3 CHAIN SURVEYING (TAPE MEASUREMENTS)

3.1 INTRODUCTION

As mentioned in chapter 1, measurements in surveying include both distances and angles performed in both the horizontal, as well as, the vertical direction. Often, distances measured in the horizontal direction (termed horizontal distances) between points on the ground surface are needed for several purposes, among which is preparing a plan for the area under consideration. The horizontal distance between two points is defined as the distance between the projections of those points on a reference horizontal plane. A horizontal plane at a point is defined, in turn, as the plane perpendicular to the direction of gravity at that point. Some of the most common methods for measuring distances are pacing, taping, tacheometry and electronic distance measurement.

Pacing is a method that is used for the approximate measurement of a relatively short distance between two points. The length of a stride is usually quite regular for each person. Thus by counting the number of strides a person takes to walk from one point to another, and then multiplying this number by the average length of that person's stride, the distance between the two points can be approximated. An experienced person can obtain an accuracy at 1σ of 1 part in 100 (that is, a relative precision of 1/100) of the distance by using pacing.

Distances can also be measured by a method called tacheometry, which requires an angle-measuring instrument (named theodolite) and a graduated rod (named staff). This method, in most cases, combines distance measurement with the measurement of elevation difference. It is best suited for topographic mapping and will be discussed in Chapter 5.

However, distances ranging from a few meters to several tens of kilometers can be measured in a short time with very high accuracy by using electronic distance measuring (EDM) equipment. Such instruments measure distances using electromagnetic waves and will be discussed in Chapter 6.

This chapter deals with the discussion of distance measurement using tapes in a simple process called *taping* or *chaining*. The term *chaining* has its origin from the use in the past of the link chain that was devised by the Englishman Edmond Gunter in the seventeenth century. Because of the wide availability and use of measuring tapes nowadays, the term *taping* is becoming more frequently used. Distances up to 100 m long can be easily measured with a tape to an accuracy (at 1σ level) of 1/3,000. By using proper care and field procedures, small areas can be mapped using a measuring tape alone with an accuracy that is adequate for many engineering projects. As in all surveying operations, the successful use of tapes for distance measurement requires a thorough understanding of measurement principles, equipment, field procedures and sources of error.

3.2 EQUIPMENT USED IN CHAIN SURVEYING

The equipment used in chain surveying falls under three broad categories: those used for linear measurement, those used for establishing right angles, as well as, other equipment.

a) Equipment used for the measurement of lines:

1) The Chain. This is made of links of tempered steel wire, each link being 0.20 m long from center to center of each middle connecting ring (Figure 3.1). Chains are 20 m or 30 m long with markers attached at every whole meter position and different color markers giving 5 m positions. They are not commonly used because of their heavy weight, especially when they are suspended, which leads to sagging errors. Also, their length easily changes with temperature because of their high coefficient of thermal expansion.

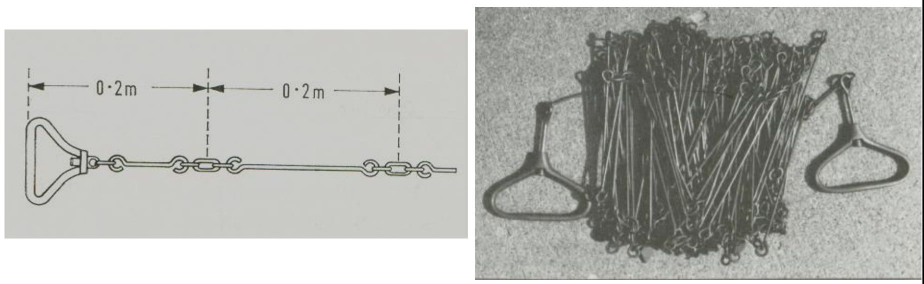

FIGURE 3.1: An example of chain links.

2) Tapes. These may be made of synthetic material, glass fiber being typical, or coated or plain steel. Tapes of lengths ranging from one meter to 50 meters are available, with 20-m, 30-m and 50-m lengths being most commonly used in surveying (Figure 3.2).

In general, most available tapes in the market nowadays are graduated and figured in a way that distances can be read and recorded to the nearest millimeter. Tapes are more accurate than chains, but their main disadvantages are their lack of robustness and the difficulty in doing field repairs.

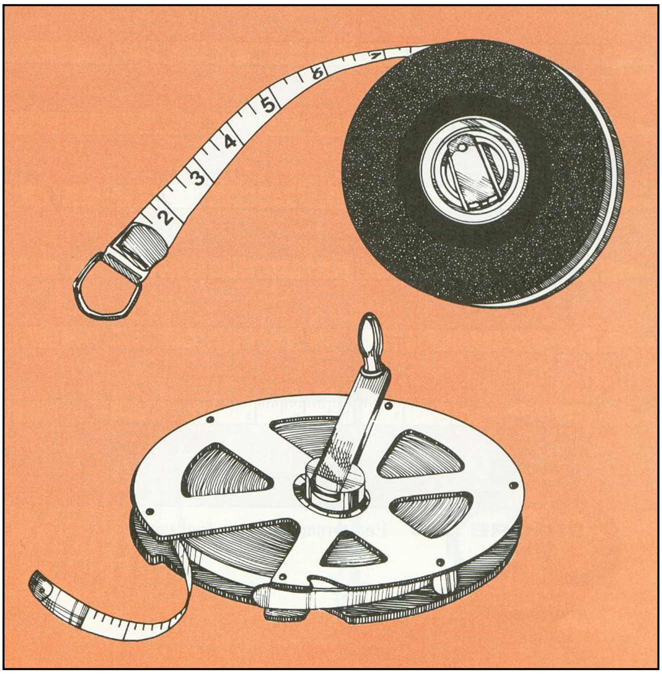

FIGURE 3.2: Typical measuring tapes.

3) Invar tapes. The word ***invar*** is an abbreviation of the English word ***invar***iable. These tapes are made of a mixture of steel (65%) and Nickel (35%), which results in a low coefficient of thermal expansion (about one-thirtieth that of steel tapes). As a result, their length is least affected by temperature, and this makes them more accurate than other types of tapes. Because they are expensive, invar tapes are primarily used for measuring lines that require a high degree of accuracy.

b) Equipment used for making right angles:

1) The cross staff. This tool consists essentially of an octagonal brass box with slits cut in each face so that opposite pairs form sight lines (Figure 3.3a). This enables sights to be taken through any two pairs of slits whose axes are perpendicular. The other two pairs enable angles of 45° and 135° to be set out. An alternate type of cross staff is shown in Figure 3.3b.

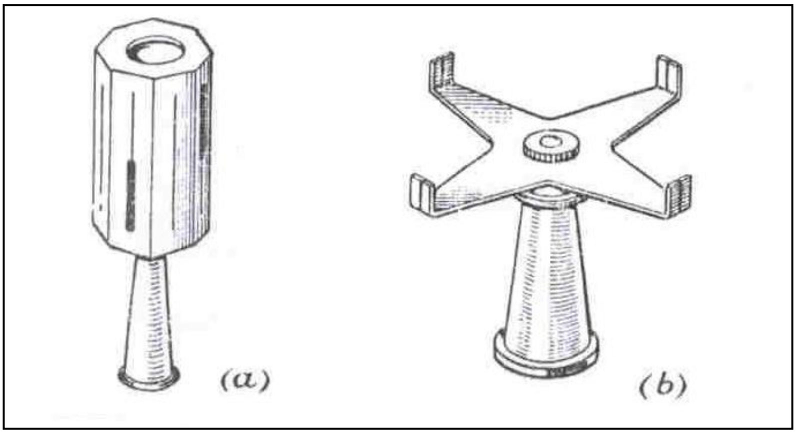

FIGURE 3.3: Cross staves.

2) The site-square. This consists basically of two telescopes, one mounted on top of the other, with their lines of sight at 90° to each other. The lower telescope is directed to a site mark positioned on one arm of the right angle to be established. The line of sight of the second telescope will lie along the other arm of the right angle and a further site mark can be positioned as required.

3) The optical square. This is a simple and compact instrument, the most widely available kind having a cylindrical shape of about 35-mm diameter and 40-mm thickness (Figure 3.5b). There are two types of optical squares, one using two mirrors and the other using a prism

The mirror type makes use of the fact that a ray of light reflected from two mirrors is turned through twice the angle between the mirrors (Figure 3.4). As can be seen from this figure, mirror A is completely silvered. Mirror B, on the other hand, is silvered to half its depth while the other half is left plain. Thus, the eye looking through the small eyehole will be able to see half an object atO_1. An object at O_2 is visible in the upper (silvered) half of mirror B, and when $O_1\hat{X}O_2$ is a right angle; the image of O_2 is in line with the bottom half of O_1 seen directly through the plain glass.

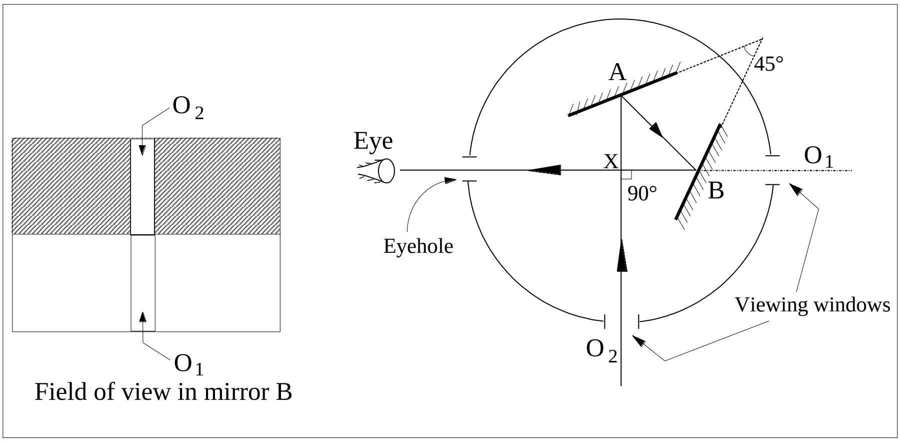

FIGURE 3.4: Mirror type optical square.

The prismatic type of optical square employs a pentagonal-shaped prism, cut so that two faces contain an angle of equal to 45° (Figure 3.5a), and is used in the same way as the mirror optical square. Figure 3.5b shows an example of the prismatic type that could contain

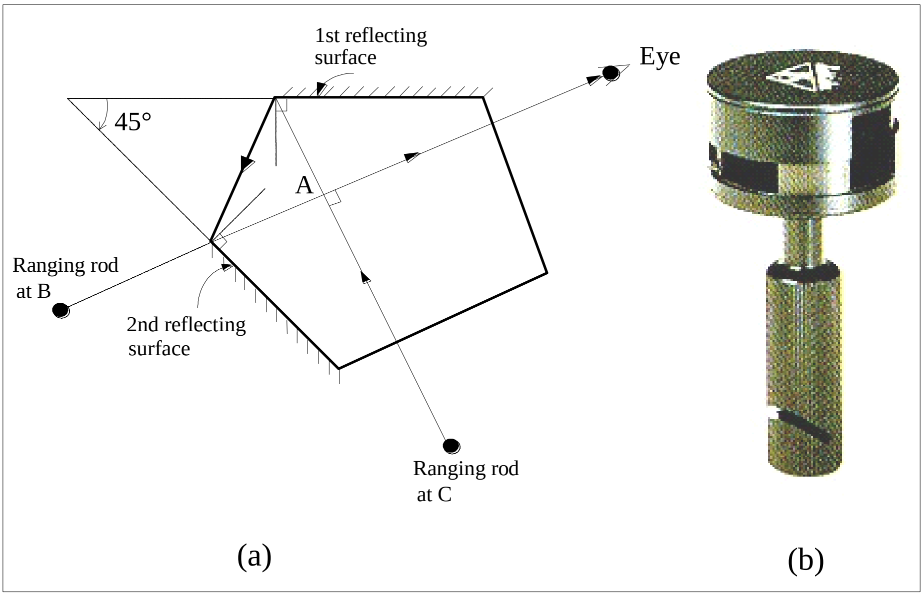

FIGURE 3.5: Prism type optical square.

only one prism (single prism) or two prisms (double prisms), with an opening on the right side of the optical square, and another opening on the left side.

c) Other equipment:

The following equipment is also used in chain surveying:

1) Ranging rods. These are poles of circular cross-section that is about 1-inch in diameter and that are 1 or 2 meters long. They are painted with alternate bands of red and white that are usually 0.5 m long, and are tipped with a pointed steel shoe to enable them to be driven into the ground (Figure 3.6). Rods that are 1-m long steel pipes are most common because they are easier to handle, and can be connected with each other to form longer rods. In general, ranging rods are used to help in the measurement of lines, and for marking any points which require to be seen. On hard surfaces (such as rocks or paved ground), a special tripod is used to support the rods.

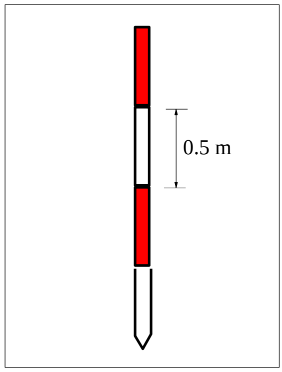

FIGURE 3.6: Ranging rod.

2) Arrows (also known as pins). These are steel skewers about 40 cm long and 3 to 4 mm in diameter (Figure 3.7). They are used to mark intermediate points when measuring a long line.

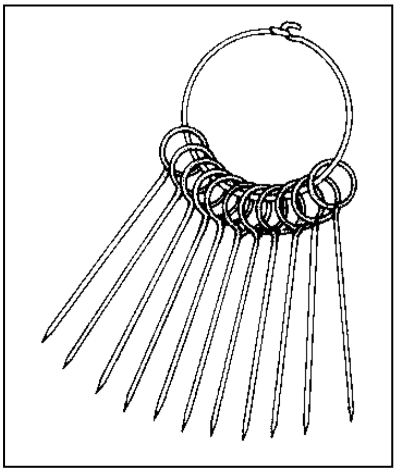

FIGURE 3.7: Arrows.

3) Pegs. Points which require to be more permanently marked, such as the intersection points of chain lines, are marked by pegs driven into the ground. These pegs can have a 4 cm x 4 cm square cross-section (Figure 3.8a), or a circular cross-section of 3 to 5 cm diameter (Figure 3.8b), both about 40 cm long. In very hard or frozen ground, steel angles are used instead (Figure 3.8c), while in asphalt roads, small 5 or 6 mm square brads are used.

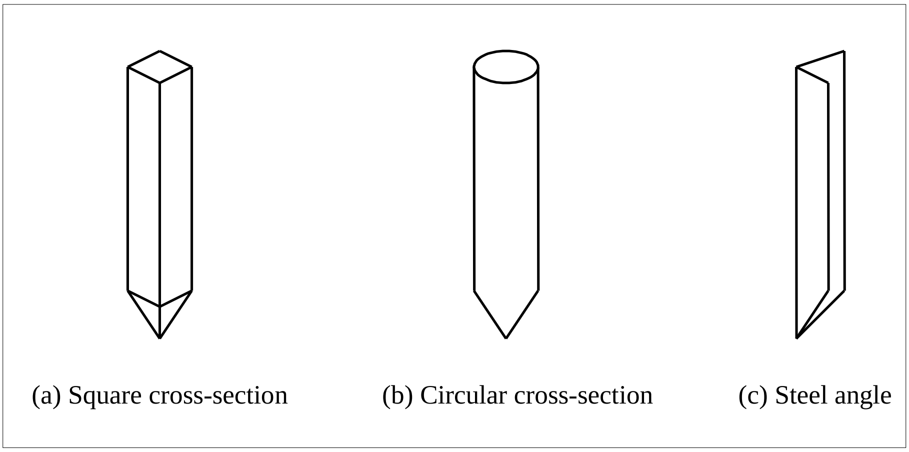

FIGURE 3.8: Types of pegs.

4) Plumb bob. The plumb bob is a metallic object in the shape of a cone. When hung freely by a strong string from the center of its base, the tip of the cone points towards the direction of gravity. It is used to project a point on the ground up to the tape, to project a point on the tape down to the ground, and to center surveying equipment above stations (Figure 3.9).

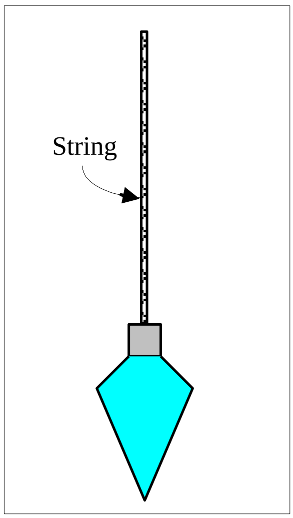

FIGURE 3.9: The plumb bob.

5) Clinometer. A small device used to measure the angle of inclination (slope) of a uniformly sloping ground. A simple clinometer can be made using a protractor and a plumb bob as shown in Figure 3.10.

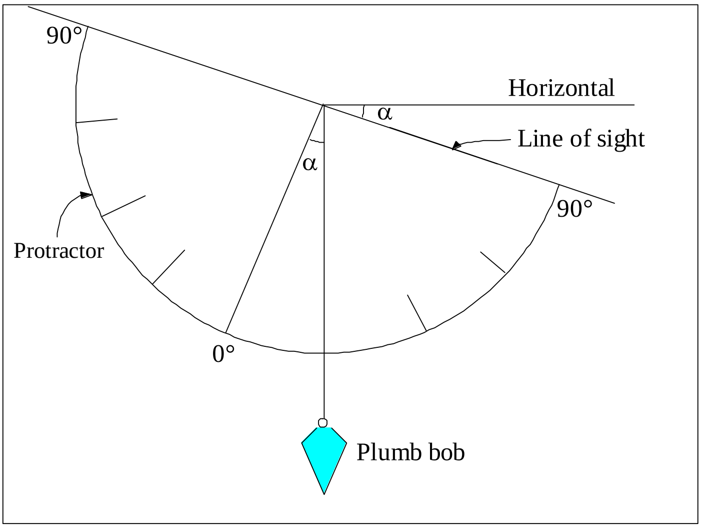

FIGURE 3.10: The clinometer.

6) Abney Level. This is an alternative device used to measure the inclination angle of uniformly sloping lines. Figure 3.11 shows a typical abney level.

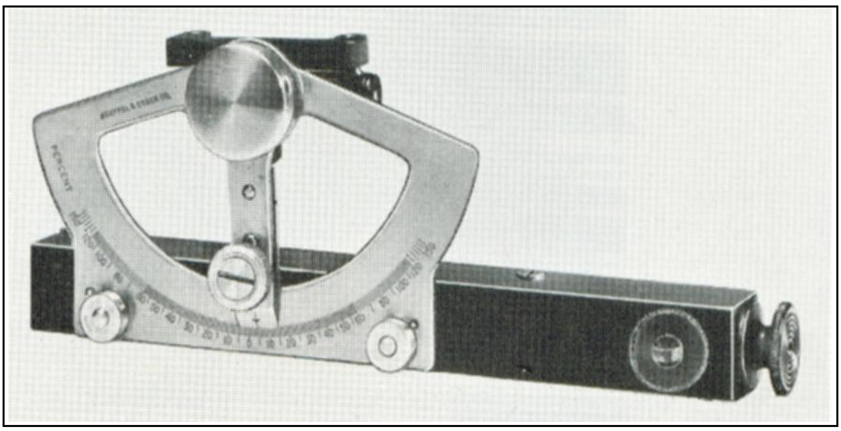

FIGURE 3.11: The Abney level.

3.3 PROCESSES IN CHAIN SURVEYING

Two types of measurement are performed in chain surveying. These are the ranging and measurement of lines, and the setting out of right angles.

3.3.1 RANGING AND MEASUREMENT OF LINES

Measuring a distance is one of the basic processes done in chain surveying. This operation is usually performed by two people, one acting as a leader and the other as a follower. If the line to be measured is shorter than one tape length, it is directly measured by extending the tape between the end points of the line. However, if the line is longer than one tape length, it is required to add intermediate points (which could be at equal or random distances) between the end points of the line by a process called forward ranging. In general, the following important points should be kept in mind when doing the measurement:

1) The measurement should be in a straight line, especially when measuring long lines. This will reduce the error caused by the individual sections of the line not lying in a straight line with each other.
2) The tape should be reasonably pulled to minimize sagging, and to avoid over-stretching the tape material at the same time.
3) A systematic way should be followed to count the number of times the tape is used between the end points of the line.

Now, depending on the topography of the ground where the line to be measured is located, the following procedure is followed:

A) ***Level or nearly level ground***. When the ground is level or nearly so, the line is measured as follows:

1. Position two ranging rods at both ends of the line (A & B in Figure 3.12). The rods should be vertical.

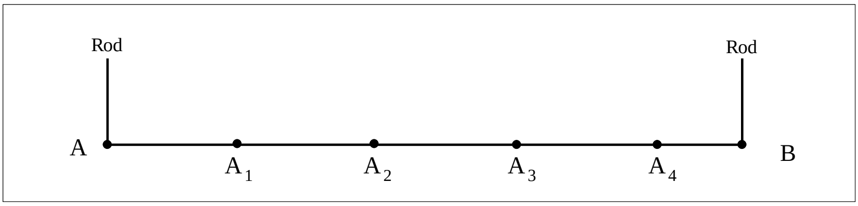

FIGURE 3.12: Line ranging.

2. The leader, holding a ranging rod and the end of the tape and several arrows (10 arrows for example), extends the tape horizontally in the direction of point B.
3. The follower, holding the zero of the tape and standing behind the rod at A, looks in the direction of B and begins giving right and left signals to the leader until the rods at A, A_1 and B lie in a straight line. The leader, then, drives an arrow at A_1.
4. The follower moves with the zero of the tape and a ranging rod to A_1. He then pulls out the arrow and drives the ranging rod in its place. At this time, the leader will extend the tape in the direction of B. The ranging process will be repeated until point A_2 is located by driving an arrow into it.
5. Step (4) is repeated to locate the next point A_3. At this moment the follower will be standing at A_2 with two arrows in his hand.
6. The previous steps are repeated until reaching a point (A_4 in Figure 3.12) so that the distance between this point and point B will be less than a tape length. When the follower stands at this point, he will have four arrows with him, which means that the distance measured so far will be four multiples of the tape length. If the last segment between A_4 & B is measured and added to the four multiples, the total horizontal distance AB will be known.

Note 1: An alternative procedure to the one explained above will be to divide the distance between the end points A and B randomly into a number of sections which are not necessarily equal. These individual sections are then measured and their lengths are added to get the total length of the line.

Note 2: The process used to divide the line above is called forward ranging whereby additional points are added between the end points of the long line. Alternatively, a short line, say line CD, might need to be extended to form a longer line behind point C. In this way, with ranging rods driven vertically at points C and D, the surveyor holds a ranging rod in a vertical direction behind C, moves backwards and aligns himself with the rods at C & D until he gets to a point such as E and drives an arrow. He could move backwards again, align himself with C & D and add another point like F, and so on. Notice that this process of backward ranging is done with only one person as compared to forward ranging, which needs two people to do it.

B) ***Uniformly Sloping Ground***. When the ground between points A and B has a uniform slope (Figure 3.13), the slope distance (S) is measured by the tape, while the slope angle (α) is measured by a clinometer or an abney level. The horizontal distance (D) and elevation difference (Δh) between points A & B will be:

$$D = S \cdot \cos\alpha \qquad (3.1)$$

$$\Delta h = S \cdot \sin\alpha \qquad (3.2)$$

If the elevation difference (Δh) between points A and B is known, then there is no need to measure the slope angle (α). The horizontal distance (D) will be calculated, instead, from the following expression:

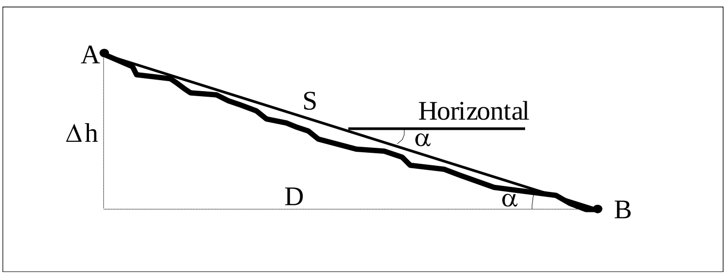

FIGURE 3.13: Distance measurement on a uniformly sloping ground.

$$D = \sqrt{S^2 - (\Delta h)^2} \quad \dots\dots\dots\dots\dots\dots\dots\dots (3.3)$$

C) ***Uneven Ground***. On uneven or non-uniformly sloping ground, line measurement is done through a process called stepping. The measurement is done in short horizontal increments of 10 to 15 m long with the help of a plumb bob. The total length in this case will be the sum of all the short increments. Figure 3.14 illustrates this process.

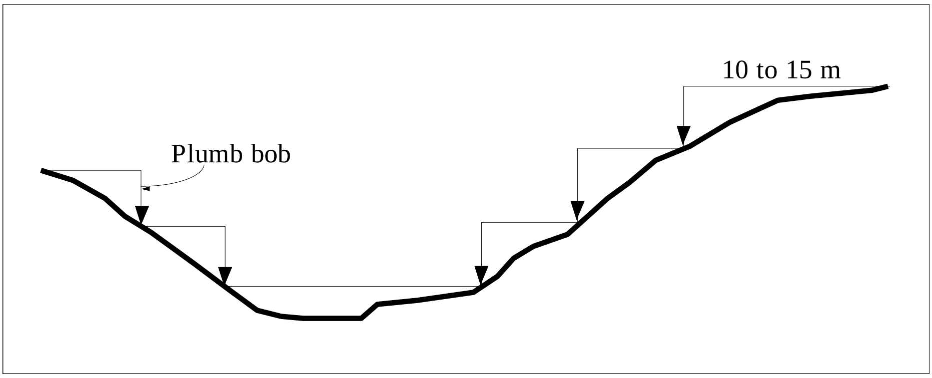

FIGURE 3.14: Stepping.

3.3.2 SETTING OUT RIGHT ANGLES

Two cases are to be considered here:

A) Dropping a perpendicular from a point C to a line AB. This can be done by any of the following methods:

1. With the free end of the tape at point C, extend it horizontally towards line AB and swing it left and right and observe the minimum reading at which it crosses the line AB (Figure 3.15a). This occurs when the tape is perpendicular to the line. This method is primarily used on smooth ground where a free swing of the tape is possible.

2. With the free end of the tape at point C (Figure 3.15b), strike an arc to cross the line AB at points D & E. Bisect DE at F. Then $C\hat{F}E = 90°$.

3. Run the tape from C to any point D on the line AB (Figure 3.15c). Bisect CD at E, and with E as center and a radius equal to ED, strike an arc to cross line AB at F. Then, $D\hat{F}C = 90°$, being the angle in a semi-circle.

4. Using the optical square with double prism. Three rods are placed at A, B & C. The surveyor carries the optical square in a vertical direction and starts moving left and right on the line AB while facing point C. When he sees the three rods at A, B & C along one line, then he will be standing at point D where $C\hat{D}B = 90°$ (Figure 3.15d).

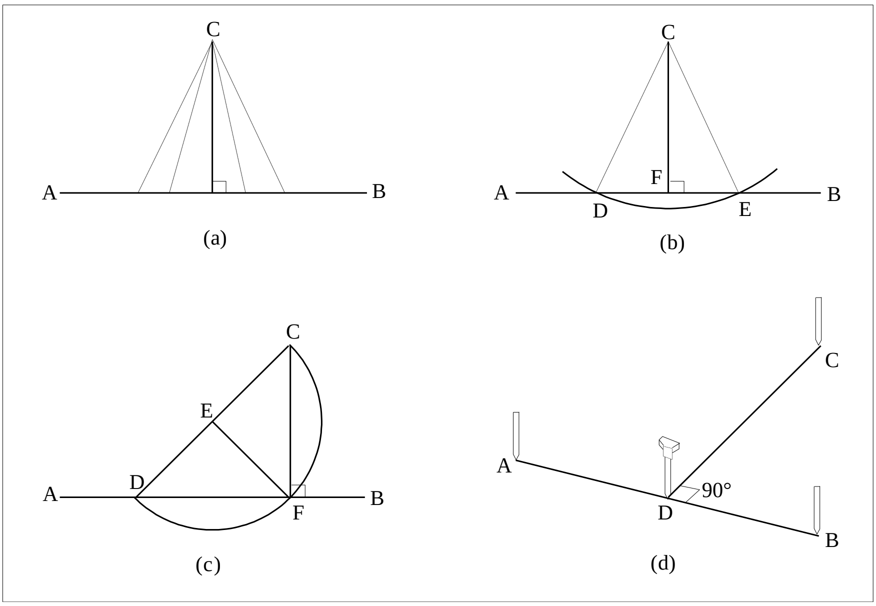

FIGURE 3.15: Methods of dropping a perpendicular from a point (C) to a chain line (AB).

B) Setting out a line at right angles to another line such as AB from a given point C on this line. This can be done by any of the following methods:

1. Using the cross staff or site-square as explained in section 3.2.

2. Using the optical square with double prism. In this method, the surveyor stands at point C, which is located on the line AB (Figure 3.16), and looks through his vertically held optical square until he sees the two rods at A and B as one continuous rod. Another person with a rod starts moving left and right in the field of view until this rod is seen by the surveyor to be in line with the rods at A & B. This rod will define the location of the end point of the perpendicular line.

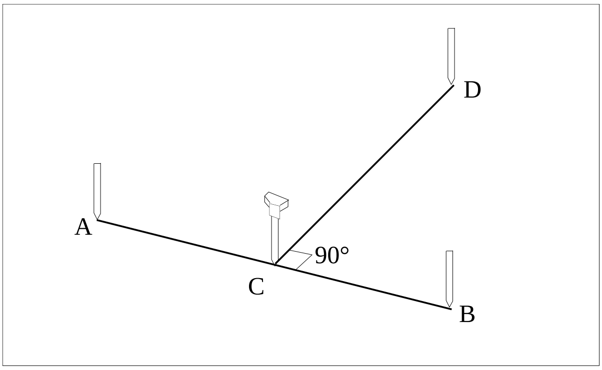

FIGURE 3.16: Erecting a perpendicular using the optical square with double prism.

3. The equilateral triangle method. Choose two points D & E on line AB such that CD is equal to CE (Figure 3.17). Then, with a radius bigger than CD or CE, strike arcs from D & E to intersect at F. Then $F\hat{C}E = 90°$.

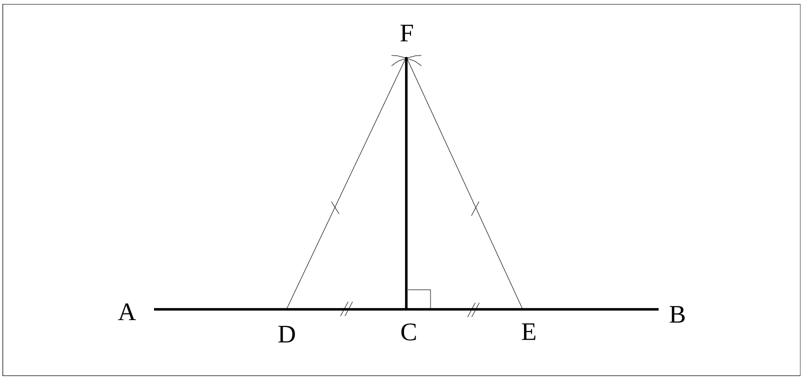

FIGURE 3.17: Setting out a perprndicular using the equilateral triangle.

4. Pythagoras' theorem method with the ratio between the right triangle sides being 3:4:5 or any multiple such as 6:8:10. To erect a perpendicular from point C at the line AB, measure a distance equal to 4 m on line AB and locate point D (Figure 3.18). Now, put the zero of the tape at C, and the 8 m mark (3 m + 5 m) at D, and with a pin or an arrow, pull the tape at the 3 m mark. The resulting point E will be the end point of the line perpendicular to AB at C.

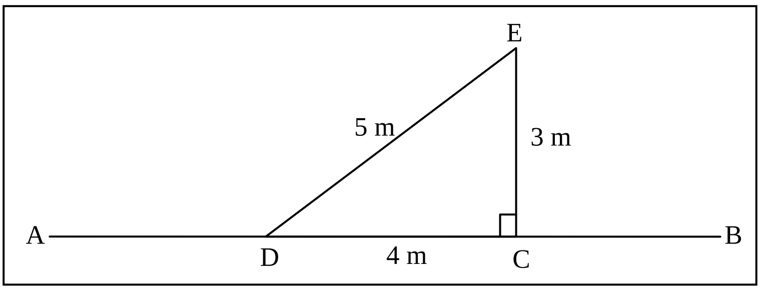

FIGURE 3.18: Pythagoras theorem method for setting out a perpendicular to a chain line.

3.4 MAPPING DETAILS USING CHAIN SURVEYING

In chain surveying, the topographical and man-made features are located and mapped by measuring with the tape the lengths of a series of selected reference straight lines, called chain lines, and then locating points on the ground relative to these lines. This is done by one of two ways:

1) The method of ties. In this method, a point (which could be an edge of a building) is located by measuring two reasonable distances, called ties, between this point and two selected points on the chain line. Figure 3.19a illustrates this process.

2) The method of offsets. In this method, a point is projected on the chain line, and then the distance between the point and its projection (called offset) as well as the distance from the beginning point of the line to the projected point are measured. Figure 3.19b illustrates this process.

Ground details may be located by the method of ties or the method of offsets or a combination of both.

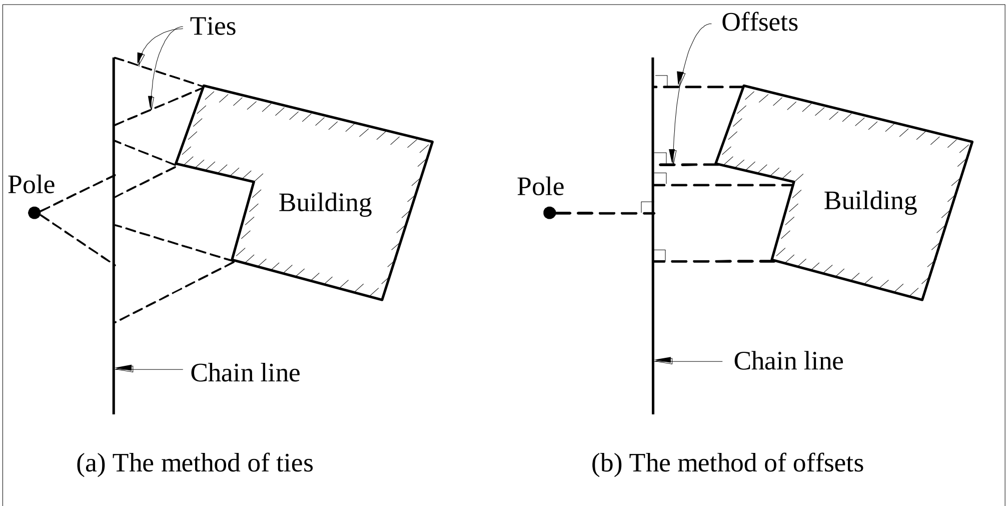

FIGURE 3.19: Methods of locating ground details.

Before performing any field measurements, the surveyor should do a reconnaissance process where he visits the area to be mapped. He notices the shape of the area, as well as, the existing details and draws a reasonable sketch of the area. The sketch is drawn by free hand using a pencil, but reasonably made so that the drawn distances will represent their counterparts on the ground. Sometimes a straight edge is used for greater clarity and time saving. All details such as roads, buildings, fences, electric poles, etc. should be included in the sketch, in addition to the approximate north direction. Figure 3.20 shows an example of a sketch.

The reconnaissance process will help the surveyor choose the most suitable location for the survey stations, which, in turn, form the chain lines. It also helps the surveyor plan his work including the time needed for the measurements, the number of people needed to do the work, the type of equipment necessary, and finally, the cost of performing the field work.

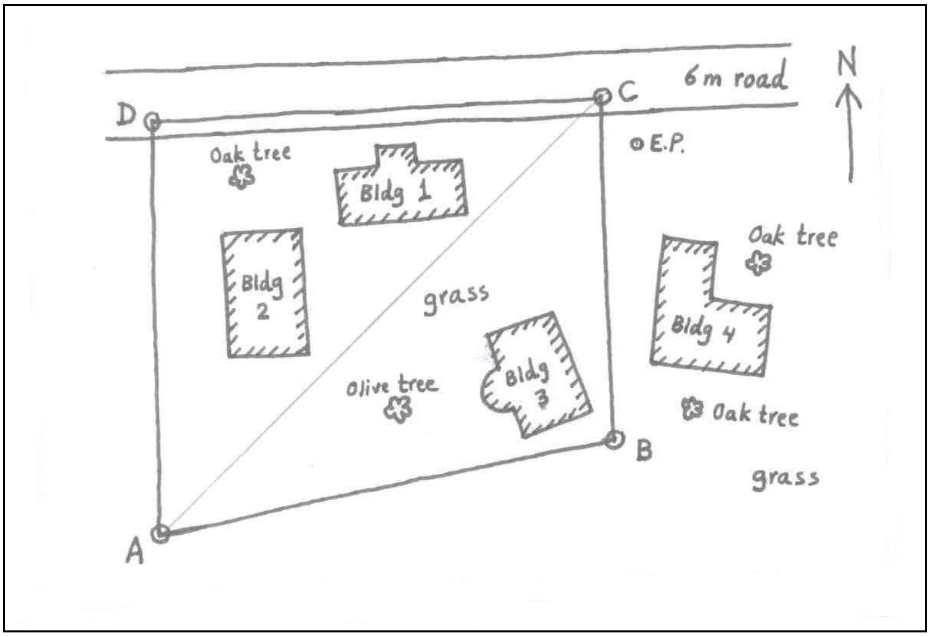

FIGURE 3.20: An example of a sketch for an area to be chained.

3.4.1 CHOICE OF CHAIN LINES

When choosing survey stations, and hence the chain lines, the following points should be taken into consideration:

1) Chain lines should form well-conditioned triangles where by the internal angles fall between 30° and 120°. This will help in forming a sharper determination of the point of intersection of the chain lines when plotting the details (Figure 3.21).

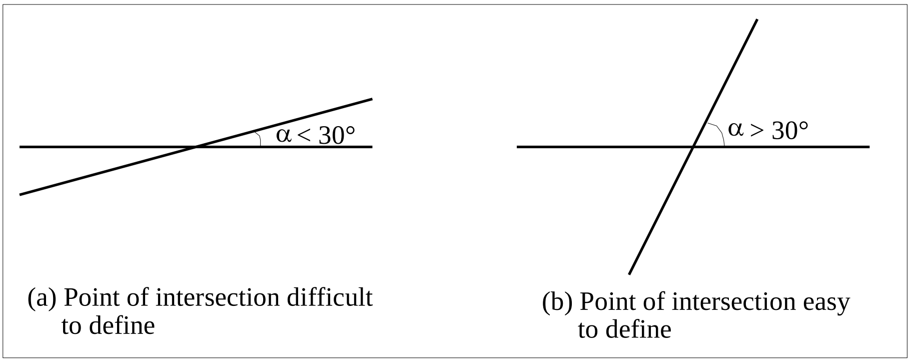

FIGURE 3.21: Relationship between the angle of intersection between chain lines and the location of the point of intersection.

2) Chain lines should be chosen as close as possible to the boundaries of the area or the details to be measured, so that the ties or offsets will be short.

3) It should be possible to see at least two other survey stations from each station.

4) The number of chain lines should be kept to a minimum, but at the meantime, enough to locate all the details. This will minimize the errors and the required amount of work.

5) Survey stations should be chosen in a way such that check lines will be provided (e.g. line AC in Figure 3.20).

6) Survey stations should be chosen on firm, easy to reach grounds. Obstacles along chain lines should be avoided as much as possible. It is an advantage to select stations close to stationary objects such as electric poles, trees, building corners, wall edges, etc. When a station is tied by at least two ties with such immovable objects, then it will be easy to recover such a station if it is lost for some reason.

3.4.2 BOOKING THE MEASUREMENTS

It is necessary to book the field measurements in an organized way so that they can be easily understood when plotting the details. Moreover, the person preparing the map could be different from those who do the fieldwork, and as a result the systematic organization of the field measurements forms the communication language between the field people and the draftsman. The booking is usually carried out in a field book that consists of good quality paper, the pages of which are approximately 20 cm long by 15 cm wide. Each page is divided in the middle by two lines, which run from the top to the bottom of the page, with a separation of about 1.5 cm between these two lines. These two lines represent a split chain line and the space between them is used for booking distances along the chain line. The spaces to either side of the chain line are used to show measurements to points of detail, whether these measurements being offsets or ties. Figure 3.22 shows the booking of details across and on both sides of chain line BC in Figure 3.20.

The following points should be taken into consideration when booking survey measurements:

1) Begin each line at the bottom of a fresh page. If one page is not enough for a particular long line, other pages can be used with special page numbering and continuation marks indicated.
2) All measurements made in the field must be recorded in the field at the time of measurement. Do not rely on memory!
3) Proceed with the booking from the bottom of the page to the top. The measurement should be recorded in the direction of chaining (i.e., left or right of the chain line).

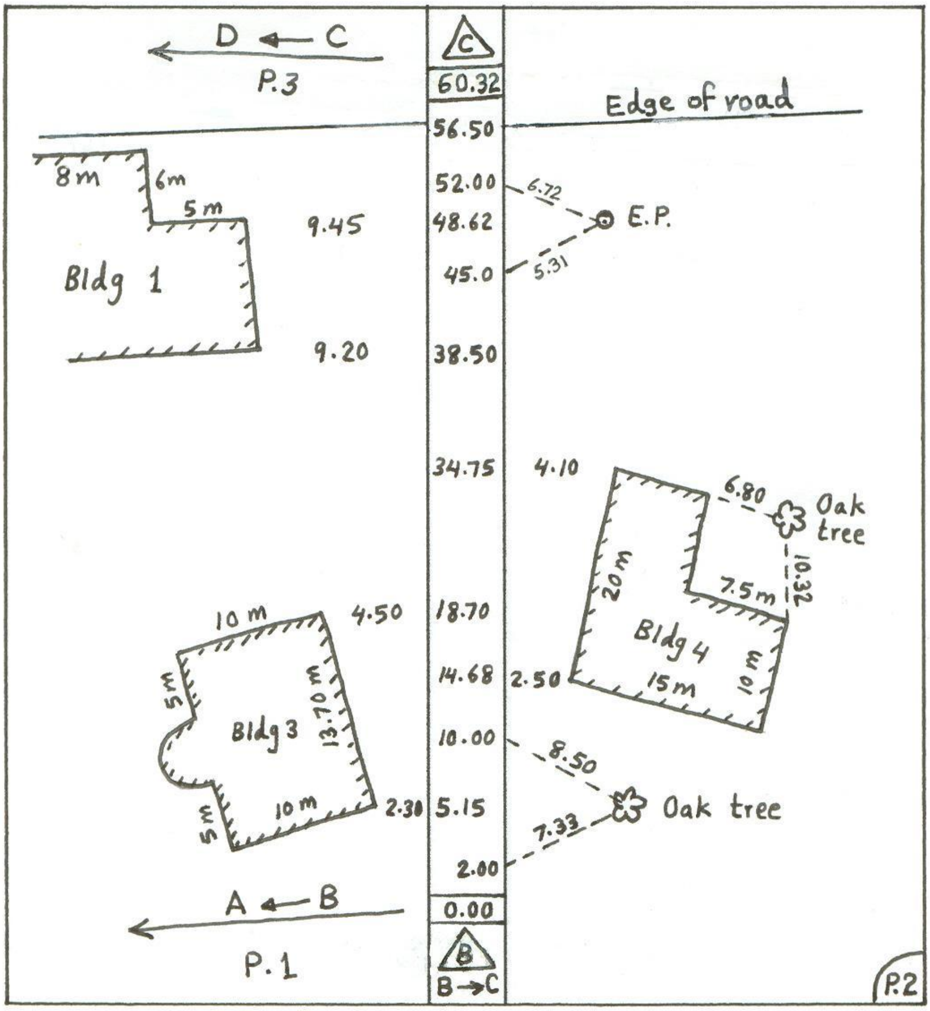

FIGURE 3.22: Booking of field measurements.

4) All details surveyed must be sketched neatly and roughly to scale in the appropriate place in the field book so that all measurements can be easily read and understood when plotting.

5) All other chain lines, which meet the chain line being measured, should be recorded in the appropriate place and a reference made to the page number of the field book on which its measurement can be found (see Figure 3.22).

6) To avoid confusion and crowding of the field book pages, offsets from the points of detail to the chain line are usually not drawn. However, offsets are booked by writing their values near the detail with the accompanying distance written in the space between the two middle lines. Ties, on the other hand, are drawn by a dashed line with their values indicated on these lines.

7) Names of houses, roads, rivers, etc. should be recorded plus any additional information about the surveyed detail that might be helpful when plotting. The name of the surveyed area, the name of the surveyor, the units of measurement, and the date of the survey should also be indicated.

3.4.3 PLOTTING THE DETAILS

After finishing the fieldwork, the plotting of the details proceeds according to the following steps:

1) Choose the appropriate scale, and hence the size of drawing paper to be used.
2) Using a pencil and necessary drawing tools, draw the chain lines on a normal (not tracing) paper. Begin plotting offsets and ties systematically in the same order in which they were measured and booked. Do not forget to indicate the north direction on your initial plan.
3) After all the details have been drawn by pencil, the plan is taken to the site and visually checked (if possible). If any mistakes or missing details are found, they are fixed in the field. Otherwise, the details are then inked on a final tracing paper. When doing so, and in order to obtain a neat looking map, try to do the following:

   a. Whenever possible, it is preferable to make the north arrow direction pointing towards the top of the sheet.
   b. Center the drawing in the middle of the sheet. Leave margins of 2 - 3 cm from the four sides. An extra space is left on the right and bottom sides of the sheet to write the relevant information which

includes the legend, scale, north arrow, office name, surveyor name, site and owner name, etc.

The plotting process has been facilitated lately by the vast developments in software and computer technology. Computer programs, such as AUTOCAD, are now available which make the drawing process much easier and more efficient than manual methods. Drawings can be revised, corrected and updated faster than ever before, and can be easily produced on plotters at any desired scale.

3.5 ACCURACY OF MEASUREMENT

To a certain extent, the accuracy of measurement depends on the plotting scale, and taking into consideration that this scale might be altered (increased or decreased), it is better to be more accurate than may appear to be strictly necessary. It is suggested that measurements be made to the nearest 10 mm (i.e. 1 cm).

A good draughtsman can plot a length to within 0.2 mm. Hence, if the plotting scale is 1/500, then 0.2 mm on the paper represents 10 cm on the ground. If the scale is 1/100, then 0.2 mm represents 2 cm on the ground. As a result, measuring a line to 1 cm accuracy is practically sufficient for most scales, especially when using the computer for drawing where lengths can be drawn with a very high accuracy.

3.6 CHAINING OBSTACLES

In general, chain lines should not be broken or obstructed by obstacles, but sometimes it is not possible to avoid the existence of such obstacles, especially when working in a field with a pond, building, standing crops, a small wood or a hilly area. The types of obstacles that arise may be grouped under the following three types:

(a) Those which obscure vision but do not prevent chaining such as a hill.
(b) Those which prevent chaining but not vision such as a pond or a river.
(c) Those which prevent both chaining and vision such as a building.

a) Vision obscured, chaining possible:

The usual obstacle in this category is a small hill, and is dealt with by the method of repeated alignment (repeated forward ranging) (Figure 3.23).

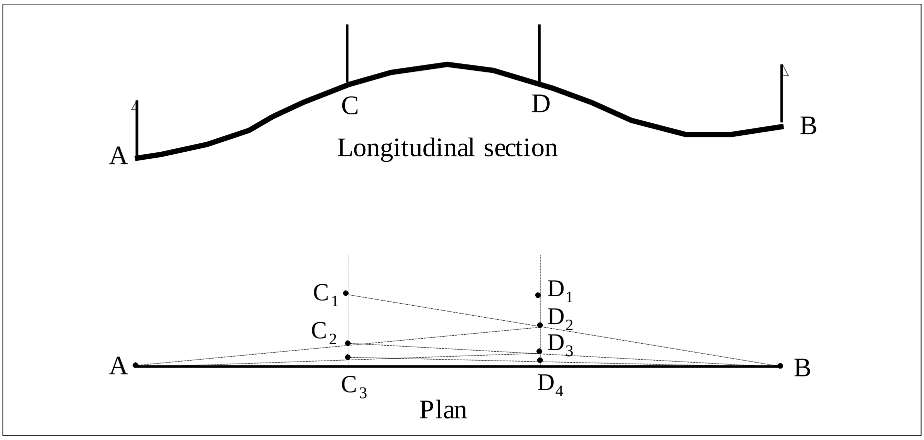

FIGURE 3.23: A hill which obscures vision but does not prevent chaining.

The surveyor and his assistant place themselves on both sides of the hill so that the person standing at C_1 can see the poles at D_1 and B, and the person standing at D_1 can see the poles at C_1 and A. Now assuming the surveyor is standing at C_1 and looking towards B, he directs his assistant to position D_2 on the line C_1B. The assistant who is now at D_2 and looking towards A ranges the surveyor to move to position C_2 on the line D_2A. This procedure is repeated alternatively between the surveyor and his assistant until the two poles C and D lie on the line AB.

b) Vision possible, chaining prevented:

Two types of obstacles can be recognized under this category. These are:

1. Closed obstacles such as a pond or standing crops. Measurements here are made around the obstacle in one of two ways:

a. The parallel line method. A distance that is parallel and equal in length to the missing one is made on the ground as explained in Figure 3.24. Two equal offsets CE and DF are set out perpendicular to AB, and then EF is chained to supply the missing length CD. As a check, GK and HL may be set out on the other side, if possible, and KL is measured. Then,

$$AB = AC + EF + DB$$
$$= AG + KL + HB \qquad \text{(3.4)}$$

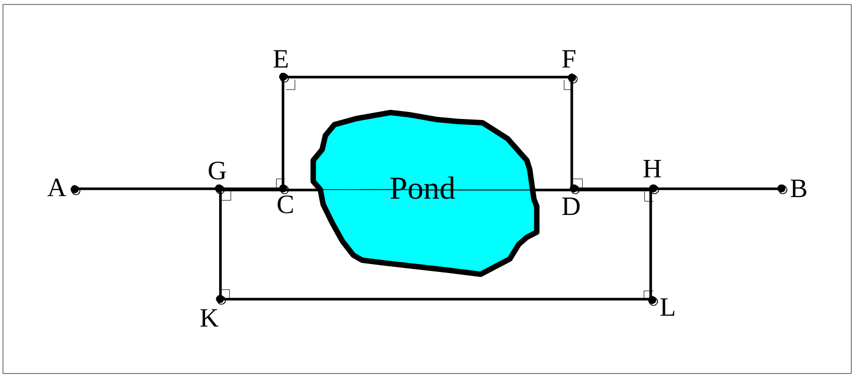

FIGURE 3.24: An obstacle which prevents chaining but not vision, such as a pond.

b. The capital letter A method. For example, assume that the distance AB (Figure 3.25) needs is be known. We choose an arbitrary point K from which points A & B can both be seen. Now, bisect KA at M and KB at N and then measure the distance MN. From the similar triangles KMN & KAB, distance $\overline{AB} = 2 \cdot \overline{MN}$. If M is chosen so that $\overline{KM} = \overline{KA}/3$ and N is chosen so that $\overline{KN} = \overline{KB}/3$, then $\overline{AB} = 3 \cdot \overline{MN}$. Any ratio other than 2 or 3 can also be used.

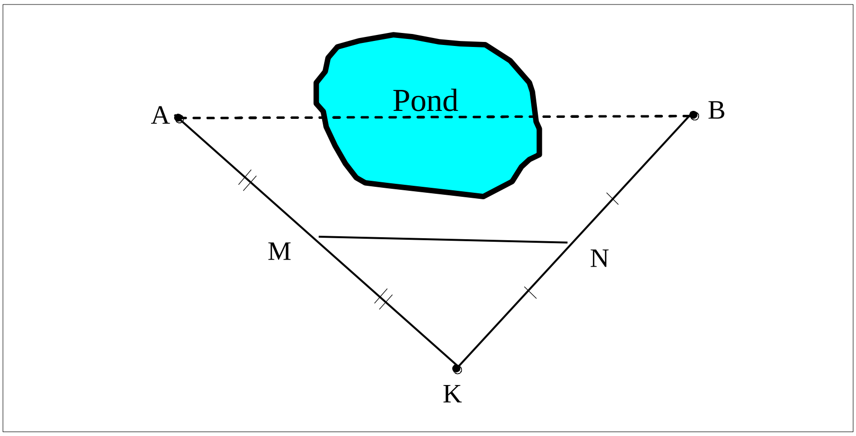

FIGURE 3.25: An obstacle which prevents chaining but not vision, such as a pond.

2. Linear obstacles such as a river. If the obstacle here is a river or a stream of greater width than a tape length, a geometrical construction is necessary. This can be done in one of three ways:

   (a) In the first method shown in Figure 3.26a, a ranging rod is placed at H on the far bank of the river. CE is constructed on the near bank perpendicular to AB, and a rod is ranged in to point F between E and H. A perpendicular is then dropped from F on to AB, meeting it at G. CE, FG, AC, CG and HB are then measured. Now, from the similar triangles EDF & FGH:

$$\frac{HG}{FD} = \frac{FG}{ED}$$

$$\Rightarrow \quad HG = FD \cdot \frac{FG}{ED} = \frac{CG \times FG}{EC - FG} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (3.5)$$

   (b) The second method gives the answer directly, and does not involve setting out any angles (Figure 3.26b). A line DE is set out on the near bank and bisected at C. The line FCG is now constructed such that FC = CG. With a rod at H on the far bank and on the line AB, a rod can be set at J on the intersection of lines EG and HC with a double backwards ranging process. The unknown distance FH is then equal to JG that can be easily measured.

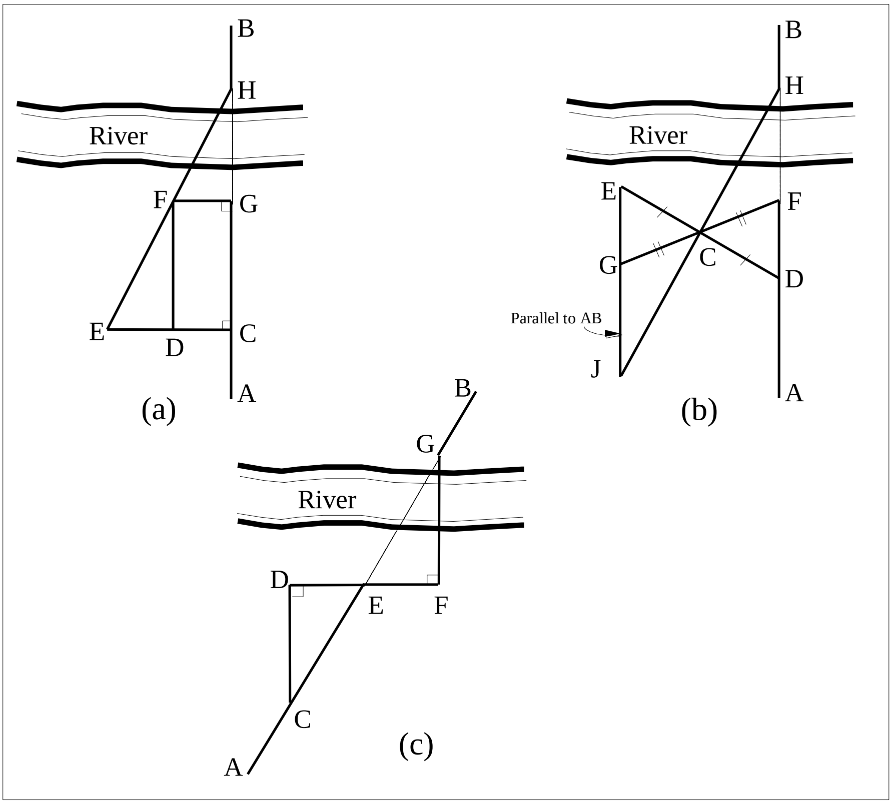

FIGURE 3.26: A river obstacle.

(c) In the third method, where the line crosses the river on the skew (Figure 3.26c), poles are placed on line AB at E and G on the near and far banks respectively. A line DF is set out along the bank, so that GF is perpendicular to DF (with the help of an optical square). A perpendicular from D is constructed to meet AB at C. Lines CE, EF & ED are measured. Then:

$$EG = \frac{CE \times EF}{ED} \qquad \text{(3.6)}$$

c) Both chaining and vision prevented:

This type of obstacle is encountered in two different situations. These are:

1) When prolonging a chain line (such as AC) past a fixed object (such as a building). It can be solved by the *Random line method* (Figure 3.27). A random line AH is constructed near the building and the lengths of AF, AG and AH are measured in addition to the length of the perpendicular CF. By similar triangles:

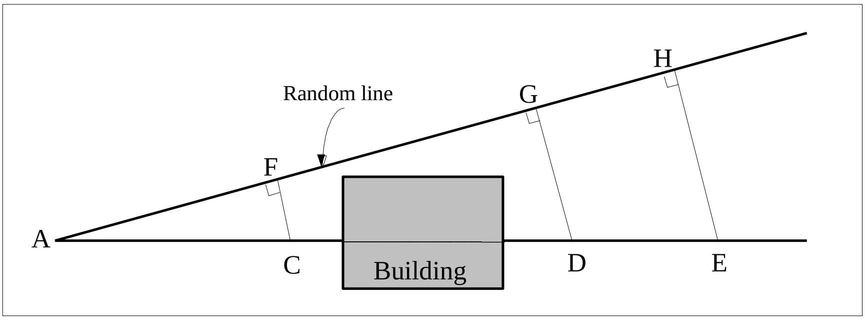

FIGURE 3.27: The random line method for prolonging a chain line past a building.

$$\frac{GD}{FC} = \frac{GA}{FA} \Rightarrow GD = FC \cdot \frac{GA}{FA}$$

$$\frac{HE}{FC} = \frac{HA}{FA} \Rightarrow HE = FC \cdot \frac{HA}{FA} \qquad \text{(3.7)}$$

By erecting perpendiculars on AH from G and H with lengths GD and HE respectively, points D & E are located. They lie on the extension of line AC.

Another method to solve this problem is illustrated in Figure 3.28.

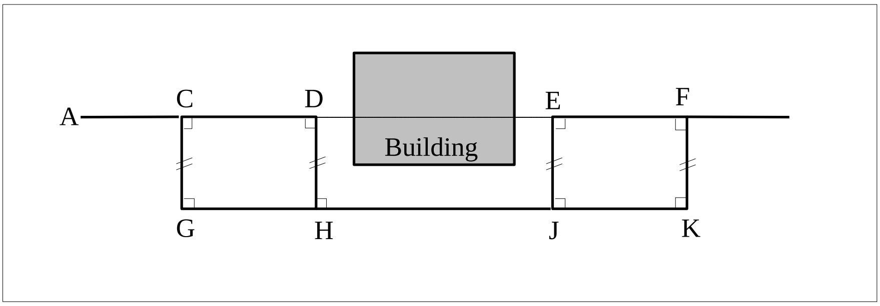

FIGURE 3.28: Prolonging a line past a building using equal offsets.

2) When trying to measure a distance between two points obstructed by a building (Figure 3.29). This problem is solved by the capital letter A method explained earlier.

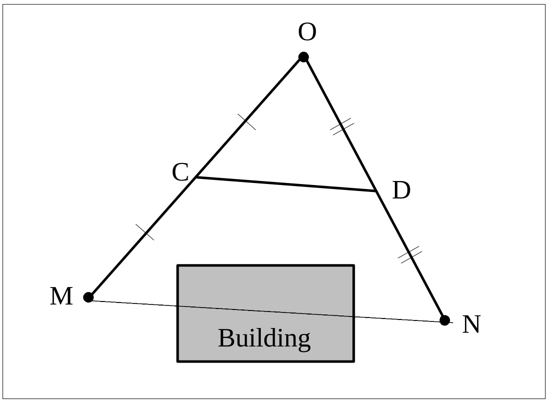

FIGURE 3.29: The letter (A) method.

3.7 ERRORS IN CHAINING AND THEIR CORRECTION

The same three types of errors explained in Chapter 2 occur in chain surveying (as all other types of surveying measurements). These are: blunders, systematic errors, and random errors.

a) Blunders (mistakes):

These are simply mistakes caused by human carelessness, fatigue and haste. They are random in both sign and magnitude. Typical mistakes in chaining a line are:

a - Omitting an entire chain length in booking.
b - Misreading the chainage by confusing the tallies - say the 14 m and 16 m tallies on a 30 m tape.
c - Erroneous booking such as writing 32.14 m instead of 23.14 m.

If allowed to pass unchecked, mistakes could lead to an unpredictable erroneous result. They can be eliminated by careful work and by using field procedures that provide checks for blunders.

b) Systematic errors:

These arise from sources that are known, and their effects, therefore, can be eliminated. Some of the systematic errors in chaining to which corrections can be applied are:

1) Temperature Correction: The correction C_t to be applied to the observed length of a survey line because of the effect of temperature on a *steel tape* can be computed as follows:

$$C_t = 0.0000116(T - T_0)L_m \qquad \text{(3.8)}$$

Where 0.0000116 is the coefficient of thermal expansion of steel per °C
T is the field temperature
T_0 is the temperature under which the tape is calibrated
L_m is the measured length of the line

2) Sag Correction: A tape supported only at the ends will sag in the center by an amount that is related to its weight and the amount of pull. Sag causes the recorded distance to be greater than the actual length being measured. When the tape is supported at its midpoint, the effect of sag in the two spans is considerably less than when it is supported at the

ends only. The sag correction C_s can be calculated by either one of the following two equations:

$$C_s = -\frac{W^2L}{24P^2} \quad \text{.......... (3.9)}$$

Or

$$C_s = -\frac{w^2L^3}{24P^2} \quad \text{.......... (3.10)}$$

Where W = the total weight of the section of tape located between supports
w = unit weight per meter of tape (or ft)
L = the interval (open length) between supports (in m or ft)
P = the tension on the tape (pull)

The units of weight and tension should be compatible (in kg or lb). The total sag correction for a tape resting on multiple supports would be the sum of the sag corrections for the separate intervals. Hence, the total sag effect for a 30 m tape supported at its midpoint and the ends would be twice the calculated sag for a 15 m span.

EXAMPLE 3.1:

Calculate the sag correction for:
(a) A 100 ft steel tape weighing 2 lb and supported at the ends only with a 12 lb pull.
(b) A 30 m steel tape weighing 0.0112 kg/m and supported at 0, 15 and 30 m points under a tension of 5 kg.

SOLUTION:

(a) $C_s = -\frac{W^2L}{24P^2} = -\frac{2^2 \times 100}{24 \times 12^2} = -0.116 \text{ ft}$

(b) $C_s = -2\left(\frac{w^2L^3}{24P^2}\right) = -2\left(\frac{0.0112^2 \times 15^3}{24 \times 5^2}\right) = -0.001 \text{ m}$

3) Tension Correction: Since the tape material is elastic to a small extent, its length is changed by variations in the tension applied. It is not related to the sag, but to the elastic deformation of the tape. It can be calculated from the following expression:

$$C_p = \frac{(P - P_0)L_m}{AE} \qquad (3.11)$$

Where C_p = the tension correction in ft or m

P = the applied tension

P_0 = the calibration tension

A = the cross-sectional area of the tape in in^2 or cm^2

E = the modulus of elasticity of the tape material (for steel: E = 29,000,000 lb/in^2)

L_m = the measured length of the line.

4) Length Correction: Checking the tape frequently is necessary for this correction to be effective, because the tape length changes due to wear and tear. The difference between the actual length used in measurement and the nominal length of a tape is known as the length correction. It can be calculated from the following equation:

$$C_\ell = (\ell_a - \ell_o)\frac{L_m}{\ell_o} \qquad (3.12)$$

Where C_ℓ = length correction in the line of length L

ℓ_a = actual length of the tape

ℓ_o = nominal length of the tape

L_m = the measured length of the line.

EXAMPLE 3.2:

A line is measured with a tape believed to be 50 m long that gives a length of 205.76 m. On checking, the tape is found to measure 50.03 m. What is the correct length of the line?

SOLUTION:

$\ell_a = 50.03\,\text{m}, \quad \ell_o = 50\,\text{m}, \quad L = 205.76\,\text{m}$

$C_\ell = (50.03 - 50)\ \text{x}\ \dfrac{205.76}{50} = +\,0.12\,\text{m}$

Corrected length = 205.76 + 0.12 = 205.88 m

Now that the different types of systematic corrections are calculated, the correct line length (L_c) will be:

$$L_c = L_m + C_t + C_s + C_p + C_\ell \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.13)$$

Note: When the length correction is the only correction to be considered, an alternative direct way to correct for lines and areas is as follows:

$$L_c = L_m + C_\ell = L_m + (\ell_a - \ell_0)\frac{L_m}{\ell_0} = L_m . \frac{\ell_a}{\ell_0} \qquad \ldots\ldots\ \ldots\ldots (3.14)$$

That is,

Correct line length = measured length . $\dfrac{\text{actual length of the tape}}{\text{nominal length of the tape}}$

Similarly,

Correct area = measured area . $\left(\dfrac{\text{actual length of the tape}}{\text{nominal length of the tape}}\right)^2$ . . . (3.15)

c) Random errors (compensating or accidental errors):

As explained in Chapter 2, these errors arise from lack of perfection in the human eye and in the method of using the equipment. As there is as much chance of these errors being negative as being positive, they tend to cancel out (i.e. tend to compensate for each other). Usually, no attempt is made to correct for them in chaining. Repeating the measurement several times and taking the average value will reduce these errors to a minimum.

PROBLEMS

3.1 The slope distance between two points was measured to be 463.21 ft with an estimated standard error of ± 0.05 ft. The difference in elevation between the two ends of the line was found to be 35.6 ± 0.5 ft. Compute:

a. The horizontal distance.

b. The estimated standard error of the computed horizontal distance.

3.2 Two edges of an axis of a road deflect by an angle = 90° (Figure 3.30). Using a tape of length = 30 m, ranging rods, pegs, arrows and an optical square, show how to connect those lines by a circular curve of radius = 26 m. Give the solution for the two cases when the center of the curve can be reached, and when the center can not be reached due to the existence of an obstacle such as a building.

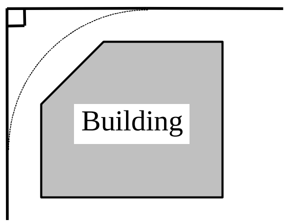

FIGURE 3.30

3.3 A survey line was measured by Mr. X and found to be 150.00 m. The same distance was measured by Mr. Y and found to be 150.08 m. The plotting scale was decided to be 1:1000 with plotting accuracy = 0.5 mm.

a. Do you think it is required to repeat the measurements?

b. If it doesn't need to be re-measured for such a scale, in what cases do you think it does need?

3.4 Using only tapes and arrows, describe how to measure the horizontal angle (α) between the two chain lines AB & AC (Figure 3.31).

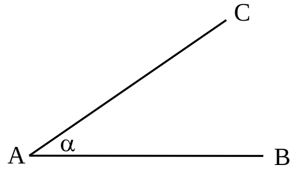

FIGURE 3.31

3.5 Using only an optical square and ranging rods, describe how to construct a circle on the ground around a line such as AB so that AB will be the diameter.

3.6 The piece of land of irregular boundaries (Figure 3.32) is to be mapped on a plan in order to calculate its area by the use of a planimeter (Chapter 8). Choose the number and location of the chain lines needed to chain this land. If this figure represented a lake instead, would the choice of chain lines be different?

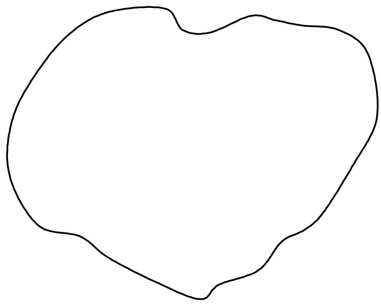

FIGURE 3.32

3.7 A four-sided land parcel ABCDA has a building inside it, which obscures vision along the diameters AC and BD. Describe a simple way to indirectly measure these diameters. Assume that the internal angles of the land parcel are different from 90°.

3.8 A line is measured along a long gentle slope using a 20 m tape. The gradient of the line is measured with an Abney level and found to be 5° 30'. The slope distance is recorded as 150.25 m. The length of the tape was found subsequently to be only 19.96 m. Calculate the correct horizontal length of the line.

3.9 A 50-m tape was calibrated under a tension of 7 kg and a temperature of 20° C while fully supported. When carefully checked, the tape was found to be 50.005 m long. In the field it was used under a tension of 7 kg, a temperature of 35° C, and supported at the two ends only. A line was measured in 4 sections with the following results: 50 m, 50 m, 50 m and 48.631 m. Determine the correct length of the line. The tape weighted 0.50 kg.