SURVEYING

II Year – I Semester

UNIT – I

Objective: To learn principles of instruments and other equipment used to conduct field surveys.

Syllabus: Introduction –primary divisions of surveying, classification of surveying, principles of surveying, basic measurements in surveying, plan and map- Brief about linear measurements and instruments-Errors in chaining.
Principles of chain surveying, basic definitions, well-conditioned triangle, selection of survey stations and survey lines, recording measurements, offsets, cross staff survey, obstacles in chaining and ranging, chain traversing.

Learning Outcomes: Student will be able to

Classify various types of surveying and explain the concept of chain survey.

Learning Material

Surveying is the science and art of determining the relative positions of the points on, above (or) beneath the earth surface.

Primary divisions of surveying: Surveying may primarily be divided into two divisions

1. Plane surveying
2. Geodetic surveying

Plane surveying: The surveys in which earth surface is assumed as plane and the curvature of the earth is ignored, are known as Plane surveys.
Geodetic surveying: The surveys in which curvature of the- earth is taken into account and higher degree of accuracy in linear and angular observations, is achieved, are known as Geodetic surveys.

Classification of surveying:

1. Based on instruments

i) Chain survey

ii) Compass survey

iii) Plane table survey

iv) Theodolite survey

v) Tacheometric survey

vi) Modern survey using electronic distance meters and total station

vii) Photographic and Aerial survey

2. Based on Nature of Survey Field

i) **Topographic Survey:** It is meant for plotting natural features like rivers, lakes, forests and hills as well as manmade features like roads, railways, towns, villages and canals.

ii) **Cadastral Survey:** It is for marking the boundaries of municipalities, villages, talukas, districts, states etc. The survey made to mark properties of individuals also comes under this category

iii) **City Survey:** The survey made in connection with the construction of streets, water supply and sewage lines fall under this category.

3. Based on Object of Survey

i) **Engineering Survey:** The objective of this type of survey is to collect data for designing civil engineering projects like roads, railway, irrigation, and water supply and sewage disposals.

ii) **Military Survey:** This survey is meant for working out plans of strategic importance.

iii) **Mines Survey:** This is used for exploring mineral wealth.

iv) **Geological Survey:** This survey is for finding different strata in the earth's crust.

v) **Archeological Survey:** This survey is for unearthing relics of antiquity.

Principles of surveying:

There are two fundamental principles.

1) To work from the whole to the part.

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

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

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

Plan and map: A plan may be defined as the graphical representation of the features on, near or below the surface of the earth as projected on a horizontal plane to a suitable scale. If the area to be represented is small, the distortion is less and large scale can be used. Such representations are called plans.

If the area to be represented is large, small, scales are to be used and distortion is large. Representation of larger areas is called maps. Representation of a particular locality in a municipal area is a plan while representation of a state/country is a map.

Liner measurements and equipments:

In engineering survey, the linear horizontal distance is to be measured to complete a survey. The measurement of this linear horizontal distance between two points on the earth surface is known as linear measurement. Linear measurement can be achieved by various instruments.

The following instruments are used while chaining:

1. Chains
2. Tapes
3. Arrows

4. Ranging rods and offset rods
5. Pegs
6. Plumb-bob

Chain

The chain is composed of 100 or 150 pieces of galvanized mild steel wire called links, joined together with oval rings and handles at both ends. The end of each link are bent into a loop and connected together by means of three oval rings. The ends of the chain are provided with brass handles for easy handling. The length of chain is measured from one handle to other handle.

Tapes

Tapes are used for more accurate measurements. The tapes are classified based on the materials of which they are made of such as:

1. Cloth or linen tape
2. Fibre tape
3. Metallic tape
4. Steel tape
5. Invar tape

Arrows or chain pins

They are also called as marking or chaining pins and are used to mark the end of chain during the process of chaining. They are made up of good quality hardened and tempered steel wire of 4mm in diameter. The arrows are made 400 mm in length. The one pointed part of an arrow is inserted into ground and the other is attached with ring.

Ranging rods or offset rods or ranging poles

Ranging rods or offset rods are round poles made up of wood or metal. These rods are used to range intermediate points of a survey and to set out straight lines on the field when the surveying length is long. The only difference between ranging rods and poles is the length. Ranging rods and offset rods are commonly occurs in 3m length but the ranging poles are available up to 8m length. The rods possess a metal point at its bottom and the rod or pole is painted with red & white or black & white successive combination. When the survey lines are too lengthy a flag with red/white/yellow colour will be attached to the top of the pole for easy identification.

Pegs

The pegs are made up with wood and they used to mark the survey positions or terminals.

The size of the pegs (40 to 60 cm) depends on the type of survey work they are used for and the type of soil they have to be driven in. Although the pegs are driven into the ground 1/5 th of its part should be visible on the ground surface.

Plumb-bob

A string suspended with a weight at the bottom will be both vertical and perpendicular to any level plane through which it passes. The plumb consists of a specially designed weight and coarse string or special threads. At one end of the string the weight is affixed. Precisely machined and balanced bobs have pointed tips, and can be made of brass, steel, or other materials, including plastic.

ERRORS IN CHAINING:

Errors in chaining may be classified as:

1. Personal errors
2. Compensating errors, and
3. Cumulative errors

Personal errors: Personal errors like wrong reading, wrong recordings, reading from wrong end or chain and miscounting of the chains are serious errors. It is not easy to detect unless they are too big. Hence, care should be taken to avoid such errors.

Compensating errors: These errors can be positive or negative. Hence, they are likely to get compensated when a large number of readings are taken. The following are the examples of such errors: 1) Incorrect marking of the end of chain

2) Fractional parts of the chain may not be correct when the chain is corrected by adding or removing a ring.

3) Graduation in the tape may not be exactly of same length throughout

4) In the method of stepping for measuring sloping ground, method of plumbing may be crude.

Cumulative errors: These are the errors which occur always in the same direction. Hence, as more number of chain lengths is required while measuring a line they go on accumulating. Hence, even if each one of such errors are small they are considerable when longer lengths are measured.

Examples of such errors are:

1. Bad ranging (+ve)
2. Bad straightening
3. Non – horizontality
4. Sag in the chain
5. Erroneous length of chain
6. Temperature variation
7. Variation in pull.

First four errors are always + ve since they make measured length more than actual. Last three errors may be +ve or –ve.

Errors in measurement with incorrect chain length:

Due to continuous uage of the chain over rough areas, the chain becomes too long or too short over a period of time. If the chain is too long, the measured distance will be less. On the other hand, if too short, the measured distance will be more.

Let ***'l'*** be the true length of the chain and ***'l^l'*** be the faulty length of the chain. Then:

True length of the line = (l^l/l) X measured length of the line

True area = $(l^l/l)^2$ X measured area

True volume = $(l^l/l)^3$ X measured volume

principle of chain surveying: Chain surveying is the type of surveying in which only linear measurements are made in the field. The main principle of chain surveying or chain triangulation is to provide a framework consist of number of well-conditioned triangles or nearly equilateral triangles. It is used to find the area of the field.

Suitability of Chain Survey

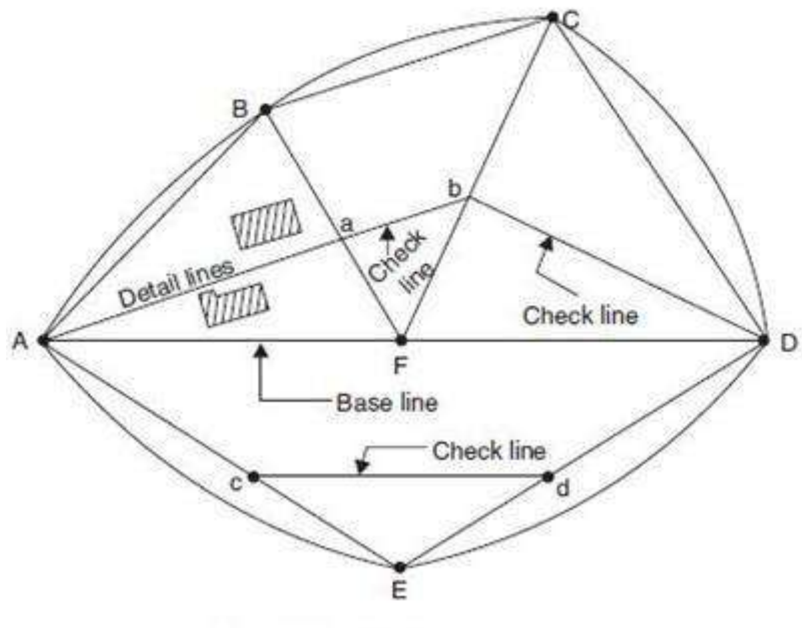
Chain survey is suitable in the following cases

1. Area to be surveyed is comparatively small
2. Ground is fairly level
3. Area is open and
4. Details to be filled up are simple and less.
5. Survey Station
6. Survey stations are of two kinds
7. Main Stations
8. Subsidiary or tie

Main Stations

Main stations are the end of the lines, which command the boundaries of the survey, and the lines joining the main stations re called the main survey line or the chain lines.

Subsidiary or the tie stations are the point selected on the main survey lines, where it is necessary to locate the interior detail such as fences, hedges, building etc.



Tie or subsidiary lines

A tie line joints two fixed points on the main survey lines. It helps to checking the accuracy of surveying and to locate the interior details. The position of each tie line should be close to some features, such as paths, building etc.

Base Lines

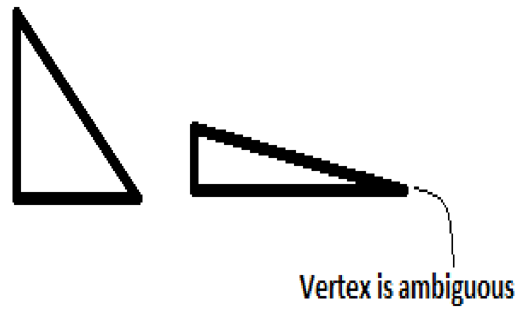
It is main and longest line, which passes approximately through the center of the field. All the other measurements to show the details of the work are taken with respect of this line.

Check Line

A check line also termed as a proof line is a line joining the apex of a triangle to some fixed points on any two sides of a triangle. A check line is measured to check the accuracy of the framework. The length of a check line, as measured on the ground should agree with its length on the plan.

Well - conditioned triangle: A well conditioned triangle is a triangle in which no angle is less than 30 degrees. One of the way to survey the area is to divide the entire area is smaller triangles and then take the measurement of sides of the triangles.

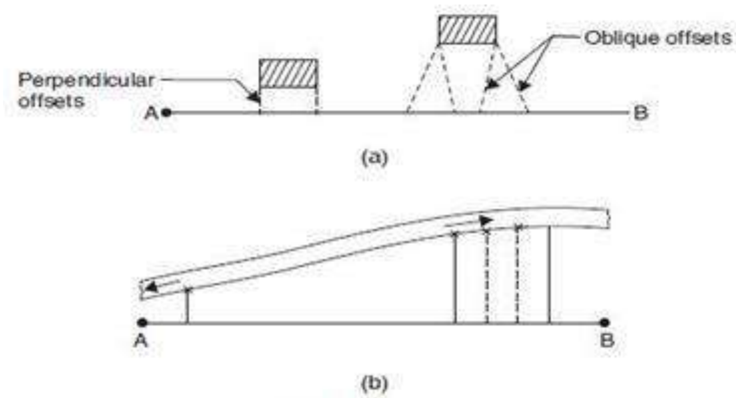
A well conditioned triangle will have its edges far enough and vertex will be clearly identified. Ill-conditioned triangle can have ambiguity in vertex position and so, it can lead to wrong measurements. Compare two triangles below:



Offsets

Offsets are the lateral measurements from the base line to fix the positions of the different objects of the work with respect to base line. These are generally set at right angle offsets. It can also be drawn with the help of a tape. There are two kinds of offsets:

1. Perpendicular offsets
2. Oblique offsets.



Perpendicular offsets and Oblique offsets.

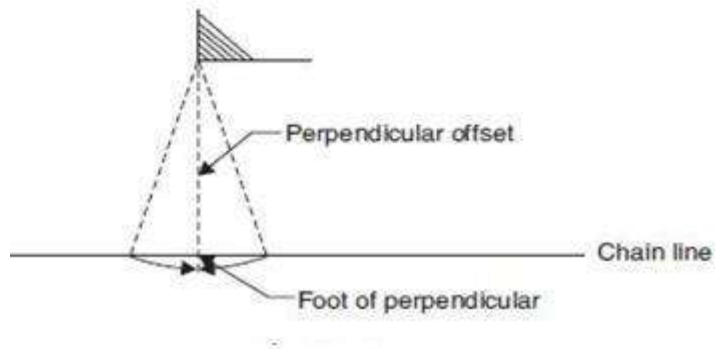
The measurements are taken at right angle to the survey line called perpendicular or right angled offsets. For setting perpendicular offsets any one of the following methods are used:

Swinging

Using cross staffs

Using optical or prism square

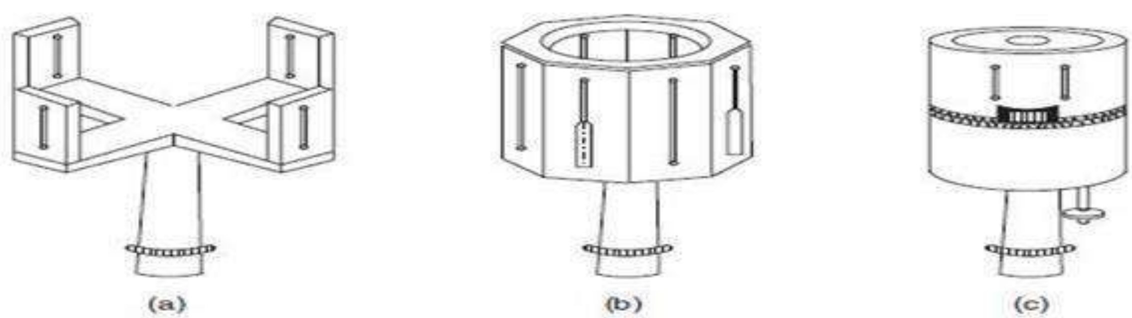
Perpendicular Offset by Swinging:



Perpendicular Offset by Swinging

Chain is stretched along the survey line. An assistant holds the end of tape on the object. Surveyor swings the tape on chain line and selects the point on chain where offset distance is the least and notes chain reading as well as offset reading in a field book on a neat sketch of the object.

Perpendicular Offsets Using Cross Staffs

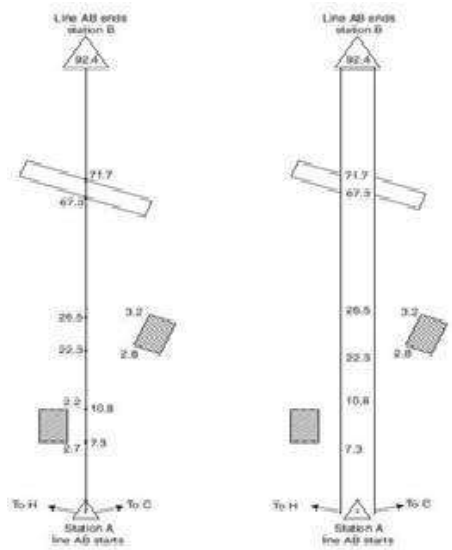


Cross staff

Figure shows three different types of cross staffs used for setting perpendicular offsets. All cross staffs are having two perpendicular lines of sights. The cross staffs are mounted on stand. First line of sight is set along the chain line and without disturbing setting right angle line of sight is checked to locate the object. With open cross staff it is possible to set perpendicular only, while with french cross staff even 45° angle can be set. Adjustable cross staff can be used to set any angle also, since there are graduations and upper drum can be rotated over lower drum.

FIELD BOOK

All observations and measurements taken during chain surveying are to be recorded in a standard field book. It is a oblong book of size 200 mm × 120 mm, which can be carried in the pocket. There are two forms of the book (i) single line and (ii) double line. The pages of a single book are having a red line along the length of the paper in the middle of the width. It indicates the chain line. All chain-ages are written across it. The space on either side of the line is used for sketching the object and for noting offset distances. In double line book there are two blue lines with a space of 15 to 20 mm is the middle of each book. The space between the two lines is utilized for noting the chain-ages. Figure shows typical pages of a field books.



Procedure in chain survey

Reconnaissance: The preliminary inspection of the area to be surveyed is called reconnaissance. The surveyor inspects the area to be surveyed, survey or prepares index sketch or key plan.

Marking Station: Surveyor fixes up the required no stations at places from where maximum possible stations are possible.

Some of the methods used for marking are:

Fixing ranging poles

Driving pegs

Marking a cross if ground is hard

Digging and fixing a stone.

Then he selects the way for passing the main line, which should be horizontal and clean as possible and should pass approximately through the center of work.

Then ranging roads are fixed on the stations.

After fixing the stations, chaining could be started.

Make ranging wherever necessary.

Measure the change and offset.

Enter in the field the book.

Chain surveying is the type of surveying in which only linear measurements are made in the field. The main principle of chain Surveying or chain triangulation is to provide a framework consist of number of well-conditioned triangles or nearly equilateral triangles. It is used to find the area of the field.

Selection of Survey Station

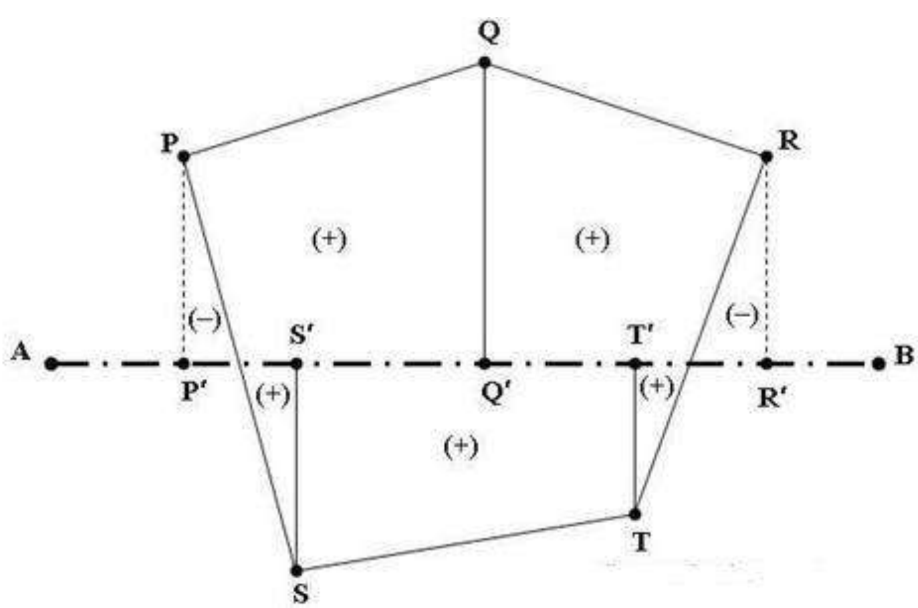
The following points should be kept in mind while selecting a station:

- The stations should be mutually intervisible
- Main principle of chain survey should strictly be observed
- If possible, line through the whole length of area should be drawn
- All triangles should be well defined
- A check line should be provided in each triangle
- Survey lines should be as few as possible
- A number of tie lines should be drawn
- Position of survey lines should be such that to avoid obstacles to chaining and ranging
- It should be on level ground
- The sides of triangle should pass as close to the boundary as possible.

Cross staff survey

Field work

1. First of all first ranging rod is established at point A and makes fixed station taking measurement revising point A to two permanent structures.
2. Second ranging rod is established at point B and for makes fixed station taking measurement revising point B to two permanent structures.
3. Established grid line A to B using ranging procedure by judgment of eye and laying chain on it.
4. Remaining ranging rod established at point P, Q, R, and S, T on right and left side of the grid line and its may be point of permanent structure at different location.
5. Sight point P perpendicular to grid line using cross staff, let's meeting point is P' on grid line.
6. Measure distance of AP' and PP' by chain (on grid line) and metallic tape (between P to P').
7. Write all observation in field book or level book immediately.
8. Repeat Sighting procedure using cross staff, let's meeting point is Q', R', S', and T' on grid line.
9. Measure distance of AQ', AR', AS' and AT' by chain (on grid line) and QQ', RR', SS', TT' using Metallic tape respectively.
10. Write all observation in field book or level book respectively.
11. When complete all observation removes all ranging rods and packed in its cover.



OBSTACLES IN CHAIN SURVEYING

There are 3 types of obstacles

1. Obstacle to ranging
2. Obstacle to chaining

1) Obstacle to Ranging: The type of obstacle in which the ends are not inter visible is quite common except in flat country. These may be two cases.

i) Both end of the line may be visible form intermediate points on the line

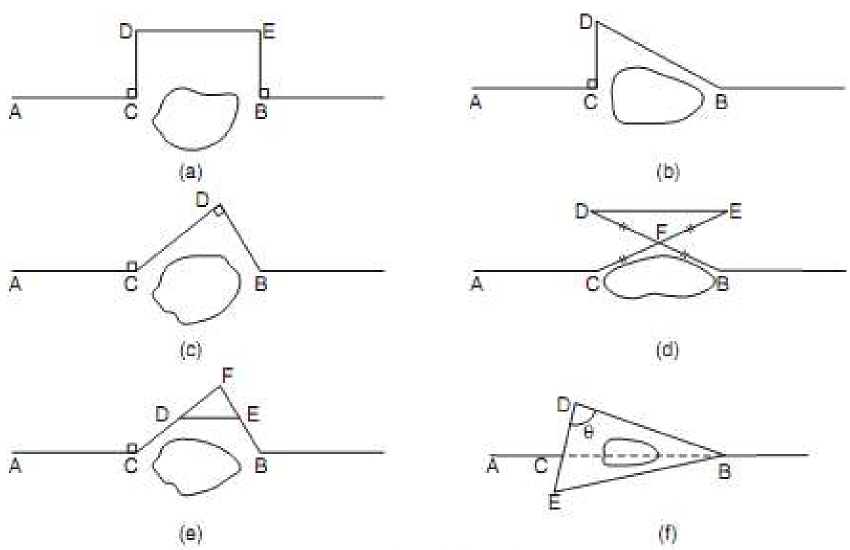
ii) Both ends of the line may not be visible from intermediate points on the line

2) Obstacle to chaining but not ranging

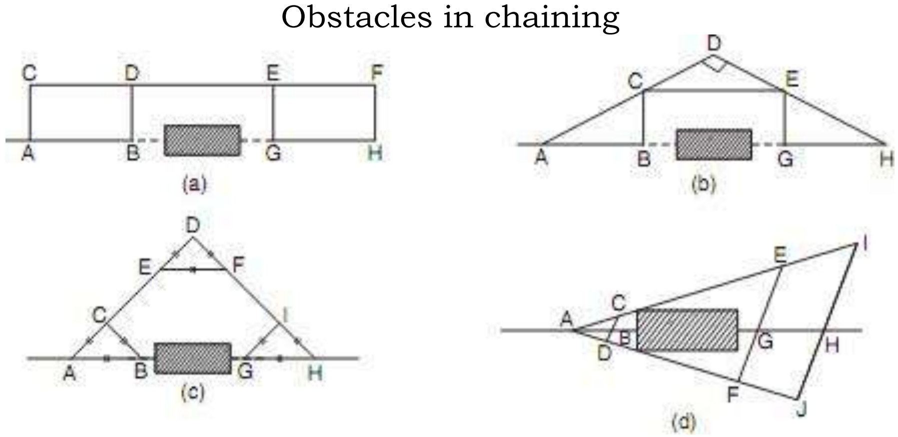
There may be two cases of this obstacle

i) When it is possible to chain round the obstacle ex: a pond

ii) When it is not possible to chain round the obstacle ex: a river



Obstacles in chaining



Obstacles in both chaining and ranging

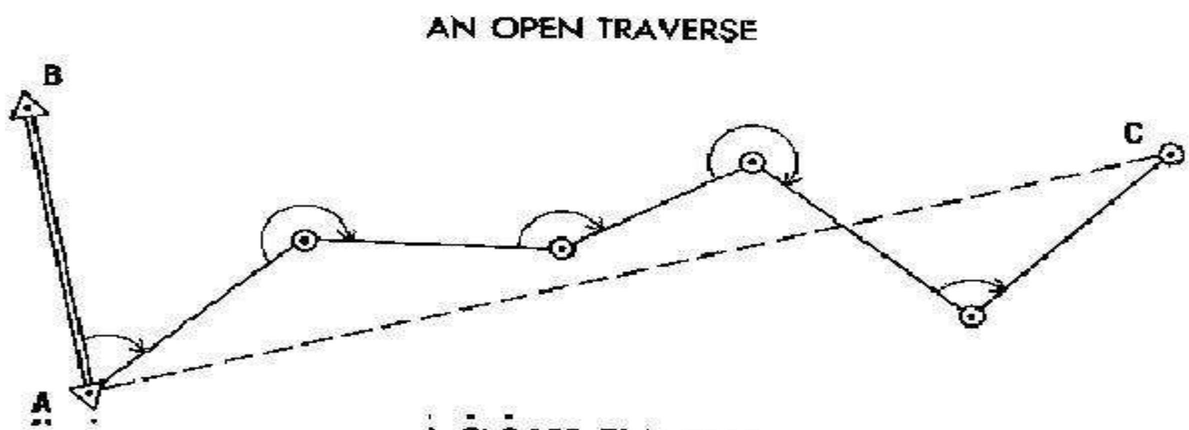
Chain traversing:

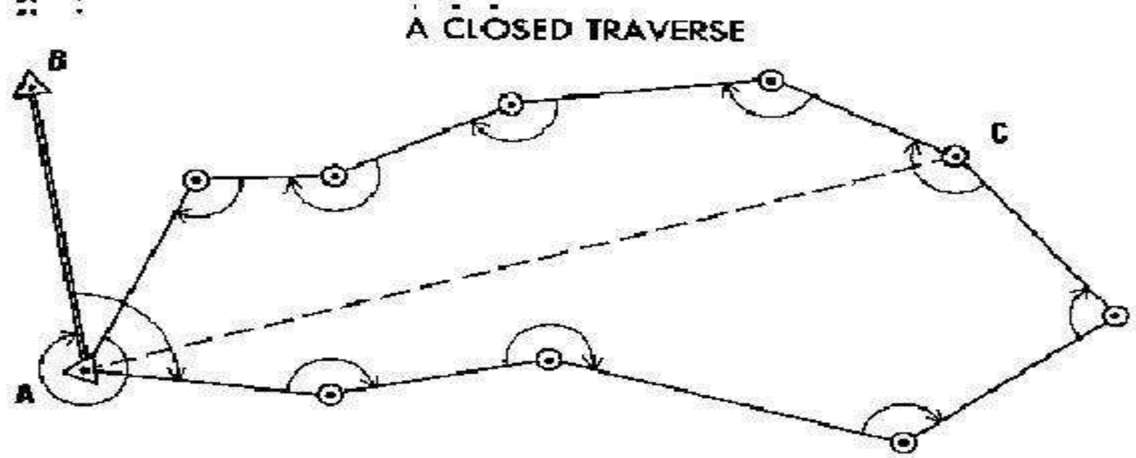
A traverse is a number of straight lines of known lengths and making known angles with each other, along or through the area to be surveyed. The traverse survey differs from the chain surveying in that the arrangement of the survey lines is not limited to any particular figure as in

Chain survey, where a system of connected triangles from the fundamental basis of skeletons

The details of the surroundings are located either by offsetting (as in chain surveying) of by other methods. There are two types of traverse

- Open traverse
- Closed traverse





SURVEYING

UNIT –II

COMPASS SURVEYING

Objective:

To know about the working of compass and its utilization in field

Syllabus:

Introduction, types of compass: prismatic & surveyor compass, included angles, types of bearings, types of meridians, compass traverse, magnetic declination, local attraction and corrections.

Learning Outcomes:

Student will be able to

- Learn about types of compass and working of compass
- Work out the bearings and included angles
- Apply the corrections in bearings if local attraction is present at the stations

Learning Material

Compass Surveying is a branch of surveying in which directions of survey lines are determined with a compass and the lengths of the lines are measured with a tape or a chain.

Units of angular measurements:

a) Sexagesimal systems: 1 Circumference = 360^0
1 Degree = 60’
1 Minute = 60"

b) Centesimal systems 1 Circumference = 400^g (grad)
1 Grad = 100^c (centigrads)
1 Centrigrad = 100^{cc} (centicentigrads)

c) Hours systems 1 Circumference = 24h
1 Hour = 60min
1 minute = 60sec

Types of Compass:

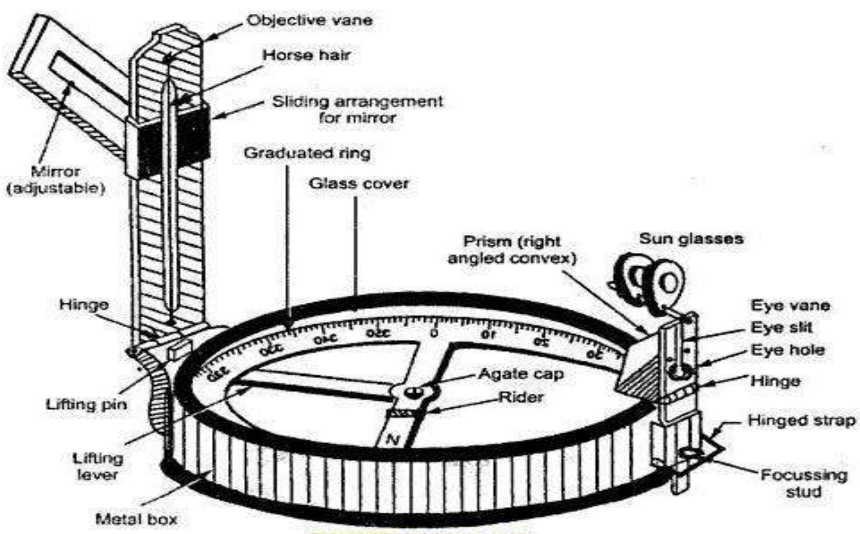
1 Prismatic Compass

2 Surveyor's Compass

Prismatic Compass

This is an instrument used for the measurement of magnetic bearings. It is small and portable usually carried on the hand. This Prismatic Compass is one of the two main kinds of magnetic compasses included in the collection for the purpose of measuring magnetic bearings, with the other being the Surveyor's Compass. The main difference between the two instruments is that the surveyor's compass is usually larger and more accurate instrument, and is generally used on a stand or tripod.

Components of a prismatic compass



Prismatic compass parts

Elements of prismatic compass:

Cylindrical metal box: Cylindrical metal box is having diameter of 8to 12 cm. It protects the compass and forms entire casing or body of the compass. It protect compass from dust, rain etc.

Pivot: pivot is provided at the center of the compass and supports freely suspended magnetic needle over it.

lifting pin and lifting lever: a lifting pin is provided just below the sight vane. When the sight vane is folded, it presses the lifting pin. The lifting pin with the help of lifting lever then lifts the magnetic needle out of pivot point to prevent damage to the pivot head.

Magnetic needle: Magnetic needle is the heart of the instrument. This needle measures angle of a line from magnetic meridian as the needle always remains pointed towards north South Pole at two ends of the needle when freely suspended on any support.

Graduated circle or ring: This is an aluminium graduated ring marked with 0o to 360o to measures all possible bearings of lines, and attached with the magnetic needle. The ring is graduated to half a degree.

Prism: prism is used to read graduations on ring and to take exact reading by compass. It is placed exactly opposite to object vane. The prism hole is protected by prism cap to protect it from dust and moisture.

Object vane: object vane is diametrically opposite to the prism and eye vane. The object vane is carrying a horse hair or black thin wire to sight object in line with eye sight.

Eye vane: Eye vane is a fine slit provided with the eye hole at bottom to bisect the object from slit.

Glass cover: its covers the instrument box from the top such that needle and graduated ring is seen from the top.

Sun glasses: These are used when some luminous objects are to be bisected.

Reflecting mirror: It is used to get image of an object located above or below the instrument level while bisection. It is placed on the object vane.

Spring brake or brake pin: to damp the oscillation of the needle before taking a reading and to bring it to rest quickly, the light spring brake attached to the box is brought in contact with the edge of the ring by gently pressing inward the brake pin.

Temporary adjustment of prismatic compass:

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

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

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

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

Operation procedure:

Remove the corner and open out the prism and window, holding the compass as level as possible.

Then focus the prism by raising or lowering its case until the divisions appear sharp and clear. Hold the compass box with the thumb under the prism and the forefinger near the stud, and sight the object or station lowering the eye to read the required bearing as soon as the needle comes to rest naturally.

The bearing read will be a forward bearing and normally a "whole circle" bearing clockwise angle between 0^o to 360^o.

Difference between Prismatic Compass and Surveyors Compass:

Item	Prismatic Compass	Surveyor's Compass
Magnetic Needle	The needle is of broad needle type. The needle doesnot act as index	The needle is of edge bar type. The needle acts as the index also
Graduated Ring	The graduated ring is attached with the needle. The graduations are in WCB system	The graduated ring is attached to the box. The graduations are in QB system
Sighting Vanes	The object vane consists of metal vane with a vertical hair. The eye vane consists of a small metal vane with slit	The object vane consists of a metal vane with a vertical hair. The eye vane consists of a metal vane with a fine slit.
Reading	The reading is taken with the help of a prism provided at the eye slit.	The reading is taken by directly seeing through the top of glass.

Tripod	Tripod may or may not be provided	The instrument cannot be used without a tripod.

MERIDIAN

The reference line with respect to which horizontal angle of survey line are measured is known as meridian. There are different types of meridians based on the type of reference.

True Meridian: The true meridian passing through a station on surface of the earth is the (imaginary) line of intersection of a (imaginary) plane passing through the geographical North and South poles of the earth with its actual surface. The direction of true meridian at any station is constant and hence, direction of a line with reference to this remains same over time. At any station, it can be determined through Astronomical survey. For any engineering works of importance, the direction of at least one line is determined with true meridian as reference.

Magnetic Meridian: The magnetic meridian at a station on surface of the earth is the (imaginary) line of intersection of a (imaginary) plane passing through the magnetic North and South poles of the earth with its actual surface. The direction of a freely suspended well balanced magnetic needle provides the magnetic meridian at a station. As the magnetic poles of the earth changes with time and so the magnetic meridian at any station. Thus, the direction of a line with reference to magnetic meridian varies with time. Magnetic meridian is employed as a line of reference for rough surveys.

Grid Meridian: To eliminate the effect of **convergence of meridian** (Meridians on the surface of the earth converge towards each other as the distance from the equator towards either of the poles increases.), a meridian through a station is adopted as a reference meridian and all other meridians are considered parallel to the reference meridian. Together, all of these are known as grid meridians and the reference meridian is known as central meridian.

Arbitrary Meridian: Any convenient direction from a survey station to some well defined permanent object is known as arbitrary meridian. This is used for small area survey or to determine the relative directions of small traverse.

BEARING:

The horizontal angle measured in clockwise or anticlockwise direction between the meridian and the survey line is termed as bearing. Different types of bearings are defined based on different criteria.

Based on meridian

***Azimuth**:* The azimuth or true bearing of a line is its horizontal angle from the North direction of the true meridian measured clockwise.

***Magnetic Bearing**:* The horizontal angle which a line makes with the magnetic meridian measured from Magnetic North line is called magnetic bearing. It varies with time. Magnetic meridian of a line can be measured in the field by using prismatic compass

***Grid Bearing**:* The horizontal angle between a line and a grid meridian is called grid bearing.

***Arbitrary Bearing**:* The horizontal angle of a line measured with respect to an arbitrary meridian is called arbitrary bearing.

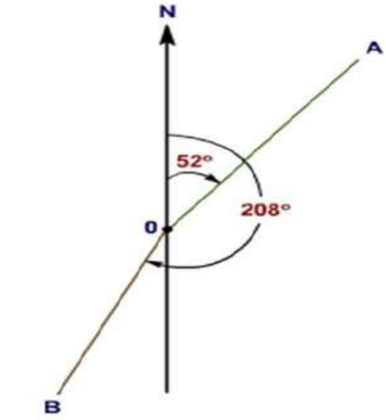
Based on direction

Fore Bearing: The bearing of a line measured in the forward direction (i.e., along the progress of survey) is known as fore bearing.

Back Bearing: The bearing of a line measured in the backward direction (i.e., opposite to the direction of progress of survey) is known as back bearing.

Based on designation

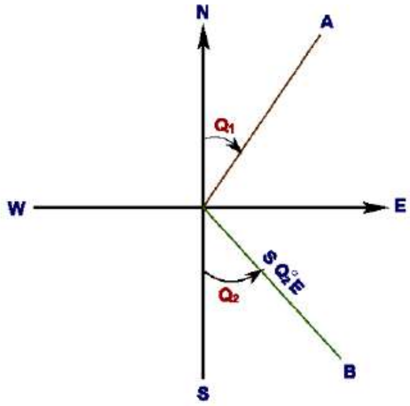
Whole circle bearing: The whole circle bearing (W.C.B) of a line is the horizontal angle measured clockwise from the North limb of the meridian. It varies from 0° to 360°.



Whole circle bearing of a line

***Quadrantal bearing (or Reduced bearing)*:** The quadrantal bearing (Q.B.) also known as reduced bearing (RB) of a line is defined by the acute angle which the line makes with the meridian. Thus, it depends on the quadrant in which the line presents. It is measured in clockwise or anti-clockwise direction either from the North or from the South limb of the meridian whichever is nearer and thus provides minimum angle. Figure represents different types of quadrantal bearings of lines. The bearings of OP, OQ, OR and OS are respectively, N 40°E, S49° E, S72° W, and N31° W. In all cases, values of bearing of angles lie between 0° and 90°.

Thus, reduced bearing of a line is designated by the direction from which it is measured (i.e., either N for North or S for South) followed by the value of the angle at the end, the direction to which it is measured (i.e., either E for East or W for West).



Quadarantal bearings of lines

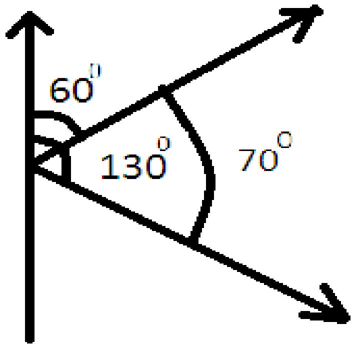
Included angles

An angle is the difference in the values of two directions observed from the same point.

The angle between the two lines can be determined if their directions or bearings are given.

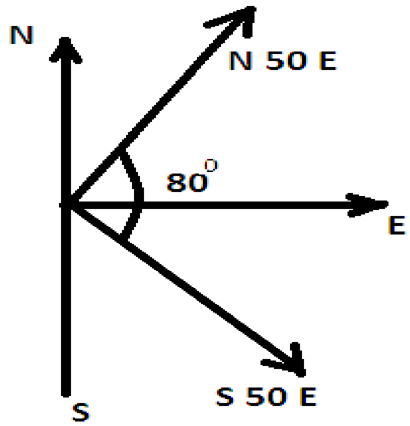
For Whole circle bearings

Included angle, $\alpha=\theta_2-\theta_1$



Included Angle using WCB

For Reduced bearings



Included angle using RB

Problem: The following bearings were observed for a closed traverse ABCDEA

Line AB $140^0 30'$

Line BC $80^0 30'$

Line CD $340^0 0'$

Line DE $290^0 30'$

Line EA $230^0 30'$

Solution:

Angle A= Bearing of AB – Bearing of AE

For bearing of AE, determined from given bearing of EA

Such that Bearing of AE= $230^0 30' - 180^0 = 50^0 30'$

Therefore Angle A= $140^0 30' - 50^0 30' = 90^0$

Likewise Angle B = Bearing of BA – Bearing of BC

$= (140^0 30' + 180^0) - 80^0 30' = 240^0$

The angle obtained is exterior so for calculating interior angle Angle B=$360^0 - 240^0 = 120^0$

Likewise the remaining angles are determined

Check: The theoretical sum of the included angle of a closed traverse should be (2N-4) right angles; N is the number of sides.

So therefore **sum of all the angles determined should be equal to (2N-4)90**

Compass Traverse

In compass traverse, a magnetic compass is used to determine the angles of the traverse. The sides of the traverse are measured with a chain or a tape. The field work consists of reconnaissance, marking and referencing stations, running survey lines, taking offsets to the detail, as in chain surveying. In compass surveying, the bearings of all lines are also measured with a magnetic compass.

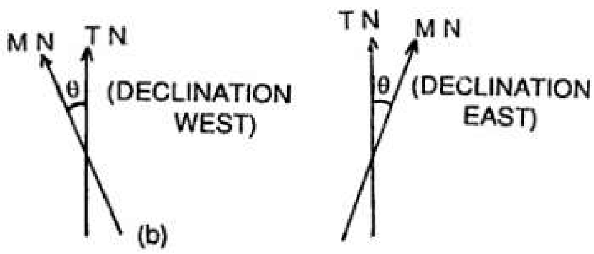
While traverse the following points are to done:

- Selection of traverse stations
- Running a compass traverse
- Problems in compass traverse
- Field book and Record

Magnetic Declination

The horizontal angle between the magnetic meridian and the true meridian is known as magnetic declination.

When a north end of the magnetic needle is pointed towards the west side of the true meridian the position is termed "Declination West"



When the north end of the magnetic needle is pointed towards the east side of the true meridian the position is termed as “Declination East”

Isogonic Line: Lines pass through the equal declination known as isogonic lines.

Agonic Line: Lines pass through the zero declination known as agonic line.

Variation of Magnetic Declination

1. Secular Variation: After every 100 years or so magnetic meridian swings from one direction to the opposite direction and hence declination varies.
2. Annual Variation: Magnetic declination varies due to the rotation of the earth. The amount of variation is about 1 to 2 minutes
3. Diurnal Variation: Magnetic declination varies due to rotation of its earth on its own axis the amount of variation 3 to 12 minutes.
4. Irregular Variation: Variation due to some natural causes such as earth quake, volcanic eruptions and so on. The variation is known as “Irregular Variation”.

Local Attraction:

Local attraction is the attraction of the magnetic field other than earth’s magnetic field. The local magnetic field is caused by iron pipes, steel bars, vehicles, steel doors and windows, iron deposits, etc.

Freely suspended magnetic needle takes the direction of the earth’s magnetic field only if there is no local attraction. The magnetic needle will deviate from the magnetic meridian under local magnetic forces. Consequently the magnetic bearings of lines would be in error. The surveyor may not know whether there is local attraction or not. To detect, it is essential to take both the fore bearing and back bearing of a line. The two bearings should be differed by 180^0, provided there are no instrumental errors. If it differs then local attraction is suspected at one station or both the stations. To discover whether it is at one end or both ends the following procedure is used.

Let us consider the line AB whose fore bearing and back bearing do not differ by 180^0. To discover whether local attraction exists at A or B, consider a third point C. Take the bearing of the line AC from A. Also take the bearing of line BC from B. Shift the compass to station C, and take back bearings of AC and BC. If the FB and BB of one line (say AC) differ exactly

180^0, there is no local attraction at either A or C. In that case the local attraction is suspected at B.

Correction for local attraction:

If there is local attraction at a station all the bearings measured at the station will be affected by equal amount, assuming that the local magnetic field does not change during the period the bearings are taken. The measuring bearing of the traverse lines can be corrected for local attraction using either of the following methods

Method: 1

In this method, the correction at each station is found. From the fore bearing and the back bearing of different lines, find the lines whose FB and BB exactly differ by 180^0. There is no local attraction at both the end stations of the line. Such that all the bearings taken at these stations will be free from local attraction.

Method: 2

In this method, the included angles are used for determining the correct bearings. At the affected station, local attraction draws the needle a certain amount away from the magnetic meridian. As all the bearings taken at that station will be the same affected equally, the included angles will not be affected at those stations.

Problem: In the following table observed Bearings are given, we will compute the corrected bearings and Internal Angles.

Line	Observed		Correction	Corrected	
	F.B	B.B		F.B	B.B
AB	70° 00′	251° 00′	A= +30′ , B= -30′	70° 30′	250° 30′
BC	328° 00′	145° 00′	-	327° 30′	147° 00′
CD	225° 00′	71° 00′	-	257° 30′	77° 30′
DA	139° 00′	316° 00′	-	136° 30′	316° 30′

By observing the table, it may be noted that no line has a difference of exactly 180° between Fore Bearing and Back Bearing. In such a case, a line where the difference is closest to 180° is selected. Such a line is called line of least disagreement, for this line correction is assign to each of the two stations of that line with opposite sign. In the above table line AB is selected for error distribution. Now, we will compute internal angles from these corrected Bearings.

A = (360° - 316° 30′) + 70° 30′ = 114° 00′

B = 327° 30′ - 250° 30′ = 77° 00′

C = 257° 30′ - 147° 30′ = 110° 00′

D = 136° 30′ - 77° 30′ = 59° 00′

Before computation of internal angles you need to draw a rough sketch of scheme based on corrected bearings so that you can judge which angle is lying in which quadrant.

Errors in compass surveying

1. **Instrumental Errors:** due to defects in compass
    - The needle is sluggish or lost its magnetism
    - The needle is not perfectly straight.
    - The pivot is not at the centre of graduated circle.
    - The needle does not remain horizontal due to dip.
    - The plane of sight is not vertical.
2. **Manipulating and Sighting Errors:** due to the manual mistakes and sighting problems.
    - The compass is not properly centred over the station.
    - The compass is not levelled properly.
    - The ranging rod at the station not exactly bisected.
    - Due to observation of bearings on graduated ring in wrong direction.
    - The observation of bearing is not properly recorded.
3. **Error due to external influences:**
    - Magnetic changes in the atmosphere on a cloudy or stormy day
    - Magnetic storms due to the earthquakes, sunspots, lunar perturbations, etc
    - Variation in magnetic declination
    - Local Attraction

SURVEYING

UNIT – III

LEVELLING

Objective:

To introduce students about basic principles of leveling

Syllabus:

Levelling principles, basic definitions, Parts of dumpy level, types of eye pieces, types of staves, temporary adjustments, methods of levelling, theory of differential levelling, profile levelling, reciprocal levelling, levelling problems, contouring, contour interval, characteristics of contours, direct and indirect methods of contouring, uses of contour maps.

Learning Outcomes:

Student will be able to

- Explain about types of levels that are used for determine the elevations.
- Differentiate various types of levelling and its usage.
- Calculate the reduced levels by using H.I and Rise and Fall method.

Learning Material

Definition, Principle, & Object of Levelling

Definition:-Levelling is defined as "an art of determining the relative height of different points on, above or below the surface".

Principle of levelling

The principle of levelling is to obtain horizontal line of sight with respect to which vertical distances of the points above or below this line of sight are found.

The objective of levelling is to

1) Find the elevation of given point with respect to some assumed reference line called datum.

2) To establish point at required elevation with respect to datum.

3) To set alignment of roads, railways, canal or sewage lines.

4) For layout of construction projects

5) To determine various levels of dams, towers etc,

Definitions/ Terms used in levelling

Level surface:-It is the surface parallel to the mean spheroidal surface of the earth

Level line:-Line lying on level surface.

Horizontal plane:-Horizontal plane through a point is a plane tangential to level surface.

Horizontal line:-It is a straight line tangential to level line.

Datum:-“It is an arbitrary level surface from which elevation of points may be referred”. In India mean sea level is considered as datum of zero elevation it is situated at Karachi.

Mean sea level is the average height of sea for all stages of tides it is derived by averaging the hourly tide height over a period of 19 years.

Elevation or Reduced level:-It is height or depth of any point above or below any datum. It is denoted as R.L.

***Bench Mark* (B.M.)**:-It is a fixed reference point of known elevation with respect to datum.

Line of collimation:-It is a line joining the intersection of cross hairs of diaphragm to the optical centre of object glass and its continuation. It is also known as line of sight.

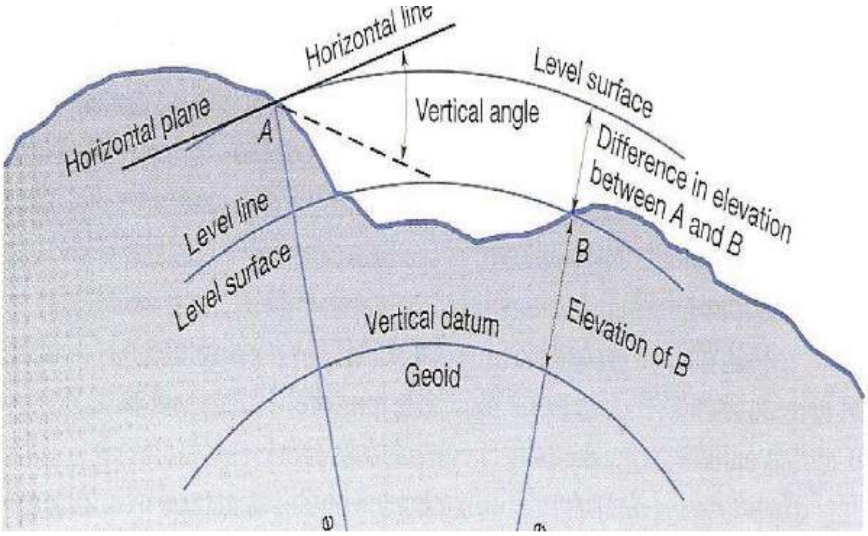
Height of instrument:-It is the elevation of line of collimation with respect to datum.

Back sight:-It is a staff reading taken at a known elevation. It is the first staff reading taken after setup of instrument.

Fore sight (F.S.):-It is the last staff reading taken denoting the shifting of the instrument.

Intermediate sight (I.S.):-It is staff reading taken on a point whose elevation is to be determined. All staff reading between B.S. and F.S. is Intermediate sight.

Change Point:-It is a point on which both fore and back sight is taken.



Instruments for levelling

The following instruments are essentially required for levelling

- Level
- Leveling staff
- Tripod

Level and types of level

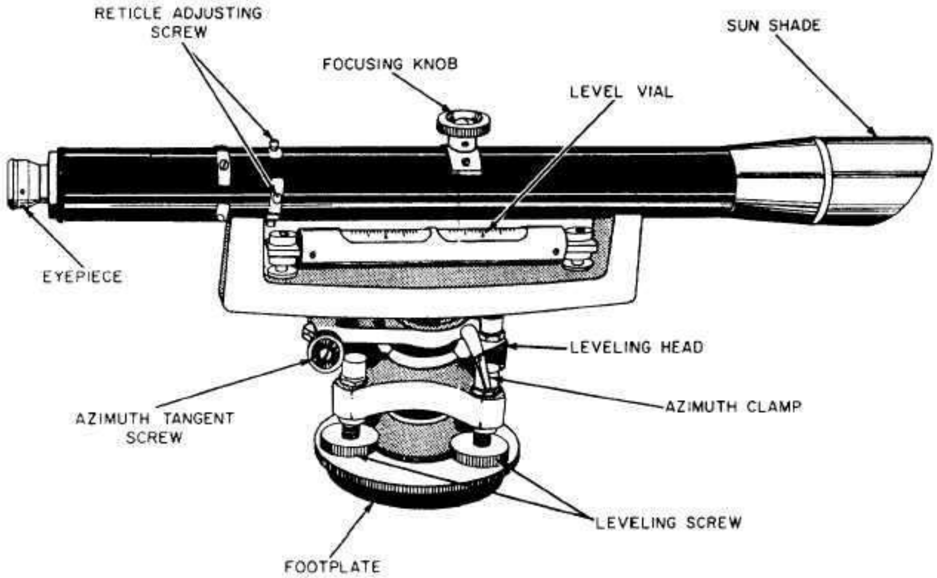
Level:-The instrument used to furnish horizontal line of sight for observing staff readings and determining R.L's.

Types

- Dumpy level
- Tilting level
- Wye level
- Automatic level

Dumpy level

The Dumpy level is a simple, compact and stable instrument. The telescope is rigidly fixed to its supports. Hence it cannot be rotated about horizontal axis.



Dumpy level has an eyepiece, spirit level and three leveling Screws as well as a focus for the telescope lens – quite often the base has a 360 degree compass. This instrument is used while surveying. Using spirit-level-bottle telescope is adjusted to plane level. In this condition all spots look at equal height.

Levelling Staffs

Levelling staffs are scales on which these distances are measured. Levelling staffs are of two types

- Self reading staff
- Target staff

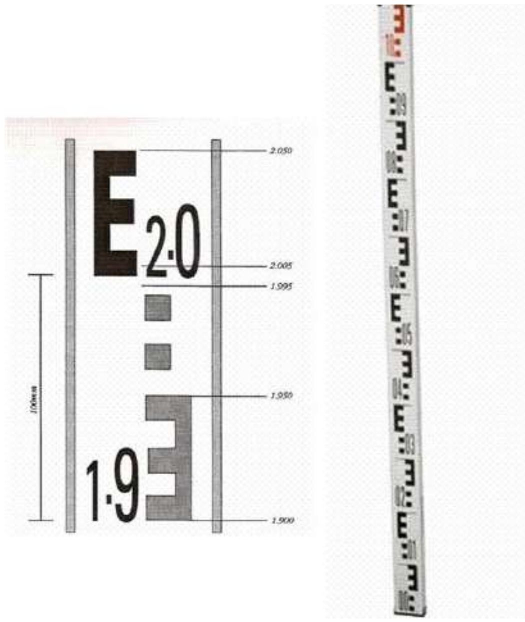
Self reading staff

The self reading staff can be read directly by the level man looking through the telescope.

Common types of self reading staffs are

- Ordinary staff
- Sop with telescopic staff
- Folding Staff

For very precise works and sight target staff is used. A movable target is provided in this staff. A vernier is provided on target to give precise reading. In target staff level man directs the staff man to move the target up and down until it bisects by the line of sight. The staff man observe the staff reading



Levelling Staff reading

Setting up the level:-This includes

- Fixing the instrument on tripod.
- 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

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

❖ 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.

❖ Turn the telescope through 90^0 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 hair is 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.

Bench Marks

Bench mark is a point of known elevation

There are 4 kinds of bench marks

- GTS (Great trigonometrically survey bench mark)
- Permanent bench mark
- Arbitrary bench mark
- Temporary bench mark

GTS Bench mark

They are the bench marks established with very high degree of precision at regular intervals by the survey of India Department all over the country.

Permanent Bench mark

Permanent bench marks are fixed in between GTS benchmarks by govt. agencies such as railways, PWD, etc. These benchmarks are written on permanent objects such as milestones, culverts, bridges etc their value is clearly written and their position is recorded for future reference.

Arbitrary bench marks:-These are reference points whose R.L's are arbitrarily assumed. They are used in small works such bench mark may be assumed as 100 or 50 m.

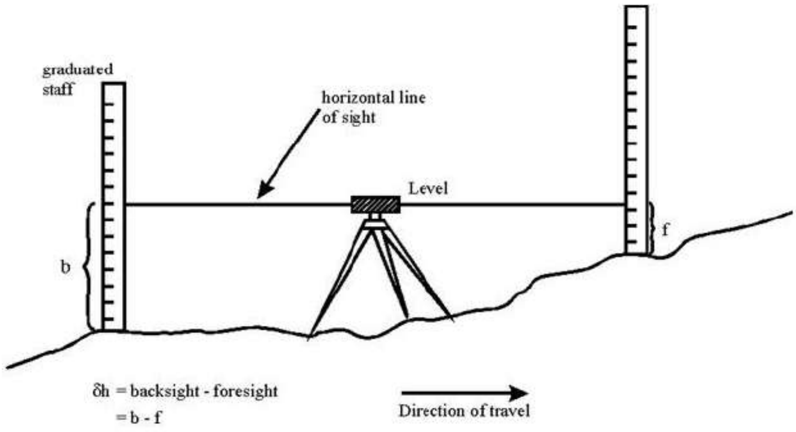
Temporary bench marks:-They are the reference points established during the levelling operations when there is a break in work, or at the end of day's work the value of reduced levels are marked on some permanent objects such as stones, trees etc.

Classification of levelling

- Simple levelling
- Differential leveling
- Fly levelling
- Check levelling
- Profile levelling
- Cross levelling
- Reciprocal levelling
- Precise levelling

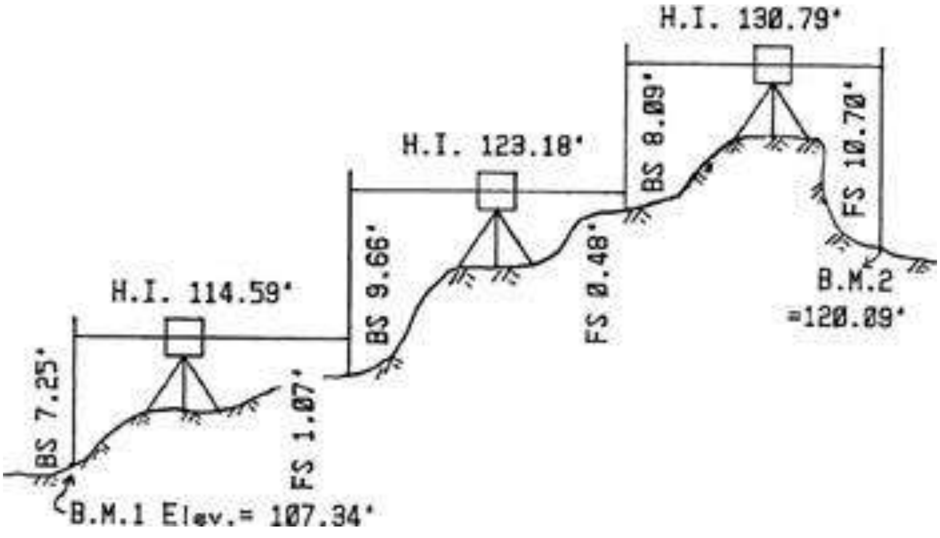
- Trignometric levelling
- Barometric levelling
- Hypersometric levelling

Simple levelling:-It is the simplest method used, when it is required to find the difference in elevation between 2 points.



Simple Levelling

Differential Levelling:-This method is used to find the difference in the elevation between points if they are too far apart or the difference in elevation between them is too much.



Differential Levelling

Fly levelling:-Fly levelling is just like differential levelling carried out to check the accuracy of levelling work. In fly levelling only B.S. and F.S. are taken

Check levelling:-This kind of levelling is carried out to check the accuracy of work. It is done at the end of the days work in the form of fly levelling to connect the finishing point and starting point.

Profile levelling or L-Section:-This method is used for taking levels along the centre line of any alignment like road, railway canal etc. The object is to determine the undulations of the ground surface along the alignment

Cross-sectioning:-This operation is carried out perpendicular to alignment at an interval of 10, 20, 30, 40 m. The idea is to make an estimate of earthwork.

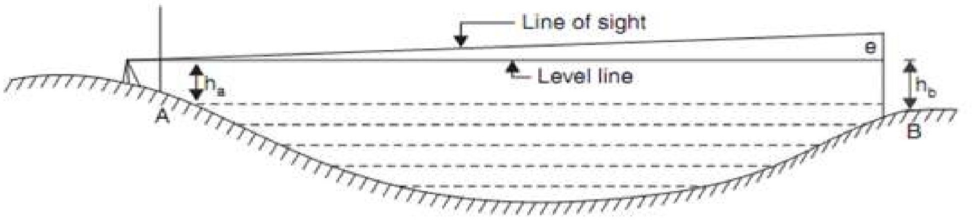
Precise levelling:-It is used for establishing bench marks for future public use. It is carried out with high degree of accuracy using advanced instruments

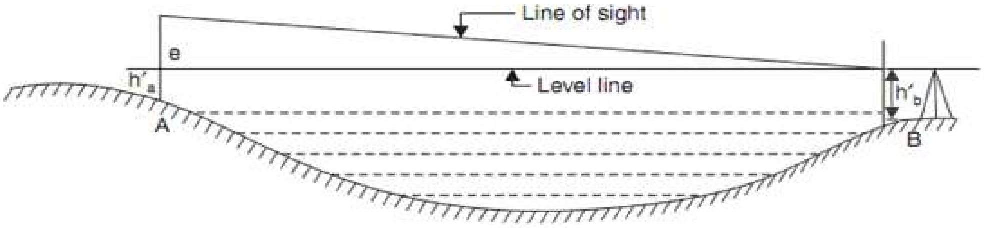
Trignometric levelling:-In this method vertical distances between points are computed by observing horizontal distances and vertical angle between points.

Barometric levelling:-In this method the altitude difference is determined by means of a barometer.

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 midway 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.
- Setup the level near to A and take the reading at A and B. let the reading be a1 and b1
- Shift the level and setup 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 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 $b_e = (b_1 - e) - a_1$
- From B the difference will $b_e = b_2 - (a_2 - e)$
- Therefore $d = \{(b_1 - a_1) + (b_2 - a_2)\}/2$

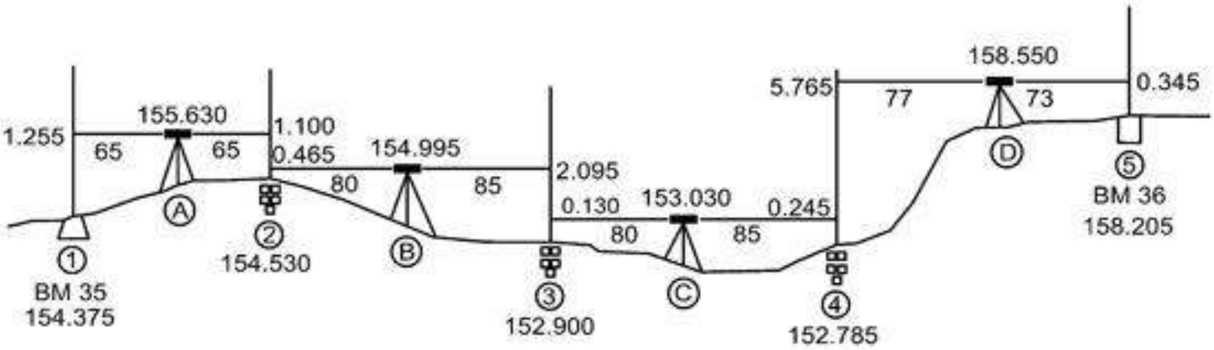




Reciprocal Levelling

- 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 = $(b_1'-e)-a_1$
- From B the difference will be= $b_2-(a_2'-e)$
- Therefore $d=\{(b_1-a_1)+(b_2-a_2)\}/2$

METHODS OF REDUCING LEVELS



Typical figure showing the differential levelling

- **Height of Instrument Method**:-This method consist of finding H.I. for every setup of instrument, and then obtaining the R.L. of point of reference with respect to H.I

Station	BS	IS	FS	HI	RL	Remarks

- **Rise and fall method**: This method consists of determining the difference of level between consecutive points by comparing each point with immediate preceding point

Station	BS	IS	FS	Rise	Fall	RL	Remarks

Example: The following staff readings were observed successively with a level the instrument is moved by third sixth and eighth readings. 2.228: 1.606: 0.988: 2.090: 2.864: 1.262: 0.602: 1.982: 1.044: 2.684 m enter the reading in record book and calculate R.L. if the first reading was taken at a B.M of 432.383m

Station	BS	IS	FS	HI	RL	Remarks
1	2.228			434.612	432.383	BM
2		1.606			433.006	
3	2.090		0.988	435.714	433.624	3rd C.P
4		2.864			432.850	
5	0.602		1.262	435.054	434.452	6th C.P
6	1.044		1.982	434.116	433.072	8th C.P
7			2.684		431.432	
Total	5.964		6.916			

Check: $\sum \boldsymbol{B.S} - \sum \boldsymbol{F.S} = 5.964 - 6.916 = -0.952$; $\boldsymbol{Last\ R.L} - \boldsymbol{First\ R.L} = -0.952$

Station	BS	IS	FS	Rise	Fall	RL	Remarks
1	2.228					432.383	BM
2		1.606		0.622		433.006	
3	2.090		0.988	0.618		433.624	3rd C.P
4		2.864			0.774	432.850	
5	0.602		1.262	1.602		434.452	6th C.P
6	1.044		1.982		1.38	433.072	8th C.P
7			2.684		1.64	431.432	
Total	5.964		6.916	2.842	3.794		

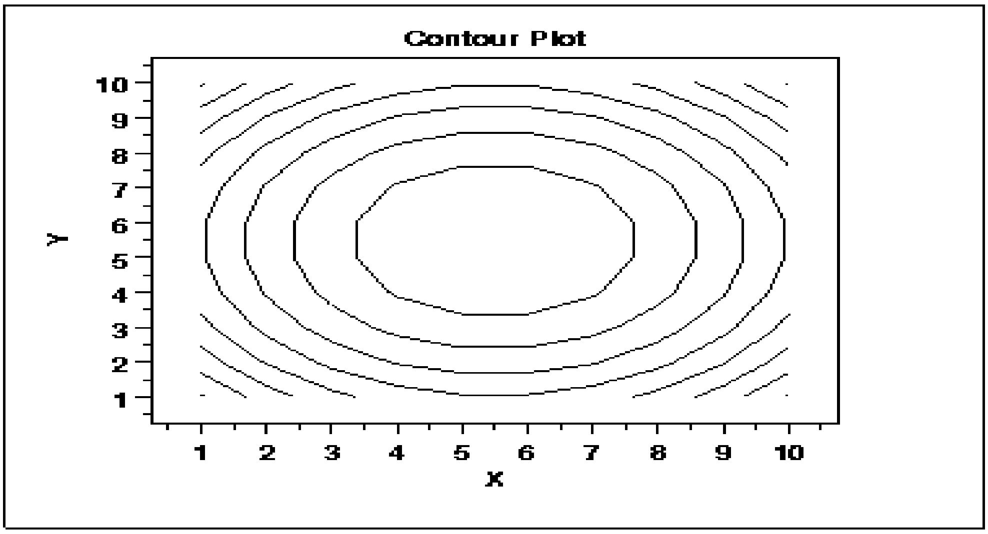
Check: $\sum \boldsymbol{B.S} - \sum \boldsymbol{F.S} = 5.964 - 6.916 = -0.952$;

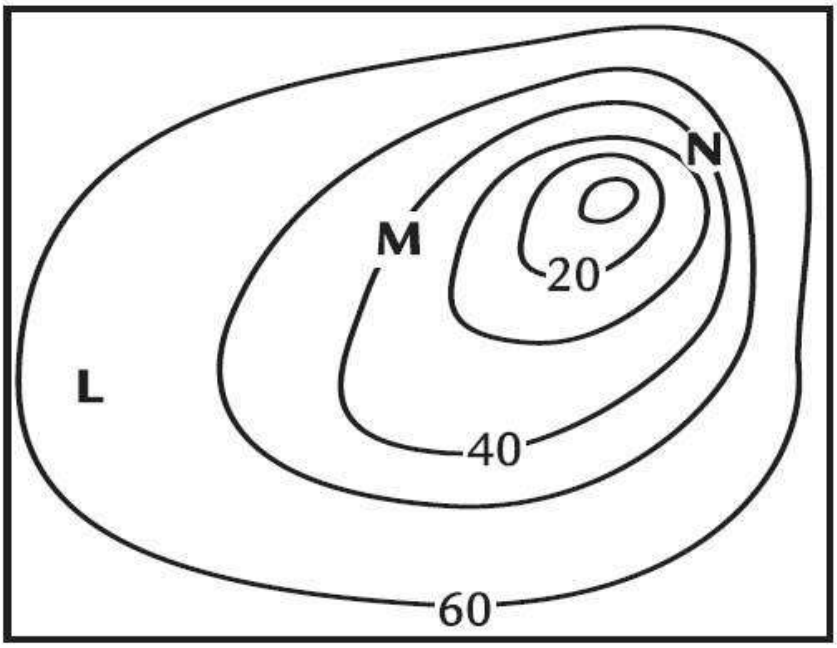
$\boldsymbol{Last\ R.L} - \boldsymbol{First\ R.L} = 431.432 - 432.383 = -0.952$

$$\sum \boldsymbol{B.S} - \sum \boldsymbol{F.S} = 2.842 - 3.794 = -0.952;$$

CONTOUR: A contour is an imaginary line joining points of equal elevation

CONTOUR INTERVAL: The vertical distance between any two consecutive contours is known as contour interval





Characteristics of contour lines

- A series of contour lines with higher value inside indicate a hill
- A series of contour lines with lower value inside the loop always indicate depression
- Close contour lines indicate steep slope
- Wide contour lines indicate flatter slope
- Contour lines never cross each other except in case of overhanging cliff.
- All points on contour lines have equal elevation

Uses of Contours

- The nature of ground surface of a region can be known
- Contour map helps in locating proper site for bridges, dams, reservoirs etc.
- Capacity of a reservoir can be calculated with the help of contour map
- The quantity of cutting and filling can be determined from contour maps.
- Routes for roads, railways, canals etc can be traced.

METHODS OF LOCATING CONTOURES

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

However, broadly speaking there are two methods of contour surveying:

1. Direct methods
2. Indirect methods.

1. Direct Methods

It consists in finding vertical and horizontal controls of the points which lie on the selected contour line.

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

2. Indirect Methods

In this method, levels are taken at some selected points and their levels are reduced. Thus in this method horizontal control is established first and then the levels of those points found. After locating the points on the plan, reduced levels are marked and contour lines are interpolated between the selected points.

For selecting points anyone of the following methods may be used:

(a) Method of squares,

(b) Method of cross-section

(c) Radial line method.

Method of Squares: In this method area is divided into a number of squares and all grid points are marked (Ref. Fig. 1).

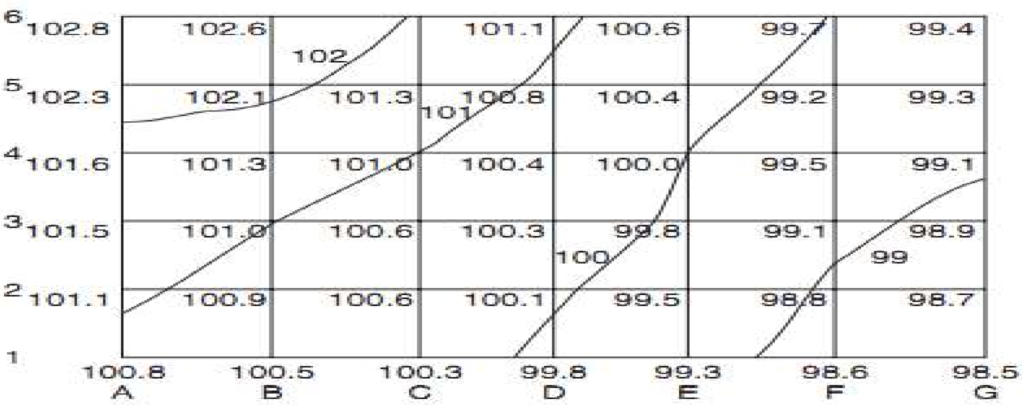


Fig. 1

Commonly used size of square varies from 5 m × 5 m to 20 m × 20 m. Levels of all grid points are established by levelling. Then grid square is plotted on the drawing sheet. Reduced levels of grid points marked and contour lines are drawn by interpolion [Ref. Fig. 1].

Method of Cross-section: In this method cross-sectional points are taken at regular interval. By levelling the reduced level of all those points are established. The points are marked on the drawing sheets, their reduced levels (RL) are marked and contour lines interpolated.

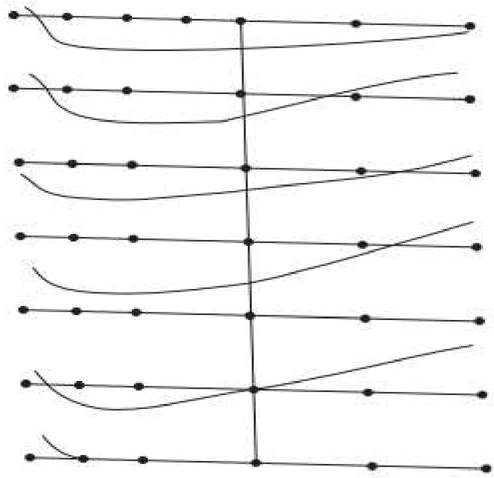


Fig. 2

Figure 2 shows a typical planning of this work. The spacing of cross-section depends upon the nature of the ground, scale of the map and the contour interval required. It varies from 20 m to 100 m. Closer intervals are required if ground level varies abruptly. The cross- sectional line need not be always be at right angles to the main line. This method is ideally suited for road and railway projects.

Radial Line Method: [Fig. 3]. In this method several radial lines are taken from a point in the area. The direction of each line is noted. On these lines at selected distances points are marked and levels determined. This method is ideally suited for hilly areas. In this survey theodolite with tacheometry facility is commonly used.

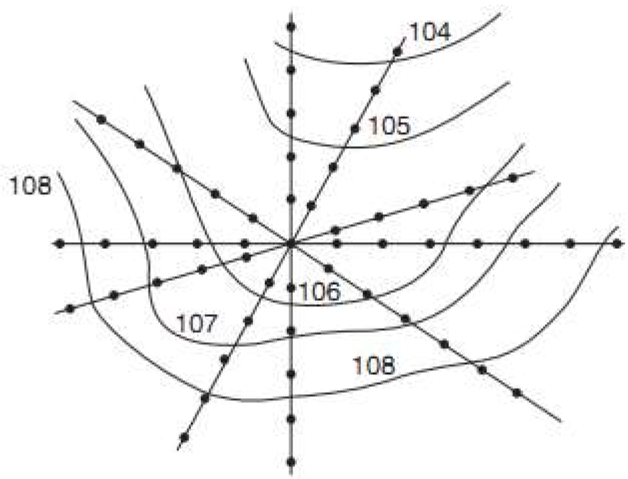


Fig. 3

UNIT-IV THEODOLITE

Objective:

To introduce students about basic principlesand applications of Theodolite

Micro Syllabus:

Main parts of a theodolite, basic definitions, the vertical axis, the horizontal axis, the line of sight, the axis of level tube, centering, transiting, swinging the telescope, face left observation, face right observation, telescope normal, telescope inverted, changing face.

Fundamental lines, temporary adjustments, setting over the station, levelling up, elimination parallax, vernier scales, horizontal angles, repetition method and reiteration method, vertical angles, direct angles, deflection angles, method of double sighting, errors, instrumental errors, personal errors, errors due to natural causes, precautions.

Trigonometric leveling- Determination of the level of the top of an object above the ground when the base is accessible and the base is inaccessible.

Learning Outcomes:

Student will be able to

- Explainthe working of the theodolite.
- Explain the measurements of horizontal and vertical angles.
- Calculate the heights and distances in various cases like base accessible and inaccessible.

Learning Material

A theodolite is an instrument which is used primarily to measure angles, both horizontal and vertical. It is also used for many other subsidiary work during surveying such as setting up of intermediate points between inter visible points, establishment of inter visible points, prolonging a line, laying out traverse etc.

There are different types of theodolite available. It may be classified into three broad categories.

- **Vernier or Transit Theodolite**: This is most commonly used. In this type of instrument, observations are taken by using the principle of vernier caliper. The precision of this type of instrument varies in the order of 10" to 20".
- **Digital Theodolite**
- **Total Station**

Each type of theodolite is peculiar in its construction and mode of operation. However, inherent fundamentals of all are same. In this course, the details will be considered for vernier type theodolite which is most popular and is being widely used. The salient parts of a vernier theodolite have been discussed below (Figure 1).

- **Leveling Head**
  - It is the lowermost part of a theodolite. It consists of two parallel horizontal plates separated by three leveling screws.
  - The lower plate with a large threaded hole in its centre is called trivet or foot plate. It provides a means to place the instrument on (tripod) stand and get it screwed. Its central aperture provides a way for suspending a plumb bob.
  - The upper plate of the leveling head is called the tribrach . It contains a tapered bearing at the centre. It has three arms each carrying a leveling screw. It provides a support for the upper part of the instrument.
  - The principal use of levelling head is to provide a means for levelling the instrument.

- **Shifting Head**

  It consists of a pair of horizontal plates and an annular treaded ring. One of the plates is placed below the lower plate but above the tribrach and the other below the tribrach. The annular treaded ring is placed in between lower plate and the tribrach which is used to tighten/untighten the whole of the instrument. The shifting head is used for exact centring of the instrument after leveling has been completed.

- **Lower Plate**

  It is a horizontal circular plate monolithically constructed with the outer spindle. A scale is engraved at its bevelled edge with divisions in degrees and minutes increasing in clockwise direction. It provides the main scale reading of a horizontal angle and a means to fix / unfix the whole of the instrument.

- **Upper Plate**

  It is a horizontal circular plate monolithically constructed with the inner spindle. It is fitted with two diametrically opposite vernier scales designated as A and B. Functions of upper plates are to support a pair of magnifiers for the verniers, a pair of plate levels, a pair of support frames for telescope and a means to fix / unfix the upper plate of the instrument with its lower plate.

Plate Levels

A pair of level tubes are placed at right angles on the upper plate. These are used to make the vertical axis of the instrument truly vertical i.e., for leveling of the instrument.

- **Standard (or a Frame)**

  Two standards resembling the letter A are attached on the upper plate. These provides the bearings of the pivots of the telescope allowing it to rotate on its trunion axis in vertical plane. The vernier frame and arm of vertical circle clamp are also attached to it.

- **Vernier Frame**

  Also called T -frame or index frame, consists of a vertical leg known as clipping arm and a horizontal bar called the index arm engraved with verniers C and D at its ends. Each of the verniers at C and D are having two scales which increases in opposite directions. It is used as seat for altitude bubble and also provides vernier reading for vertical angle measurement.

- **Telescope**

  The telescope of a theodolite is identical in structure and uses, as in case of a dumpy level. But, in theodolite, the telescope is mounted on a horizontal spindle called the horizontal axis or the trunnion axis to rotate it also in vertical plane.

- **Vertical Circle**

  The vertical circle is attached with the trunnion axis. It is engraved with a scale reading vertical angle in degrees and minutes. The vertical circle is divided into four quadrants each reading 0° to 90° with 0° - 0° either along vertical or in horizontal. It provides the main scale reading for vertical angle.

- **Altitude Bubble**

  A sensitive level tube placed on vernier frame is called altitude bubble. It is used to make horizontal axis truly horizontal.

- **Screws**

  A theodolite instrument has number of screws as its component parts. These are classified into different types depending on their functions.

  Leveling Screws:

  These are present in the leveling head of a theodolite in between trivet and tribrach. These work in threaded holes in the tribrach arms and their lower ends rest in recesses in the trivet. These screws are used for leveling the instrument i.e., to make plate level axis truly horizontal.

Clamp screws

These are used to fix the parts of a theodolite with which these are attached.

Lower plate Clamp Screw: The clamp screw attached to the lower plate of a theodolite is called lower plate clamp screw. When it is tightened, the outer spindle gets fixed with the tribrach, and, thus, the lower plate gets fixed in position.

Upper plate Clamp Screw: The clamp screw attached with the upper plate of a theodolite is called upper plate clamp screw. When it is tightened, the inner spindle gets fixed with the outer spindle and, thus, the upper plate gets fixed in position.

The manipulation of the upper plate and lower plate clamp screws provide three conditions:

- When both the upper plate clamp screw and the lower plate clamp screw are tightened, the instrument gets fully fixed.
- When the upper plate clamp screw is tightened and the lower plate clamp screw is opened, the instrument rotates on its outer axis, there is no relative motion between the two plate and the readings in the horizontal vernier scales do not change.
- When the lower plate clamp screw is tightened, and the upper plate is opened, the instrument rotates on the inner axis with outer axis fixed. The readings in the horizontal vernier scales change.

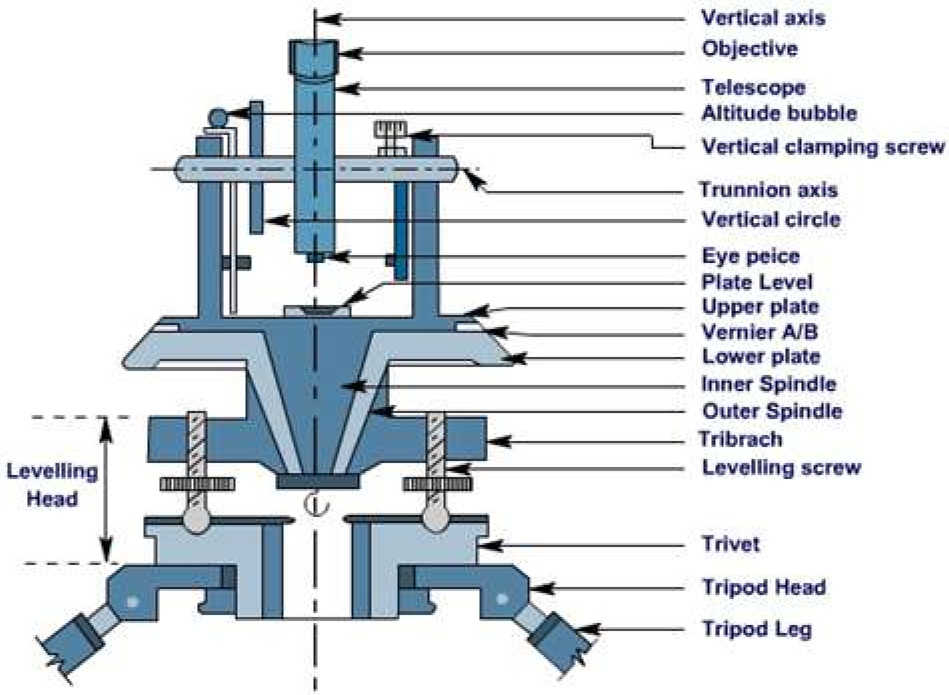
Vertical plate Clamp Screw: It is present on a frame fixed with standard and above the shaft of trunnion axis. It is used to clamp the telescope in any plane and hence at any desired vertical angle.

Tangent Screws:

With each clamping screw, there is a tangent screw present in the instrument to provide fine movement. The tangent screws work only after its clamping screws get tightened. Thus when the upper clamp screw has been tightened, small movement of the upper plate can be made by the upper tangent screw; when the lower clamp screw has been tightened, small movement of the lower plate can be made by the lower tangent screw and similarly for vertical clamp screw.

Tripod Stand

The theodolite is mounted on a strong tripod when being used in the field. The legs of the tripod are solid or framed. At the lower ends of the legs, pointed steel shoes are provided to get them pushed into ground. The tripod head has male screws on which the trivet of the leveling head is screwed.



Fundamental Lines of a Theodolite

The fundamental lines are imagined in a theodolite instrument are

1. **Vertical Axis:** the vertical axis is the axis about which the instrument can be rotated in a horizontal plane. This is the axis about the lower and upper plates rotate.

2. **Horizontal axis:** the horizontal or trunnion axis is the axis about which the telescope and the vertical circle rotate in vertical plane.

3. **Line of collimation:** It is the line passing through the intersection of the horizontal and vertical cross hairs and the optical centre of the object glass and its continuation.

4. **Axis of the altitude level tube:** the axis of the level tube or the bubble line is a straight line tangential to the longitudinal curve of the level tube at its centre. The axis of the level tube is horizontal when the bubble is central.

5. **Centering:** The process of setting the theodolite exactly over the station mark is known

as centering.

6. **Transiting:** It is the process of the turning the telescope in vertical plane through 180^0 about the trunnion axis. Since the line of sight is reversed in this operation, it is also known as Plunging or Reversing.
7. **Swinging the telescope:** It is the process of turning the telescope in horizontal plane. If the telescope is rotated in clockwise direction, it is known as right swing. If the telescope is rotated in the anti-clockwise direction, it is known as left swing.
8. **Face left observation:** If the face of the vertical circle is to the left of the observer, the observation of the angle (horizontal or vertical) is known as face left observation.
9. **Face right observation:** If the face of the vertical circle is to the right of the observer, the observation of the angle (horizontal or vertical) is known as face right observation.
10. **Telescope normal:** A telescope is said to be normal or direct when the face of the vertical circle is to the left and the bubble up.
11. **Telescope inverted:** A telescope is said to inverted or reversed when the vertical circle is to the right and the bubble down.
12. **Changing face:** It is an operation of bringing the face of the telescope from left to right and vice versa.

TEMPORARY ADJUSTMENT OF VERNIER THEODOLITE

At each station point, before taking any observation, it is required to carry out some operations in sequence. The set of operations those are required to be done on an instrument in order to make it ready for taking observation is known as temporary adjustment. Temporary adjustment of a vernier theodolite consists of following operations:

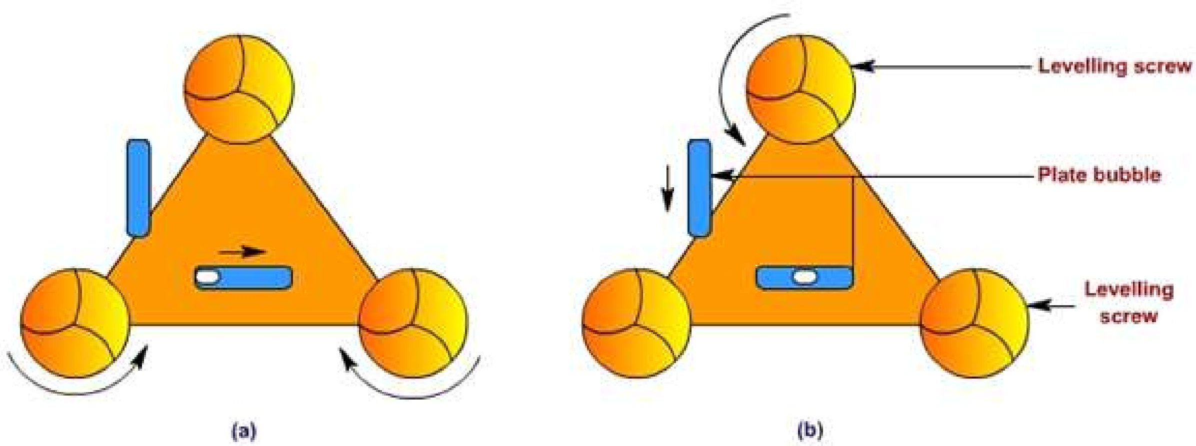
- Setting,
- Centring,
- Leveling and
- Focussing.

Setting: The setting operation consists of fixing the theodolite with the tripod stand along with approximate leveling and centring over the station. 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.

Centring: The operation involved in placing the vertical axis of the instrument exactly over the station mark is known as centring. First, the approximate centring of the instrument is done by moving the tripod legs radially 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 centring. It must be noted that the centering and leveling of instrument is done recursively. Finally, exact centring 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 centring, the screw clamping ring gets tightened.

Leveling: Leveling of an instrument is done to make the vertical axis of the instrument truly vertical. Generally, there are three leveling screws and two plate levels are present in a theodolite instrument. Thus, leveling is being achieved by carrying out the following steps



Step 1: Bring one of the level tube parallel to any two of the foot screws, by rotating the upper part of the instrument.

Step 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. [Figure (a)]

Step 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 [Figure (b)]. [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.]

Step 4: Repeat Step 2 and step 3 in the same quadrant till both the bubble remain central.

Step 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.

Focussing: 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 the eye-piece lens, the eye-piece is focused to make the appearence of cross hairs distinct and clear. This is being carried out in steps: First, point the telescope towards the sky or hold a sheet of white paper in front of the objective; Next, move the eye-piece in or out by rotating it gradually until the cross hairs appear quite sharp and clear.

Focusing of eye-piece depends on the eye-sight of observer and so for each observer it needs to adjust accordingly.

Focusing of the objective lens.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.

Elimination of Parallax:

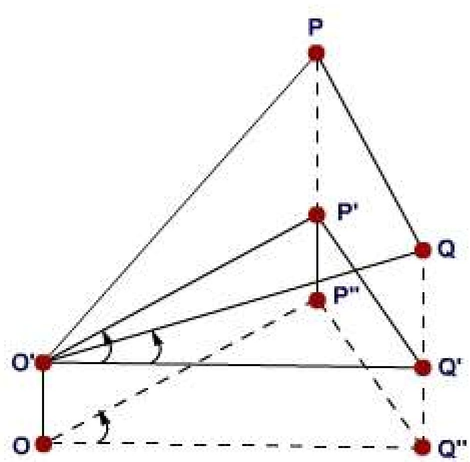
Parallax is a condition arising when the image formed by the objective is not in the plane of the cross hairs. Unless parallax is eliminated, accurate sighting is impossible. Parallax can be eliminated in two steps: 1. By focusing the eyepiece for distinct vision of the cross hairs and 2. By focusing the objective to bring the image of the object in the plane of crosshairs.

1. Focusing the eye-piece: To focus the eye piece for distinct vision of the cross hairs, point the telescope towards the sky and move eye piece in or out till the cross hairs are seen sharp and distinct. In some telescope, graduations are provided at the eye piece end so that one can always remember the particular graduation position to suit his eyes. This may save much of time.
2. Focusing the objective: the telescope is now directed towards the object to be sighted and the focusing screw is turned till the image appears clear and sharp. The image so formed is in the plane of cross hairs.

HORIZONTAL ANGLES:

Method of repetition:

When the precision of measurement of a horizontal angle is desired to be more than the least count of the instrument, repetition method is used. In this method, the desired angle is measured several times, and average of the observed values is considered as the value of the angle. The precision thus attained is to a much finer degree than the least count of the vernier. The steps involved in the measurement of the horizontal angle, say POQ at O by method of repetition are as follows:



Repetition Method

1. Two points one on each of the lines, say P and Q, are to be marked.
2. A transit theodolite is to be set at the point of intersection of the lines, say at O. Initially, the instrument is in the face left condition and its temporary adjustment is to be done over the point O.
3. Both the lower and upper plate main screws are to released and get the vernierA set to 0° (or 360°) mark on the main scale. After clamping the upper main screw, index of vernier A is to be brought exactly to the zero of the main scale using the upper plate tangent screw.
4. At this stage the reading of the vernier B should be 180°.
5. Swing the telescope in the horizontal plane and point it to the left station, say P. Tighten the lower plate clamp screw, and bisect the signal at P exactly using the lower plate tangent screw. Record the readings in the form of Table below.
6. Loosen the upper plate main screw and turn the telescope the signal at Q is sighted. Tighten the upper clamp screw and bisect the ranging pole at Q exactly using the upper plate tangent screw.
7. Read both the verniers A and B and record the readings. The reading of the vernier A is the angle POQ. The vernier B gives the value of angle POQ after deducting from it 180°. The mean of two values of the angles obtained from the verniers A and B is the required angle P'O'Q'.
8. Unclamp the lower plate, and turn the telescope to sight the signal P again. Tighten the lower clamp. Use the lower plate tangent screw for exact bisection of the signal P. (The vernier readings should be as it was during previous reading).
9. Release the upper clamp and turn the telescope to sight the signal Q. Tighten the upper clamp. Bisect the signal Q exactly using the upper tangent screw. The vernier A will give the value which is about twice the angle POQ.
10. Repeat steps (8) and (9) once again. The final reading of the vernier A will be approximately thrice the angle POQ.

If necessary, more repetitions can be done.

11. Divide the final reading by the number of repetition to obtain the value of the angle POQ.

For every completed revolution of the circle to the final reading, if necessary, add 360°.

12. Change face of the instrument to the face right. The telescope will be in the inverted condition. Repeat steps (2) to (9), with the face right, and determine another value of the angle POQ.
13. Determine the average value of the angles obtained with the face left and face right.

The method of repetition eliminates different errors present in measurement of horizontal angle. These are as follows:

1. The errors due to eccentricity of verniers and centres get eliminated as readings from both the verniers are taken.
2. The errors due to inaccurate graduations get eliminated as the readings are observed at different parts of the circle.
3. The errors due to lack in adjustment of line of collimation and the horizontal axis of the instrument get eliminated for considering both faces readings.
4. Errors due to inaccurate bisection of the object, eccentric centering etc are eliminated partially as these get counter-balanced in different observations.

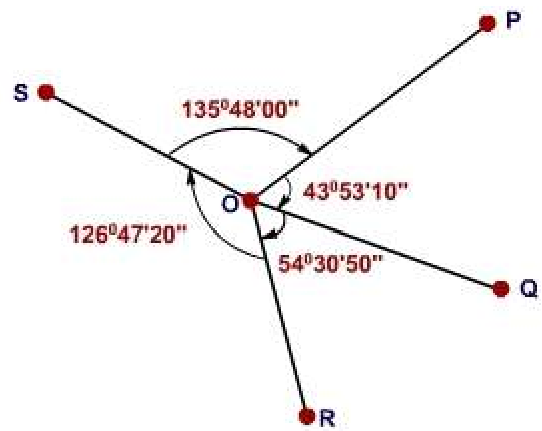
However, the errors due to slip, due to displacement of station or its signal do not get eliminated and moreover, these errors are of cumulative in nature.

Measurement of a horizontal angle

		Face left Swing Right												Face right Swing left												Average horizontal angle		
Inst. at	Sighted to	A			B		Mean			No. of repetition	Horizontal angles			A			B		Mean			No. of repetition	Horizontal angles					
		°	'	"	'	"	°	'	"		°	'	"	°	'	"	'	"	°	'	"		°	'	"	°	'	"
O	P	00	00	00	00	00	00	00	00					00	00	00	00	00	00	00	00							
	Q	58	43	20	4	20	58	43	20	1	58	43	20	58	43	40	43	40	58	43	40	1	58	43	40	58	43	30

Method of Reiteration:

Method of reiteration for measurement of horizontal angle is usually adopted in case several angles of well distributed points/ objects are to be measured from the same instrument station with high precision. In this method, angles are measured successively starting from a point termed as initial station. The angle between the terminating station and the initial station is the last observation during a set of measurement of horizontal angle by method of reiteration. This process of measuring the angles at an instrument station round the point is to obtain a check on their sum being equal to 360° and is called closing the horizon. When the horizon is closed, the final reading of the vernier should be the same as its initial reading if there is no discrepancy. Figure 22.2 shows a instrument station O where the angles POQ, QOR and ROS have to be measured by method of reiteration. The steps involved in the measurement of the horizontal angles by method of reiteration are as follows:



Reiteration Method

1. Two points one on each of the lines, say P and Q, are to be marked.
2. A transit theodolite is to be set at the point of intersection of the lines, say at O. Initially, the instrument is in the face left condition and its temporary adjustment is to be done over the point O.
3. Both the lower and upper plate main screws are to released and get the vernierA set to 0° (or 360°) mark on the main scale. After clamping the upper main screw, index of vernier A is to be brought exactly to the zero of the main scale using the upper plate tangent screw.
4. At this stage the reading of the vernier B should be 180°.
5. Swing the telescope in the horizontal plane and point it to the left station, say P. Tighten the lower plate clamp screw, and bisect the signal at P exactly using the lower plate tangent screw. Record the readings in the form of Table below.
6. Loosen the upper plate main screw and turn the telescope the signal at Q is sighted. Tighten the upper clamp screw and bisect the ranging pole at Q exactly using the upper

plate tangent screw.

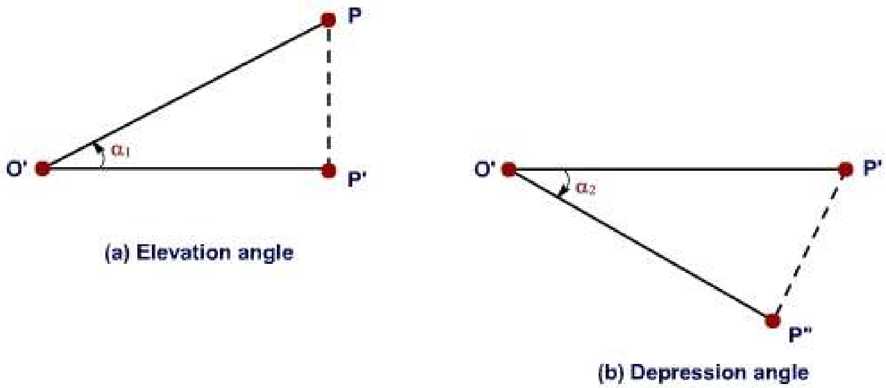
7. Read both the verniers A and B and record the readings. The reading of the vernier A is the angle POQ. The vernier B gives the value of angle POQ after deducting from it 180°. The mean of two values of the angles obtained from the verniers A and B is the required angle P'O'Q'.
8. Loosen the upper plate clamp screw and turn the telescope clockwise until the station R is sighted. Tighten the upper clamp screw. Use the upper tangent screw for placing the object R on the vertical cross hair. Read both the verniers, and record readings in the Table 22.3. Compute the angle QOR. And note down in the table.
9. Likewise, determine the angle ROS.
10. Finally, close the horizon by sighting the reference object P again. Note down the readings. The vernier A should now read zero (or 360°).
11. Now change the face left of the instrument to the face right by transiting (plunging) the telescope and swinging it through 180°. Repeat steps 3 to 10 in the anti-clockwise direction.
12. The average value of each angle obtained with the face left and the face right provides the observed values of the angles.

Measurement of a horizontal angle by reiteration method

Inst. at	Sighted to	Face left									Swing Right				Face right									Swing left			Average horizontal angle		
		A			B		Mean			Horizontal angles			A			B		Mean			Horizontal angles					
		°	'	"	'	"	°	'	"	°	'	"	°	'	"	'	"	°	'	"	°	'	"	°	'	"
O	P	00	00	00	00	00	00	00	00				00	00	00	00	00	00	00	00						
	Q	43	53	10	53	10	43	53	10	43	53	10	43	53	00	53	00	43	53	10	43	53	10	43	53	10
	R	98	24	00	24	00	98	24	00	54	30	50	98	24	00	24	00	98	24	00	54	30	50	54	30	50
	S	225	11	20	11	20	225	11	20	126	47	20	225	11	20	11	20	225	11	20	126	47	20	126	47	20
	P	360	00	00	00	00	360	00	00	134	46	40	360	00	00	00	00	360	00	00	134	48	40	134	48	40

Measurement of Vertical Angle:

A vertical angle is the angle between the inclined line of sight and the horizontal plane through the trunnion axis of the instrument. Prior to the measurement of vertical angle, instrument is required to be leveled with reference to the altitude level.Figure 22.3 shows vertical angles.



Vertical Angles

The procedure for measuring a vertical angle is as follows:

1. The temporary adjustment of the instrument is to be done on the station.
2. Then, leveling of theodolite is to be done using altitude level (the operations involved are same as leveling using plate level).
3. Loosen the vertical circle clamp, and direct the telescope towards the object whose vertical angle is required to be measured. Clamp the vertical circle, and bisect the point by turning the vertical tangent screw.
4. Read and record the scale with vernier C and D.
5. Change the face of the instrument and read the vertical angle again.
6. The required vertical angle is the average of the values in steps 4 and 5.

Measuring Direct angles:

Direct angles are the angles measured clockwise from the preceding line to the following line. They are also known as angles to the right or azimuths from back line and may vary from 0^0 to 360^0. To measure the angle PQR

1. Set the theodolite at Q an level it accurately. With face left, set the reading on vernier A to zero.
2. Unclamp the lower clamp and direct the telescope to P. Bisect it accurately using the lower tangent screw.

3. Unclamp the upper clamp and swing telescope clockwise and sight R. Bisect R accurately using upper tangent screw. Read both verniers.
4. Plunge the telescope, unclamp the lower clamp and take backsight on P. Reading on the vernier will be the same as in step 3.
5. Unclamp the upper clamp and bisect R again. Read the verniers. The reading will be equal to twice the angle. Angle PQR will then be obtained by dividing the final reading by two.

Similarly the remaining angles at other stations are also measured.

Measuring Deflection Angles:

A deflection angle is the angle which a survey line makes with the prolongation of the preceding line. It is designated as Right (R) or Left (L) according as it is measured to the clockwise or to anti-clockwise from the prolongation of the previous line. Its value may vary from 0^0 to 180^0. The deflection angle at Q is α^0 R and at R is θ^0 L.

To measure the deflection angles at Q:

1. Set the instrument at Q and level it.
2. With both plates clamped at 00, take back sight on P.
3. Plunge the telescope. Thus the line of sight is in the direction PQ produced when the reading on vernier A is 00.
4. Unclamp the upper clamp and turn the telescope clockwise to take the foresight on R. Read both the verniers.
5. Unclamp the lower clamp and turn the telescope to sight P again. The verniers still read the same reading as in 4. Plunge the telescope.
6. Unclamp the upper clamp and turn the telescope to sight R. Read both verniers. Since the deflection angle is doubled by taking both face readings, one-half of the final reading gives the deflection angle at Q.

ERRORS IN MEASUREMENTS OF ANGLES AND DIRECTIONS

An error in the measurement of angle causes error in direction as well as in the computed value of distance. Thus, it is important for a surveyor to:

(1) Visualize the effect of errors in terms of both angle and distance,

(2) Appreciate what degree of care must be exercised to keep certain errors within specified limits, and

(3) Know under what conditions various errors can be eliminated. Errors in transit work may be instrumental, personal or natural.

INSTRUMENTAL ERROR

Errors due to imperfections and/or non-adjustment of instrument are all systematic, and these can either be eliminated or reduced to a negligible amount by adopting appropriate methods. The instrumental errors involved in theodolite surveying are

- **Error in Horizontal angles (due to Imperfect adjustment of the plate level)**

When the bubbles of plate levels are not in adjustment, the vertical axis is inclined, and hence measured angles are not truly horizontal angles. The larger the vertical angle, greater is the error in direction. Thus, errors in horizontal angles due to non adjustment of plate levels or of horizontal axis become large as the inclination of the sights increases.

- **Error in vertical angles (due to Imperfect adjustment of the plate level)**

These errors vary with the direction in which the instrument is pointed. With the fixed vertical vernier they are eliminated by observing (for each sighting) the index error of the corresponding observed vertical angle.

- **Error due to line of Collimation not being perpendicular to the Horizontal axis**

With the line of sight out of adjustment by a given amount, the effect of the error depends on the vertical angle to the point sighted. For all ordinary cases, the error (E) in direction of an inclined sight is given by

$E = e \sec \theta$ (approx.)

Where e is the error in direction for a horizontal sight, where θ is the observed vertical angle. The maximum error in horizontal angles due to non adjustment of the line of sight is introduced when the telescope is plunged between backsight and foresight readings and usually appears in the measurement of a deflection angle.

- **Error due to Horizontal axis not being perpendicular to the Vertical axis**

The error in horizontal direction of a line due to horizontal axis not being perpendicular to the vertical axis

- **Other Instrumental Errors**

Other instrumental errors are

- Error due to eccentricity of the inner and outer axis
- Errors due to lack of coincidence between line of sight and optical axis

- Error due to eccentricity of vernier
- Error due to imperfect graduations on the horizontal scale;
- Vertical index error
- Vertical hair not being perpendicular to the horizontal axis
- Error due to defective tripod

All of these errors are mostly compensated and minimised by taking mean of the observations. In case of horizontal angles it is the mean of face length and face right condition and in case of vertical angles, it is the mean of telescope direct and reversed conditions.

PERSONAL ERRORS

Personal errors arise from the limitations of the human capability and experience in making temporary adjustment and in taking observations. Personal errors usually prevalent in theodolite observations are:

- Error in setting up of the Instrument
- Error in centring of the Instrument
- Errors in setting and reading the Vernier
- Error in ranging pole location or Staff Station
- Error in Focusing (parallax)

ERROR DUE TO NATURAL CAUSES

Sources of natural errors are

1. Unequal atmospheric refraction due to high temperature.
2. Unequal expansion of parts of telescope and circles due to temperature changes.
3. Unequal settlement of tripod.
4. Wind producing vibrations.

TRIGNOMETIC LEVELLING:

Trigonometric levelling is an indirect method of levelling in which the relative elevations of various points are determined from vertical angles measure with a theodolite and the horizontal a theodolite and the horizontal distances measured with tape.

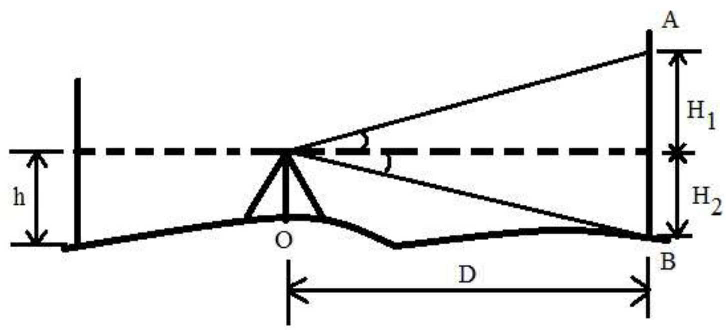
Following are the different cases which come under trigonometric levelling:

i) Base of the object accessible
ii) Base of the object is inaccessible and instrument stations are in the same vertical plane

iii) Base of the object is inaccessible and instrument stations are not in the same vertical plane

Case 1: To find the height of the object when the base of the object is accessible.

Let it be required to find the height of the object whose base is accessible as shown in fig.



Procedure:

1) Setup the instrument over station 'O' and level it accurately by using altitude level.
2) Sight to 'A' and read the elevated vertical angle (α_1)with face left and face right observations; the average gives the elevated vertical angle(α_1).
3) Repeat the process by sighting the point 'B' which gives depressed vertical angle (α_2).
4) By making line of sight horizontal take the staff reading on B.M
5) Measure the distance between 'O' and 'B' which gives horizontal distance 'D'.

From the triangle 'OAB' we have

$H_1 = D\tan\alpha_1$

$H_2 = D\tan\alpha_2$

Height of the object $H = H_1 + H_2$

$= D\tan\alpha_1 + D\tan\alpha_2$

$= D(\tan\alpha_1 + \tan\alpha_2)$

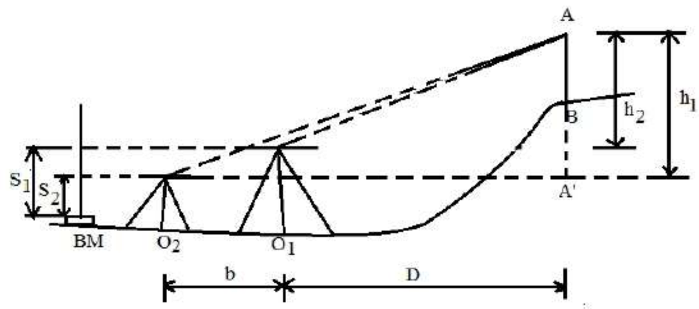
It is required to find RL of the top of the object (or) RL of the bottom of the object them, we have.

R.L of top of the object = R.L of B.M + h+ H_1

R.L of bottom of the object = R.L of B.M + h+-H_2

Case 2: To find the height of the object when the base of the object is inaccessible and instrument stations are in the same plane.

Let it be required to find the height of the top of the object whose base is inaccessible as shown in fig.



Procedure:

1) Setup the instrument over the station O_1 and level it accurately by using altitude level.
2) Sight to 'A' and read the vertical angle (α_1).
3) Plunge the telescope and mark the second instrument station 'O_2' at a distance'd' from 'O_1'so that the points 'O_1&O_2' and BM are in same vertical plane.
4) With the vertical vernierzero reading , take the staff reading 'S_1' on near BM.
5) Shift the instrument to 'O_2' and level it.
6) Sight the object 'A' andread the vertical angle (α_2).
7) Plunge the telescope and make the vertical circle zero reading, take staff reading 'S_2' on BM.

From fig

$h = D \tan\alpha_1$ --------(1)

Where $h = AA^1$

And $(h-h_1) = (d+D)\tan \alpha_2$ ---------(2)

Where $h_1 = s_2 - s_1$ = difference in elevations of instrument axes

From (1) & (2)

If the line of collimation at O_1 is higher than O_2 then h is calculated asfollows:

Therefore, R.L of A =R.L of B.M + S_1 + h.

SURVEYING

UNIT-IV

TACHEOMETRY & TOTAL STATION

Objective:

To introduce students about basic principles and usage of tacheometry in calculation of Distances and Heights

Micro Syllabus:

TACHEOMETRY

Systems of tachometric measurements: Stadia system- fixed hair method, movable hair method. Tangential System; Principle of stadia method, distance and elevation formulae for staff vertical and normal in both the systems.

TOTAL STATION

Features of total station, Functions of total station and Uses of total station systems.

Learning Outcomes:

Student will be able to

- Work on the Tacheometry readings.
- Calculate the heights and distances using tacheometry applications.
- Know the applications and features of Total Station.

Learning Material

Tacheometry or tachemetry or telemetry is a branch of angular surveying in which the horizontal and vertical distances of points are obtained by optical means. The chaining operations are completely eliminated.

The method is very rapid and convenient.

It is best adapted in obstacles such as steep and broken ground, deep revines, stretches of water or swamp and so on, which make chaining difficult or impossible

Uses of Tacheometry

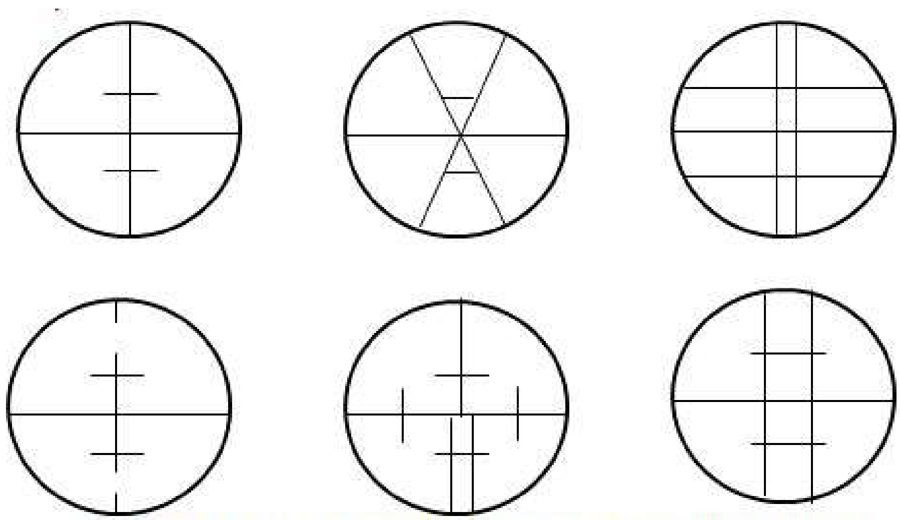
The tacheometric methods of surveying are used with advantage over the direct methods of measurement of horizontal distances and differences in elevations. Some of the uses are:

- ✓ Preparation of topographic maps which require both elevations and horizontal distances.
- ✓ Survey work in difficult terrain where direct methods are inconvenient

- ✓ Detail filling
- ✓ Reconnaissance surveys for highways, railways, etc.
- ✓ Checking of already measured distances
- ✓ Hydrographic surveys and
- ✓ Establishing secondary control.

INSTRUMENTS

An ordinary transit theodolite fitted with a stadia diaphragm is generally used for tacheometric survey. The stadia diaphragm essentially consists of one stadia hair above and the other an equal distance below the horizontal cross-hair, the stadia hairs being mounted in the ring and on the same vertical plane as the horizontal and vertical cross-hairs.



Different forms of stadia diaphragm commonly used

Characteristics of good Tacheometer

(i) The multiplying constant should have a nominal value of 100 and the error contained in this value should not exceed 1 in 1000.

(ii) The axial horizontal line should be exactly midway between the other two lines.

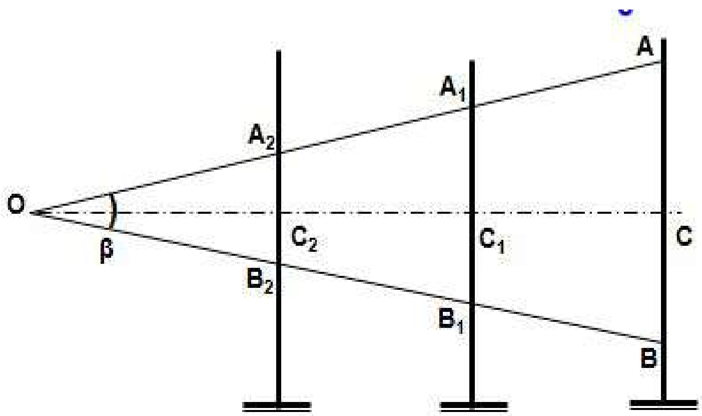
(iii) The telescope should be powerful having a magnification of 20 to 30 diameters.

(iv) The aperture of the objective should be 35 to 45 mm in diameter to have a sufficiently bright image.

(v) For small distances (say upto 100 meters), ordinary levelling staff may be used. For greater distances a stadia rod may be used.

Principle of Tacheometry

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



In figure, let two rays OA and OB be equally inclined to central ray OC. Let A_2B_2, A_1B_1 and AB be the staff intercepts. Evidently,

$$\frac{OC_2}{A_2B_2} = \frac{OC_1}{A_1B_1} = \frac{OC}{AB}$$

$$= \text{constant } k = \tfrac{1}{2} \cot \frac{\beta}{2}$$

Different systems of Tacheometric Measurement:

The various systems of tacheometric survey may be classified as follows:

- The stadia System

(a) Fixed Hair method of Stadia method

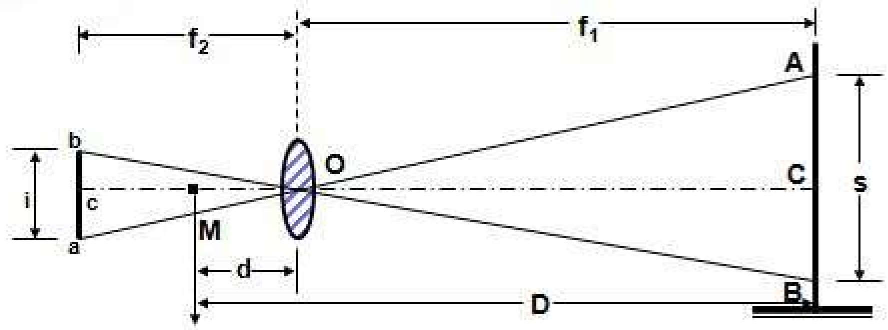
(b) Movable hair method, or Subtense method

- The tangential system

The principle common to all the systems is to calculate the horizontal distance between two points A and B and their distances in elevation, by observing.

Fixed hair method

- In this method, the distance among the stadia hairs is kept constant. The intercept varies as distance varies.
- The staff intercept, i.e., the difference of the readings corresponding to top and bottom stadia wires will therefore depend on the distance of the staff from the instrument.
- When the staff intercept is more than the length of the staff, only half intercept is read.



Consider the figure, in which *O* is the optical centre of the objective of an *external focusing telescope*.

Let A, C, and B = the points cut by the three lines of sight corresponding to three wires

b, c, and a = top, axial and bottom hairs of the diaphragm.

ab = i = interval b/w the stadia hairs (stadia interval)

AB = s = staff intercept;

f = focal length of the objective

f_1 = horizontal distance of the staff from the optical centre of the objective

f_2 = 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 instruments.

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 *AOB* and *aOb* are similar. Hence,

$$\frac{f_1}{f_2} = \frac{s}{i}$$

Again, since f_1 and f_2 are conjugate focal distances, we have from lens formula,

$$\frac{1}{f} = \frac{1}{f_2} + \frac{1}{f_1}$$

Multiplying throughout by f_1, we get

Substituting the values of $\frac{f_1}{f_2} = \frac{s}{i}$ in the above, we get

$$f_1 = \frac{s}{i} f + f$$

Horizontal distance between the axis and the staff is $D = f_1 + d$

$$D = \frac{f}{i} s + (f + d) = k \, . \, s + C$$

ii) **Movable hair method:** in this method, the vertical spacing between the stadia hairs canbe varied by moving the stadia hairs vertically by micrometer screws.

In this method, the staff intercept (s) is fixed. The staff used has two vanes (target) fixed at a constant spacing usually 3m. When taking reading, the stadia interval is measured corresponding to the staff intercept. The vertical angle (θ) is also measured. The horizontal distance D and the difference of elevations are computed.

2) **Tangential system:** In this system, the stadia hairs are not required. The method can even be used when the telescope is not provided with a stadia diaphragm.

A staff with two targets at a fixed distance (s) is used for taking the measurements. The vertical angles θ_1&θ_2 to the two targets are measured. The vertical angles and fixed distances are used to determine the horizontal distance D and the difference of elevations.

Determination of Tacheometric Constants

The stadia interval factor (K) and the stadia constant (C) are known as tacheometric constants. Before using a tacheometer for surveying work, it is required to determine these constants. These can be computed from field observation by adopting following procedure.

Step 1: Set up the tacheometer at any station say P on a flat ground.

Step 2: Select another point say Q about 200 m away. Measure the distance between P and Q accurately with a precise tape. Then, drive pegs at a uniform interval, say 50 m, along PQ. Mark the peg points as 1, 2, 3 and last peg-4 at station Q.

Step 3: Keep the staff on the peg-1, and obtain the staff intercept say s_1 .

Step 4: Likewise, obtain the staff intercepts say s_2, when the staff is kept at the peg-2,

Step 5: Form the simultaneous equations, using Equation (23-2)

$D_1 = K.\ s_1 + C$ --------------(i)

And $D_2 = K.\ s_2 + C$ -------------(ii)

Solving Equations (i) and (ii), determine the values of K and C say K_1 and C_1 .

Step 6: Form another set of observations to the pegs 3 & 4, Simultaneous equations can be obtained from the staff intercepts s_3 and s_4 at the peg-3 and point Q respectively. Solving those equations, determine the values of K and C again say K_2 and C_2.

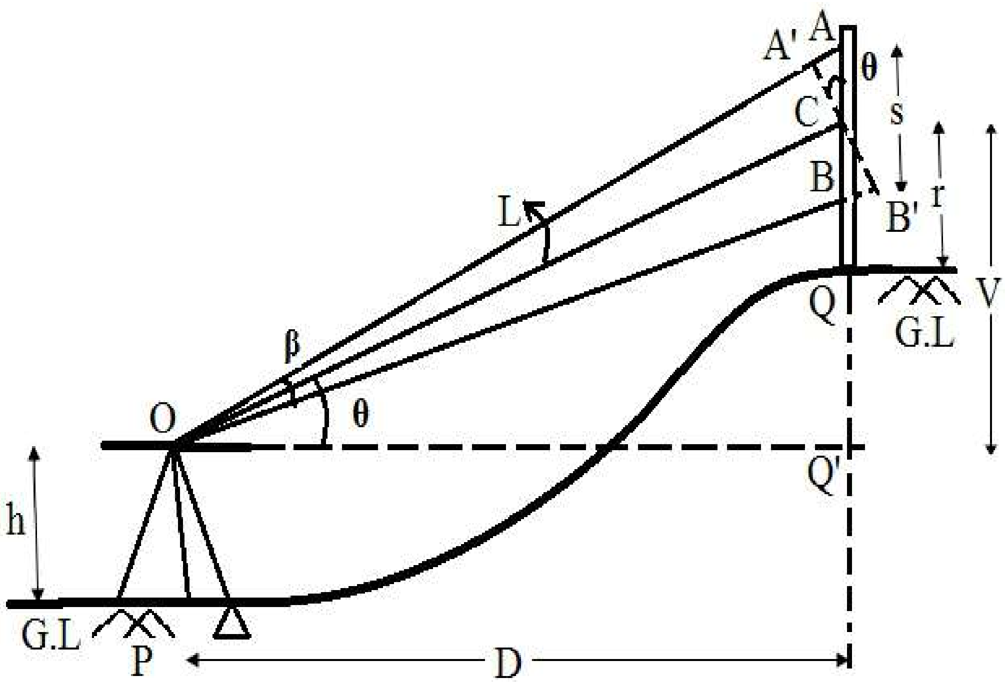
Step 7: The average of the values obtained in steps (5) and (6), provide the tacheometric constants K and C of the instrument.

Anallactic Lens

It is a special convex lens, fitted in between the object glass and eyepiece, at a fixed distance from the object glass, inside the telescope of a tacheometer. The function of the anallactic lens is to reduce the stadia constant to zero. Thus, when tacheometer is fitted with anallactic lens, the distance measured between instrument station and staff position (for line of sight perpendicular to the staff intercept) becomes directly proportional to the staff intercept. Anallactic lens is provided in external focusing type telescopes only.

Distance and elevation formula for staff vertical: the staff may be held either vertical or normal to the line of sight. The staff generally held vertical in practice, and this case is discussed below.

1) <u>ANGLE OF ELEVATION</u>:If the terrain is rough, the staff readings are taken with the line of sight inclined to the horizontal.



Let ‘s’ be the staff intercept AB. The two extreme rays OA & OB, subtended an angle ‘β’ at ‘O’. Draw a line A^1CB^1 normal to the line of sight OC at C. as the angle ‘β’ is quite small, the angles AA^1C and BB^1C may be taken as right angles.

In the triangle AA^1C

$$A^1C = AC \cos\theta$$

C is the midpoint of AB,

$$A^1C = (AB/2) \cos\theta$$

$$2\,A^1C = A^1B^1$$

$A^1B^1 = AB \cos\theta$

$\mathbf{S^1 = S\ COS\ \theta}$ ------------------(1)

In words the staff intercept normal to the line of sight is equal to the vertical intercept multiplied by $\cos\theta$

As the line A^1B^1 is normal to the line of sight,therefore the length L of inclined distance OC may be written as

$L = KS^1 + C$

$= KS\ COS\theta + C$ -----------------(2)

Horizontal distance $D = L\ COS\theta$ -------------(3)

The vertical intercept v between the horizontal line OQ^1 through O and the point c is given by

$V = CQ'$

$= L \sin \boldsymbol{\theta}$

$= (KS \cos\theta + C) \sin\theta$

$V = \frac{1}{2} KS \sin 2\theta + C \sin\theta$ -------------(4)

For an external focusing telescope fitted with an analetic lens, the second term R.H.S of eq (3) & (4) is zero.

For an internal focusing telescope, it is negligible, the following simplified eq's are commonly used in practice.

$D = KS\ COS^2\ \theta$ **--------------(5)**

$V = \frac{1}{2} KS \sin 2\theta$

$V/D = \tan\theta$

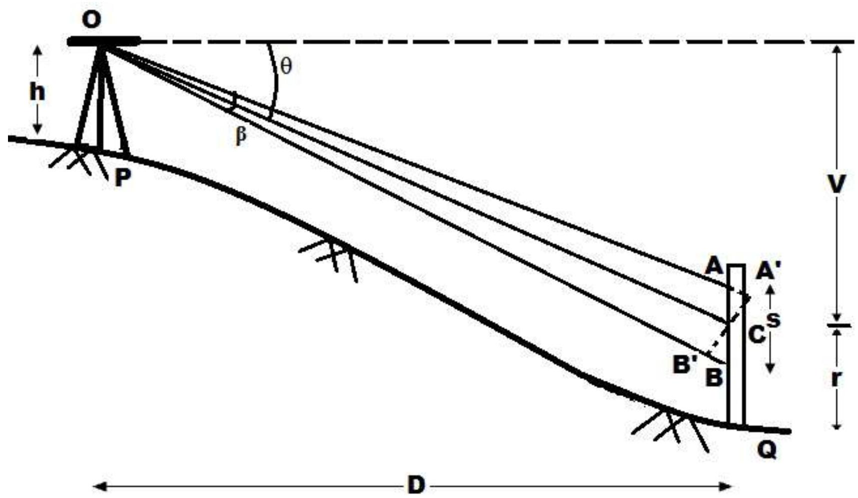
The elevation of the staff station Q can be determined using the value of V obtained above.

R.L of Q = R.L of instrument axis + V – r.

Where 'r' is the staff reading corresponding to the central hair at C.

2) ANGLE OF DEPRESSION:If the angle θ is the angle of depression. However the term V is

negative.

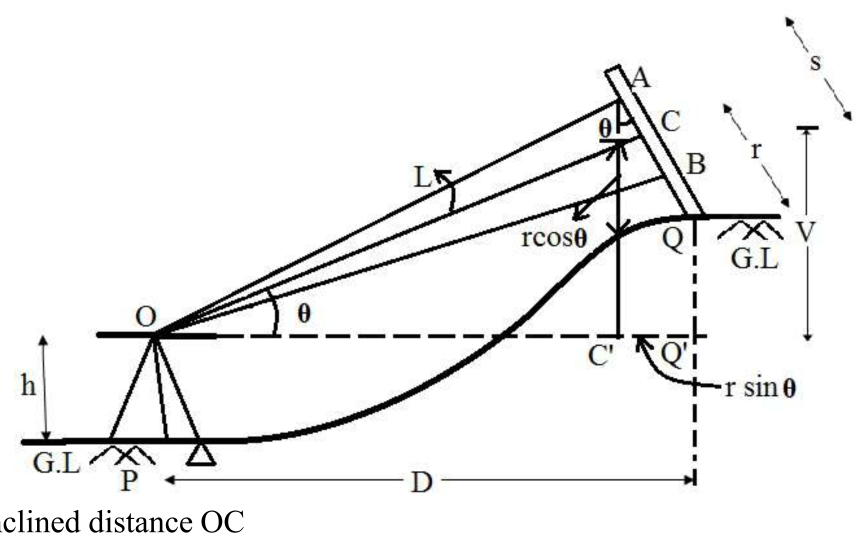


R.L of Q = R.L of instrument axis - V - r.

Distance and elevation formula for staff normal to the line of sight: In this method, the staff is held normal to the inclined line of sight.

1) <u>ANGLE OF ELEVATION</u>in this fig the staff intercept is equal to inclined distance AB. the inclined distance 'OC' can be expressed in terms of the staff intercept 'S' using

L = KS+C -----------------(1)



Where, L is the inclined distance OC

The horizontal distance 'D' between P & Q is given by

$D = L\ COS\ \theta + C^1Q^1$

$D = L\ COS\ \theta + r\ Sin\ \theta$

$D = (KS + C)\ COS\ \theta + r\ Sin\ \theta$ -------------(2)

Where, θ is the vertical angle, and 'r' is the central hair reading.

The vertical intercept 'V' between O & C is given by

$V = L \sin\theta$

$V = (KS + C) \sin\theta$ ---------------------(3)

R.L of station at Q = R.L of instrument axis + V - r COS θ

= (R.L of instrument station P + h) + V - r COS θ

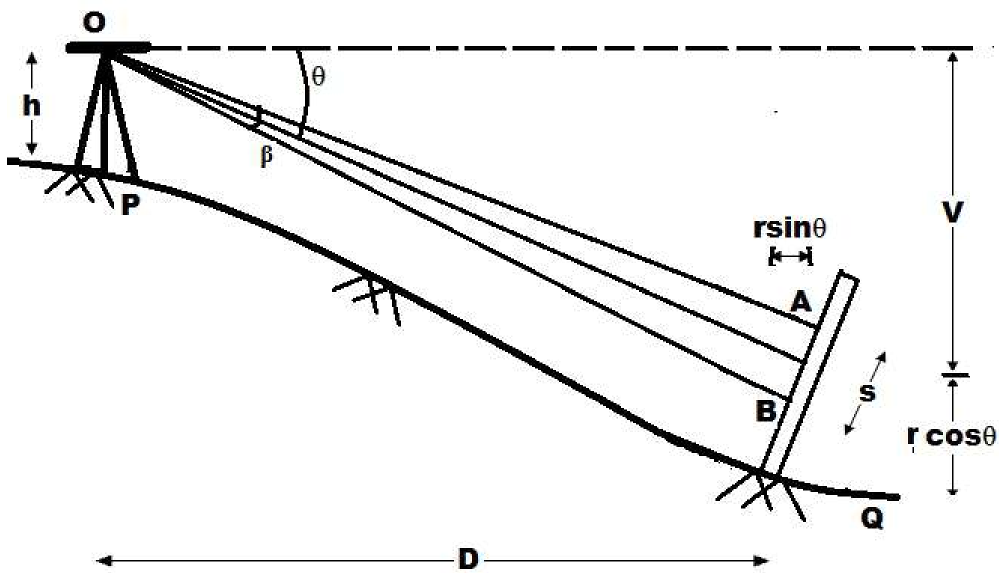
Where, h is the height of the instrument axis at p.

For analletic telescope (or) when C is negligible

$D = KS \cos\theta + r \sin\theta$

$V = KS \sin\theta$

2) <u>ANGLE OF DEPRESSION:</u>This fig shows the case when the angle θ is the angle of depression. in this case



$D = L \cos\theta + C^1Q^1$

$D = (KS + C) \cos\theta - r \sin\theta$

$V = L \sin\theta$

$V = (KS + C) \sin\theta$

R.L of station at Q = R.L of instrument axis - V - r COS θ

= (R.L of instrument station P + h) - V - r COS θ

<u>Total station:</u>Total station is a surveying equipment combination of electromagnetic distance measurement and electronic theodolite. It is also integrated with microprocessor, electronic data collector and storage system. The instrument can be used to measure horizontal and vertical angles as well as sloping distance of object to the instrument.

Use of Total Station

The total station instrument is mounted on a tripod and is levelled by operating levelling screws. Within a small range instrument is capable of adjusting itself to the level position. Then vertical and horizontal reference directions are indexed using onboard keys. It is possible to set required units for distance, temperature and pressure (FPS or SI). Surveyor can select measurement mode like fine, coarse, single or repeated.

When target is sighted, horizontal and vertical angles as well as sloping distances are measured and by pressing appropriate keys they are recorded along with point number. Heights of instrument and targets can be keyed in after measuring them with tapes. Then processor computes various information about the point and displays on screen.

This information is also stored in the electronic notebook. At the end of the day or whenever electronic note book is full, the information stored is downloaded to computers.

The point data downloaded to the computer can be used for further processing. There are software like auto civil and auto plotter clubbed with AutoCad which can be used for plotting contours at any specified interval and for plotting cross-section along any specified line.

Advantages of Using Total Stations

The following are some of the **major advantages of using total station** over the conventional surveying instruments:

1. Field work is carried out very fast.
2. Accuracy of measurement is high.
3. Manual errors involved in reading and recording are eliminated.
4. Calculation of coordinates is very fast and accurate. Even corrections for temperature and pressure are automatically made.
5. Computers can be employed for map making and plotting contour and cross-sections. Contour intervals and scales can be changed in no time.

Assignment-Cum-Tutorial Questions

A. Questions testing the remembering / understanding level of students

I) Objective Questions

1. The value of multiplying constant of a Tacheometer is ___________________.
2. The value of additive constant of a tacheometer is __________________.
3. Subtense bar is used for measurement of _____________________ in plane area.

4. The diaphragm of a stadia theodolite is normally fitted with two additional ______________.
5. If the spacing of cross hairs in a stadia diaphragm of tacheometer is 12mm, and the focal length of the object glass is 24cm, then the multiplying constant of the tacheometer is ____________.
6. The intercept of a staff is maximum, if the staff is held ________________ to the line of sight.

II) Objective Questions

1. What are the uses of tacheometry?
2. What are the characteristics of tacheometry.
3. Define tacheometry and what are the tacheometric constants?
4. What are the applications of total station?
5. What are the functions of Total station?
6. What are the uses of Total station systems?

B. Question testing the ability of students in applying the concepts.

I) Multiple Choice Questions:

1. The branch of surveying in which both horizontal and vertical positions of a point are determined by making optical observations is known as

   a) Tachometry b) levelling

   c) Telemetry d) all the above
2. Horizontal cross-wires is provided in the stadia diaphragm of a tacheometer, these may be

   a) One b) Two c) Three d) Four
3. The multiplying constant of a tacheometer is

   a) f/i b) (f/d) +I c) (f/I) +d d) f+d
4. The stadia method in tacheometry is used to determine

   a) Horizontal angles b) Vertical angles

   c) Horizontal distances d) Horizontal and Vertical distances
5. The purpose of an analletic lens in a tacheometer is to

   a) Increase magnification b) Reduce effective length of the telescope

   c) To eliminate multiplying constant

   d) Make staff intercept proportional to its distance from the tacheometer
6. The standard accuracy of tachometric distance determined is

   a) 1:10 b) 1:1000 c) 1:500 d) 1:10000
7. Tacheometric survey employees

a) Laser b) Holograph c) Tacheometer d) Telluremeter

II) Descriptive Questions

1. What is the principal of tacheometry and derive it.
2. Explain analletic lens and Tangential System.
3. Explain stadia system.
4. Derive the expression for staff held in vertical systems?
5. Derive the expression for staff held in normal systems?
6. Write the importance of EDM instruments used in civil engineering?

III) Problems

1. A Tacheometer has a diaphragm with three cross hairs spaced at distance 1.15mm. The focal length of the object glass is 23cm and the distance from the objective glass to the turnion axis is 10cm. Calculate the tachometric constants.
2. A staff was held vertically at a distance of 90m from an external focusing theodolite and stadia reading taken with line of sight horizontal are 1.158, 2.055m. If the focal length of objective glass was 20cm and distance from vertical axis was 10cm. calculate a) Stadia interval b) Multiplying constant of theodolite.
3. The following readings were taken with a transit fitted with stadia hairs. The line of sight was horizontal and the staff was held vertical.

	Reading on staff(m)
Top Hair	0.875
Middle hair	1.340
Bottom Hair	1.805

   a) If the tachometric constants K and C have the values as 100 and 0.2m, respectively, what is the horizontal distance the staff and the instrument.

   b) Determine the R.L of the staff station if the R.L of the instrument station is 201.20m and the height of the instrument above the ground is 1.51m

4. To determine the distance between two stations A and B, a tacheometer was set up at a point P on the line AB and the following observations were made.

   a) When the staff was held at A

Staff readings = 2.225, 2.605, 2.985

Vertical angle = + 8^0 24'

b) When the staff was held at B

Staff readings = 1.640, 1.92, 2.2

Vertical angle = - 1^0 06'

Also determine the R.L of B if the R.L of A is 315.673m and K=100, C=0

SURVEYING
UNIT –VI - CURVES

Objective:

To familiarize with different types of curves and curve setting

Syllabus:

Basic definitions- back tangent, forward tangent, point of intersection, point of curve, point of tangency, intersection angle, deflection angle to any point, tangent distance, external distance, length of curve, long chord, mid ordinate, normal chord, sub-chord, right hand curve, left hand curve. designation of a curve, relationship between radius and degree of curve, elements of a simple circular curve, location of the tangent points, methods of setting out, tape methods, method of offsets from the chords produced, tape and thoedolite method, two theodolite method, problems in setting out curves, compound curves, relationship between elements of a compound curve, reverse curves, elements of a reverse curve.

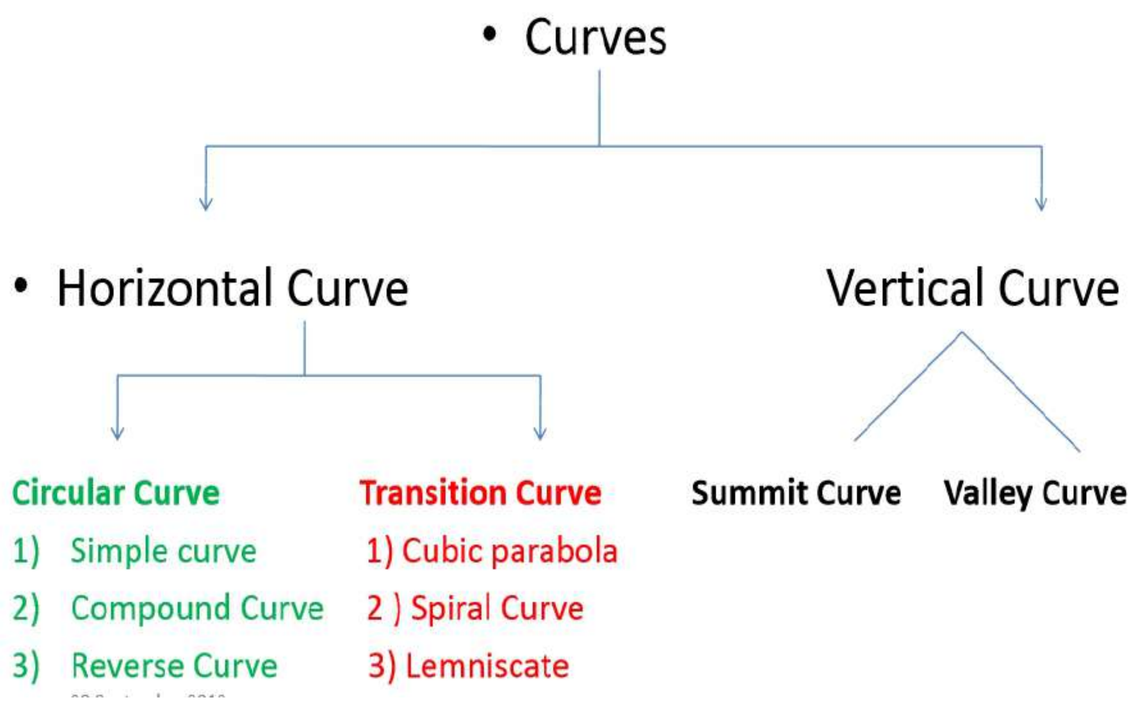
Learning Outcomes:

Student will be able to

- Explain different types of curves
- Mention the elements of curves with their relationships
- Design simple and compound curves for highways.

Learning Material

Whenever the direction of a road/railway line is to be changed, curves are provided between the intersecting straights. This is necessary for smooth and safe movement of vehicles and for the comfort of passengers. The curves required may be in horizontal planes/vertical planes. Accordingly curves are further classified as circular curves and transition curves.



Simple Circular curve

It is a circular arc between two intersecting straights of same radius.

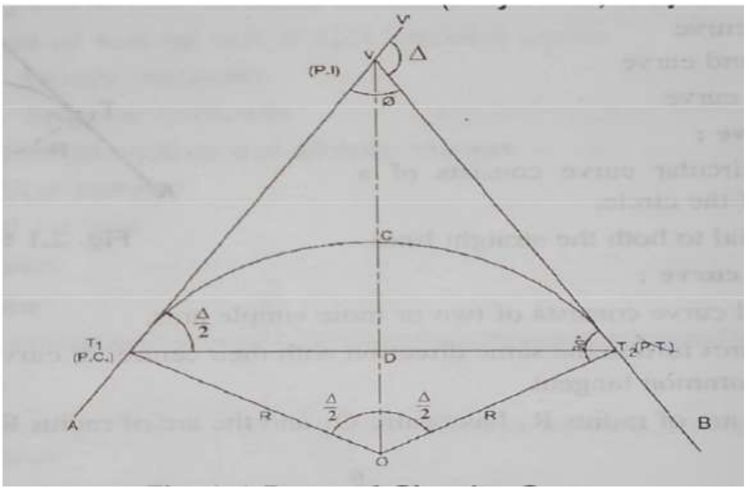
Compound Curve

Two or more circular curves of different radii turning in the same direction, join together to make a single curve between the two intersecting straight form a compound curve

Reverse Curve

Two simple circular curves of equal or different radii, having curvatures in opposite direction, join together to form a reverse curve

Definitions & Notations



1) Back tangent or First Tangent - AT_1

Pervious to the curve

2) Forward Tangent or Second tangent -BT_2

Following the curve.

3) Point of Intersection (P.I.)or Vertex.(v)-

If the tangents AT_1 and BT_2 are produced they will meet in a point called the point of intersection.

4) Point of curve (PC)

Beginning Point T_1 of a curve, Alignment changes from a tangent to curve.

5) Point of Tangency - PT

End point of curve (T_2) is called Point of Tangency

6) Intersection Angle (Ø)

The Angle AVB between tangent AV and tangent VB is called Intersection Angle

7) Deflection Angle (Δ)

The angle at P.I. between tangent AV and VB is called Deflection Angle

8) Tangent Distance

It is the distance between P.C. and P.I.

9) External Distance – CI

The distance from the midpoint of the curve to P.I, It is also called the apex distance.

10) Length of curve – L

It is the total length of curve from P.C. to P.T.

11) Long Chord

It is the chord joining P.C. to P.T., T_1 T_2 is a long chord.

12) Normal Chord:

A chord between two successive regular stations on a curve is called normal chord. Normally, the length of normal chord is 1 chain (20 mt).

13) Sub chord

The chord shorter than normal chord (shorter than 20 mt) is called sub chord)

14) Versed sine – Distance CD

The distance between midpoint of long chord (D) and the apex point C, is called versed sine. It is also called mid- ordinate (M).

15) Right hand curve:

If the curve deflects to the right of the direction of the progress of survey

16) Left hand curve

If the curve deflects to the left of the direction of the progress of survey

Designation of curve
The sharpness of the curve is designated by two ways.
(1) By radius (R)
(2) By Degree of Curvature (D)
(1) By radius (R)
Curve is known by the length of its radius- R
(2) By Degree of Curvature (D)
Arc Definition
According to arc definition degree of curvature is defined as angle in degrees subtended by an arc of standard length.
Chord Definition
According to chord definition degree of curvature is defined as angle in degrees subtended by a chord of standard length.
Relation between Radius and degree of curve.

a) By arc definition

Let R- Radius of the curve
s- Straight length
D_a- Degree of curve
D= S/R
$S=RXD_aX\pi/180$
$R= S/D_a X\pi/180$
If S=20m, $R= 1145.92/ D_a$
If S= 30m, $R = 1718.87/ D_a$

b) By Chord definition

$R \sin D_a/2 = S/2$
Here sin Da /2 can be taken approximately equal to $D_a /2$
$R = S/ D_a X\ 180/\pi$

Elements of a simple curve

1. Length of Curve (l)
   $\Delta = l/R$
   $l= R\ \Delta X\pi/180$
2. Tangent length
   $T = T_1V =VT_2$
   $= R.Tan\ \Delta/2$
3. Length of the chord (L)
   $\sin\Delta/2 = T_1D/R$
   $T_1D = R \sin\Delta/2$
4. Length of mid ordinate (M)
   $R-RCos\ \Delta/2$
5. External distance (E)
   $E = R \sec \Delta/2-R$

<u>**Methods of setting out simple circular curve**</u>
Based on the instruments used in setting out the curves on the ground there are two methods:

1) Linear method
2) Angular method

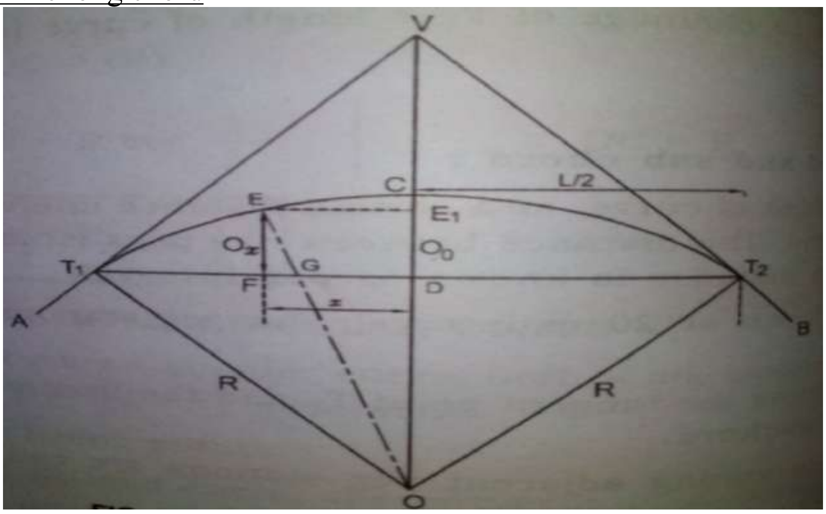
<u>Linear Method</u>

- In these methods only tape or chain is used for setting out the curve . Angle measuring instrument are not used.

Main linear methods are

- ❖ By offsets from the long chord.
- ❖ By successive bisection of arcs.
- ❖ By offsets from the tangents.
- ❖ By offsets from chords produced.

<u>By offsets from the long chord</u>

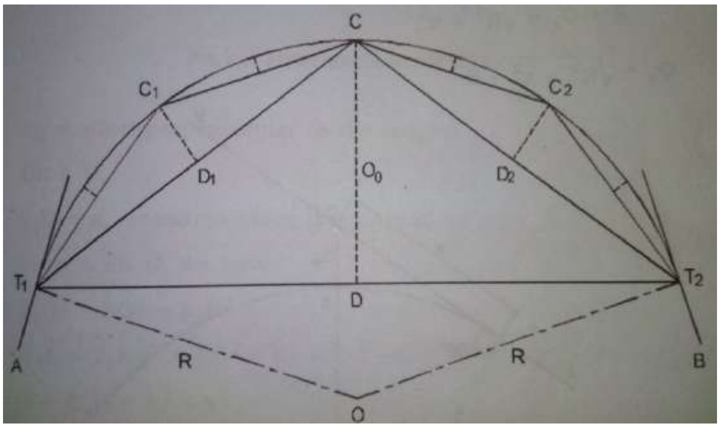


Here
R= Radius of the curve
O_o = mid ordinate
O_x = Ordinate at distance X From the midpoint of the chord
T_1 and T_2 = Tangent point

$$Oo = R - \sqrt{R^2 - (\frac{L}{2})^2}$$

$$Ox = \sqrt{(R^2 - x^2)} - (R - Oo)$$

<u>By successive bisection of arcs</u>



In this method, points on a curve are located by bisecting the chords and erecting the perpendicular of the mid ordinate.
Join the tangent points T_1, T_2 and bisect the long chord at D.
Erect perpendicular DC at D equal to the mid ordinate.
Join T_1C and T_2C and bisect them at D_1 and D_2 respectiely.

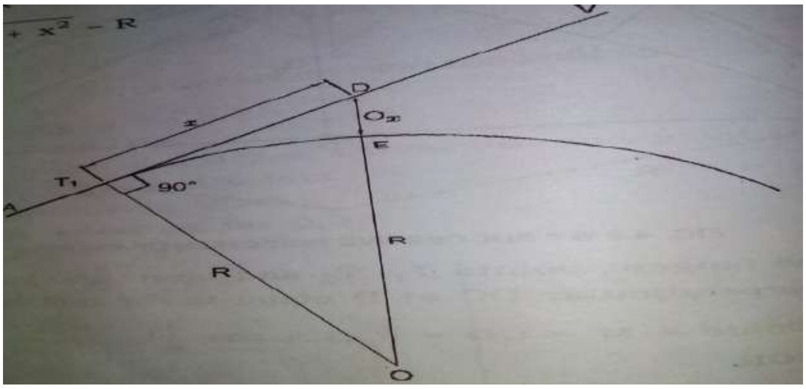
$= R(1- \cos\Delta/4)$

<u>By offsets from the tangents</u>

- ➢ The offsets from the tangents can be of two types

1) Radial offsets
2) Perpendicular offsets

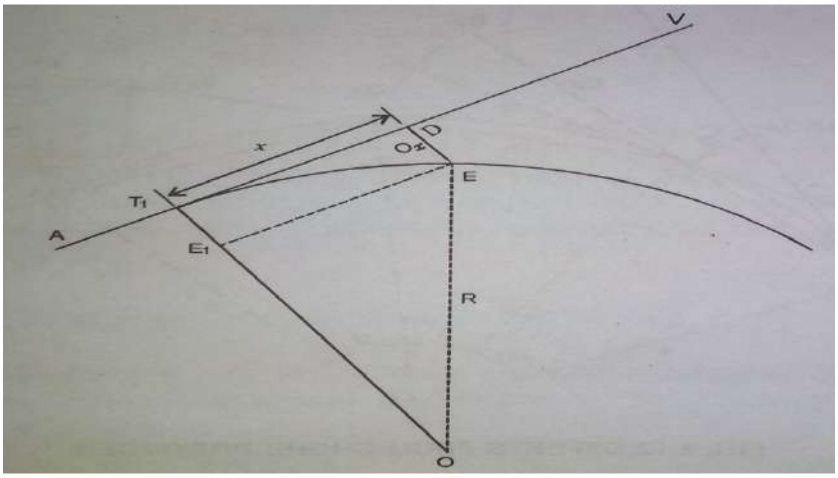
Radial offsets



If the centre of cure O is accessible from the point on tangent, this method of curve setting is possible

$$OX = \sqrt{R^2 + x^2} - R$$

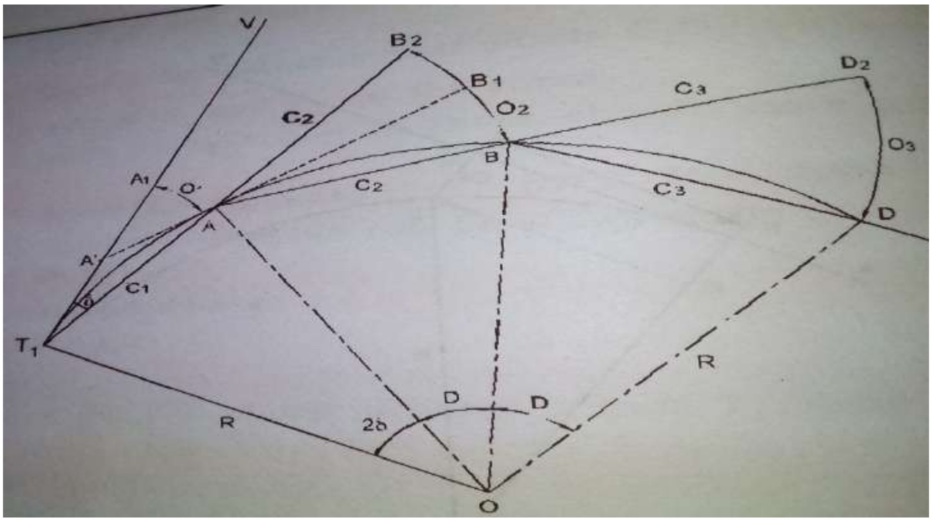
Perpendicular offsets



If the centre of a circle is not visible, perpendicular offsets from tangents can be set to locate the points on the curve.

$$Ox = R - \sqrt{R^2 - x^2}$$

<u>By offsets from chords produced</u>



This method is used for setting out long curves. In this method, a point on the curve is fixed by taking offsets from the tangent taken at the rear point of a chord.

$O_1 = C_1^2/2R$

$O_2 = C_2/2R[\Delta_1 + \Delta_2]$

--- ---

$O_n = C_n/2R[C_{n-1} + C_n]$

<u>Angular Methods</u>

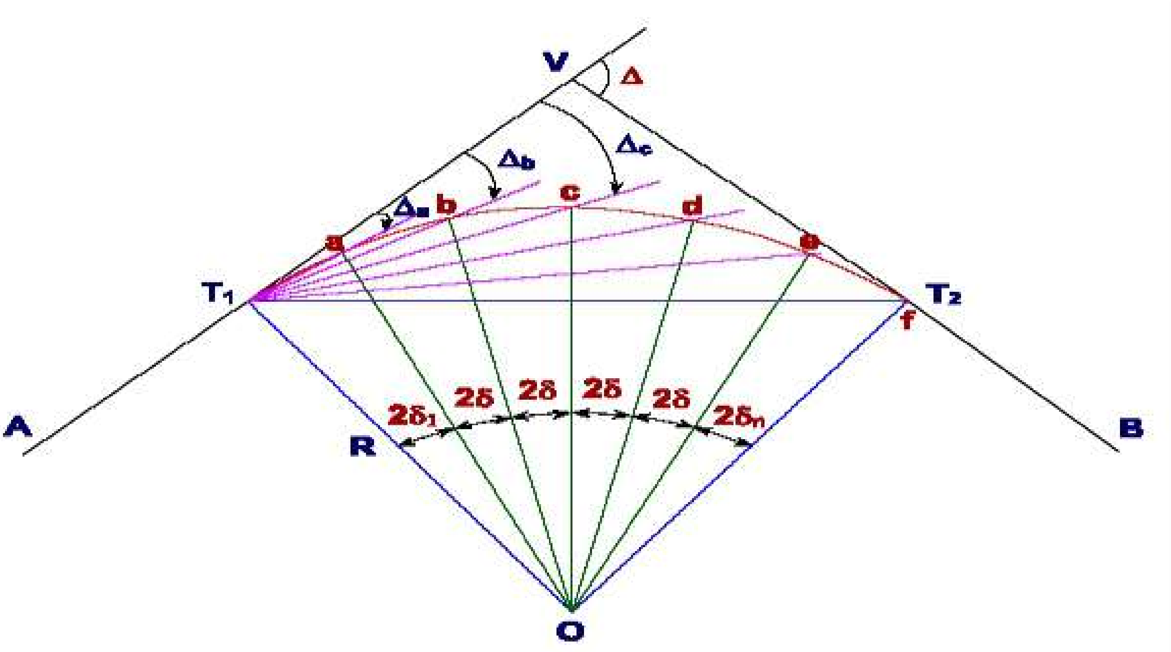
- These methods are used when the length of curve is large.

The Angular methods are:

1) Rankine method of tangential angles
2) Two theodolite method
3) Tacheometric method

TAPE & THEODOLITE METHOD:

In this method, both the linear and angular measurements are carried out simultaneously to stake points along which curve will be set out. A tape is used for the linear measurements, whereas a theodolite is used for the angular measurements. This method is quite accurate and is commonly used in practice. This method is also called as Rankine's method.



Let points a, b, c, d, e are to be identified in the field to lay out a curve between T_1 and T_2 to change direction from the straight alignment AV to VB as in figure. To decide about the points, chords ab, bc, cd, de are being considered having nominal length of 30m. To adjust the actual length of the curve two sub-chords have been provided one at the beginning, T_1 a and other, eT_2 at the end of the curve. The amount of deflection angles that are to be set from the tangent line at the P.C. are computed before setting out the points. The steps for computations are as follows:

Referring to Figure, let the tangential angles for points a, b, c,… be δ_1, δ_2,…, δ_n and their deflection angles (from the tangent at P.C.) be ${}_a$, ${}_b$, ….. , ${}_n$.

Now, for the first tangential angle δ_1, from the property of a circle

Arc T_1 a = R x 2 δ_1 radians

Assuming the length of the arc is same as that of its chord, if C_1 is the length of the first chord i.e., chord T_1 a, then

$$\delta_1 = \frac{C_1}{2R} \text{ radians}$$

$$= \frac{180^\circ C_1}{2\pi R} \text{ degrees}$$

$$= \frac{180 \times 60 C_1}{2\pi R} \text{ minutes}$$

$$= 1718.9 \frac{C_1}{R} \text{ minutes}$$

(Note: the units of measurement of chord and that of the radius of the curve should be same).

Similarly, tangential angles for chords of nominal length, say C,

$$\delta = 1718.9 \frac{C}{R} \text{ minutes}$$

And for last chord of length, say C_n

$$\delta_n = 1718.9 \frac{C_n}{R} \text{ minutes}$$

The deflection angles for the different points a, b, c, etc. can be obtained from the tangential angles. For the first point a, the deflection angle Δ_a is equal to the tangential angle of the chord to this point i.e., δ_1. Thus,

$\Delta_a = \delta_1$.

The deflection angle to the next point i.e., b is Δ_b for which the chord length is T_1 b. Thus, the deflection angle

$$\Delta_b = \frac{1}{2} \angle T_1Ob$$

$$= \frac{1}{2}(2\delta_1 + 2\delta)$$

$$= \Delta_a + \delta$$

$$\text{Similarly, } \Delta_c = \frac{1}{2} \angle T_1Oc$$

$$= \frac{1}{2}(2\delta_1 + 2\delta + 2\delta).$$

$$= \Delta_b + \delta$$

$$\text{Like wise, } \Delta_n = \Delta_{n-1} + \delta_n$$

Thus, the deflection angle for any point on the curve is the deflection angle upto previous point plus the tangential angle at the previous point.

Field Procedure for setting out the curve:

1. A theodolite is set up at the point of curvature T_1, and get it temporary adjusted.

2. The vernier A is set to zero, and get the upper plate clamped. After opening the lower plate main screw, sight the point of intersection, V. Then the lower plate main screw gets tightened and get the point V bisected exactly using the lower plate tangent screw. Now the line of sight is in the direction of the rear tangent T_1 V and the vernierA reads zero.

3. Open the upper plate main screw, and set the vernier A to the deflection angle Δ_a. The line of sight is now directed along the chord T_1 a. Clamp the upper plate.

4. Hold the zero end of the tape of a steel tape at T_1. Note a mark equal to the first chord length C_1 on the tape and swing an arrow pointed at the mark around ‘a' till it is bisected along

the line of sight. The arrow point then indicates the position of the first peg 'a'. Fix the first peg at 'a'.

5. Unclamp the upper plate, and set the vernier A to the deflection angle Δ_b. The line of sight is now directed along T_1 b.

6. With the zero end of the tape at a, and an arrow at a mark on the tape equal to the normal chord length C, swing the tape around b until the arrow is bisected along the line of sight. Fix the second peg at the point b at the arrow point.

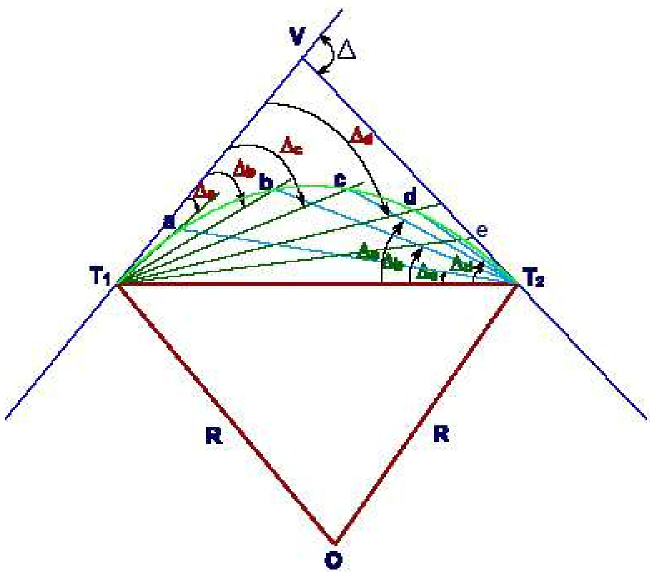
It may be noted that the deflection angles are measured from the tangent point T_1 but the chord lengths are measured from the preceding point. thus, deflection angles observed are cumulative in nature but chord lengths swung are individual in nature.

7. Repeat steps (5) and (6) till the last point is reached. The last point so located must coincide with the tangent point T_2 already fixed from the point of intersection.

Laying out a curve by Two Theodolite Method

In two theodolite method, curves are staked out by angular measurements only. Accuracy attained in this method is quite high. Thus, the method is used when higher accuracy is required and when the topography is rough or field condition is difficult.

Field Procedure:



1. Two theodolites are placed, one at the point of curvature T_1 and the other at the point of curvature T_2. Get temporary adjustment in both. The vernier A of each theodolites set to zero and clamp the upper plates.

2. Bisect the point of intersection, V from theodolites at T_1 and T_1 from the theodolite at T_2 using the lower plate main screw and then its tangent screw. Now both the theodolites are properly oriented.

3. Open the upper plate main screw of the theodolites at T_1, and set the vernier A to the deflection angle Δ_1. The line of sight is now directed along the chord T_1 a. Clamp the upper

plate.

4. Release the upper clamp of the theodolite at T_2 and set the vernier A to the angle Δ_1. The line of sight is now directed along the chord T_2 a.

Thus the lines of sight of both the theodolites are directed towards the point 'a'.

5. Now, move a ranging rod or an arrow near the expected point 'a' until it is bisected simultaneously by the cross-hairs of both the theodolites. Locate the point 'a' on the ground at the arrow point and fix a peg at that point.

6. To locate the second point 'b', set the verniers of both the theodolites at angle Δ_b and repeat steps (3) to (5) .

7. Locate all other points c,d,e..... in the same manner.

Problems in Setting out Curves:

The following cases may occur due to problems in setting out curves

Case 1: point of intersection (v) not accessible.

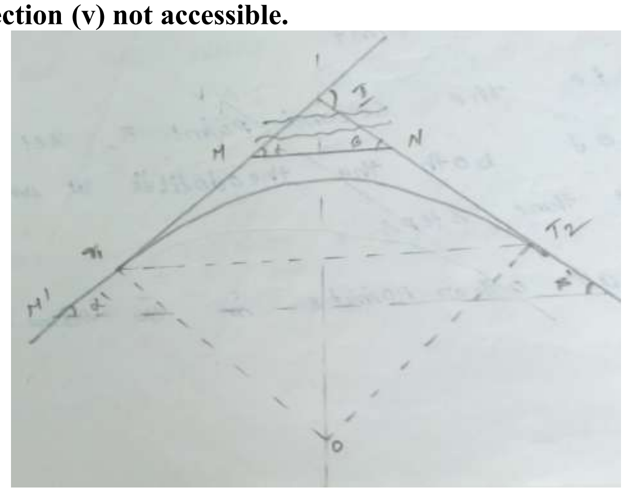
Case 2: point of curve (T_1) not accessible.

Case 3: point of tangency (T_1) not accessible.

Case 4: both point of curve and point of tangency not accessible.

Case 5: both point of intersection and point of curve not accessible.

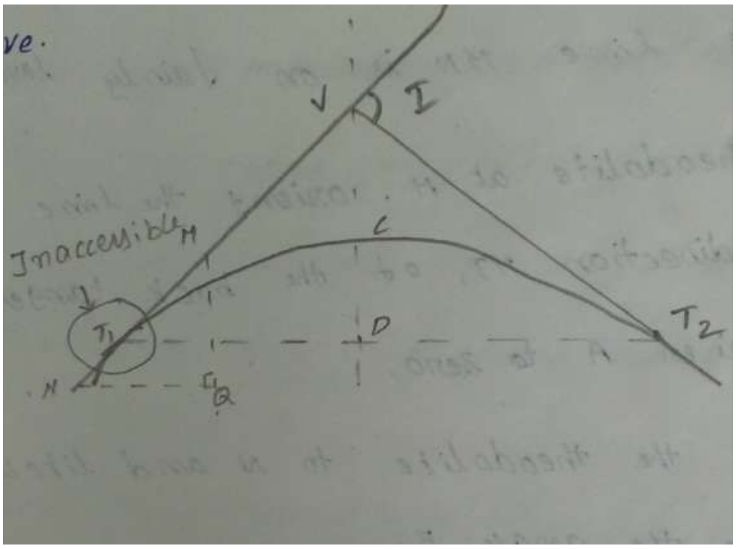
Case 1: point of intersection (v) not accessible.



The following procedure is used for setting out.

1. Fix two points M&N on tangents T_1 v & T_2 v, such that the two points are inter visible and the line MN is on fairly level ground.
2. Set up theodolite at M. orient the line of sight in the direction MT, of the back tangent. Set the Vernier A to zero.
3. Transfer the theodolite to N and likewise measure the angle B.
   Obviously the deflection angle I is equal to the sum of the angle α and β.
   $$I = \alpha + \beta$$
4. Measure the length of the line MN accurately by using steel tape.

Case 2: point of curve (T_1) not accessible

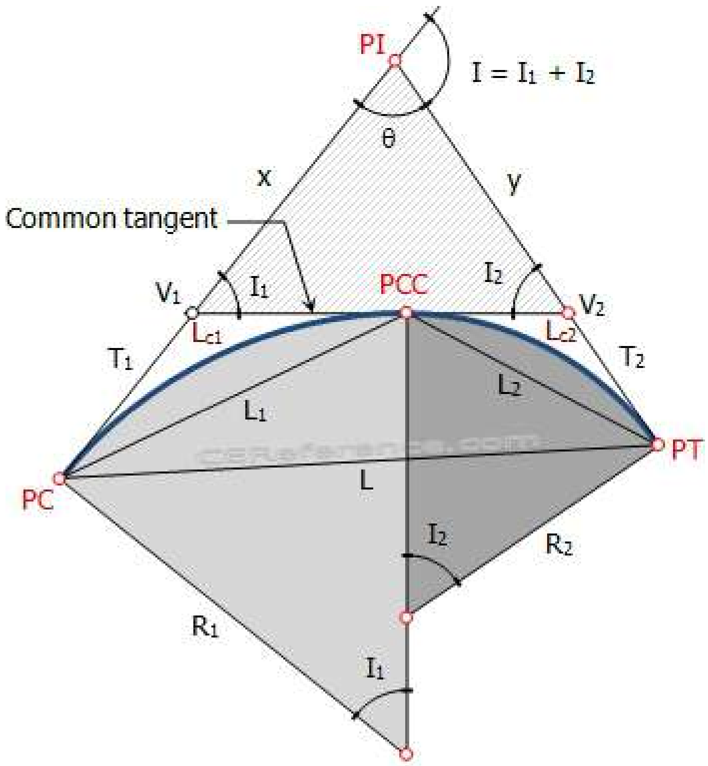


1. Select a point M on the line VT_1 near the point T_1, but clear of the obstruction.
2. Measure the distance VM & determine the distance T_1 M
   T_1 M = Tangent length (T)-VM
3. Select another point N on the line V T_1 produced, on the outer side of the obstruction. Determine the chainage of 'N' from the field record.
4. Select another point Q on one side of the line MN and measure distances MQ & NQ. Determine the length MN using any one of methods of chaining past the obstacles discussed surveying.
   If the angle MQN is a right angle

   MN =
5. Determine the chainage of T_1
   Chainage ofT_1 = chainage of N+MN- T_1 M
6. Determine the chainage of T_2 as
   T_2 = chainage of T_1 + length of curve
7. Set out the curve in reverse direction from the point T_2 , as a left hand curve.

Compound Curves

A compound curve consists of two (or more) circular curves between two main tangents joined at point of compound curve (*PCC*). Curve at *PC* is designated as 1 (R_1, L_1, T_1, etc) and curve at *PT* is designated as 2 (R_2, L_2, T_2, etc).



Compound Curves

Elements of compound curve

- *PC* = point of curvature
- *PT* = point of tangency
- *PI* = point of intersection
- *PCC* = point of compound curve
- T_1 = length of tangent of the first curve
- T_2 = length of tangent of the second curve
- V_1 = vertex of the first curve
- V_2 = vertex of the second curve
- I_1 = central angle of the first curve
- I_2 = central angle of the second curve
- I = angle of intersection = $I_1 + I_2$
- L_{c1} = length of first curve
- L_{c2} = length of second curve
- L_1 = length of first chord
- L_2 = length of second chord
- L = length of long chord from *PC* to *PT*
- $T_1 + T_2$ = length of common tangent measured from V_1 to V_2
- $\theta = 180° - I$
- x and y can be found from triangle V_1-V_2-PI.

L can be found from triangle *PC-PCC-PT*

Finding the stationing of *PT*

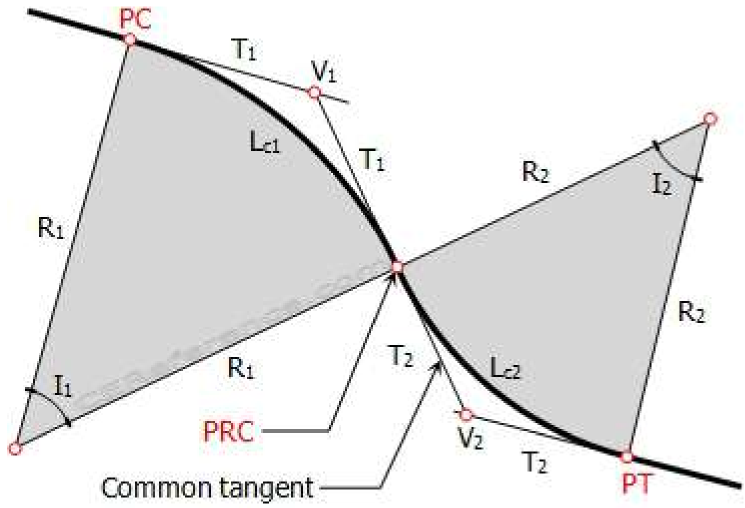
Given the stationing of PC = Sta PT = Sta PC+L_{c1}+L_{c2}

Sta PT = Sta PC+L_{c1}+L_{c2}

Given the stationing of PI = Sta PT=Sta PI−x−T_1+L_{c1}+L_{c2}

Reverse Curves

Reversed curve, though pleasing to the eye, would bring discomfort to motorist running at design speed. The instant change in direction at the *PRC* brought some safety problems. Despite this fact, reversed curves are being used with great success on park roads, formal paths, waterway channels, and the like.



Reversed Curves

Elements of Reversed Curve

- *PC* = point of curvature
- *PT* = point of tangency
- *PRC* = point of reversed curvature
- T_1 = length of tangent of the first curve
- T_2 = length of tangent of the second curve
- V_1 = vertex of the first curve
- V_2 = vertex of the second curve
- I_1 = central angle of the first curve
- I_2 = central angle of the second curve
- L_{c1} = length of first curve
- L_{c2} = length of second curve
- L_1 = length of first chord
- L_2 = length of second chord

- $T_1 + T_2$ = length of common tangent measured from V_1 to V_2