CHAPTER 01

# Introduction

## 1.1 Need of Surveying

- Surveying in the science of determining the relative positions on ground, along with their elevations.
- The relative positions are determined by measuring the horizontal distances, horizontal angles, vertical distances and the vertical angles. For this, various instruments are needed.
- After taking observations in the field, computations are done in office to prepare topographic map or plan of the area.
- These maps or plans are needed for various purposes like computing the volume of earth work, volume of reservoir, finalizing the alignment of canal, railway line or highway for this, sufficient number of points and lines have to be located on the plan.
- The new developments that would be impossible without accurate surveys include testing equipment like rocket tracks, accelerators for atomic research, as well as control for both position and direction of rockets, intercontinental missiles and space craft.

## 1.2 Types of Survey

### 1.2.1 Classification of Survey Based on Accuracy Desired

(a) Plane Survey: In this type of survey, the mean surface of earth is assumed to be flat and not the curved,one. Here the level lines are regarded as straight lines and the angle between any two such lines is taken as the plane angle and not the spherical angle.

This type of survey is used when the area under consideration is of small extent.

Almost all surveys for various engineering projects like construction of dams, highways, railway lines, canals etc. use plane survey.

(b) Geodetic Survey: In this survey, the shape or the curvature of earth is taken into account in order to have a higher degree of precision. Such surveys are required for surveying large areas and measurements are required to be made with the highest possible order. Here, a line connecting the two points is an arc and not the straight line. This distance between the two points is corrected for curvature and then plotted on the plan. The angle between the two lines is the spherical angle. Thus all this requires a high level of computation work.

Geodetic survey is needed to fix the widely spaced control points that are later on used as necessary control points for fixing the minor control points.

### 1.2.2 Classification of Survey Based on Place of Survey

(a) **Land Survey:** It is the survey being done on land. It involves running of survey lines and determining their length and directions thereby sub dividing the area into definite shapes and sizes and calculating their areas etc. in order to set up a structure.

(b) **Hydrographic Survey:** It involves survey of water bodies like the streams, sea, ponds etc. The basic purpose of this survey is to establish the shore line. Apart from this, this survey is done to determine the amount of water stored by a water body, navigation possibilities, water supply, under water construction etc.

(c) **Underground Survey:** This survey is required for construction of tunnels for highways, railways, water transport, mines etc. Here in this survey, underground plans, transfer of surface line coordinates to the underground line etc. are drown.

(d) **Aerial Survey:** This survey is carried out above ground by taking the aerial photographs with cameras fitted to airplanes, helicopters etc. This survey is particularly required for preparing large scale maps of an area, for development of projects in areas where ground survey is difficult or too much time consuming.

### 1.2.3 Classification of Survey Based on Instrument Used

(a) **Chain Survey:** Here, only the linear measurements are made with a chain (or a tape) and no angular measurements are made. This survey is of limited use, since it requires clear ground without any obstruction like intervening trees, buildings, rivers etc. This survey is particularly useful for laying of sewer lines, water supply lines, construction of roads etc.

(b) **Traverse Survey:** Here, both the linear and angular measurements are made, the former being made with a tape or a chain and the later with a compass. This survey is useful for large projects like dams and reservoirs.

(c) **Leveling:** Here, elevations of different points are determined. A graduated staff and a level are used for this purpose. Almost all projects require determination of the elevation of the different points and this is achieved by leveling.

(d) **Tacheometry:** Here, in this type of survey, both the horizontal distance and the vertical distance are measured by sighting a graduated staff with a transit telescope fitted with an anallatic lens. It is particularly useful when direct measurement of horizontal distances are not possible.

(e) **Plane Tabling:** In this, observations and plotting are done simultaneously in the field. The advantage of this method is that there is least possibility of omitting any important measurement since the actual field being surveyed is in view on the plot in the field itself. The drawbacks of this method are that it cannot be done in humid or rainy weather and the carrying of plane table apparatus is cumbersome.

(f) **Triangulation:** This method of survey is used for large areas. The entire area is divided into a network of triangles and any one side of any of the triangles so formed is measured very precisely. This line is referred to as **baseline.** All the angles of the network are measured. The lengths of the sides of the triangles are then computed using the laws of triangles.

(g) **EDM Survey:** EDM refers to Electronic Distance Measurement and in this method of survey, distances are measured electronically using wave propagation, reflection and subsequent reception of the reflected wave. Some of the examples of EDM instruments are tellurometer, distomat, geodimeter etc.

(h) **Total Station Survey:** Total station is the combination of conventional transit theodolite with EDM instrument. It reads and records the horizontal and vertical distances together with slope distances. This instrument also computes the Cartesian coordinates of the observed points, slope corrections, elevation of remote objects etc. Survey carried out using total station is referred to as total station survey.

(i) **Satellite Survey:** In this method of survey, information about the land or space is determined using satellite based navigation system like the GPS (Global Positioning System). Another method is the Remote Sensing wherein the data about an object is acquired using the sensors placed on satellite.

### 1.2.4 Classification of Survey based on Purpose

(a) **Geological Survey:** In this type of survey, information about both the surface and sub-surface is acquired for assessing the extent of different reserves like the minerals, rocks etc. It is also used for locating the faults, folds and other unconformities in the ground. This survey helps in determining the type of foundation, soil treatment required etc.

(b) **Geographical Survey:** This survey is done for preparation of geographical maps depicting the land use efficiency, irrigation intensity, surface drainage, slope profile, contours etc.

(c) **Engineering Survey:** This survey is required to be done for acquiring information for the planning and design of engineering projects like the highways, dams, railway line, water supply design, reservoirs, bridges etc. It involves topographic survey of the area, earthwork measurement etc.

(d) **Cadastral Survey:** These are done to establish boundary of properties for legal purposes. These are also called public land survey.

(e) **Defence Survey:** Such surveys are done for military purpose. They provide strategic information for deciding the future course of action. Aerial and topographical maps of the area are prepared which gives crucial information about the existing roads, airports, ordnance depots etc.

(f) **Mine Survey:** This requires both the surface and the underground surveys. It involves making the surface map and doing the underground survey for locating the reverse of minerals.

(g) **Route Survey:** It is a sort of linear survey for deciding the alignment of a highway or a railway.

(h) **Archaeological Survey:** This is done to gather information about the ancient monuments, towns, villages, kingdoms, past civilizations, temples, forts etc. buried underground due to natural forces like earthquakes, landslides, incandescent floods etc. It gives an idea about the past history, culture etc. of the civilization that existed in the past.

## 1.3 Principles of Surveying

(a) Work from whole to part
(b) There must be adequate provisions for check
(c) Choose the method of survey that is most suitable for the purpose
(d) Record the field data carefully

### 1.3.1 Work from Whole to Part

- It is the very first principle of surveying.
- By this principle, it means that the surveyor should first establish the large frame work consisting of main control points, accurately.

- In between the large frame work so established, subsidiary small frame works can be established by a relatively less accurate survey. By doing so, the errors in small frame work get localized and are not magnified and thus the accumulation of errors gets confined.
- In the reverse process of working from part to whole, small errors get magnified due to expansion of errors in small frame work.

### 1.3.2 There must be Adequate Provisions for Check

- The accuracy of a measurement cannot be ensured if it is not checked.
- While taking an observation, errors may crept in while taking a measurement, recording the measured value and computing and plotting the detail.
- There should be adequate checks available in order to ensure that the observation is correct.
- A good survey is the one in which the methods of taking the observations, recording and computations are so designed that the errors get revealed in the process.
- At the time of recording, all measurements should be checked.

### 1.3.3 Choose the Method of Survey that is Most Suitable for the Purpose

- With the advent of modern methods of surveying, any desired level of accuracy can be achieved these days.
- But the cost of surveying increases with increase in the accuracy of survey methods since accurate measurements require high quality precise instruments that are costlier than the less accurate instruments.
- Thus for a particular desired accuracy, the survey method must be so chosen that the desired accuracy is achieved at the minimum cost.
- If the accuracy achieved is less than that required then the survey results are of no use and if the accuracy achieved is more than that desired, then it will be accompanied by loss of time and energy along with increased cost.

### 1.3.4 Record the Field Data Carefully

- Measurements taken in the field are of no use if that are not recorded carefully.
- It should always be tried that all the observations are recorded immediately and nothing should be left to the reliability of one's memory.
- Apart from that, observations must be entered in a clear legible form so that more than one interpretation of the recorded value cannot be done. In order to ensure the long life of the recorded values, all entries must be made in pen.

## 1.4 Units of Measurement

- There are many units of measurement that are prevalent worldwide like the CGS System, FPS System, MKS System but the standard one is the SI System.
- Past records of all survey works are usually in FPS System. Thus to use those records and any other records that are in different units, those have to be converted into SI unit or other unit that is in use.

Length Unit Conversion

| Unit | Conversion factor for m |
|---|---|
| 1 astronomical unit | 149597870691 |
| 1 angstrom | $1 \times 10^{-10}$ |
| 1 chain | 20.1168 |
| 1 fathom | 1.8288 |
| 1 foot | 0.3048 |
| 1 furlong | 201.168 |
| 1 inch | 0.0254 |
| 1 light year | 9460730472581000 |
| 1 mile | 1609.344 |
| 1 nautical mile | 1852 |
| 1 yard | 0.9144 |

Area Unit Conversion

| Unit | Conversion factor for $m^2$ |
|---|---|
| 1 acre | 4046.85 |
| 1 are | 100 |
| 1 hectare | $10^4$ |
| 1 $ft^2$ | 0.0929 |
| 1 $inch^2$ | $6.4516 \times 10^4$ |
| 1 $mile^2$ | 2589988.11 |
| 1 $yard^2$ | 0.8361 |

Volume Unit Conversion

| Unit | Conversion factor for $m^3$ |
|---|---|
| 1 barrel | 0.1589873 |
| 1 $yard^3$ | 0.765 |
| 1 US gallon | $3.785 \times 10^{-3}$ |
| 1 UK gallon | $4.546 \times 10^{-3}$ |
| 1 liter | 0.001 |

Pressure Unit Conversion

| Unit | Conversion factor for $N/m^2$ |
|---|---|
| 1 atm | 101325 |
| 1 bar | $1 \times 10^5$ |
| 1 mm Hg | 133.3 |
| 1 pound per sq. feet (psf) | 47.88 |
| 1 pound per sq. inch (psi) | 6894.75 |
| 1 torr | 133.32 |

## 1.5 Various Measurements in Surveying

- In surveying, the direction of gravity can always be taken as reference for all measurements.
- The direction of gravity is established by suspending a plumb bob freely. This direction of gravity is taken as the vertical direction. Thus horizontal direction is at right angles to the vertical direction.
- Any plane which contains the horizontal line and perpendicular to the vertical direction is called as horizontal plane. The plane containing the vertical line is called as **vertical plane**.

In surveying, the following basic measurements are made :

(a) Horizontal distance: The horizontal distance is measured in horizontal plane. On slopping ground, the distance between two points is reduced to horizontal equivalent.

(b) Horizontal angle: The horizontal angle is measured between two lines in horizontal plane. Theoretically the angle between two lines can vary from 0° to 360°.

(c) Vertical distance: As stated above, the direction of gravity is taken as vertical direction and thus vertical distances are measured in the direction of gravity. The vertical distances are measured to determine the difference of elevations between the various points.

(d) Vertical angle: Vertical angle is measured between two lines in vertical plane.

### 1.5.1 Instruments Used for Various Types of Measurement

(a) For horizontal distance measurement : Tape, chain, tacheometer, EDM etc.

(b) **For horizontal angle measurement :** Magnetic compass, theodolites, total station, sextant etc.

(c) **For vertical distance measurement :** Tacheometer, levelling instruments like dumpy level etc.

(d) **For vertical angle measurement :** Sextant, clinometer, theodolite etc.

## 1.6 Plan and Map

- **Plan:** It is the graphical representation of various features on or near to the earth's surface as projected on a horizontal plane. Plan represents the area on a horizontal plane. The horizontal distances are measured between the various points on horizontal plane. Because of small areas involved in surveying as compared to earth's total area, the areas may be regarded as flat surface and the plan is constructed by orthographic projections. A plan is usually drawn or a relatively large scale.
- **Map:** In this, the scale of graphical projection or horizontal plane is small. Due to small scales a map depicts a large number of details as compared to plan. Some additional features are also shown on map like reliefs, contour lines, undulations etc.

### 1.6.1 Scale of Map

- A map is made on a sheet of paper which has limited dimensions.
- On this restricted area, a large number of details have to be shown.
- Thus original distances between various points on earth's surface have to be reduced so that these points can be accommodated on the sheet of paper.
- The ratio of distance between two points on map to corresponding distance on ground is called as **Scale of Map.**

Thus, $$\text{Scale of Map} = \frac{\text{Distance between two points on map}}{\text{Corresponding distance between those two points on ground}}$$

- The scale of map should neither be too small nor too large

Scales are generally classified as small, medium and large

Small scale 1 cm = 100 m or more

Medium scale 1 cm = 10 m to 100 m

Large scale 1 cm = 10 m or less

In most of the engineering projects, scale varies from 1 cm = 2.5 m to 1 cm = 100 m.

### 1.6.2 Representation of Scale

(a) **Engineer's scale:** This scale is represented by a statement like 1 cm = 50 m or 1 cm = 180 m etc. A scale of 1 cm = 80 m implies 80 m on ground is represented by 1 cm on map.

(b) **Representative fraction (RF):** This scale is expressed in same units. For example, 1 cm = 50 m is represented in RF as 1 : 5000 or 1/5000. Here 50 m is converted as 5000 cm.

(c) **Graphical scale:** It is the line drawn on map such that its map distance corresponds to a convenient unit of length on ground.

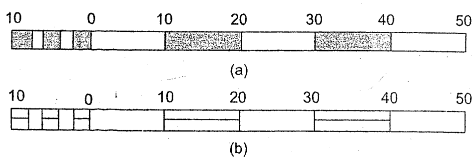


Fig. 1.1 *Graphical scale*

## 1.7 Errors incurring Due to Shrinkage of Map

- Drawing sheets or map shrink due to temperature, humidity etc.
- Obviously, the lines present on map will shrink.
- The lengths measured from the shrinked map do not represent the correct distances.
- Graphical scale has the advantage that the amount of shrinkage of map and the graphical scale is the same.
- But in the absence of graphical scale, correct lengths has to be worked out. Here, we define **shrinkage ratios** (or **shrinkage factor**) as

$$\text{Shrinkage ratio (or shrinkage factor)} = \frac{\text{Shrunk length}}{\text{Actual length}}$$

This shrinkage ratio is always less than one (or unity)

$$\text{Thus correct length} = \frac{\text{Measured length}}{\text{Shrinkage ratio}}$$

Similarly, $$\text{Correct area} = \frac{\text{Measured area}}{(\text{Shrinkage ratio})^2}$$

## 1.8 Errors incurring Due to Wrong Measuring Scale

The measured length of a line on a map (or a plan) will not be correct if a wrong measuring scale is used. To understand this, let a map is prepared with a scale of 1 : 100, but later and the length is takes with a scale of 1 : 150. Thus the measured distance of 20 cm.

From map:

On map will actually represent 20 m on ground, but would be taken as 30 m due to wrong scale.

$$\therefore \quad \text{Correct length} = \frac{\text{Wrong scale}}{\text{Correct scale}} \times \text{Measured length}$$

Similarly, $$\text{Correct area} = \left(\frac{\text{Wrong scale}}{\text{Correct scale}}\right)^2 \times \text{Measured area}$$

## Illustrative Examples

**Example 1.1** A rectangular plot was measured with a 20 m chain and its size was established as 450 m × 250 m. Later on, it was found that the chain used for measuring the sides of plot was 15 cm too long. What is the true area of the plot?

**Solution:**

Measured area of rectangular plot = 450 × 250 = 1,12,500 $m^2$

Actual length of chain = 20.15 m

$$\text{True area of plot} = \left(\frac{20.15}{20}\right)^2 112500 = 1,14,193.83 \text{ m}^2$$

Alternatively

Measured length ($L$) = 450 m; Measured breadth ($B$) = 250 m

Actual chain length = 20.15 m

$$\therefore \quad \text{True length} = \left(\frac{l'}{l}\right)L = \left(\frac{20.15}{20}\right)450 = 453.375 \text{ m}$$

$$\text{True breadth} = \left(\frac{20.15}{20}\right)250 = 257.875 \text{ m}$$

$$\therefore \quad \text{True area} = 453.375 \times 251.875 = 1,14,193.83 \text{ m}^2$$

**Example 1.2** The plan area of an old survey plotted to a scale of 10 m to 1 cm presently measures 80.5 cm². It is believed that plan has shunk so that the original line of 10 cm now measures 9.2 cm. A note on the plan states that chain used was of 20 m and was 8 cm too short. What is the true area of the survey ?

**Solution:**

$$\text{Original plan area (A)} = \left(\frac{10}{9.2}\right)^2 \times 80.5 = 95.11 \text{ cm}^2$$

Scale of plan is 10 m = 1 cm

$$\therefore \quad \text{Area on ground} = 95.11 \times 10^2 = 9511 \text{ m}^2$$

Now the chain was 8 cm too short and chain length used was of length 20 m

$$\therefore \quad l' = 20 - 0.08 = 19.92 \text{ m}$$

$$\therefore \quad \text{True area of field/survey} = \left(\frac{19.92}{20}\right)^2 \times 9511 = 9435.06 \text{ m}^2$$

**Example 1.3** The dimensions i.e. length, breadth and height of an embankment were measured with a 20 m chain and volume of embankment came out to be 550.77 cu.m. Later on, it was found that the chain used for measurement was 15 cm too short. What is the actual volume of embankment?

**Solution:**

$$\text{True volume} = \left(\frac{l'}{l}\right)^3 \times \text{measured volume}$$

$$= \left(\frac{20-0.15}{20}\right)^3 \times 550.77 = 538.47 \text{ m}^3$$

**Example 1.4** The length of a line measured from a chain was found to be 280 m. Calculate the true length of the line if:

(a) The length was measured with a 30 m chain and chain was found to be 12 cm too long.

(b) The length was measured with a 30 m chain in the beginning and 30.2 m at the end of the work.

**Solution:**

Measured length ($L$) = 280 m

True chain length ($l$) = 30 m

(a) Actual chain length used for measurement ($l'$) = 30.12 m

$$\therefore \quad \text{True length of line} = \left(\frac{l'}{l}\right)L = \left(\frac{30.12}{30}\right)280 = 281.12 \text{ m}$$

(b) Average length of chain during measurement $= \frac{30+30.2}{2} = 30.1$ m

$$\text{True length of line} = \frac{30.1}{30} \times 280 = 280.93 \text{ m}$$

**Example 1.5** The area of a field was found to be 2500 m² when measured with a 30 m tape. Determine the correct area if the tape was found to be 0.15 m too short.

**Solution:**

$$\text{Correct area} = \left(\frac{l'}{l}\right)^2 \times \text{computed area} = \left(\frac{30-0.15}{30}\right)^2 \times 2500 = 2475.06 \text{ m}^2$$

**Example 1.6** A 30 m tape was found 0.20 m too short. If the computed volume of concrete is 1600 m³ then what is the correct volume of concrete?

**Solution:**

$$\text{Correct volume} = \left(\frac{l'}{l}\right)^3 \times \text{computed volume} = \left(\frac{30-0.2}{30}\right)^3 \times 1600 = 1568.21 \text{ m}^3$$

**Example 1.7** A plan represents a rectangular area of 61965 m² and measures 8.5 cm by 10 cm. What is the scale of map?

**Solution:**

Area of plan = 8.5 × 10 cm² = 85 cm²

But actual area = Plan area × (scale)²

$$\Rightarrow \quad \text{Scale} = \sqrt{\frac{61965}{85}} = 27$$

∴ Time scale is 1 cm = 27 m.

## Objective Brain Teasers

**Q.1** Which of the following scale in the longest?

(a) 1 : 50000 (b) 1 cm = 50 m

(c) 1 cm = 500 km (d) R.F. = 1/500000

**Q.2** The R.F. of scale 1 cm = 5 km is

(a) 1/5 (b) 1/50

(c) 1/500000 (d) 1/50000

**Q.3** The main principal of survey is

(a) to work from left to right

(b) to work from top to bottom

(c) to work from to left to bottom right

(d) to work from whole to part

**Q.4** Shrinkage ratio is expressed as

(a) shrunk length/original length

(b) shrunk length + original length

(c) shrunk length × o.iginal length

(d) None of these

**Q.5** The type of surveying wherein curvature of earth is also accounted for is known as
(a) plain surveying
(b) hydrographic surveying
(c) aerial surveying
(d) geodetic surveying

**Q.6** A survey plan was plotted to a scale of 20 m to 1 cm. This scale was reduced in such a way that originally 20 cm line now measures 19 cm. If area of reduced plan is 100 $cm^2$, then actual area of survey was
(a) 44320 $m^2$ (b) 110.8 $cm^2$
(c) 36100 $m^2$ (d) Data insufficient

**Answers**

1. (b) 2. (c) 3. (d) 4. (a) 5. (d)
6. (a)

## Hints and Explanations:

6. (a)

Shrinkage factor $= \frac{19}{20}$

Reduced plan area

$= \text{Original plan area} \times (\text{shrinkage factor})^2$

$$\Rightarrow \quad 100 = \text{original plan area} \times \left(\frac{19}{20}\right)^2$$

$\Rightarrow$ Original plan area

$= 110.8 \text{ cm}^2$

$\therefore$ Actual survey area

$= 110.8 \times (20)^2 = 44320 \text{ m}^2$

## Student's Assignments

**Ex.1** Convert the following representative fractions into scales:
(a) 1/100000 (b) 1/3000000 (c) 1/50000

**Ans.** (a) 1 cm = 1 km (b) 1 cm = 30 km
(c) 1 cm = 0.5 km

**Ex.2** An old map has a shrinkage factor of 24/25 and representative fraction is 1/2400. What is the true scale of the map?

**Ans.** 1/2400

**Ex.3** A plan was drawn to a scale of 1 cm = 25 m. On this plan, a borrow pit measures 5 cm × 7 cm. If the plan has shrunk by 5% then find shrinkage factor, shrunk scale and actual dimension of borrow pit in the field.

**Ans.** SF = 0.95, 1 cm = 26.32 m, 5.26 cm × 7.37 cm.