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Introduction and Fundamentals of Surveying

1.1. DEFINITION OF SURVEYING

Surveying is the science or art, of making the measurements necessary to determine or establish the relative positions of points. The points may be on, above or below the surface of the earth. Surveying is done to ascertain and delineate on map or plan the shape and extent of any portion of the earth's surface.

Levelling is an art of determining, and representing the relative elevations of different points on the surface of the earth. It is the process in which positions of points are determined in a vertical plane. The operation of determining the elevations is required in the designing stage of the projects, whereas representing operation is required in the setting out stage of the project.

Surveying and levelling are considered as separate operations. However, surveying is a more comprehensive term and includes levelling also.

1.2. OBJECT OF SURVEY

Surveying is one of the oldest arts practised by man, because from the earliest times it has been found necessary to mark boundaries and divide lands. It is now indispensible in all branches of engineering. Surveys are required prior to and during the planning and construction of highways, railways, buildings, bridges, tunnels, canals, dams, drainage works and water supply and sewage systems. There is no field where surveying is not required for undertaking and execution of the project.

The primary object of a survey is to prepare plan or map of the area. It represents the area on a horizontal plane, *i.e.,* only horizon-

tal distances of the points are shown. The field work of certain area when plotted on drawing or graph sheet constitutes a plan. There is difference between terms, plan and map. If the scale of the drawing is quite large it is known as *plan* and if the scale is small the representation is called the *map*. Plans are prepared for engineering projects whereas maps are prepared to represent very large areas like regions and countries.

As already said that the plan represents or shows only the horizontal distances. Sometimes, however, vertical elevations are also shown on plans by means of contour lines. However, the vertical distances are correctly represented by means of vertical sections.

Now a days good knowledge of surveying is essential for any successful engineer. Surveying is a continuous process for any Engineering project right from its conception to realization. Surveys have to be conducted for preparing plans and estimates. Plans represent the topography of the area and mark the boundaries of the concerned area. After the plans are made, they will have to be staked out on the ground. As the actual construction work progresses the levels at various stages will have to be checked. So it can be said that survey work of the project continues from its conception to the stage when it is actually completed.

1.3. HISTORY OF SURVEYING

The historical records relate origination of surveying from Egypt. The land of Egypt was divided into plots for the purpose of taxation. These early surveyors were called *rope-stretchers.* Greeks adopted this science about 120 BC. They developed an instrument called Dioptra which was used for, surveying fields, drawing planes and making calculations. Romans adopted this science in big way in first century for carrying out extensive construction work throughout their Empire.

During the middle ages, Greek and Roman, science of surveying was kept alive by the Arabs. Little progress was made in the art of surveying them.

In the 18th and 19th centuries, the art of surveying advanced more rapidly. The need for maps and the location of national boundaries caused England and France to make extensive surveys, requiring accurate triangulation. Thus Geodetic surveying began. The United States Coast and Geodetic survey was established by an act of Congress in 1807.

Increased land values and the importance of exact boundries along with the demand for public improvements in the projects like, canal, and railway eras brought surveying into a prominent position. More recently, the large amount of general construction has entailed to augmented surveying programme.

During World War I and II, surveying in its, many branches played an important part. This provided stimulus to improve surveying instruments and speed up the methods of making measurements and maps. In the field of mapping, aerial surveying has replaced ground surveying on large area projects. Traditional ground surveys are still essential for establishing the locations of horizontal and vertical control points in construction and small area surveys.

1.4. PRIMARY DIVISIONS OF SURVEYING

Primarily Surveying can be divided into two classes:

1. Plane Surveying and
2. Geodetic surveying.

Before these two classes of surveying are discussed, knowledge of earth's surface and certain terms related to earth is essential.

As we all know earth is a oblate spheroid of revolution. Length along the equatorial axis is 12756.75 km. Length along the polar axis is about 43 km shorter than that along equatorial axis. The surface of the earth spheroid is curved. Considering a point on the surface of the earth, the line joining this point with the centre of the earth is known as *plumb line.* Any line passing through the point tagential to the surface of the earth is called *horizontal line* and this line is always perpendicular to the plumb line. Any line on the surface of the earth or parallel to it, is known as *level line.* When a plane surface passing through the centre of the earth and cuts the surface of the earth, a continuous curved line (more or less-circle) is generated. This curved line which is almost a circle is known as *great circle.*

(i) **Plane Surveying :** In plane surveying the curvature of the earth's surface is neglected. The earth's surface is considered plane. The line connecting any two points on the surface of the earth is considered straight line and the angles of polygons as plan angles.

This type of survey is adopted when surveys extend over small areas. In our Engineering projects we are normally concerned with small areas and thus in Engineering surveys plane surveys are almost exclusively used. The degree of accuracy required in this type of surveying is comparatively low. In USA if area covered by any survey is 260 km^2 on less, the survey is considered as plane survey and no need of any correction for curvature is felt. However degree of precision should be the criteria for fixing this limit, since plane methods of surveying are frequently employed for surveys of much greater areas when very high accuracy is not required.

The difference in length between the arc and the subtended chord on the surface of the earth is about 1 cm in 1.82 km, 3 cm in 5.454 km and 5 cm in 9.l km. The difference between the sum of the angles in a plane triangle and that of the angles of the corresponding spherical triangle is only one second for every 195 km^2 of area.

***(ii)* Geodetic Surveying :** This method of survey is adopted when large distances and areas are to be covered. In it the curvature of the earth is considered in all the measurements taken on the surface of the earth. All the lines lying in the surface of the earth are curved lines and all the polygons formed on the surface are spherical polygons. This survey is also called trignometrical survey. This method involves use of spherical trigonometry in all its computation works. The main characteristics of Geodetic survey are :

(*a*) very large distances and areas
(*b*) use of very precise instruments
(*c*) use of refined method of observation
(*d*) high degree of precision.

The object of Geodetic survey is to locate and fix the precise positions on the surface of earth, of a system of widely distant points. These points later form control points to which surveys of lesser precision are referred.

Both plane and spherical triangles *ABC* an shown in Fig. l.1.

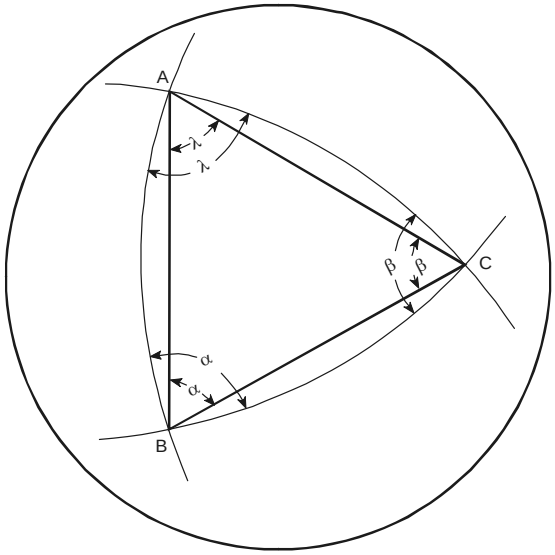

Fig. 1.1. Plane triangle and Geodetic triangle on surface of earth.

1.5. CLASSIFICATION OF SURVEYS

The surveys can be classified in a number of ways as follows.

1. Based upon the nature of field of survey

(*i*) **Land survey.** This survey work is done on the land only. It can be divided into following types.

(*a*) *Topographical surveys.* This survey is done for determining the natural features, of the country like rivers, lakes, valleys, hills, etc., and also the artificial features like canals, towns, villages, roads, bridges, railways, telephone and electric lines, etc. This survey involves horizontal and vertical locations of points by taking linear as well as angular measurements.

(*b*) *City surveys.* They are conducted for laying out plots and construction of sewers, water supply lines, streets, overbridges and other works.

(*c*) *Cadastral surveys*. These are made for fixing the property lines, calculation of areas, etc. They are also conducted for fixing the position of pathways, properties; transfer of land from one owner to another. Boundries of districts, States, Municipalities and even countries are fixed by this survey.

(*ii*) **Astronomical Survey.** It is conducted for fixing the absolute locations and directions of points and lines on the surface of the earth by viewing the heavenly bodies like sun, star, etc.,

(iii) **Marine or Navigation Surveys.** These surveys are also referred as Hydrographic surveys. They are connected with the survey of bodies of water. The object of these surveys may be Navigation, water supply, harbour works, or determination of mean sea level. The survey work includes measurement of discharge of the rivers, preparing topographs of shores and banks, determining depth of water and observing the variation in sea level.

2. Based on the Object of Surveying

(*i*) *Engineering surveys.* This survey is done for the designing engineering projects such as canal, reservoir, highway, railway, building, sewer line, etc. Engineering surveys include reconnaissance surveys, preliminary surveys and location surveys. Reconnaissance surveys fix the feasibility and rough cost of the project whereas preliminary surveys collect data useful to choose the best location for the work. Also quantities of materials required for construction are more exactly calculated. Location surveys are used for setting out the work on the ground.

(ii) Military surveying. They are conducted for fixing points of strategic importance.

(*iii*) *Mine surveys.* They are used for exploring the mineral wealth such as gold, coal, gypsum, iron pyritis etc.

(iv) Geological surveys. They are used to determine the different strata in the earth's crust.

(v) Archaeological surveys. They are used for unearthing relics of antiquity.

3. Based upon the Instruments used

(*i*) Chain survey
(*ii*) Compass survey
(*iii*) Plane table survey
(*iv*) Theodolite survey
(*v*) Tacheometric survey
(*vi*) Photographic survey
(*vii*) Aerial survey
(*viii*) Levelling.

4. Based upon the method employed in survey.

(*i*) Triangulation survey.

(*ii*) Traverse survey.

1.6. PRINCIPLES OF SURVEYING

The methods of plane surveying are based upon the following two aspects. The two aspects are also called fundamental principles of surveying.

1. In order to fix the location of any point measurements from two reference points whose position are known have to be taken. According to this fundamental, for the location of the relative position of any point at least two measurements are required from reference points the positions of reference points being already fixed. The two measurements from reference points may be: (*i*) linear measurements, (*ii*) angular measurements, (*iii*) linear and angular measurements.

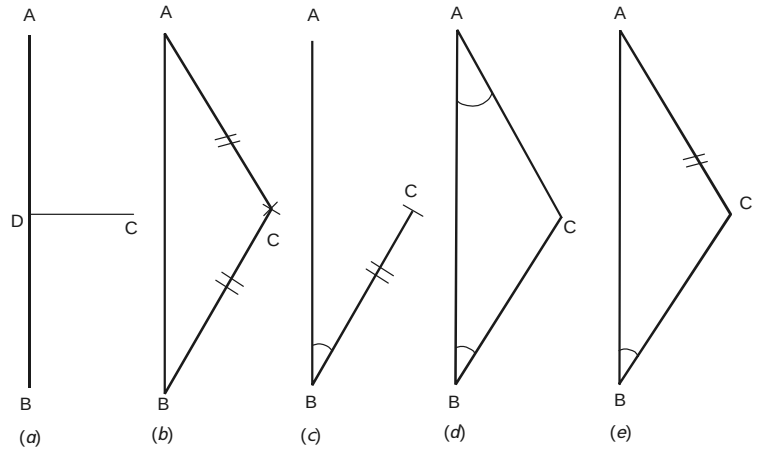

Fig. 1.2. Methods of locating of point.

Let *A* and *B* be the two reference points on the ground. The distance *AB* can be measured accurately and relative positions plotted on the drawing sheet to some scale. The plotted positions of *A* and *B* will act as reference points for fixing the relative positions of other points. The methods of fixing the relation positions of third point *C* are as follows.

(*i*) Drop perpendicular *CD* on reference line *AB* and measure

AD or *BD* and *DC*. Point *C* can be plotted using any set square. This principle is used for defining details in chain surveying.

(*ii*) Measure *AC* and *BC* in the field. With *A* and *B* as centres and radii *AC* and *BC* on the same scale as of *AB*, draw arcs. The arcs cut at point *C* which is the plotted position of *C* with respect to the reference points *A* and *B*.

(*iii*) Measure distance, *BC* and $\angle ABC$. Plot the position of *C* by means of protractor. *This method is used in tranversing*.

(*iv*) Measure $\angle ABC$ and $\angle BAC$. Distance *BC* and *AC* are not measured. At plotted positions of *A* and *B* define the measured angles $\angle BAC$ and $\angle ABC$ respectively. The lines *BC* and *AC* intersect at point *C* which is the plotted position of point *C*. This method of locating the points is very much used in triangulation.

(*v*) Measure the length *AC* and $\angle ABC$ in the field. At plotted position of *B* define measured angle $\angle ABC$ by any method. With *A* as centre and radius *AC* to the same scale of *AB*, draw arc to cut *BC* in point *C*. *C* is the plotted position in relation to reference points *A* and *B*. This principle is not very important and is sometimes, used in traversing.

2. To work from whole to part. According to this principle of surveying first of all a system of control points is fixed covering whole of area to be surveyed with very high degree of precision. Minor control points are then fixed with the help of points fixed with very high precision. Details are then located by running traverses through the minor control points and points located with very high precision. If triangulation method of surveying has been adopted the area to be surveyed is divided into larger triangles and points are located with greatest accuracy. Larger triangles are further sub-divided into smaller triangles which are located with less accuracy.

The object of this system of working is to prevent the accumulation of error and to control and localise the minor errors. If survey work is conducted conversely (*i.e.,* working from part to whole) small errors are magnified in the process of expansion of survey. The error may become uncontrollable at the end of the work and thus whole of survey work may have to be discarded and reconducted.

In Fig. 1.3 *ABCD* is a closed traverse. A little error has been committed in the alignment of line *AB A B´ C´ D´ A´* is the shifted

position of traverse because of small error in the alignment of line *AB*.

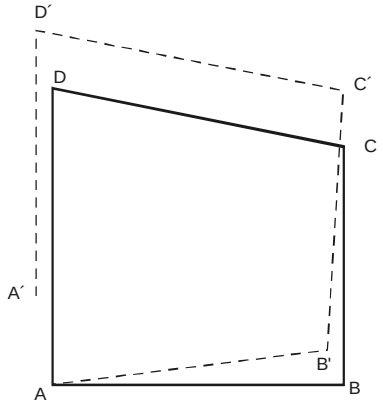

Fig. 1.3. Error in *B* affects locations of all other points.

1.7. MEASUREMENTS

In plane surveying two types of measurements are generally taken. The measurements are : (*i*) linear and (*ii*) angular.

Linear and angular measurements both may be horizontal and vertical. If measurements are taken in horizontal plane they are horizontal distances and horizontal angles and if in vertical plane they are referred as vertical heights and vertical angles. An inclined distance has two components one horizontal and other vertical. It may be remembered that irrespective of their elevations the distance between any two points on a plan or map is always the horizontal distance between them. Similarly a horizontal angle between two intersecting lines is the angle between the projections of these lines on a horizontal plane. A vertical angle at a point is the angle between the horizontal line passing through the point of observation, and the line of sight to the point being observed.

1.7.1. Units of Measurements

1. Basic units of linear measures. Metres, centimetres and millimetres are the basic units for measuring linear distances. Linear distances may be horizontal, vertical or inclined. In SI system and MKS system of units, the units of linear measurements are the

same. Prior to the introduction of metric units in India, feet, and inches used to be units of linear measurements.

Basic units of area are square metres, square decimetres, square centimetres, hectares and square kilometres. Similarly basic units for volume are cubic metres, cubic decimetres, cubic centimetres, etc.

2. Basic units of angular measures. There are three popular systems of angular measurements :

(*i*) *Sexagesimal system*
- *(a)* one circumference = 360° (degrees)
- (*b*) one degree = 60′ (minutes)
- *(c)* one minute = 60′′ (seconds)

(*ii*) *Centesimal system*
- (a) one circumference = 400^g (grades)
- (*b*) one grade = 100^c (centigrade)
- (*c*) one centrigrade = 100^{eo} (centi-centigrade)

(iii) Hours system
- *(a)* one circumference = 24^h (hours)
- *(b)* one hour = 60^m (minutes of time)
- (*c*) one minute = 60^s (seconds of time)

There is one more unit of angular measurements, *i.e.,* the radian. It is the angle between two radii of a circle which cut-off on the circumference on arc equal in length to the radius. It is the unit of plane angle USA, Britain, India and in so many other countries of the world, the sexagesimal system of angular measurement is used. Most of the survey instruments are graduated according to this system.

British and metric units for linear measurements are as follows :

Table 1.1

Metric units		*British unit*	
10 millimetres	= l centimetre	12 inches	= 1 foot
10 centimetres	= 1 decimetre	3 foot	= 1 yard
10 decimetres	= 1 metre	5½ yards	= 1 rod, pole or perch
10 metre	= 1 decametre	4 poles	= 1 chain (gunters)
10 decametre	= 1 hectametre	10 chains	= 1 furlong
10 hectametre	= 1 kilometre	8 furlong	= 1 mile
1852 metres	= 1 nautical mile (international)	6 feet	= 1 fathom
		120 fathoms	= 1 cable length
		6080 feet	= 1 nautical mile

Basic Conversion Factors

1 metre = 1.0936 yds = 3.2808 ft = 39.37 inches.

1 km = 0.53996 Nautical mile = 0.6214 miles

1 m^2 = 1.196 sq. yds = 10.7634 sq. ft = 1550 sq. inches.

1 are = 100 sq. metres = 119.6 sq. yds

1 acre = 10 sq. chain = 40.469 ares = 4840 sq. yds

1 sq. mile = 640 acres = 258.999 hectares.

1 cubic metres = 0.99917 kilo litres = 219.969 gallon (Imp)

= 1.308 cu yds

1.8. WORK OF THE SURVEYOR

The work of the surveyor may be divided into three distinct parts : They are

1. Field work
2. Office work and
3. Care and adjustment of survey instruments.

1. Field Work. Surveyor has to perform following functions in field.

(*i*) Establishing station points and bench marks in the field.

(ii) Measuring distances and angles.

(iii) Locating the details such as buildings, roads, boundry lines, rivers, bridges and other natural and artificial features.
(iv) Setting out the works like roads, buildings, etc.
(v) Finding the relative elevation of points.
(vi) Setting grades of the lines.
(vii) Setting lines parallel and perpendicular to given lines.
(viii) Survey across the obstacles:
(ix) Making observations on sun or stars, etc.
(x) Recording the field notes.

Field notes. Field notes are the written statements recorded in form of remarks during field work. They should be concise, legible, comprehensive and written neatly. The competence of the surveyor is reflected more from the field records rather than any other element of surveying. The following points must be considered while making field notes.

(a) Record directly in the field book as soon as observations are made.
(b) Use sharp 2H or 3H pencil and never use ink or soft pencil.
(c) Give neat reference sketches.
(d) Never use eraser. If any thing is to be corrected, cross the wrong statement and record the correct statement above the crossed one.
(e) Make the field notes for each day and mention the title of the survey, date, weather conditions, etc.
(f) Sign the field notes daily.

The field notes may be further divided into three parts.

1. Recording numerical values.
2. Drawing reference sketches.
3. Writing explantary notes.

Values of lengths and angles are recorded in the numerical values. Lengths should be measured to nearest 0.01 m and angles as 06° 09′ 20″ *i.e.,* using at least two digits for each degree, minute and second, parts of the value.

Topographical features should be shown by clear free hand large size sketches. Explanatory notes are written to clarify the things

which cannot be appreciated fully from numeral values and sketches. Important features are also mentioned in the explanatory notes.

2. Office work. The office work of a surveyor consists of :

(*i*) Preparing drawings like plans and elevations from the data collected in the field.

(*ii*) Calculations for areas and volumes,

(*iii*) Designing of structures.

3. Care and adjustment of survey instrument. All the survey instruments should be handled with care. For this surveyor should be familiar with the use and maintenance of the instrument. Some of the survey instruments likes levels, theodolites, compass, tacheometres, etc. Should be handled with utmost care so that their delicate parts are not subjected to undue strains. Following precautions should be taken while using the delicate type of survey instruments :

(*i*) The position of the instrument must be thoroughly studied before it is taken out of the box. This is essential to facilitate correct placement in the box after use.

(ii) Instruments must be transported from one station to another while in use by putting on shoulders.

(*iii*) Clean the objective glass and eye piece glass of the telescope by soft brush and also cover the objective glass by cap when telescope is not in use.

(iv) Instrument should be set on the tripod well fixed on the ground. Legs of the tripod should be prevented from slipping when tripod is put on a smooth floor.

(*v*) Never leave the instrument unguarded when set on or near the road.

(*vi*) Don't put any undue force on any screw of the instrument while opening or closing the screw.

(*vii*) Keep the needle of the compass lifted from the pivot when instrument is not in use.

(*viii*) Kinked steel tape should not be pulled unless kink is opened.

(*ix*) Keep the instrument held by left hand while fixing the instrument on the tripod.

There are numerous survey instruments each having its own uses, characteristics and thus care and adjustment. The above men-

tioned points are the general points which should be taken care of while using any survey instrument.

PROBLEMS

1. Explain the fundamental principles of surveying in details.
2. Give the different classifications of surveys.
3. Write down the functions of a surveyor in fields, in office and while maintaining survey instrument.
4. Define the term survey and give its various uses.