UNIT 2 CHAIN SURVEYING

Structure

2.1 INTRODUCTION

In plane surveying, we usually measure horizontal linear distances between two points and angles between two lines. The linear measurement of distance between two points on the earth's surface can be carried out by several methods depending upon the degree of accuracy and precision required.

Chain surveying is the simplest method of surveying in which only linear measurements are made in the field. It is suitable for survey of smaller areas on open ground to obtain measurements for plotting exact description of boundaries of a piece of land or for taking simple details. The principle of chain surveying is to provide a framework consisting of a number of connected triangles, as the triangle is the only simple figure that can be plotted from the lengths of its side measured in the field. The area to be surveyed is divided into a number of triangles and the sides of the triangle are measured in the field. To get good results in plotting, the framework should consist of triangles which are as nearly equilateral as possible. Preferably all the sides of a triangle should be nearly equal having each angle nearly 60^{o} to ensure minimum distortion due to errors in measurements of sides and plotting.

Objectives

After studying this unit, you should be able to

- identify equipment and instruments used for chain surveying,

- describe the principles and procedures of chain surveying like fixing of survey stations, ranging of survey lines and setting of offsets,
- explain the errors and obstacles in chain surveying, and
- record the measurements in the field book.

2.2 INSTRUMENTS

Various methods used for linear measurements of distances between two points on the earth's surface can be broadly classified (based on instruments used) as :

(a) direct measurements by chain or tape,

(b) measurements by optical instruments and/or with calculation, e.g. tachometry or triangulation, telemeter, substance bar etc. and

(c) electronic devices, e.g. Geodimeter, Distomat, EDM etc. based on propogation, reflection and reception of radio/light waves.

The most commonly used method of measuring linear distances particularly in field and engineering surveys is by chain or tape. This process of measuring distances by chain is termed chain surveying.

2.2.1 Chains

The basic instrument or equipment used in chain surveying is a chain or a tape. A survey chain is generally composed of 100 or 150 links formed by pieces of galvanised mild steel wire of 4 mm diameter. The ends of each link are looped and connected together by means of three circular or oval shaped wire rings to provide flexibility to chain. The length of each link is measured as the distance between the centres of two consecutive middle rings. The joints of links are welded to avoid length changes due to stretching.

The ends of chain are provided with brass handles with swivel joints. This helps in turning the chain without twisting. The end link length includes the length of handle and is measured from the outside of the handle, which is considered as zero point or the chain end. Tallies, which are metallic tags of different patterns, are provided at suitably specified points in the chain to facilitate quick and easy reading. A semi-circular grove is provided in the centre on the outer periphery of handle of chain for fixing the mild steel arrow at the end of one chain length.

The number of links in a chain could be 100 in a 20 m chain and 150 in a 30 m chain. The details of a metric chain are as shown in Figure 2.1.

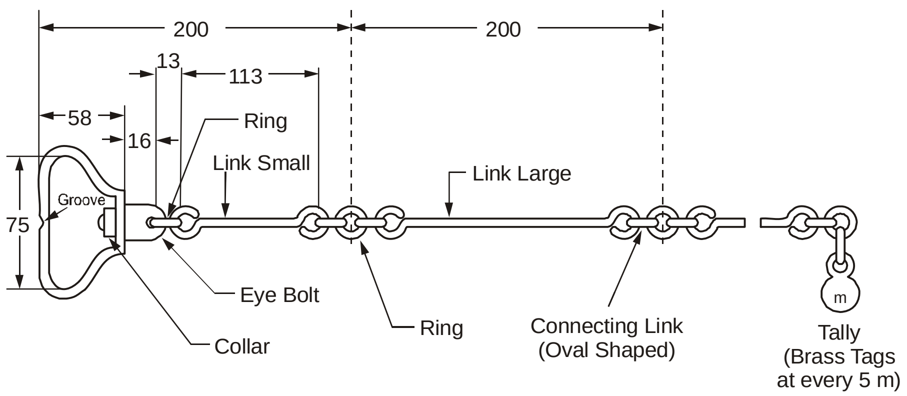


Figure 2.1 : Details of Metric Chain

The chain can be used conveniently in a rugged terrain and can be subjected to rough use under adverse site conditions. It can be read easily by even semi-literate persons. However, the length is liable to be changed due to continued usage. Its comparatively heavy weight may cause sagging in the chain thereby affecting the measurement accuracy.

2.2.2 Tapes

Tapes can be used for more accurate measurements of lengths. They are lighter and easier to handle and comparatively less liable to change in length than chain. Depending on the material, these can be of following types :

(a) Cloth or linen tape

(b) Metallic tape

(c) Steel tape or Steel band

(d) Invar tape

(e) Fiber glass tape

Cloth or linen tapes are 12 to 15 mm wide closely woven linen varnished for moisture proofing. Commonly used lengths are 10 m, 20 m, and 30 m. Since these are liable to shrink when wet and alter in length due to twisting or stretching, these are rarely used for accurate measurements. The better ones are interwoven with small brass, copper or bronze wires to provide strength and resistance to shrinkage and stretching. These are available in range varying from 2 m to 50 m in length.

For accurate measurements, steel tapes are used. These consist of light strip of steel with width ranging from 6 to 10 mm, in lengths of 2 to 50 m. Alternatively, steel bands consisting of ribbon of steel with brass swivel handle at each end are used. The width is usually 16 mm and length of 20 or 30 m.

Steel tapes and bands can be more accurately graduated. The graduations are etched as meters, decimeters and centimeters on one side and 0.2 m links on other side. Band is normally divided by brass studs at every 20 cm and numbered at every one metre. The tapes and bands are very delicate and hence not suitable for rough usage. These also require frequent cleaning and drying to avoid rusting. It is also difficult to read as compared to chain.

Invar tapes of alloy of Nickel (36%) and steel can be used for higher accuracy as their coefficient of thermal expansion is very low. However, it is costly and more delicate in use. In recent times, fibreglass tapes are extensively used in the field survey because of its low thermal expansion, cheapness, strength, ruggedness and durability. These are available in ranges varying from 5 m to 30 m in length.

2.2.3 Other Auxiliary Equipment

In addition to chain or tape, several other auxiliary equipment are required in a chain surveying exercise. These are listed in subsequent paragraphs.

Arrows

Arrows or chain pins, as these are called sometime, are made of stout steel wire 4 mm in diameter, 400 to 450 mm long and black enameled. These are used to mark the end of each chain length as shown in Figure 2.2(a).

Wooden Pegs

These are made of stout timber generally 25 to 30 mm square or circular size and 150 mm long as shown in Figure 2.2(b). Wooden pegs are normally used to mark station position on ground on a quasi-permanent state. These are tapered at one end so that they can be driven in the ground with a hammer. These are kept at about 40 mm (minimum) projecting above the ground.

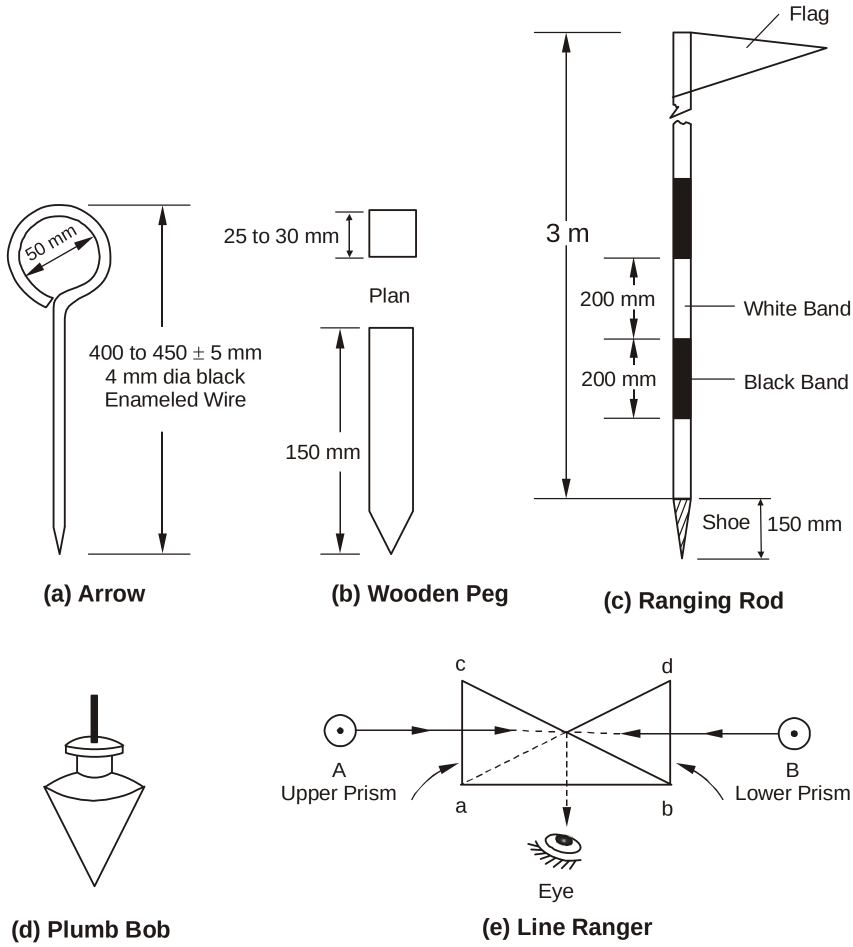


Figure 2.2 : Auxiliary Equipment

Ranging Rods

These are octagonal or circular in plan normally 25 to 30 mm diameter straight timber or tubular steel rods, 3 m in length and provided with an iron shoe at lower end as shown in Figure 2.2(c). These are painted in black and white alternate bands and normally have a flag at the top for easy recognition and identification from a distance. If the ranging roads are graduated in meters and one tenth of a meter, they are called offset rods and are used for measurement of short offsets.

Plumb Bob

It is usually heavy spherical or conical ball, as shown in Figure 2.2(d), of metal and is used to transfer points on ground by suspending it with the help of a strong thread. It is used in measuring distances on sloping ground by stepping. Compass, Dumpy levels and Theodolites are also positioned over the station point accurately with the help of plumb bobs.

Line Ranger

A line ranger consists of either two plane mirrors or two right angled isosceles prisms placed one above the other as depicted in Figure 2.2(e). The diagonals of both the prisms are silvered so as to reflect the incident rays. Line rangers are provided with a handle to hold the instrument. A line ranger can also be used to draw offset on a chain line.

2.3 PROCEDURES OF CHAIN SURVEYING

2.3.1 Principle

The principle of chain surveying is derived from principle of triangulation. The whole area to be surveyed is divided into framework of triangles of suitable sizes. Network of triangles is selected as these are simple geometrical figures which can be easily plotted with the measurements of its sides only. It is advisable to use well conditioned triangles whose sides are as nearly equal as possible with angles between 30^o to 120^o. This shaping of triangles result in higher accuracy. The triangulation of area avoids the need of measuring angles hence can be surveyed and plotted easily by measuring distances by changing alone.

The chain survey is preferred when the ground is nearly flat and open (avoiding crowded areas with many details, or areas which are heavily wooded or undulating) and also when the area to be surveyed is smaller.

2.3.2 Technical Terms

Survey Stations

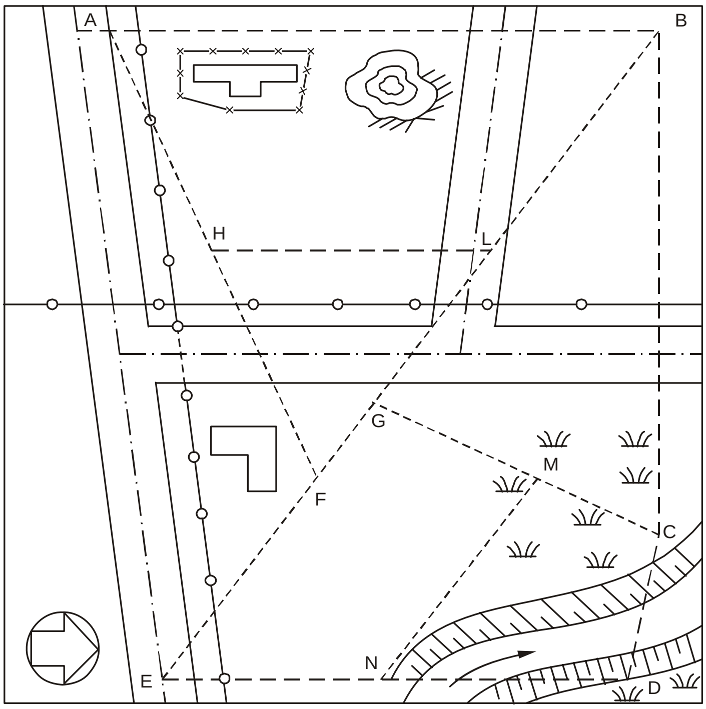
These are important point fixed on ground indicating the starting point and the end point of the survey line. These are also the basic control points of the survey. There can be two types of survey stations.

Main Station

Main stations are control points at the ends of the chain lines commanding the boundaries of survey.

Subsidiary or Tie Station

These are stations selected on the main survey lines for running auxiliary lines drawn to locate, measure and plot interior details. (Figure 2.3).



Main Survey Stations : A, B, C, D, E Subsidiary Stations : F, G, H, L
Main Diagonal (Base Line) : BE Main Survey Lines : AB, BC, CD, DE, EA
Subsidiary or Tie Lines : AF, GC Check Lines : HL, MN

Figure 2.3 : Layout of Chain Survey

The survey stations are suitably selected with care so that at least main survey stations are mutually visible and survey lines run through as flat ground as possible and are as close to the boundaries as possible. The main survey lines should form well conditioned triangles. These should be as few as possible and suitably selected so as to avoid obstacles in chaining and ranging.

Survey Lines

The lines joining survey stations are the survey lines. The survey lines between main stations are thus called main survey lines or chain lines. The longest of the main survey line is normally called *Base Line* (Line *BE* in Figure 2.3) running primarily through the middle of the area to be surveyed. The framework of triangles shall have one or two base lines since the entire survey is built around base line. It shall be measured with higher care and accuracy.

The survey line joining the subsidiary or tie stations on main line is termed *Tie Line*. These are run to account for interior details on the area, e.g. buildings etc.

Apart from main and tie lines, other survey lines are also selected for cross checking the accuracy of survey measurements. Such lines are known as *check lines* or *proof lines*. It is preferable to have at least one check line in each triangle of the framework.

Offsets

The details on ground such as fences, buildings and towers, etc. are to be located with reference to main chain lines by means of lateral measurements. These lateral measurements with reference to the chain line are referred to as offsets. The two types of offsets are exhibited in Figure 2.4. These are perpendicular offset PP_1 and the oblique offset *PQ*. *Perpendicular offsets* are the lateral distances taken at right angles (normal) to the chain line. If the inclination of offset line to chain line is anything other than 90^o, the offsets are termed *oblique offsets*.

The offsets have two important characteristics, by which they are identified, measured, recorded and referred to :

(a) Chainage on chain line at which offset is measured, i.e. chainage of point P_1 on chain line in Figure 2.4.

(b) Distance of offset point of interest from point P_1 on chain line, i.e. distance PP_1 in Figure 2.4.

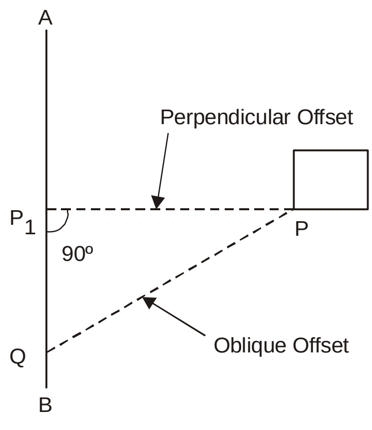


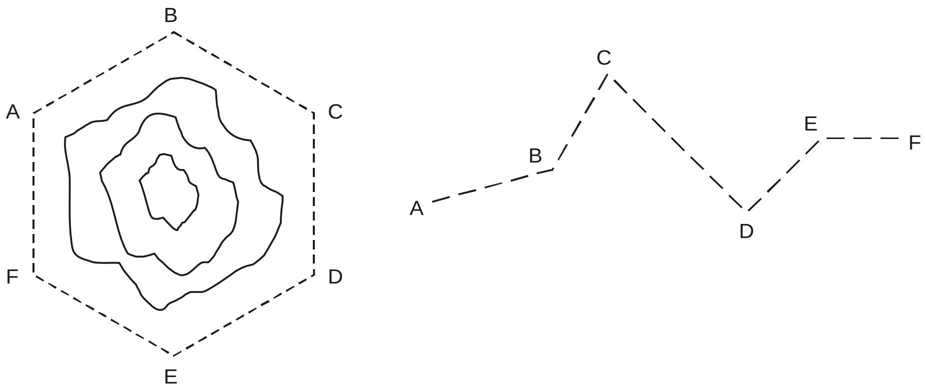
Figure 2.4 : Offsets

Traverse

A traverse is a framework of survey lines obtained by connecting a series of survey lines in which the length and direction of survey lines are measured with the help of tape and angle measuring instrument. In chain traversing, the whole work is done with the chain and tape. No angle measuring instruments is used and the directions of the lines are fixed entirely by linear measurements.

A traverse is termed a *closed traverse* if a complete circuit of survey line is provided. The interconnected main survey lines forms a closed polygon (Figure 2.5(a)) so that the originating station and end station are one and the same. This type of traverse is designed for locating the boundaries of the area of interest, e.g. lake, wooded land or plot of land to construct buildings, dams, reservoirs, industrial structures etc.

If the inter-connected main survey lines do not form a closed polygon and normally extend in one general direction then the traverse is called an *open traverse* (Figure 2.5(b)). End station in an open traverse will never coincide with the originating station. The open traverse survey is conducted to decide the alignment of highway, railway track, pipeline or transmission lines etc.



(a) Closed Traverse **(b) Open Traverse**

Figure 2.5 : Traverse

Ranging

In general, the length of the survey line is many times the chain length. Hence, along the survey lines intermediate points are required to be located to ensure that the survey lines are located and measured in a straight line. The distance can be directly measured by chain and or tape only if its length is more than that of a survey line. In all other cases, intermediate points help in pulling the chain/tape along the proper survey line on the required straight line. This process of locating intermediate points along a straight line is called ranging.

If the end survey stations on the survey line are inter-visible, direct ranging by eyes or line rangers is possible. In case of optical obstructions occurring between end stations, indirect ranging or reciprocal ranging is adopted.

SAQ 1

(a) Describe in brief the procedure to be adopted in chain surveying.

(b) Explain the function of survey line in a chain survey. Differentiate between main lines, base line, tie line, and check line giving illustrative example of each one of them.

2.4 OPERATIONS INVOLVED IN CHAIN SURVEYING

Various operations involved in the process of chain surveying are as follows :

(a) Marking the stations

(b) Ranging

(c) Measurement of survey lines

(d) Offset measurements.

2.4.1 Marking the Stations

The first step in chain survey is to decide and locate stations so that they are distinctly visible and are quasi-permanently fixed during the surveying process. The position of stations are located on map such that the base survey line and other main survey lines are so aligned that the positions of all salient ground features, either natural or man made, can be located and measured. The position of stations is fixed with reference to some permanent ground features so that they can be unambiguously and accurately located on ground at anytime in future also, if the station pegs are removed/misplaced (Figure 2.6).

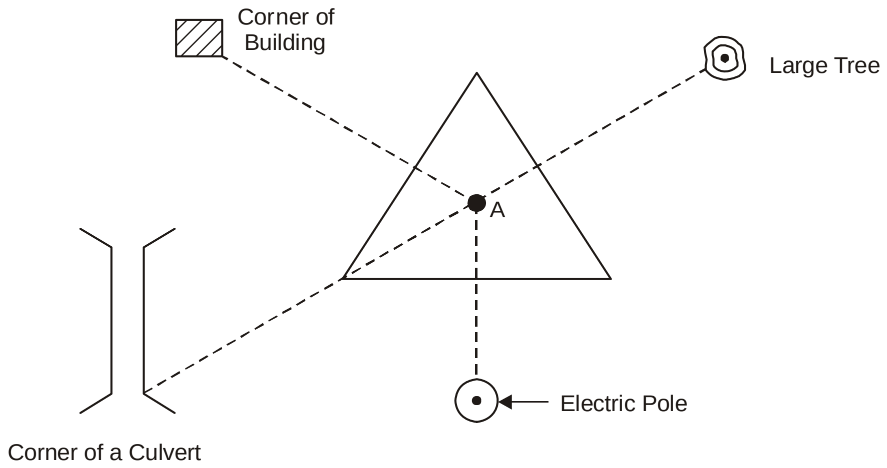


Figure 2.6 : Station Location

It can be noted that the distance of station *A* must be measured from atleast three permanent ground features, e.g. large tree, electric pole, building or culvert etc. existing in the vicinity of the station. The location sketch of the station as given in Figure 2.6 is very helpful in retracing the station position in future.

The survey stations are marked temporarily on ground by fixing the ranging rod at their location. A wooden peg is driven in the ground such that it is projecting at least 40 mm above the ground to provide some permanency. A cross can be painted or etched on ground if some hard surface like road, pavement or rock is encountered at station location. For permanent marking, a stone or concrete block can be embedded in ground.

Intermediate stations along the main survey lines of large lengths are generally located by the process of ranging.

2.4.2 Ranging

Ranging is essential step in chain surveying to ensure that measurements are made in a straight path along the survey line. If the end stations are inter-visible, direct ranging can be resorted.

Ranging by Vision

Direct ranging by vision alone is done by stretching the tape or chain approximately along the survey line *AB* as in Figure 2.7. At least two persons are involved in chaining and ranging. One surveyor called **follower** is stationed behind starting station *A* at the end of chain, while the other one called **leader** is situated at the distance of equal to or less than the chain length from *A*, holding the other ranging rod at an arms length from the body (position *L* in Figure 2.7). Follower, situated behind *A* directs leader to align ranging rod *L* along line *AB*. If the distance *AL* is large, sign language can be used in giving and following the directions. When *L* is perfectly aligned to exactly lie along sight line *AB*, the intermediate station *L* is fixed by driving the ranging rod or wooden peg in ground at correct position.

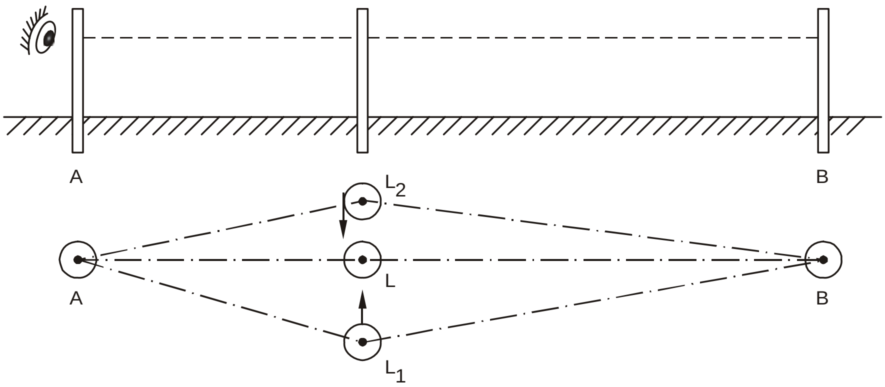


Figure 2.7 : Ranging by Sight/Vision

Ranging using Line Ranger

For more accurate ranging, instruments like *line rangers* are used. Line ranger consists of either two plane mirrors or two right angled isosceles prisms, as shown in Figure 2.8(a), silvered to reflect the incident rays.

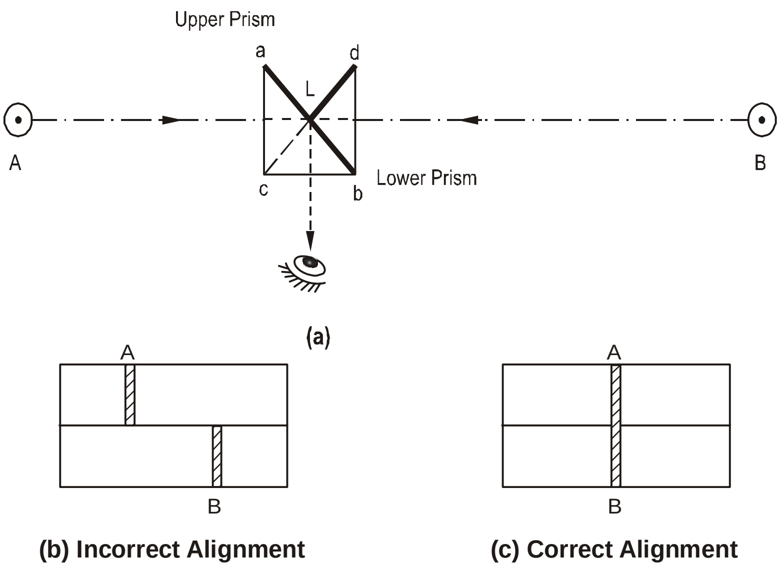


Figure 2.8 : Ranging Using Line Ranger

A handle is provided to hold the ranger in hand which also helps in transferring correct location of *L* (intermediate station) on ground. The line ranger is held at approximate position of *L* along line *AB*. Upper prism receives light rays from ranging rod at *A* and reflects it towards surveyor by diagonal *ab*. Similarly, the lower prism reflects the light rays from ranging rod at *B* by diagonal *cd*. The surveyor can, thus, see the images of both the ranging rods *A* and *B*. Simultaneously, if the instrument does not lie exactly along survey line *AB*, the two images do not coincide and a parallax is obtained as shown in Figure 2.8(b).

The observer removes this parallax by moving the line ranger sideways till the two images, respectively, of *A* and *B* coincide indicating the correct alignment of intermediate station *L* (Figure 2.8(c)). Apart from higher accuracy, another advantage of using the line ranger is that only one surveyor can perform the ranging operation as against two surveyors required for vision ranging.

Reciprocal Ranging

The vision ranging and line ranger can be adopted only when the end stations are inter-visible. However, in many real life situations, the line of sight between two stations is obstructed by natural or man-made objects (Figure 2.9), or they being too far apart to be clearly visible. Under such conditions, indirect or reciprocal ranging is resorted to. In this method, two intermediate points C_1 and D_1 are selected which are not along the line of sight *AB* (survey line). Stations C_1 and D_1 are approximately in line such that line $C_1 D_1$ is approximately paralleled to *AB*. C_1 is so situated that both D_1 and *B* are visible from it, while from D_1 both *A* and C_1 can be sighted.

The surveyors are situated at C_1 and D_1 originally. Surveyor at C_1 directs surveyor at D_1 to move such that he is aligned in direction $C_1 B$ to occupy new position at D_2. Next surveyor at D_2 directs the surveyor at C_1 to align along line AD_2 to occupy new position C_2. This process of alignment and realignment continues till both the surveyors occupy positions *C* and *D* which are situated along line *AB* ensuring that survey line is aligned along *ACDB* as shown in Figure 2.9.

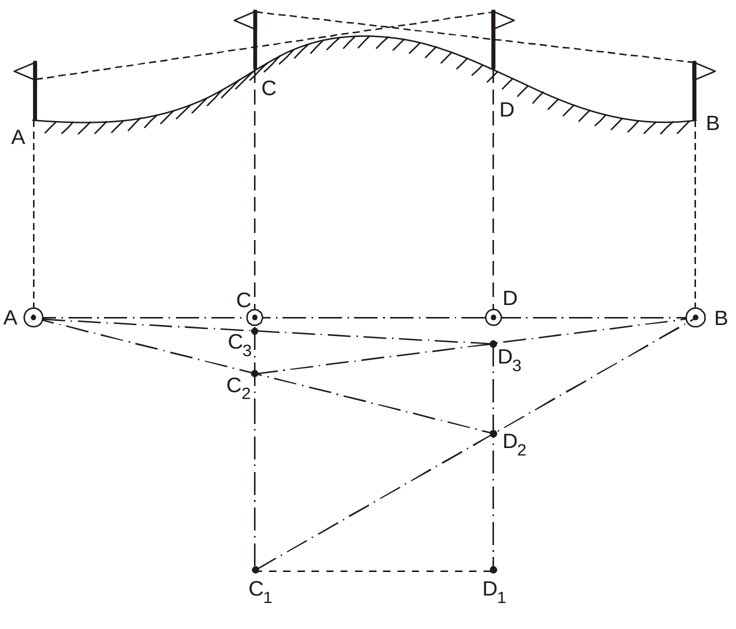


Figure 2.9 : Indirect or Reciprocal Ranging

2.4.3 Measurement of Survey Lines

After fixing the survey stations and ranging the survey lines by locating the intermediate stations, the next step in chain surveying is to measure the horizontal distances along the survey lines and the distances of features of interest from the survey line (offsets) so that a representative and authentic survey map is constructed.

The measurement process is started with unfolding the chain and ends up with its folding back. To unfold a chain, both of its end handles are held in one hand and the bundled chain is thrown along the direction of survey line with the help of other hand. The follower surveyor at starting station with zero end and the leader surveyor drags the other end of chain along the survey line, till the chain is fully stretched and lies along the straight survey line. Arrows are fixed at the end of each chain length indicating intermediate stations aligned along original main survey line. The arrows are so fixed that they just touch the groove marks on the chain. Each arrow represents a distance equal to chain length. Any fractional distance at end is measured by counting the tags on chain and its links (Figure 2.1). The total length of survey line can, thus, be easily obtained.

At the end of the measurement process, the chain is required to be folded back and bundled before keeping it in survey store for any future use. The folding process starts with holding the chain from middle and folding it by holding each pair of links at a time, and bundling till both the ends are obtained.

2.4.4 Offset Measurements

As discussed earlier, the chain survey is started with measurements along base line and extended along all the frameworks of survey lines. The laying of chain line and making measurement of distances along the survey line were described in earlier section. The next important part of distance measurement is locating the important details of features in the vicinity of survey lines by means of offsets. Offsets up to or less than 15 m from the survey lines are generally termed **short offsets** while those larger than 15 m are called **long offsets**. In normal course of chain surveying, perpendicular offsets are measured. Oblique offsets are recorded only in exceptional cases when it is difficult to obtain normal offsets or else these are absolutely essential.

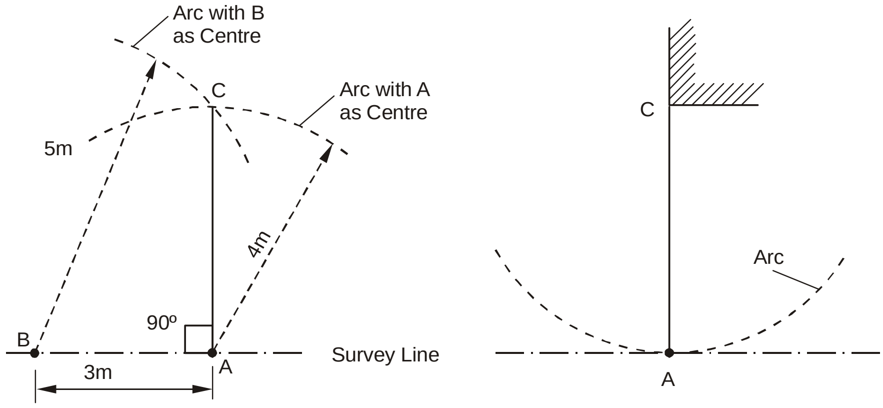
Perpendicular offsets can be set either (a) manually or (b) with the help of offset instruments like cross staff or optical square.

Manual Offsets

Manual offsets are obtained directly without the help of any instrument by following procedures :

3-4-5 Offset

Perpendicular offset of chain line at any point A is obtained using the following mathematical expression ($3^2 + 4^2 = 5^2$). A point *B* is located on chain line at a distance of 3 m from *A* such that *AB* = 3 m. Next, an arc is set on ground with centre at A and radius equal to 4 m. Another arc is laid with center at *B* and radius equal to 5 m intersecting the previous arc at *C* as shown in Figure 2.10(a). Line *AC* will then be perpendicular to line *AB*.



(a) 3-4-5 Offset **(b) Swing Offset**

Figure 2.10 : Manual Offset

Swing Offset

The perpendicular distance of an important feature, e.g. building corner, from the chain line is measured using swing offset method. The zero end of tape is kept at point of interest (Figure 2.10(b)) and point *A* (i.e. normal from *C* on chain line) is located by swinging the tape with *C* as center. The point *A* is characterized by a point at which the arc generated by swing is tangential to survey line and the distance of *C* from any point on chain line is minimum.

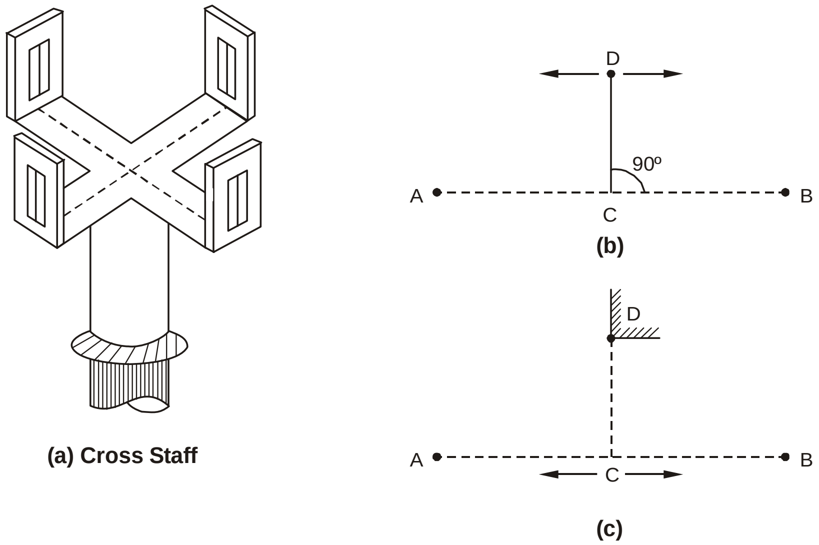
It may be noted that usually only small offsets can be set by manual methods.

Offset Instruments

Offsets can be accurately set up, particularly long offsets, by use of optical instruments like cross staff or optical square etc.

Cross Staff

Two pairs of vertical slits, mounted orthogonally on a pole staff constitute a simple instrument for setting out normal offsets as depicted in Figure 2.11(a). Each pair of slits can form a line of sight. The pole staff has adjustable length to keep the line of sight adjusted to surveyor's individual comfort.



(a) Cross Staff

Figure 2.11 : Offset by Cross Staff

The normal to survey line *AB* at chain point *C* can be drawn by first adjusting the cross staff stationed at *C* such that one pair of vertical slits is aligned along line *AB*. A ranging rod *D* is then placed approximately at right angle to line *AB* from *C* and is moved sideways till it is sighted along the other pair of slits in line with slit's hairline. In such a position, line *CD* will be perpendicular to chain line *AB* as shown in Figure 2.11(b).

If perpendicular is sought to be drawn on chain line *AB* from a fixed location *D*, characterising some special ground feature, the cross staff is set at a point *C* on survey line *AB* such that *CD* is approximately perpendicular to *AB*. One line of sight formed by one pair of vertical slits is then aligned along line *AB*. The cross staff is then moved side ways along line *AB* keeping one pair of slit aligned along *AB* and the other line of sight (i.e. second pair of vertical slits) brings *D* to coincide with its hairlines. This locates the position of *C* on the line *AB* such that *CD* is perpendicular to *AB*.

Optical Square

It may be noted that at least two surveyor's are required to set normal offsets while using cross staff. This disadvantage can be overcome if optical square is used for this purpose as only single surveyor can perform this task.

The optical square, as shown in Figure 2.12(a), is constructed on the basis of simple law of optics that the angle between the first incident ray and the final reflected ray is twice that of the angle between a pair of plane mirrors. Hence, in optical square two mirrors M_1 and M_2 are mounted on a frame such that the included angle between them is 45^o. The incident ray from object *D* is reflected from mirror M_1 in line $M_1 M_2$ to mirror M_2 and finally along AM_2 by mirror M_2. Since included angle between mirrors M_1 and M_2 is 45^o, the angle between rays DM_1 and AM_2 will be $2 \times 45 = 90^o$.

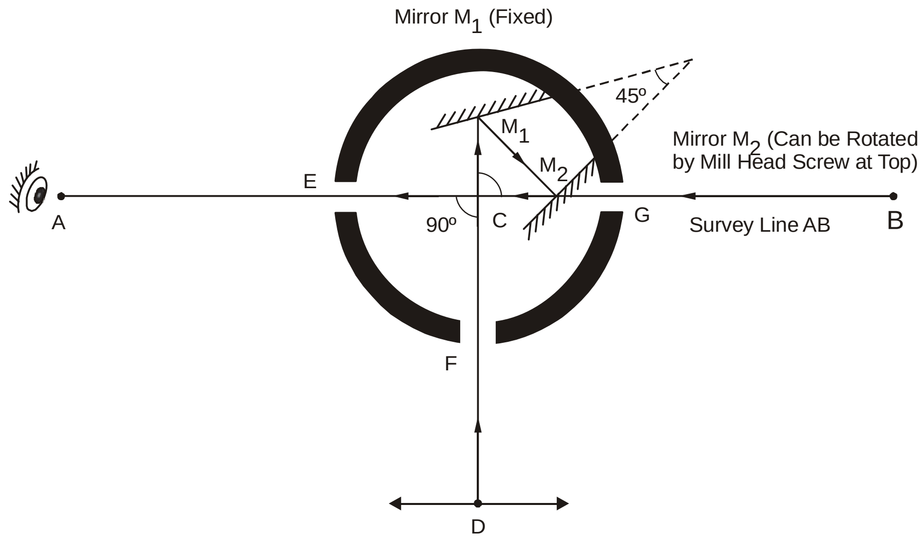


Figure 2.12(a) : Optical Square

In order to set the offset at point *C* on survey line *AB*, the optical square is held horizontally over the station *C* with the help of a plumb bob, and line of sight is aligned along line *AB* by observing ranging rod at *B* through opening at *G*. Next the ranging rod at *D* is observed through mirrors. The image of rod *D* is made to coincide with the image of rod *B* by moving ranging rods sideways (Figure 2.12(b)). When the two images coincide, then the line *CD* becomes perpendicular to line *AB*.

If location *D* is fixed, denoting some important ground fixture, e.g. an electrical pole and offset is required from it on survey line. The surveyor aligns the instrument along *AB* and then moves sideways along line *AB*, till, once again, the ranging rod at *B* and image of *D* coincide locating the position of *C* on ground such that *CD* is perpendicular to *AB*. The position of *C* is transferred on ground with the help of the plumb bob, hanging from the centre of instrument.

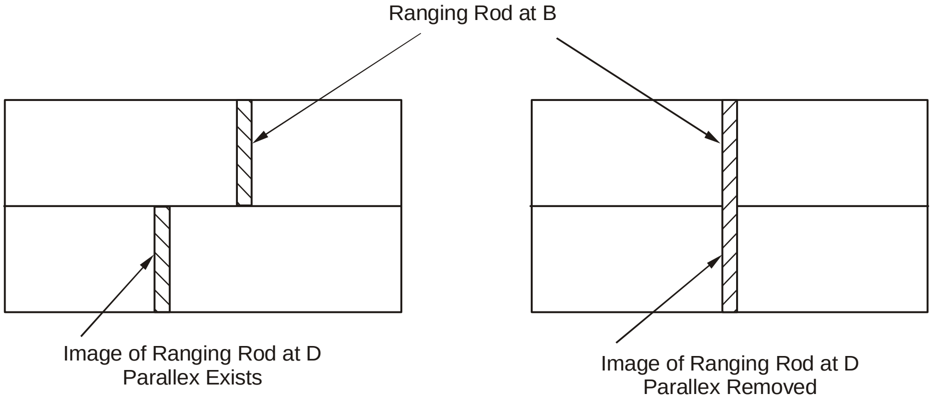


Figure 2.12(b) : Offsetting by Optical Square

The continuous use of optical square over a period of time and the rough handling of instruments may cause the included angle between the mirrors M_1 and M_2 to change from original 45°. This will induce errors in setting the offsets. If the angle becomes, say, 40°, the offset will be at 80° in place of 90° with the survey line, while if included angle becomes 50°, the offset angle becomes 100°. The instrument can be tested for accuracy and adjusted very easily by procedure described in following paragraph.

Observe the ranging rod at *A* with optical square stationed at some intermediate point *C* and aligned along line *AB* (Figure 2.12(c)). Mark the point *a* as perpendicular offset at *C*. Next, observe the ranging rod at *B*, while keeping instrument stationed at *C* and aligned along *AB*, and mark the offset point *b*. If the optical square is accurately adjusted, points *a* and *b* will be coinciding. If this is not so, the instrument requires adjustment. The distance *ab* is bisected at *D*. Then *CD* will be true offset. Keep the ranging rod at *D*. And rotate mirror M_2, till image of *A* and *B*, i.e. point *a* or *b* coincides with *D* as depicted in Figure 2.11(a). The process is repeated till both the observations, by optical square, give a single offset position *D* in place of *a* and *b*.

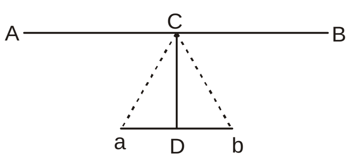


Figure 2.12(c) : Testing the Optical Square

SAQ 2

(a) Define Ranging and discuss its utility in chain surveying. If an intervening hillock is situated in survey line *AB*, making the station *B* invisible from station *A*, how will you range the survey line *AB*?

(b) Define "offset". Why offset setting and measuring is required? What are the different types of offsets that are required to be measured in chain surveying? Describe different methods of setting out offsets.

(c) Explain the principle, construction and use of an optical square. How can you test its accuracy and how will you adjust the instrument?

2.5 ERRORS AND OBSTACLES IN CHAINING

2.5.1 Errors in Chaining

Any field surveying including chain surveying is fraught with many errors including observational errors, affecting the accuracies of measurements and mapping. It is essential to identify, rectify and adjust these errors before the results of surveying can be used for any engineering applications. The errors can be broadly classified as

(a) Instrumental errors, and

(b) Observational errors.

Instrumental errors are caused by imperfections in instruments, wear and tear of instruments due to continuous use and their rough handling. Instruments are thus required to be tested for accuracy, adjusted and calibrated at frequent intervals to ensure that the results of surveying exercises are well within the prescribed limits of accuracy and tolerances.

Observational errors are introduced because of involvement of human factor in surveying process. It should be accepted that whenever a human element is involved, the process result will be influenced by the attitude, efficiency and perception of individual human being in a subjective manner. These can be avoided by proper training of surveyors, prescribing adequate and suitable precautions to be undertaken in each observational and measurement process, and specifying proper and detailed method statements for performing each operation of the process.

Both these types of errors, i.e. instrumental and observational, can be further classified into :

(a) gross errors,

(b) systematic errors, and

(c) accidental or random errors.

Gross Errors

Gross errors or mistakes are blunders that occur due to inexperience or carelessness on the part of the surveyor. In chain surveying, these could be due to

- displacement or loss of pegs or arrows, provided to identify and fix the location of various types of stations and other places of interest,

- reading the chain or tape in a wrong manner or using an instrument in an incorrect way, and
- wrong recoding of measurements in the record book, e.g. field book.

There is no room for gross errors or blunders in the surveying processes. If gross errors are detected, the entire surveying process and measurements are required to be repeated afresh, resulting in substantial loss of time and resources. Such errors can be avoided by proper training and testing of surveyors, adopting standard procedures, even to the minute details and carrying out the survey work with utmost care.

Systematic Errors

Systematic errors follow some specific pattern according to some mathematical or physical law. The error could be cumulative, i.e. occurring in the same direction and tends to accumulate affecting the accuracy of measurements to a great extent. In the context of chain surveying, these could be due to :

(a) erroneous length of chain or tape (+ve or –ve),

(b) erroneous ranging,

(c) links in chain not straight (local bends) due to rough handling or twisting of metallic tapes, etc.,

(d) non-horizontally of chain/tape over rough ground terrain,

(e) sag in chain or tape, when it is stretched across a depression in ground,

(f) variation in temperature and/or dampness, and

(g) variation in pull applied during measurement.

These errors could be identified and adjusted and can be modelled. Suitable corrections can be applied to the measurements for obtaining greater accuracy. Following are some of the important corrections applied to measurements using chain or tape :

Correction for Erroneous Length of Chain/Tape

The chain surveying depends only on linear measurement of distances. For traversing only the errors in distance measurements are of importance and significance. Measuring devise either chain or tape can either be longer or shorter than the designated length. The measured distance will be smaller than the actual if the length of chain is longer than the designated length. It will be larger than the actual if the chain is shorter than the designated length. The actual measured distance can be corrected by the following formula :

$$\text{True or Correct Distance} = \frac{L'}{L} \times \text{Measured Distance}$$

where, L' = Actual incorrect length of chain, and

L = Designated length of chain.

Correction for Temperature

Correction for temperature is applied if the temperature in the field is more than the temperature at which the tape/chain was standardised. This correction (C_t) is given by the following formula :

$$C_t = \alpha\,(T_m - T_0)\,L$$

where, α = Coefficient of thermal expansion,

T_m = Mean temperature in the field during measurement,

T_0 = Standard temperature for the tape, and

L = Measured distance.

Correction for Pull

Correction for pull or tension is applied when during measurement the applied pull is more than the pull at which the tape was standardised. As far as possible the pull applied during the field observation should be equal to the standardised pull so that the correction becomes zero. However, if different pull is necessary, this correction (C_P) is given by :

$$C_p = \frac{P - P_0}{AE} L$$

where, P = Pull applied during measurements (kg or N),

P_0 = Standard pull,

L = Measured length,

A = Cross-sectional area of the tape (cm^2 or mm^2), and

E = Young's modulus of elasticity (kg/cm^2 or N/mm^2).

Correction for Sag

Correction for sag is applied when the tape is stretched on supports between two points, it takes the form of a horizontal catenary. The horizontal distance will be less than the distance along the curve. The difference between horizontal distance and the measured length along catenary is called sag correction and it is always negative. This correction (C_s) is given by :

$$C_s = \frac{l\,(wl)^2}{24P^2}$$

where, l = The length of the tape (in m) suspended between the supports,

P = Pull applied in kg or N, and

w = Weight of the tape in kg or N per m run.

Random or Accidental Errors

Random or Accidental errors can occur due to lack of perfection of human eye and or human behaviour. Even the best and efficient surveyor can have fatigue effect after working for long duration in strenuous environment causing observational errors. The random errors cannot be eliminated entirely, whatever precautions are undertaken. These may, however, occur in either direction and hence, tend to compensate and, thus, are not serious in nature. These normally follow the law of chance and, thus, can be analysed with the help of probability theory. Using suitable probability distribution functions, these errors can then be adjusted, distributed among various measurements and accounted for. Each surveying method or process can be assigned a reliability factor (or risk factor) for accuracy depending on the analysis of probability behaviour.

Example 2.1

A 30 m chain was found to be 3 cm too long after chaining 1800 m. The same chain was observed to be 5 cm too long after chaining the total distance of 3600 m. Assuming that the chain was correct at the commencement of work, find the true length of the total distance chained.

Solution

(a) During chaining from 0 m to 1800 m :

Initial length of chain at commencement of work = 30.0 m

Final length of chain at end of chaining up to 1800 = 30.03 m

Average true length of chain during this exercise

$$= \frac{30.03 + 30.00}{2} = 30.015 \text{ m}$$

True distance of measured distance 1800 m = $\frac{L'}{L} \times 1800$

$$= \frac{30.015}{30.00} \times 1800 = 1800.90 \text{ m} \qquad \text{. . . (i)}$$

(b) During measurements from 1800 to 3600 m :

Initial length of chain = 30.03 m

Final length of chain = 30.05 m

Average true length of chain during this measurement

$$= \frac{30.03 + 30.05}{2} = 30.04 \text{ m}$$

Measured distance = 3600 – 1800 = 1800 m

True measured distance $= \frac{30.04}{30.00} \times 1800 = 1802.40$ m . . . (ii)

Total true distance chained = 1800.90 + 1802.40 = 3603.30 m.

Example 2.2

A chain was calibrated to be of exact length 30.00 m at 20°C. When this chain was used for chain surveying in field, the temperature was recorded to be 45°C. If the coefficient of linear expansion of steel used in chain is 8×10^{-6} per °C, find the true total distance chained if measured distance on ground is 6000 m.

Solution

True length of chain at 20°C = 30.00 m

True length of chain at 45°C would be $L = L_0 (1 + \alpha\, t)$

$$= 30.00 [1 + (8 \times 10^{-6}) \times (45 - 20)]$$

$$= 30.00 \times (1 + 0.0002) = 30.06 \text{ m}$$

True measure distance $\frac{30.06}{30.00} \times 6000 = 6012$ m.

Example 2.3

A survey line AB was measured by a chain of 30 m length and was found to be 2340 m. The same line AB when measured by a 20 m chain, the length was recorded as 2350 m. While calibrating the 30 m chain was found to be 2 cm too short. What was the error in 20 m chain?

Solution

Actual length of 30 m chain = 30.0 – 0.02 = 29.98 m

True length of $AB = \frac{L'}{L} \times \text{Measured Length}$

$$= \frac{29.98}{30.0} \times 2340$$

$$= 2338.44 \text{ m}$$

When AB was measured by 20 m chain.

True length $= \frac{L'}{L} \times \text{Measured Length}$

$$2338.44 = \frac{L'}{20} \times 2350$$

$$L' = \frac{2338.44 \times 20}{2350} = 19.902 \text{ m}$$

$$\approx 19.90 \text{ m}$$

Hence, the incorrect actual length of 20 m chain is 19.90 m, i.e. 10 cm too short.

Example 2.4

A sloping ground with a gradient of 1 in 10 was surveyed with a 30 m chain. The chain was checked at commencement of work, at mid station C of survey line AB and at the end of survey and was found to be 2 cm, 6 cm and 10 cm too long respectively. If the measured length of survey line AB = 6000 m, find the true length of AB.

Solution

Actual length of 30 m chain at A = 30.02 m

Actual length of 30 m chain at C = 30.06 m

Average length of chain during measurement from A to C

$$= \frac{30.02 + 30.06}{2} = 30.04 \text{ m}$$

Actual length of AC measured along slope

$$= \frac{30.04}{30.0} \times 3000 = 3004 \text{ m}$$

Actual chain length at C = 30.06 m

Actual chain length at B = 30.10 m

Average length of chain during measurement from C to B

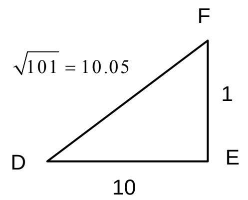
$$= \frac{30.06 + 30.10}{2} = 30.08 \text{ m}$$

Actual length of *CB* measured along slope

$$= \frac{30.08}{30.0} \times 3000 = 3008 \text{ m}$$

Actual length of line *AB* along slope = 3004 + 3008 = 6012 m

A slope of ground is 1 in 10, i.e. 1 m vertical in 10 m horizontal, e.g. *EF* = 1 m and *DE* = 10 m.



Then *DF* along slope = $\sqrt{10^2 + 1^2} = \sqrt{101}$

$= 10.0499$

$\simeq 10.05$

Thus, when sloping length is 10.05 m, horizontal length is 10.00 m. Hence, true horizontal distance between *AB* would be

$$= \frac{10.00}{10.05} \times 6012 \text{ m} = 5985.07 \text{ m}.$$

Example 2.5

A survey map is required to be drawn to a scale of 1/10000. A 30 m chain was used which was found to be accurate at commencement of work while 20 cm too long at the closure. The area of plot surveyed was found to be 80 cm^2 on map. Calculate the actual area of plot in hectares.

Solution

Length of chain at commencement = 30.00 m

Length of chain at closure = 30.20 m

Length of chain during survey $= \frac{30.00 + 30.20}{2} = 30.10 \text{ m}$

Area of plot surveyed as measured on map = 80 cm^2

Area of plot surveyed as measured on ground = $80 \times 10^4 \times 10^4$ cm^2

$= 80 \times 10^4$ m^2 = 80 ha.

True plot area on ground $= \left(\frac{30.10}{30.00}\right)^2 \times 80 = 80.5344 \text{ ha.}$

Example 2.6

A 20 m steel tape was standardised on flat ground, at a temperature of 20^{o}C and at a pull of 15 kg. The tape was used in catenary at a temperature of 30^{o}C and the pull applied was 10 kg. The cross-sectional area of the tape is 0.02 cm^2, and its total weight is 400 gm. The Young's modulus of elasticity (E) and coefficient of thermal expansion (α) is 2.1×10^6 kg/cm^2 and 11×10^{-6} per ^{o}C respectively. Find the correct horizontal distance.

Solution

Correction for temperature $C_t = \alpha \, (T_m - T_0) \, L$

$$= 11 \times 10^{-6} \, (30 - 20) \times 20$$

$$= 0.00220 \text{ m}$$

Correction for pull $C_p = \frac{P - P_0}{AE} \, L$

$$= \frac{(10 - 15) \times 20}{0.02 \times 2.1 \times 10^6}$$

$$= - \, 0.00238 \text{ m}$$

Correction for sag $C_s = \frac{l \, (wl)^2}{24 \, p^2}$

$$= \frac{20 \, (0.4)^2}{24 \, (10)^2} = 0.00133$$

Because correction for sag is always negative so it will be subtracted. Therefore, total correction per tape length would be :

0.00220 – 0.00238 – 0.00133 = – 0.00151 m

Correct horizontal distance = 20 – 0.00151 = 19.99849 m.

2.5.2 Errors in Traversing

In a closed traverse, errors of traversing may creep in due to any or all of the errors described above. The closed traverse is obtained by a circuiting network of survey lines (Figure 2.5(a)) running between main stations located at salient positions all along the periphery of the plot to be surveyed. If all the lengths of the sides of the polygon are measured accurately, the traverse polygon should close, e.g. the starting station and end station should coincide. However, because of errors introduced in the measurements, there will be difference between the computed value and geometric values and the originating station will not coincide with end station. This is called as closing error. The closing error can be distributed evenly or according to the magnitude of each length.

Since angles are also measured in most of the traverse surveying like chain and compass survey, a better way of adjusting the closing error is by adjusting the interior angles of traverse polygon. This aspect is described in Unit 3 in detail.

2.5.3 Obstacles in Chain Surveying

Due to various specific characteristics of ground features, some obstacles are encountered during chain surveying which require special consideration. These could be :

(a) obstacles in ranging,

(b) obstacles in chaining (measuring horizontal distance), and

(c) obstacles in recording details.

Obstacles in Ranging

Topography of land can create difficulties in ranging, i.e. ground undulations hindering clear visibility between main stations, e.g. existence of a hillock in the line of sight. These problems of obstacles in ranging can be solved by establishing mutually visible intermediate stations by reciprocal ranging as explained in Section 2.4.2.

If the two ends of a survey line A and B are not visible from intermediate point on it, then reciprocal ranging cannot solve the problem. In such cases, a random line AB_1 is drawn in any convenient direction but as close to point B as possible (Figure 2.13). The point B_1 is chosen such that it is visible from B and BB_1 is perpendicular to the random line. Measure BB_1, select points C_1 and D_1 on the random line and erect perpendicular C_1C and D_1D on it. The value of C_1C and D_1D can be calculated as

$$C_1C = \left(\frac{AC_1}{AB_1}\right) \times BB_1 \text{ and } D_1D = \left(\frac{AD_1}{AB_1}\right) \times BB_1$$

After getting points C and D, join CD and prolong it.

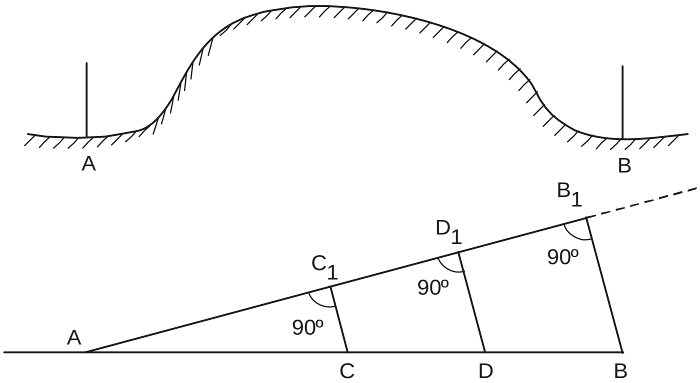


Figure 2.13 : Ranging when Ends not Inter-visible

Obstacles in Chaining

Horizontality of distance measurements can be maintained easily on a comparatively level ground. Ground undulations tend to introduce errors in measurements as the natural tendency of chain and/or tape will be to follow ground level. The distances so measured will be larger than the actual horizontal distances between two stations. Larger the ground slope, larger will be the error introduced. To overcome this obstruction, chain is stretched horizontally between two stations, as tightly as possible as shown in Figure 2.14(a). The stretched chain will form a catenary. By measuring the sag at mid point, horizontal distance AB can be mathematically related to length of chain S and the sag δ.

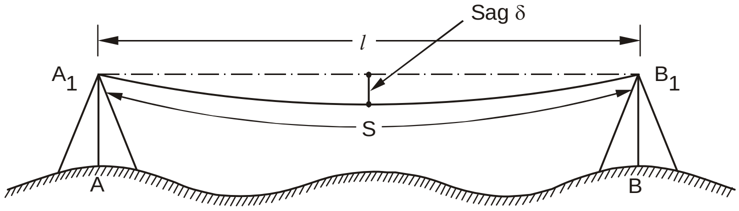


Figure 2.14(a) : Distance Measurement on Undulating Ground

A better method will be to divide the entire chain into several smaller segments, particularly when the ground slope is larger, the sags between the segments will be negligibly small and the segment of the chain/tape will require much smaller physical effort in stretching (Figure 2.14(b)). Hence, the total length L between A (A_0) and B (A_n) will be $L = \sum_{i=1}^{n} \delta l_i$

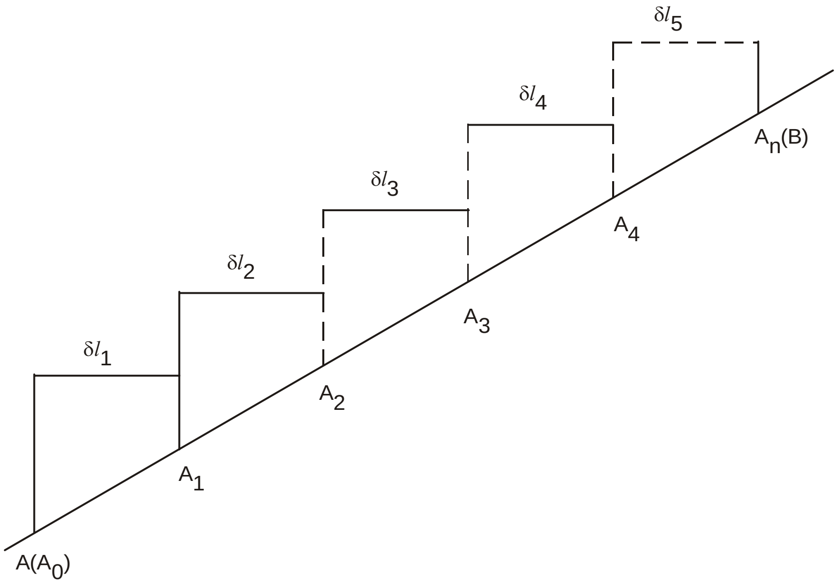


Figure 2.14(b) : Ground with Large Slope

Obstacles in Recording Details

When the outline of the object representing important ground feature changes frequently, it is difficult to measure and plot the details of the object. If the object is straight, it is only necessary to measure offset distances at two ends and draw a straight line between the ends. If however the object is having irregular boundaries as shown in Figures 2.15(a) and (b), it is necessary to set offset at much less intervals, particularly at points where the object boundary changes direction.

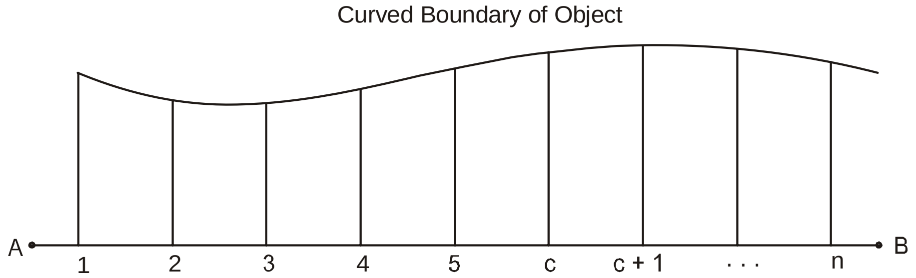


Figure 2.15(a) : Object with Curved Boundary

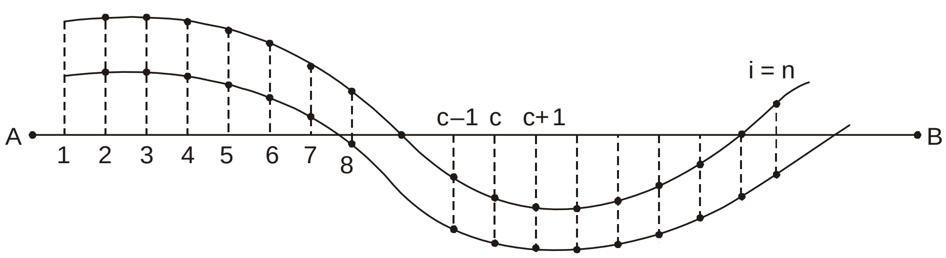


Figure 2.15(b) : Curved Road/Railways or Nallah

SAQ 3

(a) What can be the errors in chaining? Classify them and give example of each one of them. If the measuring chain/tape is found to be of incorrect length, how will you obtain the actual distance measured with this chain/tape?

(b) What are the different tape corrections and how are they applied?

SAQ 4

(a) The true length of a line is known to be 500 m. The line was again measured with a 20 m tape and found to be 502 m. What is the correct length of the 20 m tape?

(b) A line was measured with a steel tape which was exactly 30 m at 25^{o}C at a pull of 10 kg, the measured length being 1700.00 m. The temperature during measurement was 34^{o}C and the pull applied was 18 kg. Compute the length of the line, if the cross-sectional area of the tape is 0.025 cm^2. The Young's modulus of elasticity (E) and coefficient of thermal expansion (α) is 2.1×10^6 kg/cm^2 and 3.5×10^{-6} per ^{o}C respectively.

(c) A 30 m steel tape was standardised at a temperature of 20^{o}C and under a pull of 5 kg. The tape was used in catenary at a temperature of 25^{o}C and under a pull of P kg. The cross-sectional area of the tape is 0.02 cm^2, its weight per unit length is 22 g/m, the Young's modulus of elasticity (E) and coefficient of thermal expansion (α) is 2.0×10^6 kg/cm^2 and 11.0×10^{-6} per ^{o}C respectively. Find the correct horizontal distance, if P is equal to (i) 5 kg, and (ii) 11 kg.

2.6 RECORDING OF MEASUREMENTS

The measurements and other data collected during the process of chain surveying, or for that matter, for any exercise of surveying, it is necessary that these are properly and adequately recorded in a systematic way. The records should be easily understood and retrieved by concerned engineers at any time of future reference. There should be provisions to draw explanatory sketches on the record sheets to supplement the information to be provided by such data and measurements.

In general, standard field books are used for recording the data and measurements. The field books are made with good quality plain paper properly and securely bound. It is about 200 mm × 120 mm or 200 mm × 150 mm in size as shown in Figure 2.16 which also exhibits the sample of records. The chain line is represented by a ruled double line at the centre of each page. Distances along the chain lines are recorded between two lines preferably to scale. There shall be sufficient space beyond these lines to record offset distances and other distances and also to draw explanatory sketches.

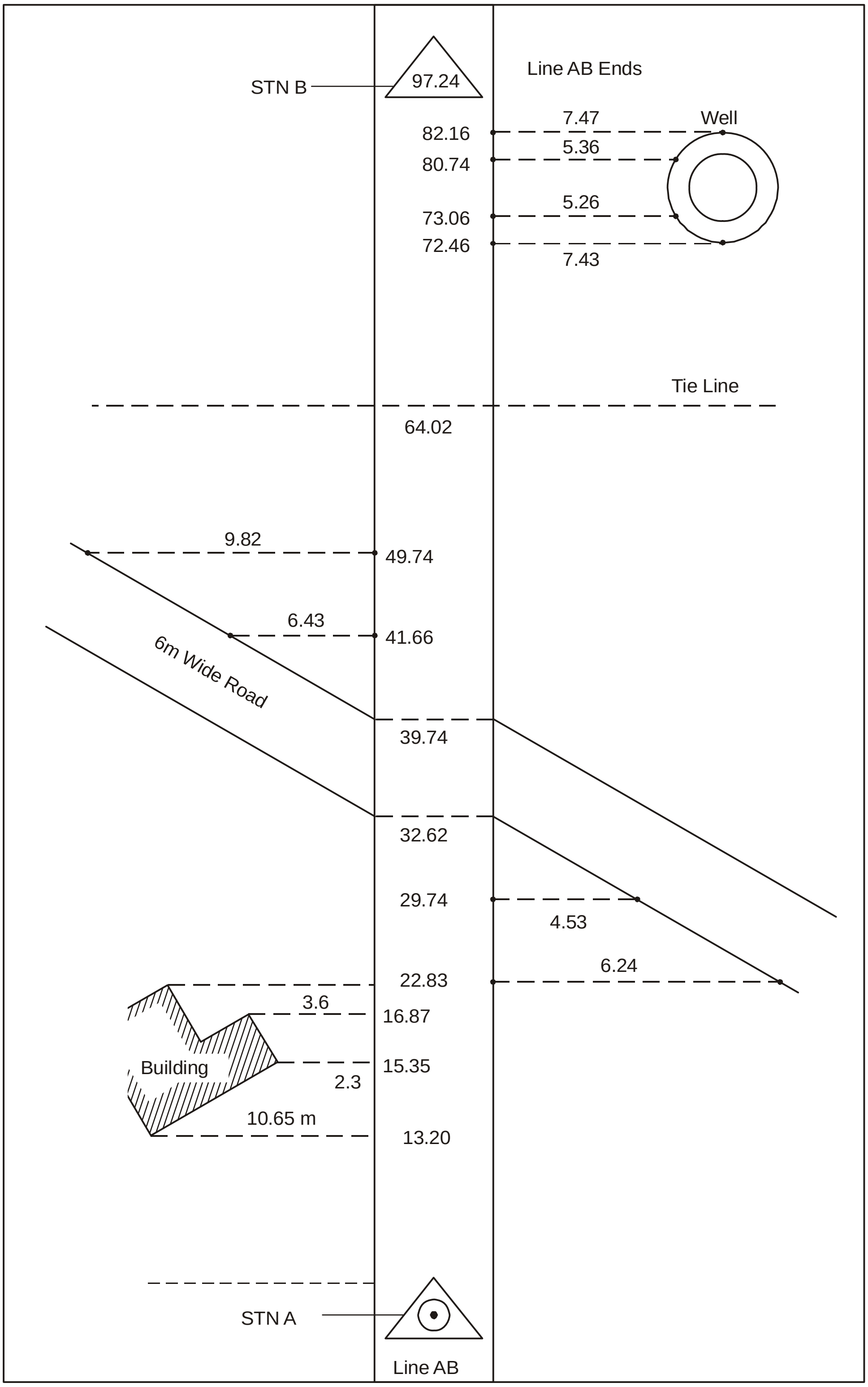


Figure 2.16 : Typical Record on a Field Book Page

In general, following procedure can be adopted.

(a) Chainage record, i.e. distance along chain line starts from the bottom of the page and continued in the upward direction.

(b) Survey stations are recorded as a triangle at the end and beginning of a chain line. Their chainage is recorded inside the triangle.

(c) The chainage of points at which any offset is taken is written along the centre of ruled line as the recording progresses from bottom towards the top of the page.

(d) The perpendicular offsets (also oblique offset, if any) are noted on the side nearer to the object which is approximately sketched on the space beyond centre line. The objects are not drawn to scale but drawn proportionately in free hand. The sketch shall not cross the space between central lines.

(e) The record of a chain line on a page should end with end station. The record of new chain line shall start on a fresh page.

2.7 SUMMARY

In this unit, you have studied the basics of chain surveying. In chain surveying, different equipment and instruments are used for measuring distances along survey lines and thereform important ground features by setting out offsets. The offsets can be set at desired points on survey lines or from ground features on survey line. Various technical terms commonly used in chain surveying are also defined and explained.

Procedures of chain surveying including fixing of survey stations, ranging of survey lines and setting the offsets have been discussed in detail. Commonly experienced difficulties and obstructions in surveying exercise are explained along with possible errors in measurements of distances and their adjustments.

The procedure for recording measurements in field books has been explained so that the records can be easily understood, retrieved and referred to at any future date.

2.8 ANSWERS TO SAQs

SAQ 4

(a) 19.92 m

(b) 1700.13 m

(c) (i) 29.97987 m

(ii) 30.00166 m