UNIT-1

FUNDAMENTALS OF CONVENTIONAL SURVEYING AND LEVELLING

DEFINITION OF SURVEYING

- Surveying is the Art of determining the relative position on above or beneath the Surface of the earth by means of direct or indirect measurements of distance, direction and elevation.
- It also includes the art of establishing points by predetermined angular & Linear Measurements.

CLASSIFICATION OF SURVEYING

i) PLANE SURVEYING

- Plane Surveying is defined as the division of Surveying in which all the survey works are carried based on the assumption that, the surface of earth is a plane and curvature of the earth is Ignored.
- In Dealing with the plane Surveying, plane geometry and Trigonometry are only required.
- The Surveys having an area of about 260km2 may only be treated as plane surveys.

USES:

- Plane Surveys which generally include the area upto 260km2 are carried out for engineering projects, on large scales to determine relative positions of individual features on the earth's surface.
- Plane Surveys are used to prepare the layout for highways, canals, railways, construction of various features etc.

ii) GEODETIC SURVEYING:

- The Surveys in which curvature of the earth is taken into account and higher degree of accuracy required is called geodetic surveying.

USES:

- Geodetic Surveys carried out with higher degree of accuracy to provide the spaced control points on the earth surface.
- It Requires advanced instruments. In India Surveys carried out by the department of survey of India under the control and direction of surveyor general of India.
SURVEYING

Plane Surveying

Geodetic Surveying

CLASSIFICATION BASED ON

PURPOSE OF SURVEYING  NATURE OF FIELD  METHODS ADOPTED INSTRUMENT USED


ii. Military or Defence a. Topographical 2. Traversing 2. Compass Surveying

iii. Mine Surveys b. Cadastral Survey 3. Levelling 3. Plane Table Surveying


vi. Route and Location Surveys
CLASSIFICATION BASED ON PURPOSE OF SURVEYING

i) ENGINEERING SURVEYS

- The Determination of quantities or to afford sufficient data for the designing of engineering works such as roads and reservoirs, or those connected with sewage disposal or water supply.

II) MILITARY OR DEFENCE SURVEY

- This is used for determining points of strategic importance.

III) MINE SURVEY

- This is used for the exploring mineral wealth.

OBJECTS OF THE SURVEY

- To Calculate The Distances Between Various Points And To Calculate The Levels Of Various Points.
- To check out the alignment of various engineering structures.
- To calculate the areas and volumes, involved in the various engineering projects.
- To Prepare the plans and maps sections and profile, contours etc.
- To Measure and to determine the relative positions of the various objects of the earth's surface.

EQUIPMENT AND ACCESSORIES FOR CHAINING AND RANGING:

(i) Chain
(ii) Arrows
(iii) Pegs
(iv) Surveyors' band
(v) Ranging rods and ranging poles
(vi) Offset rods
(vii) Laths
(viii) Whites
(ix) Plumb bobs and
(x) Line ranger.

(i) CHAIN

The Chain Is Made Up Of Steel Wire Which Is Divided Into Links And Togs (Rings) To Facilitate Folding.
- It Is Sometimes Used As A Unit Of Measurement
- It Has Brass Handles At Both Ends For Easy Handling. The Link Is 0.2m Or 200mm In Diameter.
- The Length Is 20m Or 30m.

(ii) ARROWS:

- Arrows are made of steel wire of diameter 4mm and their ends are bent into a circle where red cloth is tied to facilitate visibility. They are used for showing points on the ground.

(iii) PEGS

- Pegs are made of wood 40mm square by 50cm long and are used for permanently marking positions during survey.
iv) SURVEYORS' BAND

- The surveyor’s band is made of a steel strip which is rolled into a metal frame with a winding handle. It is 30m, 50m or 100m long. Is used in projects where more accuracy measurement is required.

(v) RANGING RODS AND RANGING POLES:
- A ranging rod is a surveying instrument used for marking the position of stations and for sightings of those stations as well as for ranging.
- Ranging poles are used to mark areas and to set out straight lines on the field. They are also used to mark points which must be seen from a distance, in which case a flag may be attached to improve the visibility.

(vi) OFFSET RODS

- These rods are also similar to ranging rods and they are 3 m long. They are made up of hard wood and are provided with iron shoe at one end.
- A hook or a notch is provided at other end. At height of eye, two narrow slits at right angles to each other are also provided for using it for setting right angles.

(vii) LATHS

- Laths are 0.5 to 1.0 m long sticks of soft wood. They are sharpened at one end and are painted with white or light colours. They are used as intermediate points while ranging or while crossing depressions.

(viii) WHITES

- Whites are the pieces of sharpened thick sticks cut from the nearest place in the field. One end of the stick is sharpened and the other end is split. White papers are inserted in the split to improve the visibility. Whites are also used for the same purpose as laths.

(IX) PLUMB BOBS:

- In measuring horizontal distances along sloping ground plumb bobs are used to transfer the position to ground. They are also used to check the verticality of ranging poles.

(X) LINE RANGER:

- It is an optical instrument used for locating a point on a line and hence useful for ranging. It consists of two isosceles prisms placed one over the other and fixed in an instrument with handle.

METHODS OF RANGING

i) Direct Ranging
ii) Indirect Ranging

i) DIRECT RANGING:

- Direct Ranging is done when the two ends of the survey lines are intervisible.
ii) INDIRECT RANGING
- It is done when both the ends of the survey line are not intervisible either due to Long distance between them.

COMPASS SURVEYING
- Compass surveying is a type of surveying in which the directions of surveying lines are determined with a magnetic compass, and the length of the surveying lines are measured with a tape or chain or laser range finder.

i) PRISMATIC COMPASS
- A prismatic compass is a navigation and surveying instrument which is extensively used to find out the bearing of the traversing and included angles between them, waypoints (an endpoint of the course) and direction.

ii) SURVEYOR COMPASS
- Surveyor’s compass consists of a circular brass box containing a magnetic needle which swings freely over a brass circle which is divided into 360 degrees. The horizontal angle is measured using a pair of sights located on north – south axis of the compass. They are usually mounted over a tripod and leveled using a ball and socket mechanism.

BASIC PRINCIPLE OF COMPASS SURVEY
- The Principle of Compass Survey is Traversing; which involves a series of connected lines the magnetic bearing of the lines are measured by prismatic compass and the distance (lengths) of the are measured by chain.

BEARING
- The Bearing of a line is the Horizontal Angle which it makes with a reference line (meridian) depending upon the Meridian.

TYPES OF BEARING
i. True Bearing
ii. Magnetic Bearing
iii. Arbitrary Bearing

i) TRUE BEARING
- True Bearing of a line is the horizontal angle which it makes with the true meridian through one of the extremities of the line.
ii) MAGNETIC BEARING
- The Magnetic Bearing of a line is the horizontal angle which it makes with the magnetic meridian passing through one of the extremities of the line.

iii) ARBITRARY BEARING
- Arbitrary Bearing of a line is the horizontal angle which it makes with any arbitrary meridian passing through one of the Extremities.

LEVELLING
Levelling is a branch of surveying, the object of which is:
- To Find The Elevations Of Given Points With Respect To A Given Or Assumed Datum, And
- To Establish Points At A Given Or Assumed Datum.

BASIC PRINCIPLE OF LEVELING
- The fundamental principle of leveling lies in finding out the separation of level lines passing through a point of known elevation (B.M.) and that through an unknown point (whose elevation is required to be determined).

METHODS OF LEVELLING
i) BAROMETRIC LEVELLING
- Barometric Leveling. Barometer is an instrument used to measure atmosphere at any altitude. So, in this method of leveling, atmospheric pressure at two different points is observed, based on which the vertical difference between two points is determined.

ii) DIRECT LEVELLING
- It is the most commonly used method of leveling. In this method, measurements are observed directly from leveling instrument.

iii) TRIGONOMETRIC LEVELLING
- The process of leveling in which the elevation of point or the difference between points is measured from the observed horizontal distances and vertical angles in the field is called trigonometric leveling.

SOURCES OF ERRORS IN LEVELLING
There are following types of Errors in Leveling:
1. Instrumental Errors
2. Collimation Error
3. Error due to Curvature & Refraction
4. Other Errors

1. INSTRUMENTAL ERRORS & CORRECTION

1. Collimation error
   - Correction: Check before use and equalise sights.
3. Errors in staff graduation
   - Correction: Check
4. Loose tripod head.
5. Telescope not parallel to bubble tube
   - Correction: Permanent adjustment.
6. Telescope not at right angles to the vertical axis
   - Correction: Permanent adjustment

2. COLLIMATION ERROR

- Collimation error occurs when the collimation axis is not truly horizontal when the instrument is level. The effect is illustrated in the sketch below, where the collimation axis is tilted with respect to the horizontal by an angle \( \alpha \).

3. CURVATURE OF THE EARTH:

The earth appears to “fall away” with distance. The curved shape of the earth means that the level surface through the telescope will depart from the horizontal plane through the telescope as the line of sight proceeds to the horizon.

This effect makes actual level rod readings too large by:

\[
(C - r) = 0.0206D^2
\]

where \( D \) is the sight distance in thousands of feet.
PART - A (2 marks)

1. Describe the principle of surveying. (AUC Apr/May 2011) (AUC Nov/Dec 2011)

   The fundamental principles upon which the surveying is being carried out are
   - Working from whole to part.
   - After deciding the position of any point, its reference must be kept from at least two permanent objects or stations whose positions have already been well defined.

2. What is the purpose of an optical square? (AUC Apr/May 2011) (AUC May/June 2012)

   It is more accurate than the cross staff and it can be used for locating objects situated at larger distances. It is small and compact hand instrument and works on the principle of reflection.

3. What do you mean by reciprocal ranging? (AUC Apr/May 2010)

   When the end stations are not intervisible due to high ground or a hill or if the ends are too long. In such cases, intermediate points can be fixed on the survey line by a process known as Reciprocal ranging or Indirect ranging.

4. What do you mean by scale in surveying? (AUC Nov/Dec 2011)

   Scale is a fixed ratio that every distance on the plan bears with corresponding distance on the ground. For example: 1cm = 10m.

5. Define conditioned triangles. (AUC Nov/Dec 2010)

   The accuracy of a triangulation system, in which any error in angular measurement has a minimum effect upon the computed lengths, is known as well-conditioned triangle.

6. Explain the range of reciprocal ranging. (AUC May/June 2013)

   The vision ranging and line ranger can be adopted only when the end stations are inter-visible. The line of sight between two stations is obstructed by natural or man-made objects or not clearly visible. Under such conditions, indirect or reciprocal ranging is applicable.

7. What do you mean by plane surveying? (AUC May/June 2013)

   Plane surveying is a process of surveying in which the portion of the earth being surveyed is considered a plane. In this training manual, we used in plane surveying rather
than those used in geodetic surveying.

8. What is meant by geodetic surveying? (AUC Nov/Dec 2012)

Geodetic surveying is a process of surveying in which the shape and size of the earth are considered. The methods used in geodetic surveying are beyond the scope of this training manual.

9. Explain the Methods Of Ranging.
   i) Direct Ranging
   ii) Indirect Ranging
   i) DIRECT RANGING:
      • Direct Ranging is done when the two ends of the survey lines are intervisible.
   ii) INDIRECT RANGING:
      • It is done when both the ends of the survey line are not intervisible either due to Long distance between them.

    • True Meridian is defined as the line Joining the Geographical North and South Pole.
    • True Meridian at various Places are not Equal

11. What is Magnetic Meridian? (AUC May/Jun 2012)
    • Magnetic Meridian is defined as the Longitudinal axis indicated by the freely Suspended, properly balanced Magnetic Needle.
    • It Does not coincide with the true Meridian except in certain places during the year

12. What are the types of corrections to be applied? (AUC Nov/Dec 2014)
    • Correction for Length.
    • Correction for Temperature.
    • Correction for Pull.
    • Correction for Sag.
    • Correction for Slope.

13. What Is Two Point Problem? (AUC May/Jun 2013)
    Two Point Problem is defined as the process of locating the plane table on the sheet by sighting two well defined Points And its locations are already plotted on the Paper.

    Two Point Problem is defined as the process of locating the plane table on the sheet by
sighting two well defined Points And its locations are already plotted on the Paper.

15. **Distinguish Between Angle And Bearing.** (AUC May/Jun 2012)
   - An Angle is defined as the deviation of one straight line with respect to the other one.
   - Bearing is defined as the angle or Inclination of a survey Line with respect to the north - South Direction.

16. **What are the Sources Of Local Attraction?**
   - Magnetic Materials such As magenetic Rocks, iron Ores, Electrical cables etc.. are sources of Local Attraction.

17. **Name the different ways of classification of Surveying.**
    Classification Of Survey is based on
    i. Purpose of Surveying
    ii. Nature of the field
    iii. Methods employed
    iv. Instruments Used

18. **How do you fix a point from control points(or a Survey Line)?**
    The position of a third point can be located from control points by anyone of the following Ways.
    1. Two linear measurement
    2. Two Angular Measurement
    3. One linear measurement & one Angular Measurement.

19. **Write the equation for correction of temperature**
    Temperature correction     \[ Ct = \alpha(Tm-To)L \]
    \( \alpha \) - coefficient of thermal expansion
    \( Tm \) - mean temperature during measurements
    \( To \) - normal temperature at standardization
    \( L \) - measured length of the line.

20. **What circumstances in which reciprocal ranging is used ?(or) When do you require ranging? (or) Explain the use of reciprocal ranging?**
    i. Reciprocal ranging is the method of indirect ranging and it is adopted when the
    ii. Two end stations are move to raised grounds

21. **In a chain how will you set out a right angle?**
    i) Cross-staff is the instrument used to locate the intersection point of a particular offset on a chain line.
    ii) Optical Squares are also like cross-staves used for setting out the right angles in change-surveying.

22. **What are the Instruments Used for chain Surveying?**
    1. Chain
    2. Tape
    3. Ranging Rods
    4. Offset Rods
    5. Plumb Bob
    6. Pegs
    7. Cross-staff
23. Write a difference between a map & Plan.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Factor</th>
<th>Map</th>
<th>Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Scale</td>
<td>Maps are the Drawing with Small Scale</td>
<td>Plans are the drawing with Large Scale</td>
</tr>
<tr>
<td>2.</td>
<td>Details</td>
<td>A map generally deals about the Geographical Details</td>
<td>A Plan deals with the details of the engineering Structures.</td>
</tr>
</tbody>
</table>

24. List out various Classification of surveying.
   i. Chain Surveying.
   ii. Compass Surveying.
   iii. Plane table Surveying.
   iv. Theodolite Level Surveying.
   v. Tacheometric Surveying.
   vi. Total station Surveying.

**PART-B**

1. A survey line ABC crossing a river angles cuts its banks at B and C. To determine the width BC of the river. The following operation was carried out. A point E was established on the perpendicular BE such that angle CEF is a right angle where F is a point on the survey line. If the chainage of F and B are respectively 1200 m and 1320 m and the distance EB is 90 m. Calculate the width of the river and also the chainage of C.  

(AUC Apr/May 2011)

\[ BF = \text{Chainage of } B - \text{Chainage of } F \]
\[ = 1320 - 1200 \]
\[ BF = 120 \text{ m} \]
From $\triangle EBF$,
\[
\tan BEF = \frac{120}{90} = 1.33
\]
\begin{align*}
\angle BEC &= \angle CEF \quad \angle BEF \\
&= 90^\circ - 53^\circ 3' \\
\angle BEC &= \angle 36^\circ 57'
\end{align*}
\begin{align*}
\text{From } \triangle BEC, \\
\tan (36^\circ 57') &= \frac{CB}{BE} = \frac{CB}{90} \\
CB &= 90 \times \tan (36^\circ 57') \\
CB &= 67.69 \text{ m}
\end{align*}

The width of the river, $CB = 67.69$ m

Chainage of $C = \text{chainage of } B + \text{width of the river}$
\[
= 1320 + 67.69
\]

Chainage of $C = 1387.69$ m

2. Explain the methods of chaining while there are obstacles such as building or river. (AUC Nov/Dec 2011) (AUC May/June 2012) (AUC Apr/May 2010).

In this case it is required to prolong the chain line beyond the obstacle and to find the distance across it. In this case the typical obstacle is a building. One of the following two methods may be adopted.

FIRST METHOD:

On one side of the chain line $AB$, two points $P$ and $Q$ are selected. Perpendiculars of equal length $PP'$ and $QQ'$ are erected. The line $P'Q'$ is extended till the building is passed. On the extended line, two points $R$ and $S$ are selected. The perpendicular at $R$ and $S$ are so erected such that $RR' = SS' = QQ' = PP'$. then the points $P'$, $Q'$, $R'$ and $S'$ will lie on the same line. Then $Q'R = QR$ and the distance $Q'R'$ is measured to set $QR$, then the line is extended.

SECOND METHOD:

This method is also equally applicable for this condition. Two points $P$ and $Q$ on the chain line $AB$ are selected on the one side of the chain line. A perpendicular $QR$ is erected at $Q$ such that $QR = PR$. Points $P$ and $R$ are jointed and extended upto $S$. A perpendicular $SV$ is set at $S$ such that $PS = SV$. On the line $SV$ a point $T$ is marked such that $ST = SR$. with $V$ as centre and radius equal to $QR$ cut an arc such that $PQ = QR = VT = UT$. Then $U$ and $V$ are on the chain line $AB$. The distance $RT$ is measured. Thus the obstructed length, $QU = RT$. 

\begin{center}
\includegraphics{diagram.png}
\end{center}
3. Determine the sag correction for a 30 m steel tape under a pull of 80 N in 3 bays of 10 m each. The area of the cross section of the tape is 8 mm\(^2\) and the unit weight of steel may be taken as 77 kN/m\(^3\). (AUC Nov/Dec 2011)
Solution:

Given:

\(L = 30\,\text{m};\, n = 3;\, P = 80\,\text{N};\, \text{Area} = 8\,\text{mm}^2 = 8 \times 10^{-6}\,\text{m}^2;\, \gamma = 77\,\text{kN/m}^3\)

Total weight of tape = \(77 \times 10^3 \times 8 \times 10^{-6} \times 10 = 6.16\,\text{N}\)

\[C_s = \frac{LW^2}{24n^2P^2}\]

\[= \frac{10 \times 6.16^2}{24 \times 1^2 \times 80^2}\]

\[= 0.00247\,\text{m}\]

\[C_s = 3 \times 0.00247 = 0.00741\,\text{m}\]

True length = \(30 - 0.00741\)

True length = \(29.993\,\text{m}\)

4. Explain the field and office work in chain surveying? (AUC May/June 2013)

Field and Office work:

The practice of surveying actually boils down to fieldwork and office work. The Fieldwork Consists Of Taking Measurements, Collecting Engineering Data, And Testing Materials. The Office Work Includes Taking Care Of The Computation And Drawing The Necessary Information For The Purpose Of The Survey.

Field Work:
Field work is of primary importance in all types of surveys. To be a skilled surveyor, you must spend a certain amount of time in the field to acquire needed experience.

The study of this training manual will enable you to understand the underlying theory of surveying, the instruments and their uses, and the surveying methods.

However, a high degree of proficiency in actual surveying, as in other professions, depends largely upon the duration, extent, and variation of your actual experience.

You should develop the habit of STUDYING the problem thoroughly before going into the field, you should know exactly what is to be done; how you will do it; why you prefer a certain approach over other possible solutions; and what instruments and materials you will need to accomplish the project.

It is essential that you develop SPEED and CONSISTENT ACCURACY in all your fieldwork. This means that you will need practice in handling the instruments, taking observations and keeping field notes, and planning systematic moves.

It is important that you also develop the habit of CORRECTNESS. You should not accept any measurement as correct without verification. Verification, as much as possible, should be different from the original method used in measurement.

The precision of measurement must be consistent with the accepted standard for a particular purpose of the survey. Fieldwork also includes adjusting the instruments and caring for field equipment.

Do not attempt to adjust any instrument unless you understand the workings or functions of its parts. Adjustment of instruments in the early stages of your career requires close supervision from a senior EA.

Office Work:

Office work in surveying consists of converting the field measurements into a usable format. The conversion of computed, often mathematical, values may be required immediately to continue the work, or it may be delayed until a series of field measurements is completed.

Although these operations are performed in the field during lapses between measurements, they can also be considered office work. Such operations are normally done to save time.

Special equipment, such as calculators, conversion tables, and some drafting equipment is used in most office work. In office work, converting field measurements (also called reducing) involves the process of computing, adjusting, and applying a standard rule to numerical values.

5. Explain how you will conduct chain survey to measure a land parcel in agriculture field.
   (AUC May/June 2013)
   - Using chaining and ranging the distance between two points can be measured. The instruments required are chain, arrows, ranging rods, pegs and hammers.

Procedures:

- First mark a straight line of a standard length on a flat firm ground. The two end points A and B are selected on a survey line which is to be measured.
A ranging rod is erected at the point B, while the surveyor stands with another rod at point A. A rod is established at a point in line with AB at a distance not greater than one chain length from A.

The surveyor at A then signals the assistant to move transverse to the chain line till he is line with A and B. Similarly other intermediate points can be established.

Then by using chain, the distance is measured. To find the pacing length, we should walk along the chain line and it is found from pacing length.

Pacing length = Distance between the points/No of steps

The distance between two points = (No of arrow x Nominal length + Fractional length) m

The distance between two points can be calculated and also same procedure is used to find the other side of the line. The finally land parcel of agricultural field is measured

UNIT II

THEODOLITE AND TACHEOMETRIC SURVEYING

THEODOLITE

- 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.

- A modern theodolite consists of a movable telescope mounted within two perpendicular axes the horizontal or trunnion axis, and the vertical axis. When the telescope is pointed at a target object, the angle of each of these axes can be measured with great precision.

TYPES OF THEODOLITE

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

- Vernier or Transit Theodolite
- Digital Theodolite
- Total Station

TRANSIT THEODOLITE

- A Transit Theodolite Is One In Which The Telescope Can Be Revolved Through A Complete Revolution About Its Horizontal Axis In A Vertical Plane.

DIGITAL THEODOLITE

- Digital theodolite is a modern engineering instrument for measuring both horizontal and vertical angles, It is a key tool in surveying and engineering work.
- The theodolite consists of a telescope movable within two perpendicular axes- the horizontal axis, and the vertical axis. When the telescope is pointed at a desired object, the angle of each of these axes can be measured with great precision.

TOTAL STATION

- A total station or TST (total station theodolite) is an electronic/optical instrument used for surveying and building construction.
• The total station is an electronic theodolite (transit) integrated with an electronic distance measurement (EDM) to read slope distances from the instrument to a particular point, and an on-board computer to collect data and perform advanced coordinate based calculations.

DIFFERENT PARTS OF THEODOLITE

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

• Leveling Head
• Shifting Head
• Lower Plate
• Upper Plate
• Plate Levels
• Standard (or a Frame)
• Vernier Frame
• Telescope
• Vertical Circle
• Altitude Bubble
• Screws
• Tripod Stand

METHODS OF HORIZONTAL ANGLE MEASUREMENT:

• General Method
• Repition Method
• Reiteration Method

PERMANENT ADJUSTMENTS OF THEODOLITE:
The permanent adjustments are made to establish the relationship between the fundamental lines of the theodolite and, once made, they last for a long time. They are essential for the accuracy of observations.

The permanent adjustments in case of a transit theodolites are:

i) **Adjustment of Horizontal Plate Levels.**
   - The axis of the plate levels must be perpendicular to the vertical axis.

ii) **Collimation Adjustment.**
    - The line of collimation should coincide with the axis of the telescope and the axis of the objective slide and should be at right angles to the horizontal axis.

iii) **Horizontal axis adjustment.**
    - The horizontal axis must be perpendicular to the vertical axis.

iv) **Adjustment of Telescope Level or the Altitude Level Plate Levels.**
    - The axis of the telescope levels or the altitude level must be parallel to the line of collimation.

v) **Vertical Circle Index Adjustment.**
    - The vertical circle vernier must read zero when the line of collimation is horizontal.

**TEMPORARY ADJUSTMENTS OF THEODOLITE**

- The temporary adjustments are made at each set up of the instrument before we start taking observations with the instrument. There are three temporary adjustments of a theodolite:
  i) Centering.
  ii) Levelling.
  iii) Focussing.

**STADIA CONSTANT**

- The distance is chosen so that there is a fixed, integer ratio between the distance observed between the marks and the distance from the telescope to the measuring device observed. This is known as the **stadia constant** or **stadia interval factor.** For example, a typical stadia mark pair are set so that the ratio is 100.

**ANALYTIC 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.

**TACHEOMETER**

- A tacheometer is similar to an ordinary transit theodolite fitted with stadia wires in addition to the central cross-hairs.
- As accuracy and speed are necessary, the telescope fitted with a tacheometer must fulfill additional requirements. Also, the vertical circle should be more refined.
- The telescope of the tacheometer is usually longer than that of the Ordinary theodolite and has a higher power of magnification.
- The object glass is of greater diameter, and the lens system is of better quality. The magnification power should not be less than 20-25.
- The effective aperture should not be less than 3.5-4.5 cm in diameter facilitating the obtaining of a bright image.
- The multiplying constant of the instrument (f/I) is generally kept as 100. Sometimes an additional pair cross-hairs is provided such that the multiplying constant (f/I) is 50.

**TACHEOMETRY SURVEY**

- Tachometry is a branch of angular surveying in which A horizontal & vertical distance is of points are obtain by optical means as suppose to ordinary slow process of measure by tape chain.
- This methods is very rapid & convenient. All though the accuracy of tachometry is low it is best adopted in obstructed such as steep & broken ground stretches of water etc which make drawn age difficult.
- They primary object of tachometry is the preparation of contour maps are plans required with both horizontal & vertical measurements also accuracy improvement it provides at check an distance measure with tape.

At the instruments a normally transit theodalite pitted with stadia diaphragm is generally used for tachometry survey. A stadia diaphragmessentially consist of one stadia hair above on the other an equal distance below the horizontal cross hair. Telescope is used in stadia surveying are of 3 types :-

| a. Simple external focusing telescope |
| b. External focusing analytic |
| c. Internal focusing telescope |

**METHODS OF TACHOMETRIC SURVEY:**

(1) Stadia system
(2) Tangential system

**1) STADIA SYSTEM OF TACHEOMETRY**

In the stadia system, the horizontal distance to the staff Station from the instrument station and the elevation of the staff station concerning the line of sight of the instrument is obtained with only one observation from the instrument Station.

In the stadia method, there are mainly two systems of surveying.

(1) fixed hair method and,
(2) movable hair method.

(i) FIXED HAIR METHOD:
In the fixed hair method of tacheometric surveying, the instrument employed for taking observations consist of a telescope fitted with two additional horizontal cross hairs one above and the other below the central hair.

- These are placed equidistant from the central hair and are called stadia hairs.
- When a staff is viewed through the telescope, the stadia hairs are seen to intercept a certain length of the staff and this varies directly with the distance between the instrument and the stations. As the distance between the stadia hair is fixed, this method is called the “fixed hair method.”

(ii) MOVABLE HAIR METHOD
- In the movable Hair method of tacheometric surveying, the instrument used for taking observations consist of a telescope fitted with stadia hairs which can be moved and fixed at any distance from the central hair (within the limits of the diaphragm).
- The staff used with this instrument consists of two targets (marks) at a fixed distance apart (say 3.4 mm).
- The Stadia interval which is variable for the different positions of the staff is measured, and the horizontal distance from the instrument station to the staff station is computed.

(2) TANGENTIAL SYSTEM OF TACHEOMETRIC SURVEYING:
- In this system of tacheometric surveying, two observations will be necessary from the instrument station to the staff station to determine the horizontal distance and the difference in the elevation between the line of collimation and the staff station.
The only advantage of this method is that this survey can be conducted with ordinary transit theodolite. As the ordinary transit theodolite are cheaper than the intricate and more refined tacheometer, so, the survey will be more economical.

So, far as the reduction of field notes, distances and elevations are concerned there is not much difference between these two Systems.

But this system is considered inferior to the stadia system due to the following reasons and is very seldom used nowadays.

This involves measurement of two vertical angles, and the instrument may get disturbed between the two observations. The speed is reduced due to more number of observations and the changes in the atmospheric conditions will affect the readings considerably.

The staff used in this method is similar to the one employed in the movable hair method of stadia surveying. The distance between the targets or vanes may be 3-4 m.

**CONTOUR**

A Contour Line May Be Defined As “An Imaginary Line Passing Through Points Of Equal Reduced Levels”. A contour Line May Also Be Defined “As The Intersection Of A Level Surface With The Surface Of The Earth”. Thus, Contour Lines On A Plan Illustrates The Topography Of The Area.

**CONTOUR INTERVAL**

The vertical distance between consecutive contours is termed as contour interval. Generally the contour intervals are taken in the range of 1 to 15 m. The contour interval is inversely proportional to the scale of the map. When we have less time to complete a survey for a large area contour interval is kept larger.

**METHODS OF CONTOURING**

1. **DIRECT METHOD:**
   - In this method a series of points are located on the ground having same elevation. For a particular contour value the staff man is directed to move right or left until the required reading is obtained, this method is time consuming but it gives accurate result.

2. **INDIRECT METHOD:**
   - In Block Contouring the given area is divided into number of grids with a known interval and the staff reading is taken on the respective grid points to find the R.L values, by the method of interpolation the contour is plotted. In Radial contouring the same method is adopted but the R.L values are found on the radial lines running from the center point. This method is normally preferred on hilly areas.

**CHARACTERISTICS OF CONTOUR LINES:**
i. Steep slopes - contours are closely spaced
ii. Gentle slopes - contours are less closely spaced
iii. Valleys - contours form a V-shape pointing up the hill - these V's are always an indication of a drainage path which could also be a stream or river
iv. Ridges - contours form a V-shape pointing down the hill
v. Summits - contours forming circles
vi. Depressions - are indicated by circular contour with lines radiating to the center
vii. If the middle value is higher in a contour it means it is an elevation
viii. If the middle value is lesser in an contour it means it is an depression

**CONTOUR GRADIENT**
- An imaginary line on the surface of the earth having a constant inclination with the horizontal (slope) is called contour gradient.
- The inclination of a contour gradient is generally given either as rising gradient or falling gradient, and is expressed as ratio of the vertical height to a specified horizontal distance.

**CONTOUR PLAN**
- A plan drawn to a suitable scale showing surface contours or calculated contours of coal seams to be developed. These plans are important during the planning stage of a project.

**CONTOUR MAP**
- A map showing elevations and surface configuration by means of contour lines

**USES OF CONTOUR MAPS**
- Determination of intervisibility between two points.
- Drawing of sections.
- Measurement of drainage area is another use of contour maps
- Measurement of earthwork.
- Calculation of reservoir capacity.
CONTROL SURVEYING AND ADJUSTMENTS

CONTROL SURVEYING

- Horizontal and vertical control are developed to create a framework around which other surveys can be adjusted. These control surveys are used for accurate mapping projects in the construction of underground utility systems, roadways, power lines, tunnels, and many other high precision projects.

HORIZONTAL CONTROLS & ITS METHODS

- The horizontal control consists of reference marks of known plan position, from which salient points of designed structures may be set out. For large structures primary and secondary control points are used. The primary control points are triangulation stations. The secondary control points are reference to the primary control stations.
- Reference grids are used for accurate setting out of works of large magnitude. The following types of reference grids are used:
  - SURVEY GRID
  - SITE GRID
  - STRUCTURAL GRID
  - SECONDARY GRID

SURVEY GRID

- Survey grid is one which is drawn on a survey plan, from the original traverse. Original traverse stations form the control points of the grid.

SITE GRID

- The site grid used by the designer is the one with the help of which actual setting out is done. As far as possible the site grid should be actually the survey grid. All the design points are related in terms of site grid coordinates.

STRUCTURAL GRID

- The structural grid is used when the structural components of the building are large in numbers and are so positioned that these components cannot be set out from the site grid with sufficient accuracy. The structural grid is set out from the site grid points.

SECONDARY GRID

- The secondary grid is established inside the structure, to establish internal details of the building, which are otherwise not visible directly from the structural grid.

VERTICAL CONTROL & ITS METHODS:
The vertical control consists of establishment of reference marks of known height relative to some special datum. All levels at the site are normally reduced to the nearby bench mark, usually known as master bench mark.

The setting of points in the vertical direction is usually done with the help of following rods:

1. Boning rods and travelers
2. Sight Rails
3. Slope rails or batter boards
4. Profile boards

1. BONING RODS AND TRAVELERS

- A boning rod consist of an upright pole having a horizontal board at its top, forming a ‘T’ shaped rod.
- Boning rods are made in set of three, and many consist of three ‘T’ shaped rods, each of equal size and shape, or two rods identical to each other and a third one consisting of longer rod with a detachable or movable ‘T’ piece. The third one is called traveling rod or traveler.

2. SIGHT RAILS:

- A sight rail consist of horizontal cross piece nailed to a single upright or pair of uprights driven into the ground.
- The upper edge of the cross piece is set to a convenient height above the required plane of the structure, and should be above the ground to enable a man to conveniently align his eyes with the upper edge.
- A stepped sight rail or double sight rail is used in highly undulating or falling ground.

3. SLOPE RAILS OR BATTER BOARDS:

- These are used for controlling the side slopes in embankment and in cuttings. These consist of two vertical poles with a sloping board nailed near their top.
- The slope rails define a plane parallel to the proposed slope of the embankment, but at suitable vertical distance above it. Travelers are used to control the slope during filling operation.

4. PROFILE BOARDS:

- These are similar to sight rails, but are used to define the corners, or sides of a building. A profile board is erected near each corner peg.
- Each unit of profile board consists of two verticals, one horizontal board and two cross boards. Nails or saw cuts are placed at the top of the profile boards to define the width of foundation and the line of the outside of the wall.

TRIANGULATION SURVEYING

- Triangulation surveying is the tracing and measurement of a series or network of triangles to determine distances and relative positions of points spread over an area, by measuring the length of one side of each triangle and deducing its angles and length of other two sides by observation from this baseline.

CLASSIFICATION OF TRIANGULATION SYSTEM:

- The basis of the classification of triangulation figures is the accuracy with which the length and azimuth of a line of the triangulation are determined. Triangulation systems of different accuracies depend on the extent and the purpose of the survey. The accepted grades of triangulation are:

  1. First order or Primary Triangulation
1. FIRST ORDER OR PRIMARY TRIANGULATION:

- The first order triangulation is of the highest order and is employed either to determine the earth’s figure or to furnish the most precise control points to which secondary triangulation may be connected.
- The primary triangulation system embraces the vast area (usually the whole of the country). Every precaution is taken in making linear and angular measurements and in performing the reductions. The following are the general specifications of the primary triangulation:

  1. Average triangle closure: Less than 1 second
  2. Maximum triangle closure: Not more than 3 seconds
  3. Length of base line: 5 to 15 kilometers
  4. Length of the sides of triangles: 30 to 150 kilometers
  5. Actual error of base: 1 in 300,000
  6. Probable error of base: 1 in 1,000,000
  7. Discrepancy between two measures of a section: 10 mm kilometers
  8. Probable error or computed distance: 1 in 60,000 to 1 in 250,000
  9. Probable error in astronomic azimuth: 0.5 seconds

2. SECONDARY ORDER OR SECONDARY TRIANGULATION

The secondary triangulation consists of a number of points fixed within the framework of primary triangulation. The stations are fixed at close intervals so that the sizes of the triangles formed are smaller than the primary triangulation. The instruments and methods used are not of the same utmost refinement. The general specifications of the secondary triangulation are:

  1. Average triangle closure: 3 sec
  2. Maximum triangle closure: 8 sec
  3. Length of base line: 1.5 to 5 km
  4. Length of sides of triangles: 8 to 65 km
  5. Actual error of base: 1 in 150,000
  6. Probable error of base: 1 in 500,000
  7. Discrepancy between two
measures of a section : 20 mm kilometers

8. Probable error or computed distance : 1 in 20,000 to 1 in 50,000

9. Probable error in astronomic azimuth : 2.0 sec

3 THIRD ORDER OR TERTIARY TRIANGULATION:

- The third-order triangulation consists of a number of points fixed within the framework of secondary triangulation, and forms the immediate control for detailed engineering and other surveys. The sizes of the triangles are small and instrument with moderate precision may be used. The specifications for a third-order triangulation are as follows:

1. Average triangle closure : 6 sec

2. Maximum triangle closure : 12 sec

3. Length of base line : 0.5 to 3 km

4. Length of sides of triangles : 1.5 to 10 km

5. Actual error of base : 1 in 75,000

6. Probable error of base : 1 in 250,000

7. Discrepancy between two measures of a section : 25 mm kilometers

8. Probable error or computed distance : 1 in 5,000 to 1 in 20,000


BASE LINE.

- In *surveying*, a baseline is a line between two points on the earth's surface and the direction and distance between them. In a triangulation network, at least one baseline needs to be measured to calculate the size of the triangles by trigonometry.

FACTORS TO BE CONSIDERED WHILE SELECTING BASE LINE.

- The measurement of base line forms the most important part of the triangulation operations. The base line is laid down with great accuracy of measurement and alignment as it forms the basis for the computations of triangulation system.

- The length of the base line depends upon the grades of the triangulation. Apart from main base line, several other check bases are also measured at some suitable intervals. In India, ten bases were used, the lengths of the nine bases vary from 6.4 to 7.8 miles and that of the tenth base is 1.7 miles.
• Selection of Site for Base Line. Since the accuracy in the measurement of the base line depends upon the site conditions, the following points should be taken into consideration while selecting the site:

1. The site should be fairly level. If, however, the ground is sloping, the slope should be uniform and gentle. Undulating ground should, if possible be avoided.
2. The site should be free from obstructions throughout the whole of the length. The line clearing should be cheap in both labour and compensation.
3. The extremities of the base should be intervisible at ground level.
4. The ground should be reasonably firm and smooth. Water gaps should be few, and if possible not wider than the length of the long wire or tape.
5. The site should suit extension to primary triangulation. This is an important factor since the error in extension is likely to exceed the error in measurement.

SATELLITE STATION
• A Satellite Station Is Used When The Instrument Cannot Be Set Up At The Main Station. The Distance Of The Satellite From Its Station Is Usually Very Small As Compared To The Length Of The Sides Of The Triangulation.
• In order to secure well condition triangle or better intervisibility objects such as church tops, plag poles or towers etc. are sometimes selected as triangulation stations.
• If the instrument is impossible to set up over that point a subsidiary station known as a satellite station or false station is selected as near as possible to the main station.
• Observations are made to the other stations with the same precision from the satellite station.

REDUCTION TO CENTER
• The angles are then corrected and reduced to what they would be from the true station.
• The operation applying to this correction due to the eccentricity of the station is generally known as reduction to center.
• Distance between true station and satellite station is determined by method of trigonometric leveling.

TRIGONOMETRIC LEVELING
• The process of leveling in which the elevation of point or the difference between points is measured from the observed horizontal distances and vertical angles in the field is called trigonometric leveling.
• Trigonometric Leveling is the branch of Surveying in which we find out the vertical distance between two points by taking the vertical angular observations and the known distances.
The known distances are either assumed to be horizontal or the geodetic lengths at the mean sea level (MSL). The distances are measured directly (as in the plane surveying) or they are computed as in the geodetic surveying.

The trigonometric Leveling can be done in two ways:
1. **Observations taken for the height and distances**
2. **Geodetic Observations**

(1) **OBSERVATIONS TAKEN FOR THE HEIGHT AND DISTANCES**:
- In this way, we can measure the horizontal distance between the given points if it is accessible.
- We take the observation of the vertical angles and then compute the distances using them. If the distances are large enough then we have to provide the correction for the curvature and refraction and that we provide to the linearly to the distances that we have computed.

(2) **GEODETIC OBSERVATIONS**:
- In the second way, i.e geodetic observations, the distances between the two points are geodetic distances and the principles of the plane surveying are not applicable here. The corrections for the curvature and refraction are applied directly to the angles directly.

**TRAVERSING**

- Traverse is a method in the field of surveying to establish control networks. It is also used in geodesy.
- Traverse networks involve placing survey stations along a line or path of travel, and then using the previously surveyed points as a base for observing the next point.

There are two types of traverses:

- Open Traverse
- Closed Traverse.

**OPEN TRAVERSE**
- An open traverse originates at a point of known position and terminates at a point of unknown position.
CLOSED TRAVERSE

- A closed traverse originates and terminates at points of known positions. When closed traverse originates and terminates at the same point, it is called the closed-loop traverse.

METHODS TRAVERSING

- There are four methods by which the direction of the survey lines are determined are as follow.
  17. By the chain angle
  18. By the free or loose needle method
  19. By the fast needle method
  20. By the measurement of angles between the successive lines.

1. BY THE CHAIN ANGLE

- In this method, the entire work is done with a chain/tape only and the angle between the successive lines is measured with the chain.

- Angles fixed by the measurements are known as chain angle.

2. BY THE FREE OR LOOSE NEEDLE METHOD

- In this method, an angular instrument such as compass or theodolite, is set up at each of the successive stations and the bearing of each lines is taken with reference to the magnetic meridian and not with reference to the adjacent lines.

3. BY THE FAST NEEDLE METHOD

- In this method, a theodolite is used to determine the bearing of each line. The bearing of first line is measured with the magnetic meridians and the bearing of the successive lines are found from the deflection angle or from the included angle.
4. BY THE MEASUREMENT OF ANGLES BETWEEN THE SUCCESSIVE LINES:
In this method, a theodolite is used for measurement of angles. The horizontal angles measured in a traverse may be

- Included angles or
- Deflection angles (between the successive lines)

This is the most accurate method and is generally used for large surveys and accurate work.

GALE’S TABLE
- Traverse computations are usually done in a tabular form is called Gale’s table

CHARACTERISTICS:

- The sum of all the observed interior angles is found which should be equal to \((2n-4)\) right angle.
- If exterior angles are measured then the sum should be equal to \((2n+4)\) right angles.

Use Of Gale’s Table
- The sum of latitudes \((\sum L)\) and departures \((\sum D)\) are found.
- Necessary corrections are done in closed traverse such that \(\sum L = 0\) and \(\sum D = 0\).
- The independent coordinates of the lines are obtained from corrected consecutive coordinates.
- The coordinates are positive and the entire traverse lie in the first quadrant.

SOURCES OF ERROR IN MEASUREMENT
1. Instrumental errors
2. Personal errors
3. Natural errors

1. Instrumental errors
   - Error may arise due to imperfection or faulty adjustment of the instrument with which measurement is being taken.

For example:
   - A tape may be too long or an angle measuring instrument maybe out of adjustment. Such errors are known as Instrumental errors.

Personal Error
   - Error may also arise due to want of perfection of human sight in observing and of touch in manipulating instruments.

For example:
   - An error maybe taking the level readings or reading an angle on a circle of theodolite. Such errors are known as Personal errors.

Natural errors
• Errors may also be due to variations in natural phenomena such as temperature, humidity, wind, refraction and magnetic declination. If it is not properly observed while taking measurements, the results will be incorrected.

TERMS USED FOR ERRORS IN SURVEYING

TRUE VALUE OF A QUANTITY

• The value of a quantity which is absolutely free from any error is called the true value. It can never be found out and the true value of a quantity is indeterminate.

MOST PROBABLE VALUE OF A QUANTITY

• Most probable value of a given quantity from the given available set of observation is the one for which the sum of the squares of the residual errors is a minimum.
• The most probable value of a quantity is one which is most likely to be true value than any other values. This is most likely to be free, but not likely to be absolutely free, from errors. In case of direct observations of equal weight, the most probable value is the arithmetic mean. In case of direct observations of unequal weights, the most probable value is the weights; the most probable value is the weighted arithmetic mean.

WEIGHT OF AN OBSERVATION

• The weight of an observation is a number giving an indication of its precision and trustworthiness, when making a comparison between several quantities of different worth.
• If a certain observation of weight 4 it means that it is 4 times as much reliable as an observation of weight 1. When two quantities (or) observations are assumed to be equally reliable, the observed values are said to be of equal weight (or) of unit weight
• The weight of an observation is a factor depending on the importance attached to the observation. It actually give an indication of the precision and trustworthiness of the observation when making a comparison between several quantities of different worth.

PRINCIPLES OF LEAST SQUARES

• The least squares principle states that the SRF should be constructed (with the constant and slope values) so that the sum of the squared distance between the observed values of your dependent variable and the values estimated from your SRF is minimized (the smallest possible value).
• It is found from the probability equation that the most probable values of a series of errors arising from observations of equal weight are those for which the sum of the squares is a minimum.
• The fundamental law of least squares is derived from this. According to the principle of least squares, the most probable value of an observed quantity available from a given set of observations is the one for which the sum of the squares of the residual errors is a minimum.
• When a quantity is being deduced from a series of observations, the residual errors will be the difference between the adopted value and the several observed values,
• Let V1, V2, V3 etc. be the observed

NORMAL EQUATION

• Is The One Which Is Formed By The Multiplying Each Equation By The Coefficient Of
• The Unknown, Whose Normal Equation Is To Be Formed Out By Adding The Equation Thus Formed
ADJUSTMENTS OF SIMPLE TRIANGULATION NETWORKS.
- Single angle
- Station adjustment
- Figure adjustment

STATION ADJUSTMENT
- Sum Of The Angles About A Station Should Be 360°. If Not, Find The Difference And Adjust The Difference Equally To All The Angles Algebraically To Make Their Sum Equal To 360°. Suppose; For A Station B.

<table>
<thead>
<tr>
<th>Angles</th>
<th>Observed Value</th>
<th>Correction</th>
<th>Corrected Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>∟ 1</td>
<td>---</td>
<td>-12&quot;</td>
<td>---</td>
</tr>
<tr>
<td>∟ 2</td>
<td>---</td>
<td>-12&quot;</td>
<td>---</td>
</tr>
<tr>
<td>∟ 3</td>
<td>---</td>
<td>-12&quot;</td>
<td>---</td>
</tr>
<tr>
<td>∟ 4</td>
<td>---</td>
<td>-12&quot;</td>
<td>---</td>
</tr>
<tr>
<td>∑ = 360° 00' 48&quot;</td>
<td></td>
<td>∑ = 360° 00' 00&quot;</td>
<td></td>
</tr>
</tbody>
</table>

FIGURE ADJUSTMENT
- The determination of most probable values of angles involved in any geometrical figure so as to fulfill the geometrical conditions is called the figure adjustment. All cases of figure adjustment necessarily involve one or more conditional equations. The geometrical figures used in a triangulation system are:
  (a). Triangles.
  (b). Quadrilaterals.
  (c). Polygons with central stations.
HYDROGRAPHIC SURVEYING

- Hydrographic survey is the science of measurement and description of features which affect maritime navigation, marine construction, dredging, offshore oil exploration/offshore oil drilling and related activities.
- Hydrographic surveying or bathymetric surveying is the survey of physical features present underwater. It is the science of measuring all factors beneath water that affect all the marine activities like dredging, marine constructions, offshore drilling etc.

- Hydrographic surveying is mainly conducted under authority concerns. It is mainly carried out by means of sensors, sounding or electronic sensor system for shallow water.
- The information obtained from hydrographic surveying is required to bring up nautical charts which involves,
  i. Available depths
  ii. Improved Channels
  iii. Breakwaters
  iv. Piers
  v. The aids to navigation harbor facility
- These survey also take part in necessary data collection relating to construction and developments of port facilities, such as pier construction. This help in finding the loss in capacity due to silt and many uncertainties.

Applications of Hydrographic Surveying
Following are the applications of hydrographic surveying:

- Dock and Harbor Engineering
- Irrigation
- River Works
- Land reclamation
- Water Power
- Flood Control
- Sewage Disposal

**Uses of Hydrographic Surveying**

Uses of hydrographic surveying are given below:

1. Depth of the bed can be determined
2. Shore lines can be determined
3. Navigation Chart Preparation
4. Locate sewer fall by measuring direct currents
5. Locating mean sea level
6. Scouring, silting and irregularities of the bed can be identified
7. Tide measurement
8. River and stream discharge measurement
9. Massive structures like bridges, dams harbors are planned

**Preliminary Steps in Hydrographic Surveying**

- The method starts by locating special control points along the shore line. The sounding method is employed to determine the depth at various points by means of stationary boats.
- Sounding locations can be either made from boat to the control points or by fixing a point in the boat and taking sounding from the control point. Before this procedure certain preliminary steps have to be made:
  1. Reconnaissance
  2. Locate Horizontal Control
  3. Locate vertical Control

**1.Reconnaissance**

- As every project require a start-up plan to complete it effectively and economically, reconnaissance has to be undergone. A complete reconnaissance of whole survey area to choose the best way of performing the survey.
This would facilitate satisfactory completion of the survey in accordance with the requirements and specifications governing such work. Aerial photographs would help this study.

2. Locating Horizontal Control

- The horizontal control is necessary to locate all features of the land and marine in true relative positions. Hence a series of lines whose lengths and azimuths are determined by means of either triangulation or any other methods.
- Tachometric and plane table survey can be conducted in order to undergo rough works. No rules are kept for establishing horizontal control as topography, vegetation, type, size of topography affect the rules.
- But in general a rules can be kept for type of control say:
  - It is advisable to run traverses along each shore, connecting each other by frequent tie lines – If water body > 1km wide
  - It is advisable to run transverse line only along one of the banks - If water body is narrow
  - Triangulation system - If shorelines filled by vegetation
  - Large network of triangulation system for large lakes and ocean shore lines
- A combined triangulation and traversing is shown in figure 1.

3. Locating Vertical Control

- Before sounding establishment of vertical control is essential to determined. Numerous benchmarks are placed in order to serve as vertical control. Setting and checking the levels of the gauges are uses of benchmarks

![Diagram of Combined Triangulation and Traversing in Hydrographic Survey](image)

**Fig. 1: Combined Triangulation and Traversing in Hydrographic Survey**
SOUNDING IN HYDROGRAPHIC SURVEY

- The process of determining depth below water surface is called as sounding. The step before undergoing sounding is determining the mean sea level.
- If the reduced level of any point of a water body is determined by subtracting the sounding from mean sea level, hence it is analogous to levelling.

Methods of Locating Soundings in Hydrographic Surveying

- The soundings are located by the observations made from the boat or from the shore or from both.
- There are four methods are there to locate the soundings by:
  1. Conning the survey vessel
  2. Observations with theodolite or sextant
  3. Theodolite angles and EDM distances from the shore
  4. Microwave systems

SOUNDING BY CONNING THE SURVEY VESSEL

- In this method, conning means keeping the boat at known course. This method is suitable for rivers, open sea up to 5 km off shore. The markers are fixed on the shore called as ranges along which vessel or boat is run. This method is again sub divided into two types as follows.
  - Location by cross rope
  - Location by range and time interval

Location by Cross Rope

- In this method, a wire or rope with markings or tags at known distances is stretched across the channel. The starting point of rope at the shore is marked as reference point. Then using boat, the sounding at different distances of wire are determined by weighted pole.
- This method is more accurate. This is most suitable for rivers, narrow lakes and for harbors. This is also suitable for knowing the amount of material removed by dredging.

Location by Range and Time Interval

- In this method, the boat is positioned in range with two signals provided on the shore. Then, the boat is rowed at constant speed and time required to reach the instant of sounding is measured which gives the distance of total point along the range. This method is more suitable for less width channels or rivers. It is not so much accurate.

SOUNDING BY OBSERVATIONS WITH THEODOLITE OR SEXTANT
Theodolite or sextant is used to measure angles in surveying. In this method, the sounding is located by measuring angles. Here also, there are a lot of subdivided methods are there to locate sounding.

They are
- By range and one angle from the shore
- By range and one angle from the boat
- By two angles from the shore
- By two angles from the boat
- By one angle from the shore and one angle from boat
- By intersecting angles
- By tachometry

**By Range and One Angle from the Shore**
- In this method, boat is kept in range line with the help of two signals on the shore. The boat is moved and the point where sounding is measuring is observed by the theodolite or sextant and angle is noted. Using this angle, we can fix the point in the range.
- Likewise, all other soundings are observed from different stations. The angle should be more than 30 degrees otherwise fix should be poor. so, whenever the angle is less than 30°, new instrument station is selected. This method is so accurate and easy for plotting the sounding details.

**By Range and One Angle from the Boat**
- This method is similar to the above method, but in this case, the angular measurements are taken from the boat to different stations positioned on the shore. This is also having similar accuracy to the above method.
- But, there are some advantages in this method as compared with above method. Angle measured from the shore from different stations is difficult when compared to angle observed from the boat to all stations.
- So, the surveyor in this case has better control over the operations. Check can be made by measuring second angle towards some other signal on the shore for important fixes.
By Two Angles from the Shore

- In this method, two instrument stations are fixed on the shore with proper distance. Two instruments and two instrument men are required to do this job. From the two instrument stations, angular observations are made and a point is located where sounding is measured.
- If the angle made by instrument is less than $30^0$ then new instrument station is selected. In this case, primary setting out and erecting range signals are eliminated. This method is useful when water currents are strong and difficult to row the boat along range line.

By Two Angles from the Boat

- In this method, three constant points on the shore are selected. Using three-point problem, boat is positioned in range line and angles are observed from the boat to two of the three known positions.
- The known positions may be light house, church spire, etc. like objects on the shore. If fixed positions are not available, then go for shore signals or ranging rods.
By One Angle from the Shore and One Angle from Boat

- This method also requires two instruments and two men to operate. This is the combination of above two methods. In this method, two instrument points are located on the shore and instrument is placed only at one point. Other instrument is placed in the boat.
- The first angle is measured from the first point on the shore to boat and from the boat second angle is measured from boat to second point. At that instant sounding is measured.

By Intersecting Angles

- In this method, sounding is determined periodically at same points. This method is essentially used for harbors, reservoirs etc. to know the amount of silting or scouring happened at that points.
- Number of signals are erected on the shore and a boat is rowed perpendicular to the shore and measure the sounding at a point where inclined line of signal intersect the line of signal next to it as shown in fig.
- Flag rods are erected at sounding points to avoid confusion for the next round of measuring.
**By Tachometry**

- In this method, tachometer is placed on the shore and staff is placed on a boat. The staff intercept “s” is known by tachometer from this the distance between boat and instrument is known. This method is suitable when water is stable and sounding location is nearer to the shore.

**SOUNDING BY THEODOLITE ANGLES AND EDM DISTANCES FROM SHORE**

- In this method, EDM and Theodolite are placed on the shore in fixed positions. From this set up, the reflector placed on the boat is targeted and point of sounding is located.
- This method is more accurate when the water is still. This is one of the modern methods of fixing sounding vessel.

**SOUNDING BY MICROWAVE SYSTEMS**

- In this method, a device called Tellurometer is used which contains three units’ namely master unit, remote unit and master antenna. Master unit is fixed to the boat and other two units are located on the shore at two shore stations.
The distances are measured from boat to the shore stations using micro waves produced by tellurometer. Now from all these known distances the antenna produces the two sets of range information. Tellurometer is useful for distances up to 100km from the shore.

The specific need for sounding are
1. Preparation of navigation charts that is an all-time information for future purpose also
2. Material that to be dredged has to be determined early to facilitate easy movement in project without any confusion
3. Material dredging should also accompany where filling has to be done. Material dumping is also measured
4. Design of backwaters, sea wells require detailed information that is obtained from sounding

EQUIPMENT FOR SOUNDING
The essential equipment used for undergoing sounding are

1. Shore signals and buoys
2. Sounding Equipment
3. Instruments for measuring angles

1. SHORE SIGNAL AND BUOYS
- These are required to mark the range lines. A line perpendicular to shore line obtained by line joining 2 or 3 signals in a straight line constitute the range line along which sounding has to be performed. Angular observations can also be made from sounding boats by this method. To make it visible from considerable distance in the sea it is made highly conspicuous.
- A float made of light wood or air tight vessel which is weighted at bottom kept vertical by anchoring with guywires are called buoys. In order to accommodate a flag a hole is drilled. Under water deep, the range lines are marked by shore signals & the buoys.

2. SOUNDING EQUIPMENT
The individual units involved are explained one by one:

A. SOUNDING BOAT
A flat bottom of low draft is used to carry out sounding operation. Large size boats with motor are used for sounding in sea. The soundings are taken through wells provided in the boat. A figure depicting sounding boat is shown in fig.2.
B. SOUNDING POLE OR ROD
Rod made of seasoned timber 5 to 10cm diameter and 5 to 8m length. A lead shoe of sufficient weight is connected at bottom to keep it vertical. Graduations are marked from bottom upwards. Hence readings on the rod corresponding to water surface is water depth.

C. LEAD LINE
A graduated rope made of chain connected to the lead or sinker of 5 to 10kg, depending on current strength and water depth. Due to deep and swift flowing water variation will be there from true depth hence a correction is required.

- Other sounding equipment used are Weddell’s sounding machine. These are employed when large sounding work has to be undergone. A standard machine to measure maximum of 30 to 40m is designed that are bolted over the well of the sounding boat.

- Another equipment used is fathometer which is an echo-sounding instrument used to determine ocean depth directly. Recording time of travel by sound waves is the principle employed. Here the time of travel from a point on the surface of the water to the bottom of the ocean and back is recorded.

- Knowing the velocity of sound waves the depth can be calculated as shown in fig.4.
TIDES

- All celestial bodies exert a gravitational force on each other. These forces of attraction between earth and other celestial bodies (mainly moon and sun) cause periodical variations in the level of a water surface, commonly known as tides.
- There are several theories about the tides but none adequately explains all the phenomenon of tides. However, the commonly used theory is after Newton, and is known as the equilibrium theory.
- According to this theory, a force of attraction exists between two celestial bodies, acting in the straight line joining the centre of masses of the two bodies, and the magnitude of this force is proportional to the product of the masses of the bodies and is inversely proportional to the square of the distance between them.
- We shall apply this theory to the tides produced on earth due to the force of attraction between earth and moon. However, the following assumptions are made in the equilibrium theory:
  1. The earth is covered all round by an ocean of uniform depth.
  2. The ocean is capable of assuming instantaneously the equilibrium, required by the tide producing forces. This is possible if we neglect
     (i) Inertia Of Water,
     (ii) Viscosity Of Water,
     (iii) Force Of Attraction Between Parts Of Itself.

TYPES OF TIDES:

i) LUNAR TIDE
- Lunar Tide, also known as moon tide, is the tide caused in the sea due to the gravitational attraction caused by the moon. A tide is generally defined as the rise and fall in the level of the sea with respect to the land. ... The tides produced due to gravitational attraction caused by the sun are called solar tides.

ii) THE SOLAR TIDES
- The phenomenon of production of tides due to force of attraction between earth and sun is similar to the lunar tides.
- Thus, there will be superior solar tide and an inferior or anti-solar tide. However, sun is at a large distance from the earth and hence the tide producing force due to sun is much less.
- Solar tide = 0.458 Lunar tide.
- Combined effect : Spring and neap tides
  Solar tide = 0.458 Lunar tide.
• Above equation shows that the solar tide force is less than half the lunar tide force. However, their combined effect is important, specially at the new moon when both the sun and moon have the same celestial longitude, they cross a meridian at the same instant.

**MEAN SEA LEVEL**

• For all important surveys, the datum selected is the mean sea level at a certain place.
• The mean sea level may be defined as the mean level of the sea, obtained by taking the mean of all the height of the tide, as measured at hourly intervals over some stated period covering a whole number of complete tides.
• The mean sea level, defined above shows appreciable variations from day to day, from month to month and from year to year.
• Hence the period for which observations should be taken depends upon the purpose for which levels are required.
• The daily changes in the level of sea may be more. The monthly changes are more or less periodic. The mean sea level in particular month may be low while it may be high in some other months.
• Mean sea level may also show appreciable variations in its annual values. Due to variations in the annual values and due to greater accuracy needed in modern geodetic levelling, it is essential to base the mean sea level on observations extending over a period of about 19 years.
• During this period, the moon’s nodes complete one entire revolution. The height of mean sea level so determined is referred to the datum of tide gauge at which the observations are taken.
• The point or place at which these observations are taken is known as a tidal station. If the observations are taken on two stations, situated say at a distance of 200 to 500 kms on an open coast, one of the station is called primary tidal station while the other is called secondary tidal station.
• Both the stations may then be connected by a line of level.

**ASTRONOMICAL SURVEYING**

• An astronomical survey is a general map or image of a region of the sky which lacks a specific observational target. Alternatively, an astronomical survey may comprise a set of many images or spectra of objects which share a common type or feature.
ASTRONOMICAL TERMS AND DEFINITIONS

- To observe the positions / direction and movement of the celestial bodies, an imaginary sphere of infinite radius is conceptualized having its centre at the centre of the earth. The stars are studded over the inner surface of the sphere and the earth is represented as a point at the centre.

CELESTIAL SPHERE:

- An imaginary sphere of infinite radius with the earth at its centre and other celestial bodies studded on its inside surface is known as celestial sphere.

GREAT CIRCLE (G.C):

- The imaginary line of intersection of an infinite plane, passing through the centre of the earth and the circumference of the celestial sphere is known as great circle.

ZENITH (Z):

- If a plumb line through an observer is extended upward, the imaginary point at which it appears to intersect the celestial sphere is known as Zenith. The imaginary point at which it appears to intersect downward in the celestial sphere is known as Nadir (N).

VERTICAL CIRCLE:

- Great circle passing through zenith and nadir is known as vertical circle.

HORIZON:

Great circle perpendicular to the line joining the Zenith and Nadir is known as horizon.

POLES:

- If the axis of rotation of the earth is imagined to be extended infinitely in both directions, the points at which it meets the celestial sphere are known as poles.
- The point of intersection in the northern hemisphere is known as north celestial pole and that in the southern hemisphere as south celestial pole.

EQUATOR:

- The line of intersection of an infinite plane passing through the centre of the earth and perpendicular to the line joining celestial poles with the celestial sphere.

HOUR CIRCLE:

- Great circle passing through celestial poles is known as hour circle, also known as declination circle.

MERIDIAN:

- The hour circle passing through observer's zenith and nadir is known as (observer's) meridian. It represents the North-South direction at observer station.

ALTITUDE (H):

- The altitude of a celestial body is the angular distance measured along a vertical circle passing through the body. It is considered positive if the angle measured is above horizon and below horizon, it is
considered as negative.

AZIMUTH (A):
- The azimuth of a celestial body is the angular distance measured along the horizon from the observer's meridian to the foot of the vertical circle passing through the celestial body.

THREE POINT PROBLEM
- In this method, three well defined points, having locations already being plotted on the drawing are involved. These are used to find and subsequently plot the location of the plane table station.

![Figure 35.1 Principle of Three-point problem solution](image)

- The method is based on the fact that, in a correctly oriented plane table, resectors through well defined points get intersected at a point which represents the location of the plane table station on the drawing.

There are several methods for solution of the three point problem:
(i) trial and Error method,
(ii) mechanical method,
(iii) Graphical method,
(iv) Analytical method and
(v) geometrical construction method.

Of these, the trial and error method is easy, quick and accurate. It is commonly used in practice and hence, has been discussed in detail.
- In three point problem, if the orientation of the plane table is not proper, the intersection of the resectors through the three points will not meet at a point but will form a triangle, known as triangle of error (Figure).
- The size of the triangle of error depends upon the amount of angular error in the orientation.

- The trial and error method of three point problem, also known as Lehman's method minimises the triangle of error to a point iteratively. The iterative operation consist of drawing of resectors from known points through their plotted position and the adjustment of orientation of the plane table.
- The estimation of location of the plane table depends on its position relative to the well defined points considered for this purpose. Depending on their relative positions, three cases may arise:
(i) The position of plane table is inside the great triangle;

(ii) The position of plane table is outside the great triangle;

(iii) The position of plane table lies on or near the circumference of the great circle.

In case of (iii), the solution of the three-point problem becomes indeterminate or unstable. But for the cases (i) and (ii), Lehmann’s rules are used to estimate the location of plane table.

**STEPS FOR THREE POINT PROBLEM**

- Let X, Y, and Z represent the ground location of the well defined objects whose plotted positions are x, y, and z, respectively. Let P be the plane table station whose plotted position, say p, is to be determined.

(i) Select a plane table position inside the great triangle XYZ and set up the table over P and orient it by judgment so that apparent line xy is approximately parallel to the imaginary side XY.

(ii) Pivoting the alidade on x, y, and z bisect the signals placed at X, Y, and Z in turn and draw rays. If the orientation of the table is correct, the three rays will meet at one point which is the desired location of p on the sheet. If not, the rays will form a triangle of error.

(iii) Choose a point p’ inside the triangle of error such that its perpendicular distances from each ray is in proportion to the respective distances of P from the three ground objects. For selection of location of p’, Lehmann’s rules (1) and (3) need to be applied.

(iv) Align the alidade along p’ x (assuming X to be the farthest station) rotate the table till flag at X is bisected, and clamp the table.

(v) Pivoting the alidade on x, y, and z repeat the process as in step (ii) above. If the estimation of p as p’ is correct, the three rays will intersect at a point otherwise again a triangle of error will be formed but of smaller
size and within the previous triangle of error.

(vi) Estimate again the location of p' in the new triangle of error applying the rules, (i) and (iii), and repeat the steps (iv) and (v).

(vii) The method is repeated till all the three rays intersect at a point. The point of intersection is the required location p of the plane-table station P.

STRENGTH OF FIX

- The accuracy with which a plane table station can be located through three point problem is known as its fix.
- The degree of accuracy of solution of the three point problem is designated as its strength i.e., if the accuracy is high, the fix is termed as strong and for low accuracy, fix is called as poor.
- The accuracy of fix depends on the relative positions of the plotted points and that of location of the plane table station. Thus, the choice of plotted objects and location of table should be made to get a strong fix.

The strength of fix is good if
- the location of station is chosen within the great triangle formed by joining the three well defined objects X;
- the middle object is nearer to the position of the plane table than other two objects;
- of the two interior angles subtended by the three objects at the plane table stations, one is small and the other is large. However, the objects subtending small angle should be widely separated to each other.

The strength of fix is poor if
- The location of the plane table is on or near the circumference of the great circle.
- Both the interior angles, subtended, by well defined objects, at the plane table stations, are small.

Figure 35.7 provides a pictorial representation of the quality of strength of figure with reference to the location of the three chosen objects.
CELESTIAL COORDINATE SYSTEM

- In astronomy, a celestial coordinate system is a system for specifying positions of celestial objects: satellites, planets, stars, galaxies, and so on.
- Coordinate systems can specify an object's position in three-dimensional space or plot merely its direction on a celestial sphere, if the object's distance is unknown or trivial.
- The coordinate systems are implemented in either spherical or rectangular coordinates. Spherical coordinates, projected on the celestial sphere, are analogous to the geographic coordinate system used on the surface of Earth.
- These differ in their choice of fundamental plane, which divides the celestial sphere into two equal hemispheres along a great circle.
- Rectangular coordinates, in appropriate units, are simply the cartesian equivalent of the spherical coordinates, with the same fundamental (x, y) plane and primary (x-axis) direction. Each coordinate system is named after its choice of fundamental plane.

AZIMUTH OF A LINE

- Azimuth of a line is its horizontal angle measured clockwise from geographic or true meridian.
- For field observation, the most stable and retraceable reference is geographic north. Geographic north is based on the direction of gravity (vertical) and axis of rotation of the earth.
- A direction determined from celestial observations results in astronomic (Geographic) north reference meridian and is known as geographic or true meridian.
- The azimuth of a line is determined from the azimuth of a celestial body. For this, the horizontal angle between the line and the line of sight to the celestial body is required to be observed during astronomic observation along with other celestial observation.
Let AB be the line whose azimuth ($A_{AB}$) is required to be determined (Figure 26.1). Let O be the station for celestial observations. Let S be the celestial body whose azimuth ($A_s$) is determined from the astronomical observation taken at O. The horizontal angle from the line AB to the line of sight to celestial body (at the station O) is observed to be $q^\circ$ clockwise. The azimuth of the line, AB can be computed from

$A_{AB} = A_s - q^\circ$ (clockwise).

If $A_{AB}$ computes to be negative, $360^\circ$ is added to normalize the azimuth.
In order to compute the azimuth of a line with proper sign, it is better to draw the known parameters. The diagram itself provides the azimuth of the line with proper sign. For example, in Figure 26.2, first a line of sight to celestial body, OS is drawn.

Then, the azimuth of the celestial body, As is considered in counter-clockwise from the line OS and obtained the true north direction i.e, the line ON. Similarly, the horizontal angle \( q^\circ \) is represented in counter clockwise (since the angle from the line to the celestial body is measured clockwise) direction from OS to obtain the relative position of the line. The angle NOB represents the azimuth of the line AB.

**DETERMINATION OF AZIMUTH OF A CELESTIAL BODY**

In field astronomy, a celestial body provides the reference direction. So, from the geographic location (latitude and longitude) of the station, ephemeris data of celestial body and either time or altitude of the same celestial body, the azimuth of the celestial body is computed by solving astronomical triangle.

If time is used, the procedure is known as the hour-angle method. Likewise, if altitude is measured, the procedure is termed as the altitude method.

The basic difference between these two methods is that the altitude method requires observation of approximate time and an accurate vertical angle of the celestial body, whereas the hour angle method requires observation of accurate time.

Recent developments of time receivers and accurate timepieces, particularly digital watches with split-time features, and time modules for calculators, the hour-angle method is more accurate, faster. It requires shorter training for proficiency.

It has fewer restrictions on time of day and geographic location and thus is more versatile. The method is applicable to the sun, Polaris, and other stars. Consequently, the hour-angle method is emphasized, and its use by surveyors is encouraged.

**HOUR ANGLE METHOD**

In this method, precise time is being noted when the considered celestial body is being bisected. The observed time is used to derive the hour angle and declination of the celestial body at the instant of observation.

The geographic position (latitude and longitude) of the observation station is required to be known a priori for the hour angle method. Usually, these values are readily obtained from available maps. However, to achieve better accuracy, latitude and longitude must be more accurately determined specially during observations for celestial bodies close to the equator--e.g., the sun-than for bodies near the pole--e.g., Polaris.
• The declination of the celestial bodies at the instant of observation is required to be known for computation of azimuth of the celestial body. It is available in star almanac at the 0, 6, 12 and 18 hours of UTI of each day (Greenwich date). Thus, the declination at the instant of observation (of celestial body) is determined by linear interpolation for corresponding the UT1 time of observation. However, since the declination of the sun varies rapidly, its interpolation is done using the relation:

\[ \text{Declination, } d = \text{Decl} 0^h + (\text{Decl} 24^h - \text{Decl} 0^h) \left( \frac{\text{UT1}}{24} \right) + (0.0000395) (\text{Decl} 0^h) \sin (7.5 \text{ UT1}) \]

\[ \text{--(Equation 26.2)} \]

• The hour-angle of the celestial body is being derived using the GHA (available in star almanac with reference to Greenwich date) and the longitude of the observation station. For observations in the Western Hemisphere, if UTI is greater than local time, the Greenwich date is the same as local date and if UTI is less than local time, Greenwich date is the local date plus one day. For the Eastern Hemisphere, if UTI is less than local time (24-hr basis), Greenwich date is the same as local date and if UTI is greater than local time, Greenwich date is local date minus one day. The hour angle of the celestial body at the observation station is the LHA.

• Thus, it is the LHA at UTI time of observation which is necessary to compute the azimuth of a celestial body. Hence, as can be seen from Figure 26.3, the equation for the LHA is

\[ \text{LHA} = \text{GHA} - \text{Wl} \text{ (west longitude)} \]

\[ \text{Or LHA} = \text{GHA} + \text{El} \text{ (east longitude)} \]

\[ \text{--(Equation 26.3)} \]

\[ \text{--(Equation 26.4)} \]

• LHA should be normalized to between 0° and 360° by adding or subtracting 360°, if necessary.

• The Greenwich hour angle (GHA) of celestial bodies—the sun, Polaris, and selected stars—is tabulated in star almanac from 0 hr to 24 hr at an interval of 6 hours of UTI time of each day (Greenwich date). Thus, to find GHA at the time of observation linear interpolation is required to be performed.

• The GHA can also be derived by making use of the equation of time E (apparent time minus mean time) by using the relation:

\[ \text{GHA} = 180^\circ + 15 \text{ E} \]

\[ \text{--Equation (26.5)} \]

where E is in decimal hours. In those cases where E is listed as mean time minus apparent time, the algebraic sign of E should be reversed.

• Once the parameters (declination and Hour angle of the celestial body, latitude of the observation station) required to compute the azimuth of the celestial body are available, the computation of azimuth of the celestial body is carried out using the relations of astronomical triangle

UNIT 5
MODERN SURVEYING

TOTAL STATION
• 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.

BASIC PRINCIPLE
• Although taping and theodolites are used regularly on site – total stations are also used
extensively in surveying, civil engineering and construction because they can measure both distances and angles.

CAPABILITY OF A TOTAL STATION

Microprocessor unit in total station processes the data collected to compute:

i. Average of multiple angles measured.
ii. Average of multiple distance measured.
iii. Horizontal distance.
iv. Distance between any two points.
v. Elevation of objects and
vi. All the three coordinates of the observed points.

IMPORTANT OPERATIONS OF TOTAL STATION

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.

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.
DATA PROCESSING

- This 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.

DISPLAY

- Electronic display unit is capable of displaying various values when respective keys are pressed.
- The system is capable of displaying horizontal distance, vertical distance, horizontal and vertical angles, difference in elevations of two observed points and all the three coordinates of the observed points.

ELECTRONIC BOOK

- Each point data can be stored in an electronic note book (like compact disc).
- The capacity of electronic note book varies from 2000 points to 4000 points data. Surveyor can unload the data stored in note book to computer and reuse the note book.

USES 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:

Field work is carried out very fast.
Accuracy of measurement is high.
Manual errors involved in reading and recording are eliminated.
Calculation of coordinates is very fast and accurate. Even corrections for temperature and pressure are
automatically made.
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.

**OPERATIONS INVOLVED WHILE USING TOTAL STATIONS:**

1. Establishing the site Datum:
   a) Selecting the site Datum
   b) Establishing North

2. Setting up the Total station:
   a) Placing and leveling Tripod on Datum
   b) Placing and leveling the Gun on Tripod
   c) Linking the data connector to Gun

3. Data collector options and setting
   a) Main menu
   b) Basic settings

4. Creating and Operating Job files:
   a) Creating a new Job file
   b) Opening an existing file

5. Shooting points
   a) Identifying the important points to shoot
   b) shooting points
   c) Shooting additional points
   d) Noting the special features

6. Post Processing – Data down loading, conversion

7. Plotting/Map generation.

**TOTAL STATION ERRORS**

1. HORIZONTAL COLLIMATION OR LINE OF SIGHT ERROR
• Horizontal collimation or line of sight error is when the line of sight is not perpendicular to the tilting axis of the instrument. This is an axial error.
• Line of sight error effects the horizontal angle readings and increases with steep sightings. The error can be overcome or eliminated by observing on two faces.
• For single face measurements, an on-board calibration function is used to determine the deviation ($c$) of actual line of sight and deviated line of sight. The on-board software then apply a correction for each measured horizontal angles reading automatically.

The catch is here if the deviation of line of sight from actual line of sight exceeds more than a desired value, the instrument must be send to service centre or manufacturer for manual calibration.

2. TILTING AXIS ERROR OR TILT ERROR
• Tilting axis or tilt error is the error when the axis to the total station is not perpendicular to the vertical axis or plumb line. The error effect on horizontal readings when the instrument is tilted (steep sightings) but have no effect on sightings taken when the instrument is horizontal.
• Like horizontal collimation error the tilting error can be eliminated by two face measurement. Another method is to apply the measured tilting error at the time of calibration process for all readings.

If the tilt error is more than the specified error for instrument, must be send to calibration lab.

3. VERTICAL COLLIMATION ERROR OR VERTICAL INDEX ERROR
• If the horizontal base line of angle from $0^\circ$ to $180^\circ$ in the vertical circle does not coincide with the
vertical axis of instrument. This zero point error is present in all vertical circle readings and like the horizontal collimation error, it is eliminated by taking FL and FR readings or by determining $i$.

4. COMPENSATOR INDEX ERROR

- This error is caused by not leveling the total station correctly and carefully. This error can’t be eliminated by taking two face (face left and face right) readings unlike the horizontal collimation error.
- If the instrument is fitted with a compensator it will measure residual tilts of the instrument and will apply corrections to the horizontal and vertical angles for these.

- However all compensators will have a longitudinal error $l$ and traverse error $t$ known as zero point errors. These are averaged using face left and face right readings but for single face readings must be determined by the calibration function of the total station.

SEGMENTS OF GPS

- For better understanding of GPS, we normally consider three major segments viz. space segment, Control segment and User segment. Space segment deals with GPS satellites systems, Control segment describes ground based time and orbit control prediction and in User segment various
types of existing GPS receiver and its application is dealt.

- Table 2 gives a brief account of the function and of various segments along with input and output information.

<table>
<thead>
<tr>
<th>SEGMENT</th>
<th>INPUT</th>
<th>FUNCTION</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td>Navigation message</td>
<td>Generate and Transmit code</td>
<td>P-Code C/A Code L1, L2</td>
</tr>
<tr>
<td>Control</td>
<td>P-Code Observations Time</td>
<td>Produce GPS time predict ephemeris</td>
<td>Navigation message</td>
</tr>
<tr>
<td>User</td>
<td>Code observation</td>
<td>Navigation solution</td>
<td>Position velocity time</td>
</tr>
<tr>
<td></td>
<td>Carrier phase</td>
<td>Surveying</td>
<td></td>
</tr>
<tr>
<td></td>
<td>observation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- GLONASS (Global Navigation & Surveying System) a similar system to GPS is being developed by former Soviet Union and it is considered to be a valuable complementary system to GPS for future Application.

SPACE SEGMENT
- Space segment will consist 21 GPS satellites with an addition of 3 active spares. These satellites are placed in almost six circular orbits with an inclination of 55 degree.
- Orbital height of these satellites is about 20,200 km corresponding to about 26,600 km from the semi major axis.
- Orbital period is exactly 12 hours of sidereal time and this provides repeated satellite configuration every day advanced by four minutes with respect to universal time.

SATELLITE CONFIGURATIONS
- The satellite configuration specifies the GlobalProtect LSVPN configuration settings to deploy to the connecting satellites. You must define at least one satellite configuration.

OBSERVATION PRINCIPLE AND SIGNAL STRUCTURE
- NAVSTAR GPS is a one-way ranging system i.e. signals are only transmitted by the satellite. Signal travel time between the satellite and the receiver is observed and the range distance is calculated through the knowledge of signal propagation velocity.
- One way ranging means that a clock reading at the transmitted antenna is compared with a clock reading at the receiver antenna. But since the two clocks are not strictly synchronized, the observed
signal travel time is biased with systematic synchronization error.

- Biased ranges are known as pseudoranges. Simultaneous observations of four pseudoranges are necessary to determine X, Y, Z coordinates of user antenna and clock bias.
- Real time positioning through GPS signals is possible by modulating carrier frequency with Pseudorandom Noise (PRN) codes.
- These are sequence of binary values (zeros and ones or +1 and -1) having random character but identifiable distinctly. Thus pseudoranges are derived from travel time of an identified PRN signal code.
- Two different codes viz. P-code and C/A code are in use. P means precision or protected and C/A means clear/acquisition or coarse acquisition.

<table>
<thead>
<tr>
<th>Atomic Clock (G, Rb) fundamental frequency</th>
<th>10.23. MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1 Carrier Signal</td>
<td>154 X 10.23 MHz</td>
</tr>
<tr>
<td>L1 Frequency</td>
<td>1575.42 MHz</td>
</tr>
<tr>
<td>L1 Wave length</td>
<td>19.05 Cm</td>
</tr>
<tr>
<td>L2 Carrier Signal</td>
<td>120 X 10.23 MHz</td>
</tr>
<tr>
<td>L2 Frequency</td>
<td>1227.60 MHz</td>
</tr>
<tr>
<td>L2 Wave Length</td>
<td>24.45 Cm</td>
</tr>
<tr>
<td>P-Code Frequency (Chipping Rate)</td>
<td>10.23 MHz (Mbps)</td>
</tr>
<tr>
<td>P-Code Wavelength</td>
<td>29.31 M</td>
</tr>
<tr>
<td>P-Code Period</td>
<td>267 days : 7</td>
</tr>
<tr>
<td>C/A-Code Frequency (Chipping Rate)</td>
<td>1.023/MHz(Mbps)</td>
</tr>
<tr>
<td>C/A-Code Wavelength</td>
<td>293.1 M</td>
</tr>
<tr>
<td>C/A-Code Cycle Length</td>
<td>1 Milisecond</td>
</tr>
<tr>
<td>Data Signal Frequency</td>
<td>50 bps</td>
</tr>
<tr>
<td>Data Signal Cycle Length</td>
<td>30 Seconds</td>
</tr>
</tbody>
</table>

**STRUCTURE OF THE GPS NAVIGATION DATA**

- Structure of GPS navigation data (message) is shown in Fig. The user has to decode the data signal to get access to the navigation data.
- For on line navigation purposes, the internal processor within the receiver does the decoding. Most of the manufacturers of GPS receiver provide decoding software for post processing purposes. With a bit rate of 50 bps and a cycle time of 30 seconds, the total information content of a navigation data set is 1500 bits.
- The complete data frame is subdivided into five subframes of six second duration comprising 300 bits of information. Each subframe contains the data words of 30 bits each. Six of these are control bits. The first two words of each subframe are the Telemetry Work (TLM) and the C/A-P-Code Hand over Work (HOW). The TLM work contains a synchronization pattern, which facilitates the access to the navigation data. Since GPS is a military navigation system of US, a limited access to the total system accuracy is made available to the civilian users.

**CONTROL SEGMENT**

- Control segment is the vital link in GPS technology. Main functions of the control segment.
  - Monitoring and controlling the satellite system continuously
  - Determine GPS system time
  - Predict the satellite ephemeris and the behavior of each satellite clock.
  - Update periodically the navigation message for each particular satellite.

**USER SEGMENT**

- Appropriate GPS receivers are required to receive signal from GPS satellites for the purpose of navigation or positioning. Since, GPS is still in its development phase, many rapid
advancements have completely eliminated bulky first generation user equipments and now miniature powerful models are frequently appearing in the market.

**ORBIT DETERMINATION:**
- Orbit Determination is the process to estimate the position and velocity (state vector) of a satellite at a specific epoch based on models of the forces acting on the satellite, integration of satellite orbital motion equations and measurements to the satellites.
- Orbit Determination (OD) is generally divided into two categories:
  i. preliminary orbit determination
  ii. precise orbit determination (POD).

**PRELIMINARY ORBIT DETERMINATION**
- Preliminary Orbit Determination is a geometric method to estimate orbit elements from a minimal set of observations before the orbit is known from other sources.
- Traditionally, and still typically used, ground-based satellite observations of angles, distance or velocity measurements, which depend on the satellite’s motion with respect to the centre of the Earth.

**PRECISE ORBIT DETERMINATION**
- Precise Orbit Determination is a dynamic, or combined geometric and dynamic method, a process completed with two distinct procedures: orbit integration and orbit improvement.
- Orbit integration yields a nominal orbit trajectory, while orbit improvement estimates the epoch state with all the measurements collected over the data arc in a batch estimation process.

**ORBIT REPRESENTATION**
- Orbit Representation is a means of representing a satellite orbit as a continuous trajectory with discrete observation data at the time of interest.
- The simplest orbit representation is the “osculating Keplerian elements” method, which describes an orbit as an ellipse.
- The most typical example is the satellite almanacs published by NASA for almost all spacecrafts in orbit. Figure 1.1 illustrates the concepts of the Keplerian elements with respect to the earth-centred inertial coordinate system.

**ANTI-SPOOFING**
- The function of anti-spoofing (AS) of the GPS system is designed for an anti potential spoofer (or jammer). A spoofer generates a signal that mimics the GPS signal and attempts to cause the receiver to track the wrong signal.
- When the AS mode of operation is activated, the P code will be replaced with a secure Y code available only to authorised users, and the unauthorised receiver becomes a single L1 frequency receiver. AS had been tested frequently since 1 August 1992 and formally activated at 00:00 UT on 31 January 1994 and now is in continuous operation on all Block II and later satellites.
- The broadcasted ionospheric model (in the navigation message) may be used to overcome the problem of absence of the dual-frequencies, which are originally implemented for eliminating the ionospheric effects. Of course, the method of using the ionospheric model cannot be as accurate as the method of using dual-frequencies data, and consequently the precision is degraded. Carrier phase smoothed C/A code may be used to replace the absence of the P code.

**SELECTIVE AVAILABILITY**
- Selective availability (SA) is a degradation of the GPS signal with the objective to deny full position and velocity accuracy to unauthorised users by dithering the satellite clock and manipulating the ephemerides.
In case SA is on, the fundamental frequency of the satellite clock is dithered, so that the GPS measurements are affected. The broadcast ephemerides are manipulated so that the computed orbit will have slow variations. Several levels of SA effects are possible. The SA is enabled on Block II and later satellites (Graas and Braasch 1996).

**The authorised users may recover the** un-degraded data and exploit the full system potential. For doing so they must possess a key that allows them to decrypt correction data transmitted in the navigation message (Georgiadou and Daucet 1990).

For high-precision users, IGS precise orbit and forecast orbit data may be used. Using known positions (or monitor stations), the range corrections can be computed. Differential GPS may also eliminate at least a part of the SA effects. SA has been switched off since May 2000.

**HANDHELD GPS RECEIVERS**

- Handheld GPS receivers are used for absolute positioning or for relative positioning using DGPS-services or WAAS/EGNOS signals. The positioning is realized using code pseudo-ranges.
- Moreover it is well known that some of the handheld receivers use phase-smoothed code for positioning. This means that the phase signal is available and may be used for Precise Differential GPS (PDGPS) positioning.

**GEODETIC RECEIVER**

- Geodetic GPS receivers have the advantage of providing additionally the P-code observations, with a noise level smaller than the noise on the C/A code.
- The accuracy requirements of geodetic receivers are usually about 1-5 cm (or even better).