# Level Set-Out

## 8.1 Introduction

Often during the construction stage of a project a surveyor is required to establish points at a particular height. The RLs of these points will have been predetermined by calculations completed by either a surveyor or an engineer.

These heights could be required for any number of reasons, including the formation heights of roads, the level of the floor of buildings, levels for landscaping or trenches for water or sewerage pipes. Regardless of the reason for the height, it will be precalculated. This height is normally referred to as the design height.

## 8.2 Determining the Location of the Design Height

To determine the exact location of the required design height, a stake approximately 1.0m in length is placed in the ground. This then leaves three possibilities:

1. the required design height is above the top of the stake,

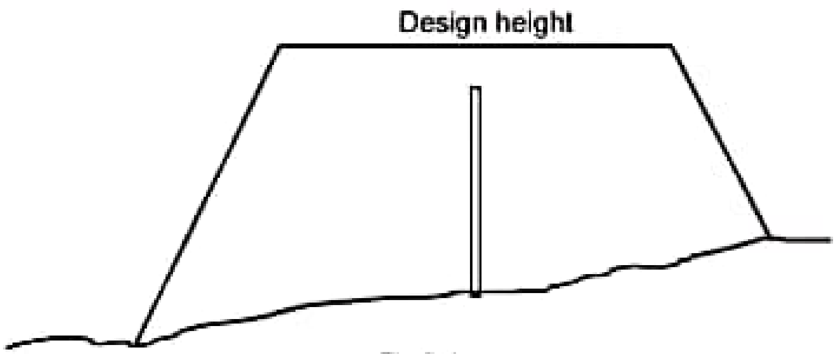


Fig 8.1

2. the required design height falls somewhere on the stake, or

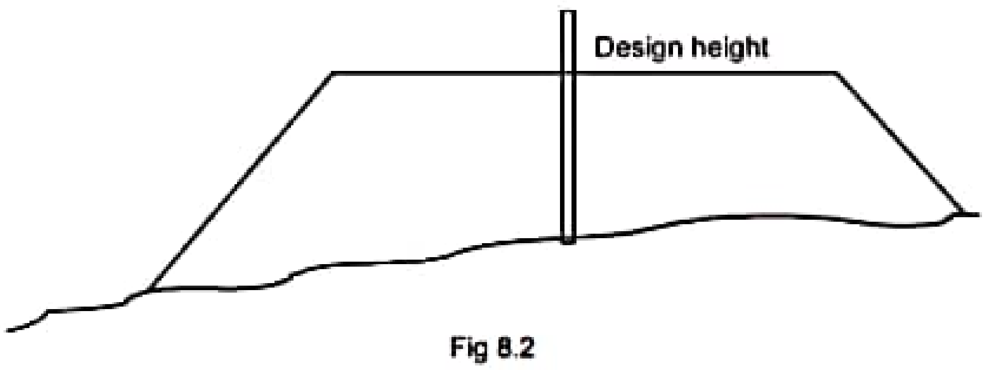


Fig 8.2

3. the required design height is below the bottom of the stake.

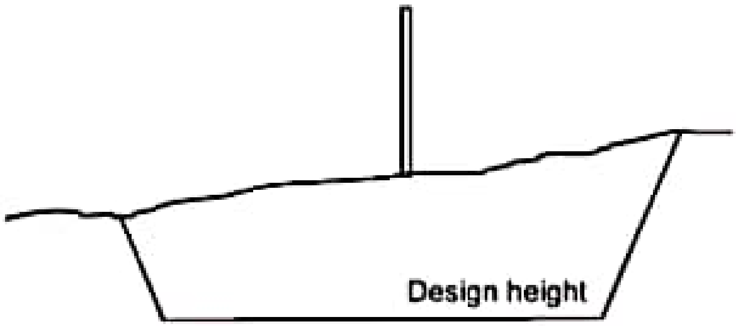


Fig 8.3

If the required design height falls on the stake, then it is marked at that height on the stake.

If the required design height does not fall on the stake, then a reference height needs to be marked on the stake that is a set distance above or below the required design height.

This reference mark must be an even half metre interval from the design height, ie 0.5m, 1.0m, 1.5m, 2.0m, 2.5m, 3.0m etc.

This distance can be calculated in one of two ways, the moving staff method and the static staff method.

## Moving Staff Method

The reference height above or below the design height can be determined using the Moving Staff Method:

1. Calculate the height of collimation of the instrument.
2. Determine the difference in height between the design height and the height of collimation.
3. Place the staff against the side of the stake and move it up or down until the sum or the difference of the staff reading and the difference in height between the design height and the height of collimation totals an even half metre interval.
4. Mark the stake at the bottom of the staff. This is the reference mark that is an even half metre interval from the design height.

This can best be shown using three examples:

*Example 1* - The design height is above the top of the stake.

The design height is shown as 32.580m
The height of collimation is calculated at 30.713m

# Set-Out Surveys

## 23.1 Stages In Setting Out

Any surveying set-out work associated with general building construction or engineering projects such as dams, bridges, roads, railways, stormwater and sewerage lines, natural gas pipelines, power transmission lines, etc, requires a certain order of stages. This will vary, depending on particular requirements for the job, and there will inevitably be some overlap between stages, but a broad classification is as follows:

- reconnaissance
- approximate location of site/route
- establishment of suitable control (both horizontal and vertical)
- Investigation survey to collect data for final design
- complete design of project and preparation of working drawings
- on-site set-out for construction from the design drawings
- check of the work as executed after construction has taken place
- Real Property surveys to connect the engineering work with the cadastral system; that is, easements for access, resumptions, etc.

Some of these stages are dealt with below.

## Reconnaissance and Trial Route/Site Location

The first stage on any engineering project is to collect all the existing survey information, plans, aerial photographs, etc, for the region involved. Most preliminary work is presently carried out using information taken from aerial photographs. If suitable up-to-date aerial photos are not available, then it may well prove worthwhile to undertake photography specifically for the project.

Using this collected material, particularly the aerial photographs, trial locations are selected. In making these selections the surveying point of view is essentially a topographical one; that is, arranging the project in its best relationship to existing surface features. Things to be considered would include surface slopes, drainage patterns, major topographical features (rivers, cliffs, ravines, etc), existing property boundaries and land ownership, and other development (dwellings, farm paddocks, dams, access tracks, etc).

Other points of view must also be considered. These would include those of the geologist (soil and rock types, stability of surface and sub-surface formations) and the environmentalist (the location that would cause least damage).

Using the aerial photographs in stereo pairs, GPS or satellite imagery, it is possible to obtain relatively accurate information (both horizontally and vertically) by the methods of photogrammetry. Alternative locations can be compared, and the associated earthworks volumes for cutting or filling and the approximate gradients calculated.

These calculations can be done quickly using plotting machines and associated computers. The most desirable location can usually be determined in the office with very little actual field surveying being required. On most projects the majority of the location work can be done quickly and confidently in this way, leaving a few critical problem areas for closer examination on site.

## Establishment of Control

In topographical surveying the main reason for a control survey is to prevent errors from accumulating. It is the principle of 'working from the whole to the part'. In engineering work this rule still applies, but further reasons can be given for establishing an accurate control.

1. Many different surveys (involving different survey personnel) are usually carried out in conjunction with an engineering project. Unnecessary duplication and problems with discrepancies between surveys will be greatly reduced if all are based on a common, accurate control survey.

2. The same control survey that was used to control the investigation surveys on which the design is based can be used to control the setting out surveys during construction. This will ensure that the structure is placed at the correct designed location.

The exact nature of the control will vary depending on the purposes for which it is required. This is governed mainly by the nature and extent of the engineering project.

The general principles to be adopted are:

1. Control marks should cover the entire area of the project, be intervisible to each other, and be placed close enough together so that later survey work can be carried out anywhere on the project to a sufficient accuracy.

2. Measurements for the control survey should be made to a uniformly high standard of accuracy.

3. Control marks must be as stable as possible, preferably anchored firmly to bedrock, and located where the risk of damage (for example, during construction) is minimised. The erection of a framework around the mark is often done for 'protection' (see chapter 2).

3. To provide a framework of marks that can be used to set line and level for construction pegs and stakes at a later stage.

The road survey is usually carried out with total station or theodolite and EDM. The terminal points of the road are located from whatever control marks are nearby, and the intervals between these terminal points are marked on line and at the appropriate interval. The current accepted practice with regard to centre-line intervals is as follows:

**Rural Roads**

**On Straights**

| Terrain | Interval |
|---|---|
| Flat | 20 m |
| Undulating | 20 m |
| Mountains | 10 m |

**On Curves**

| Radius | Interval |
|---|---|
| Less than 150 m | 10 m |
| 150 m to 1 000 m | 20 m |
| Over 1 000 m | 20 m |

**Urban Roads**

| | |
|---|---|
| On Straights | 20 m Interval |
| On Curves | 20 m Interval |

It is customary for the pegged intervals to be identified in terms of the measured distance from the accepted point of origin. This is called *running chainage* and it may start at chainage Zero or, if the project is an extension of an existing road, then the chainage of the point at which the extension starts will generally be adopted (see Figure 23.2):

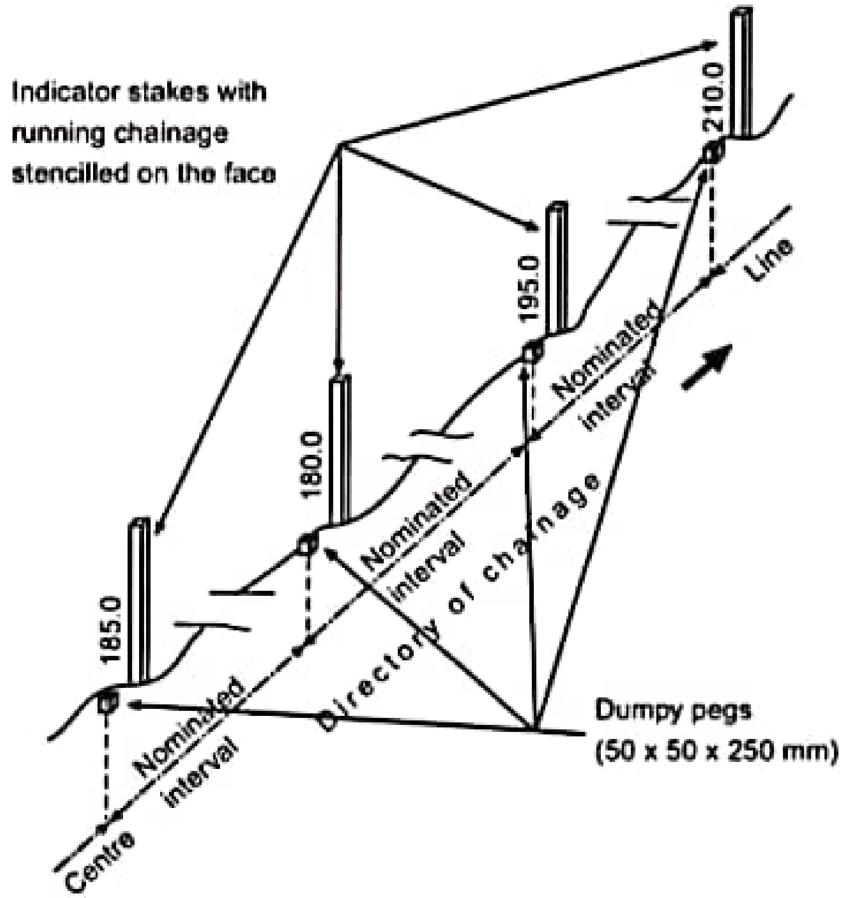


Fig 23.2

*Example*

To set out the centre-line marking of Leicester Way for new roads within the subdivision (see Figure 23.3):

*Step 1* Calculate radiations to terminal points as follows:

(a) Station 108 to Ch. 00 in Coonawarra Drive
(b) Station 108 to Ch. 20.805 (TP) Leicester Way
(c) Station 107A to Ch. 86.1 (CTP) Leicester Way
(d) Station 107A to Ch. 70.965 intersection of new road
(e) Station 107 to Ch. 115.975 (TP) Leicester Way
(f) Station 107 to Ch. 129.64 Leicester Way; that is, intersection with Merino Court.

Radiation - that is, the setting out of distance and direction of various points from a control station - is based on the control figure coordinates and the road centre-line design coordinates. From these rectangular values, bearings and distances are calculated for the set-out.

For example, to set out the 00 chainage at ⑦ from station 108 in Coonawarra Drive the following calculations are made.

# Setting Out During Construction

## 25.1 Roads – Set-out During Construction Phase

Surveys in this section are for the purpose of controlling the road construction and the location of drainage structures. The first requirement is for the controlling of excavation and filling operations.

Some construction supervisors prefer to maintain a survey team on the site during the period that earth-moving machinery is in operation. In this way continual supervision of line and level can be maintained, using either the centre-line pegs or recovery pegs for datum purposes. This would almost certainly be the method used on large projects.

For smaller construction jobs it is often possible to set out a series of construction stakes with level marks on them, and the plant operators can proceed with the earth movement, maintaining the correct level by visual checks on the stakes. In this way, a survey team may only need to visit the site at the start of construction and then later when earthworks are completed.

The marking pattern adopted will need to be relatively simple and easy to interpret. Offset marks should be placed at the nearest half metre interval, and level marks should, as far as possible, define the finished level. This will avoid misinterpretation by the plant operators. A number of commercial laser devices are available for the controlling of line and level during excavation.

A further problem, especially in highway construction, is the control of road batters. In many projects this can be achieved by using fixed profile boards set at the slope of the batter.

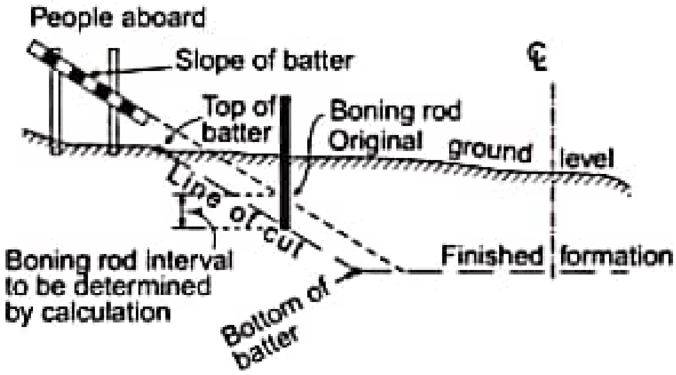


Fig 25.1 Batter profiles in cut

One advantage of this method is the simplicity of checking the slope of the constructed batter.

The batter profile can be set at the required slope and placed in position clear of the construction area, but near enough to the top (or toe) of the slope to be able to be related to the level of the top (or toe). Where possible the boning rod interval should be kept to an even half metre.

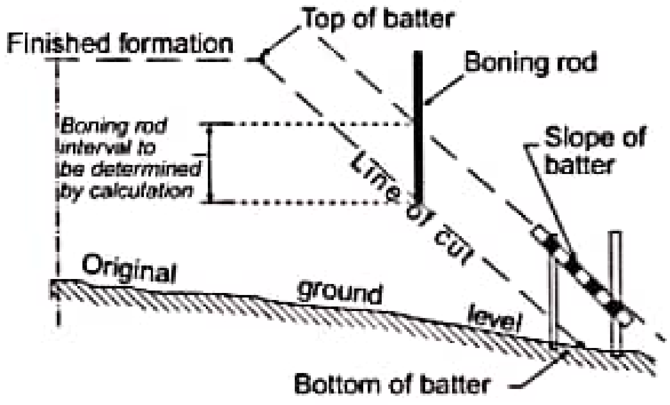


Fig 25.2 Batter profile in fill

Profiles and boning rods can be used in a similar manner for controlling the finished excavation or formation level, provided the depth of cut or fill is not too great.

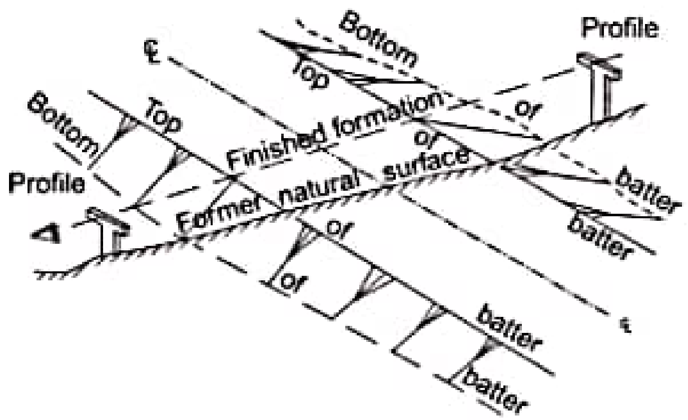


Fig 25.3 Providing depth of fill

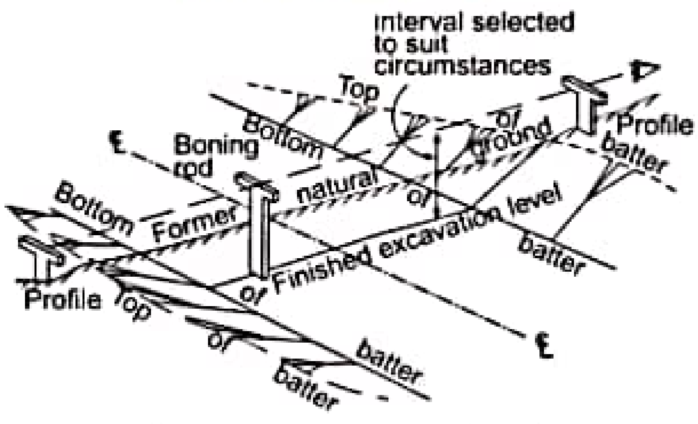


Fig 25.4 Providing depth with cut

In some cases, however, where very deep cuttings or embankments occur during highway construction in rugged terrain, it will be necessary to locate the top of the cut or the toe of the batter before construction commences. Owing to the depth of the cutting or the height of the embankment, the batter must be correctly constructed as the job proceeds, since no trimming will be possible at a later stage

## 25.2 Set-out for Kerb and Gutter

The control of line and level for kerb-laying is often done with level pegs placed 0.50 m behind the face of the proposed kerb and driven into the ground until the top of the peg is at the reduced level of the top of the kerb. If this is not possible, the correct level can be chalked on the peg.

Pegs should not be more than 15m apart on straights or horizontal curves, and not more than 8m apart on vertical curves. If the laying is to be carried out with a 'kerb and gutter' machine, some provision for the offset string line should be made in setting out.

Kerb 'returns' at the intersection of streets need special attention; the intervals between pegs should be reduced so that the correct profile of the kerb return is constructed and no false low points occur. Visual checks of the formwork before pouring is one method of avoiding this problem.

## 25.3 Sewerage and Drainage Lines

In sewerage reticulation the design of grades for pipes is critical, as too high a grade will result in liquid waste running down the pipe and leaving suspended solids behind. If the sewer grade is too low, the liquid waste will not carry the solids with it. Both examples will result in solids eventually blocking the sewer line. Most domestic sewer connections are laid at a grade of approximately 1:100.

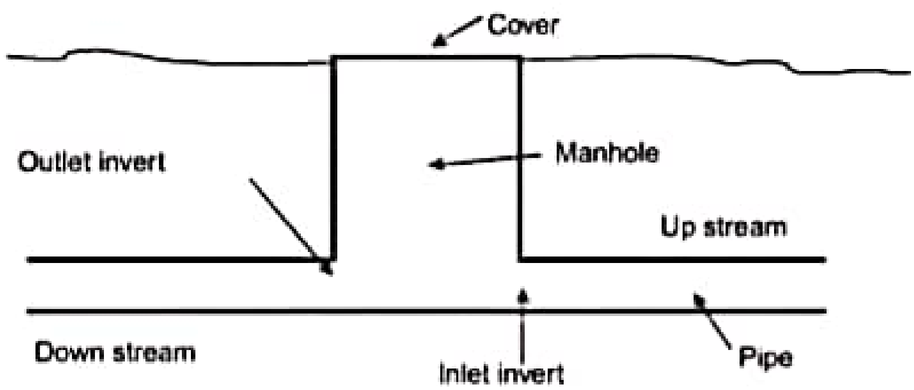


Fig 25.5

In any description of pipe reticulation the term *invert level* is used, be it a surveyor setting out, or the actual construction of the pipe network. The invert is the RL of the inside diameter of a pipe at its lowest point. Naturally for any pipe length laid at a grade, there will be an inlet invert and an outlet invert level. The invert level is sometimes termed the flow line.

In any engineering project which includes drainage or sewerage reticulation, invert levels of the Water Corporation drainage and sewerage services must be ascertained so that building foundations and drainage will be facilitated by having a fall to the Water Corporation outlet connections.

In setting out for construction of sewerage or drainage lines the same principles apply as in road construction; that is, centre-line pegs are used to provide a regular profile along the length of the project, and after design is completed the pegs are used to provide offset marking to control line and level for the construction of the pipeline.

The intervals adopted for sewerage and drainage lines are seldom the same as in road construction. As a general rule, pegs need only be placed at angle points in the line or at the location of structures such as manholes or pits.

Where long lengths of straight pipeline occur, some intermediate marks will be required at the discretion of the supervising surveyor. The pegs are generally driven flush with the ground together with an indicator or a stake for easy location. The distance between these pegs should be less than 25m, making easy sighting distances.

For construction purposes the centre-line pegs should be offset by recovery marks well clear of the excavation area. During excavation, checks on line and level can be made either directly, using a level and staff, or by using boning rods from profile boards.

Care should be exercised in determining the level of 'the bottom of the trench' from the given design invert level. Allowance must be made for the thickness of the pipe collar and for the pipe to be laid in sand bedding.

A taut string line, or a laser, can be used as a substitute for the timber cross-member of the profile board. The profile string must be at right angles to the centre-line and vertically above the point to which it refers.

When excavation is completed, pipe-laying may be controlled by boning rods from profile boards if these are available, or by the use of level and staff from recovery pegs.

There are a number of choices of method that could be adopted. The technique chosen will depend to a large extent on the pipe-laying method in use, the machinery available and the needs of the pipe-laying foreman. The figures below show one of the techniques available using profiles and boning rods to control the depth of the trench.

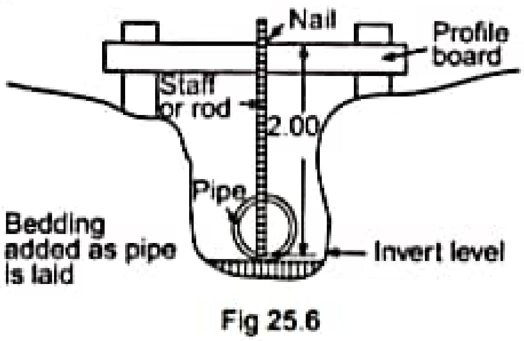


Fig 25.6

The profile uprights are first hammered firmly into the ground. Levels are taken from a nearby TBM and RLs are calculated to the tops of the uprights. With the proposed depth of the excavation known, a suitable boning rod is chosen. These vary in height (even metre or half-metre lengths are common for rods between 1m and 4m in length). Alternatively a staff may be used. The difference between the level at which the top edge of the cross-member of the profile is to be set and the top of each upright is calculated. As pipes are laid, bedding is added so that the bottom edge of the boning rod sets the pipe invert level.

## Setting of Profiles

This is normally carried out by the builder but is included for information.

Profiles are erected at each corner of the building, and set at floor level. String lines are run between the profiles, as shown in the figures below.

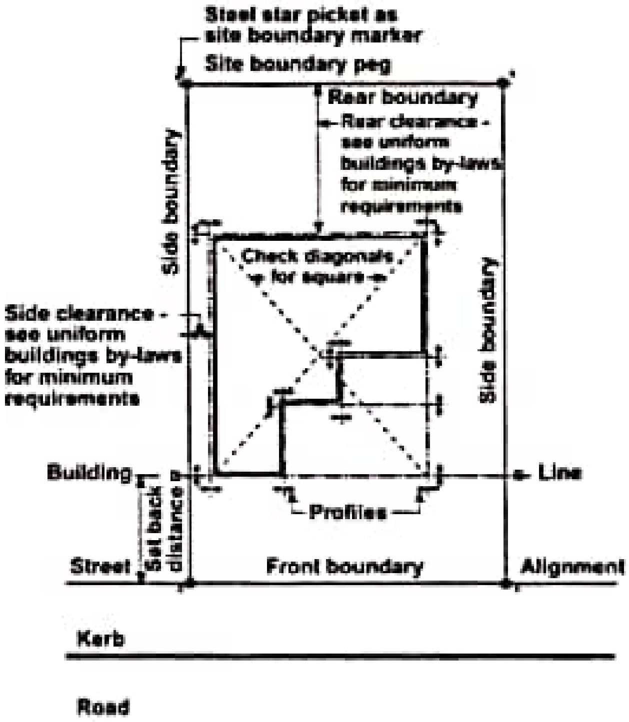


Fig 25.10

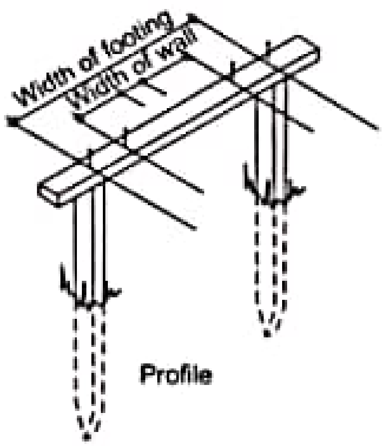


Fig 25.11

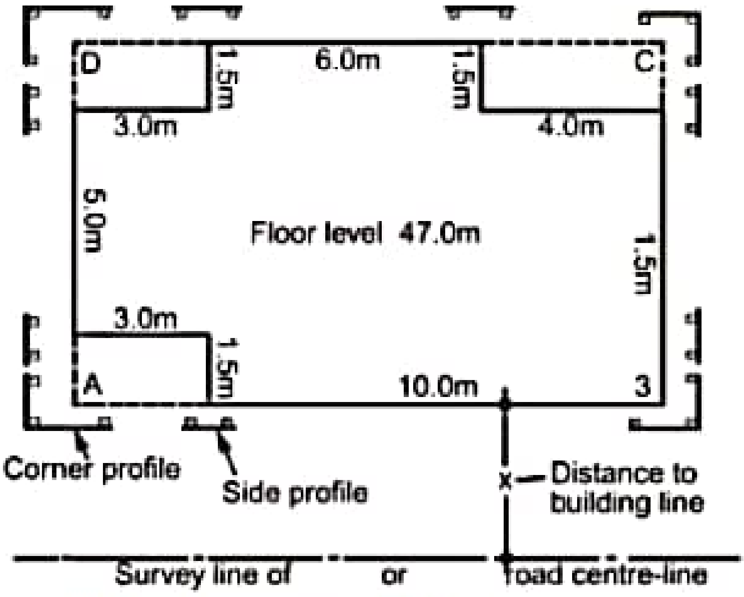


Fig 25.12 Profile boards for a simple building

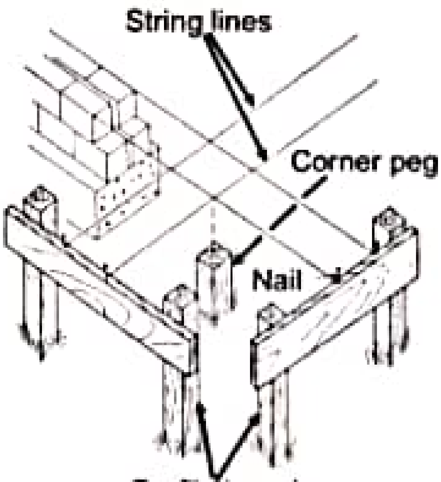


Fig 25.13 String lines

*Example of a Simple Building Set-out*

Given:

- The 4 corners of the lot have been accurately pegged previously.
- The floor level is 1100mm above the sewerage manhole datum.
- Corner C is to be set back 9m from street frontage (R) on a line DCR. (This will enable the distance ZX to be accurately calculated.)

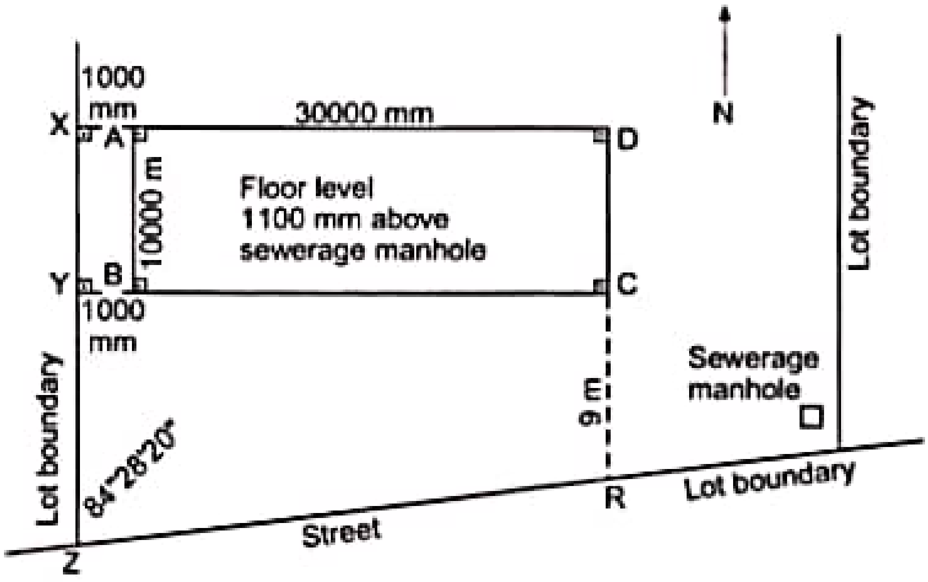


Fig 25.14

## A Setting Out Method

1. Position pegs Z, Y and X in a straight line separated by the calculated design lengths.

2. Centre and level the theodolite over peg Z and set out the horizontal angle 84° 28' 20".

3. Position peg R at the calculated length from Z.

4. Centre and level the theodolite over peg X, sight to Z, and set out the horizontal angle of 90° to position pegs A and D.

5. (a) Centre and level the theodolite over peg Y and set out the horizontal angle of 90° to position peg B and C. Check measure DC.

   OR

   (b) Use the calculated diagonals and known sides to position pegs B and C and check them.

6. To check the positioning of the building on the lot, measure the length CR; it should be equal to 9m, with DCR a straight line.

7. Position the profile boards and string lines.

8. Use the height of collimation method to define the floor level.