to the station occupied should be exactly over the station on the ground. This operation is known as the ***centering*** of the table. This may be done using a plumbing fork or U frame.
- In this operation, the table top is made truly horizontal. For rough and small scale work, leveling can be done by eye estimation whereas for accurate and large scale work, leveling achieved with an ordinary spirit level. The leveling is especially important in hilly terrain where some of the control points are situated at higher level and some other at lower level. The dis-leveling of the plane table, throws the location of the point considerably out of its true location.

1.4 Orientation – Orientation by Magnetic Compass, Orientation by Back sighting

Orienting the Plane Table

- The operation of keeping the table at each of the successive stations parallel to the position which it occupied at the first station is known as orientation. It is necessary when the instrument has to be set up at more than one station.

There are two methods of orienting the table:

1. Orientation by the Magnetic Needle
2. Orientation by Back sighting

Orienting by Magnetic Needle

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

Orienting by Backsighting

- In this method the table is orientated by back sighting through the ray which is drawn from the previous station. This is the most accurate and reliable method of orientation of plane table.

1.5 Methods of Plane Table Surveying – Radiation Method, Intersection Method

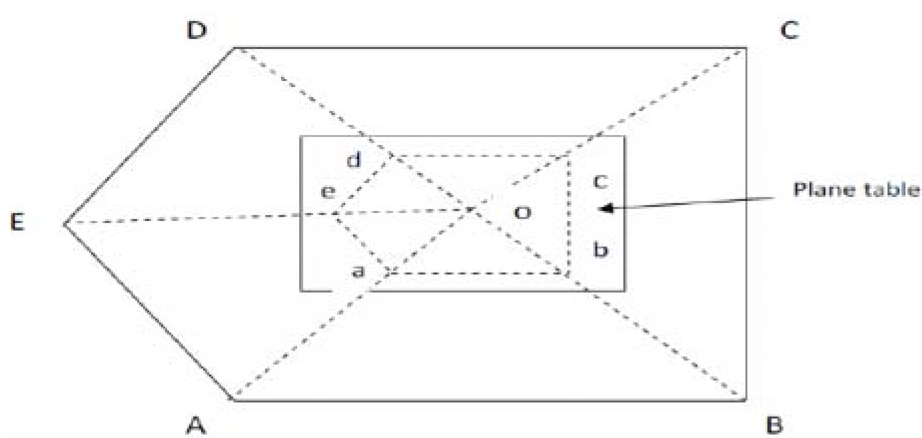
There are four methods of surveying with the Plane table:

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

Radiation Method

In this method the objects are located by radiating lines from the point, and measuring the distance with chain or tape with suitable scale. It is chiefly used for locating the details from the station, which have been established previously by other methods triangulation, or traversing.

Here, the plane table is set up at one station which allows the other station to be accessed. The points to be plotted are then located by radiating rays from the plane table station to the points. After reducing the individual ground distances on the appropriate scale, the survey is then plotted. This method is suitable for small area surveys. It is rarely used to survey a complete project but is used in combination with other methods for filing in details within a chain length.



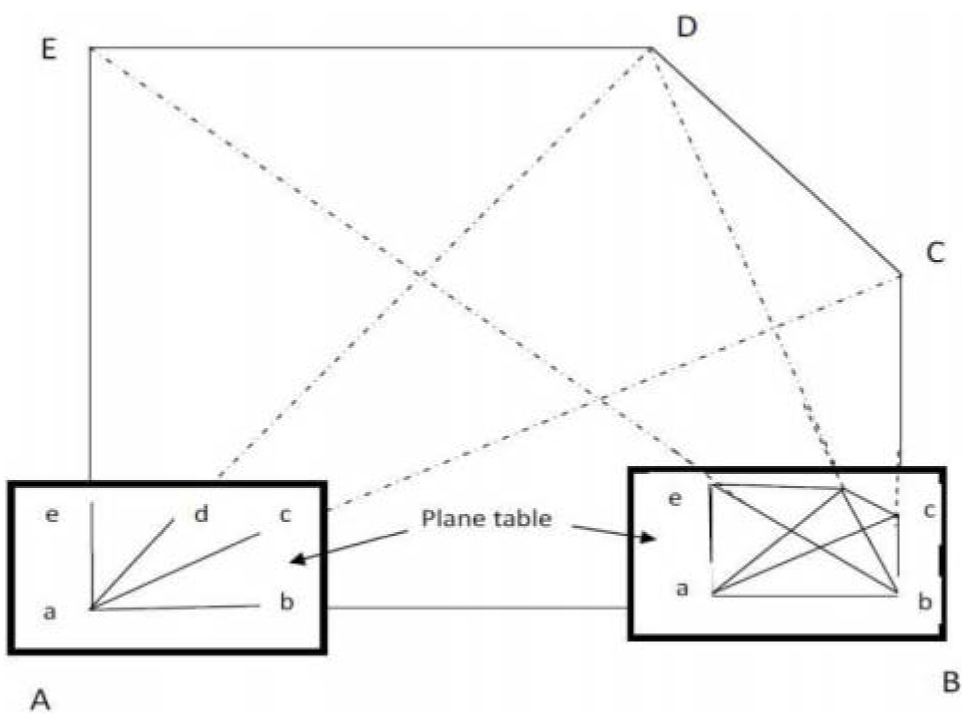
Plane Tabling using Radiation Method

The following steps are taken:

1. Select a point O such that all the points are visible
2. Set up and level the instrument at O
3. From O align the Alidade and draw radial lines towards. The stations A, B, C, D and E.
4. Measure the distances OA, OB, OC, OD and OE: scale and draw Oa, Ob, Oc, Od and Oe on the paper.
5. Join the point a, b, c, d, and e to give the outline of the survey.

Intersection Method

- In this method the point is fixed on the plane by the intersection of the rays drawn from the two instrument stations. The line joining the stations is called *Base line*. The method requires only the linear measurements of this line.



Plane Tabling using Intersection Method

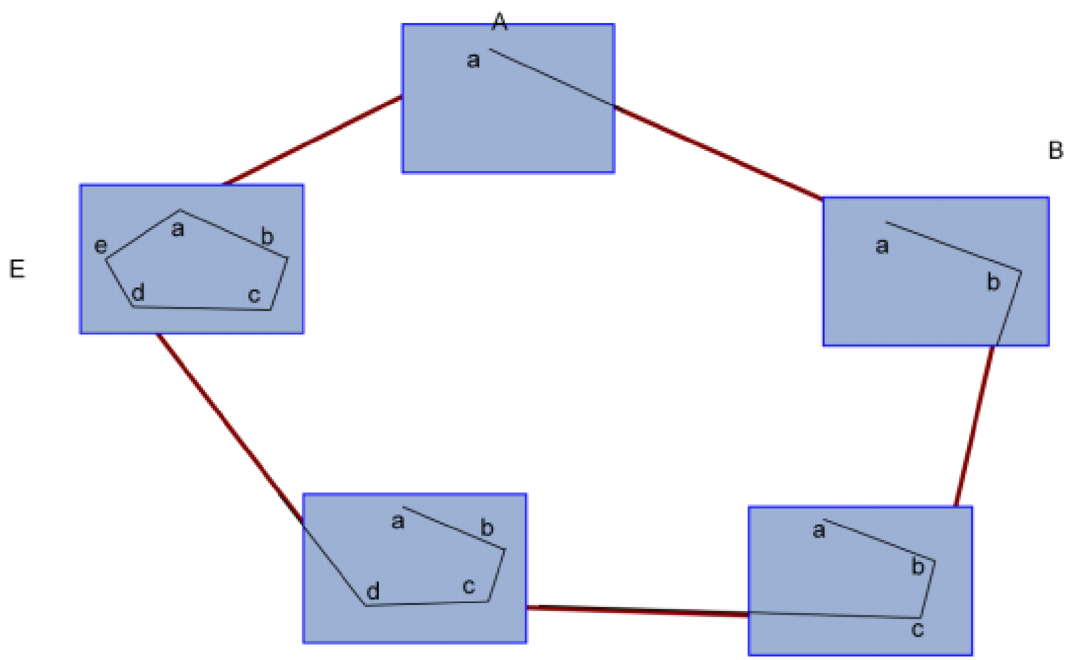
The following steps are taken:

1. 2 points A and B are selected from which the rest of the stations can be seen.

2. Set up and level the plane table at A and mark it as a in the paper to coincide with A on the ground.
3. Sight B, C, D and E with the Alidade from a and draw rays which forwards them.
4. Measure AB, AC, AD and AE and using appropriate scale draw the corresponding paper distance.
5. Remove the equipment from A to B and repeat the procedure using B as the measuring station.

Traversing Method

- This is similar to that of Compass Survey or Transit Traversing. It is used for running survey lines between stations, which have been previously fixed by other methods of survey, to locate the topographic details. It is also suitable for the survey of roads, rivers, etc.



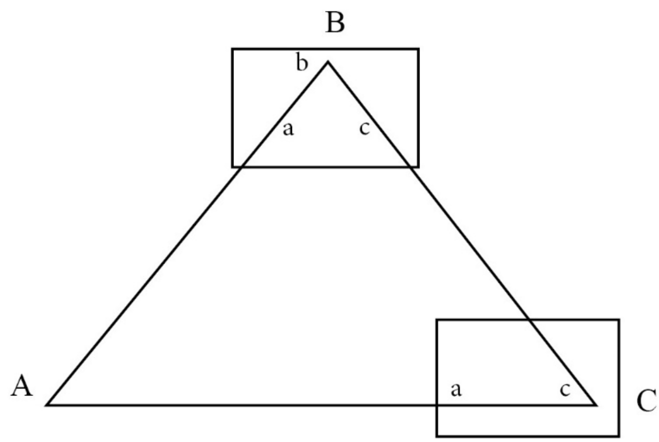
Plane Tabling using Traversing Method

Resection Method

This method of plane table surveying is employed to locate and plot the position of the plane table during surveying. This also results in the orientation of the plane table. The basic principle of resection is opposite to that of the method of intersection. In this method, the position of the plane table is determined by drawing resectors from already plotted points. There are different methods for locating plane table by method of resection and are primarily based on the type of orientation which precedes resection.

- This method is used for establishing the instrument stations only. After fixing the stations, details are located either by radiation or intersection.

RESECTION METHOD



1.6 Errors in Plane Tabling – Instrumental Error, Personal Error (Non-horizontality of table, Inaccurate Centering, Defective Orientation, Defective sighting), Plotting Error

- Instrumental Error

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

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

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

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

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

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

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

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

Error of Manipulation and Sighting

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

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

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

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

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

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

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

Error due to Inaccurate Centering

Centering is very important for plotting detail through plane table surveying. Error in centering leads to error in plotting of location of objects. So, the operations involved in centering need careful consideration. On the other hand, plotting accuracy provides a limit within which no error gets perceptible in plotting. Thus, accuracy with which centering should be done depends on the scale of plotting and accordingly care in centering of plane table should be taken.

Thus, if S is the scale of plotting and 0.25mm is the minimum dimension of plotting, then 0.25 X S is the amount of error in field distance which may be allowed during centering without any effect on actual plotting.

For example, if the plotting scale is 1: 1000, then centering within 0.25 meter distance on ground can be permitted without any error in plotting.

1.7 Advantages and Disadvantages of Plane Tabling

ADVANTAGES OF PLANE TABLING

i) It is most suitable for preparing small-scale maps.

ii) It is most rapid.

iii) The field book is not necessary as plotting is done in the field concurrently with the field work, and hence the mistakes in booking the field notes are avoided.

iv) The surveyor can compare the plotted work with the actual features of the area surveyed and thus can ascertain if it represents them properly.

v) It is particularly advantageous in magnetic areas where compass survey is not reliable.

vi) It is less costly than a Theodolite survey.

vii) No great skill is required to prepare a satisfactory map.

DISADVANTAGES OF PLANE TABLING

i) It is not suitable for work in a wet climate.

ii) It is heavy, cumbersome and awkward to carry.

iii) There are several accessories to be carried, and, therefore, they are likely to be lost.

iv) It is not intended for accurate work.

v) If the survey is to be re-plotted to a different scale or quantities are to be computed, it is a great inconvenience in absence of the field notes.

1.8 Numerical Practice

Unit 2
Leveling

1. Learning outcomes

At the end of this unit following are the learning outcomes of this unit:

a) Determination of the relative position of the object.

b) Find out the exact elevation of the surface.

c) To transfer the level one point to another point.

d) To find out the height of the object.

e) To find out the longitudinal and x-section profile of the ground.

2. lesson

2.1 Definitions of the terms used in Leveling – Leveling, Datum, Bench Mark (Permanent, Temporary, Arbitrary), Reduced Level, Line of Collimation, Back Sight, Fore Sight, Intermediate Sight, Change Point or Turning Point

2.2 Principle of Leveling – Simple Leveling, and Differential Leveling

2.3 Types of Level – Dumpy Level, Tilting Level, Automatic Level

2.4 Temporary Adjustment of Level – Setting up the Level, Leveling up, Elimination of Parallax (Focusing the Eye-piece, Focusing the Objective)

2.5 Booking and Reduction of Levels– Rise and Fall Method, and Height of Instrument Method

2.6 Uses of Leveling – Longitudinal Sections, Cross Sections, Contouring, Setting out Levels

2.7 Two Peg Test

2.8 Fly Leveling

2.9 Reciprocal Leveling

2.10 Curvature and Refraction Correction

2.11 Plotting - Longitudinal Sections, Cross Sections

2.12 Errors in Leveling – Instrumental Error, Personal Error, Natural Error

2.13 Numerical Practice

3. Contents

3.1 Definitions of the terms used in Leveling – Leveling, Datum, Bench Mark (Permanent, Temporary, Arbitrary), Reduced Level, Line of Collimation, Back Sight, Fore Sight, Intermediate Sight, Change Point or Turning Point

Leveling

Leveling is a branch of surveying, the object of which is to. Find the elevation of a given point with respect to the given or assumed datum. Establish a point at a given elevation with respect to the given or assumed datum.

Datum

Datum is a standard position or level that measurements are taken from

Bench mark

A reference point or mark of known height. A readily identifiable, relatively permanent, recoverable benchmark that is intended to maintain its elevation withoutchange over a long period of time with reference to an adopted datum, and is located where disturbing influences are believed to be negligible.

Temporary Bench Mark (TBM)- A marking, or location, with a known elevation. These markings are not usually permanent. They are used by a person doing leveling work as other points when carrying a known elevation from one point to another.

Reduced Level

Reduced Level in surveying refers to equating elevations of survey points with reference to a common assumed datum. It is a vertical distance between survey point and adopted datum plane. Thus it is considered as the base elevation which is used as reference to reckon heights or depths of other important places.

Line of Collimation

Line of collimation: The axial line of the telescope of an astronomical or geodetic instrument, or the line which passes through the optical center of the object glass and the intersection of the cross wires at its focus.

Back Sight

Back sight (BS) – short for "back sight reading", the first staff reading taken by the surveyor after the leveling instrument is set up and leveled. B.S is generally taken on the point of known reduced level as on the benchmark or a change point.

Fore Sight

In levelling, the last reading to be taken from one setting of the instrument. A foresight must be taken on a fixed point, which then becomes a benchmark.

Intermediate Sight

In leveling, a sight which is neither a back sight nor a foresight. It is the reading or sight between back sight and fore sight.

Change Point

Is the point at which foresight and back sight are taken.

3.2 Principle of Leveling – Simple Leveling, and Differential Leveling

Principle of Leveling

1. Simple leveling

It is the simplest operation in leveling when it is required to find the difference in elevation between two points both of which are visible from a single position of the level. Suppose A and b are two such point and level is set up at 0, approximately mid way between. A and B but not necessary on the line joining them, after finding the reading on point A and point B, let the respective reading on A and B be 2.340 and 3.315 difference between them is 3.315-2.340=0.795 m.

OR

The operation of levelling for determining the difference in elevation, if not too great between two points visible from single position of the level is known as simple levelling.

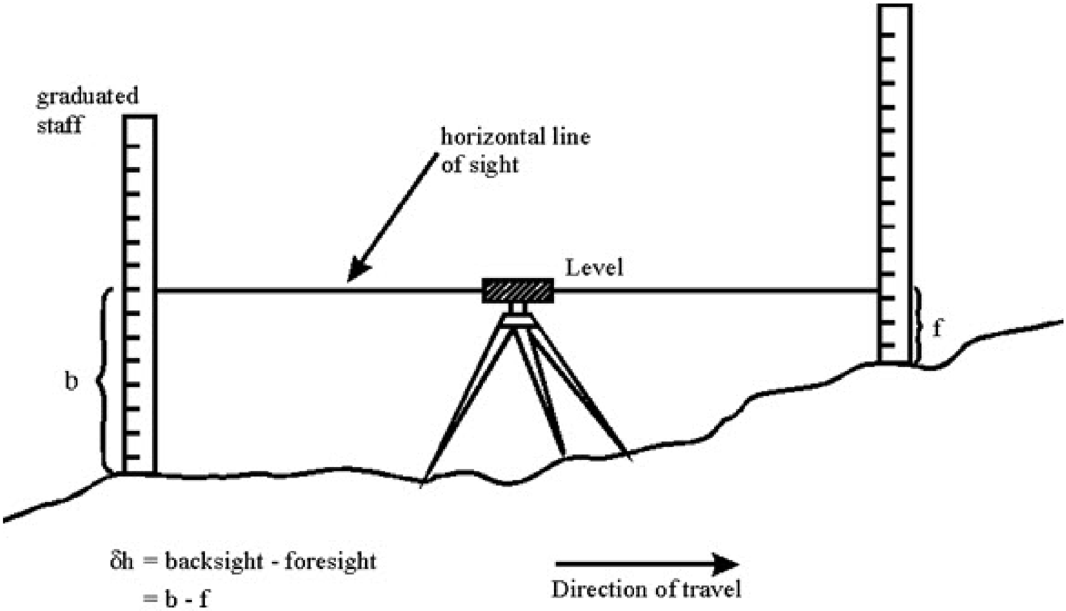


Fig: simple levelling

Procedure to be followed

1. Level the instrument correctly.
2. Direct the telescope towards the staff held
3. Take the reading of Central, horizontal hair of the diaphragm, where it appears to cut the staff ensuring that the bubble is central.
4. Send the staff to next point
5. Direct the telescope towards it and focus it again
6. Check up the bubble is central, if not bring it to the central position by the foot screw nearest to the telescope.
7. Take the reading of Central Horizontal cross hair.
8. Find the difference between readings of these two points.

2. Differential leveling

This method is used in order to find out the difference in elevation between two points.

1. If they too apart.

2. If the difference in elevation between them is too great.

In such cases it is necessary to set up the level in several positions and to work in a series of stages. The method of simple leveling is employed each of the successive stages. The process is also known as compound continues leveling.

OR

Any number of change points is established as required during levelling. This method is known as fly levelling.

It is adopted to find the difference in level between two points, when

(i) The two points are too far away

(ii) The difference in level between two points is large

(iii) There are no obstructions in between the two points concerned.

This method is used in order to find the difference in elevation between two points.

i) If they are too far apart

ii) if the difference in elevation between them is too great.

iii) If there are obstacles intervening. In such case it is necessary to set up the level in several positions and to work in series of stages.

The difference of level of the points A&B is equal to the algebraic sum of these difference between the sum of back sights and sum of the fore sights i.e. Σ BS - Σ FS.

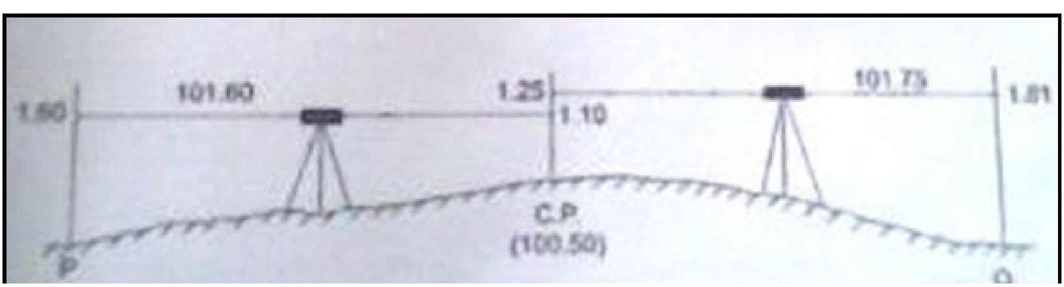


Fig: Differential levelling

The elevation of change point = Elevation of P + Back sight at P – Fore Sight at change point (C.P)

= 100.00+1.60-1.10 = 100.50 m

The second height of the instrument = the elevation of change point+ Back Sight at change point

= 100.50+1.25 = 101.75 m

The elevation of Q = the second height of instrument – Foresight at Q

= 101.75 – 1.81 = 99.94 m

3.3 Types of Level – Dumpy Level, Tilting Level, Automatic Level

Dumpy Level

A dumpy level, builder's auto level, leveling instrument, or automatic level is an optical instrument used to establish or verify points in the same horizontal plane. It is used in surveying and building with a vertical staff to measure height differences and to transfer, measure and set heights.

Tilting Level

A surveying instrument with sighting telescope so mounted that it can be raised or lowered through a limited arc without impairing accuracy of reading, though axis of rotation is not precisely horizontal. The bubble tube is usually mounted alongside the telescope and is viewed from the eyepiece and through an optical sighting arrangement, which either brings opposite halves of the bubble image into coincidence or the end of the bubble to a reference line.

Automatic Level

An Auto Level is a Professional Leveling Tool used by Contractors, Builders, Land Surveying Professionals, or the Engineer who demands accurate leveling every time. Auto Levels set up fast, are easy to use, and save time and money on every job. We have a large selection of Automatic Levels for your choice of options like magnification, accuracy, and price. Some Auto Levels come in kits that include the grade rod and tripod. Auto-Levels are great for Fence Builders, Foundation Installers, Deck Builders, Landscaping Pros, Swimming Pool Builders, Home Builders, Roadwork Jobs, Excavations and More. Auto Levels require that you level the instrument by hand, but you're only required to get the bubble within the black circle on the bubble vial, from there the internal compensator takes over and precisely levels itself. Easier to Level, Quick to Level, and Greater Accuracy. Brands like Agatec, CST Berger, David White, Laser Line, Leica, North West Instrument, Pacific Laser Systems, Pentax, Seco, Sokkia, and Topcon Levels.

3.4 Temporary Adjustment of Level – Setting up the Level, Leveling up, Elimination of Parallax (Focusing the Eye-piece, focusing the Objective)

Temporary Adjustments of a level

These adjustments are performed at every setup of instrument

- Setting up of level
- Levelling of telescope
- Focusing of the eye peace
- Focusing of object glass

Setting up the level:-This includes

A) Fixing the instrument on tripod

B) Levelling the instrument approximately by Tripod

Levelling: Levelling is done with the help of foot screws. The purpose of levelling is to make vertical axis truly vertical. It is done with the help of foot screws

A) Place the telescope parallel to a pair of foot screw then hold the foot screws between thumb and first finger and turn them either inward or outward until the longitudinal bubble comes in the centre.

B) Turn the telescope through 90 so that it lies parallel to third foot screw, turn the screw until the bubble comes in the centre.

Focusing the eye piece:-To focus the eye piece, hold a white paper in front of object glass, and move the eye piece in or out till the cross hairs are distinctly seen. Focusing of object glass:- Direct the telescope to the levelling staff and on looking through the telescope, turn the focusing screw till the image appears clear and sharp.

3.5 Booking and Reduction of Levels– Rise and Fall Method, and Height of Instrument Method

Rise and Fall Method

It consists of determining the difference of elevation between consecutive points by comparing each point after the first that immediately preceding it. The difference between their staff reading indicates a rise fall according to the staff reading at the point. The R.L is then found adding the rise to, or subtracting the fall from the reduced level of preceding point.

Arithmetic check Sum of B.S. – sum of F. S. = sum of rise – sum of fall = last R. L. – first R.L.

This method is complicated and is not easy to carry out. Reduction of levels takes more time. Visualization is necessary regarding the nature of the ground. Complete check is there for all readings. This method is preferable for check leveling where number of change points is more.

Observation table

Station	Reading			Rise	Fall	Reduced Level	Remarks
	B.S	I.S	F.S				

Arithmetical check

The difference between the sum of the back sights and the sum of the fore sights should be equal to the difference between the last and first reduced levels. i.e ∑B.S - ∑ F.S.= LAST R.L –FIRST R.L

Height of Instrument Method

It consist of finding the elevation of the plane of collimation (H.I.) for every set up of the instrument, and then obtaining the reduced level of point with reference to the respective plane of collimation.

1. Elevation of plane of collimation for the first set of the level determined by adding back side to R.L. of B.M.
2. The R.L. of intermediate point and first change point are then obtained by subtracting the staff reading taken on respective point (IS & FS) from the elevation of the plane collimation. [H.I.]
3. When the instrument is shifted to the second position a new plane of collimation is set up. The elevation of this plane is obtained by adding B.S. taken on the C.P. From the second position of the level to the R.L. C.P. The R.L. of successive point and second C.P. are found by subtract these staff reading from the elevation of second plane of collimation Arithmetical check Sum of B.S. – sum of F.S. = last R.L. – First R.L. This method is simple and easy. Reduction of levels is easy. Visualization is not necessary regarding the nature of the ground. There is no check for intermediate sight readings. This method is generally used where more number of readings can be taken with less number of change points for constructional work and profile leveling.

Observation table

Station	Reading			R.L. of plane collimation (H.I)	Reduced Level	Remarks
	B.S	I.S	F.S			

Arithmetic check: - The difference between the sum of back sight and the sum of fore sight= difference between the sum of rise and the sum of fall = the difference between the last R.L. and the first R.L.

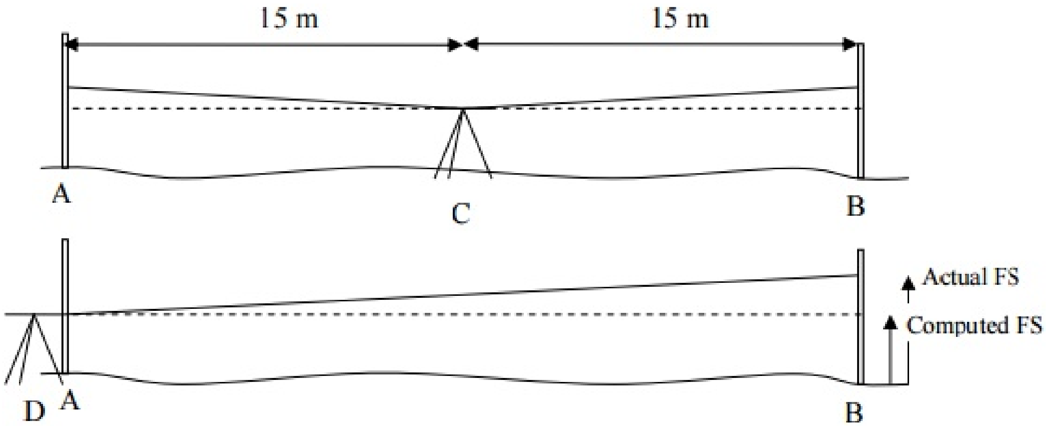
$\sum$B.S-$\sum$F.S =$\sum$RISE -$\sum$FALL =LAST RL- FIRST RL

3.6 Uses of Leveling – Longitudinal Sections, Cross Sections, Contouring, Setting out Levels

1. To establish bench mark as vertical control points which serve as references for other leveling.
2. To enable surveyor calculate whether two points are inter visible from each other on the ground surface.
3. To enable surveyor measurements to be reduced to the horizontal at sea level.
4. To enable drainage works to be surveyed so that water way flows in the desired direction.
5. To provide information for scientists about the shape and structure of the earth and its movement.

3.7 Two Peg Test

This method is either for an optical or digital level, or a transit being used as a level. If this error is corrected with a transit, it also improves the accuracy of its vertical angle readings. The two-peg test is very simple, but provides a way to test the accuracy of a level, and if you know which screw to turn (for analog instruments) or menu to follow (for the digital level), you can adjust it to remove the error. See specific instrument instructions for making adjustments.



The basic principle is that since the error in level readings results from the instrument not sighting exactly horizontally, is thus looking up or down at some angle, and that this angle is the same whichever way it's sighting: if you place the instrument exactly midway between two rod sightings, the vertical error reading on the rod is the same for each, thus the difference in reading between the rods will still give you an accurate elevation difference. Knowing this, we can accurately determine the elevation of B relative to A above. If we then move the instrument to sight from A to B, with the instrument exactly on a reading at A, we can detect the error at that distance, and can adjust the reading to give us the true reading predicted for B.

Process

1. In reasonably level terrain, mark out two rod positions (A and B) on stable surfaces about 30 m apart, and set up the instrument exactly midway between them at C. A good place is along a sidewalk (preferably in a shaded area, or on an overcast day, to avoid optical problems from heat-derived air turbulence), using sidewalk chalk to mark your points.
2. Sight to A to get a rod reading, then to B to get a reading. Assign zero to A, and derive B as A-B. Say we get 1.524 at A and 1.501 at B, the elevation at B is 0.023. (It doesn't matter what the elevation above sea level is – we only need what its elevation is relative to A.)
3. Move the instrument to ~3m from position A, and get a new reading to A.

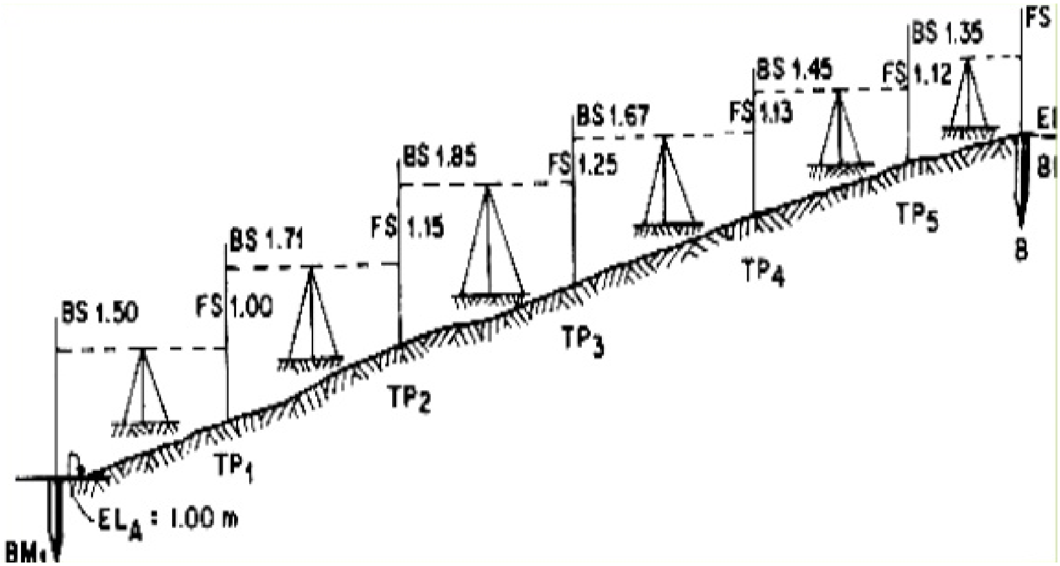
Subtract the elevation at B (0.023) to get the foresight you should expect to get. Say your reading at A is 1.257: FS computed = 1.257 – 0.023 = 1.234

4. Now sight to B to get a reading, and compare it to the expected reading.
5. If there's an error, your Factual will be different from this, and requires an adjustment. Your task is to move it up or down until you get the computed FS.

- For analog instruments, you can adjust the cross hairs by (a) loosening the top capstan
- Screw that allows it to move up, or the bottom capstan screw that allows it to move down; then (b) tightening to other capstan screw. Think of the capstan screws as two ends of a continuously adjusting screw – you're pulling (loosening) with one and simultaneously pushing (tightening) with the other. The capstan screws are turned with adjustment tools (or drill bits, if the tools are missing) that are inserted in the side of the capstan so you can turn the screw tiny amounts. For the Sokkisha level, the capstans are just behind the eyepiece, and can be exposed by unscrewing the cover that is slightly larger than the eyepiece.

3.8 Fly Leveling

Fly leveling is a leveling that is done to connect benchmark to the starting point of the survey line. In this leveling only back sight and fore sight readings are taken and auto level is moved strictly on the line joining benchmark and starting point of survey line. It is just like differential leveling carried out to check the accuracy of leveling work.



Stn	BS	FS	HI	RL	Remarks
A	1.50	-	101.50	100.00	BM
1	1.71	1.00	102.21	100.50	TP1
2	1.85	1.15	102.91	101.06	TP2
3	1.67	1.25	103.33	101.60	TP3
4	1.45	1.13	103.65	102.20	TP4
5	1.35	1.12	103.88	102.53	TP5
B	-	1.10	-	102.76	B

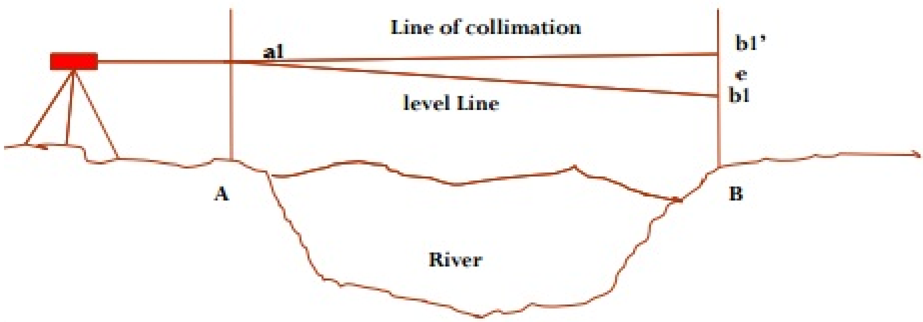
3.9 Reciprocal Leveling

Reciprocal levelling: This method is adopted to accurately determine the difference of level between two points which are far apart. It is also used when it is not possible to set up level in mid way between two points

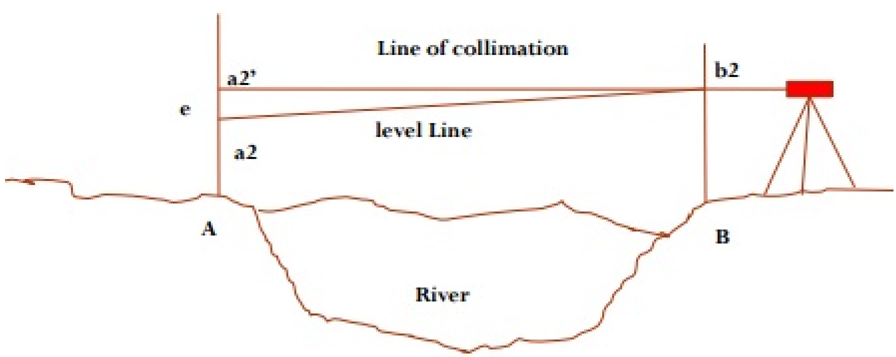
- Let A and B be the two points on opposite banks of a river. It is required to find out the level difference between A & B
- Set up the level very near to A and take the reading at A and B let the reading be a1 and b1
- Shift the level and set up very near to B and observe A and B to get reading a2 and b2
- Let d is the true difference of level between A and B, and e= error due to

curvature, refraction and imperfect adjustment.

- Thus to eliminate the error take an average of the difference in elevation taken from 2 points
- i.e. from A the true difference will be =(b1-e)-a1
- From B the difference will be= b2-(a2-e)
- Therefore d={(b1-a1)+ (b2-a2)}/2



- Thus to eliminate the error take an average of the difference in elevation taken from 2 points
- i.e. from A the true difference will be =(b1'-e)-a1
- From B the difference will be= b2-(a2'-e)
- Therefore d={(b1-a1)+ (b2-a2)}/2

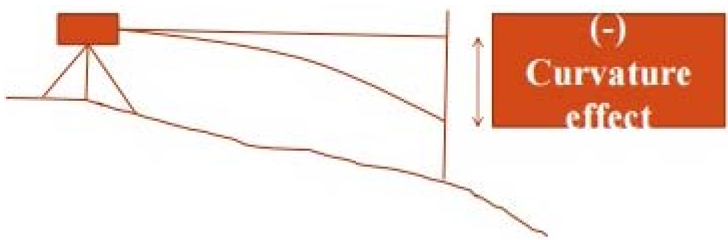


3.10 Curvature and Refraction Correction

Curvature

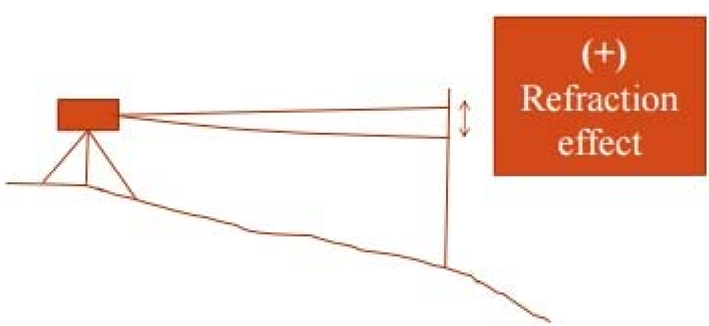
- For long sights the curvature of earth can affect staff readings. The line of sight is horizontal but the level line is curved and parallel to the mean spheroid surface of the earth. The vertical distance between the line of sight and level line at particular place is called the curvature correction
- The effect of curvature is to cause the object sighted to appear lower than they really are.
- Curvature correction is always Subtractive (-)
- True staff reading= (Observed staff reading- 0.0785 D^2) m

  Where D= distance in km



Refraction

- The ray of light passes through layers of air of different densities and refracts or bent down. The effect of refraction is to make the object appear higher than they really are. Refraction varies considerably with climate conditions.
- However it is taken as
- Cr= 0.0112 D2 m (+)
- Refraction is always additive
- True staff reading= Observed staff reading + Refraction correction.

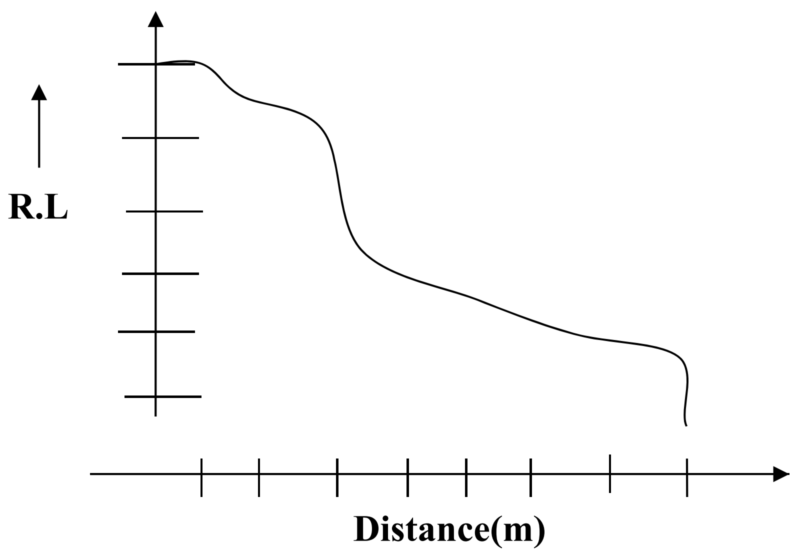


3.11 Plotting - Longitudinal Sections, Cross Sections

Longitudinal Sections

The following procedure is adopted:

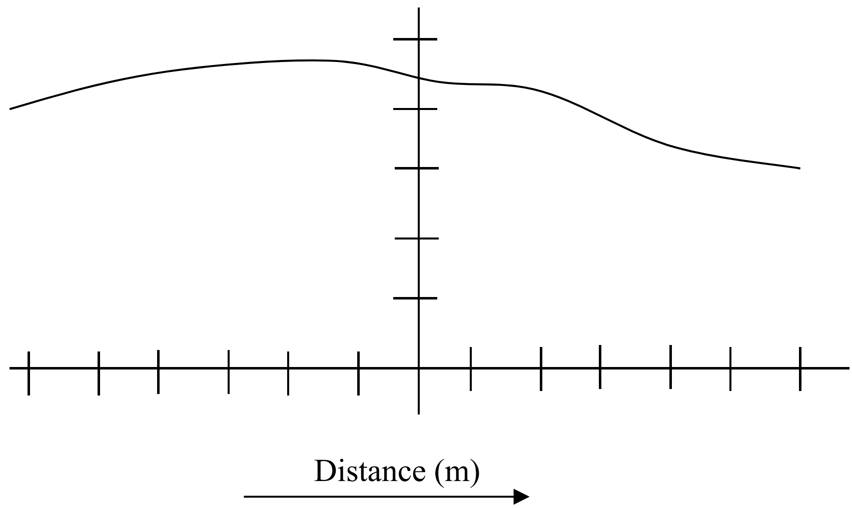
Draw a straight line AB to represent the total horizontal distance between the end stations to a convenient scale. The distance between the consecutive point are marked there on verticals are drawn at each point and their elevations patterns by the Cartesian co-ordinate. The end points of all vertical are joined by straight lines, to show the project of the ground. Generally, horizontal scale is adopted as 1cm=10cm and vertical scale is kept 10 times the horizontal scale i.e. 1cm=1m. So that in equalities of the ground may be shown clearly.



Cross Section

The cross section is plotted same manner as the longitudinal section. In this case, the horizontal and vertical measurement is plotted to same scale. The most commonly adopted scales are 1:100 and 1:200. The elevation of datum lines is for each cross section may be kept different to have the co-ordinates formally short.

R.L



3.12 Errors in Leveling – Instrumental Error, Personal Error, Natural Error

The following are the different sources of Errors

Personal Error

- The Instruments may not be leveled
- The focusing of eye piece and objective glass may not be perfect
- The parallax may not be eliminated
- The position of staff may have changed
- Entry and recording in the field book may not be correct
- The staff may not be fully extended, may not be held vertical.

Instrumental Error

- The Permanent adjustment of the instrument may not be perfect.
- That is the line of collimation may not be horizontal line
- The internal arrangement of focusing tube may not be correct
- The graduation of the staff may not be perfect

Errors due to Natural Causes

- The Curvature of the Earth may affect the staff readings when the distance of sight is long.

- The effect of refraction may cause a wrong staff reading
- There are some errors in staff readings due to high velocity wind

3.13 Numerical Practice

S.N	B.S	I.S	F.S	Rise	Fall	R.L	Remark
	3.202					?	B.M.1
	1.883		?		0.550	?	
	2.204		2.853		0.970	?	
	?		1.153	?		?	
		0.420		1.606		?	B.M.2
	1.245		?		1.092	?	
	1.793		0.716	?		?	
	1.557		0.690	?		?	
			?	1.065		?	B.M.3
Total							

Solution

S.N	B.S	I.S	F.S	Rise	Fall	R.L	Remark
	3.202					652.771	B.M.1
	1.883		3.752		0.550	652.221	
	2.204		2.853		0.970	651.251	
	2.026		1.153	1.051		652.302	
		0.420		1.606		653.908	B.M.2
	1.245		1.512		1.092	652.816	
	1.793		0.716	0.529		653.345	
	1.557		0.690	1.103		654.448	
			0.492	1.065		655.513	B.M.3
Total	13.910	0.420	11.168	5.354	2.612		

Check:

ΣB.S – ΣF.S= 13.910—11.168=2.742

ΣRise -- ΣFall= 5.354-- 2.612= 2.742

Last R.L – 1st R.L = 655.513—652.771 = 2.742

Q. Complete the R.L. of the each point by rise and fall method?

S.No.	Points	B.S.	F.S.	Rise	Fall	R.L.	Remarks
1	A	2.365				100.000	
2	B	0.685	1.235				
3	C	1.745	3.570				
4	D		2.340				

Unit 3
Theodolite survey

1. Learning Outcomes

The following are the learning outcomes from this at the end of this unit:

a) To prepare map from the Theodolite survey

b) To calculate horizontal and vertical angle of any two points

c) To complete survey by using Theodolite

d) To help to know the system of advanced surveying equipments

2. Lesson

3.1 Introduction

3.2 Geometry of the Theodolite

3.3 Uses of Theodolite

3.4 Temporary Adjustment of Theodolite

3.5 Methods of Measuring Horizontal Angle – General Procedure of Measurement of Horizontal Angle, Measurement of Horizontal Angle by Repetition Method, Measurement of Horizontal Angle by Direction Method (or Reiteration Method)

3.6 Sources of Errors in Theodolite

3.7 Numerical Practice

3. Contents

3.1 Introduction

Theodolite is a surveying instrument with a rotating telescope for measuring horizontal and vertical angles.

Theodolite may be either transit or non-transit. Transit Theodolite (or just "transits") are those in which the telescope can be inverted in the vertical plane, whereas the rotation in the same plane is restricted to a semi-circle for non-transit Theodolite. Some types of transit Theodolite do not allow the measurement of vertical angles.

3.2 Geometry of the Theodolite

Upper Plate: It is the base on which the standards and vertical circle are placed. For the instrument to be in current adjustment it is necessary that the upper plate must be perpendicular to the alidade axis and parallel to the trunnion axis.

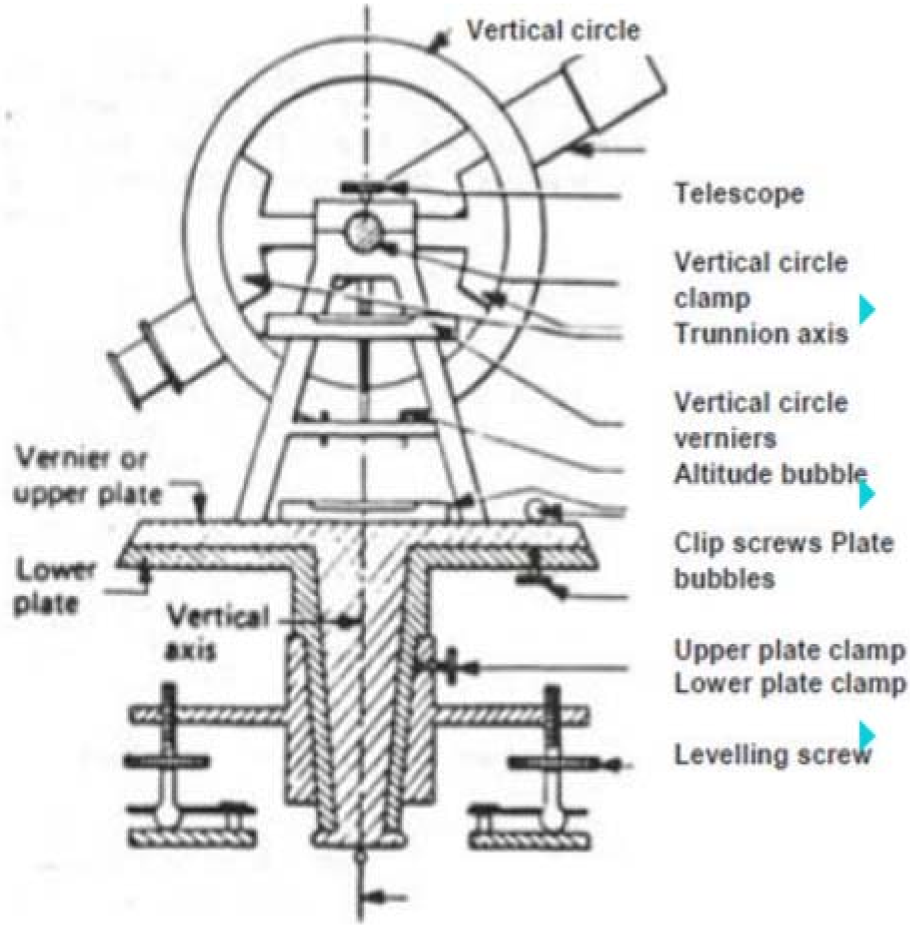
Telescope: It has the same features as in} a level graticule with eyepiece and internal focusing for the telescope itself.

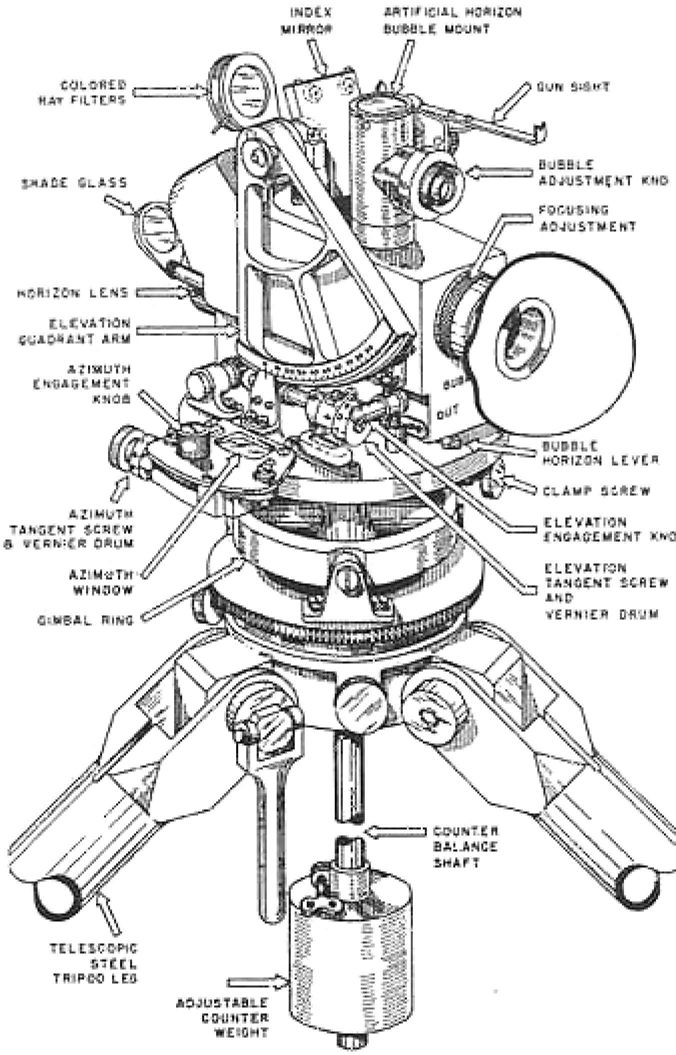
Vertical Scale (Circle): It is a full 400g} scale. It is used to measure the angle between the line of sight (collimation axis) of the telescope and the vertical axis.

Vertical Clamp and Tangent Screw: This allows free transiting of the telescope. When clamped, the telescope can be slowly transited using vertical tangent screw.

The Lower Plate: It is the base of the whole instrument. It houses the foot screws and the bearing for the vertical axis. It is rigidly attached to the tripod mounting assembly and does not move.

Horizontal Scale (Circle): It is a full 400g scale. It is often placed between the upper and lower plates. It is capable of full independent rotation about the trunnion axis. The Upper Horizontal Clamp and **Tangent Screw:** used during a sequence or "round" of horizontal angle measurements. The Lower Horizontal Clamp and Tangent Screw: These must only be used at the start of horizontal angle measurements to set the first reading to zero Circle Reading and **Optical Micrometer:** The vertical and horizontal circles require illumination in order to read them. This is usually provided by small circular mirrors.


Vertical circle
Telescope
Vertical circle clamp
Trunnion axis
Vertical circle verniers
Altitude bubble
Clip screws Plate bubbles
Upper plate clamp
Lower plate clamp
Levelling screw
Vernier or upper plate
Lower plate
Vertical axis



3.3 Uses of Theodolite

Following are the uses of Theodolite:

1. Mapping applications and in the construction industry.
2. Measurement of Horizontal and vertical angle.
3. Measurement of magnetic bearing of lines.
4. Locating points on line.
5. Prolonging survey lines.
6. Determining difference in elevation.

7. Setting out curves.
8. Aligning of tunnels.etc.

3.4 Temporary Adjustment of Theodolite

Temporary adjustments are set of operations which are required to be done on a Theodolite in order to make it ready for taking observations. Temporary adjustments of Theodolite include its setting up, centering, leveling up and elimination of parallax. Therefore these adjustments can be achieved in 4 steps:-

1. Setting

The setting operation includes fixing the Theodolite with tripod along with approximate leveling and centering over the station mark. For setting up the instrument, the tripod is placed over the station with its legs widely spread so that the centre of the tripod head lies above the station point and its head approximately level (by eye estimation). The instrument is then fixed with the tripod by screwing through trivet. The height of the instrument should be such that observer can see through telescope conveniently. After this, a plumb bob is suspended from the bottom of the instrument and it should be such that plumb bob should point near to the station mark.

2. Centering

Centering implies that bringing vertical axis of Theodolite immediately over station mark.. To do this the following procedure is followed:-

- First, the approximate centering of the instrument is done by moving the tripod legs radically or circumferentially as per need of the circumstances.

It may be noted that due to radial movement of the legs, plumb bob gets shifted in the direction of the movement of the leg without seriously affecting the level of the instrument. On the other hand, when the legs are moved sideways or circumferentially, the plumb does not shift much but the level gets affected. Sometimes, the instrument and the tripod have to be moved bodily for centering. It must be noted that the centering and leveling of instrument is done recursively. Finally, exact centering is done by using the shifting head of the instrument. During this, first the screw-clamping ring of the shifting head is loosened and the upper plate of the shifting head is slid over the lower one until the plumb bob is exactly over the station mark. After the exact centering, the screw clamping ring gets tightened.

3. Levelling

Leveling of an instrument is done to make the vertical axis of the instrument truly vertical. For accurate levelling the following steps are strictly followed:-

1. Bring one of the level tubes parallel to any two of the foot screws, by rotating the upper part of the instrument.
2. The bubble is brought to the centre of the level tube by rotating both the foot screws either inward or outward. The bubble moves in the same direction as the left thumb.
3. The bubble of the other level tube is then brought to the centre of the level tube by rotating the third foot screw either inward or outward. [In step 1 itself, the other plate level will be parallel to the line joining the third foot screw and the centre of the line joining the previous two foot screws.]
4. Repeat Step 2 and step 3 in the same quadrant till both the bubble remain central.
5. By rotating the upper part of the instrument through 180°, the level tube is brought parallel to first two foot screws in reverse order. The bubble will remain in the centre if the instrument is in permanent adjustment.

Otherwise, repeat the whole process starting from step1 to step5.

4. Focusing

To obtain the clear reading, the image formed by the objective lens should fall in the plane of diaphragm and the focus of eye-piece should also be at the plane of diaphragm. This is being carried out by removing parallax by proper focusing of objective and eye-piece. Thus, focusing operation involves two steps:

- Focusing of eye-piece.

For focusing of the eye piece, point the telescope to the sky or hold a piece of white paper in front of telescope. Move the eye-piece in and out until a distinct sharp black image of the cross-hairs is seen. This confirms proper focusing.

- Focusing of object glass.

It is done for each independent observation to bring the image of the object in the plane of cross hairs. It includes following steps of operation: First, direct the telescope towards the object for observation. Next, turn the focusing screw until the image of the object appears clear and sharp as the observer looks through properly focused eye-piece. If focusing has been done properly, there will be no parallax i.e., there will be no apparent movement of the image relative to the cross hairs if the observer moves his eye from one side to the other or from top to bottom.

3.5 Methods of Measuring Horizontal Angle – General Procedure of Measurement of Horizontal Angle, Measurement of Horizontal Angle by Repetition Method, Measurement of Horizontal Angle by Direction Method (or Reiteration Method)

For angle measurement with Theodolite vertical hair is used. Basically there are two methods horizontal angle measurement,

- Repetition method (For single angle)
- Reiteration method (For more than one angle)

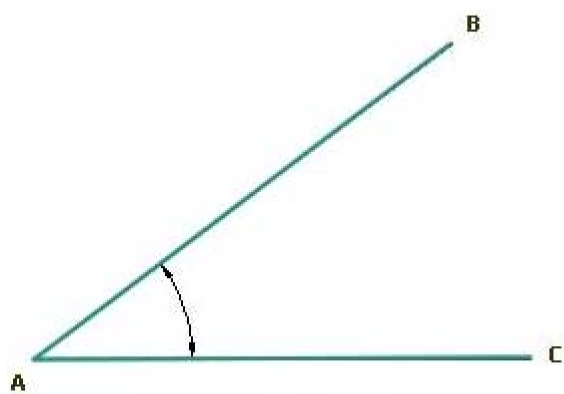


Fig: Repitition Method

1. By Repetition method

Let suppose it is desire to measure the angle A from the following figure. We will use repetition method for this purpose.

Procedure

- Setup the Theodolite at station A.
- Bisect the point B with vertical hair of Theodolite and move telescope in clockwise and direction to bisect at point C.
- Note this circle reading in the book and fix this circle reading, then again bisect the point B by keeping the circle reading fixed.
- Now, release the circle reading and rotate the telescope again in clockwise direction till it bisects again point C.
- Similarly get 3rd and 4th repetition and note the circle reading after 4th repetition in the book.
- Change the face of telescope and repeat the above steps, an example and method of booking observations have given below,

Inst. Station	Angle	Face	Repetition	Circle Reading (° ′ ″)	Angle value (° ′ ″)	Mean of faces (° ′ ″)
A	BAC	L	1	25 20 00	25 20 10	25 20 9.5
			4	101 20 40		
		R	1	25 20 03	25 20 09	
			4	101 20 36		

2. By Reiteration method

This method is used if there are more than one angles to be measure from a certain station point. Consider the following figure; we will measure angles AOB and BOC using this method.

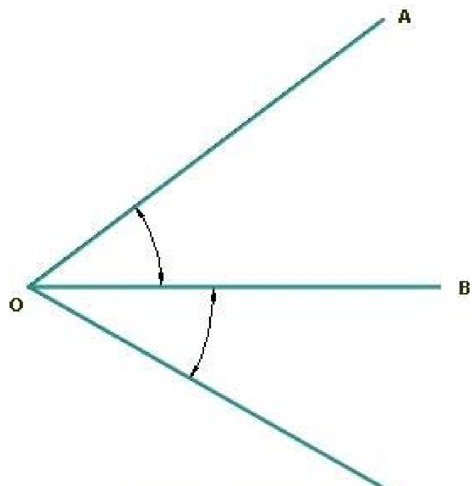


Fig: Reiteration method

Procedure

- Setup the theodolite at station O, bisect the point A with a certain circle reading with face left.
- Rotate the instrument in clockwise direction and bisect B, note the circle reading.
- Then rotate and the telescope till it bisect the point C, note this circle reading also. All these reading will book into face left position.
- Transit the telescope and rotate the instrument through 180°, this time bisect the point C firstly and then rotate telescope in anti clockwise direction towards B and then ultimately towards A. Put these readings in face right position.
- You can do more than one sets of measurements for the accurate results, i have done one set and booking method is as follows,

Inst. Station	**Stn. Sighted**	**Face**	**Circle reading (° ′ ″)**	**Mean of faces (′ ″)**	**Angle value (° ′ ″)**
O	A	L	10 20 05	20 06	AOB 37 10 05
		R	190 20 07		
	B	L	47 30 10	30 11	
		R	227 30 12		BOC 41 10 14

	C	L	88 40 20	40 25	
		R	268 40 30		

One should start observation with some initial circle reading say 25°, if we start our observation with zero circle reading our calculations for computing mean will be little bit difficult.

3.6 Sources of Errors in Theodolite

The sources of errors in Theodolite are:

1. Instrumental errors.
2. Personal errors and
3. Natural errors.

Instrumental errors

1. Plate bubble's out of adjustment
2. Horizontal axis not perpendicular to vertical axis
3. Axis of sight not perpendicular to horizontal axis (Collimation error)
4. Plate bubble axis not perpendicular to vertical axis
5. Vertical Circle Index Error
6. Eccentricity of Circle Centers
7. Circle Graduation Errors
8. Worn components and peripherals.

Personal errors

1. Centering incorrectly
2. Bubbles not centered
3. Poor focusing Leaning targets

Natural errors

1. Wind causes vibrations (difficult sightings)
2. Temperature variations cause bubbles to run
3. Refraction

4. Tripod settlement

OR

SOURCES OF ERROR IN THEODOLITE WORK

The sources of error in transit work are:

1. Instrumental
2. Personal, and
3. Natural

The instrumental errors are due to

(a) Imperfect adjustment of the instrument.

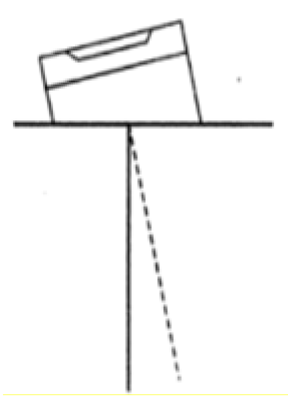
(b) Structural defects in the instrument and

(c) Imperfections due to wear.

The total instrumental error to an observation may be due solely to one or to a combination of these. The following are error due to the imperfect adjustment of the instrument.

i. Error due to imperfect adjustment of plate levels

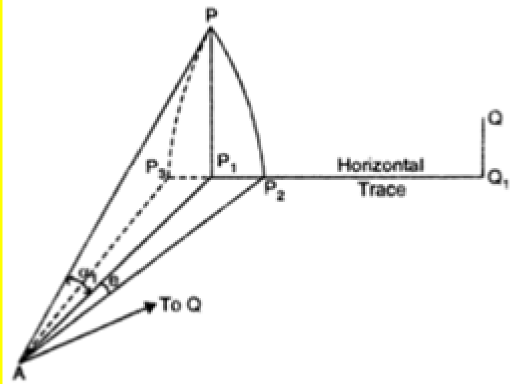
If the upper and lower plates are centered, the vertical axis of the instrument will be truly vertical.



The horizontal angles measured will also be incorrect. The error may be serious in observing the points the difference in elevation of which is considerable. The error can be eliminated only by careful leveling with respect to the altitude bubble if it is in adjustment. The errors cannot be eliminated by double sighting.

(i) Error due to line of collimation not being perpendicular to the horizontal axis.

If the line of sight is not perpendicular to the trunnion axis of the telescope, it will not revolve in a plane when the telescope is raised or lowered but instead, it will trace out the surface of the cone. The trace of the intersection of the conical surface with the vertical plane contacting the point will be hyperbolic. This will cause error in the measurement of horizontal angles between the points which are at considerable difference in elevation. Thus in the figure, let P and Q be the two points at different elevation and letP1 and Q1 be the projections on a horizontal trace. Let the line AP be inclined at an angle α1 to the horizontal line AP1. When the telescope is lowered after sighting P the hyperbolic trace will cut the horizontal trace p1 Q1 in P2 if the intersection of the cross hairs is to the left of the optical axis. The horizontal angle thus measure will be with respect of AP2 and not with respect to AP1. The error ε introduced will be thus be ε=β sec α1, where β is the error in the collimation. On changing the face however, the intersection of the cross hairs will be to the right of the optical axis and the hyperbolic trace will intersect the line P1Q1 in P3.The horizontal angle thus measured will be with respect to AP3, the error being ε=β sec α1 to the other side. It is evident, therefore, that by taking both face observation the error can be eliminated. At Q also, the error will be ε'=β sec α2.Where α2 is the inclinations of AQ with horizontal, and the error can be eliminated by taking both face observations. If, however, only one face observation are taken to P and Q, the residential error will be equal to β(sec α1-sec α2) and will be zero when both the points are at the same elevation.



(ii) Error due to horizontal axis not being perpendicular to the vertical axis.

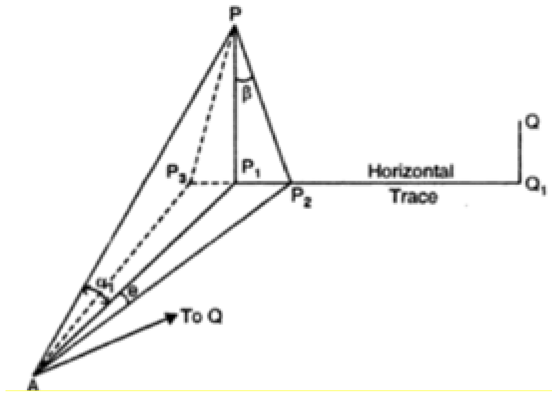
If the horizontal axis is not perpendicular to the vertical axis, the line of sight will move in the inclined plane when the telescope is raised or lowered. Thus, the horizontal and vertical angles measured will be incorrect. The error will be of serious nature if the points sighted are at very different levels. Let P and Q be the two points to be observed, P1and Q1 being their projection on a horizontal trace (shown in fig.) . Let the line of sight AP makes an angle α1 with horizontal. When the telescope is lowered after sighting P it will move in an inclined plane APP2 and not in the vertical plane APP2 and not in the vertical plane A P P1. The horizontal angle measured will now be with the reference to AP2 and not with AP1. If β is the instrumental error and ε is the resulting error, we get tan ε = (P1 P2)/AP1 = (PP1 tan β)/AP1 = tan α1tan β

Since ε and β will usually be small,

we get ε = β tan α1

On changing the face and lowering the telescope after observing P, the line of sight

Will evidently more in the inclined plane AP3. The angle measured will be with reference to AP3 and not with AP1, the error being ε=β tan α2, where α2 is inclination of AQ with horizontal and the error can be eliminated by taking both face observations. If however only one face observation is taken to both P and Q the residual error will be equal to $\beta(\tan \alpha 1 - \tan\alpha 2)$ and will be zero when both the points are at the same elevation.



(iii) Error due to non- parallelism of the axis of telescope level and line of collimation

If the line of sight is not parallel to the axis of telescope level, the measured vertical angles will be incorrect since the zero line of the vertical verniers will not be a true line of reference. It will also be a source of error when the transit is used as a level.

The error can be eliminated by taking both face observations.

(iv) Error due to imperfect adjustment of the vertical circle vernier

If the vertical circle verniers do not read zero when the line of sight is horizontal, the vertical angles measured will be incorrect. The error is known as the index error and can be eliminated either by applying indec correction or by taking both face observations.

(v) Error due to eccentricity of inner and outer axes

If the centre of the graduated horizontal circle does not coincide with the centre of the vernier plate, the reading against vernier will be incorrect. In figure let o be the centre of the circle and o1 be the centre of the circle and o1 be the centre of the vernier plate.

Let a be the position of vernier A while taking a back sight and a1 be its corresponding position when a foresight is taken on another object. The positions of the vernier B are represented by b and b1 respectively. The telescope is thus, turned though an angle a o1 a1 while the arc aa1 measures an angle aoa1 and not the true angle ao1a.

Now, ao1a1= aca1-o1ao

Ao1a1= (aoa1 + a1a1o) – a1ao …….. (1)

Similarly bo2b1=(boo1 + a1bo

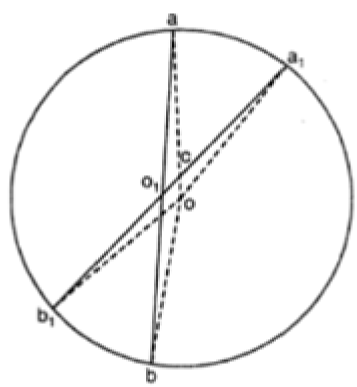
Bo2b1= bob1 += a1oo- a1a1o ………(2)

Adding (1) and (2) , we get

Ao1a1+ bo2b1 = aoa1 + bob1

Or 2ao1a1 = aoa1 + bob1

Or ao2a1= (aoa1+ bob1)/2



Thus, the true angle is obtained by taking the mean of two vernier readings.

(i) Error due to imperfect graduations

The error due to defective graduations is in the measurement of an angle may be eliminated by taking the mean of the several readings distributed over different portions of the graduated circles.

(ii) Error due to eccentricity of verniers

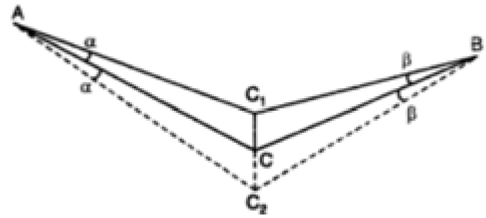
The error is introduced when the zeros of the vernier are not at the enda of the same diameter.Thus,the difference between the two vernier readings will not be 180 degree, but there will be a constant difference of other than 180 degree. The error can be eliminated by reading both the vernier and taking the mean of the two.

2. PERSONAL ERRORS

The personal errors may be due to

(a) Error in manipulation,

(b) Error in sighting and reading



a) Error in Manipulation

They include:

(i) Inaccurate centering: If the vertical axis of the instrument is not exactly over the station mark, the observed angles will either be greater or smaller than the true angle. Thus in Fig.6.27, C is the station mark while instrument is centred over C1. The correct angle ACB will be given by ,<ACB =<AC1B – α-β= <AC1B – (α+β)

It should always be remembered to use lower tangent screw while taking a backsight and to use upper tangent screw while taking the foresight reading.

(a) Error in sighting and reading. They include:

(i) Inaccurate bisection of points observed

The observed angles will be incorrect if the station mark is not bisected accurately due to some obstacles etc. Care should be always be taken to intersect the lowest point of a ranging rod or an arrow placed at the station mark if the latter is not distinctly visible. The error varies inversely as the length of the line of sight.

If the ranging rod put at the station mark is not held vertical, the error ε is given by

Tan ε=Error in vertically /

Line of sight

(ii) Parallex: Due to parallex, accurate bisection is not possible. The error can be eliminated by focusing the eye- piece and objective.

(iii) **Mistakes:** in setting the vernier, taking the reading and wrong booking of the readings

3. NATURAL ERRORS

Sources of Natural errors are:

(i) Unequal atmospheric refraction due to high temperature.

(ii) Unequal expansion of parts of telescope and circles due to temperature changes.

(iii) Unequal settlement of tripod.

(iv) Wind producing vibrations.

The error i.e $\pm$ ($\alpha+\beta$) depends on (i) the length of line of sight, and (ii) the error in centering. The angular error due to the defective centering varies inversely as lengths of sights. The error is therefore, of very serious nature if the sights are short. It should be remembered that the error of sight is to be about 1' when the error of centering is 1 cm and the length of sight is 35m.

(i) **Inaccurate leveling:** The error due to inaccurate leveling is similar to that due to non adjustment of the plate levels. The error will be of serious nature when the points observed are at considerable difference in elevation. The error can be minimized by leveling the instrument carefully.

(ii) **Slip:** The error is introduced if the lower clamp is not properly clamped, or the shifting head is loose, or the instrument is not firmly tightened on the tripod head. The error is of a serious nature since the direction of the line of sight will change when such slip occurs, thus making the observation incorrect.

(iii) Manipulating wrong tangent screws: The error is introduced by using the upper tangent screw while taking the backsight or by using the lower tangent screw while taking a foresight. The error due to the former can be easily detected by checking the vernier reading after the backsight point is sighted, but the error due to the latter can't be detected.

3.7 Numerical Practice

Example of the theodolite traversing

Instrument station and ht. of instruments	sighted to	HA(L)	HA/R	Average HA	VA	Staff readings	Remarks
A/1.455	B	106 15 30	285 15 30	335 11 33	90 00 00	1.205/0.955/0.705	BEARING AB=105 15 30(25m)
	C	155 10 36	335 12 30		90 00 00	1.050/0.750/0.450	
C/1.305	A	355 11 33	155 11 33	225 26 28	90 00 00	1.345/1.045/0.745	
	D	45 20 26	225 32 30		90 00 00	1.250/1.000/0.750	
D/1.256	C	225 26 28	45 26 28	165 03 58	90 00 00	1.530/1.280/1.030	
	E	345 05 26	165 02 30		90 00 00	0.855/0.605/0.355	
E/1.256	D	165 03 58	345 03 58	85 43 00	90 00 00	1.855/1.605/1.355	
	B	265 45 55	85 40 05		90 00 00	1.055/0.755/0.455	
B/1.355	E	85 43 00	265 43 00	105 1 58	90 00 00	1.355/1.055/0.755	
	A	285 15 26	105 12 30		90 00 00	1.555/1.305/1.055	

Instrument at & HI	Sighted to	Face	HCR observation			Mean			Horizontal Angle			VCR Observation		
			°	′	″	°	′	″	°	′	″	°	′	″
A	F	L	0	0	0									
	B	L												
	B	R												
	F	R												
B	A	L	0	0	0									
	C	L												
	C	R												
	A	R												
C	B	L	0	0	0									
	D	L												
	D	R												
	B	R												
D	C	L	0	0	0									
	E	L												
	E	R												
	C	R												

E	D	L	0	0	0									
	F	L												
	F	R												
	D	R												
F	E	L	0	0	0									
	A	L												
	A	R												
	E	R												

Unit 4
Contour

1. Learning Outcomes

The following are the learning outcomes of this unit after finishing this unit:

1. To know the features of the ground from the contour map
2. To prepare contour map
3. To study of the contour map
4. To calculate the roughly data from the map
5. Preliminary estimate of any project without visiting site
6. To prepare contour map by using different methods

2. Lesson

2.1 Definitions of the terms – Contour Line, Horizontal Equivalent, Contour Interval, Index Contour

2.2 Selection of Proper Contour Interval

2.3 Characteristics of Contours

2.4 Uses of Contour Map

2.5 Methods of Contouring – Direct Method, and Indirect Method (Square Method, Cross-Section Method, Tacheometric Method)

2.6 Interpolation of Contours – Estimation Method, Arithmetical Calculation Method, Graphical Method

2.7 Numerical Practice

3. Contents

4.1 Definitions of the terms – Contour Line, Horizontal Equivalent, Contour Interval, Index Contour

Define Contour Line

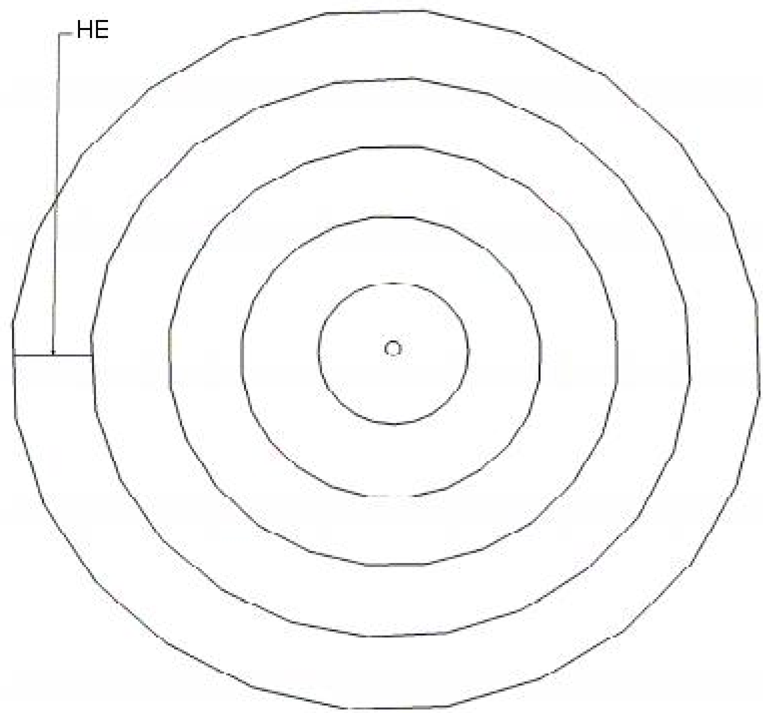
A Contour line is an imaginary outline of the terrain obtained by joining its points of equal elevation. In our example of the cone, each circle is a contour line joining points of same level.

Define Contour Interval (CI)

Contour interval is the difference between the levels of consecutive contour lines on a map. The contour interval is a constant in a given map. In our example, the contour interval is 1m.

Define Horizontal Equivalent (HE)

Horizontal equivalent is the horizontal distance between two consecutive contour lines measured to the scale of the map.



Define Index Contour

A contour line centered by a heavier line weight to distinguish it from intermediate contour lines. Index contour are usually shown as every fifth contour with their assigned values, to facilitate reading elevations.

4.2 Selection of Proper Contour Interval

The following factors govern the selection of contour interval for a project:

S.N	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

4.3 Characteristics of Contours

Contours show distinct characteristic features of the terrain as follows:

i) All points on a contour line are of the same elevation.

ii) No two contour lines can meet or cross each other except in the rare case of an overhanging vertical cliff or wall

iii) Closely spaced contour lines indicate steep slope

iv) Widely spaced contour lines indicate gentle slope

v) Equally spaced contour lines indicate uniform slope

vi) Closed contour lines with higher elevation towards the centre indicate hills

vii) Closed contour lines with reducing levels towards the centre indicate pond or other depression.

viii) Contour lines of ridge show higher elevation within the loop of the contours. Contour lines cross ridge at right angles.

ix) Contour lines of valley show reducing elevation within the loop of the contours. Contour lines cross valley at right angles.

x) All contour lines must close either within the map boundary or outside.

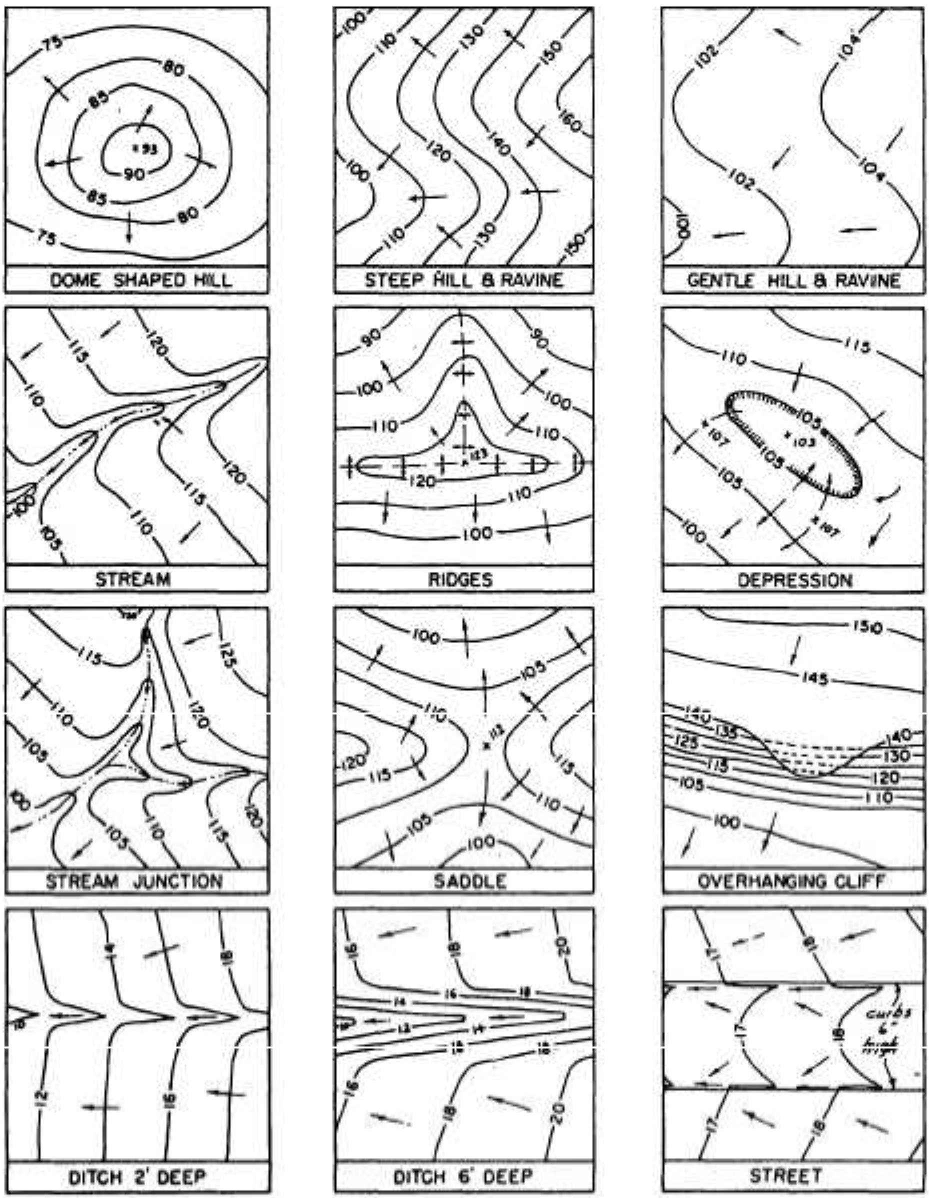


Fig. Characteristics of Contours

4.4 Uses of Contour Map

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

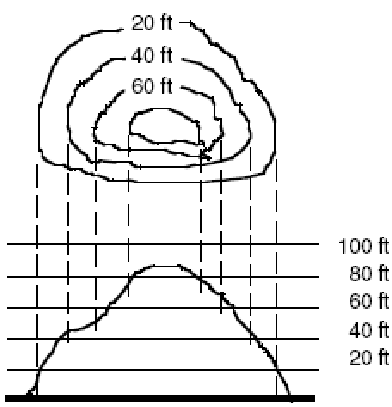
i) The nature of the ground and its slope can be estimated

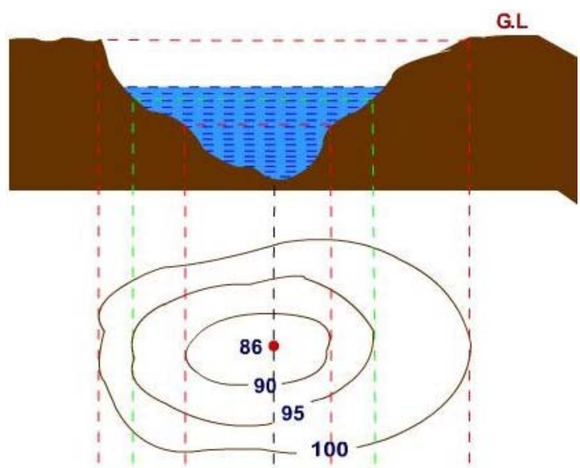
ii) Earth work can be estimated for civil engineering projects like road works, railway, canals, dams etc.

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.

Military uses contour maps for strategic planning.





Pond and its contour

3.5 Methods of Contouring – Direct Method, and Indirect Method (Square Method, Cross-Section Method, Tachometric Method)

Two methods of Contouring are:

i) Direct Method

ii) Indirect Method

Direct Method

In direct method, the points of equal elevation on the terrain are physically located and then plotted on map. This is a very tedious process and requires more time and resources than the indirect method.

Indirect Method

In the indirect method of contouring on one of these three methods are adopted:

a) Cross Section Method

b) Squares Or Grid Method

c) Tacheometric Method

a) Cross Section Method

Cross section method is most suitable for preparing contour maps for road works, rail works, canals etc. The method is adopted for the land which has a very long strip but narrow width.

Typically, this type of land has a very long strip but narrow width.

The steps involved are as follows

i) The centre line of the strip of land is first marked

ii) Lines perpendicular to the longitudinal strip are marked dividing the strip into equal sections

iii) The perpendicular lines are divided into equally spaced divisions, thus forming rectangular grids.

iv) Levels are taken at the intersection of the grid lines to obtain the cross-section profile of the strip of land.

v) Contour map is plotted in the office by interpolating points of equal elevation based on the levels taken at site.

b) Squares or Grid Method

Squares or grid method is suitable for contouring of plains or gently sloping grounds.

The steps adopted are as follows

i) Mark square grids on the land to be surveyed. The grid size would depend on the extent of survey. Generally a 1m x 1m grid is selected for small works and a larger grid size for large works

ii) Levels are taken at all the corners of the square and the intersection of the diagonal.

iii) Levels taken on the intersection of diagonals is used for verification of the interpolation.

Contour map is plotted in the office by interpolating points of equal elevation based on the levels taken on the corners of the square.

c) Tacheometric Method

Tacheometric method is adopted for contouring of very steep hills.

The steps are as follows

i) Set up the tachometer at the top of the steep hill. Tachometer is a Theodolite fitted with stadia diaphragm. The stadia diaphragm has three horizontal parallel hairs instead of one as found in a conventional cross hair diaphragm.

ii) With the help of a tachometer it is possible to determine the horizontal distance of the point from the telescope as well its vertical level.

iii) The steep hill is surveyed at three levels – the base of the hill, the mid-level of the hill and the top level of the hill.

iv) Using the tachometer reading are taken all around the hill at equal angular intervals on all these three levels.

v) The radial plot thus obtained is worked in the office to interpolate points of equal elevation for contour mapping.

4.6 Interpolation of Contours – Estimation Method, Arithmetical Calculation Method, Graphical Method

- By estimation method

The position of the contour points between ground points is estimated and the contour is then drawn through them. This method is rough and accuracy depends upon the skill and experience of surveyor.

- By Arithmetical Method

In this method the position of contour between two points are located by making accurate calculation. Hence, this method through very accurate is time consuming and laborious. It is generally adopted when higher accuracy is demanded for a limited area.

- By Geographical Method

In this method actual calculation for interpolation of contours between known heights is not done but the location of the contour are obtained graphically with the help of tracing paper or tracing cloth.

There are two methods:

- By drawing radiating lines
- By drawing parallel lines.

96.65	100.15	101.35	102.4
99.6	99.8	101.5	103
99.5	100.3	101.75	103.15
99.52	100.25	102.15	103.15

Unit 5
Tacheometric Surveying

1. Learning Outcomes

The following are the learning outcomes of this unit at the end of this unit:

1. To prepare map by using tacheometric surveying
2. To calculate the relative positions of a point in the surface of land
3. To calculate horizontal and vertical distances of any two points
4. Calculate the different data in surveying to prepare plan or map
5. To find out the point in ground from the map or plan

2. Lesson

2.1 Introduction

2.2 Instrument used in Tacheometric Surveying

2.3 Methods of Tacheometric Measurements – Stadia Method (Fixed Hair Method, Movable Hair Method or Subtense Method), Tangential Method, and Self Reducing Method

2.4 Stadia Method - Principle of Stadia Method, Distance and Elevation Formula for Horizontal Sight with Staff Vertical, Distance and Elevation Formula for Inclined Sight with Staff Vertical, Method of Reading the Staff, Determination of Constants K and C, Analectic Lens, Errors in Stadia Surveying

2.5 Subtense Method - Subtense Bar, Principle of Subtense Method, Horizontal Base Subtense Measurement,

2.6 Tangential Method – Both Angles are Angle of Elevation, Both Angles are Angle of Depression, One Angle of Elevation and the other Angle of Depression

2.7 Self Reducing Method

2.8 Numerical Practice

3. Contents

3.1 Introduction

Tachometry is the branch of Surveying in which we determine the horizontal and vertical distances with the angular measurements with an instrument, Tachometer. It is not so accurate method of finding the horizontal distances as the Chaining is, but it is most suitable for carrying out the surveys to find the distances in the hilly area where other methods are quite difficult being carried out. It is generally used to locate contours, hydrographic surveys and laying out routes of highways, railways etc.

3.2 Instrument used in Tacheometric Surveying

The instruments required for carrying out the Tacheometric survey are:

(1) A Tachometer

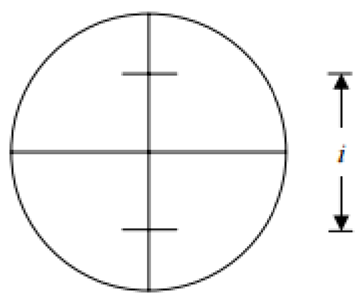
(2) A Stadia Rod.

- **Tachometer:** Tachometer is more or less a Theodolite installed with a stadia diaphragm. Stadia diaphragm is equipped with three horizontal hairs and one vertical hair. So we can take three vertical staff reading at the same instruments setting, lower most hair reading, central hair reading and the top hair reading. The difference between the lower hair reading and the upper hair reading gives the staff intercept(s).

The Tachometer with the analectic lens are famous because their additive constant is 0. There is one concave lens introduced between the eye piece and the object piece to eliminate the additive constant of the instrument. It simplifies the calculations.

OR

A tachometer is similar to an ordinary transit Theodolite, generally a venire Theodolite itself, fitted with two stadia wires in addition to the central cross-hair. The stadia diaphragm has three horizontal hairs viz., a central horizontal hair and upper and lower stadia hairs. The upper and lower stadia hairs are equidistant from the central horizontal hair. Stadia hairs are sometimes called stadia lines. For the purpose of tachometry, even though an ordinary transit can be employed, accuracy and speed are increased if the instrument is specially designed for the work. The magnification of the telescope in tachometer should be at least 20 to 30 diameters, with an aperture of at least 40 mm for a sufficiently bright image. The magnifying power of the eyepiece is also greater than for an ordinary transit to produce a clearer image of a staff held far away. Further, the altitude bubble is made more sensitive, since vertical angles form an important part of the data for calculation of elevation differences. Figure shows a more commonly used pattern of stadia diaphragm. For long sights, special staff called stadia rod is generally used. The graduations are in bold type (face about 50 mm to 150 mm wide and 15 mm to 60 mm thick) and the stadia rod is 3 m to 5 m long. To keep the staff or stadia rod vertical, a small circular spirit level is fitted on its backside. It is hinged to fold up.



3.3 Methods of Tacheometric Measurements – Stadia Method (Fixed Hair Method, Movable Hair Method or Subtense Method), Tangential Method, and Self Reducing Method

Methods of Tacheometric Survey:

(A) Stadia Hair Method

1. Fixed Hair Method
2. Movable Hair Method

(B) Tangential Method

(C) Self reducing method

Stadia Hair Method

A method of surveying in which distances are read by noting the interval on a graduated rod intercepted by two parallel cross hairs (stadia hairs or stadia wires) mounted in the telescope of a surveying instrument, the Staff (rod) being placed at one end of the distance to be measured and the surveying instrument at the other.

Fixed Hair Method

It is the most prevalent method for tachometric surveying. In this method, the telescope of the Theodolite is equipped with two additional cross hairs, one above and the other below the main horizontal hair at equal distance. These additional cross hairs are known as stadia hairs. This is also known as tachometer.

Movable Hair Method

In this method, the staff interval is kept constant by changing the distance between the stadia hairs. Targets on the staff are fixed at a known interval and the stadia hairs are adjusted to bisect the upper target at the upper hair and the lower target at the lower hair. Instruments used in this method are required to have provision for the measurement of the variable interval between the stadia hairs. As it is inconvenient to measure the stadia interval accurately, the movable hair method is rarely used.

Tangential Method

The tangential method of tachometry is being used when stadia hairs are not present in the diaphragm of the instrument or when the staff is too far to read.

In this method, the staff sighted is fitted with two big targets (or vanes) spaced at a fixed vertical distances. Vertical angles corresponding to the vanes, say $\theta 1$ and $\theta 2$ are measured. The horizontal distance, say D and vertical intercept, say V are computed from the values s (pre-defined / known) $\theta 1$ and $\theta 2$. This method is less accurate than the stadia method.

Depending on the nature of vertical angles i.e., elevation or depression, three cases of tangential methods are there.

3.4 Stadia Method- Principle of Stadia Method, Distance and Elevation Formula for Horizontal Sight with Staff Vertical, Distance and Elevation Formula for Inclined Sight with Staff Vertical, Method of Reading the Staff, Determination of Constants K and C, Analectic Lens, Errors in Stadia Surveying

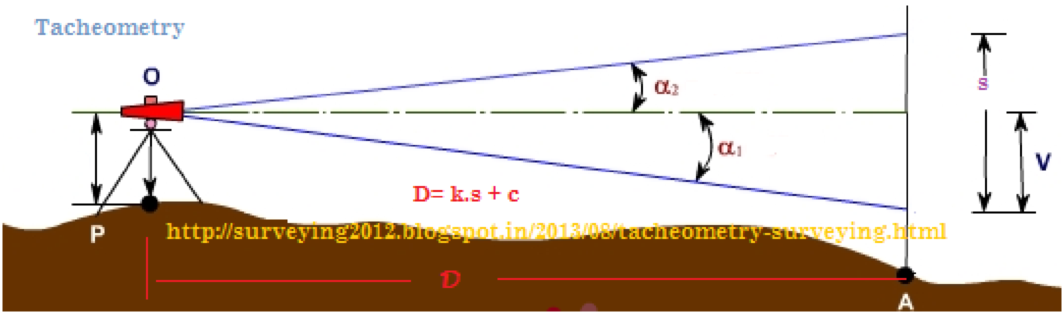
Principle of Stadia Method

Principle of Stadia hair method is that the ratio of the length of perpendicular to the base is constant in case of similar triangles.

Formula to carry out calculation works:

Case

(a) Staff held vertical



Tacheometry -Staff held vertical

D = (f/i).s+ (f+d)

where, f/i = multiplying constant

s = staff intercept between the bottom and top hair

f+d = Additive constant

D = Horizontal distance between the staff station and the observer's position

(b) Inclined sights staff held vertical:

D = (f/i).s. cos^2A + (f+d) cosA

V = {(f/i).s.} .[{sin(2A)}/2] + (f+d) sinA

Where A is the angle of elevation or angle of depression.

(c) Inclined sights upwards, staff held normal:

D = [(f/i).s+ (f+d)]cosA - h.sinA ; V= [(f/i).s+ (f+d)].sinA

h= central hair reading.

R.L. of staff = H.I. + [(f/i).s+ (f+d)].sinA - hcosA

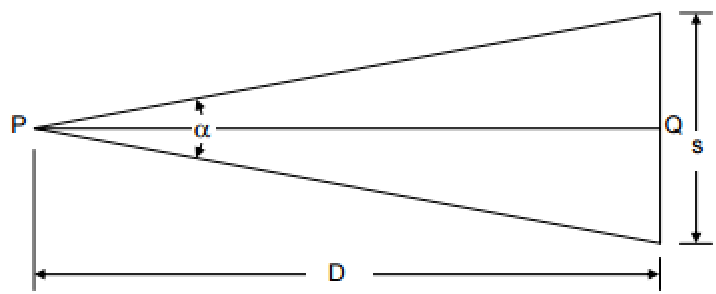
(d) Inclined sights downwards, staff held normal:

D = [(f/i).s+ (f+d)]cosA - h.sinA ; V= [(f/i).s+ (f+d)].sinA

R.L. of staff = H.I. + [(f/i).s+ (f+d)].sinA - hcosA

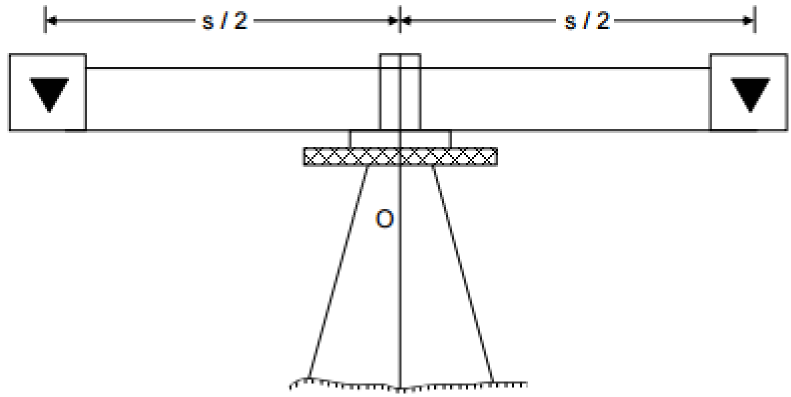
3.5 Subtense Method - Subtense Bar, Principle of Subtense Method, Horizontal Base Subtense Measurement,

Subtense bar is a bar of fixed length generally 2 m fitted with two targets at the ends. The targets are at equal distance apart from the centre. The Subtense bar can be fixed on a tripod stand and is kept horizontal. As shown in Figure, angle α subtended by the two targets at station P is measured by a Theodolite. The distance s between the targets and the angle α enable the distance D between station P and Q to be determined.

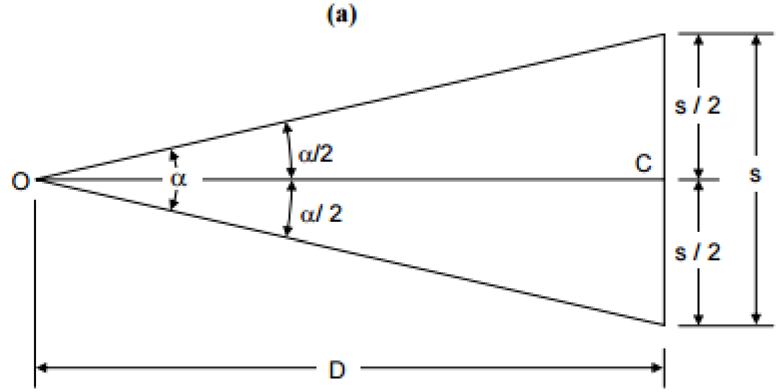


OR

In the Subtense bar method, the horizontal angle subtended by two targets fixed on a horizontal bar at a known distance apart is measured at instrument station by Theodolite. A Subtense bar is as shown in Figure (a). The two targets are at a distance s apart, and each at s/2 from the centre, i.e. vertical axis. The bar can be mounted on a tripod stand and can be rotated about its vertical axis. The Subtense bar should be kept perpendicular to the line of sight, which is set through a sight rule or a small telescope fitted at the centre of the subtense bar. The horizontal angle α, as shown in Figure (b), is measured carefully by means of a Theodolite. Method of repetition of horizontal angle measurement is used to measure angle α.



(a)



(b)

From the geometry,

$D = 1/2\ S.\cot\alpha/2$ . . .

Where, s = the distance between the targets of Subtense bar, and

α = apex angle subtended by targets at O.

As α is small

$\tan \alpha/2 = \alpha/2$

$D = s/\alpha$,

where α is in radians.

or $D = 206265s/\alpha''$ (α in seconds)

If the vertical angle to the centre of the bar is measured, elevation differences can be determined. The Subtense bar method can be used for measuring the length of traverse lines in rough country. This system can also be used for contouring.

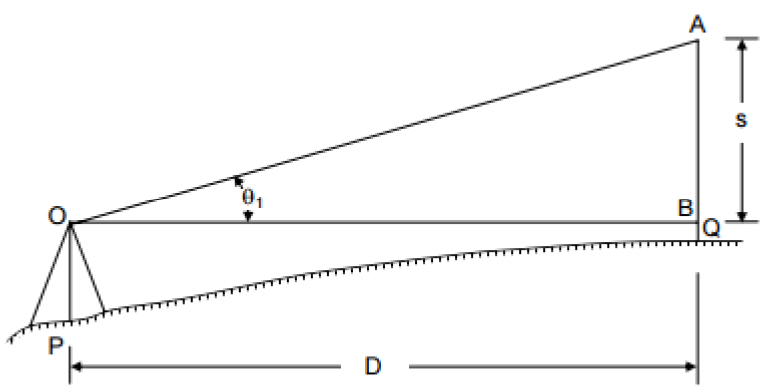
3.6 Tangential Method – Both Angles are Angle of Elevation, Both Angles are Angle of Depression, One Angle of Elevation and the other Angle of Depression

The method of tangential tachometry can be used when staff is held much away Tacheometric Surveying from the instrument making it difficult to read it. This method is useful when the diaphragm does not have stadia hairs. The staff used in this method is similar to the one employed in movable hair method. The distance between the target vanes may be 2 m or 3 m. Vertical angles θ1 and θ2 to the top and bottom targets are measured from the instrument station. The horizontal distance D and the vertical intercept V are computed from the values of s, θ1 and θ2. Depending upon the angles (i.e., angles of elevation or depression), there can be three case.

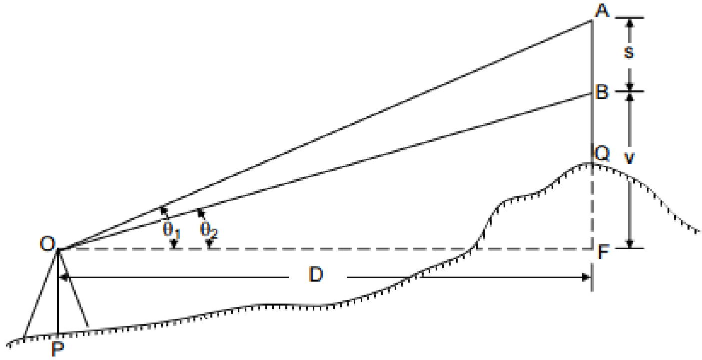
Both the Angles being Angles of Elevation

As shown in the figure the simplest case in which the ground is such that the horizontal line of sight is possible. The reading at B is observed by keeping the telescope level at A. The reading of A is noted and the angle θ1 is also measured. By knowing the staff intercept, the horizontal distance D can be given as,

D = s. cot θ1 . . .



The elevation of Q is determined from the reading obtained at B as in ordinary leveling. When the ground does not permit a horizontal sight, two vertical angles θ1 and θ2 are measured as shown in Figure.



Now AF = D tan θ1

and BF = D tan θ2

∴ s =AF - BF = D (tan θ1- tan θ2)

∴ D = s /(tan θ1- tan θ2). . . (2.8)

And V=D tan θ2 = s tan θ2 /(tan θ1- tan θ2).. . . (2.9)

Knowing HI, i.e., the height of the axis of the instrument above datum, the elevation of Q is given as,

RL of Q = HI + FB − QB

= HI + D. tan θ2 – QB

Both the Angles being Angles of Depression

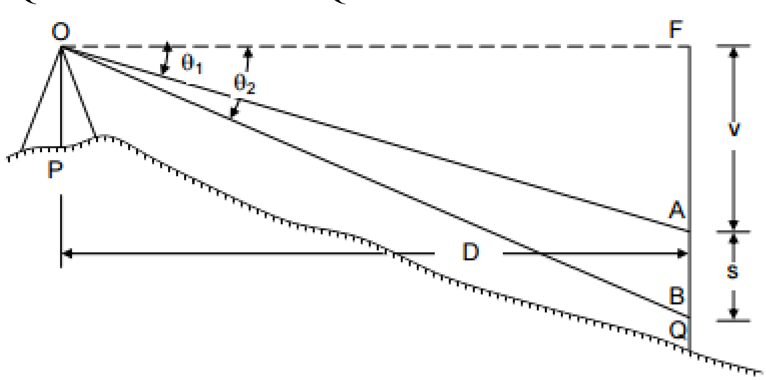
From Figure 2.10

s = BF – AF

∴ D = s /(tan θ1- tan θ2). . . (2.10)

And V=D tan θ2 = s tan θ2 /(tan θ1- tan θ2).. . . (2.11)

RL of Q = HI – D tan θ1 – s – QB



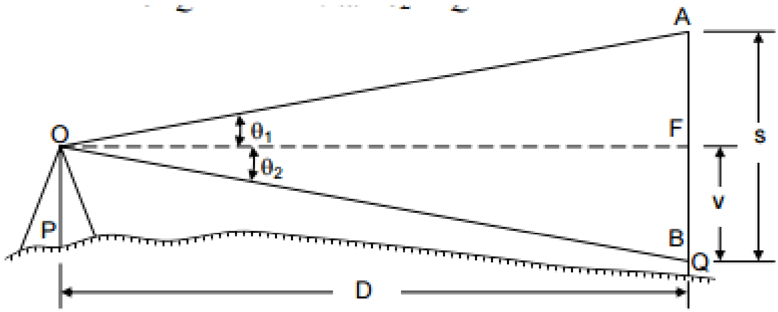
One Angle of Elevation and another Angle of Depression

s = AF + BF

= D tan θ1 + D tan θ2

and V = D tan θ2 . . . (2.12)

RL of Q = HI – D. tan θ2 − QB



3.8 Numerical Practice

1. The following notes refer to a traverse run by a tachometer fitted with an analectic lens, with constant 100 and staff held vertical.

Line	Bearing	Vertical Angle	Staff Intercept
PQ	30°24′	+ 5°06′	1.875
QR	300° 48′	+ 3°48′	1.445
RS	226° 12′	– 2°36′	1.725

Find the length and bearing of SP.

2. A tachometer is setup at an intermediate point on a traverse course PQ and the following observations are made on a staff held vertical.

Staff Station	Vertical Angle	Staff Intercept	Axial Hair Readings
P	+ 9°30′	2.250	2.105
Q	+ 6°00′	2.055	1.975

The constants are 100 and 0. Compute the length PQ and the reduced level of Q. RL of P = 350.50 m.

Line	Bearing	VA(θ)	s	D=KsCoseθ(m)
PQ	30°24′	5°06′	1.875	186.02
QR	300°48′	3°48′	1.445	143.87
RS	226°12′	2°36′	1.725	172.145

Practical Part

Unit 1

Plane Table Surveying

1.1 Perform Field Procedure of Plane Table Traversing – Reconnaissance, Selection and Marking of Traverse Stations, Index Sketch of the Field, Setting Up Plane Table, Leveling Plane Table, Centering Plane Table, Orientating Plane Table – Orientation by Magnetic Compass, Orientation by Back sighting

Objective

a) Uses of plane table

b) Procedure of plane table surveying

c) Fixing of plane table

Instruments Required

- Tripod
- Plane Table
- Plumbing Fork
- Level
- Magnetic needle compass
- Alidade
- Measuring Tape
- Ranging Rods (For demonstration purpose)
- Other accessories
    - 28in x 22in drawing sheet
    - Scotch Tape
    - Chisel pointed Pencil
    - Eraser

Procedure

SETTING UP THE PLANE TABLE

- The table should be set up at a convenient height. (say about 1m). The legs of the tripod should be spread well apart, and firmly fixed into the ground.
- The table should be so placed over the station on the ground that the point plotted on the sheet corresponding to the station occupied should be exactly over the station on the ground. This operation is known as the ***centering*** of the table. This may be done using a plumbing fork or U frame.
- In this operation, the table top is made truly horizontal. For rough and small scale work, leveling can be done by eye estimation whereas for accurate and large scale work, leveling achieved with an ordinary spirit level. The leveling is specially important in hilly terrain where some of the control points are situated at higher level and some other at lower level. The disheveling of the plane table, throws the location of the point considerably out of its true location.

ORIENTING THE PLANE TABLE

- The operation of keeping the table at each of the successive stations parallel to the position which it occupied at the first station is known as orientation. It is necessary when the instrument has to be set up at more than one station.

  There are two methods of orienting the table:

1. Orientation by the Magnetic Needle
2. Orientation by Back sighting

ORIENTING BY MAGNETIC NEEDLE

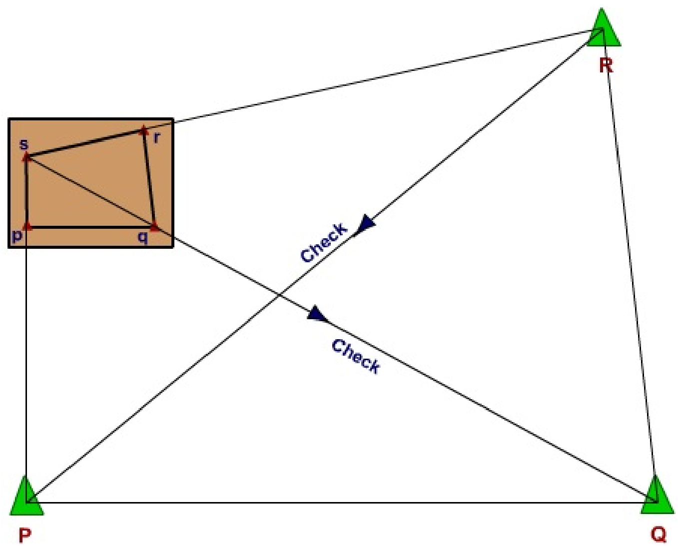
- This method is used when it is not possible to bisect the previous station from the new station. This method is not much reliable and prone to errors due to variations of magnetic field.

ORIENTING BY BACKSIGHTING

- In this method the table is orientated by back sighting through the ray which is drawn from the previous station. This is the most accurate and reliable method of orientation of plane table.

Procedure

This method of plane table surveying is used to plot a traverse in cases stations have not been previously plotted by some other methods. In this method, traverse stations are first selected. The stations are plotted by method of radiation by taking back sight on the preceding station and a fore sight to the following station. Here distances are generally measured by tachometric method and surveying work has to be performed with great care.



Let us consider the stations P, Q, R and S which are to plotted by method of traversing. Stations are to be chosen in such a way that adjoining stations are visible. First, the plane table is to be set at station P and then plotted as p. The orientation of the table and scale of plotting should be such that all other stations will be accommodated within the boundary of the sheet. With the alidade pivoted at p, draw the rays to Q and S. Distances PQ and PS are measured and plotted on the respective rays, PQ and PS respectively.

The plane table is then shifted to station Q, get it set and then oriented by back sighting to station P. With the alidade pivoted at q, draw a ray to R. Distance QR is measured and plotted on the ray as qr. In this way, plane table is shifted to stations R and S and corresponding rays are drawn to obtain the plotting of the traverse PQRS.

Check lines. To check the accuracy of the plane table traverse, a few check lines are taken by sighting back to some preceding station. In this example, a check line RP is drawn from the station R to P when the plane table is occupying the station R. If the traverse is correct, the check line rp would pass through p, the plotted position of station P. Likewise, a check line sq is drawn from S to Q. In case there is no suitable preceding station visible, any well-defined point, such as a corner of a building or a tree, which has been previously plotted, can be used for checking.

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

Conclusion

By the end of this practical we can able to handle/use plane table.

1.2 **Perform Taking Sights on Objects –** By Radiation Method, By Intersection Method

Title

Perform Taking Sights on Objects – By Radiation Method, By Intersection Method

Objective

a) To prepare plan or map by using plane table surveying.

b) Can prepare map in site simultaneously surveying.

c) Working principle of plane table surveying.

Instruments Required

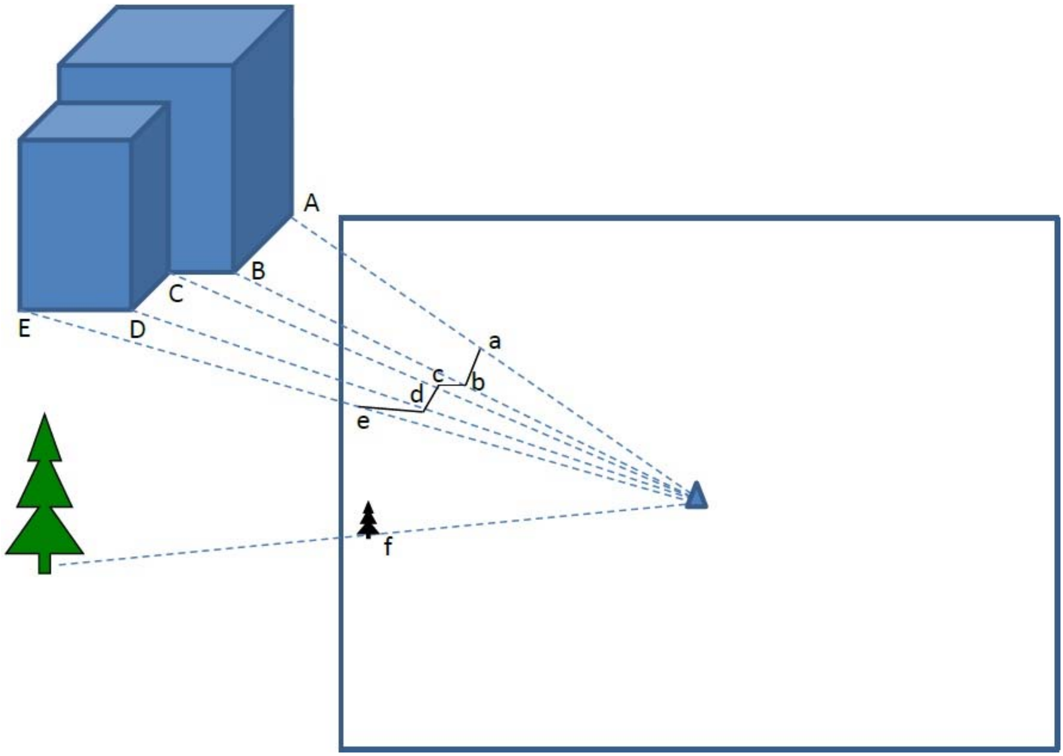
- Tripod
- Plane Table
- Plumbing Fork
- Level
- Magnetic needle compass
- Alidade

- Measuring Tape
- Ranging Rods (For demonstration purpose)
- Other accessories
    - 28in x 22in drawing sheet
    - Scotch Tape
    - Chisel pointed Pencil
    - Eraser

Procedure

1. Select a suitable point **P** on the ground such that all the details are visible from it
2. Center and level the plane table over P
3. Mark the direction of the North on the sheet by using compass
4. Locate instrument station p on the sheet by using plumbing fork, such that p on sheet is exactly over P on ground
5. Centering the alidade on point p sight various details step by step and draw a ray from each detail along the fiducial edge of the alidade
6. Let the details be named as A, B, C, D, E etc.
7. Now measure the distances of each point from P i.e. PA, PB, PC, PD, PE and plot them to scale on the sheet as pa, pb, pc, pd, pe respectively
8. Joint a, b, c, d, and e to give the outline of the details

NOTE: These details may be building corners, electric towers, tree, manhole etc. But for demonstration purpose we will put ranging rods.



Intersection

Instruments Required for Plane Table Survey (for Intersections):

1. Tripod
2. Plane Table
3. Plumbing Fork
4. Level
5. Magnetic needle compass
6. Alidade
7. Measuring Tape
8. Ranging Rods (For demonstration purpose)
9. Other accessories
    - 28in x 22in drawing sheet
    - Scotch Tape

- Chisel pointed Pencil
- Eraser

Procedure

1. Select two instrument stations P and Q, such that all the points or details to be located are visible from both the stations.
2. Now set the table on P and make it centered and level.
3. Using the plumbing form locate the ground station on the sheet i.e. p, such that the point p on the sheet is exactly over the point P on the ground.
4. Measure the distance between P and Q.
5. Now using the alidade pivoted at P orient the table so that other instrument station Q is sighted and clamp the table and draw a line along the fiducial edge of the alidade according to a suitable scale. This line PQ is a base line and hence must be measured and drawn accurately
6. With the alidade pivoted on p sight other details and draw rays as a', b' c', d' etc
7. Now shift the table to station Q and make it cantered and levelled such that point q on sheet is exactly above the Q on the ground
8. With the alidade placed along line PQ orient the table and back sight the station P and clamp the table.
9. With the alidade pivoted on q sight other details and draw rays as a'', b'' c'', d'' etc
10. The intersection of a', b' c', d', e' with a'', b'' c'', d'', e'' are named as a, b, c, d, e respectively. Join a, b, c, d, e

NOTE: These details may be building corners, electric towers, tree, manhole etc. But for demonstration purpose we will put ranging rods.

Conclusion: at the end of this practical we can prepare map by using plane table.

Unit 2
Leveling

2.1 Introduce Different Parts and Operation of Level, Perform Temporary Adjustment of Level – Setting up the Level, Leveling up, Elimination of Parallax (Focusing the Eye-piece, Focusing the Objective)

Title: Introduce Different Parts and Operation of Level, Perform Temporary Adjustment of Level – Setting up the Level, Leveling up, Elimination of Parallax (Focusing the Eye-piece, focusing the Objective)

Instruments required

a) Level machine

b) Staff

THEORY: 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) Elimination of parallax

Procedure

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 radically or circumferentially, the instrument is approximately leveled. Some instruments are provided with a less sensitive circular bubble on tribrach for this purpose.

Levelling

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.

(ii) Turn the two screws inward or outward equally and simultaneously till bubble is centered.

(iii) Turn the telescope by 90° so that it lies over the third screw and level the instrument by operating the third screw.

(iv) Turn back the telescope to its original position and check the bubble. Repeat steps (ii) to (iv) till bubble is centered for both positions of the telescope.

(v) Rotate the instrument by 180°. Check the levelling.

Elimination of parallax

Parallax is the apparent movement of the image produced by movement of the observer's eye at the eyepiece. It is eliminated by focusing the telescope on infinity and then adjusting the eyepiece until the cross-hairs appear in sharp focus. The setting will remain constant for a particular observer's eye.

Focusing

Focusing is necessary to eliminate parallax while taking reading on the staff. The following two steps are required in focusing:

(i) Focusing 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) Focusing the objective: For this telescope is directed towards the staff and the focusing screw is turned till the reading appears clear and sharp.

Focusing the eye piece:-To focus the eye piece, hold a white paper in front of object glass, and move the eye piece in or out till the cross hairs are distinctly seen.

Focusing of object glass:- Direct the telescope to the leveling staff and on looking through the telescope, turn the focusing screw till the image appears clear and sharp.

Conclusion: by the end of this practical we can set up the level machine ready to take data.

2.2 Perform Principle of Leveling – Simple Leveling, and Differential Leveling

TITLE: Fixing bench mark with respect to temporary bench mark with dumpy level by fly leveling and check leveling.

Apparatus Required

1. level,
2. levelling staff,
3. tripod stand,
4. arrows,
5. pegs

Theory

Fly leveling

It is a very approximate from of levelling in which distances are not measured and sights are taken as large as possible. In this method a line of levels is run to determine approximately reduced levels of the points carried out with more rapidly and less precision.

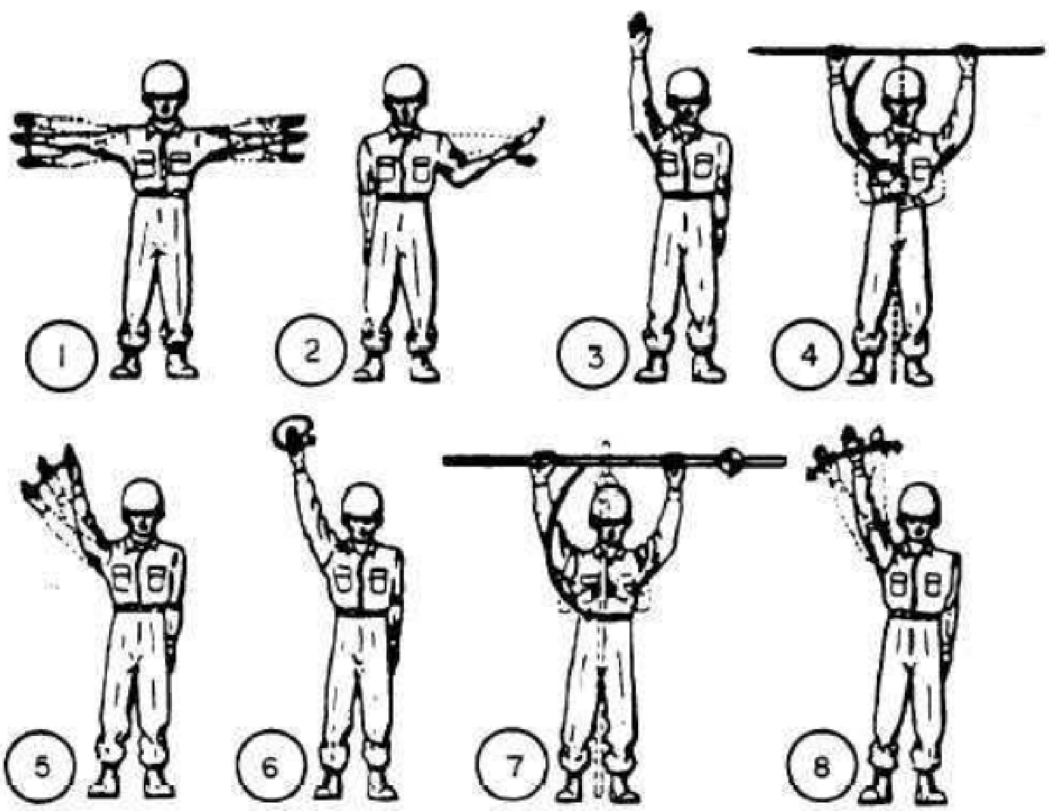
Check leveling

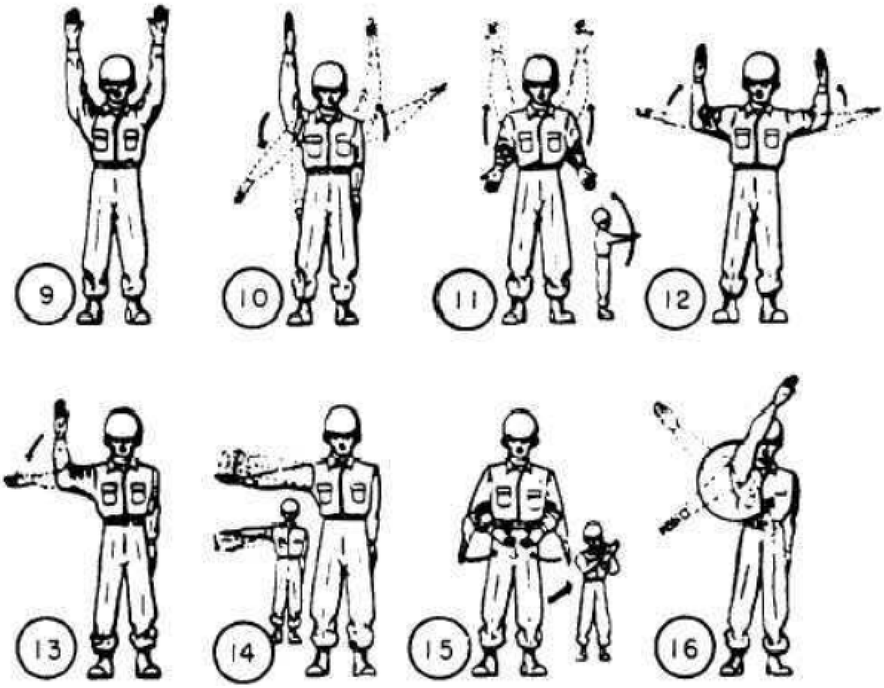
The main purpose of this type of levelling is to check the values of the reduced levels of the bench marks already fixed. In this method only back sight and foresight are taken. There is no need of intermediate sights. However great care has to be taken for selecting the change points and for taking reading on the change points because the accuracy of levelling depends upon these.

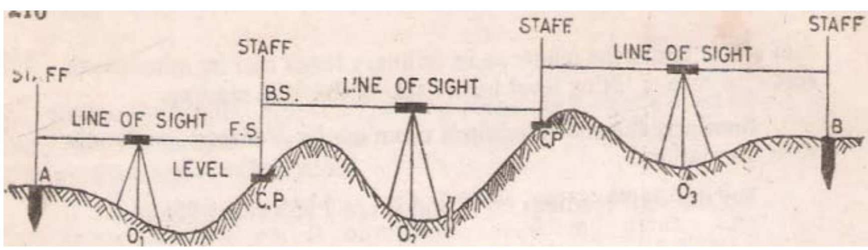
Surveyor's Handle Signals:

1. All right
2. Move right or left
3. Give me a back sight
4. Give me a line or this is a hub
5. Plumb the rod
6. Establish a turning point

7. This is a turning point
8. Wave the rod
9. Face the rod
10. Reverse the rod
11. Boost the rod
12. Move forward
13. Move back
14. Up or down
15. Pick up the instrument
16. Come in







PROCEDURE

1) Let A and B the two points as shown in figure, they are too for apart. The position of each set up of level should be so selected that the staff kept on the two points is visible through the telescope.

2) Let O1, O2, O3 be the positions of the level to be setup. Choose the change points 1,2 etc. on a stable ground so that the position of the level should be midway between the two staff reading to avoid error due to imperfect adjustment of the level.

3) Now setup the level at O1 take the reading on the staff kept vertically on A with bubble central. This will be a back sight and R.L of the A isto assumed or say known. Record these values in the same line in the level book.

4) Now select the position of C.P (1) so that the distance of it from O1 is approximately equal to that O1A

5) With the bubble in the centre take the reading of the staff held vertically over the change point. This will be a fore sight and book this value in the level book on the next line in the column provided.

6) Now shift the level to O2 and set up it there carefully, with the bubble in the centre take reading on the staff kept vertically as the fore sight over C.P(1). This will be a back sight, book it in the same line as the fore sight already recorded in the column provided.

7) Select another CP (2) on the stable ground as before so that station O2 is approximately midway between C.P (1) and C.P (2).

8) With the bubble central, take the reading on the staff kept vertically over the CP2.This will be fore sight and book it in the level book page in next line.

9) Repeat the process until the point B.M reached .The last reading will be a foresight

10) Now find out the reduced levels by height of instrument method or by rise and fall method.

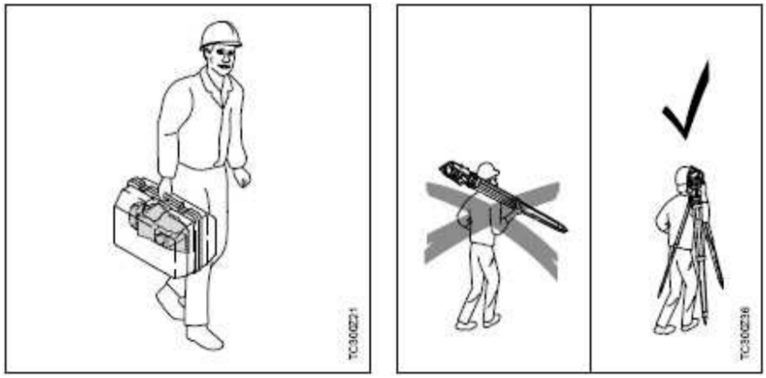
11) Complete the remakes column also. Apply the arithmetical check

Observation table

Station	Readings		Height of instrument	Reduced Levels	Remarks
A	B.S.	F.S			
B					
C					
D					
E					

RESULT: The difference of level between the point be equal to R.L of the last point minus the R.L at the B.M is found to be ------

Precautions: proper handling of instruments as per pictures.



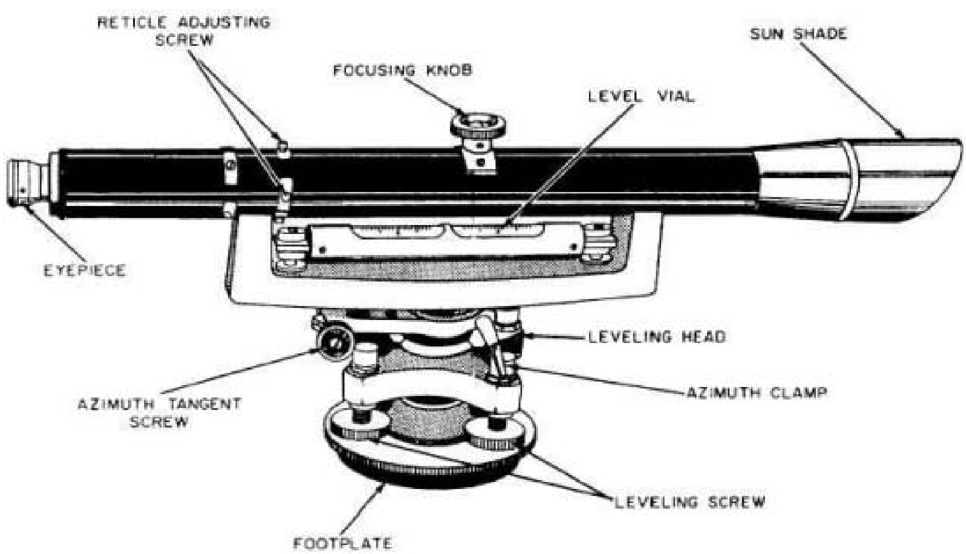
2.3 Practice Booking and Reduction of Levels– Rise and Fall Method, and Height of Instrument Method

Title: Determination of elevation of various points with dumpy level by collimation plane method and rise & fall method.

APPARATUS REQUIRED

1. Dumpy level,
2. levelling staff

Figure



Dumpy Level

THEORY

Levelling: The art of determining and representing the relative height or elevation of different object/points on the surface of earth is called levelling. It deals with measurement in vertical plane.

By levelling operation, the relative position of two points is known whether the points are near or far off. Similarly, the point at different elevation with respect to a given datum can be established by levelling.

LEVELLING INSTRUMENTS

The instruments which are directly used for levelling operation are:-

1. Level,
2. Levelling staff

Level: An instrument which is used for observing staff reading on levelling staff kept over different points after creating a line of sight is called a level.

The difference in elevation between the point then can worked out. A level essentially consists of the following points:

1) Levelling Heads
2) Limb plate
3) Telescope

Telescope consists of two tubes, one slide into the other and fitted with lens and diaphragm having cross hairs. it creates a line of sight by which the reading on the staff is taken The essential parts of a telescope are 1) body 2) object glass 3)Eye-piece 4) Diaphragm 5) Ray shade 6) The rack and pinion arrangement 7) Focusing screw 8) Diaphragm screw.

4) Bubble tube
5) Tripod stand

Dumpy level

The dumpy level is simple, compact and stable instrument. The telescope is rigidly fixed to its supports. Hence it cannot be rotated about its longitudinal axis or cannot be removed from its support. The name dumpy is because of its compact and stable construction. The axis of telescope is perpendicular to the vertical axis of the level. The level tube is permanently placed so that its axis lies in the same vertical plane of the telescope but it is adjustable by means of captain head not at one end.

The ray shade is provided to protect the object glass. A clamp and slow motion screw are provided in modern level to control the movement of spindle, about the vertical axis. The telescope has magnifying power of about thirty diameters. The level tube is graduated to 2mm divisions and it has normally a sensitiveness of 20 seconds of are per graduation. The telescope may be internally focusing or external Focusing type.

Adjustment of the level

The level needs two type of adjustment

1) Temporary adjustment and
2) Permanent adjustment

Temporary adjustments of dumpy level

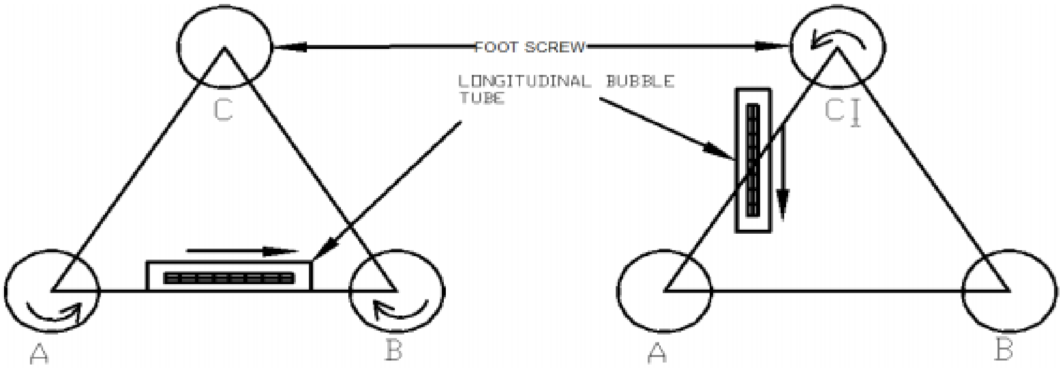
These adjustments are performed at each set-up the level before taking any observation.

A) Setting up the level: - this includes

1) Fixing the instrument in the tripod: the tripod legs are well spread on the ground with tripod head nearly level and at convenient height. Fix up the level on the tripod.

2) Leg adjustment: Bring all the foot screws of the level in the centre of their run .Fix any two legs firmly into the ground by pressing them with hand and move the third leg to leg to right or left until the main bubble is roughly in the centre. Finally the legs are fixed after centring approximately both bubbles. This operation will save the time required for levelling.

B) Levelling: Levelling is done with the help of foot screws and bubbles. The purpose of levelling is to make the vertical axis truly vertical. The method of levelling the instrument depends upon whether there are three foot screws or four foot screws. In all modern instruments three foot screws are provided and this method only is described.



(Source:http://bhagwantuniversity.ac.in/wp-content/uploads/2016/02/SURVEYING-LAB-MANUAL.pdf)

1) Place the telescope parallel to pair of foot screws.

2) Hold these two foot screw between the thumb and first finger of each hand and turn them uniformly so that the thumbs move either toward each other until the bubble is in centre.

3) turn the telescope through 90°so that it lies over the third foot screw.

4) Turn this foot screw only until the bubble is centred.

5) Bring the telescope back to its original position without reversing the eye piece and object glass ends.

6) Again bring the bubble to the centre of its run and repeat these operation until the bubble remains in the centre of its run in both position which are at right angle to each other.

7) Now rotate the instrument through 180°,the bubble should remain in centre provided the instrument is in adjustment: if not ,it needs permanent adjustment.

c) **Focusing the eye piece:** To focus the eye piece, hold a white paper in front of the object glass ,and move the eye piece in or out till the cross hairs are distinctly seen. Care should be taken that the eye piece is not wholly taken out ,some times graduation are provided at the eye piece and that one can always remember the particular graduation position to suit his eyes, This will save much time of focussing the eye piece.

(d) **Focusing the object glass:** Direct the telescope to the levelling staff and on looking through the telescope, turn the focusing screw until the image appears clears and sharp. The image is thus formed inside the plane of cross hairs, Parallax, if any is removed by exact focusing. It may be noted that parallax is completely eliminated when there is no change in staff reading after moving the eye up and down.

Reduced Levels

The system of working out the reduced level of the points from staff reading taken in the field is called as reduced level (R.L) of a point is the elevation of the point with reference to the same datum.

There are two systems of reduced levels

1) The plane of collimation system (H.I. method)

2) The Rise and fall system

1) The plane of collimation system (H.I. method)

In this system, the R.L. of plane of collimation (H.I) is found out for every set-up of the level and then the reduced levels of the points are worked out with the respective plane of collimation as described below.

1) Determine the R.L. of plane of collimation for the first set up of the level by adding B.S. to the R.L. of B.M. i.e. (R.L of plane of collimation= R.L. of B.M. +B.S.)

2) Obtained the R.L. of the intermediate points and first change point by subtracting the staff readings (I.S. and F.S. from the R.L. of plane of collimation (H.I). (R.L. of a point=R.L of plane of collimation H.I.-I.S or F.S)

3) When the instrument is shifted and set up at new position a new plane of collimation is determined by addition of B.S. to the R.L of change point. Thus the levels from two set-ups of the instruments can be correlated by means of B.S. and F.S. taken on C.P.

4) Find out the R.L.s of the successive points and the second C.P. by subtracting their staff readings from this plane of collimation R.L.

5) repeat the procedure until all the R.Ls is worked out.

Observation table

Station	Reading			R.L. of plane collimation (H.I)	Reduced Level	Remarks
	B.S	I.S	F.S			

Arithmetical check

The difference between the sum of the back sights and the sum of the fore sights should be equal to the difference between the last and first reduced levels. i.e ∑B.S - ∑ F.S.= LAST R.L –FIRST R.L

2) The Rise and fall system

In this system, there is no need to determine R.L. of plane of collimation .The difference of level between consecutive points is obtained as described below.

1) Determine the difference in staff readings between the consecutive point comparing each point after the first with that immediately preceding it.

2) Obtained the rise or fall from the difference of their staff reading accordingly to the staff reading at the point is smaller or greater than that of proceeding point.

3) Find out the reduced level of each point by adding the rise to or subtracting fall from the R.L. of a proceeding point.

Observation table

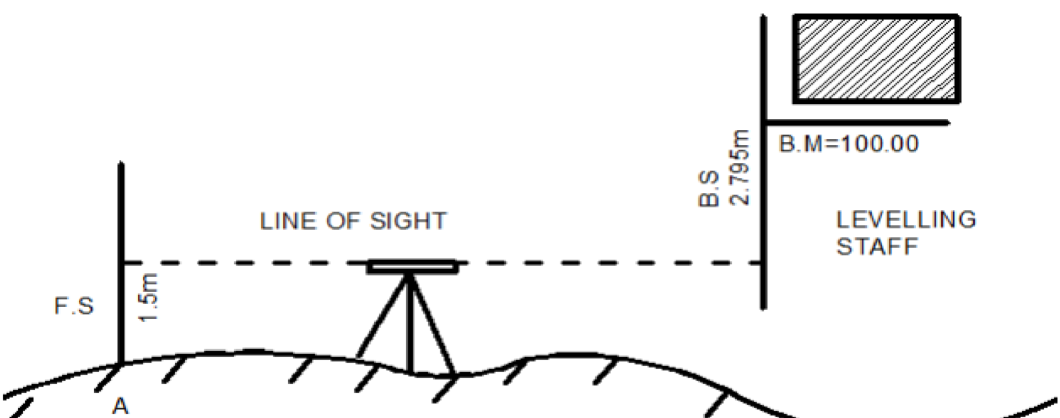
Station	Reading			Rise	Fall	Reduced Level	Remarks
	B.S	I.S	F.S				

Arithmetic check: - The difference between the sum of back sight and the sum of fore sight= difference between the sum of rise and the sum of fall = the difference between the last R.L. and the first R.L.

$\sum$B.S-$\sum$F.S =$\sum$RISE -$\sum$FALL =LAST RL- FIRST RL

Inverted staff reading

When the B.M of staff station is above the line of collimation (or line of sight) the staff is held inverted on the point and reading is taken .This reading being negative is entered in the level field book with minus sign, or to avoid confusion, 'Staff inverted' should be written in the remarks column against the entry of the reading.



INVERTED STAFF READING

(Source:http://bhagwantuniversity.ac.in/wp-content/uploads/2016/02/SURVEYING-LAB-MANUAL.pdf)

The results are tabulated as below

B.S.	I.S	F.S	H.I	R.L	Remarks
-2.795			97.215	100.000	B.M.Staff inverted
		1.500		95.715	Point A

When the reading on the inverted staff is a foresight or intermediate sight .it should also be recorded in field book with minus sign.

The R.L. of such points may be worked at as:

R.L. of the point (where the inverted staff is held)

=R.L. of H.I +F.S. or I.S. reading

RESULT

The various reduced levels are calculated by rise and fall method and by using height or plane of collimation method and are shown in observation table.

2.4 Perform Longitudinal Sections, Cross Sections

Title: L-Section and cross section of the road (one full size drawing sheet each for L- section and cross section)

APPARATUS REQUIRED

1. Dumpy level,
2. levelling staff,
3. ranging rod,
4. tape etc

THEORY

Profile levelling/Longitudinal levelling: The process of determining elevations at points at short measured intervals along a fixed line is called Longitudinal or profile levelling. Cross sectioning: It is a method of levelling to know the nature of Ground on either side of the centreline of the proposed route.

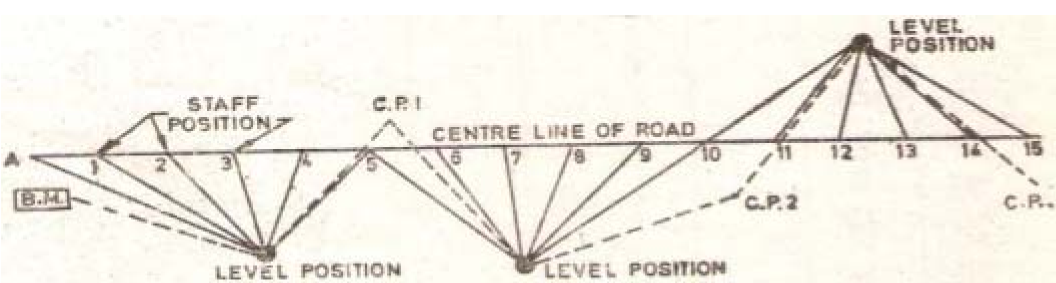
Levels are taken at right angles to the proposed Direction of the road end at suitable distances and levelling is carried out along this cross Section. During location and construction of highways, Rail tracks sewers and canals strakes or other marks are placed at various aligned points and the undulation of the ground surface along a predetermined line is adjoined. The line of section may be A single straight lines changing directions. Levels are taken at right angles to the proposed Direction of the road end at suitable distances and levelling is carried out along this cross section. Cross section are the sections run at right Angles to the centreline and on the either side of it for the purpose They are taken at each 10,m station on the centreline. The length of Cross section depends upon the nature of the work if cross sections are Short they are set square out by edge. If long they are set out by the Optical square, box sextant or theodolite.

They are serially numbered from the beginning of the Centreline and are taken simultaneously with the longitudinal section they may be taken at the hand level, level, abney level or theodolite.

PROCEDURE

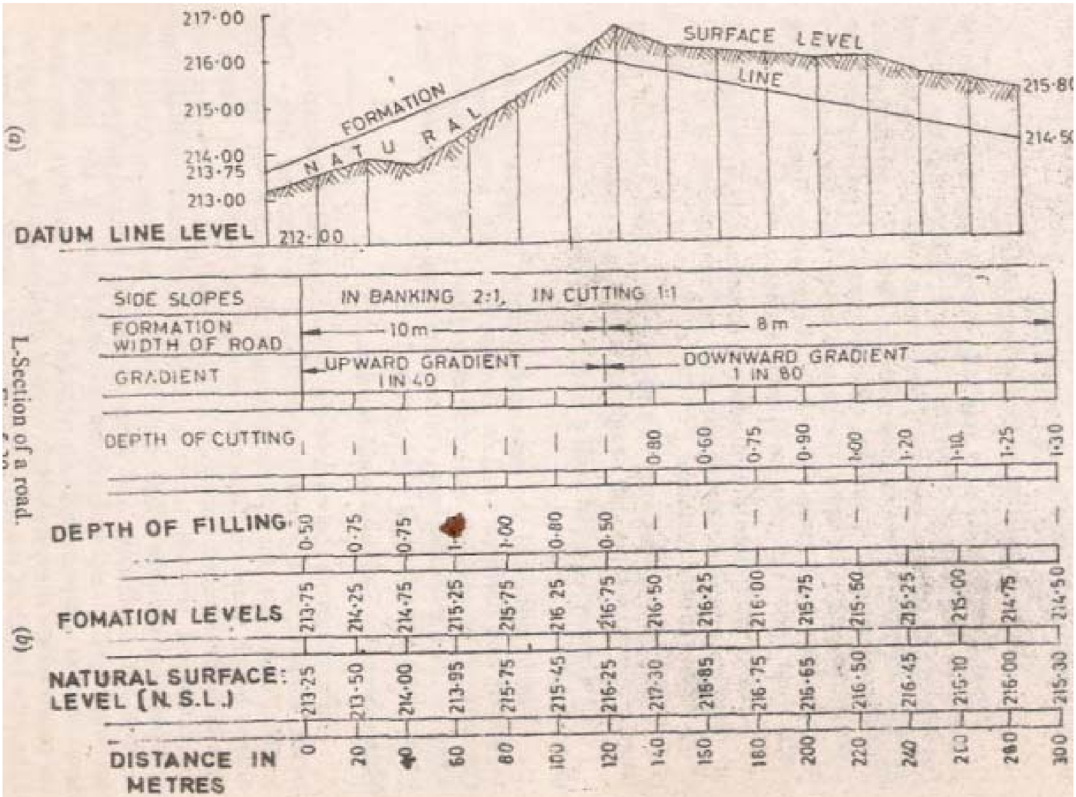
Let ABC be the line of section set out on the ground and marked with pegs driven at equal interval (say 20m to 30m) as in the figure. The level is set up generally on one side of the profile to avoid too short sight on the points near the instrument and care is taken to set up the level approximately midway between two change points. The levelling is started from the bench mark of known value. From each set up staff reading are taken on pegs already fixed at the desired interval and also at significant points where abrupt changes of slope etc. occur. All these readings are recorded as intermediate slight against the respective chain ages along the line in the level book. Other data of the level book is also filled up before starting the work. When the length of sight is beyond the power of the telescope (usually it is 100m) ,the foresight on the change point is taken. The level is then is then shifted and setup in an advanced position and a back sight is taken on the change point. The change point may or may not lie in the line of section. Chaining and reading are then continued as before, till the whole line of section is completed.

The work is to be checked in the progress of levelling by taking reading on other bench marks, on the way or on bench marks fixed by differential levelling. The fore and back bearing of the section line should be taken and recorded. Next sketches of the bench mark, change points, and other feature such as nallah, a road, canal, etc. crossing the section line be drawn and fully described in the remarks column of the level-book. The procedure and corresponding reading and values are represented on the page of a level-book for a part of road project.



(Source:http://bhagwantuniversity.ac.in/wp-content/uploads/2016/02/SURVEYING-LAB-MANUAL.pdf)

Plotting the Longitudinal section



LEVEL BOOK

Whenever levelling operation is carried out the staff reading taken in the field is entered in the note book called a Level-Book. Each page of it has the following columns which help in booking of reading and reduction of levels.

Page of Level-Book

Page of Level-Book										
Name of work survey for:-								Page No:-		
Levelling from --------------------------------To-------------------------										
Instrument No--					Conducted by:-					
Station	Distance In meters	Bearings		Staff Reading			Height of Instrument or		Reduced Level	Remarks
		FORE	BACK	Back (B.S)	Inter (I.S)	Fore (F.S)	Rise	Fall		

2.5 Perform Two Peg Test

Title: TWO PEG TEST

A. OBJECTIVES

a. To check the permanent adjustment of a level.

b. To check the error in the level.

B. INSTRUMENT REQUIRED:

a. Levelling machine with Tripod stand

b. Tape

c. Pegs

d. Levelling staff

e. Hammer

f. Measuring tape

g. Arrows

C. THEORY

The two peg test is the process of checking on level whether the permanent adjustment is required or not. It is performed to make the line of collimation parallel to the axis of the bubble line. Though all the instruments are properly adjusted by the manufacture this fundamentals lie get distributed due to mishandling of the instruments in field. To establish the fixed relationships between fundamental lines of a level is the main objective of the permanent adjustments.

The fundamental lines of a level are:

i. The axis of the bubble.

ii. The vertical axis.

iii. The axis of the telescope.

iv. The line of collimation.

The desired relationship of the fundamental lines and permanent adjustment are:

i. The line of collimation should be parallel to the axis of the bubble tube. This is applicable to every type of levelling instrument.

ii. The axis of the telescope and line of collimation should coincide.

iii. The axis of the bubble tube should be perpendicular to the vertical axis of the level.

D. TERMS

i. Line of sight: The line passing through the optical centre of the objective, traversing the eye piece and entering the eye is known as a line of sight.

ii. Line of collimation: The line passing through the optical centre of the objective and the point of intersection of the cross hair stretched in front of the eye piece and its continuation is called the line of collimation.

iii. Optical centre of lens: The point in the lens through which rays passes without any lateral displacement is called the optical centre.

iv. Axis of telescope: The line joining the optical centre of the objective and the centre of eye piece is called the axis of telescope.

Instrument station: The point where the instrument is setup for observation.

Station: The point where levelling staff is held is called station.

E. PROCEDURE

To make the line of collimation parallel to the axis of bubble tube in level, two peg tests was preformed.

i. Two stations were fixed say A and B at a distance 60 on fairly level ground.

ii. The instrument, i.e. the level is fixed at the midpoint of the stations A and B.

iii. After levelling the level machine, it was used to sight to the staff on both the station A and B and reading were noted.

iv. Again the levelling machine was set upped 5m away from the first station i.e. A. From that point, the staffs were observed at both the stations and readings were noted.

If the reading difference of these two stations is equal, there is not necessity of permanent adjustment. If they are not equal, there is the need of the permanent adjustment. This instrument can be used for ordinary work.

F. OBSERVATION AND CALCULATION

i. When the level instrument is in between two stations A and B.

Instrument station	Sighted to	Reading in staff			Level difference (A-B)1m
		Top hair(m)	Middle hair(m)	Bottom hair(m)	
	BM	0.691	0.640	0.583	
Midway(C)	A	1.249	1.246	1.244	0.169
Midway(C)	B	1.560	1.415	1.265	

ii. When the level instrument is 5m apart from B.

Instrument station	Sighted to	Reading in staff			Level difference (A-B)2m
		Top hair(m)	Middle hair(m)	Bottom hair(m)	
5m apart B	A	1.200	1.175	1.150	0.165
5m apart B	B	1.635	1.340	1.020	

Discrepancy = level difference by 1st case- level difference by 2nd case

= (A-B) 1-(A-B) 2

= 0.169-0.165

= 0.004m

$$\text{Precision} = \frac{e}{\text{Mean distance}}$$

$$= \frac{0.004}{30}$$

$$= \frac{1}{7500}$$

G. CONCLUSION

In two peg test the precision ratio should be1:10000 but from surveying the result was not obtained. This may be due to either error of the instrument or due to carelessness of the surveyors. But studying both the readings we can conclude that the error is due to error in instrument.

2.6 Perform Fly Leveling

Title: Perform Fly levelling

Objectives

To determine the level difference between given station points

Apparatus Required

1. Dumpy level,
2. Tripod and
3. leveling staff

Principle

Reduced level=Bench mark+-Rise and fall

staff reading indicates rise or fall according to the reading is smaller or greater the preceding level

Procedure

The levelling instrument was placed on the tripod and leveled accurately, the station points A,B and C .The levelling instrument was placed at a convent distance from the station point C and B,A back sight was taken on C and fore sight was taken on B. The points A and B were not inter visible in a single set up. The inter visible point A' was taken at a convenient distance from A and B. The instruments placed between B and A',A back sight was taken to B and for sight was taken to A', then instrument shifted to a convenient distance from A' and A,A back sight to A' and fore sight to A was taken

Result

Level difference between A and B=

Level difference between B and C=

Level difference between C and A=

2.7 Perform Reciprocal Leveling

Title: RECIPROCAL LEVELLING

Objectives

To find the level difference between points

Apparatus Required

1. Dumpy level with tripod.
2. Leveling staff,
3. ranging rod

Principle

When there is a difficulty in setting the instrument between the points, we use reciprocal levelling for finding the level difference between the points equation.

Where, ha, hb, h'a, h'b are the staff reading

Procedure

A and B were the two points ,set up the levelling instrument close to A .a back sight was taken on A (ha) by looking through the object vane, and a fore sight was taken on B(hb).then the instrument was shifted to a new station close to B .Then repeated the process same as at A and founded h'a. h'b. The difference between h'a and h'b and ha and hb was calculated .then the level difference were calculated by using the formula

Result

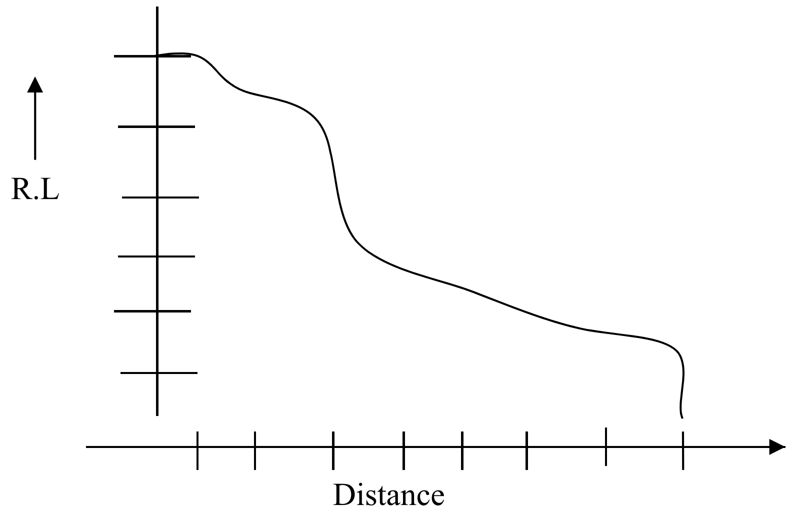
Level difference between A and B were calculated A is --- higher than B

2.8 Practice Plotting - Longitudinal Sections, Cross Sections

Longitudinal Sections

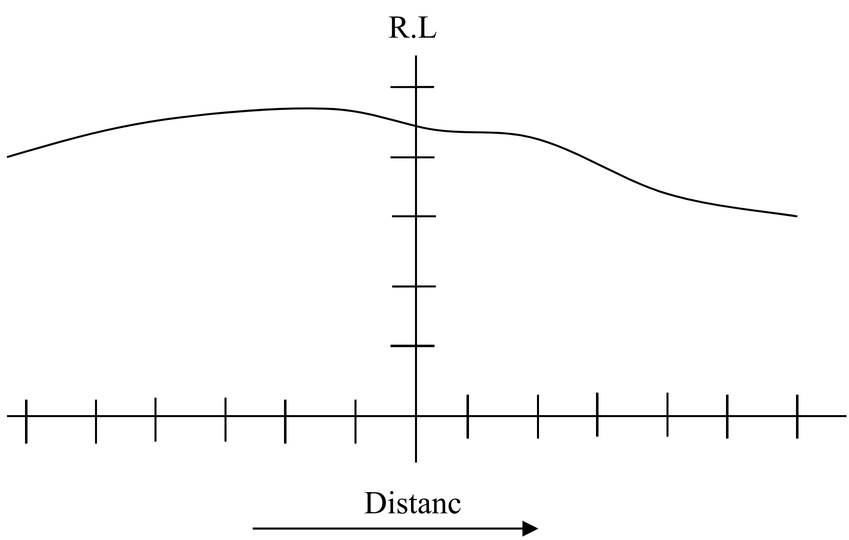
The following procedure is adopted:

Draw a straight line AB to represent the total horizontal distance between the end stations to a convenient scale. The distance between the consecutive point are marked there on verticals are drawn at each point and their elevations patterns by the Cartesian co-ordinate. The end points of all vertical are joined by straight lines, to show the project of the ground. Generally, horizontal scale is adopted as 1cm=10cm and vertical scale is kept 10 times the horizontal scale i.e. 1cm=1m. So that in equalities of the ground may be shown clearly.



Cross Section

The cross section is plotted same manner as the longitudinal section. In this case, the horizontal and vertical measurement is plotted to same scale. The most commonly adopted scales are 1:100 and 1:200. The elevation of datum lines is for each cross section may be kept different to have the co-ordinates formally short.



Unit 3
Theodolite survey

3.1 Introduce Different Parts and Principles of Operation of Theodolite

Title: Introduce Different Parts and Principles of Operation of Theodolite

Objectives

1. To know the different parts of the theodolite
2. To understand the function of the different parts of theodolite
3. To understand the principle of the theodolite

Instruments Required

1. One set of theodolite
2. Picture of all parts of the theodolite

Theory

The theodolite is the most intricate and accurate instrument used for measurement of horizontal and vertical angles. It consists of telescope by means of which distant objects can be sighted. The telescope has two distinct motions on in the horizontal plane and the Other in the vertical plane. The former being measured on a graduated Horizontal vertical circle of two verniear. Theodolite are primarily classified as

1) Transit theodolite
2) Non-transit theodolite

A theodolite is called transit theodolite when its telescope can be resolved through a complete revolution about its horizontal axis. In a vertical plane. The transit type is largely used. Various parts of transit theodolite

1) Telescope: it is an integral part and is mounted on the spindle known as horizontal axis or turn on axis. Telescope is either internal or external focusing type.

2) The leveling head: It may consists of circular plates called as upper and lower Parallel plates. The lower parallel plate has a central aperture through which a plumb bob may be suspended. The upper parallel plate or tribranch is supported by means of four or three leveling screws by which the instrument may be leveled.

3) **To lower plate or screw plate:** It carries horizontal circle at its leveled screw. It carries a lower clamp screw and tangent screw with the help of which it can be fixed accurately in any desired position.

4) **The upper plate or vernier plate:** it is attached to inner axis and carries two vernier and at two extremities diametrically opposite.

5) **Compass:** the compass box may be either of circular form or of a rough type. The former is mounted on the vernier plate between the standards while the latter is attached to the underside of the scale or lower plate or screwed to one of the standards. Modern theodolite is fitted with a compass of the tubular type and it is screwed to one of the standards.

6) **Vertical circle:** the vertical circle is rigidly attached to the telescope and moves with it. It is silvered and it is usually divided into four quadrants.

7) **Index bar or T-frame:** the index bar is T shaped and centered on horizontal axis of the telescope in front of the vertical axis. It carries two vernier of the extremities of its horizontal arms or limbs called the index arm. The vertical leg called the clip or clipping screws at its lower extremity. The index arm and the clipping arm are together known as T-frame.

8) **Plumb bob:** To centre the instrument exactly over a station mark, a plumb bob is suspended from the hook fitted to the bottom of the central vertical axis.

Procedure

1. Set the theodolite to seen by all students
2. Attach pictures of showing different parts of the theodolite
3. Explain about different part of theodolite by showing theodolite and pictures

Results

By the end of this practical students can know the different parts of the theodolite and their functions

3.2 Perform Temporary Adjustment of Theodolite

Title : Perform Temporary Adjustment of Theodolite

Objectives

To know the temporary adjustment of the theodolite before taking reading

Instruments Required

1. Theodolite set
2. Staff
3. Ranging rod
4. Tape
5. Plumb bob

Theory

Adjustment of a theodolite means the operation of tightening or loosening of moveable parts to prepare the instrument for accurate measurement. It also includes other operations meant for this purpose. There are two types of adjustments for a theodolite - Temporary Adjustment & Permanent Adjustment.

Procedure

Temporary adjustments of dumpy level these adjustments are performed at each set-up the level before taking any observation.

A) Setting up the level:- this includes

1) Fixing the instrument in the tripod: the tripod legs are well spread on the ground with tripod head nearly level and at convenient height. Fix up the level on the tripod.

2) Leg adjustment: Bring all the foot screws of the level in the centre of their run .Fix any two legs firmly into the ground by pressing them with hand and move the third leg to leg to right or left until the main bubble is roughly in the centre. Finally the legs is fixed after centering approximately both bubbles. This operation will save the time required for leveling.

B) Levelling: - Levelling is done with the help of foot screws and bubbles. The purpose of levelling is to make the vertical axis truly vertical. The method of leveling the instrument depends upon whether there are three foot screws or four foot screws. In all modern instruments three foot screws are provided and this method only is described.

1) Place the telescope parallel to pair of foot screws.
2) Hold these two foot screw between the thumb and first finger of each hand and turn them uniformly so that the thumbs move either toward each other until the bubble is in centre.
3) Turn the telescope through 90°so that it lies over the third foot screw.
4) Turn this foot screw only until the bubble is centred.
5) Bring the tescope back to its original position without reversing the eye piece and object glass ends.
6) Again bring the bubble to the centre of its run and repeat these operation until the bubble remains in the centre of its run in both position which are at right angle to each other.
7) Now rotate the instrument through 180°,the bubble should remain in centre provided the instrument is in adjustment: if not ,it needs permanent adjustment.

c) Focusing the eye piece: To focus the eye piece, hold a white paper in front of the object glass ,and move the eye piece in or out till the cross hairs are distinctly seen. Care should be taken that the eye piece is not wholly taken out ,some times graduation are provided at the eye piece and that one can always remember the particular graduation position to suit his eyes,This will save much time of focssing the eye piece.

(d) Focusing the object glass: Direct the telescope to the leveling staff and on looking through the telescope, turn the focusing screw until the image appears clears and sharp. The image is thus formed inside the plane of cross hairs, Parallax,if any is removed by exact focusing. It may be noted that parallax is completely eliminated when there is no change in staff reading after moving the eye up and down.

Results

By the end of this practical we can adjust theodolite temporarily before taking reading.

3.3 Practice and Perform Methods of Measuring Horizontal Angle– General Procedure of Measurement of Horizontal Angle, Measurement of Horizontal Angle by Repetition Method, Measurement of Horizontal Angle by Direction Method (or Reiteration Method)

Title: Practice and Perform Methods of Measuring Horizontal Angle – General Procedure of Measurement of Horizontal Angle, Measurement of Horizontal Angle by Repetition Method, Measurement of Horizontal Angle by Direction Method (or Reiteration Method)

Objectives

1. To calculate the horizontal angles by using different methods

Instruments Required

1. Theodolite set
2. Staff
3. Ranging rod
4. Tape
5. Plumb bob
6. pegs

Theory

Theodolite : The theodolite is the most intricate and accurate instrument used for measurement of horizontal and vertical angles. It consists of telescope by means of which distant objects can be sighted. The telescope has two distinct motions on in the horizontal plane and the Other in the vertical plane. The former being measured on a graduated Horizontal vertical circle of two verniear. Theodolite are primarily classified as

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2) Non-transit theodolite

A theodolite is called transit theodolite when its telescope can be resolved through a complete revolution about its horizontal axis. In a vertical plane. The transit type is largely used.

Various parts of transit theodolite

1) **Telescope:** it is an integral part and is mounted on the spindle known as horizontal axis or turn on axis. Telescope is either internal or external focusing type.

2) **The leveling head:** It may consists of circular plates called as upper and lower Parallel plates. The lower parallel plate has a central aperture through which a plumb bob may be suspended. The upper parallel plate or tribranch is supported by means of four or three leveling screws by which the instrument may be leveled.

3) **To lower plate or screw plate:** It carries horizontal circle at its leveled screw. It carries a lower clamp screw and tangent screw with the help of which it can be fixed accurately in any desired position.

4) **The upper plate or vernier plate:** it is attached to inner axis and carries two vernier and at two extremities diametrically opposite.

5) **Compass:** the compass box may be either of circular form or of a rough type. The former is mounted on the vernier plate between the standards while the latter is attached to the underside of the scale or lower plate or screwed to one of the standards. Modern theodolite is fitted with a compass of the tubular type and it is screwed to one of the standards.

6) **Vertical circle:** the vertical circle is rigidly attached to the telescope and moves with it. It is silvered and it is usually divided into four quadrants.

7) **Index bar or T-frame:** the index bar is T shaped and centered on horizontal axis of the telescope in front of the vertical axis. It carries two vernier of the extremities of its horizontal arms or limbs called the index arm. The vertical leg called the clip or clipping screws at its lower extremity. The index arm and the clipping arm are together known as T-frame.

8) **Plumb bob:** To centre the instrument exactly over a station mark, a plumb

bob is suspended from the hook fitted to the bottom of the central vertical axis.

Repetition method of measuring Horizontal angles

When it is required to measure horizontal angles with great accuracy as in the case of traverse, the method of repetition may be adopted. In this method the same angle is added several times by keeping the vernier to remain clamped each time at the end of each measurement instead of setting it back to zero when sighting at the previous station. The corrected horizontal angle is then obtained by dividing the final reading by the number of repetitions. Usually six reading, three with face left and three with face right, are taken The average horizontal angle is then calculated.

Procedure

1) Let LOM is the horizontal angle to be measured as shown in fig. O is the station point fixed on the ground by a peg. Set up the theodolite over the peg 'o' and level it accurately.
2) Set the horizontal graduated circle vernier A to read zero or 360° by upper clamp screw and slow motion screw. Clamp the telescope to bisect the bottom shoe of the flag fixed at point 'L' and tighten the lower clamp. Exactly intersect the centre of the bottom shoe by means of lower slow motion screw. Check that the face of the theodolite should be left and the telescope in normal position.
3) Check the reading of the vernier A to see that no slip has occurred .Also see that the plate levels are in the centre of their run. Read the vernier B also.
4) Release the upper clamp screw and turn the theodolite clockwise. Biset the flag bottom shoe fixed at point M by a telescope. Tighten the upper clamp screw and bisect the shoe exactly by means of upper slow motion screw.
5) Note the reading on both the vernier to get the approximate value of the angle LOM.
6) Release the lower clamp screw and rotate the theodolite anticlockwise ai azimuth. Bisect again the bottom shoe of the flag at 'L' and tighten the lower clamp screw. By means of slow motion screw bisect exactly the centre of the

shoe.

7) Release now the upper clamp screw and rotate the theodolite clockwise. Bisect the bottom shoe of the flag fixed at M and tighten the upper clamp screw. By means of slow motion screw bisect exactly the centre of the shoe. The vernier readings will bw now twice the of the angles.

8) Repeat the process until the angle is repeated the required number of times (usually 3). Add 360° for every complete revaluation to the final reading and divided the total angle by number of repetitions to get the value of angle LOM. 9) Change the face of the theodolite the telescope will now be inverted. Rrpeat the whole process exactly in the above manner and obtain value of angle LOM. 10)The average horizontal angle is then obtained by taking the average of the two angles obtained with face left and face right.

11) Usually three repetitions face left and three with face right should be taken and the mean angle should be calculated.

Observation

S.N.	Instrument Station	Shifted to	Face left readings			
		Venier A 0,I,II	Venier B 0,I,II	Total angle	No of Repetition	Mean horizontal angle 0,I,II
	o	L				
		M				
		L				
		M				
		L				
		M				

S.N.	Instrument Station	Shifted to	Face Right readings				
		Venier A 0,I,II	Venier B 0,I,II	Total angle 0,I,II	No of Repatition	Mean horizontal angle 0,I,II	Average horizontal angle 0,I,II
	o	L					
		M					
		L					
		M					
		L					
		M			3		

RESULT: Average horizontal angle is found to be ------------

Unit 4
Contouring

4.1 Perform Methods of Contouring– Direct Method, and Indirect Method (Square Method, Cross-Section Method, Tacheometric Method)

Title: Perform Methods of Contouring – Direct Method, and Indirect Method (Square Method, Cross-Section Method, Tacheometric Method)

Objectives

To prepare contouring map by using different methods

APPARATUS REQUIRED

1. Dumpy level,
2. prismatic compass,
3. chain 20m, 30m,
4. metallic Tape,
5. ranging road
6. Leveling staff,
7. pegs.

Theory

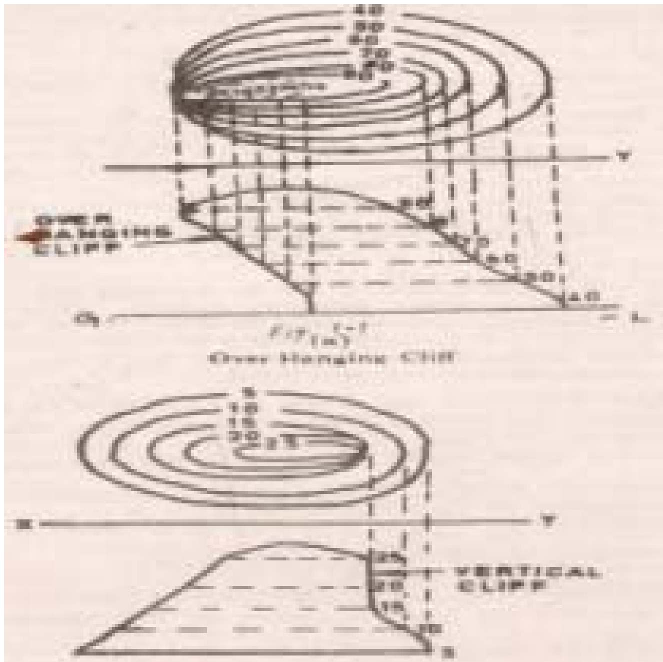
CONTOURING: The elevation and depression the undulations of the surface of the ground are shown as map by interaction of level surface with by means of contour line. a contour may be defined as the line of intersection of a level surface with the surface of the ground.

Characteristics of Counter Lines

The following are the Characteristics of the contours/ contour lines.

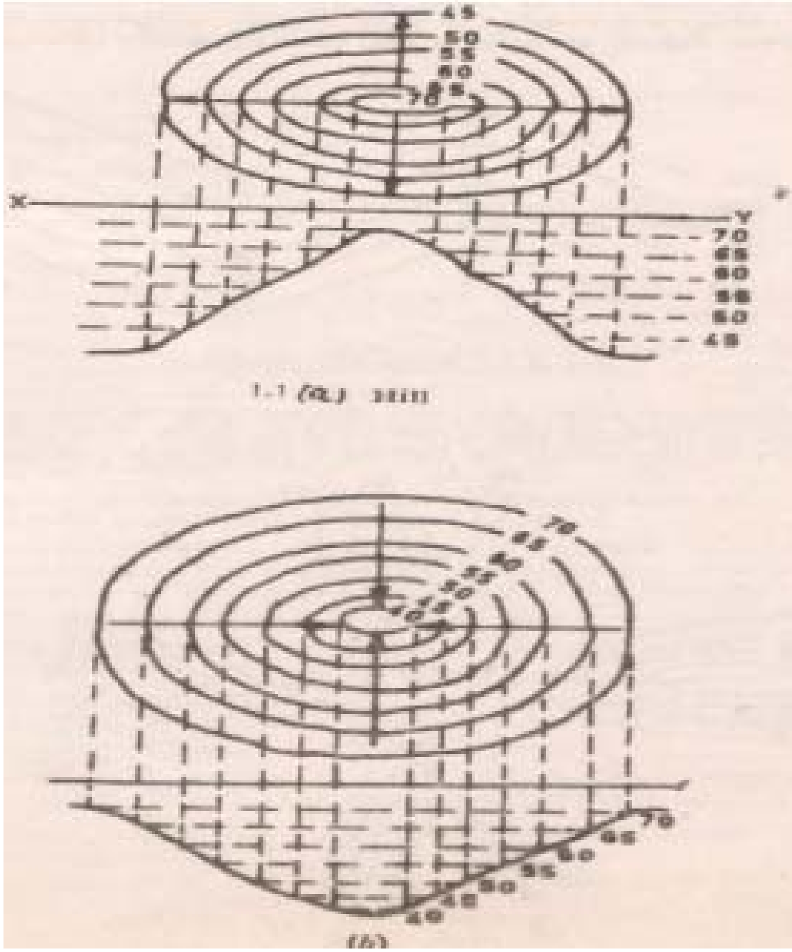
1) All points on the same contour line will have the same elevation.
2) Contour lines close together represent steep ground, while uniform slope is indicated when they are uniformly spaced. A series of straight, parallel and equally spaced contours show a plane or flat surface.
3) Contour lines of different elevation cannot merge or cross one another on the

map, expect in the case of an overhanging cliff. A vertical cliff is indicated when several contours coincide [see fig (a) and (b)]



4) A contour line must close upon itself either within or without the limits of the map.

5) Series of closed contour lines on the map either represent a hill or a depression according as the higher or lower values are inside them as shown in figs [(a) and (b)]



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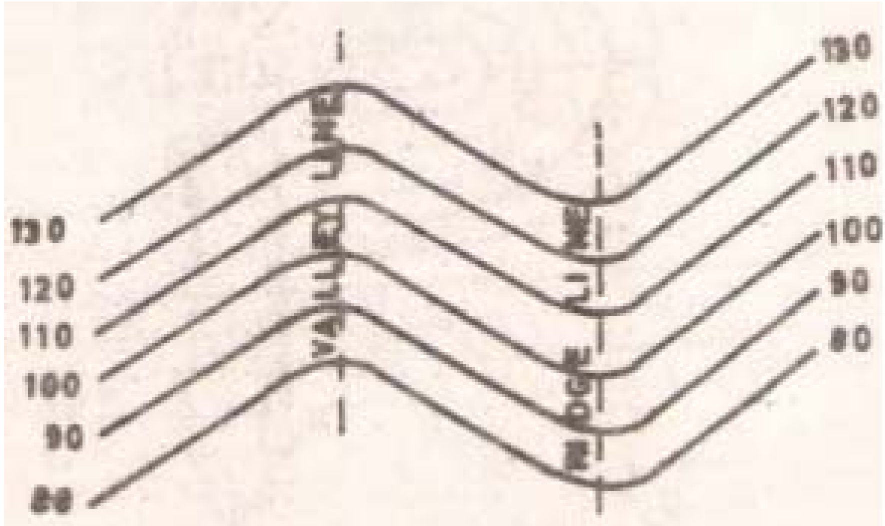
6) A contour will not stop in the middle of the plan. It will either close or go out of the plan.

7) Ridge or water shad and valley lines are the lines joining the top most or the bottom most points of hill and valley respectively, cross the contours at right angles. A ridge line is shown when the higher values are inside the loop, while in the case of a valley line, the lower values are inside the loop as shown in fig (1.3)



8) Contour lines are not drawn across the water in the stream or river because the water level in the it is not constant; but contours are drawn along the bed of a river or a stream.

Uses of contour map

1) For preparing contour map in order to select the most economical or a suitable site.
2) For getting the importance about ground whether it is undulating or Mountainous.
3) To locate the alignment of canal so that it should follow a ridge line, thus canal construction will be economical and will command maximum irrigated area.
4) To make the alignment for the road, railway so that the quantity of earthwork both in cutting and filling should be minimum.
5) To find out the capacity of the reservoir or a volume of earthwork especially in the Mountainous region.
6) For preparing contour map in order to select the most economical or suitable site.
7) As its definition itself indicates the line joining the points of same elevation that means it naturally prefers the condition of nature of ground itself.

8) It is also used for irrigation purpose as from it capacity of reservoir is shown.

Procedure

LOCATING CONTOURS

a) By cross-section method:

This method is commonly used in rough survey, cross sections are run traverse to the contour line of road, and railway as canal and the point of change of slope (Representations) are located. The cross-section line may be inclined at any angle to the centerline if necessary. The spacing of the cross sections depends upon the characteristics of the ground.

By interpolation of contour is meant the process of spacing the contour proportioning between the plotted ground points. Contour may be interpolated by

1) Estimation
2) Arithmetical calculations
3) Graphical method .in all these methods

It is assumed that the slope of the ground between any two random points is

Uniform

Result: We can prepare contour from the survey data in various methods showing different characteristics of contours.

Unit 5
Tacheometric Surveying

5.1 Perform Stadia Method- Determination of Constants K and C

Title: Determination of Constants K and C (Determination of the Multiplying and additive constant of given Tacheometer.

Objectives

To determine the additive and multiplying constant

Equipments required

1. A tacheometer with tripod,
2. Tape,
3. leveling staff,
4. wooden pegs,
5. Ranging rods etc.

Theory

Formulae: When the line of sight is horizontal, then

$D = KS + c$

Where,

D = Horizontal distance between instrument station and staff station.

K = Multiplying constant of a tacheometer

S = Staff intersect i.e. difference between top and bottom stadia hair reading.

When line of sight is inclined and staff vertical then:

$D = KS \cos2 \theta + c \cos\theta$

Where,

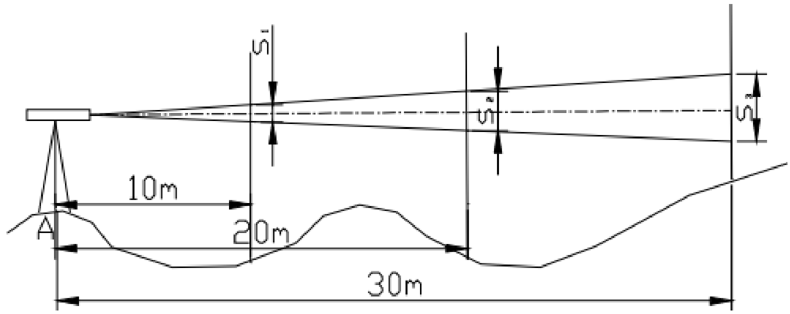
D = Horizontal distance between instrument station and staff station.

K = Multiplying constant of a tacheometer

S = Staff intersect i.e. difference between top and bottom stadia hair reading.

θ = The inclination of the line of collimation to the horizontal.

c = The additive constant of the tacheometer



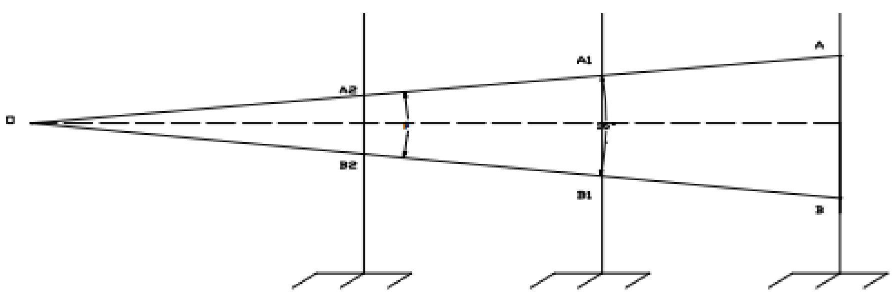
PRINCIPLE OF STADIA METHOD

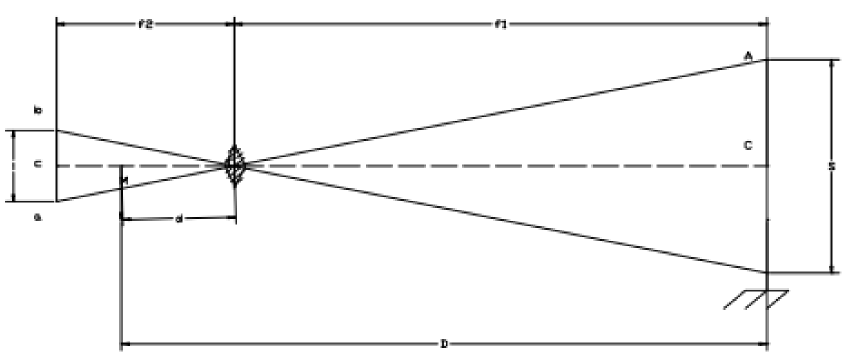
The stadia method is based on the principle that the ratio of perpendicular to the base is Constant in similar isosceles triangles.

In fig let two rays OA and OB be equally inclined to the central ray OC. Let A2B2, A_1B_1 and AB be staff intercepts.

Evidently

$OC_2 / A_2B_2 = OC_1/A_1B_1 = OC/AB = \text{cons tan tk} = 1/2\cot \beta/2$





This constant k entirely depends upon the magnitude of the angle β. If β is made equal to 34’22”, the constant k=1/2Cot 17’11”=100. In this case the distance between the staff and the point o will be 100 times the intercept. In actual practice, observation may be made with inclined line of sight. in the later case, the staff may be kept either vertically or normal to the line of sight. We shall first derive the distance elevation formulae for the horizontal sights.

Horizontal Sight: Considering fig in which o is the optical centre of the objective of an external focusing telescope. Let A,C and B= The point cut by the three lines of sight corresponding to the three wires.

b, c and α (Top, axial and bottom)hairs of the diaphragm.

a b= i= interval between the stadia hairs (stadia interval)

AB=s=Staff intercept.

f=focal length of the objective.

f1=Horizontal distance of the staff from the optical centre of the objective.

f2 = Horizontal distance of the cross-wires from O.

d = Distance of the vertical axis of the instrument from O.

D = Horizontal distance of the staff from the vertical axis of the instrument.

M = Centre of the instrument, corresponding to the vertical axis.

Since the rays Bob and AOa pass through the optical centre they are straight so that Δs

AOB and aob are similar.

F1/f2 = s/i ---------------------------------(1)

Again, since f1 and f2 are conjugate focal distances, we have, from lens formula

1/f=1/f1+1/f2= --------------------------(2)

Multiplying throughout by ff1, we get

F1=f1/f2*f+f

Substituting the values of F1/f2 = s/i in the above, we get

F_1= s/i*f+f -------------------------(3)

The horizontal distance between the axis and the staff is

D = f + d

D = f/i*s+(f+d) -------------------(4)

D = ks + C

Equation (4) is known as the distance equation. In order to get the horizontal distance, therefore, the staff intercept s is to be found by subtracting the staff reading corresponding to the top and bottom stadia hairs.

The constant k = f/i is known as the multiplying constant or stadia interval factor and the constant (f+d)=C is known as the additive stadia if the instrument.

Determination of Constant k and C

The values of the multiplying constant k and the additive constant C can be computed by the following methods:

1st Method

In this method ,the additive constant C=(f +d) is measured from the instruments while the multiplying constant k is computed from field observations

1) Focus the instruments to a distant object and measure along the telescope the distance between the objective and crosshair.

   1/f=1/f1+1/f2

Since f1 is very large in this case, f is approximately equal to f2 i.e. equal to the distance of the diaphragm from the objective.

2) The distance d between the instrument axis and the objective is variable in case of external focusing telescope, being greater for short sights and smaller for long sights. It should, therefore, be measured for average sight. Thus, the additive constant (f +d) is known.

3) To calculate the multiplying constant k, measure a known distance and take the S1 on the staff kept at that point, the line of sight being horizontal. using equation

D1 = KS1 + C

$K=(D1-C)/ S1$

For the average value, staff intercepts, s2, s3 etc., can be measured corresponding to distance d2, d3 etc., and mean value can be calculated.

2nd Method

In this method, both the constants are determined by field observations as under:

1) Measure a line, about 200 m long on fairly level ground and drive pegs at some intervals, say 50 meters.
2) Keep the staff on the pegs and observe the corresponding staff intercepts with horizontal sight.
3) Knowing the values of d and s for different points, a number of simultaneous equations can be formed by substituting the values of d and s in equation (1.1). The simultaneous solution of successive pairs of equations will give the values of k and c, and the average of these can be found.

If s1 is the staff intercept corresponding to distance D1 and s2 corresponding to D2, we have,

$D1 = KS1 + C$ and---(1)

$D2 = KS2 + C$ ---(2)

Subtracting (1) from (2) we get,

$K =(D2-D1)/(S2-S1)$ ---(3)

Substituting the values of k in (1) we get,

$C=D_1-(D2-D1)/(S2-S1)* S1$

$C=(D1S2-D1S1-D2S1+D1S1)/(S2-S1)$

$C =(D1S2-D2S1)/)/(S2-S1)$ ---(4)

Thus, equations 3 and 4 give the values of K and C.

1) Tacheometry: It is a branch of angular Surveying in which horizontal and vertical distance of point are obtained by instrumental observation.) Tacheometer: It is a transit theodolite having a stadia telescope i.e. telescope

fitted with stadia diaphragm.

A leveling staff can be used for sighting purpose up to 100m distance.

Procedure:

1) Select an instrument station A on a fairly leveled ground and fix a peg.
2) Do the temporary adjustment over A.
3) With vertical circle to the left of the observer and reading 00000’00” bisect staff held at 10m, 20m, and 30m from A along straight line.
4) Note down the staff reading against top and bottom stadia hair on staff held at 10m, 20, 30m from A.
5) In case of inclined line of sight the same procedure as stated above is followed step by step with a vertical angle of 05000’00” in the vertical circle of the theodolite. In this case, the vertical circle is held to the left of the observer and with the reading 05000’00” in the circle the staff is bisected at 10m, 20m, and 30m from A along straight but inclination line of collimation.

Observation Table

Instrument station	Staff station	Distance	Vertical angle	Stadia hair Reading			Remark
				Top	Center	Bottom	
A	D1						
	D2						
	D3						

Calculation

D = Ks + c

For three staff stations,

D1 = Ks1+c ------- (1)

D2 = Ks2+c ------- (2)

D3 = Ks3+c ------- (3)

As ; s1, s2, s3 can be known solving (1) &(2), (2) & (3) , (1) & (3) to get 3 values of m & c ,then average of three values is required answer.

$D = Ks \cos^2 \theta + c \cos\theta$

For, three station the equations are;

$D1 = Ks1 \cos^2 \theta1 + C \cos\theta1$ ------- (1)

$D2 = Ks2 \cos^2 \theta2 + C \cos\theta2$------- (2)

$D3 = Ks3 \cos^2 \theta3 + C \cos\theta3$------- (3)

As ; s1, s2, s3 can be known solving (1) &(2), (2) & (3) , (1) & (3) to get 3 values of K & C ,then average of three values is required answer.

Result:

a) for horizontal line of collimation;

1) The additive constant 'c' for a given tachometer is found out to be ---------

2) The multiplying constant 'm' for a given tachometer is found to be ---------

b) For inclination line of collimation;

1) The additive constant 'c' for a given tachometer is found out to be ----------

2) The multiplying constant 'k' for a given tachometer is found to be ---------