CE 104

Practical Surveying

(Lab Manual)



Department of Civil Engineering
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Lab OIC
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PREFACE

For many Civil Engineering project like building a house, constructing a dam, laying out a road, setting up of an industry etc., the first requirement is to have a plan/map of the area. To prepare a plan/map of any area, it is required to collect proper related information and data about the terrain as well as the objects present in that area by taking necessary measurements using different types of instruments. Data thus collected are being subsequently used to prepare the plan/map of the area.

The domain of engineering which involves the collection of field data and subsequently preparation of plan/map of the area is termed as 'Surveying'. Surveying is defined as the science of finding the relative position of different features on the surface of the earth. Different methods and instruments are being used to facilitate the work of surveying.

This course is designed to provide engineering undergraduates with basic understanding of the theory and practice of engineering surveying techniques. Students will apply the knowledge gained from theoretical surveying to practice. Fieldworks covered in this manual include chain surveying, plane table surveying, theodolite, traverse surveying, leveling, tachometry, curve setting, house setting, total station and GPS. It is hoped that students will gain valuable insight into surveying after completion of this course, which will also help them in their professional field.

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PRINCIPLES OF SURVEYING

The fundamental principles upon which the surveying is being carried out are

1. Working from whole to part.
2. After deciding the position of any point, its reference must be kept from at least two permanent objects or stations whose position have already been well defined.

The purpose of working from whole to part is

1. To localize the errors and
2. To control the accumulation of errors.

This is being achieved by establishing a hierarchy of networks of control points (Stations having known position). The less precise networks are established within the higher precise network and thus restrict the errors. To minimize the error limit, highest precise network (primary network) Fig.1 of control points are established using the most accurate / precise instruments for collection of data and rigorous methods of analysis are employed to find network parameters. This also involves most skilled manpower and costly resources which are rare and cost intensive.

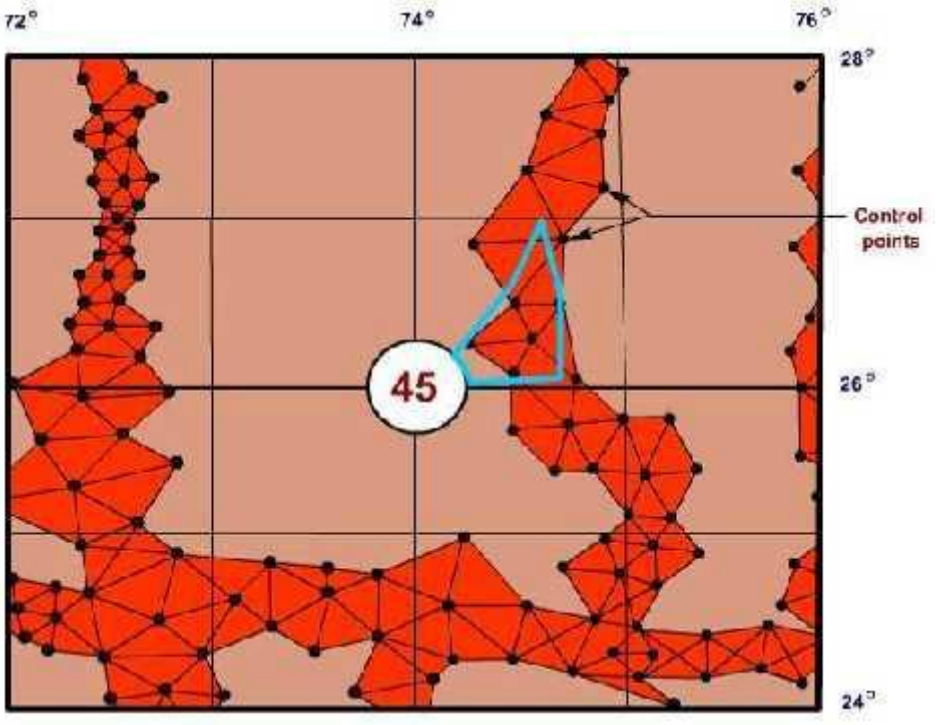


Fig.1 Network of control points

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Fieldwork No. 1
TRAVERSE SURVEYING



Objective: To survey a plot bounded by a polygon (a pentagon in this case).

Theory:
Traversing is a type of survey where the framework is formed by a number of connected survey lines. The directions of the survey lines are measured by a direction-measuring instrument (like theodolite), while the lengths are measured by a tape (or chain).

Bearing: The Bearing of a line is its direction relative to a given meridian and always measured in the clockwise direction.

Backward Bearing (B.B.): If the bearing of a line **AB** is measured from **B** toward **A**, it is known as **Backward Bearing** or **Back Bearing**.

Forward Bearing(F.B.): If the bearing of a line **AB** is measured from **A** toward **B**, it is known as **Forward Bearing** or **Fore Bearing**.

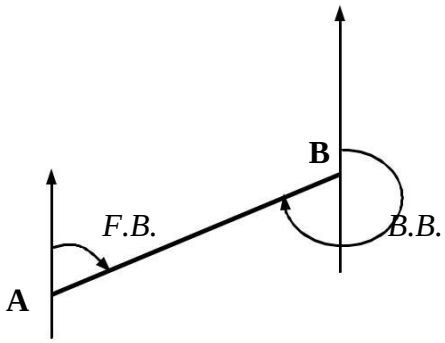


Fig. 5.1: Forward and Back Bearing

Closing Error:

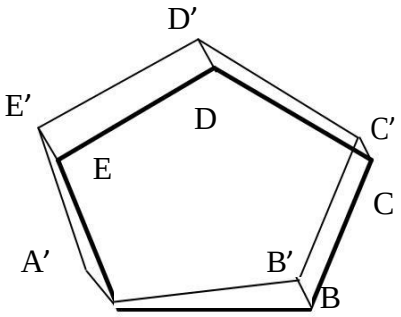
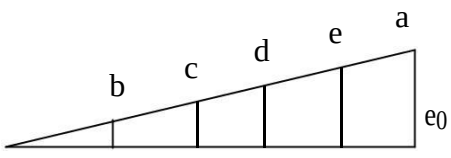


Fig 5.2 Closing error



A B′ C′ D′E′ A′

Fig 5.3: Correction of Closing Error

In Fig. 5.2, AB′C′D′E′A′ represents an unbalanced traverse with a closing error equal to AA′ since the first point A and the last point A′ are not coinciding.

In Fig. 5.3, AB′, C′D′, D′E′, E′A′ represent the length of the sides of the

traverse. Ordinate aA′ = Closing Error AA′

aA′ ‖ bB′‖cC′‖ dD′‖ eE′, also AA′ ‖ BB′‖CC′‖ DD′‖ EE′.
aA′ = e_0, bB′ = BB′, cC′ = CC′, dD′ = DD′, eE′ = EE′.

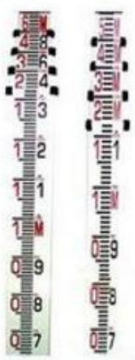
The polygon ABCDE so obtained represents the adjusted traverse.This is the Graphical method of closing error.

Instruments:

1. Theodolite
2. Staff Rod
3. Drawing Sheet
4. Drawing Board
5. Pencil.



Theodolite



Staff Rod

Fig. 5.4: Instruments Used in Theodolite Surveying

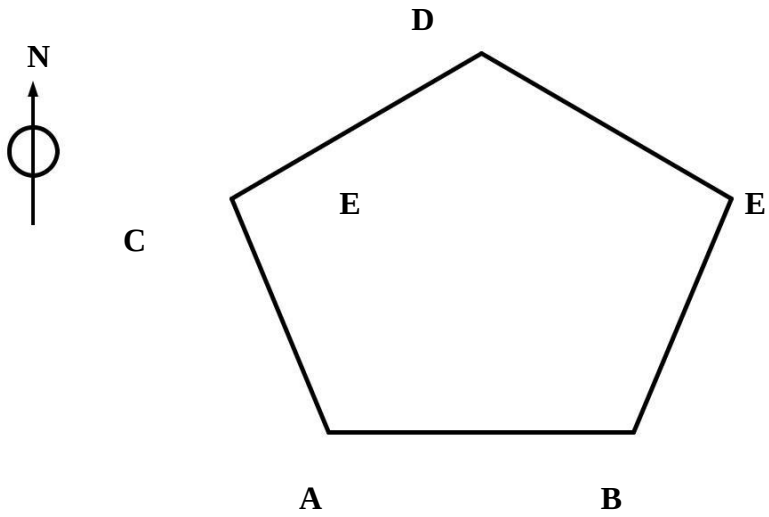


Fig. 5.5: Polygon Area

Procedure:

(i) Take forward bearing and backward bearing of line AB, BC, CD, DE and EA.
(ii) Make corrections for local attraction and plot the area in a drawing sheet.
(iii) Adjust the closing error by Graphical Method.

Line	Forward Bearing	Backward Bearing
AB		
BC		
CD		
DE		
EA		

Students should have clear concept regarding **whole circle bearing** and **reduced bearing**. Besides, students should know about **magnetic declination** and its effect on bearings. Moreover, the student needs to understand **true meridian, true bearing, magnetic meridian and magnetic bearing**. Furthermore, students need to grasp adequate knowledge regarding **latitude** and **departure**. All such concepts are covered in **CE 103 Surveying** theory course. Math problems may be used to assess student's knowledge regarding bearings, latitudes and departures

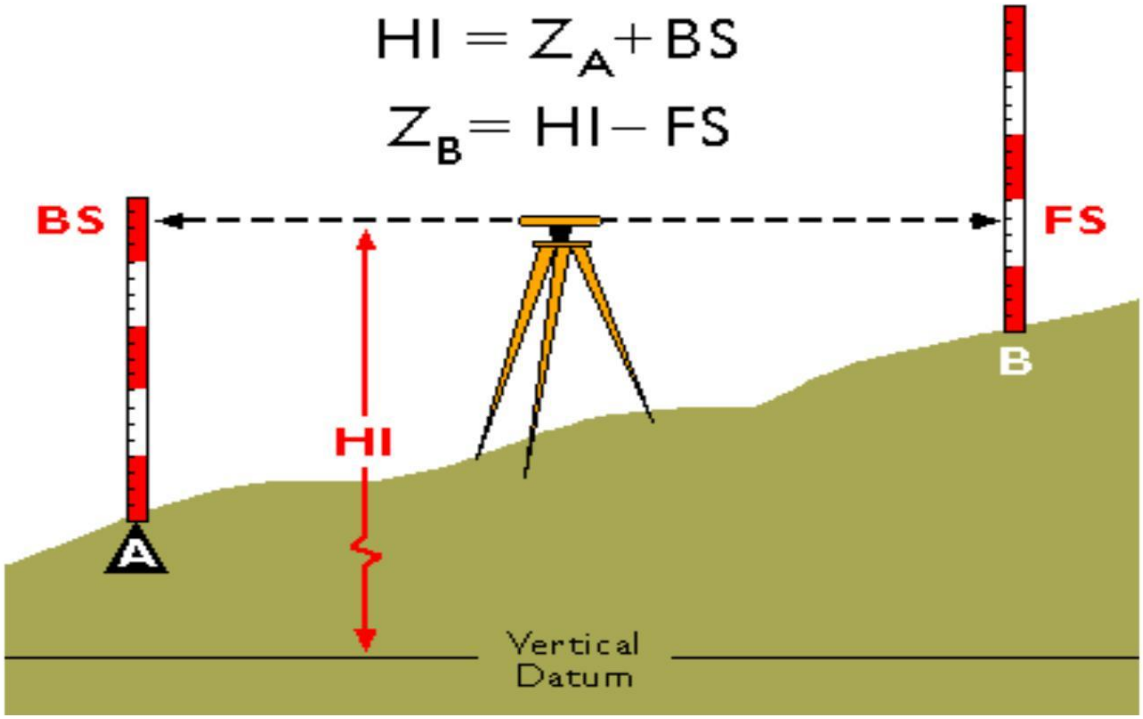
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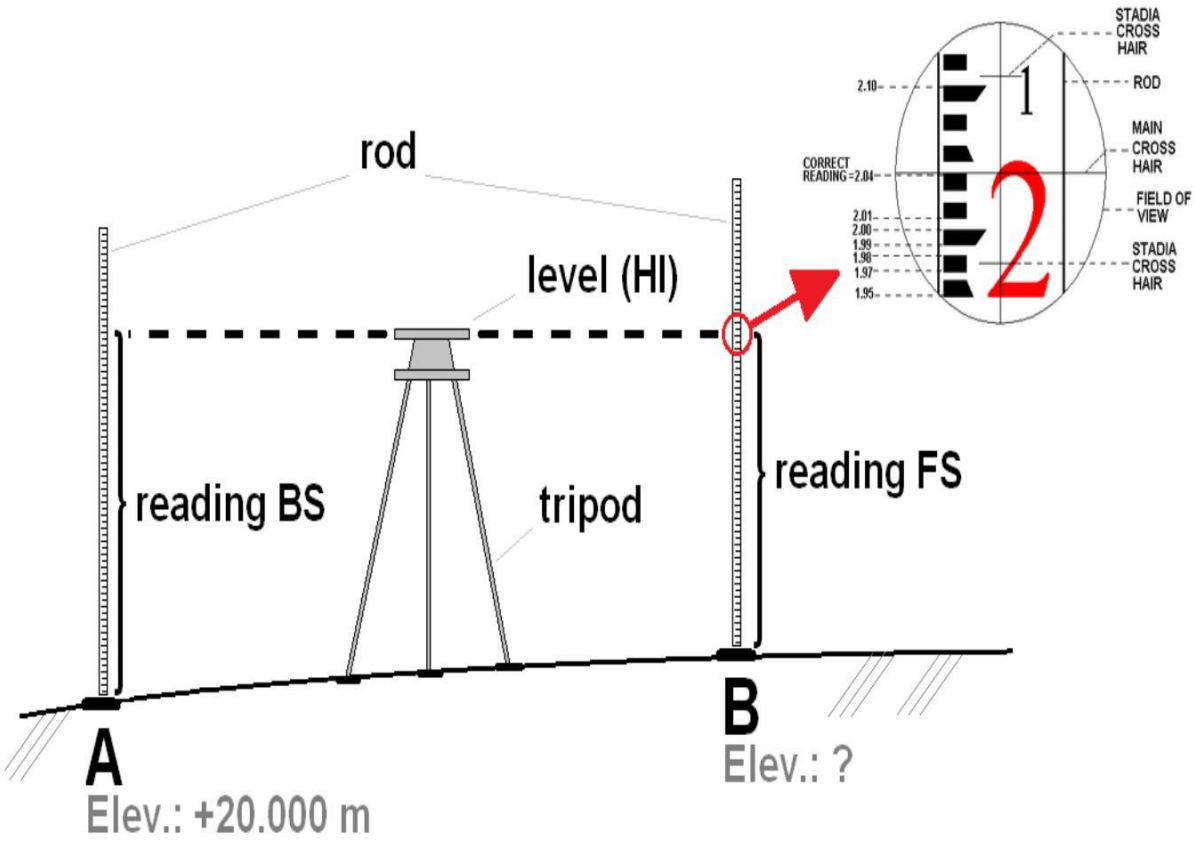
(i) Traverse chart of the area showing corrections for local attraction.
(ii) Plot of the area on a drawing sheet showing closing error by Graphical Method.

Bowditch Chart
Traverse Survey

	TRAVERSE CHART																											
	Instrument stations	Station observed	Length of side	Included angle	Correction	Corrected angle	Whole circle bearing	Reduced bearing	Cardinal direction	Consecutive coordinates								Corrected consecutive coordinates				Independent coordinates							
										Latitude				Departure				Latitude		Departure		Latitude		Departure					
										Northing	Corr.	Southing	Corr.	Easting	Corr.	Westing	Corr.	Northing	Southing	Easting	Westing	Northing	Southing	Easting	Westing				
	A	B F																										
	B	C A																										
	C	D B																										
	D	E C																										
	E	F D																										
	F	A E																										
	Sum																											
	Note: Second rule (Bowditch's rule) is applied for correction.									Difference				Difference														

Fieldwork No. 2
LEVELING/ROUTE SURVEYING





Objective:
To determine the reduced level of different points on the ground

Methodology:
1. Line of Collimation Method / Height of Instrument Method
2. Rise and Fall Method

Instrument:
1. Level
2. Leveling Staff
3. Tape or chain
4. Leveling field book (optional)



Fig. 4.1: Level

Definitions:
1. Mean Sea-Level: It is the average elevation of the surface of the sea. In Bangladesh, the mean sea-level at Cox's Bazar is taken as zero.

2. Datum: It is an imaginary surface with respect to which the heights of different points on the earth surface are determined.

3. Reduced Level: The reduced level of a point is its vertical distance above or below the datum.

4. Bench Mark: A bench mark is a fixed point on the ground of known elevation.

5. Height of the instrument: The elevation of the line of collimation above datum is termed as the height of the instrument.

6. Level Surface: Any surface parallel to the mean spheroid of the earth is called a level surface and the line drawn on the level surface is known as a level line.

7. Horizontal surface: Any surface tangential to the level surface at a given point is called a horizontal surface. It is the surface defined by the bubble tube.

8. Vertical Line: The vertical line is the plumb line at that point.

9. Station: A station is a point whose elevation is to be determined.

10. Change point/ Turning Point: It is an intermediate station on which two readings are taken while the position of the instruments is shifted.

11. Back, Inter and Fore readings: In any set up of the leveling instrument, the first staff reading on a station is termed as back reading (B.R.) and the last staff reading on a station is termed as the fore reading (F.R.) and the reading on the intermediate stations are termed as inter readings (I.R.)

Procedure:

1. Select any suitable place for setting up the instrument. Place the instrument and try to adjust it. Adjustment procedure should be consist of the followings,
   (a) Setting up the level (b) Leveling up (c) Elimination of parallax
2. Consider the station A as Bench Mark whose elevation is 7.00 m
3. Take staff reading at every station. Mind it at change point (station E) you have to take both back and fore readings.

Errors in Leveling:

1. Instrumental errors (level, bubble tube, staff)
2. Personal errors (errors in reading the staff, errors in recording and computing, errors in sighting and defective focusing, etc.)
3. Errors due to natural causes

Example of a Data Sheet:

Elevation of Bench Mark (B.M.): 7.00 m (which is the average elevation of Dhaka city)

Station	Distance (m)	Staff Reading at station			H. I.	Difference		Reduced Level (m)	Remarks
		Back (m)	Inter (m)	Fore (m)		Rise (m)	Fall (m)		
A	0								B.M.
B	15								
C	30								
D	45								
E	60								Change Point
F	75								
G	90								
H	100								

H.I.: Height of the Instrument

Assignments:

1. Find out the reduced levels of the above points by both methods,
   Group 1 : Line of Collimation Method
   Group 2 : Rise and Fall Method

2. Check your result using the following formula:

   = Total Rise – Total Fall
   = Last R.L. – First R.L.

3. Draw the profile of the earth surface through this points

4. If you want to make a road whose elevation is average of the minimum and maximum stations elevation, then show the filling and cutting areas by giving hatch lines on your graph.

5. Compare the two methods.

6. Viva-voce

Exam questions: Your exam questions will be given completely on your job.

FLY LEVELLING

Aim:

To find the reduced levels of the given stations by differential levelling.

Equipment and Accessories:

Automatic Level, levelling staff, Levelling book, pencil and eraser.

Principle:

In order to find difference of level between two points on the ground, it is necessary to establish a level surface above the two points and measure the vertical distance from it to the points. The difference between these measurements will give the difference in level between the points. It is possible to get a horizontal surface from the line of sight of a telescope adjusted into the horizontal position. This is done by any Leveling instrument.

Therefore by setting up a Leveling instrument at a suitable location on the ground it is possible to obtain difference between levels of two points. Automatic level is a very convenient Leveling instrument. When the difference in level between two points cannot be obtained by one set-up of Leveling instrument, it is necessary to repeat the process. This process of using a series of several set-ups of Levelling instrument to find the level difference between two distantly placed points is called fly Leveling.

Procedure:

1. Set-up the automatic level at point 'P' near to the Bench Mark (BM) (the R.L of BM is 100.000 m) as shown in figure and level the instrument.
2. Focus the telescope towards BM and bisect the staff correctly and take the back sight (BS) on it and record the reading in the Leveling book.
3. Keep the leveling staff at a convenient intermediate point(s) and take the intermediate sight (IS) and enter the reading.
4. Before shifting the instrument to the next station enter the last staff reading in the FS column.
5. Shift the instrument to the next station 'Q' and follow the steps from 3 to 4.
6. Calculate the Reduced levels by Height of Instrument Method and also by Rise and Fall Method which can be shown in Table 6 & 7 respectively.

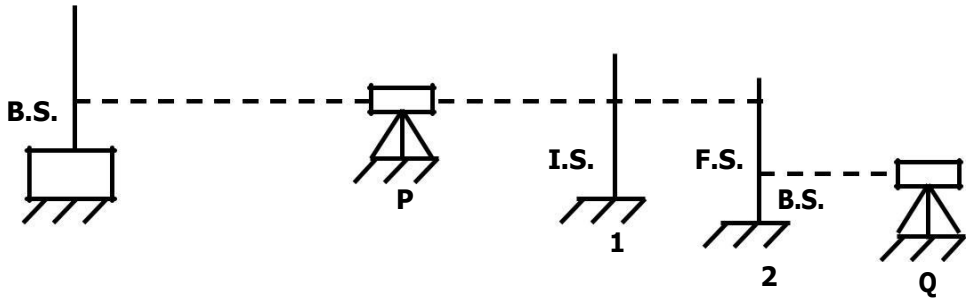


Fig.25 Fly leveling

Observations and Calculations:

TABLE - Height of Instrument Method

S. No.	Station	Sight to	B.S. (m)	I.S. (m)	F.S. (m)	H.I. (m)	R.L. (m)	Remarks

TABLE - Rise and Fall Method :

S. No.	Station	Sight to	B.S. (m)	I.S. (m)	F.S. (m)	Rise (m)	Fall (m)	R.L. (m)	Remarks

a) Height of Instrument Method:

Height of Instrument (H.I.)	=	R.L. of A.B.M. + B.S.
R.L. of a station	=	H.I. – I.S. or F.S.
Height of Instrument at C.P. (H.I.)	=	R.L. of C.P. + B.S.
R.L. of a station	=	R.L. of C.P. – I.S. or F.S.
CHECK : Sum of B.S. – Sum of F.S.	=	First R.L. – Last R.L.

b) Rise and Fall Method:

If the difference of successive observations is +ve, it indicates fall, otherwise it indicate rise.

R.L. of a station	=	R.L. of B.M. + Rise or (– Fall)
CHECK : Sum of B.S. – Sum of F.S.	=	Sum of Rise – Sum of Fall
	=	First R.L. – Last R.L.

LONGITUDINAL AND CROSS SECTIONING

Aim:

To plot the longitudinal section and cross section along a proposed alignment of a highway.

Equipment and Accessories:

Automatic Level, tripod, Levelling staff, chain, tape, cross staff, arrows, ranging rods, pegs, hammer, Levelling book, pencil and eraser.

Principle:

Profile Levelling is an operation to determine elevations of points spaced apart at known distances along a given line. The purpose of profile Levelling is to provide data from which a vertical section of the ground surface along a surveyed line can be plotted. Longitudinal sectioning and cross sectioning are examples of profile Levelling.

1. Longitudinal sectioning: to find out the elevations of the points on the ground at fixed intervals along the centre line of proposed sewer lines, pipelines, highways, railways, canals, etc.
2. Cross sectioning: to find out the elevations of the points on the ground at fixed intervals on either side and perpendicular to centre line of proposed highways, canals, etc.

Procedure:

1. Establish points on the ground at fixed interval say 5 m along the proposed centre line of the highway by direct ranging and fix arrows as shown in figure given below.
2. Establish perpendicular lines on either side of the proposed centre line of the highway using cross staff as shown in figure given below.
3. Along the perpendicular lines that are established in the previous step fix arrows on the ground at a fixed interval say 2 m as shown in figure given below.
4. Carry out differential Leveling to find the R.Ls of every arrow point and enter the readings in table.
5. Calculate the R.Ls of all the points.
6. Draw the longitudinal section along the centre line of the proposed highway to a suitable scale.
7. Draw cross section in the transverse direction at each chainage point along the centre line of the proposed highway to a suitable scale.

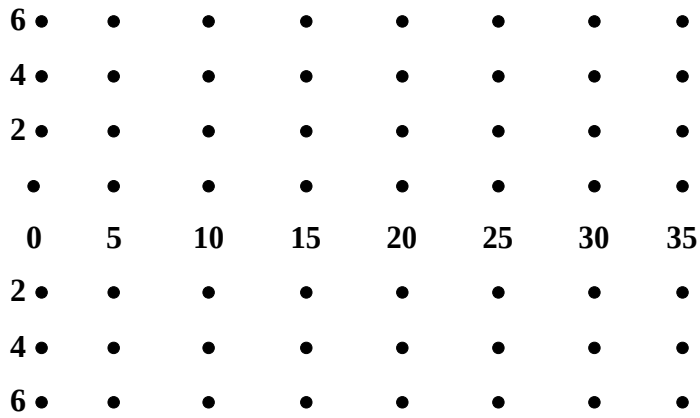


Fig.26 Longitudinal and cross sectioning

Observations and Calculations:

TABLE

S. No.	Chainage of centre line	Chainage Left C.S.	Chainage Right C.S.	B.S. (m)	I.S. (m)	F.S. (m)	H.I. (m)	R.L. (m)	Remarks

Height of Instrument = R.L. of B.M. + B.S.

R.L. of each arrow point = H.I. – I.S. or F.S.

Result:

Profile of the centre line of the proposed highway and various cross sections along the centre line of the proposed highway are shown on the drawing sheet.

Fieldwork No. 3
HOUSE SETTING



Objective:

To mark the excavation lines, centre lines of all the columns of the plan of a proposed building on the actual site of work as per plan of the building to facilitate earth cutting.

Requirements:

Detailed plan and drawings of the building and site plan of the area are required. Site plan and detailed plan should be studied thoroughly. These drawings are commonly known as “Foundation Trench Plan” or “Lay-out Plan”.

Materials required:

1. Strings
2. Wooden Pegs
3. Lime powder

Procedure:

1. First locate any back corner on the ground of the plan.
2. Then establish the two lines intersect at that point by inserting pegs on the ground at some distances (say 6 ft). Check with 3-4-5 rule.
3. Fixed other two exterior lines.
4. Check the diagonals after fixing the perimeter of the building.
5. All the pegs lie on the column line are driven at equal distances
6. Intersection of rope indicates the position of the column.
7. Mark the excavation lines on the ground with the help of lime powder.
8. Check the diagonals of all grids and adjust if necessary.
9. Mark the plinth level
10. From the plinth level fixed the depth of the footings by using water level at two points.

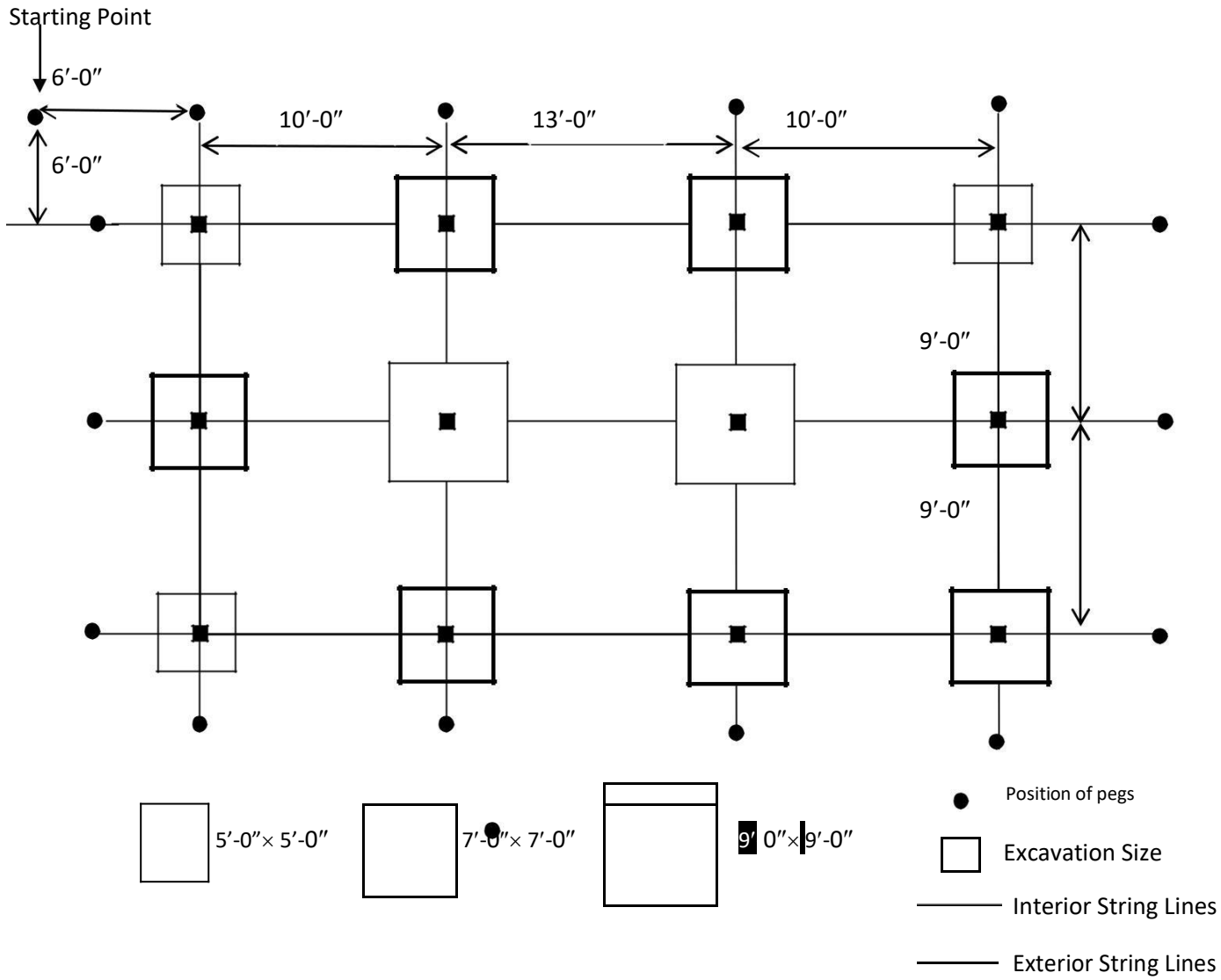


Fig. 5.1: Foundation Trench Plan

Fieldwork No. 4

SETTING OUT A SIMPLE CIRCULAR CURVE ON THE FIELD

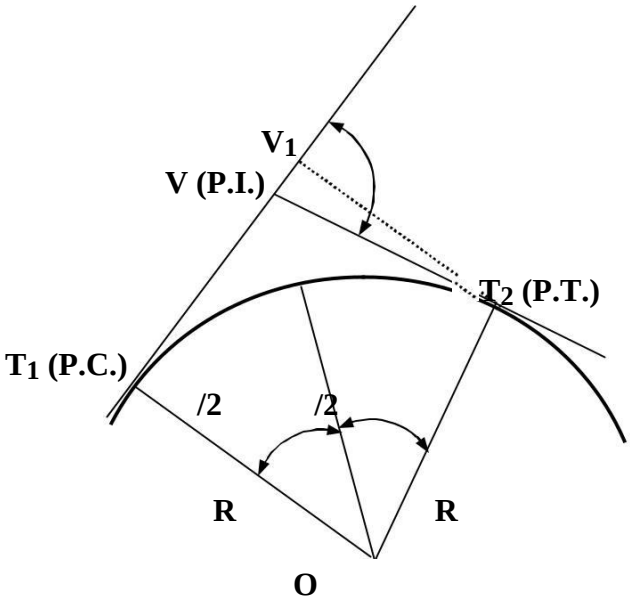


Objective: Setting out a simple circular curve in the field by a linear method and checking it by an angular method.

Theory:

Curves are generally used on highways and railways where it is necessary to change the direction of motion. A curve may be circular, parabolic or spiral and is always tangential to the two straight directions. There are three types of circular curves: (i) Simple Curve, (ii) Compound Curve and (iii) Reverse Curve.

Simple Curve: A simple curve is the one that consists of a single arc of a circle.



T_1 = Point of Curve (P.C.)

T_2 = Point of Tangency (P.T.)

V = Point of Intersection (P.I.)

= Intersection or Deflection Angle

D = Degree of Curvature

Radius of Curvature, R = 5730/D

Length of Curve, l = 100 /D

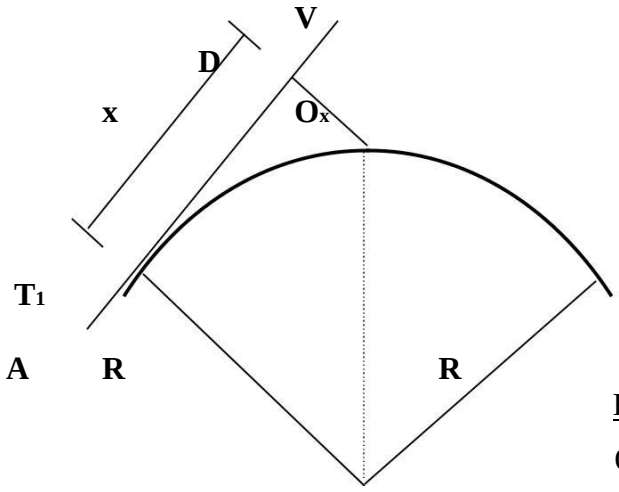
Super-Elevation, e = B (s f)/(1+ s f)

where s = v^2/gR, f = Friction Factor, v = Maximum speed of vehicle, g = Acceleration due to gravity

Fig. 6.1: Elements of Simple Circular Curve

Depending on the instruments used, there are two main methods for setting out of Simple Curves; i.e., (i) Linear methods and (ii) Angular methods.

One of the linear methods is by **Perpendicular Offsets from Tangents**



Perpendicular Offset, $O_x = R - \sqrt{(R^2 - x^2)}$

x = Distance along the tangent from P.C.

R = Radius of Curvature

$T_1V = R \tan(\ /2)$

$T_1V_1 = R \sin(\ )$

Fig. 6.2: Linear Method by Perpendicular Offsets from Tangents

One of the angular methods is **Rankine's Method of Tangential (or Deflection) Angle**.

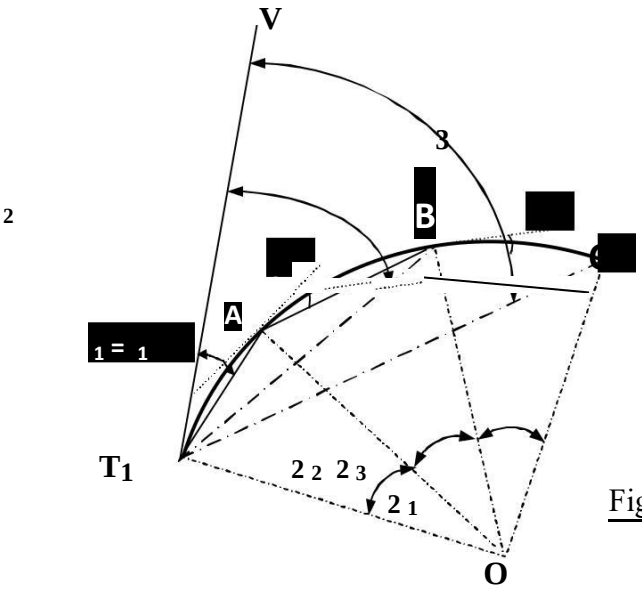


Fig. 6.3: Angular (Rankine's) Method

T_1V = Rear Tangent

$_1$, $_2$, $_3$ …..= The Deflection angles or the angles which each of the successive cords T_1A, AB, BC….. make with the respective tangents to curve at T_1, A, B, C…...

$_1$, $_2$, $_3$….. = Total tangential angles or the deflection angles to points A, B, C…...

C_1, C_2, C_3 …..= Lengths of the cord T_1A, AB, BC…..…..

$_1 = 1718.9\ C_1/R$ min, $_2 = 1718.9\ C_2/R$ min, $_3 = 1718.9\ C_3/R$ min…...

$_1 = 1$, $_2 = _1 + 2$, $_3 = _2 + _3$ …….. $_n = _{n-1} + _n$

Instruments:

Theodolite, Rope, Pegs (e.g., bamboo, steel), Tape.

Procedure:

Method of Perpendicular Offsets from Tangents

(i) Measure distances x_1, x_2, x_3 …..…… from the first tangent point T_1 along the tangent

(ii) Set perpendicular offsets O_x at the corresponding point.

(iii) Set the Super-elevation along the road width.

Check by Rankine's Method of Tangential Angle

(iv) Set the theodolite at T_1 along the back tangent VT_1

(v) Rotate it to the pegs at A, B, C……, measure the successive cord distances C_1, C_2, C_3 …… and deflection angles $_1$, $_2$, $_3$ ……..

(vi) Compare the deflection angles with the calculated deflection angles.

Data: Deflection angle, Degree of curvature, Cord interval for circular curve, Super-elevation, Road width, Maximum speed of vehicle.

Submission:

Detailed calculation for necessary data and drawing using

(i) Perpendicular offsets from tangents, (ii) Rankine's Method

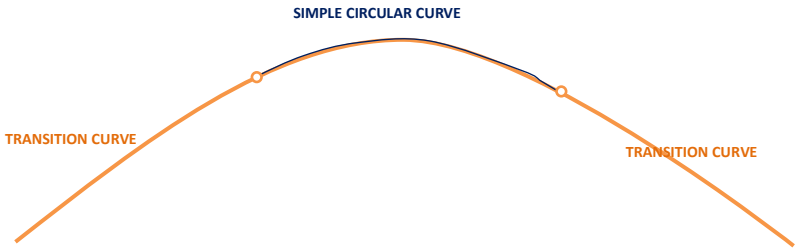
Fieldwork No. 5

SETTING OUT TRANSITION CURVE ON THE FIELD

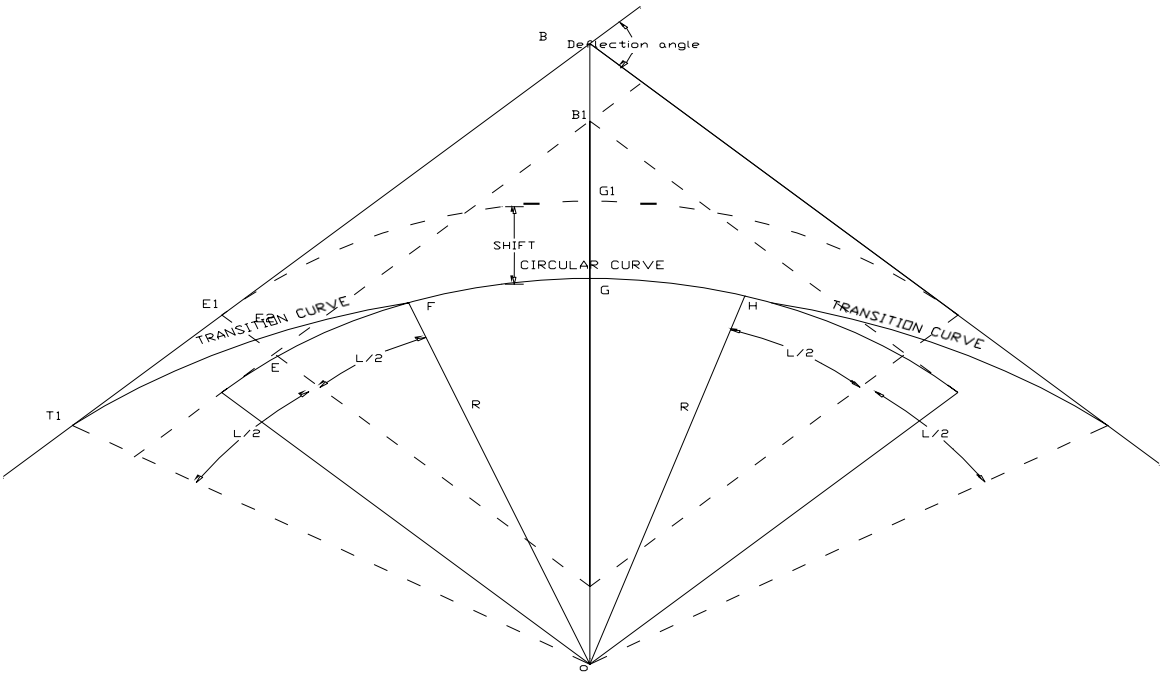
Objective: Setting out of simple transition curve by tangential angle methods

THEORY

- A curve of varying radius is known as Transition Curve.
- Radius for such a curve varies from infinity to a certain fixed value.



- Transition curve is provided on both ends of Simple Circular Curve.
- The curvature varies from zero at the tangent point to a definite value just at the junction which is circular curve.
- Transition curves are provided in railway tracks to ensure safe running of trains.



Instruments:

Theodolite, Rope, Pegs (e.g., bamboo, steel), Tape.

Procedure for setting out a transition curve and circular curve by tangent offsets method.

1) Locate the tangent point T_1 .
2) Calculate the offsets for the transition curve by formula perpendicular offset

   $'y' = \frac{x^3}{6RL}$ where x is measured along the tangent T1B and Tangential offset

   $'y' = \frac{x^3}{6RL}$ where l is measured along the curve.
3) Starting from the point T1, with the help of tape and chain calculated perpendicular offsets or tangential offsets such as y_1, y_2, y_3----------at a length of
   x_1, x_2, x_3----------or l_1, l_2, l_3---------are laid at the end of the chainages x_1,x_2 ---------- or l_1, l_2 ------- likewise the junction point F is located. The number of chord in which the length of transition curve is divided depends on the length of the transitioncurve.
4) **Check: -** at x=L/2, the transition curve bisects the shift and at x=L the perpendicular Offset=4s.
5) The process is repeated to layout the other transition curve from T_2.
6) The circular curve between the point F and H laid in the same manners as explained in laying simple circular curve.

SHIFT OF CURVE

When a transition curve is introduced in a circular curve, the circular curve is found to be shifted by some distance towards the center.

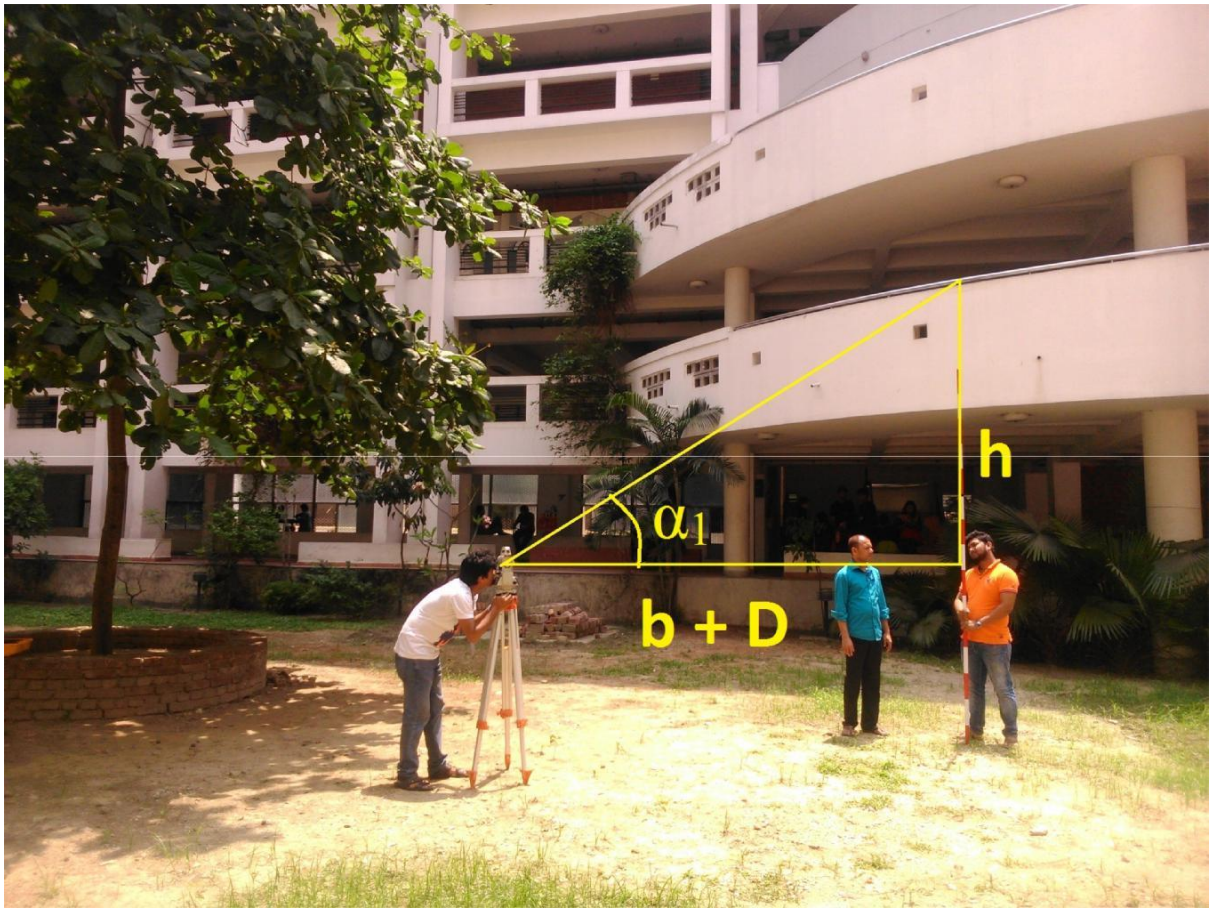
1. Checks of Total Deflection Angle
   1. $R = L_t + 1/3\ \Phi$
   2. Total Deflection Angle = ½ (Central Angle)

Submission:

Detailed calculation for necessary data and drawing using
(i) Perpendicular offsets from tangents, (ii) Rankine's Method

Fieldwork No. 6

HEIGHT MEASUREMENT



Objective: To determine the height of a tower by Trigonometric Leveling.

Instrument:

1. Theodolite
2. Staff
3. Measuring Tape
4. Arrow/ peg
5. Ranging rod

Base of the object inaccessible: Instrument stations in the same vertical plane as the elevated object

If the horizontal distance between the instrument and the object can be measured due to obstacles etc., two Instrument stations are used so that they are in the same vertical plane as the elevated object.

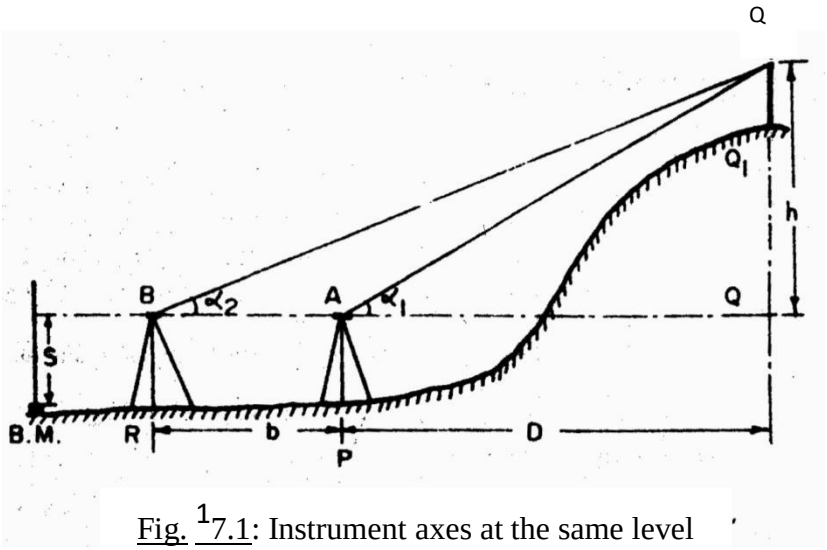


Fig. 7.1: Instrument axes at the same level

Procedure:

1. Set up the theodolite at P and level it accurately with respect to the altitude bubble.

2. Direct the telescope towards Q and bisect it accurately. Clamp both the plates. Read the vertical angle a

3. Transit the telescope so that the line of sight is reversed. Mark the second instrument station R on the ground. Measure the distance RP accurately.

Repeat steps (2) and (3) for both face observations. The mean values should be adopted.

4. With the vertical vernier set to zero reading, and the altitude bubble in the centre of its run, take the reading on the staff kept at the nearby B.M.

5. Shift the instrument to R and set up the theodolite there. Measure the vertical angle $_2$ to Q with both face observations.

6. With the vertical vernier set to zero reading, and the altitude bubble in the centre of its run, take the reading on the staff kept at the nearby B.M.

In order to calculate the R.L of Q, there can be three cases:

(a) When the instrument axes at A and B are at the same level.

(b) When they are at different levels but the difference is small, and

(c) When they are at very different levels.

Only Case (a); i.e., Instrument axes at the same level (Fig. 7.1) is considered in this work

Let h = QQ

$_1$= Angle of elevation from A to Q

$_2$ = Angle of elevation from B to Q

S =staff reading on B.M., taken from both A and B, the reading being the same in both the cases.

b = horizontal distance between the instrument stations.

D = horizontal distance between P and Q

From triangle AQQ , h= D tan $_1$ ……..(9.1)

From triangle BQQ , h= (b + D) tan $_2$ ……..(9.2)

Equating (9.1) and (9.2) D tan $_1$ = (b + D) tan $_2$

D = b tan $_2$/(tan $_1$ tan $_2$) ……..(9.3)

h = D tan $_1$ = b tan $_1$ tan $_2$/(tan $_1$ tan $_2$) ……..(9.4)

R.L. of Q = R.L. of B.M. + S + h

Data Sheet:

Reduced level of bench mark: 0.00 m

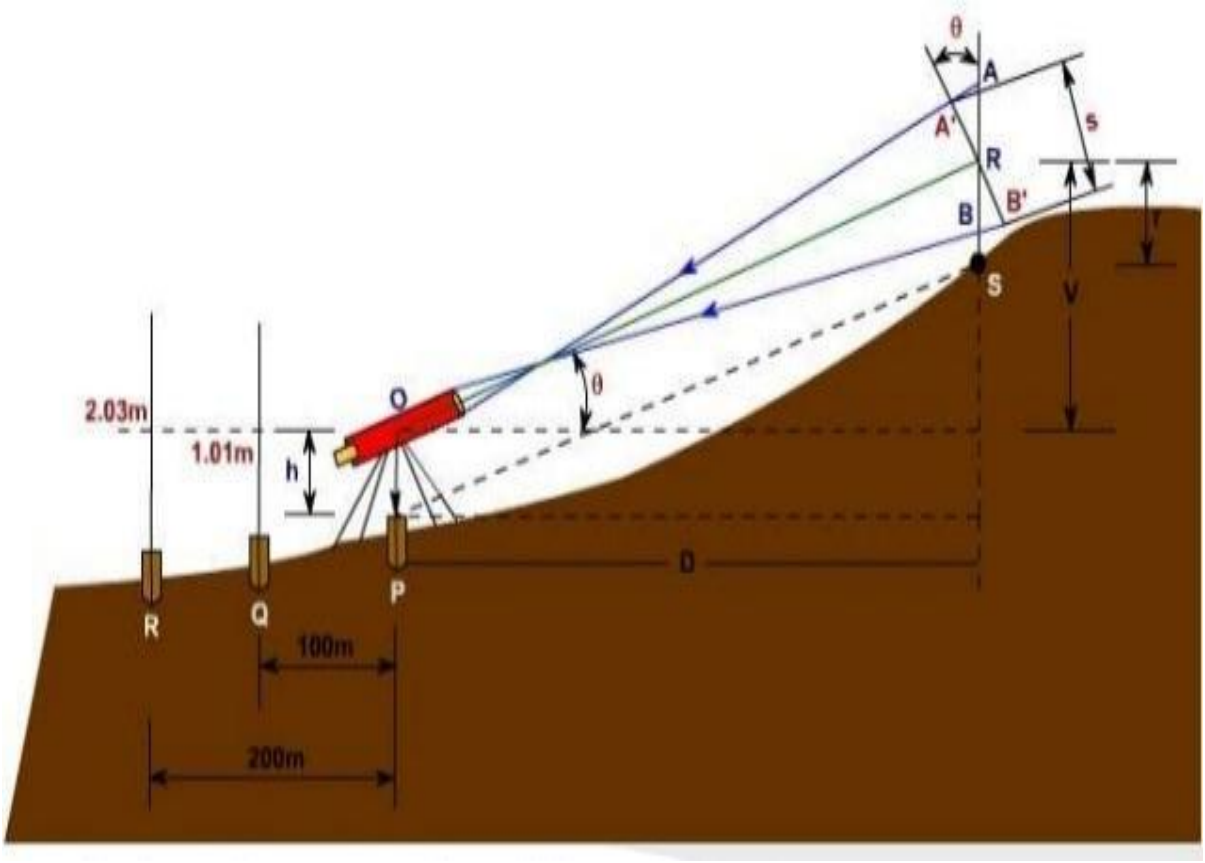
Sl. No	Parameters	Value
01		
02		
03		
04		
05		
06		

Assignments:

1. Height of the building.
2. Height of the flagpole.
3. Compare your result with the actual values.
4. Write some benefits of this method

Fieldwork No. 7

STADIA SURVEY/ TACHEOMETRY



Tacheometry is the type of surveying in which vertical and horizontal distances are computed from stadia readings without using chain or tape. This is done by the help of a special type of transit theodolite known as tacheometer and a staff known as stadia rod.

Stadia:

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.

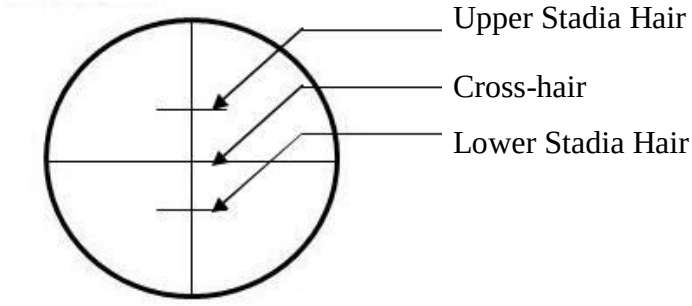


Figure 7.1: Stadia Diaphragm

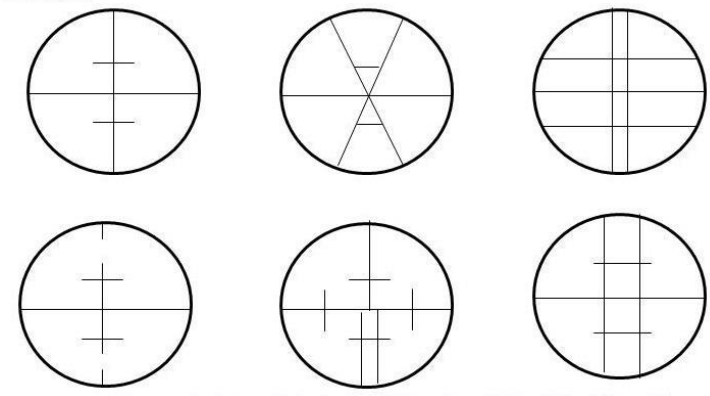


Figure 7.2: Different forms of stadia commonly used

Principle of Tacheometry:

In stadia tacheometry, the line of sight of the tacheometer may be kept horizontal or inclined depending upon the field conditions. In the case of horizontal line of sight, the horizontal distance between the instrument at A and the staff at B is

$$D = (f/i)S + (f+d)$$

$$D = K S + C$$

The value of (f + d) is called the additive constan, i.e. C; while (f/i) is called the multiplying constant, i.e. K.

Tacheometry can be used on horizontal or inclined sights. This lecture focuses on horizontal sights.

Tacheometric Equation for Horizontal Sights:

$D = KS + C$

S= Staff intercept = $S_T - S_B$, where S_T and S_B are the top hair and bottom hair readings respectively.

K = Multiplying constant of the tacheometer.

C = Additive constant of the tacheometer

D = horizontal distance between the instrument at A and the staff at B

Operating principle of a tacheometer:

In a theodolite, if two additional wires are placed symmetrically on either side of the horizontal cross-hair, the horizontal distance and vertical difference in height from the centre of the instrument to the staff point can be found out without actually measuring it. Such a diaphragm with additional horizontal wires is called a stadia diaphragm. The constant of the instrument depends upon the stadia interval, i.e. the interval between the two stadia wires. Normally, there are two constants.

i. The multiplying constant (K), normally kept at 100 or 150.
ii. The additive constant (C), the value of which varies from 20 to 30 cm. This value is greater in external focusing telescopes and smaller in internal focusing telescopes and sometime quite negligible. By imposing an additional lens in the telescope, the additive constants can be reduced to zero. Such a lens is called an anallactic lens.

By observing the vertical angels, if any, from the instrument to the staff point, the horizontal distances and vertical height can be computed by applying proper equations.

Determination of Tacheometric Constants:

Set up the instrument on fairly level ground giving horizontal sights to a series of pegs at known distances, D, from the instrument. Now, using the equation D = KS + C.

For example,

Distance measured (ft)	Stadia Readings (cm)
50	135.5, 128, 120.5
75	140.5, 129, 118

For the 1st observation, distance measured, D_1 = 50 ft = 1524 cm & staff intercept (difference in readings between upper and lower stadia hair), S_1 = 135.5 – 120.5 cm = 15 cm.

$D_1 = KS_1 + C$ >>1524 = K (15) + C……(i)

For the 2nd observation, distance measured,

$D_2 = KS_2 + C$ >>2286 = K (22.5) + C …….(ii)

Solving the above two equations gives K = 101.6 and C = 0

So, **D = 101.6 * S**

Anallactic lens: Am additional lens is sometimes placed between the object glass and the eye piece of the telescope on order to eliminate the additive constant (f+d). This is done to make the expression for the distance D between instrument station and staff position more simplified. The anallactic lens is provided only in an external focusing telescope, but not in the internal focusing one, which is virtually anallactic since the value of (f+d) is very small. This arrangement simplifies the calculation of heights and distances from field book, specially for inclined sights. But the drawback is that it reduces the brilliance/ refulgence of the image due to absorption of light.

Problem sums:

Problem (1): Calculate the tacheometric constants from the following observations:

Distance measured (ft)	Staff Intercepts
200	1.988
300	2.991

Answer: 100 and 1

Problem (2): A tacheometer was placed with its axis horizontal 5.10 ft above a station A whose RL is 320 ft. staff was held at b vertically and the stadia readings were 4.50, 6.50 and 8.50. Calculate the distance between A and B and the R.L. of B. Given, f/i = 100 and f + d = 1.

Answer: 401 ft; 318.60 ft.

Problem (3): Calculate the tacheometric constants from the following observations:

Distance measured (ft)	Staff Intercepts
400	3.98, 5.975, 7.97
600	5.76, 8.755, 11.75

Answer: 100 and 1

Problem (4): A tacheometer was placed over a station whose reduced R.L. is 100.00, stadia readings were taken on another point with the staff vertical and the telescope horizontal. The readings were 4.28, 5.88 and 7.48. The height of the instrument axis over the station was 5.30 ft and the values of 9F+d) and F/I were 1 and 100 respectively. Calculate the R.L. of the staff station and the distance between the staff position and the instrument station.

Answer: 99.42 ft; 321 ft.

Fieldwork No. 8

CONTOURING



Objective: To draw a contour map

Methodology: Square or Grid System

Instruments:

1. Level
2. Leveling Staff
3. Arrows
4. Tape

Definitions:

1. **Contours:** Contours are imaginary lines joining points of equal altitudes upon the earth's surface with reference to a fixed datum.

2. **Contouring:** The process by which a contour map is prepared is known as contouring.

3. **Contour map/topographic map:** The map showing the altitudes of all these points is called contour map or topographic map.

Procedure:

1. Select any suitable place for setting up the instrument. Place the instrument and try to adjust it. Adjustment procedure should be consist of the followings,
   (i) Setting up the level (ii) Leveling up (iii) Elimination of parallax

2. Mark an area of 100 m^2; i.e., length 10 m and width 10m.

3. Take staff reading at every station at an interval of 2.5 m. (e.g. 2.5 m × 2.5 m grid). The grid points are determined using tape, and marked using arrows.

4. Take the elevation of top left corner as 7.00 m (A-1) which may be considered as bench mark.

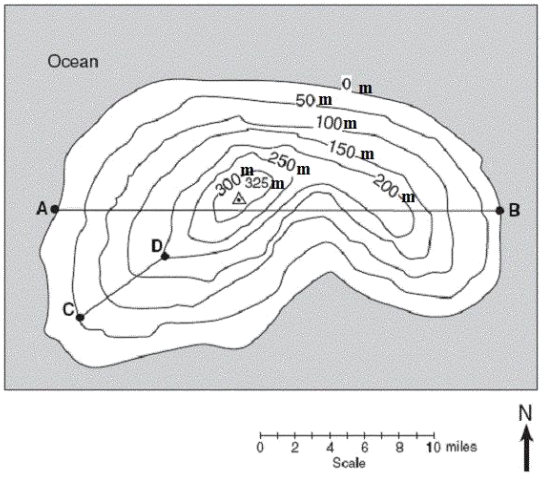


Fig. 9.1: Typical Contour Diagram

Data Sheet:

Station	Distance (m)	Staff Reading at station			H. I.	Difference		Reduced Level (m)	Remarks
		Back (m)	Inter (m)	Fore (m)		Rise (m)	Fall (m)		
A1									B.M.
A2									
A3									
A4									
A5									
B1									
B2									
B3									
B4									
B5									
C1									
C2									
C3									
C4									
C5									
D1									
D2									
D3									
D4									
D5									
E1									
E2									
E3									
E4									
E5									

Contour Map:

Assignments:

1. Find out the reduced levels of each points by any methods
2. Draw contour lines of 0.1 m interval
3. Draw the contour map using EXCEL
4. Viva –voce

Fieldwork-10

GLOBAL POSITIONING SYSTEM (GPS)











Objective: To plot a small area using GPS measurements.

Theory:

The Global Positioning System (GPS) is a satellite-based navigation and surveying system for determination of precise position and time, using radio signals from the satellites, in real time or in post-processing mode. The NAVSTAR Global Positioning System is a satellite based navigation system being developed and maintained by the DoD since 1972, for providing extremely accurate 3-D position fixes and UTC information to properly equipped users anywhere on or near the Earth, at any time, regardless of weather conditions. The system consists of three segments: Space Segment, Control Segment and User Segment. The satellites continuously transmit dual frequency navigation signals consisting of information of satellites position with time tag, along with other data, which is periodically uploaded in satellite memory from the Control Segment. The User Segment receives navigation signals from at least 4 satellites, available any time globally, allowing the user to simultaneously solve 4 independent range-difference equations to yield his position - latitude, longitude and height and also the time.

GPS Segments: The Global Positioning System basically consists of three segments: the Space Segment, The Control Segment and the User Segment.

1. Space Segment

The Space Segment contains 24 satellites, in 12-hour near-circular orbits at altitude of about 20000 km, with inclination of orbit 55°. The constellation ensures at least 4 satellites in view from any point on the earth at any time for 3-D positioning and navigation on world-wide basis. The three axis controlled, earth-pointing satellites continuously transmit navigation and system data comprising predicted satellite ephemeris, clock error etc., on dual frequency L1 and L2 bands (see Figs. 1 & 2).

2. Control Segment

This has a Master Control Station (MCS), few Monitor Stations (MSs) and an Up Load Station (ULS). The MSs are transportable shelters with receivers and computers; all located in U.S.A., which passively track satellites, accumulating ranging data from navigation signals. This is transferred to MCS for processing by computer, to provide best estimates of satellite position, velocity and clock drift relative to system time. The data thus processed generates refined information of gravity field influencing the satellite motion, solar pressure parameters, position, clock bias and electronic delay characteristics of ground stations and other observable system influences. Future navigation messages are generated from this and

loaded into satellite memory once a day via ULS which has a parabolic antenna, a transmitter and a computer. Thus, role of Control Segment is: - To estimate satellite [space vehicle (SV)] ephemerides and atomic clock behaviour. - To predict SV positions and clock drifts. - To upload this data to SVs.

3. User Segment

The user equipment consists of an antenna, a receiver, a data-processor with software and a control/display unit. The GPS receiver measures the pseudo range, phase and other data using navigation signals from minimum 4 satellites and computes the 3-D position, velocity and system time. The position is in geocentric coordinates in the basic reference coordinate system: World Geodetic reference System 1984 (WGS 84), which are converted and displayed as geographic, UTM, grid, or any other type of coordinates. Corrections like delay due to ionospheric and tropospheric refraction, clock errors, etc. are also computed and applied by the user equipment / processing software.

Significance:

Through this fieldwork, students will learn about taking data using a GPS receiver and using that data to plot surveyed areas as well as make other calculations including area of that place. Surveying Surveyors are responsible for mapping and measuring features on the earth's surface and under water with high accuracy. This includes things like determining land boundaries, monitoring changes in the shape of structures or mapping the sea floor. Surveyors have historically required line-of-sight between their instruments in order to undertake such work, but the availability of high accuracy GPS receivers has reduced the need for this. GPS can either be setup over a single point to establish a reference marker, or it can be used in a moving configuration to map out the boundaries of various features. This data can then be transferred into mapping software to create very quick and detailed maps for customers.

Instruments:

1. Antenna and cables
2. Batteries and power cables
3. Tripods, tribrachs and adapters
4. Tape measures
5. Flashlights
6. Radios

7. Station log sheets
8. Writing apparatus (pens)
9. Station descriptions
10. Observing schedule and station lists
11. Special equipment required
12. Traffic cones, safety equipment
13. Maps, keys, lock combinations.

Procedure:

1. Reconnaissance for a GPS Survey.
2. Antenna is set up. Check that tripod is stable. Weights, such as sand bags, must be used to stabilize legs on hard paving surfaces. Check that antenna/tribrach is level.
3. Keep signal path clear; heads, trucks, etc. Check for reflective objects (e.g. any nearby vehicles).
4. Orient the phase center offset.
5. Follow the manufacturer's recommended procedure for determining the antenna height. Make at least two antenna height measurements per session. Verify the height at the end of station occupation. Measure the antenna height in meters and preferably in feet as well.
6. Operate the receiver following the instructions of the instructor.
7. Initialize the session according to the requirements of the survey method utilized.
8. Key in all necessary station and session related information.
9. Coordinate the length of the session with other stations.
10. If other stations are not ready, you may start observing early.
11. Check receiver and antenna frequently during observations. Check for power loss, tripod movement, etc. Record weather data and note any drastic changes during sessions. Monitor data logs and note unusual occurrences during sessions.

Reconnaissance for a GPS Survey:

Reconnaissance is one of the most important parts of a GPS survey. For the actual collection of GPS data, the observing station must have a clear view of the sky when satellites are passing over the job site. Steps involved in a typical GPS reconnaissance include:

a. Mark the general area where GPS control points are to be located on maps or aerial photographs.

b. Visit the job site and select the best location for the control point.
c. Using a "Station Visibility Diagram," locate and record all obstructions exceeding 20 degrees above the horizon, as well as any radio frequency (RF) sources. Ideal tools for this are a compass and an Abney level.
d. Using the station visibility diagrams and a skyplot of visible satellites at the time the GPS survey is to take place, the proper observing session can be planned for each station.

Methodology – Point positioning:

In point positioning, coordinates of the antenna position at an unknown point are sought with respect to the WGS84 reference frame. In this method, the known positions of the tracked GPS satellites (the position of a satellite can be computed from ephemerides) are being used to determine the position of unknown point using single GPS receiver by a method similar to the method of resection used in plane table surveying (Fig. 10.1).

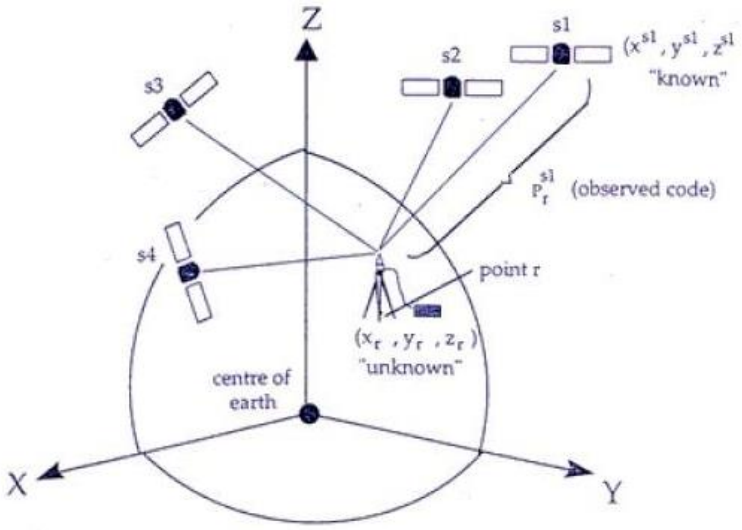


Figure 10.1: Point Positioning of GPS receiver

In this figure, s1, s2, s3 and s4 represent four different satellites (least required) being tracked. The positions of these satellites are referenced to the centre of the earth in the X, Y, Z coordinate frame. The coordinates for s1 are shown as (xs1, ys1, zs1). The coordinates of r, the unknown point, as referenced to the centre of the earth, are assumed to be (xr, yr, zr). The observed code, Prs1, relates the known coordinates of satellite 1 with the unknown coordinates of the receiver using the equation for a line in three-dimensional space. That is,

Prs1 = Ö [(Xs1 – Xr)2 + (Ys1 – Yr)2 + (Zs1 – Zr)2] + error

Thus, from four satellites, four distance equation can be formed leading to computation of the four unknowns (xr, yr, zr and clock bias) can be computed.

Control Point:

Land surveyors measure horizontal positions in geographic or plane coordinate systems relative to previously surveyed positions called **control points**. Control points are those whose position and coordinates are already known before start of survey. A geodetic control network consists of stable, identifiable points with published datum values derived from observations that tie the points together. The control point is used to enable to plot a map based on GPS data. Good site characteristics of a control point for GPS observation include:

- A clear view of the sky;
- No obstructions above the cut-off angle (say 15°);
- No reflecting surfaces that could cause multi-path;
- Safe, away from traffic and passers-by;
- Possibility to leave the receiver unattended;
- No powerful transmitters (radio, TV antennas etc.) in the vicinity

Assignments:

Plot the interior details of the area surveyed in a drawing sheet. Find the area of the plot. Compare it with manual measurements taken with a tape/chain.

Instruction: Drawing has to be submitted individually.

Fieldwork-10

TOTAL STATION (TS)







Objective: To plot a small area using measurements taken from a Total Station.

Theory:

Total station is a surveying equipment combination of Electromagnetic Distance Measuring Instrument 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.

Total stations with different accuracy, in angle measurement and different range of measurements are available in the market. Figure 1 shows one such instrument manufactured by SOKKIA Co. Ltd. Tokyo, Japan.

Important Operations of Total Station:

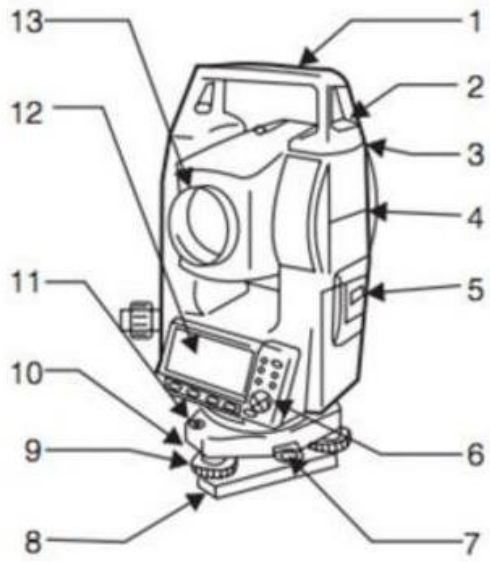
1. **Distance Measurement:** Electronic distance measuring (EDM) instrument is a major part of total station. Its range varies from 2.8 km to 4.2 km. The accuracy of measurement varies from 5 mm to 10 mm per km measurement. They are used with automatic target recognizer. The distance measured is always sloping distance from instrument to the object.
2. **Angle Measurements:** The electronic theodolite part of total station is used for measuring vertical and horizontal angle. For measurement of horizontal angles any convenient direction may be taken as reference direction. For vertical angle measurement vertical upward (zenith) direction is taken as reference direction. The accuracy of angle measurement varies from 2 to 6 seconds.
3. **Data Processing:** The instrument is provided with an inbuilt microprocessor. The microprocessor averages multiple observations. With the help of slope distance and vertical and horizontal angles measured, when height of axis of instrument and targets are supplied, the microprocessor computes the horizontal distance and X, Y, Z coordinates. The processor is capable of applying temperature and pressure corrections to the measurements, if atmospheric temperature and pressures are supplied.

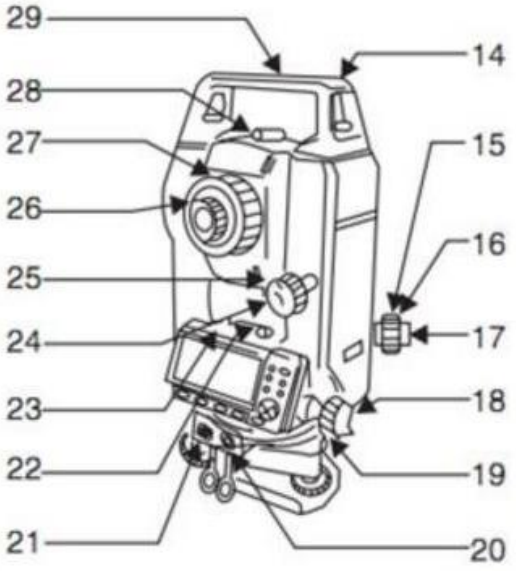
Significance:

Through this fieldwork, students will learn the operation of and data usage from total station to plot a surveyed area. Total Station is used in Mine Survey, Cadastral Survey, Engineering Survey, Large Scale Survey, Road / Rail / Canal Survey, etc. It is particularly useful in Remote Distance Measurement (RDM) and Missing Line Measurement (MLM).

Instruments:

1. Total Station
2. Tripods
3. Batteries and Chargers
4. Data and Power cables
5. Prisms
6. Prism Poles
7. Tribraches





1. Handle
2. Handle securing screw
3. Data input/output terminal (Remove handle to view)
4. Instrument height mark
5. Battery cover
6. Operation panel
7. Tribrach clamp (SET300*S*/500*S*/600S: Shifting clamp)
8. Base plate
9. Levelling foot screw
10. Circular level adjusting screws
11. Circular level
12. Display
13. Objective lens
14. Tubular compass slot
15. Optical plummet focussing ring
16. Optical plummet reticle cover
17. Optical plummet eyepiece
18. Horizontal clamp
19. Horizontal fine motion screw
20. Data input/output connector (Besides the operation panel on SET600/600*S*)
21. External power source connector (Not included on SET600/600*S*)
22. Plate level
23. Plate level adjusting screw
24. Vertical clamp
25. Vertical fine motion screw
26. Telescope eyepiece
27. Telescope focussing ring
28. Peep sight
29. Instrument center mark



Figure 11.2: Accessories Used with Total Station

(http://www.gisresources.com)

Procedure:

1. 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.
2. 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.
3. 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.
4. 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.
5. 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.

However, surveyor should check the working condition of the instruments before using. For this standard points may be located near survey office and before taking out instrument for field work, its working is checked by observing those standard points from the specified instrument station.

Assignments:

Plot the interior details of the area surveyed in a drawing sheet. Find the area of the plot. Compare it with manual measurements taken with a tape/chain.

Instruction: Drawing has to be submitted individually.