Indian Standard

CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF FOUNDATIONS IN SOILS : GENERAL REQUIREMENTS

(Third Revision)

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(*Continued on page* 2)

(*Continued from page* 1)

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(*Continued on page* 22)

Indian Standard

CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF FOUNDATIONS IN SOILS : GENERAL REQUIREMENTS

(Third Revision)

0. FOREWORD

0.1 This Indian Standard (Third Revision) was adopted by the Indian Standards Institution on 31 October 1986, after the draft finalized by the Foundation Engineering Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 Series of Indian Standards on design and construction of various types of foundations (shallow, deep and special types) have been formulated covering their specific requirements. Many of the requirements for designing of such foundations are common for all types of foundations. In order that these general requirements are not repeated in each of such Indian Standards, this basic Indian Standard covering such general requirements has been formulated. This Indian Standard was first published in 1961 and revised in 1966 and 1978, which covered requirement for shallow foundations. During the past seven years, new Indian Standards covering design and construction of various types of foundations have been formulated. It was, therefore, decided to revise this standard so as to cover the general requirements for design and construction not only for shallow foundation but also for all types of foundations. Opportunity has also been taken to transfer the general requirements covered in IS : 1080-1980*, which is also being revised simultaneously, so that it covers only the specific requirements applicable to design and construction of shallow foundations.

0.3 The design of the foundation, super-structure and the characteristics of the ground are inter-related. In order to obtain maximum economy, the supporting ground, foundation and super-structure should be studied as a whole. The design of a foundation involves both geotechnical aspects of supporting ground and the structural aspects of the foundation materials. The aim is to proportion the foundation (plan dimensions) in such a way that net loading intensity of pressure coming on the soil does not

*Code of practice for design and construction of simple spread foundations (*first revision*).

exceed the safe bearing capacity and that structural design which involves the determination of the thickness of elements so that maximum stress in concrete (plain or reinforced) and masonry is within permissible limits.

0.4 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard covers the general structural requirements for all types of foundations (shallow, deep and special types).

2. TERMINOLOGY

2.1 For the purpose of this standard, the definition of terms given in IS : 2809-1972† shall apply.

3. TYPES OF FOUNDATIONS

3.1 Shallow Foundations — These cover such types of foundations in which load transference is primarily through shear resistance of the bearing strata (the fractional resistance of soil above bearing strata is not taken into consideration) and are laid normally to depth of 3 m.

3.1.1 The various types of shallow foundations are as under:

a) *Spread of pad* — *See* IS : 1080-1986‡.

b) *Strip* — *See* IS : 1080-1986‡.

c) *Raft foundation* — *See* IS : 2950 (Part 1)-1981§.

d) *Ring and shell foundation* — *See* IS : 11089-1984|| and IS : 9456-1980¶.

3.2 Deep Foundations — This is a foundation generally in the form of piles, caissons, diaphragm walls, used separately or in combination to transmit

*Rules for rounding off numerical values (*revised*).

†Glossary of terms and symbols relating to soil engineering (*first revision*).

‡Code of practice for design and construction of shallow foundations in soils (other than raft, ring and shell) (*second revision*).

§Code of practice for design and construction of raft foundations : Part 1 Design (*second revision*).

||Code of practice for design and construction of ring foundation.

¶Code of practice for design and construction of conical and hyperboloidal types of shell foundations.

the loads to a deeper load bearing strata when, no adequate bearing strata exists at shallow depths. The transference of load by a deep foundation may be through friction, end-bearing or a combination of both.

3.2.1 The various types of deep foundations are as under:

a) *Pile Foundations*

1) *Driven cast in-situ* — *See* IS : 2911 (Part 1/Sec 1)-1979*.
2) *Board cast in-situ* — *See* IS : 2911 (Part 1/Sec 2)-1979*.
3) *Driven precast* — *See* IS : 2911 (Part 1/Sec 3)-1979*.
4) *Board precast* — *See* IS : 2911 (Part 1/Sec 4)-1984*.
5) *Timber* — *See* IS : 2911 (Part 2)-1980†.
6) *Under-reamed pile* — *See* IS : 2911 (Part 3)-1980‡.

b) *Caissons* — *See* IS : 9527 (Part 1)-1981§.
c) *Diaphragm walls* — *See* IS : 9556-1980‖.
d) *Well foundation*¶.

e) *Combined foundations* — Two or more types of above foundations.

3.3 Foundations for Special Structure — Foundations for certain structures and/or machineries require special design and detailing procedure taking into consideration the impact and vibration characteristics of the load and the soil properties under dynamic conditions and may have combination of foundation structure.

3.3.1 The various types of such foundations are as under:

a) *Machine foundations*

1) *Reciprocating type* — *See* IS : 2974 (Part 1)-1982**.
2) *Impact type* — *See* IS : 2974 (Part 2)-1980††.

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*Code of practice for design and construction of pile foundations : Part 1 Concrete piles (Sections 1 to 4) (*first revision*).

†Code of practice for design and construction of pile foundations : Part 2 Timber piles (*first revision*).

‡Code of practice for design and construction of pile foundations : Part 3 Under-reamed piles (*first revision*).

§Code of practice for design and construction of port and harbour structures : Part 1 Concrete monoliths.

‖Code of practice for design and construction of diaphragm walls.

¶A detail code on this subject is formulated by IRC.

**Code of practice for design and construction of machine foundations : Part 1 Foundation for reciprocating type machines (*second revision*).

††Code of practice for design and construction of machine foundations : Part 2 Foundations for impact type machine (Hammer foundations) (*first revision*).

3) *Rotary type (medium and high frequency)* — *See* IS : 2974 (Part 3)-1975*.

4) *Rotary type low frequency* — *See* IS : 2974 (Part 4)-1975†.

5) *Impact type (other than hammer)* — *See* IS : 2974 (Part 5)-1987‡.

b) *Tower foundations*

1) *Transmission line towers and poles* — *See* IS : 4091-1979§.

2) *Radar antenna, microwave and TV tower* — *See* IS : 11233-1985‖.

4. GROUND

4.1 The natural geological deposits over, base rock extending to the surface level of the earth should be examined.

5. SITE INVESTIGATION

5.1 The investigation of the site is an essential prerequisite to the construction of all civil engineering works with a view to assess the general suitability of the site for the proposed new works and to enable in preparing an adequate and economic design.

In particular, it is necessary to assess the changes that may occur during or after the construction of the structure due to the choice of materials or methods of construction which may adversely affect safety of structure or after its performance or utility.

5.2 The investigation of the site should be carried out in accordance with the principles set in IS: 1892-1979¶. As a preliminary, it is usually judicious to collect information relating to the site prior to commencing its exploration. The exploration of the site for an important structure requires the exploration and sampling of all strata likely to be significantly affected by the structural load. The extent of this exploration will depend on the site and structure. In any case, particular attention shall be paid to the ground water level, underground water courses, old drains, pits, wells, old foundation, etc, and presence of excessive sulphates or other

*Code of practice for design and construction of machine foundations : Part 3 Foundations for rotary type machines (medium and high frequency) (*first revision*).

†Code of practice for design and construction of machine foundations : Part 4 Foundations for rotary type machines of low frequency (*first revision*).

‡Code of practice for design and construction of machine foundations : Part 5 Foundations for impact type machines other than hammers (*first revision*).

§Code of practice for design and construction of foundations for transmission line towers and poles (*first revision*).

‖Code of practice for design and construction of radar antenna, microwave and TV tower foundations.

¶Code of practice for subsurface investigation for foundations (*first revision*).

injurious compound in the ground water and soil. The site should also be explored in detail, where necessary, to ascertain the type consistency, thickness, sequence and dip of the strata.

5.3 Mass movements of the ground are liable to occur from causes independent of the loads imposed by the structure. These include mining subsidence, land slips, unstable slopes and creep on clay slopes. These factors shall be observed in detail during site investigation and taken into account in the layout and design of the proposed works. However, if necessary, expert advice regarding the geological and hydrological characteristics of the site shall be sought.

5.3.1 Mining subsidence is liable to occur in mining areas. The magnitude of the movement and its distribution over the area of the workings and their vicinity can be roughly estimated. Where future subsidence is likely, care should be taken to design the superstructure and foundation sufficiently strong or sufficiently flexible to cater for probable ground movements. Long continuous buildings should be avoided and large building should be divided into independent sections of suitable size, each with its own foundations. Expert advice from appropriate mining authority should be sought.

5.3.2 Cuttings, excavations or sloping ground near foundations may increase the possibility of shear failure in the ground supporting the foundations.

On sloping ground on clay soils there is always a tendency for the upper layers of soil to move downhill, the extent, however, depends on the type of soil, the angle of slope, ground water regime and climatic conditions. Instability may develop even after a long period of apparent stability, particularly in stiff, fissured and over consolidated clay soil.

Uneven surface of a slope on virgin ground, curved tree trunks, tilted fence posts, tilted boundary walls, etc, indicate the creep of the surface layers. Areas subject to land slip and unstable slopes shall, therefore, be avoided.

5.3.3 Some clayey soils are susceptible to shrinkage and cracking in dry and hot weather, and swelling in wet weather. These conditions are simulated, sometimes, by extraneous agencies like trees, boiler installations, furnaces, kilns, underground cables, services and refrigeration installations. These factors shall be studied carefully before designing any foundations. Shrinkage of clay soils may be increased by the drying effect produced by nearby trees and shrubs. Swelling may occur, if they are cut down. No trees which grow to a large size shall be planted within 8 m of foundations of buildings.

5.3.4 New constructions may interfere with drainage regime of the ground and affect the stability of existing structure. Adequate precautions should be taken to protect these. On the uphill side of a building on a sloping site, land drainage requires special consideration for diverting the natural flow of water away from the foundations. If excavation involves cutting through existing land drains, consideration should be given for diverting into the ground-drainage system.

5.3.5 Increase in moisture extent results in substantial loss of bearing capacity in case of certain types of soils which may lead to differential settlements. On sites liable to be water logged in wet weather, it is desirable to determine the contour of the water-table surface in order to indicate the directions of the natural drainage and to obtain the basis of the design of intercepting drains to prevent the influx of ground water into the site from higher ground. The seasonal variation in the level of the water table is of importance in some cases. In case of soils with low permeability, the water levels in boreholes or observation wells may take a considerable time to reach equilibrium with ground water Spot readings of water level in boreholes may, therefore, give an erroneous impression of the true ground water level. It is generally determined by measuring the water level in the borehole after a suitable time lapse for which a period of 24 hours or more be used as the case may be. In soils with high permeability, such as sand and gravels, lapse of sometime is usually sufficient, unless the hole has been sealed with drilling mud. In these cases it may be necessary to resort to indirect means to establish the approximate location of the water table. Where deep excavation is required, the location of water bearing strata should be determined with particular care and the water pressure in each should be observed so that necessary precautions may be taken during excavation.

5.3.6 In certain localities where considerable quantities of soluble salts are contained in ground water and soil, portland cement concrete, especially thin members or buried metals are subjected to deterioration and corrosion. Certain soils have a corrosive action on metals, particularly on cast iron, due to either chemical or bacteriological agency. In industrial areas, corrosive action may arise from industrial wastes that have been dumped on the site. Chemical analysis of samples of ground water or soil (or sometimes both) should be done to assess the necessity of special precautions. The following are some of suggested methods:

a) Dense cement concerete M20 mix or richer may be used to reduce permeability and increase resistance to attack from sulphates (*see* IS : 456-1978*).

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*Code of practice for plain and reinforced concrete (*third revision*).

b) Portland pozzolana cement may be used to control and reduce the activities of the sulphates.

c) Special cements like high alumina cement, super sulphated cement, which are sulphate resistant, may be used.

d) A thick coating of bitumen may be given over the exposed surfaces of foundation below the water table to prevent infiltration of water into the foundation (*see* IS : 5871-1970*).

e) A thick layer of cement concrete (with sulphate resistant cement) and coated with bitumen be laid before laying of foundation concrete to prevent infiltration of water from sulphate bearing soil.

NOTE — The soluble salts are usually sulphates of calcium, magnesium and sodium. Water containing these salts gets into the concrete and reacts with the set cement or hydraulic lime. This reaction is accompanied by considerable expansion which leads to the deterioration and cracking of the concrete. The amount of soluble sulphates may be considered excessive from the point of attack on concrete if it is more than 30 parts of SO_3 per 100 000 parts of subsoil water or in the case of clays if more than 0·2 percent SO_3 by weight of clay in air-dry condition, which should be determined by proper analysis.

6. METHODS OF SITE EXPLORATION

6.1 The most common and satisfactory methods of site explorations are given below:

a) Trial pits,
b) Boring, and
c) Headings.

The details of these methods are given in IS : 1892-1979†.

7. DEPTH OF FOUNDATION

7.1 The depth to which foundations should be carried depends upon the following principal factors:

a) The securing of adequate allowable bearing capacity.

b) In the case of clayey soils, penetration below the zone where shrinkage and swelling due to seasonal weather changes, and due to trees and shrubs are likely to cause appreciable movements.

c) In fine sands and silts, penetration below the zone in which trouble may be expected from frost.

*Specification for bitumen mastic for tanking and damp-proofing.
†Code of practice for subsurface investigation for foundation (*first revision*).

d) The maximum depth of scour, wherever relevant, should also be considered and the foundation should be located sufficiently below this depth.

e) Other factors such as ground movements and heat transmitted from the building to the supporting ground may be important.

7.2 All foundations shall extend to a depth of at least 50 cm below natural ground level. On rock or such other weather resisting natural ground, removal of the top soil may be all that is required. In such cases, the surface shall be cleaned and, if necessary, stepped or otherwise prepared so as to provide a suitable bearing and thus prevent slipping or other unwanted movements.

7.3 Where there is excavation, ditch, pond, water course, filled up ground or similar condition adjoining or adjacent to the subsoil on which the structure is to be erected and which is likely to impair the stability of structure, either the foundation of such structure shall be carried down to a depth beyond the detrimental influence of such conditions, or retaining walls or similar works shall be constructed for the purpose of shielding from their effects.

7.4 A foundation in any type of soil shall be below the zone significantly weakened by root holes or cavities produced by burrowing animals or works. The depth shall also be enough to prevent the rainwater scouring below the footings.

7.5 Clay soils, like black cotton soils, are seasonally affected by drying, shrinkage and cracking in dry and hot weather, and by swelling in the following wet weather to a depth which will vary according to the nature of the clay and the climatic condition of the region. It is necessary in these soils, either to place the foundation bearing at such a depth where the effects of seasonal changes are not important or to make the foundation capable of eliminating the undesirable effects due to relative movement by providing flexible type of construction or rigid foundations. Adequate load counteraction swelling pressures also provide satisfactory foundations.

8. FOUNDATION AT DIFFERENT LEVELS

8.1 Where footings are adjacent to sloping ground or where the bottoms of the footings of a structure are at different levels or at levels different from those of the footings of adjoining structures, the depth of the footings shall be such that the difference in footing elevations shall be subject to the following limitations:

a) When the ground surface slopes downward adjacent to a footing, the sloping surface shall not intersect a frustum of bearing material under the footing having sides which make an angle of 30° with the horizontal for soil and horizontal distance from the lower edge of the footing to the sloping surface shall be at least 60 cm for rock and 90 cm for soil (*see* Fig. 1).

b) In the case of footings in granular soil, a line drawn between the lower adjacent edges of adjacent footings shall not have a steeper slope than one vertical to two horizontal (*see* Fig. 2).

c) In case of footing of clayey soils a line drawn between the lower adjacent edge of the upper footing and the upper adjacent edge of lower footing shall not have a steeper slope than one vertical to two horizontal (*see* Fig. 2).

8.2 The requirement given in **8.1** shall not apply under the following conditions:

a) Where adequate provision is made for the lateral support (such as with retaining walls) of the material supporting the higher footing.

b) When the factor of safety of the foundation soil against shearing is not less than four.

9. EFFECT OF SEASONAL WEATHER CHANGES

9.1 During periods of hot, dry weather a deficiency of water develops near the ground surface and in clay soils, this is associated with a decrease of volume or ground shrinkage and the development of cracks. The shrinkage of clay will be increased by drying effect produced by fast growing and water seeking trees. The range of influence depends on size and number of trees and it increases during dry periods. In general, it is desirable that there shall be a distance of at least 8 m between such trees. Boiler installations, furnaces, kilns, underground cables and refrigeration installations and other artificial sources of heat may also cause increased volume changes of clay by drying out the ground beneath them, the drying out can be to a substantial depth. Special precautions either in the form of insulation or otherwise should be taken. In periods of wet weather, clay soils swell and the cracks lend to close, the water deficiency developed in the previous dry periods may be partially replenished and a subsurface zone or zones deficient in water may persist for many years. Leakage from water mains and underground sewers may also result in large volume changes. Therefore, special care must be taken to prevent such leakages.

10. EFFECT OF MASS MOVEMENTS OF GROUND IN UNSTABLE AREAS

10.0 In certain areas mass movements of the ground are liable to occur from causes independent of the loads applied by the foundations of

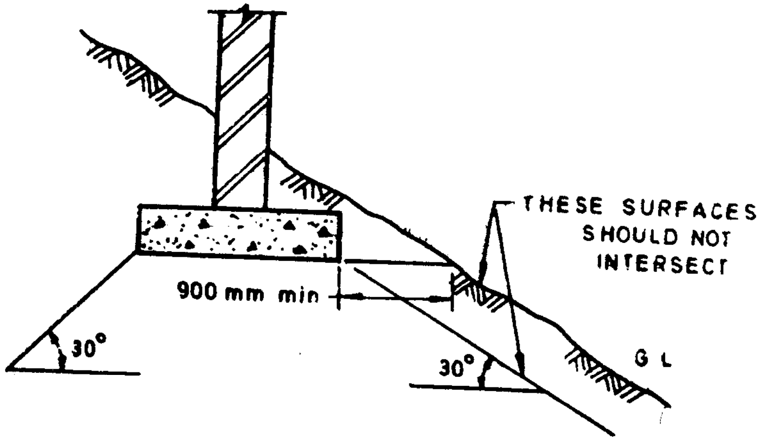

FIG. 1 FOOTING IN SLOPING GROUND

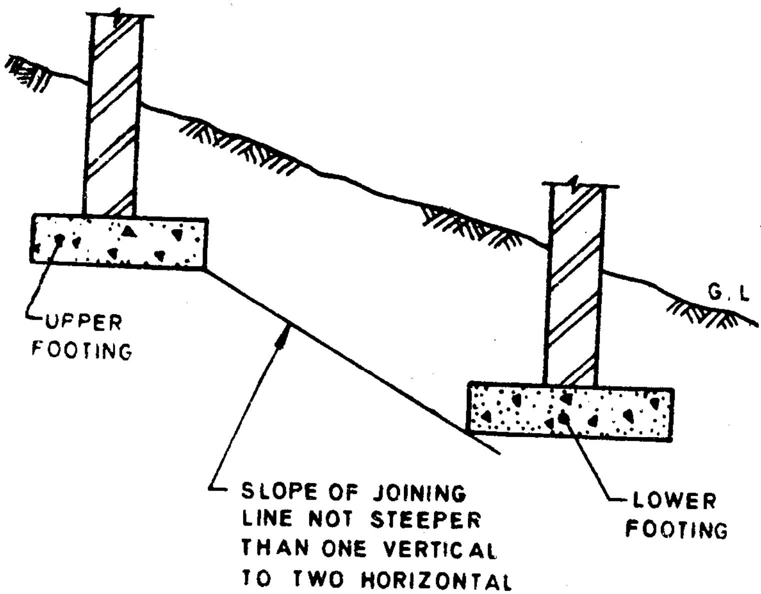

FIG. 2 FOOTING IN GRANULAR SOIL OR CLAYEY SOIL

structures. These include mining subsidence, landslips on unstable slopes and creep on clay slopes.

10.1 Mining Subsidence — In mining areas, subsidence of the ground beneath a building or any other structure is liable to occur. The magnitude of the movement and its distribution over the area are likely to be uncertain and attention shall, therefore, be directed to make the foundations and structures sufficiently rigid and strong to withstand the probable worst loading condition. In this connection, reference should also be made to **5.3.1**.

10.2 Landslip Areas

10.2.1 The construction of structures on slopes which are suspected of being unstable and are subject to landslip shall be avoided.

10.2.2 On sloping ground on clay soils, there is always a tendency for the upper layers of soil to move downhill, depending on type of soil, the angle of slope, climatic conditions, etc. In some cases, the uneven surface of the slope on a virgin ground will indicate that the area is subject to small land slips and, therefore, if used for foundation, will obviously necessitate special design consideration.

10.2.3 Where there may be creep of the surface layer of the soil, protection against creep may be obtained by following special design considerations.

10.2.4 On sloping sites, spread foundations shall be on a horizontal bearing and stepped. At all changes of levels, they shall be lapped at the steps for a distance at least equal to the thickness of the foundation or twice the height of the step, whichever is greater. The steps shall not be of greater height than the thickness of the foundation, unless special precautions are taken.

10.2.5 Cuttings, excavations or sloping ground near and below foundation level may increase the possibility of shear failure of the soil. The foundation shall be well beyond the zone of such shear failure.

10.2.6 If the probable failure surface intersects a retaining wall or other revetment, the latter shall be made strong enough to resist any unbalanced thrust. In case of doubt as to the suitability of the natural slopes or cuttings, the structure shall be kept well away from the top of the slopes, or the slopes shall be stabilized.

10.2.7 Cuttings and excavations adjoining foundations reduce stability and increase the likelihood of differential settlement. Their effect should be investigated not only when they exist but also when there is possibility that they are made subsequently.

10.2.8 Where a structure is to be placed on sloping ground, additional complications are introduced. The ground itself, particularly if of clay, may be subject to creep or other forms of instability, which may be enhanced if the strata dip in the same direction as the ground surface. If the slope of the ground is large, the overall stability of the slope and substructure may be affected. These aspects should be carefully investigated.

11. PRECAUTIONS FOR FOUNDATIONS ON INCLINED STRATA

11.1 In the case of inclined strata, if they dip towards a cutting or basement, it may be necessary to carry foundation below the possible slip planes, land drainage also requires special consideration, particularly on the uphill side of a structure to divert the natural flow of water away from the foundations.

12. STRATA OF VARYING THICKNESS

12.1 Strata of varying thickness, even at appreciable depth, may increase differential settlement. Where necessary, calculations should be made of the estimated settlement from different thicknesses of strata and the structure should be designed accordingly. When there is large change of thickness of soft strata, the stability of foundation may be affected. Site investigations should, therefore, ensure detection of significant variations in strata thickness.

13. LAYERS OF SOFTER MATERIAL

13.1 Some soils and rocks have layers of harder material between thin layers of softer material, which may not be detected unless thorough investigation is carried out. The softer layers may undergo marked changes in properties if the loading on them is increased or decreased by the proposed construction or affected by related changes in ground water conditions. These should be taken into account.

14. SPACING BETWEEN EXISTING AND NEW FOUNDATION

14.1 The deeper the new foundation and the nearer to the existing it is located, the greater the damage is likely to be. The minimum horizontal spacing between existing and new footings shall be equal to the width of the wider one. While the adoption of such provision shall help minimizing damage to adjacent foundation, an analysis of bearing capacity and settlement shall be carried out to have an appreciation of the effect on the adjacent existing foundation.

15. LOADS ON FOUNDATIONS

15.1 Loads on a foundation are those forces imparted by the structure, it is supporting, in any of the form (i) vertical either upwards or downwards,

(ii) horizontal or lateral, and (iii) moment or couple. The following loads shall be considered for design of foundations.

15.1.1 *Permanent Load* — This is the actual service load/sustained load consisting of dead loads and live loads of a structure which give rise to stresses and deformations in the soil below foundation causing its settlement.

15.1.2 *Transient Load* — This is a momentary or sudden load imparted to a structure due to wind or seismic vibrations. Due to its transitory nature, the stresses in the soil below the foundation carried by such loads are allowed certain percentage increase over the allowable safe values.

15.1.3 Foundations shall be proportioned for the following combination of loads:

a) Dead load + live load, and

b) Dead load + live load + wind load or seismic load.

15.1.4 Dead load also includes the weight of column/wall, footings, foundations, the overlying fill but excludes the weight of the displaced soil.

15.1.5 Live loads from the floors above as specified in IS:875 (Part 2)-1987* shall be taken in proportioning and designing the foundations.

15.1.6 Where wind or seismic load is less than 25 percent of that due to dead and live loads, it may be neglected in design and first combination of load shall be compared with the safe bearing load to satisfy allowable bearing pressure.

15.1.7 Where wind or seismic load is more than 25 percent of that due to dead and live loads, foundations may be so proportioned that the pressure due to combination of load (that is, dead + live + wind load) does not exceed the safe bearing capacity by more than 25 percent. When seismic forces are considered, the safe bearing capacity shall be increased as specified in IS : 1893-1984†. In non-cohesive soils, analysis for liquefaction and settlement under earthquake shall also be made.

16. SETTLEMENT

16.1 Uniform Settlement — The magnitude of the settlement that should occur, when foundation loads are applied to the ground, depend on the rigidity of substructure and compressibility of the underlying strata. In

*Code of practice for structural safety of buildings : Loading standards : Part 2 Imposed loads (*second revision*).

†Criteria for earthquake resistant design of structures (*fourth revision*).

silts and clays the settlement may continue for a long period after the construction of structure. Due allowance shall, therefore, need be made for this slow consolidation settlement. In sand and gravels, the settlement is likely to be complete to a great extent by the end of the construction activities. In strata of organic soils, settlement may continue almost indefinitely. For the safety of foundations, the engineer-in-charge should be well familiar with all causes of settlement. Foundations may settle due to some combination of the following reasons:

a) Elastic compression of the foundation material and the underlying soil;

b) Consolidation including secondary compression;

c) *Ground Water Lowering*—specially repeated lowering and raising of water level in loose granular soils tend to compact the soil and cause settlement of the foundations. Prolonged lowering of the water table in fine grained soils may introduce settlements because of the extrusion of water from the voids. Pumping water or draining water by wells or pipes from granular soils without adequate filter material as protection may, in a period of time, carry a sufficient amount of fine particles away from the soil and cause settlement;

d) Seasonal swelling and shrinkage of expansive clays;

e) Ground movement on earth slopes, for example, surface erosion, slow creep or land slides;

f) Other causes, such as adjacent excavation, mining subsidence and underground erosion by streams or floods; and

g) The effects of vegetation leading to shrinking and swelling of clay soils.

16.2 Differential Settlements — The foundations of different elements of a structure may have unequal settlements and the difference between such settlements will cause differential settlement. Some of the causes for differential settlements are as follows:

a) Geologic and physical non-uniformity or anomalies in type, structure, thickness, and density of the soil medium (pockets of sand in clay, clay lenses in sand, wedge like soil strata, that is, lenses in soil), an admixture of organic matter, peat, mud, etc;

b) Non-uniform pressure distribution from foundation to the soil due to non-uniform loading and incomplete loading of the foundations;

c) Varying water regime at the construction site;

d) Over stressing of soil at adjacent site by heavy structures built next to light ones;

e) Overlap of stress distribution in soil from adjoining structures;

f) Unequal expansion of the soil due to excavation for footings;

g) Non-uniform development of extrusion settlements; and

h) Non-uniform structural disruptions or disturbance of soil due to freezing and thawing, swelling, softening and drying of soils.

16.3 Criteria for Settlement Analysis for Shallow Foundation

16.3.1 For foundations resting on coarse grained soils, the settlements shall be estimated corresponding to the load mentioned in **15.1.3**(b). since in such type of soils, settlements occur within a very short period of loading.

16.3.2 For fine grained soils, the settlements shall be estimated corresponding to permanent loads. Dead load and all fixed equipments are considered as permanent. Generally, one half of the design live load may be taken as being permanent. The engineer shall use his judgement in each project work to determine what loads are permanent and what are temporary. Therefore, it appears reasonable to reduce the differential settlement due to live load variation by maintaining equal pressure for all foundations under the service load. This may be done by the following procedure:

a) Determine the required bearing area for a column having the largest live load to dead load ratio. In the conventional method of design, the area (A) is given by:

$$A = \frac{\text{Dead load} + \text{live load}}{\text{Allowable bearing capacity}}$$

b) Compute for this same column the design bearing value

$$q_d = \frac{\text{service load}}{A}$$

c) Determine the area for all other columns by the use of q_d, that is,

$$\text{Bearing area} = \text{service load} / q_d$$

d) For calculation of settlement of foundations, IS : 8009 (Part 1) -1976* may be referred.

16.3.3 The total settlement of the foundations shall be not more than permissible.

*Code of practice for calculation of foundations : Part 1 Shallow foundations subjected to symmetrical static vertical loads.

16.3.4 The permissible value of settlement for different types of structures are given in Table 1.

16.3.5 Differential settlement and/or tilt (angular distortion) of the structures shall not be more than the permissible values. The differential settlement shall be obtained by taking the difference maximum and minimum settlement. Tilt shall be calculated by dividing the differential settlement by the distance between points of related maximum and minimum settlement.

16.4 Settlement Analysis for Deep Foundation

16.4.1 The permissible value of total settlement, differential settlement, and tilt (angular distortion) have been specified in the relevant Indian Standard (*see* **3**). The settlement shall be calculated according to IS : 8009 (Part 2)-1980*.

17 STABILITY AGAINST OVERTURNING AND SLIDING

17.1 The stability of the foundation against sliding and overturning shall be checked, and the factors of safety shall conform to the following requirements.

17.1.1 *Sliding* — The factor of safety against sliding of structures which resist lateral forces (such as retaining walls) shall be not less than 1·5 when dead load, live load and earth pressures are considered together with wind load or seismic forces. When dead load, live load and earth pressure only are considered, the factor of safety shall be not less than 1·75.

NOTE — For structures founded on soils with low frictional coefficient (that is, slippery material), safety against sliding may be improved by providing anchor type cut-off walls or piles to take the excess load over that resisted by friction or an inclined underside of the base.

17.2 Overturning — The factor of safety for shallow foundation against overturning shall be not less than 1·5 when dead load, live load and earth pressures are considered together with wind load or seismic forces. When dead load, live load and earth pressures only are considered, the factor of safety shall be not less than 2. The factor of safety of other types of foundation is covered in relevant Indian Standard (*see* **3**).

18. BEARING CAPACITY

18.1 The safe bearing capacity for shallow foundation shall be calculated in accordanee with IS : 6403-1981†. The method of computation of safe bearing capacity for other types of foundations has been specified in the

*Code of practice for calculation of foundations: Part 2 Deep foundations subjected to symmetrical static vertical loading.

†Code of practice for determination of bearing capacity of shallow foundations (*first revision*).

TABLE 1 PERMISSIBLE DIFFERENTIAL SETTLEMENTS AND TILT (ANGULAR DISTORTION) FOR SHALLOW FOUNDATION IN SOILS

(*Clause* 16.3.4)

Sl No.	Type of Structure	Isolated Foundations						Raft Foundations					
		Sand and Hard Clay			Plastic Clay			Sand and Hard Clay			Plastic Clay		
		Maximum settlement	Differential settlement	Angular distortion	Maximum settlement	Differential settlement	Angular distortion	Maximum settlement	Differential settlement	Angular distortion	Maximum settlement	Differential settlement	Angular distortion
		mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
i)	For steel structure	50	·003 3L	1/300	50	·003 3L	1/300	75	·003 3L	1/300	100	·003 3L	1/300
ii)	For reinforced concrete structures	50	·001 5L	1/666	75	·001 5L	1/666	75	·002 1L	1/500	100	·002L	1/500
iii)	For multistoreyed buildings												
	a) RC or steel framed buildings with panel walls	60	·002L	1/500	75	·002L	1/500	75	0·002 5L	1/400	125	0·003 3L	1/300
	b) For load bearing walls												
	1) L/H = 2[+]	60	·000 2L	1/5 000	60	·000 2L	1/5 000	Not likely to be encountered					
	2) L/H = 7[+]	60	·000 4L	1/2 500	60	·000 4L	1/2 500						
iv)	For water towers and silos	50	·001 5L	1/666	75	·001 5L	1/666	100	·002 5L	1/400	125	·002 5L	1/400

NOTE — The values given in the table may be taken only as a guide and the permissible total settlement/different settlement and tilt (angular distortion) in each case should be decided as per requirements of the designer.

L denotes the length of deflected part of wall/raft or centre-to-centre distance between columns.

H denotes the height of wall from foundation footing.

[+]For intermediate ratios of L/H, the values can be interpolated.

relevant Indian Standards. It is recommended that safe bearing capacity shall be calculated on the basis of soil test data and in the absence of such data for preliminary design, the local values may serve as guidelines.

19. PRELIMINARY WORK FOR CONSTRUCTION

19.1 The construction of access roads, main sewers and drains should preferably be completed before commencing the work of foundations; alternatively, sufficient precautions shall be taken to protect the already constructed foundations during subsequent work.

19.2 Clearance of Site — Any obstacles, including the stump of trees, likely to interfere with the work shall be removed. Holes left by digging, such as those due to removal of old foundation, uprooted trees, burrowing by animals, etc, shall be back-filled with soil and well compacted.

19.3 Drainage — If the site of a structure is such that surface water shall drain towards it, land may be dressed or drains laid to divert the water away from the site.

19.4 Setting Out — Generally the site shall be levelled before the layout of foundations are set out. In case of sloping terrain, care shall be taken to ensure that the dimensions on plans are set out correctly in one or more horizontal planes.

19.5 The layout of foundations shall be set out with steel tapes. Angles should be set out with theodolites in the case of important and intricate structures where the length of area exceeds 16 m. In other cases these shall be set out by measurement of sides. In rectangular or square setting out, diagonals shall be checked to ensure accuracy. The setting out of walls shall be facilitated by permanent row of pillars, parallel to and at a suitable distance beyond the periphery of the building. The pillars shall be located at junctions of cross walls with the peripheral line of pillars. The centre lines of the cross walls shall be extended to and permanently erected on the plastered tops of the corresponding sets of pillars. The datum lines parallel to and at the known fixed distance from the centre lines of the external walls also be permanently worked on the corresponding rows of pillars to pillars to serve as checks on the accuracy of the work as it proceeds. The tops of these pillars shall be at the same level and preferably at the plinth or floor level. The pillars shall be of sizes not less than 25 cm wide and shall be bedded sufficiently deep into ground so that they are not disturbed.

20. PROTECTION OF EXCAVATION

20.1 The protection of excavation during construction of timbering and dewatering operations, where necessary, shall be done in accordance with IS : 3764-1966*.

20.2 After excavation, the bottom of the excavation shall be cleared of all loose soil and rubbish and shall be levelled, where necessary. The bed shall be wetted and compacted by heavy rammers to an even surface.

20.3 Excavation in clay or other soils that are liable to be effected by exposure to atmosphere shall, wherever possible, be concreted as soon as they are dug. Alternatively the bottom of the excavation shall be protected immediately by 8 cm thick layer of cement concrete not leaner than mix 1 : 5 : 10 over which shall come the foundation concrete; or in order to obtain a dry hard bottom, the last excavation of about 10 cm shall be removed only before concreting.

20.4 The refilling of the excavation shall be done with care so as not to disturb the constructed foundation, and shall be compacted in layers not exceeding 15 cm thick with sprinkling of minimum quantity of water necessary for proper compaction.

*Specification for safety code for excavation work.

(*Continued from page* 2)

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*Sales Office in Bombay is at Novelty Chambers, Grant Road, Bombay 400007 — 89 65 28

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