CHAPTER 03

# Chain Surveying

## 3.1 Introduction

- Chain surveying is a method of survey of land wherein only linear measurements are made and no angular measurements are taken.
- Chain surveying is used for small ground areas with simple details.
- It is the simplest method of surveying and consists of measuring the lengths of the lines marked on the ground/field.
- In order to perform chain surveying, only a chain or a tape is required with few ranging rods.
- However chain surveying is not possible for large areas with too many details.
- By the term **details,** it implies either the natural or the man-made features like buildings, rivers, trees, tower etc.
- Chain surveying is used for marking the boundaries and other details of land for preparation of maps.

## 3.2 Principles of Chain Surveying

- In chain surveying, the area to be surveyed is divided into a frame work of triangles. One such typical triangle is as shown in Fig. 3.1.
- The three sides of the triangle viz. *AB*, *BC* and *CA* are measured in the field.
- For locating the details, offsets are taken.

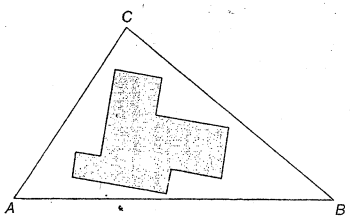


**Fig. 3.1** *Triangle for chain surveying*

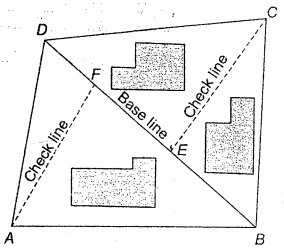


**Fig. 3.2** *Framework of triangles in chain surveying*

- The plan of the ground area and details (taken trough offsets) are plotted on to the map .
- For large areas to be surveyed, the area is divided into a frame work of triangles. The exact arrangement of triangles will depend upon the extent and the type of the area to be surveyed. In general, a long base line is run through the traverse.

In Fig. 3.2, line *BD* is the base line. Two triangles viz. *ABC* and *BCD* are built on the base line. The five sides *AB*, *AD*, *BD*, *CD* and *BC* are measured in the field and the requisite details are located by offsets. While plotting on a drawing sheet, base line is drawn first. Any point (say *A*) is then fixed by drawing an arc equal to *AD* from *A* and *AB* from *B* and finding the point of intersection. Similarly point *C* is located by arcs *CD* from *C* and *BC* from *B*. Thus the required plan is plotted by linear measurements only.

## 3.3 Terminologies in Chain Surveying

### 3.3.1 Main Survey Stations

These are the prominent points that are connected by survey lines to form triangles. Alternatively, these are the points at the start and end of the survey lines.

### 3.3.2 Main Survey Lines

The line joining the main survey stations are called as survey lines also known as main survey lines.

### 3.3.3 Check lines/Proof lines

- These lines are run to check the accuracy of the traverse consisting of a frame work of triangles.
- Check lines are measured in the field during the survey process of the land.
- After plotting the plan from the survey lines, the length of the check line is scaled off from the drawing and compared with the measured line in the field. If there is no error then length of the check line as measured from the plan should confirm to measured value in the field. In Fig. 3.2, line CE and AF are the check lines.

### 3.3.4 Offsets

- These are the lateral distances measured from the survey lines in order to locate the details.
- Two types of offsets are there viz. **perpendicular offsets** and **oblique offsets.**
- Perpendicular offset is perpendicular / normal to the survey line.
- Oblique offset is the short measurement which is inclined to the survey line.

### 3.3.5 Plus Measurements

These are the measurements of the building taken along the its walls. In Fig. 3.3, plus measurements are marked which are in fact helpful for plotting the complete plan.

### 3.3.6 Range Ties

These are the oblique offsets taken along the wall of the building.

### 3.3.7 Tie Lines

If the distance of the point or detail from the chain line is very large, then long offsets need to be taken. Tie lines are the lines that are run to locate details in order to avoid long offsets.

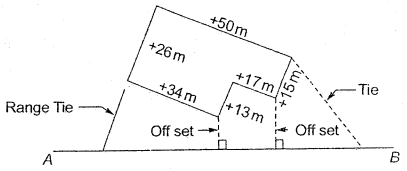


**Fig. 3.3** *A typical figure showing range tie, tie, plus measurements and offsets*

### 3.3.8 Base Line

It is the long survey line which is run through the middle of the area to be surveyed. The frame work of triangles is built on the base line.

### 3.3.9 Chainage

It is the distance of a prominent point from the start point.

## 3.4 Chain

- Chains are used to measure distances which do not require very high accuracy.
- The chain consists of a number of links made of 4 mm mild steel wire. Each end of a large link is bent into a loop and the various loops are connected to each other.
- The connecting link consists of two oval rings at the ends and a circular ring in the middle. In fact it is these connecting links that provide flexibility to chain.

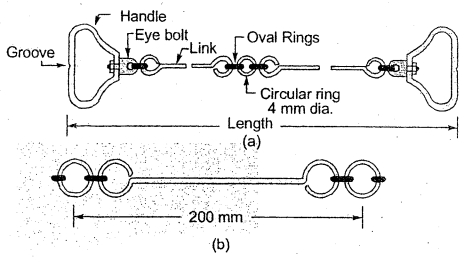


**Fig. 3.4** *A typical chain*

- The two ends of the chain are provided with brass handles which are used to handle the chain and are often used to drag the chain on the ground. This end handle can rotate about the eye bolt without causing twisting of chain and thus gives flexibility to the chain.

The length of a typical link is usually 200 mm measured from center of one circular ring to the center of next circular ring except the end links.

As per IS 1492:1970 the surveying chains are of four different lengths viz.:

(a) Chain of length 5 m (25 links)
(b) Chain of length 10 m (50 links)
(c) Chain of length 20 m (100 links)
(d) Chain of length 30 m (150 links)

- In order to read out the fraction of a chain length, brass tallies or tags or rings are provided at some fixed interval on the chain.

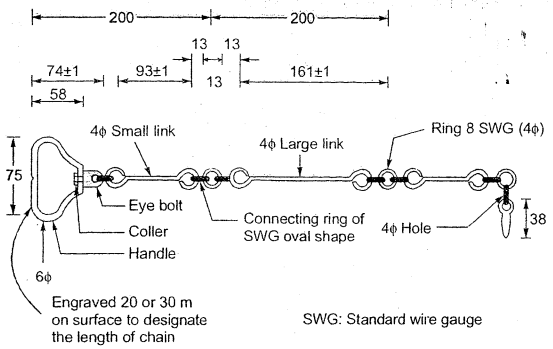


**Fig. 3.5** *Details of metric chain*

- For 5 m and 10 m long chains, brass tallies are provided at every 1 m of chain. For 20 m and 30 m long chains, small brass rings are provided at every meter length and tallies are provided at every 5 m length.
- The shape of tallies at 1 m and 4 m are the same. Similarly, for 2 m and 3 m, the shape of tallies are the same since the distance can be measured from either end on the chain.

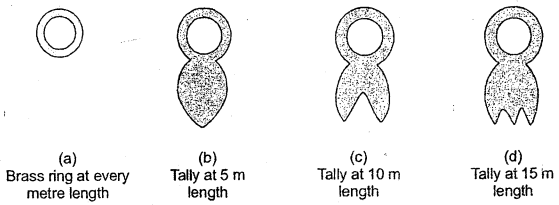


**Fig. 3.6** *Ring and tallies of a chain*

- Advantages:
  (a) A chain is useful for rough measurement.
  (b) Chain can easily be read in the field.
- Disadvantages:
  (a) The problem with chain is that it is quite heavy.
  (b) It sags considerably when suspended in air.
  (c) Its length gets changed due to shortening or elongation of links and is thus suitable for low precision work only.

## 3.5 Well Conditioned Triangle

- A triangle is said to be well conditioned if it can be plotted accurately by the intersection of arcs from the ends of the base line.
- The survey stations should be so selected that they form well-conditioned triangles.

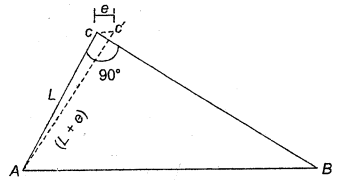


**Fig. 3.7** *Well conditioned triangle*

- In Fig. 3.7, the accuracy of plotting the point $C$ will be maximum when the arcs from the base line intersect at right angles. Let there be an error of '$e$' in the measurement of one side AC so that the actual point $C$ will be plotted as $C'$. The displacement of point $C'$ from $C$ will depend on $\angle ACB$. If the $\angle ACB$ is 90°, then the displacement $CC'$ will be very nearly equal to '$e$'. The location point $C$ will be quite inaccurate in case $\angle ACB$ is less than 30°, since in that case, the displacement $CC'$ will be equal to around '$2e$'.

  Now when $\angle ACB$ is 90° then,

  $$\angle CAB + \angle CBA = 90°$$

- When there has to be an equal liability of error in all the three sides of the triangle then all the three angles must be equal i.e. triangle must be equilateral. In that case (i.e. when $\angle ACB = 60°$), the displacement CC' is about '1.15 $e$'.

- However it may not be always possible to have equilateral triangles and for that, it must be ensured that no angle of the triangle is less than 30° and greater than 120°. In situations, where this is also not possible, then extra care must be taken to measure the sides and in plotting of the triangle.

## 3.6 Required Field Work in Chain Surveying

- **Reconnaissance:** It is the preliminary inspection of the area to be surveyed in order to have an idea about the terrain, main features present on the area to be surveyed, major undulations or depressions in the ground etc. After that, suitable positions of the main survey stations and survey lines are selected. The inter-visibility of the selected stations is checked after fixing the ranging rods. During reconnaissance, the surveyor makes a rough index sketch of the area showing the principal features like buildings, towers etc.
- **Marking stations:** After reconnaissance, main stations are marked on the ground. The stations are marked either by fixing the ranging rods in soft grounds or by placing the heap of stones in case the ground is hard. For extensive survey works, wooden pegs are used to mark the survey stations. These wooden pegs are required to be treated with anti-termite solutions in case the ground is infected with insects.
- **Running the survey lines:** Survey lines are run on the ground to measure the distance between the main survey stations. At least three persons are required to perform the chain survey; one who directs the work and records the measurements, a leader and a follower. Offsets are required to be taken and chainages of all the important features like drain, roads, fence etc. are recorded down.
- **Taking the offsets:** Offsets are the lateral distances measured from the main survey lines. Offsets are of two types viz. (i) perpendicular offsets and (ii) oblique offsets.
  - (i) **Perpendicular Offsets:** In this, the chainage of the foot of the perpendicular '*p*' from the starting station *A* is measured i.e. the distance *Ap*. After that, the length of the perpendicular *Pp* is measured.
  - (ii) **Oblique Offsets:** In this, the chainages of the points $p_1$ and $p_2$ are recorded and the oblique distances $Pp_1$ and $Pp_2$ are measured.

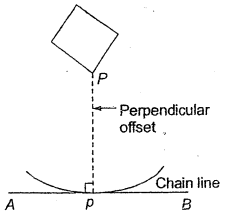


**Fig. 3.8** *Perpendicular offset*

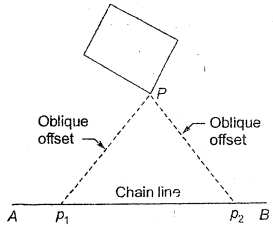


**Fig. 3.9** *Oblique offset*

- The error due to measurement of offset or due to the incorrect direction of offset increases as the length of offset increases. Thus offset should be so selected such that offset distance is as short as possible.

## 3.7 Limiting Length of the Offset

- The maximum length of the offset is generally determined from the view point that the error produced in plotting the detail on the drawing sheet is not very significant.
- Alternatively, the displacement of the detail on the drawing sheet should not be more than **0.25 mm** from its correct position.
- The maximum length of the offset in fact depends on:
  - (a) The scale of the plot
  - (b) Error in the direction and length of a line
  - (c) The desired level of accuracy

## 3.8 Error in the Direction of Offset

Let an offset *Pp* is taken to the detail *P* from the running chain line at *p*. Let there be an error of $\alpha$ in the direction of *Pp* i.e. the offset makes an angle $\alpha$ with the true perpendicular and let *l* be the length of the offset.

When the offset is plotted on the drawing sheet, it will be plotted as $pP_1$ and thus the actual point *P* gets displaced to $P_1$. Draw perpendicular $PP_2$ from P on the line $pP_1$. Thus displacement along the chain line is $PP_2$. This displacement is due to the error $\alpha$ and on the drawing sheet, this displacement should not exceed **0.25 mm**.

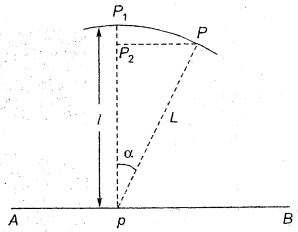


**Fig. 3.10** *Error in direction of offset*

Thus, $$PP_2 = 0.25 \text{ mm} = \left(\frac{1}{40}\right)\text{cm}$$

For a map/plan of scale, 1 cm = *s* meters,

the distance $PP_2$ in the field will be $\frac{s}{40}$ meters.

Now, $$PP_2 = L.\sin\alpha = \left(\frac{s}{40}\right)\text{meters}$$

or, $$L = 0.025s \operatorname{cosec}\alpha \qquad \ldots(3.1)$$

The above expression gives the maximum length of the offset.

## 3.9 Error in Offset Length and Direction Both

Let *P* be the point whose detail is to be located. The measured length of the offset is *l*. Let $\alpha$ be the error in the direction of offset.

The plotted position of the point *P* is $P_2$.

$PP_1$ = Displacement due to incorrect length

$P_1P_2$ = Displacement due to incorrect direction

$PP_2$ = Total displacement due to incorrect length and direction

Let, length of the offset has been measured to an accuracy of 1 in *r* then,

$$\delta l = \frac{l}{r}$$

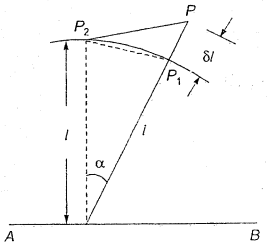


**Fig. 3.11** *Error in length of offset and direction both*

Let displacement of the point $P$ due to error in the measurement of length is equal to that due to the incorrect direction,

Then, $$P_1P_2 = PP_1$$

$$l \sin \alpha = \delta l = \frac{l}{r}$$

$$r = \text{cosec}\, \alpha$$

The above relation gives the accuracy of the offset with which it should be measured so that errors due to both the sources are equal.

If, $$\angle PP_1P_2 = 90°$$

Then total displacement $PP_2$ is given by,

$$PP_2 = \sqrt{(P_1P_2)^2 + (PP_1)^2} = \sqrt{(P_1P_2)^2 + (P_1P_2)^2}$$

$$= P_1P_2\sqrt{2} = l \cdot \sin\alpha\sqrt{2} \quad ...(3.2)$$

If scale of the plot/map is 1 cm = $s$ meters, then displacement on the drawing sheet is limited to 0.25 mm if,

$$PP_2 = 0.25 \text{ mm} = 0.025 \text{ cm} = \left(\frac{1}{40}\right)\text{cm}$$

$$\Rightarrow \quad l = \frac{l \cdot \sin\alpha\sqrt{2}}{s} = \frac{1}{40}$$

$$\Rightarrow \quad l = \frac{s \cdot \text{cosec}\alpha}{40\sqrt{2}}$$

$$\Rightarrow \quad l = \frac{s \cdot r}{40\sqrt{2}} \quad ...(3.3)$$

**The Eq. (3.3) gives the limiting length of the offset in meters.**

The Eq. (3.3) is based on the assumption that displacement due to error in linear measurement is equal to the error due to incorrect direction. However, in case this assumption is not true then the total displacement $PP_2$ is given by,

$$PP_2 = \sqrt{(P_1P_2)^2 + (PP_1)^2}$$

$$= \sqrt{(l\sin\alpha)^2 + (\delta l)^2}$$

For maximum permissible displacement of 0.25 mm on the drawing sheet;

$$\frac{\sqrt{(l\sin\alpha)^2 + (\delta l)^2}}{s} = 0.25 \text{ mm} = 0.025 \text{ cm}$$

$$\Rightarrow \quad \frac{(l\sin\alpha)^2 + (\delta l)^2}{s^2} = (0.025)^2 = \left(\frac{1}{40}\right)^2$$

$$\Rightarrow \quad l = \frac{1}{\sin\alpha}\left[\left(\frac{s}{40}\right)^2 - (\delta l)^2\right]^{\frac{1}{2}} \quad ...(3.4)$$

The Eq. (3.4) can be used for calculating the maximum length of the offset so that maximum displacement on the drawing sheet does not exceed 0.25 mm.

## 3.10 Obstacles/Difficulties in Ranging

- Ranging requires clear sight between the two ends.
- But this is not always the case. Often, some obstructions are encountered like a hill or a forest or a building etc. This makes the two ends invisible.
- In order to overcome this difficulty, appropriate other methods of ranging has to be employed. This in fact, depends on whether the two ends are visible from a distinct intermediate point.
- If however the two ends are not visible, then method of random line is used.

### 3.10.1 Random Line Method of Ranging

- If a survey line passes through a thick forest then obviously it is not possible to range out by direct method.
- Method of indirect ranging is also not possible as the end stations are not visible from an intermediate point. For such a case, random line method is used.

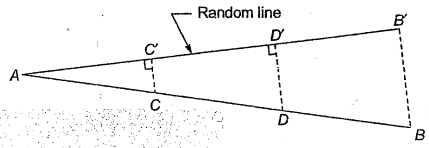


**Fig. 3.12** *Random line method of ranging*

- In Fig. 3.12, let $AB$ be the survey line which is passing through a thick forest. Range out a random line $AB'$ roughly along the direction of $AB$ such that line $AB'$ is clear of the forest and point $B$ is visible from $B'$. Draw a perpendicular $B'B$ at $B'$ on line $AB'$. Measure the distance $BB'$. Calculate the length of $AB$ as,

$$AB = \sqrt{(AB')^2 + (BB')^2}$$

Select intermediate points $C'$ and $D'$ on line $AB'$ and determine the lengths of perpendicular offsets $CC'$ and $DD'$ as,

$$CC' = \frac{AC'}{AB'} \cdot BB'$$

$$DD' = \frac{AD'}{AB'} \cdot BB'$$

Measure the distances $CC'$ and $DD'$ accurately and thus points $C$ and $D$ are located on the line $AB$.

## 3.11 Obstacles in Chaining and Ranging both

Often the surveyor encounters difficulties in chaining and ranging both. For example, if a large building comes in the path of chain line then it will not be possible to range across the building and to continue with the chaining. As far as possible, such situations must be avoided. In case, these situations are unavoidable, then following methods are used:

### 3.11.1 Method-I: Jackson's Method

1. Select two points $A$ and $C$ on the chain line before the obstacle.
2. Construct normal $AE$ and $CF$ of equal lengths. Ensure that the length of the diagonals $AF$ and $CE$ are also equal.

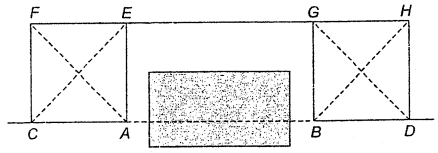


**Fig. 3.13** *Jackson's method*

3. Join $E$ and $F$ and produce the line $FE$ to point $G$ beyond the obstacle. Draw normal $GB$ on $FG$ such that $GB = AE$.
4. Produce $FG$ to $H$ and draw normal $HD$ on $FH$ and make $HD = AE$.
5. Join $B$ and $D$. Line $BD$ is the extension of the chain line $CA$ beyond the obstacle.

### 3.11.2 Method-II

1. Select point $A$ on the chain line on one side of the obstacle. Draw normal $AE$ from $A$.
2. Measure distance $AE$ and mark a point $C$ on the chain line such that $AC = AE$.
3. Join $C$ to $E$ and produce $CE$ to $F$.
4. Draw normal $FD$ to $CF$ such that $FD = FC$.
5. Mark point $G$ on $FD$ such that $FG = FE$.
6. With point $D$ as center and $AE$ as radius, draw an arc. Now with $G$ as center and $AE$ as radius, draw another arc intersecting the first arc at $B$.
7. Join $B$ and $D$. Line $BD$ is the extension of the chain line $CA$ beyond the obstacle.

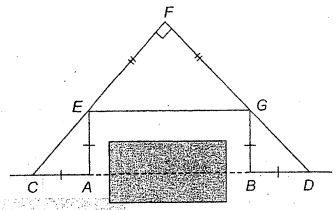

**Fig. 3.14**

### 3.11.3 Calculation of Length of Inaccessible Line

- Many a times, surveyor has to determine the length of a line drawn between two points which are inaccessible.

In Fig. 3.15, let $O$ and $D$ be the two inaccessible points. Due to inaccessibility of the points $O$ and $D$, length $OD$ cannot be measured directly.

1. Locate a point $A$ as shown in Fig. 3.15. Determine the distance $OA$ and $DA$.
2. Take a point $E$ on $AO$ and measure $AE$.
3. On $AD$, take a point $F$ such that

$$\frac{AE}{AO} = \frac{AF}{AD}$$

or
$$AF = \left(\frac{AE}{AO}\right) \cdot AD$$

4. Measure distance $EF$.
5. The distance $OD$ is computed as,

$$\Delta ODA \sim \Delta EFA$$

$$\therefore \quad \frac{OD}{EF} = \frac{AO}{AE} = \frac{AD}{AF}$$

$$\Rightarrow \quad OD = \frac{AO}{AE} \cdot EF = \frac{AD}{AF} \cdot EF$$

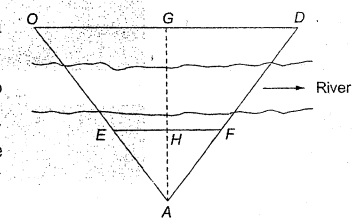

**Fig. 3.15** *Calculation of length of inaccessible line*

The perpendicular distance $AG$ when point $G$ is inaccessible can be determined as,

$$\frac{AG}{AH} = \frac{AO}{AE} = \frac{AD}{AF}$$

$$AG = \frac{AO}{AE} \cdot AH = \frac{AD}{AF} \cdot AH$$

## 3.12 Cross Staff Survey

- This type of survey is used for locating the boundaries of a field which are usually not of regular shape, for the purpose of finding the area of the field.
- A base line is selected in the middle of the field and the field area is divided into simple regular figures.
- Cross staff is used for setting out the perpendicular/normal to the base line.
- The length of the base line and the perpendicular distances are measured with the help of chain or tape.
- Cross staff (and also the optical square) is used for setting out the offsets.
- The base line should be so selected that the offsets on either side of the base line should nearly be equal. The calculation of areas is usually done in a tabular form.

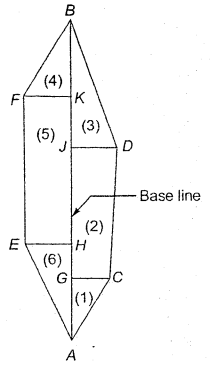

**Fig. 3.16** *Cross staff survey*

## 3.13 Plotting of Chain Survey Work

The object of chain surveying is to plot the plans and maps of the area surveyed.

- **Selection of Scale for Plotting the Plan:** A suitable scale needs to be decided before hand before the commencement of work of plotting the plan. The scale selected should be such that neither should it depict too many details that are actually not required nor it should be so that essential details are not clearly seen on the map.
- **Plotting of Framework:** Firstly the longest line i.e. the base line is plotted first on the drawing sheet. It is a good practice to first plot the survey lines on a tracing paper and rotate the tracing paper on the drawing paper so that frame work of triangles is centered and oriented properly. Once the best orientation has been decided, the ends of the base line are pricked through the tracing paper on the drawing sheet. By doing this, the points are thus transferred to the drawing sheet. Now the tracing paper is removed and the base line is drawn on the drawing sheet. Intermediate stations on the base line are marked carefully by a pencil or a sharp pin by scaling the corresponding chain distances. The positions of other main stations are located by drawing arcs from the ends of the base line. The main stations so marked are joined with the ends of the base line to form triangles. These triangles are checked by drawing check lines as measured in the field. If error is within the permissible limits then the triangle is adjusted. However if the error is large then field work must be repeated.
- **Plotting the Offsets:** Once the frame work of triangles has been plotted, offsets are plotted.
  (i) **Set Square Method:** In this, the perpendicular lines are drawn with set square. The chainages of the offset points are marked to scale on the respective lines on the drawing sheet. Perpendiculars are drawn and lengths of the offsets marked off. However oblique offsets are drawn with scale.

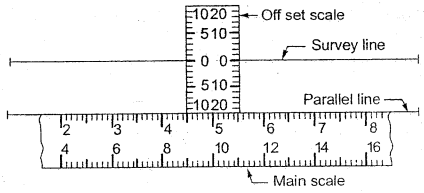

**Fig. 3.17** *Plotting of chain surveying work*

(ii) **Offset Scale Method:** Here, offset scale is used for plotting the offset. Offset scale is a small scale of length 50 mm to 80 mm. The main scale is held securely with its zero exactly at the beginning of the chain line (i.e. zero chainage). Offset scale is then placed at right angles to the main scale and moved along the main scale to the required chainage. Length of the offset is then marked along the offset scale. After plotting offsets on one side of the chain line, offset scale is moved to the other side and offsets are plotted on the other side.

## 3.14 Precautions to be Taken While Plotting the Offsets

- Chainages must be scaled from the correct end.
- Try not to omit any of the offsets.
- Care should be taken not to plot offset on the wrong side.
- Care must be taken not to join wrong offset points.

### Objective Brain Teasers

Q.1 Survey stations should be so selected that they must form
(a) Equilateral triangle
(b) Well conditional triangle
(c) Well conditional quadrilateral
(d) Isosceles triangles

Q.2 Which type of survey is most preferred for an area bounded by irregular boundaries?
(a) Cross staff survey
(b) Compass survey
(c) Theodolite survey
(d) All of the above

Q.3 The maximum displacement of point due to errors in plotting of offset is
(a) 0.5 mm (b) 0.25 cm
(c) 0.25 mm (d) 0.5 cm

Q.4 Which of the following code gives specifications of survey chain?
(a) IS : 13920 (b) IS : 3370
(c) IS : 1893 (d) IS : 1492

Q.5 The problem(s) with chain is (are)
I. Chain is very light
II. Chain sags considerably when suspended in air
Of the above statements, the correct one(s) is(are):
(a) I and II (b) II only
(c) I only (d) Neither I nor II

Q.6 The complete frame work of triangles in chain survey in built on
(a) Range line (b) Tie line
(c) Base line (d) None of these

Q.7 Lines joining the main survey stations in chain survey are called as
I. Survey lines
II. Chain lines
The correct one(s) is(are)
(a) I only (b) II only
(c) Neither I nor II (d) Both I and II

**Answers**

1. (b) 2. (a) 3. (c) 4. (d) 5. (b)
6. (c) 7. (d)