differential floors becomes possible. The garage and the miscellaneous utilities can be accommodated in the basement.

10. The site should be connected with good communication lines such as good system of roads and railways.
11. The site should possess good soil at reasonable depths so that the foundation cost is reduced.
12. The selected site should be adequate to accommodate all the essential accessories required in the building.
13. Residential buildings should not be located near workshops and factories since such locations are subjected to continuous noise.
14. A site along seashore is good from the entertainment point of view but sea breeze being damp affects health. Metallic fittings are liable to corrode here.
15. The topographical features of the site with natural and artificial surroundings affect the selection of site to great extent. For instance, in a region of the city having large buildings, a small residential building may not be aesthetically appealing.
16. For industrial buildings, the site selected should be such that
    (a) all the raw materials required for the industry must be available nearby
    (b) the labourers should be available from the nearby areas
    (c) the site must have enough space for future expansion, of industry, for the construction of residential areas for workers, etc.
    (d) suitable disposal plant to treat the solid or liquid wastes produced by the industry must be available at reasonable distance
17. Climate plays an important role in selecting sites for industrial buildings. For example, a cool and moist weather is more favourable for weaving and textile mills.

4.2 SUBSTRUCTURE [Nov, Dec 2014; Apr, May 2015, Regulation 2008]

A structure essentially consists of two parts, namely, the *super structure* which is above the plinth level and the *substructure* which is below the plinth level. Substructure is otherwise known as the foundation and this forms the base for any structure. Generally, about 30 per cent of the total construction cost is spent on the foundation. The soil on which the foundation rests is called the *foundation soil*.

4.3 OBJECTIVES OF A FOUNDATION [Nov, Dec 2011, 2012]

A foundation is provided for the following purposes:

1. To distribute the total load coming on the structure on a larger area
2. To support the structures
3. To give enough stability to the structures against various disturbing forces, such as wind and rain

4. To prepare a level surface for concreting and masonry work

4.4 SITE INSPECTION

The general inspection of the site serves as a good guide for determining the type of foundation to be adopted for the proposed work. Hence, it is desirable to visit the site of work and inspect the same carefully. The inspection of the site helps in getting the data with respect to the following items:

1. Behaviour of ground due to variations in the depth of water table
2. Disposal of storm water at the site
3. Nature of soil by means of visual examination
4. Movement of ground due to earthquake, landslide, etc.

In order to know the quality and thickness of underground soil, test pits are made up to the foundation level, the soil is excavated and examined. Electrical methods are also adopted to determine the soil quality from the resistance offered by the soil for the passage of current.

4.5 SOILS

4.5.1 General

Soil is a complex material produced by the weathering of solid rock. It is the unaggregated or uncemented deposits of mineral and/or organic particles or fragments covering a large portion of the earth's crust.

For engineering purposes, soil is defined as a natural aggregate of mineral grains, that have the capacity of being separated by means of simple mechanical processes, e.g., by agitation in water. Soil Engineering, Soil Mechanics or Geotechnique is one of the youngest disciplines of civil engineering involving the study of soil, its behaviour and application as an engineering material.

4.5.2 Types of Soils

The various types of soils are as follows:

1. Gravel
2. Sand
3. Silt
4. Clay

1. Gravel Soil particles of which more than 50 per cent have a size larger than 4.75 mm are called gravel. It is cohesionless and consists of unaltered mineral grains, which are angular to well-rounded in shape. Gravel is a very good foundation soil.

2. Sand It consists of cohesionless particles, of which more than 50 per cent have a size smaller than 4.75 mm. Sand particles are mostly unaltered mineral grains. Sand is also a good foundation soil.

3. Silt Silt comprises fine particles of weathered rocks with little or no plasticity. The presence of flake-shaped particles and/or organic and vegetable matters makes the silt-plastic. Organic silts are highly compressible and they have a light grey to dark grey colour. Silt is not quite suitable for building foundation.

4. Clay It is composed of microscopic and sub-microscopic particles of weathered rock. Clay becomes plastic in the presence of water. Plastic clay has very low permeability. Clay is not a good foundation soil at places where water is likely to come in contact with the soil.

4.5.3 Soil Classification

The purpose of soil classification is to arrange various types of soils into groups according to their various engineering properties. For civil engineering purposes, soils may be classified by the following systems:

1. Particle size classification
2. IS classification system and unified soil classification
3. Textural classification

1. Particle size classification In this system, soils are classified according to the grain size. To indicate grain sizes, terms such as boulder, cobble, gravel, sand, silt and clay are used. The grain size of the various types of soils is given in Table 4.1.

2. IS classification system and unified soil classification This system is based on both grain size and plasticity properties of the soil and is therefore applicable to any engineering use. In this system of classification, soils are broadly divided into the following three categories.

(i) Coarse-grained soils
(ii) Fine-grained soils
(iii) Highly organic soils

Table 4.1 Grain size of various types of soils

S.No.	*Soil*	*Grain-size*
1.	Boulder	Greater than 300 mm
2.	Cobble	80 mm–300 mm
3.	Gravel	4.75 mm–80 mm
	1. Fine gravel	4.75 mm–20 mm
	2. Coarse gravel	20 mm–80 mm
4.	Sand	0.075 mm–4.75 mm
	1. Fine sand	0.075 mm–0.425 mm
	2. Medium sand	0.425 mm–2.0 mm
	3. Coarse sand	2.0 mm– 4.75 mm
5.	Silt	0.002 mm–0.075 mm
6.	Clay	Less than 0.002 mm

(i) Coarse-grained soils In these soils, more than half the total material by mass is larger than 0.075 mm IS sieve size. They are further divided into the following two subdivisions.

(a) Gravel

(b) Sand

(ii) Fine-grained soils In these soils, more than half the material by mass is smaller than 0.075 mm IS sieve size. They are further divided into the following three subdivisions.

(a) Inorganic silts and very fine sands

(b) Inorganic clays

(c) Organic silts and clays and organic matter

(iii) Highly organic soils These soils contain large percentages of fibrous organic matter, such as peat and the particles of decomposed vegetation. In addition, certain soils containing shells, concretions, cinders and other non-soil materials in sufficient quantities are also grouped in this division.

3. Textural classification Classification of composite soils based on the particle size distribution is known as textural classification. This classification is based on the percentages of sand, silt and clay sizes making up the soil. Such a classification is more suitable to describe coarse-grained soils rather than clay soils whose properties are less dependent on the particle size distribution. Probably the best known of these textural classifications is the triangular classification of US Public Roads Administrations shown in Fig. 4.1.

In the figure for the given percentages of the three constituents forming a type of soil, lines are drawn parallel to the three sides of the equilateral triangle, as shown by arrows in the chart. For example, if a soil is composed of 20 per cent sand, 20 per cent silt and 60 per cent clay, the three lines drawn accordingly intersect in the zone marked for clay. Hence, such a soil will be termed clay.

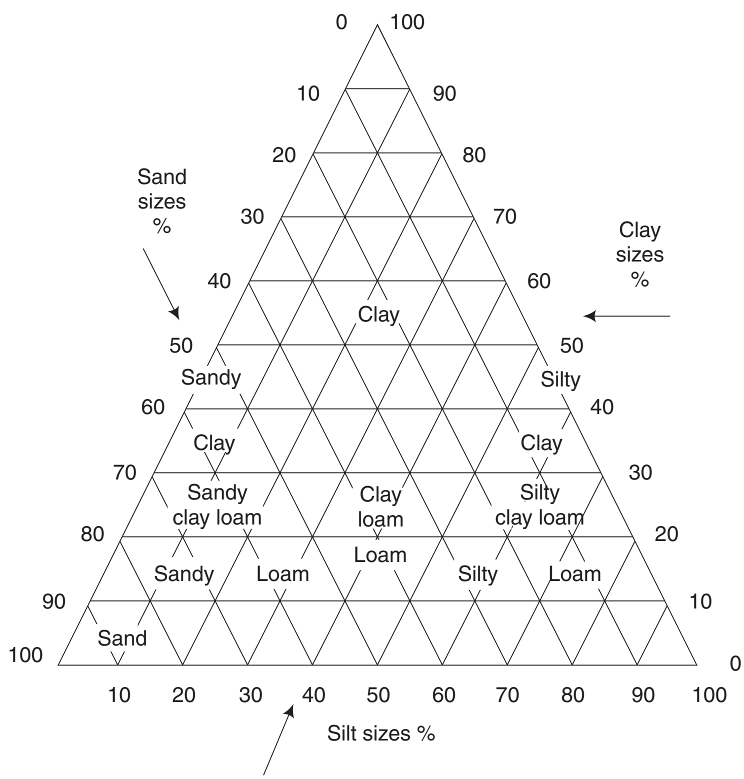

Fig. 4.1 *Textural classification*

4.5.4 Bearing Capacity of Soil [May, June 2009, 2010, 2011; Nov, Dec 2009, 2012]

This term is used to indicate the maximum load per unit area which the soil will resist safely without displacement. By dividing the ultimate bearing power of soil by a factor of safety, the safe bearing capacity is obtained.

On completion of a structure, there may be some displacement in the position of the foundation. For ordinary framed structures of concrete, the permissible angular distortion is 1/500 and the desirable value is 1/1000. The maximum differential settlement should not exceed 25 mm in case of foundations on sandy soil and 40 mm in case of foundations on clayey soil.

In case of non-cohesive soils, such as sand and gravel, the allowable bearing capacity should be reduced by 50 per cent, provided that the water table is above or near the bearing surface of the soil. The bearing capacity of reclaimed soils or shrinkable soils can be taken as 50 kN/m^2 in the absence of the site data.

The bearing capacity of the soil can be found by loading the soil, noting the settlement and by dividing the maximum load by the area on which the load is applied. The maximum load is obtained from the graph between the load and settlement.

4.5.5 Methods of Improving Bearing Capacity of Soils [May, June 2009; Nov, Dec 2012]

In some cases, the bearing capacity of soil is so low that the dimensions of the footings, work out to be very large and uneconomical. Under such situations, it becomes necessary to improve the bearing capacity of the soils, which can be done by the following methods.

- (i) Increasing the depth of foundation
- (ii) Compacting the soil. This can be done by using the following methods.
  - (a) Running moist soil
  - (b) Rubble compaction into the soil
  - (c) Flooding the soil
  - (d) Vibrating the soil
  - (e) Vibroflotation method
  - (f) Compaction by pre-loading
  - (g) Using sand piles
- (iii) Draining the subsoil water
- (iv) Confining the soil mass
- (v) Grouting with cement
- (vi) Chemical treatments like injecting silicates, etc.

4.6 LOADS ON FOUNDATIONS

The type of foundation to be used depends upon the loads borne by it. There are three types of loads borne by the foundation—dead load, live load and wind load.

4.6.1 Dead Load

This is the self-weight of the various components of a building. The provision for the future construction must also be made in the dead-load calculation. In order to calculate the dead load, a knowledge of weight of the common building materials is necessary.

4.6.2 Live Load

This is also known as superimposed load and is the moveable load on the floor. This includes the weight of persons standing on a floor, weight of materials stored temporarily on a floor, weight of snow, etc.

4.6.3 Wind Load

In case of tall buildings, the effect due to wind should be considered. The exposed sides and roofs of such buildings are subjected to wind pressure and its effect is to reduce the pressure on the foundation in the windward side and to increase the pressure in the leeward side.

4.7 ESSENTIAL REQUIREMENTS OF A GOOD FOUNDATION

[May, June 2009, 2012; Apr, May 2015]

The following are the essential requirements of a good foundation:

1. The foundation should be so located that it is able to resist any unexpected future influence which may adversely affect its performance.
2. The foundation should be stable or safe against any possible failure.
3. The foundation should not settle or deflect to such an extent that will impair its usefulness.

4.8 TYPES OF FOUNDATION

[Nov, Dec 2009; May, June 2010; Apr, May 2015]

Foundation may be broadly classified into the following two categories.

1. Shallow foundation
2. Deep foundation

A *shallow foundation* is one in which the depth is equal to or less than its width. When the depth is more than the width, it is termed as a *deep foundation*.

4.8.1 Shallow Foundation

[May, June 2010, 2011, 2012; Nov, Dec 2010, 2014; Apr, May 2015, Regulation 2008]

When the depth of the foundation is less than or equal to its width, it is defined as a shallow foundation. The two main types of shallow foundation discussed in this section are the isolated footing and the combined footing.

The various types of shallow foundations are

- Isolated column footing
- Wall footing
- Combined footing