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शैल पर उथली नींव पर बने भवनों की संरचना सुरक्षा – रीति संहिता

Indian Standard

STRUCTURAL SAFETY OF BUILDINGS ON SHALLOW FOUNDATIONS ON ROCKS — CODE OF PRACTICE

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BUREAU OF INDIAN STANDARDS
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Price Group 7

Rock Mechanics Sectional Committee, CED 48

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Rock Mechanics Sectional Committee had been approved by the Civil Engineering Division Council.

Shallow foundations cover such type of foundations in which the load transfer is directly on the bearing strata and whose width is greater than its depth. Depth of foundation is normally up to 3 m from natural ground level.

Since most unweathered intact rocks are stronger and less compressible than concrete, the determination of allowable bearing pressure on such rocks may be unnecessary. However, intact rock masses without weathered zones, joints or other discontinuities are encountered rarely in nature. The existence or location of specific discontinuities of foundation rocks often remain unknown until the rock mass is exposed by excavation. Thus, design engineers should be aware of dangers associated with the hetrogeneity, anisotropy and unfavourable rock conditions. This is because overstressing a rock foundation may result in large differential settlements tilts or perhaps sudden failure.

In the formulation of this standard due weightage has been given to the standards and practices prevailing in different countries and that in our country.

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 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

STRUCTURAL SAFETY OF BUILDINGS ON SHALLOW FOUNDATIONS ON ROCKS — CODE OF PRACTICE

1 SCOPE

1.1 This standard lays down the general requirements for stuctural safety of buildings having shallow foundations on rock mass.

1.2 The provisions of this code does not cover the special requirements/conditions for foundations under tensile loads.

2 REFERENCES

The Indian Standards listed in Annex A are necessary adjuncts to this standard.

3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 2809 : 1972 and IS 1904 : 1986 shall apply.

4 SITE INVESTIGATIONS AND OTHER GENERAL CONDITIONS

4.1 Objective of Site Investigation

The objective of any site investigation shall be for the determination of the followings:

a) The character of ground, identification of rock types together with their discontinuities which tend to influence the behaviour of rock mass [*see* IS 11315 (Parts 1 to 11)];

b) Character of ground water, measurement of piezometric pressures and location of the more permissible zones.

c) Engineering properties of the rocks as determined by laboratory and field testing.

4.2 Existing Information

In areas which have already been developed, advantage should be taken of existing local knowledge, records of trial pits and bore holes, etc, in the vicinity and behaviour of existing structures, particularly those of a nature similar to that of the proposed structures. In such cases, exploration may be limited to checking that the existing ground conditions are similar as in neighbourhood.

4.3 Site Reconnaissance

4.3.1 If the existing information is not sufficient or is inconclusive, the site should be explored in detail so as to obtain a knowledge the of type, uniformity, consistence, thickness, sequence and dip of the strata and of the ground water conditions.

4.3.2 The site reconnaissance would help in deciding the future programme of field investigations, that is, to assess the need for preliminary or detailed investigations. This would also help in determining the scope of work, method of exploration to be adopted, field tests to be conducted and administrative arrangement required for the investigation. Where detailed published information on the geotechnical condition is not available, an inspection of site and study of topographical features are helpful in getting information about soil, rock and ground water conditions. Site reconnaissance includes a study of local topography, excavations, revines, quarries, escarpments, evidence of erosion or land slides, beaviour of existing structures at or near the site, water marks, natural vegetation, drainage pattern, location of seeps, springs and swamps. Information on some of these may be obtained from topographical maps, geological maps, pedological and soil survey maps and aerial photographs.

4.4 Preliminary Exploration

The scope of preliminary exploration is restricted to the determination of depth, thickness, extent and composition of overlying soil strata, location of rock and ground water and also to obtain approximate information regarding strength and compressibility of various strata. During preliminary investigation, geophysical methods are useful guides.

4.4.1 *Geophysical Investigations*

Geophysical surveys make use of difference in physical properties like elastic modulus, electrical conductivity, density and magnetic susceptibility of geological formations in the area to investigate the subsurface. Out of the four methods of geophysical surveys, namely, seismic, electrical, magnetic and gravity surveys, only seismic refractive surveys are widely used in geotechnical investigations.

4.4.1.1 *Seismic Survey*

The seismic survey method makes use of the variation of elastic properties of the strata which affect the velocity of the shock waves travelling through them, thus providing the useful information about the subsurface formations. This method has the outstanding advantages of being relatively cheap and rapid to apply and influencing large volume of rock-mass. The following information in respect of the rock mass is obtained from these tests:

a) Location and configuration of bed rock and geological structures in the subsurface;

b) The effect of discontinuities in rock mass can be estimated by comparing the *in situ* compressional wave velocity with laboratory sonic velocity of intect core obtained from the same rock mass.

RQD percent $\doteqdot$ Velocity Ratio

$$= (V_F/V_L)^2 \times 100$$

where

V_F = compressional wave velocity in rock mass, and

V_L = compressional wave velocity in intact rock core.

4.4.1.2 For seismic method, Appendix B to IS 1892 : 1979 may be referred.

4.5 Detailed Exploration

Detailed investigations follow preliminary investigation and should be planned on the basis of data obtained during reconnaissance and preliminary investigations. Detailed investigation includes the following:

a) Open pit trials,

b) Exploratory drilling,

c) Sampling,

d) Laboratory testing, and

e) Field testing.

4.5.1 *Open Pit Trials*

The method of exploring by open pit consists of excavating trial pits at site and thereby exposing the rock surface for visual inspection, geological mapping, *in situ* field testing and for obtaining rock samples for laboratory testing. This method is generally used for small depths fissures and zones of weak rocks which would breakup in core barrel.

4.5.2 *Exploratory Drilling*

The purpose of a drilling investigation is to:

a) Confirm the geological interpretations,

b) Examine the cores and bore holes to determine the quality and characteristics of the rock mass,

c) Study the ground water condition, and

d) Provide cores for laboratory testing and petrographic analysis.

4.5.2.1 Various methods of exploratory drilling have been described in IS 1892 : 1979. Following methods are recommended for exploration in rock mass:

a) *Percussion drilling*

This method is more suitable in boulderous and gravelly strata. As percussion drilling does not provide us even the representative samples, they are not suitable for careful investigation.

b) *Core-drilling*

An object of the drilling is to obtain rock cores for interpretation and testing. It is necessary to obtain cent percent core recovery as far as possible. To ensure a successful drilling operation, the following aspects should be remembered:

i) The drilling facilities permitting cores of at least NX size (54 mm diameter) and featuring split double tube core barrels to minimize drilling vibrations.

ii) It should also include for performing water pressure tests.

iii) Examination of bore hole walls by bore hole cameras should also be considered.

iv) Cores should be photographed as soon as possible and should be carefully marked, placed in protective wrappings in the core boxes and properly stored.

v) A systematic method should be used for geotechnical logging of cores which should include the history of drilling, for example, type of bit, rate of drilling and water test data, core recovery, RQD, weathering and description of rock.

vi) Each bore hole shall contain one piezometer set at the bottom of the bore hole so that once installed piezometers can be observed over an extended period.

vii) If ground water contain harmful chemicals, its sulphate content and *p*H value shall be measured by chemical analysis of ground water.

c) *Shot drilling*

The system is used on large diameter holes, that is, over 150 mm. Due to necessity of maintaining the shots in adequate contact with the cutting bit and the formation, holes inclined over 5° to 6° can not be drilled satisfactorily. The system is different from other types of core drillings because the coarser cuttings do not return to the surface but are accumulated in a chip cup immediately above the bit and here the chilled shot is used as an abrasive in place of the drill head.

4.6 Sampling

4.6.1 Rock samples commonly used in laboratory testing are lumped samples, block samples and core samples. IS 9179 : 1979 should be referred to for methods of sample preparation.

4.6.2 Rock lumps are obtained from exposed rock formations or pieces of block samples. However, core samples may be used as lumped samples.

4.6.3 *Block Samples*

Such samples taken away from the rock formation shall be dressed to a size convenient for packing to about 100 mm × 75 mm × 75 mm. Many times a large blocks of size 300 mm × 300 mm × 300 mm are ob tained from site and specimens of required sizes are prepared in the laboratory.

4.6.4 *Core Samples*

Core obtained from core drilling or shot drilling process are used as core samples.

4.7 Laboratory Testing

The strength of the rock material may be estimated by means of laboratory tests on intact rock specimens. Most frequently used laboratory tests are described in **4.7.1** to **4.7.6**.

4.7.1 *Point Load Strength Index Test*

This test is very fast and cheap for estimating the point load strength index (I_s). The test may be conducted on core pieces of length more than 1·5 times the diameter. Provisions of IS 8764 : 1978 shall be complied with for this test.

4.7.2 *Point Load Lumped Strength Index Test*

This test is conducted on lump pieces of rock material. The depth of the specimen (D) between the points should be less than the width of the specimen but should be more than one third width of the specimen. Point load lump strength index (I_L) is calculated by the following formula:

$$I_L = \frac{P}{(DW)^{0.75} \times \sqrt{5.0}}$$

where

I_L = point load lump strength index, in kg/cm²;

P = the peak load, in kg, at failure; and

(DW) = the cross-sectional area of fractured surface, in cm²;

Uniaxial compressive strength q_c is related to point load lump strength index by:

$$q_c \simeq 15 \times I_L$$

4.7.3 *Uniaxial Compressive Strength Test*

This test is conducted on the core samples or block samples having length about 2·0 and 3·0 times the diameter/breadth of the sample on the universal compression testing machine. For carrying out this test and analysis of the test data provisions of IS 9143 : 1979 shall be complied with.

4.7.4 *Brazilian Test*

It is an indirect method of estimating the tensile strength of rock material. In this, a cylindrical rock specimen lying on its sides is loaded diametrically with compression load so as to bring about a uniformly distributed tensile stress over the vertical, central and diametrical plane. This test should be conducted according to the provisions of IS 10082 : 1981.

4.7.5 *Direct Shear Strength Tests*

These tests may be conducted without normal stress or with normal stress on shear planes. These tests are conducted for shearing through intact rock specimen as well as along the weak planes, for example, joints surfaces, bedding planes, etc.

4.7.6 *Ultra Sonic Interferometry Tests*

These tests are conducted on core sample to measure the time of travel of p-wave in rock material and then the p-wave velocity and elastic modulus of rock material is calculated. It is a quick and cheap test for determining the elastic modulus of intact rock material.

4.8 *In Situ* **Tests**

Rock strength tests are performed because rock mass may contain various discontinuities and plane of slippages which reduces its strength to a fraction. Following *in situ* tests on Rock masses are recommended.

4.8.1 *Plate Load Test*

Plate load test shall be performed on the foundation rocks according to IS 1888 : 1981 and a curve between pressure on plate *versus* its settlement is obtained. Using pressure-settlement curve the allowable bearing capacity corresponding to the permissible maximum settlement of foundation can be evaluated as per **8** of IS 12070 : 1987. This curve is also used to calculate the settlement of the footing for the actual bearing pressure on them.

NOTE — Horizontal plate load test may be conducted where vertical plate load test is not feasible.

4.8.2 *Block Shear Test*

Block shear test shall be conducted on the foundation rocks *in situ* as per IS 7746 : 1975 to evaluate the shear characteristics of the rock mass. These tests shall be carried out along the surface parallel to the base of the footing. In case of laminated/jointed rock mass, these tests shall also be conducted along the lamination planes or joint planes to assess the shearing characteristics along the planes. Concrete block shear test shall also be carried out on the *in situ* foundation rocks to assess the shear characteristics of joint between the rock mass and the concrete.

4.8.3 *Pressure Meter Test*

Pressure meter test allows for a direct determination of the strength of rock mass including discontinuities and weathering for design of foundation on weak rocks.

4.8.4 Uniaxial Jacking Test as per IS 7317 : 1974 may be conducted on the two opposite walls of a drift or gallery to determine the modulus of deformation of rock mass.

4.8.5 Seismic refractive surveys are conducted to delineate the rock profile and to measure the velocity of *p*-waves in rock mass.

4.9 Choice of Method

4.9.1 The choice of method of exploration and the tests depends upon the nature of ground, topography, importance and size of building and cost.

4.9.2 In case of lightly loaded foundation (wall footings up to three storey actual bearing pressure on foundation up to 20 t per square metre) may be less than safe allowable pressure for weakest rock and size of foundation in such cases would be decided by other considerations. In such cases, it would be adequate to ensure that any type of rock other than boulder exists at foundation level.

4.9.3 Where rock is exposed over large area of building prior to construction or will be exposed after excavation, visual inspection of the rock surface provides a very reliable estimate of the type and quality of rock and the discontinuities of rock mass can be mapped from the exposed surface. The number of drill holes and tests to be conducted will depend upon the nature and type of rocks exposed and the size and importance of the building.

4.9.3.1 *Number of drill holes*

a) In massive crystalline rocks, drilling may be omitted altogether, except in case of very large/important buildings in which case one hole for every 1 000 m^2 of area with a minimum of 3 holes shall be drilled.

b) In moderately jointed and foliated rocks, one drill hole for every 300-500 m^2 of area shall be drilled. A minimum of 5 drill holes shall be drilled in case of foundations for very large, heavy and important buildings.

c) In heavily jointed, sheared and weathered rock mass, one drill hole for every 200-300 m^2 area shall be drilled.

4.9.3.2 *Depth of holes*:

a) The depth of drill hole below the foundation level should be equal to half of effective width of the foundation system in case of massive and sound rocks.

b) In moderately jointed and foliated rocks, the depth of drill holes below the foundation level should be equal to the effective width of the foundation system.

c) In heavily jointed and weathered rocks the depth of drill holes below the foundation level should be equal to twice the effective width of the foundation system.

d) Drill holes shall extend inside the rock mass to a minimum depth of 3 m.

e) In the case of solid rock below jointed rock the drill hole shall extend below the foundations as per (b) and (c) above as appropriate or half the effective width into solid rock whichever is shorter.

4.9.4 Where the rock is not exposed on the surface, one hole shall be drilled for every 300-500 m^2 of the area to know about the subsurface formations. If the depth of rock is irregularly varying with the adjacent holes, more holes shall be drilled to fairly estimate the rock profile. The criteria for depth of hole shall be same as **4.9.3.2**.

4.9.5 If the foundation rock happens to be lime stone and dolomite associated with ground water flow, there is a likely chance of solution cavities underneath. In such cases, drill holes shall be drilled up to depth of at least one and half time the effective width of the foundation below the foundation level.

4.9.6 If the foundation rock happens to be consolidated sand rock; silt stone or clay shale with likely chance of getting saturated, necessary exploration and testing shall be conducted assuming it to be the soil.

4.9.7 *Selection of Tests*

4.9.7.1 For foundations on massive rocks, subjected to mainly vertical loads, only the tests for point load strength index or uniaxial compressive strength may be required.

4.9.7.2 For foundations on massive rocks subjected to heavy horizontal loads, concrete block shear tests and *in situ* shear test shall be conducted to check stability against sliding.

4.9.7.3 For foundations on moderately jointed rocks, the tests for points load strength index or uniaxial compression strength and *in situ* shear test shall be carried out.

4.9.7.4 For foundations on very weak and weathered rocks, plate load test or pressure meter test and *in situ* sheer test shall be carried out.

4.10 Presentation of Geological Data

4.10.1 In summary, the following geotechnical and geological informations are considered important in the stability of the building foundations on rock mass:

a) Rock type and origin;

b) Orientation of discontinuities in the rock mass;

c) Spacing of discontinuities in the rock mass;

d) Condition of discontinuities including roughness separation, continuity, weathering and infilling (gauge);

e) Ground water conditions;

f) Major faults;

g) Properties of the rock material that is uniaxial compressive strength, point load lump strength index; and

h) Drill Core Quality (RQD).

For evaluation and presentation of the above data, IS 11315 (Parts 1 to 11) shall be referred.

4.10.2 Communication between the engineering geologist and the design engineer will be greatly enhanced, if the data is presented in standard format. The followings are recommended:

a) Bore hole should be presented in well executed geotechnical logs.

b) Mapping data should be presented as spherical projection or surface projections.

c) Longitudinal and cross-sections of structural geology at the site should form an integral part of a geological report.

d) For every important structures consideration should be given to constructing a geological model of the site.

e) A summary of all the geotechnical and geological data including the ground water conditions should be entered in the input data sheet for rock mass classification purpose.

4.11 General Stability of Area

4.11.1 When slopes develop instability, there is little that can be done to protect an existing building in the affected areas. Area subject to land slips, mass movements and unstable slopes, shall, therefore, be avoided.

4.11.2 If there happen to be an old slip zone near the site of the buildings, detailed stability analysis of the area shall be carried out and worst probable slip zone shall be demarcated. No buildings shall be constructed in the area which is 200 m or less away from the boundary of the maximum probable slip zone.

4.11.3 If the area happen to be hilly terrain, before planning and approving a building complex on the slopes, detailed stability analysis of the slopes shall be carried out and maximum amount of the load that can be placed by way of buildings construction and their occupants on particular area shall be worked out and notified. Regulations shall be promulgated to effectively control construction in sensitive areas.

4.11.4 While carrying out the stability analysis of the zone where building complex is proposed, change in the subsurface water conditions due to development of township shall be accounted for.

4.11.5 Mass movements of the ground are liable to occur from causes independent of the presence of the building. These include excavation, saturation, mining subsidence, land slips on unstable slopes and creep on slopes. These factors shall be taken into account in the design and expert advice shall be sought, wherever required.

4.11.6 On uphill side of a building on a sloping site, drainage requires special considerations. The natural flow of water shall be diverted away from the foundation.

4.11.7 No trees which grow to a large size shall be planted within 8 m of the foundations of buildings.

5 GENERAL CONSIDERATIONS FOR DESIGN (SAFETY)

5.1 Loads on Foundation

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

a) Dead load, live load, earth pressure, water pressures/snow load in areas where it is encountered.

b) Dead load, live load, earth pressure, water pressures/snow load where it is encountered with wind or seismic load.

5.1.2 Dead load also includes the mass of column/wall, footings, foundations, the overlying fill including frost, if encountered, ignoring the mass of soil displaced by foundation system.

NOTE — There are a number of states in India where snow will be encountered during winter or perenially over underlying bed rock on which the foundation system is intended to be constructed.

5.1.3 Live loads from the floors above, as specified in IS 875 : 1964 shall be taken into account.

5.2 Allowable Bearing Pressures

5.2.1 Pressures coming on the rock due to building foundation shall not be more than the safe bearing capacity of rock-foundation system taking into account the effect of eccentricity. The effect of interference of different foundations should also be taken into account.

5.2.2 The total settlement of the foundation(s) shall not be more than permissible (recommended/allowable/tolerable) settlement (Sper) value that is

$$S \leqslant Sper$$

where

S = Calculated maximum average settlement due to imposed load under the footing; and

Sper = Permissible value of total settlement.

5.2.3 Differential settlement (ΔS) and/or tilt of the building (T) or/and part of a building shall be not more than the recommended values ΔSper and Tper respectively.

$$\Delta S \leqslant \Delta\ Sper$$

$$\text{and } T \leqslant Tper$$

where

ΔS = Calculated maximum value of differential settlement;

ΔSper = Permissible value of differential settlement;

T = Estimated value of maximum Tilt; and

Tper = Permissible value of Tilt.

5.2.4 The recommended values of permissible settlements, differential settlements and angular distortion (tilt) are tabulated in Table 1. Higher values of maximum settlement can be adopted in case of highly weathered and disintegrated rock masses.

5.2.5 For satisfying the conditions of **5.2.1**, **5.2.2** and **5.2.3**, load combinations as described in **5.1.1** shall be considered.

5.2.6 For satisfying the conditions laid down in **5.2.1** and **5.2.2**, safe bearing pressures shall be estimated in accordance with IS 12070 : 1987. When wind loads or seismic loads are considered, the safe bearing pressure may be increased by 25 percent and 33 percent respectively. The safe bearing pressure shall not exceed the allowable pressures for the grade of concrete/masonry of foundation slab or grade of concrete laid over the rock surface, whichever is lower.

5.2.7 The allowable bearing pressure should, then, be determined by the following steps:

a) Proportion footing making use of the safe bearing pressures value determined as per **5.2.5**;

b) Calculate differential settlements of footings;

c) Calculate angular distortions;

d) Compare the above values with those given in Table 1, and

e) If the comparison is not satisfactory, revise the allowable bearing pressure and repeat the steps (b), (c) and (d) until the comparison is satisfactory.

5.2.8 *Causes of Settlements*

For safety of building foundations, the engineer-in-charge should be well familiar with all causes of settlements. Foundations on rocks may settle due to combination of the following reasons:

a) Elastic compression of the foundation and the underlying bearing strata;

b) Ground movement on slopes due to erosion, creep or land slides;

c) Increase in ground water may soften the joint fill material, causing slippage along the joints;

d) Other causes such as adjacent excavation, mining, subsidence and underground erosion; and

e) Rock like schist, soft shale, etc, weather rather quickly and may cause post construction settlements within its life time.

Table 1 Maximum and Differential Settlements of Buildings on Rock Mass

(*Clause* 5.2.4)

Sl No.	Type of Structure	Maximum Settlement mm	Differential Isolated Footing mm	Settlement Raft Foundation mm	Angular Isolated Footing	Distortion Raft Foundation
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	For steel structure	12	·003 3L[1]	·003 3L	1/300	1/300
ii)	For reinforced concrete structures	12	·001 5L[1]	·002L	1/666	1/500
iii)	For plain bricks block walls in multistoreyed buildings					
	a) For $L^1/H^2 \leqslant 3$	12	·000 25L	—	1/400	—
	For $L^1/H^2 > 3$	12	·000 33L	—	1/300	—
iv)	For water towers and silos	12	—	0·002 5L	—	1/400

NOTE — The values given in the table may be taken only as a guide and the permissible settlement and differential settlement in each ease should be decided as per requiremets of the designer depending upon importance of structure.

[1]L — denotes the length of deflected part of wall/raft or centre to centre distance between columns.

[2]H — denotes the height of wall from foundation footing.

5.2.9 *Causes of Differential Settlements*

Some of the causes of differential settlement are as follow:

a) Non-uniform pressure distribution from foundation to rock mass;

b) Overlap of stress distribution in rock mass due to loads of adjacent structures;

c) Geological and physical non-uniformity of rock mass under the foundation;

d) Slippage along the weaker planes of rock mass;

e) Water table fluctuations at construction site;

f) Non-uniform structural disruptions or disturbances of foundation rocks due to freezing and thawing;

g) Movement of the rock mass due to instability of general slopes;

h) In soluble rocks, solution cavities may become larger with time and may lead to differential settlements; and

j) Seepage of water in foundation of a part of a building.

5.2.10 The foundations shall normally be so proportioned that no tension is created at the foundation plane.

5.2.11 If tension is created under the foundation, the maximum tensile stress shall be less than three fourth of the 7 day modulus of rupture of foundation concrete or of concrete laid between the foundation and rock surface whichever is less. For this purpose, tensile strength of rock or cable anchors, if any, shall not be considered.

5.2.12 If tension is created under the base, the maximum bearing pressure shall be calculated on the modified base area which remain in compression only.

5.3 Stability Against Overturning and Sliding

Stability of foundation against overturning and sliding shall be checked and factors of safety shall conform to the requirements specified in **5.3.1** and **5.3.2**.

5.3.1 *Sliding*

5.3.1.1 The factor of safety against sliding of structures shall not be less than 1·5 when dead loads, live loads, earth pressures, water pressures and uplift pressures are considered together with wind load or seismic force. When only dead load, live load, earth pressure, water pressure and uplift are considered; the factor of safety against sliding shall be not less than 1·75.

5.3.1.2 For buildings founded on sloping rock surface, the factor of safety against sliding shall be calculated along the rock surface. The factor of safety against sliding may be improved by anchoring the foundation to the deeper strata of rock.

5.3.1.3 The adhesion and the coefficient of friction between the concrete and the rock mass under dry and submerged conditions and also of foundation rocks along weak shear zones and bedding planes shall be determined by *in situ* block shear tests at site. For preliminary design the value given in Table 2 may be used.

Table 2 Values of Adhesion and Coefficient of Friction

(*Clause* 5.3.1.3)

Sl No.	Material	Adhesion kg/cm^2	Coefficient of Friction
i)	Massive and sound rock	5-10	0·80-1·0
ii)	Fractured, jointed rock	1-3	0·80

5.3.2 *Overturning*

The factor of safety against overturning shall be not less than 1·5 when dead loads, live loads, earth pressures and unlift are considered together with wind load or seismic forces. When only dead load, live load, earth pressures and uplift pressures are considered, the factor of safety shall be not less than 2.

5.4 Depth of Foundation

5.4.1 The minimum depth of foundation below the natural ground surface shall be 0·5 m.

5.4.2 In case of massive intact and unweathered rocks, the foundation can be laid over the rock surface after chipping off the top surface for preparation of a proper seat for the foundation.

5.4.3 In case of jointed, sheared and partially weathered rocks, the base of the foundation shall be kept at least 50 cm inside the rock surface, so that the upper portion of highly weathered rock mass is avoided. This would also take care of the error in judgement about the depth of rock surface.

5.4.4 In case of rock of very low strength, highly weathered rocks (for example: clay shales, sand rock and soft silt stone in *SHIVALIKS*), the depth of foundation shall be decided in accordance with provisions of IS 1904 : 1986, considering the foundation material to be as soil.

5.4.5 A foundation on any type of rock mass shall be below the zone significantly weakened by root holes or cavities produced by burrowing animals or worms. The depth shall also be enough to prevent the rain water scouring below the footing.

5.4.6 Where there is excavation, ditch or sloping ground adjacent to the foundation which is likely to impair the stability of a building, either the foundation of such building shall be carried down to depth beyond the deterimental influence of such conditions or retaining walls or similar works shall be constructed for the purpose of shielding from their effects.

5.4.7 It is usually accepted that if the foundation is bearing on sound and massive rock, it may be founded above the limit of frost penetration in areas where it is encountered. Any large or extensive seams, cracks, areas of disintegration in the rock should be cleaned and grouted up to the depth of maximum frost penetration by (1:1) cement sand mortar. For other type of rocks, the base of foundation shall lie below the depth of maximum frost penetration.

6 GENERAL REQUIREMENTS

6.1 Concerning of Foundation

6.1.1 Wherever a foundation is embedded partially or fully in rock mass, the foundation concrete shall be laid from surface to surface of rock mass on sides. This will prevent any chance of rock mass movement due to loosening effect on the sides of foundation (*see* Fig. 1).

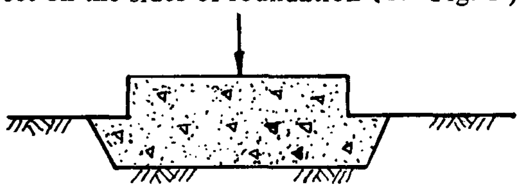


FIG. 1 EMBEDDED FOUNDATION

6.1.2 In case of presence of gypsum salt in the foundations, care be exercised to use sulphate resistant cement in the foundation.

6.2 Foundation Drainage

6.2.1 The surface drains in the building and around the building shall be so planned that water is drained away from the building.

6.2.2 All the surface drains, traversing jointed and weathered rocks in the built up area, shall be lined so as to prevent the entry of water to the foundation rocks.

6.2.3 If the springs/seepage of water is noticed on down slopes of a building complex, a suitable arrangement for free exist of water, provided with well designed filter, shall be made so as to prevent the flow material along with water.

6.2.4 If the foundations are laid on the water bearing rock mass either the well designed ground water drainage arrangement shall be provided so as to keep the ground water pressure below the foundations or the foundation shall be designed for the water pressures and uplift pressures which will be exerted on the foundations.

6.2.5 If the bearing rocks are overlain by water bearing strata, suitable drainage arrangement shall be provided around the building foundations and the water pressures and uplift pressures shall be accounted for in design of foundations.

6.3 Foundation on Soluble Rocks

If the foundation rocks are dolomite on lime stone and there is a possibility of g tting its joints charged with water, the joints shall be grouted with (1:1) cement sand motar up to the depth equal to effective width of the foundation. For grouting of foundation rocks, IS 6066 : 1984 may be referred.

6.4 Settlement Joints

It is recommended that settlement joints shall be provided on the buildings at places of abrupt change in the nature of foundation rock, superstructure or its layout in plan, for example, at the junction of the parts of a building with appreciably different number of storeys (*see* Fig. 2A) or where the outline of building in plan is sharply changed (*see* Fig. 2B) or where the compressibility of foundation strata abruptly changes (*see* Fig. 2C).

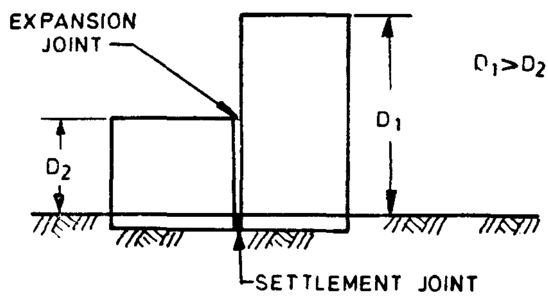


FIG. 2A ABRUPT CHANGE IN SUPERSTRUCTURE HEIGHT

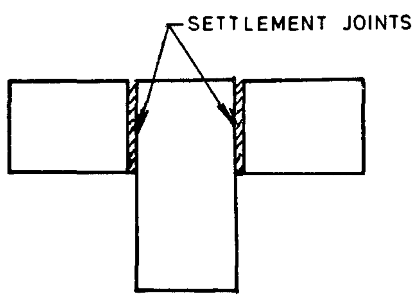


FIG. 2B ABRUPT CHANGE IN PLAN

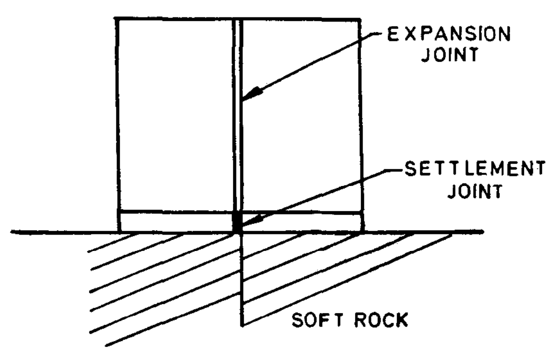


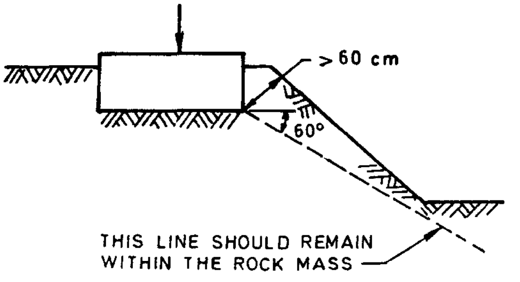
FIG. 2C FOUNDATION ON ROCK MASS OF TWO DIFFERENT COMPRESSIBILITIES

6.5 Foundations Adjacent to Sloping Ground

Where a foundation is to be constructed adjacent to the sloping ground, the following conditions shall be satisfied.

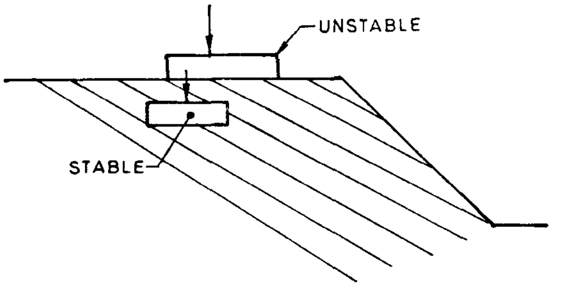
6.5.1 The frustum of bearing rock under the footing with sides, which make 60° with horizontal, shall remain within the sloping surface of rock (*see* Fig. 3A).

6.5.2 The minimum horizontal distance of lower edge of the footing shall be at least 60 cm away from the sloping surface (*see* Fig. 3A).



3A

6.5.3 If the bedding planes/weak shear planes of the rock mass are dipping towards the slope, the footing should be so located that any weak plane through the base or the footing is not exposed on the sloping rock surface. To achieve this, either the foundation may be shifted away from the slopes or the depth of foundation may be increased (*see* Fig. 3B).



3B

FIG. 3 FOUNDATION ADJACENT TO SLOPING GROUND

6.6 Foundation at Different Levels

Where foundations of the adjacent buildings are to be located at different levels, the following conditions shall be satisfied (*see* Fig. 4).

6.6.1 The minimum horizontal distance between the adjacent foundations shall be such that the loads from foundation at higher level are not transferred to the other foundation at lower level for which the lower foundation shall be outside the bearing frustum (making an angle of 60 with horizontal) and also the weak planes

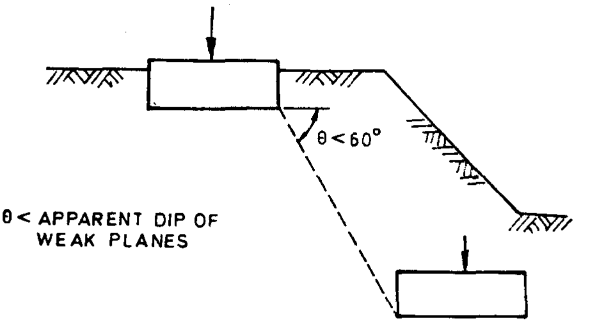


FIG. 4 FOUNDATION AT DIFFERENT LEVELS

crossing the base of higher foundation shall not cross the lower foundation.

6.6.2 If condition of **6.6.1** can not be complied with, the lower foundations shall be designed for the additional loads (horizontal and vertical) transferred from higher foundation and the construction of the lower foundation shall be done prior to construction of higher foundation.

NOTE — In hills, there is bad practice to construct the walls of a building directly over the retaining walls which are constructed in dry Random Rubble Masonry. Since the deformability of dry Random Rubble Masonry is very high in comparison to that of the wall masonry as well as the foundation rock mass, they normally give way leading to cracking of the houses and sometimes results in total collapse of the building. Such practice should be discontinued.

6.7 Detailing of Reinforcement

6.7.1 The requirement of IS 456 : 1978 shall be complied with.

6.7.2 In case of strip footings, the main reinforcement is provided along the width of footings. Some longitudinal reinforcement in the footing is desirable to assist in bridging over soft spots associated with heterogeneous conditions in rock masses. The longitudinal reinforcement in strip footing shall be not less than:

a) 0·15 percent (in case of mild steel) or 0·12 percent (when high steel deformed bars or welded wire fabric are used) of the total cross-sectional area on each face (top and bottom) of the RCC footing.

b) 25 percent of the main reinforcement.

7 TREATMENT OF ROCK DEFECTS

7.1 Open Vertical Joints

7.1.1 More or less vertical joints from one to several centimetres are sometimes encountered even in unweathered rocks. These joints may either be open or clay filled. Such joints shall be cleaned out to a depth of four to five times their width und filled with cement grout, a mixture of one part of cement and one part of sand with enough water to permit pouring of grout into the joints (*see* Fig. 5A). Large spaces, wider at top are commonly filled with dental concrete.

7.1.2 If the foundation rocks comprises of nearly vertical joints so wide that they constitute an appreciable fraction of area (more than 20 percent), the excavation is usually deepened until the joints are no longer within the base or they narrow down to acceptable limits (within 20 percent of base area).

than 20 percent of the total area, the joint shall be washed and cleaned for depth equal to 2 to 3 times the width of the joint and shall be filled up with the (1:1) cement sand grout (*see* Fig. 6).

8.1.2 If the area of weak seams under the foundation is more than 20 percent of the total base area, treatment as per **8.2** shall be done (*see* Fig. 7).

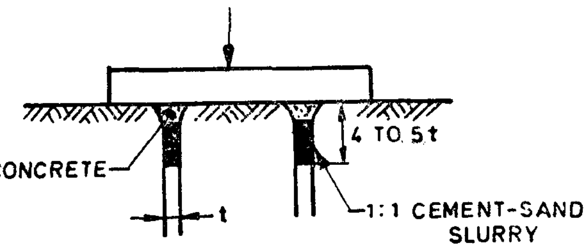


FIG. 5A STEEPLY DIPPING OPEN JOINTS

7.2 Open Horizontal Joints

Many rocks contain nearly horizontal joints which gets opened up due to relief in vertical stress. If such open joints are located beneath the foundations as shown in (Fig. 5B), the rock mass above the open joints shall be removed, if economically feasible, otherwise, the open space of the joints shall be filled with cement sand grout.

8.2 Foundation Rocks of Different Compressibilities

When foundation spans rock material of different compressibility, the following conditions should be complied with.

8.2.1 The design of the foundation shall be carried out for bearing pressures inversely proportional to the compressibility of the strata. The foundation section shall be designed for one and half times the moments and shear forces so calculated. Alternatively, the design of foundation can be carried out considering no bearing on weaker strata.

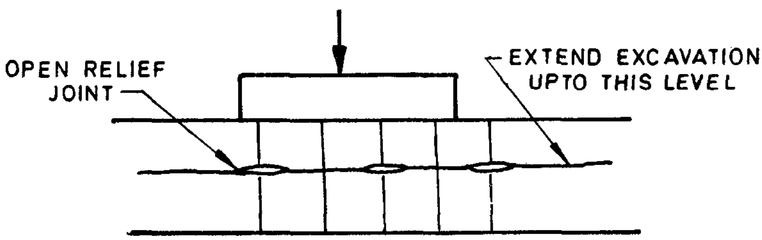


FIG. 5B OPEN HORIZONTAL JOINTS

7.3 Solution Cavities

Solution cavities require detailed attention. In bedded lime stone, cavities are more likely to occur in some horizons than in others. Exploration shall be carried out to locate the horizon where unfavourable conditions exist. If the area of cavities is less than 20 percent of the base area of foundation, the safe bearing pressure shall be reduced as prescribed in IS 12070 : 1987.

8 SPECIAL TREATMENTS

8.1 Weak Seams Under the Foundation

8.1.1 When inclined seams filled with soft material are located on the excavated rock surface under the foundation base covering less than 20 percent of the total area (continued above).

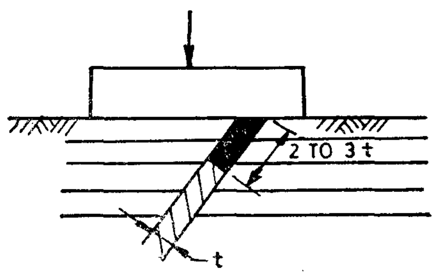


FIG. 6 WEAK SEAMS UNDER FOUNDATION LESS THAN 20 PERCENT OF AREA

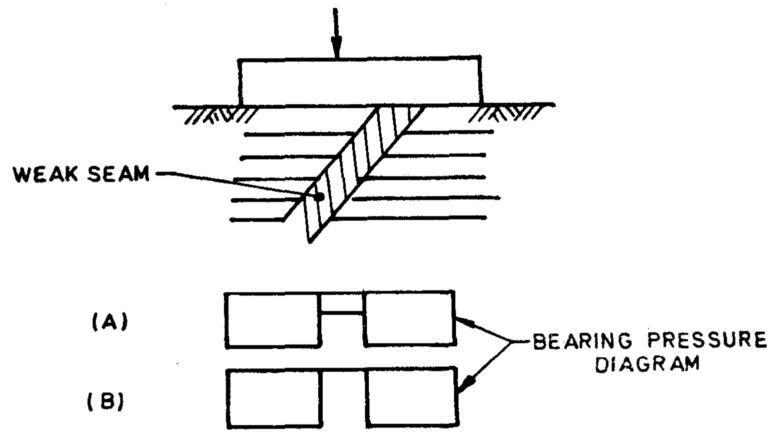


FIG. 7 WEAK SEAMS UNDER FOUNDATION MORE THAN 20 PERCENT OF BASE AREA

8.2.2 The maximum bearing pressure under the foundation shall also not exceed the allowable bearing pressure for the weaker strata.

8.2.3 The minimum reinforcement spanning the the weaker strata shall be not less than 0·5 percent of the cross section of foundation.

8.3 Foundation on Steeply Dipping Rock Surface

The foundations on steeply sloping (more than 15° with horizontal) rock surface shall normally be avoided. If it is obligatory to do so, the following safety measures shall be adopted in their design:

a) The foundation shall be embedded to a certain depth (*d*) inside the rock such that the prescribed factor of safety in sliding along the foundation plane are obtained. In these calculation, the support provided by the rock on down slope face of footing is accounted for (*see* Fig. 8). Shear strength of rock/cable anchors, even if provided, is not considered in these calculations;

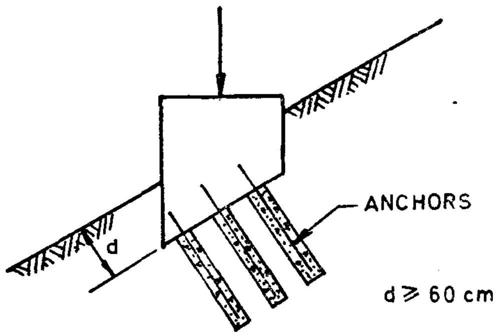


FIG. 8 FOUNDATION ON STEEPLY DIPPING SLOPES

b) The stability of foundation without bearing resistance on the down slope face shall also be checked. To ensure the desired factor of safety against sliding, rock/cable anchors may be provided. The size and number and depth of the anchors shall be worked out considering the required shearing strength of anchors, foundation size and the foundation rock;

c) Depth (*d*) shall not be less than 60 cm in any case;

d) Foundation level benches may be provided if possible at site. In such cases also the sliding stability shall be checked as if no benching was there; and

e) Wherever provisions of anchors is necessitated for increasing the stability of the structure, caution may be exercised to ensure that the sufficient length of anchors are embedded in the massive and fresh rock to mobilies rock action, and anchors extend well beyond slumpmass and computations for the mass of slumpmass be also taken into consideration.

8.4 Foundation on Moderate Slopes

At locations, where the rock surface is gently dipping (less than 15° with horizontal), the rock footing shall be taken deep enough (not less than 30 cm) inside the rock such that desired factor of safety in sliding along the rock surface is achieved having considered the bearing resistance on down slope face. It should also be checked that even without the bearing support on down slope face of foundation, the factor of safety against sliding in worst loading condition is not less than 1·10 (*see* Fig. 9).

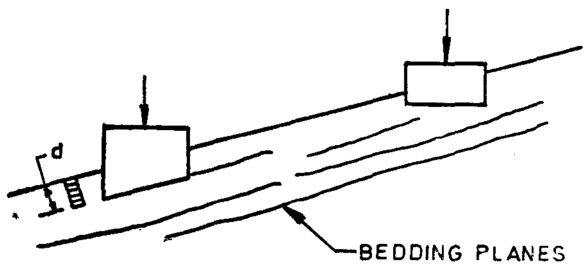


FIG. 9 FOUNDATIONS ON MODERATE SLOPES

8.5 Foundation on a Bench

If a foundation is provided over a bench whose bedding planes, or weaker planes are steeply dipping and getting exposed on the slope face, the stability of the rock mass alongwith the superimposed loads by the foundation, shall be checked along the deepest exposed weak plane and it shall be ensured that:

a) Desired factor of safeties are achieved. If not, rock anchors may be provided to achieve it (*see* Fig. 10).

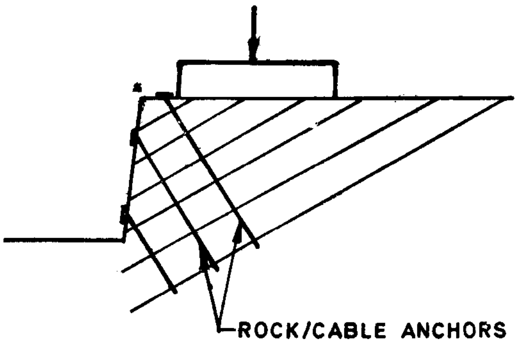


FIG. 10 FOUNDATION OF STEEPLY DIPPING STRATA ON A BENCH

b) If rock anchors are required to make the wedge stable, factor of safety against sliding shall also be checked ignoring the shearing strength of rock anchors and it shall be not less than 1·10 in worst probable condition.

8.6 Foundation on Rock Shelf

8.6.1 If a foundation is so located that the bearing strata is underlain by soft material and the minimum depth of the hard rock under the base of footing is more than the thickness of footing (*see* Fig. 11A). In such cases, the soft material shall be removed up to a distance and filled up with concrete so that the soft material is not encountered up to the thickness equal to half the width or twice the thickness of the footing whichever is larger.

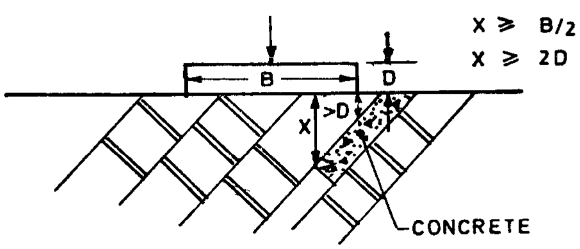


FIG. 11A FOUNDATION ON STEEPLY DIPPING CLAY SEAM

8.6.2 If removal of soft material, as required in **8.6.1**, loosen or dislocate the top rock mass or the thickness of top hard rock is less than the thickness of footing, the top rock shall be removed and the foundation shall be laid on the lower hard strata (*see* Fig. 11B). In such case, the side support from top hard strata shall be ignored in calculations.

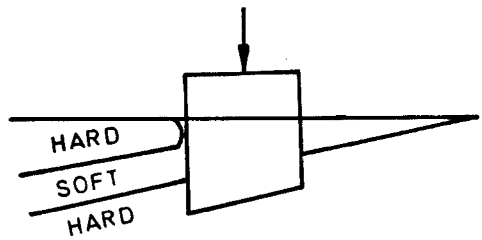


FIG. 11B FOUNDATION ON MODERATELY DIPPING CLEAR SEAM

8.7 Undulating Rock Surface

If the rock surface profile is highly undulating due to solution cavities or any other reason (*see* Fig. 12) the loose material from the undulations shall be removed up to the depth that remaining surface area of loose material be not more than 20 percent of total area and shall be backfilled with lean concrete having allowable bearing stress more than maximum bearing pressure under the footing.

8.8 Foundation on Soft Rock Over Laid on Steeply Dipping Hard Rock

The footing shall be so located that the minimum thickness of bearing strata over the hard rock shall be more than one third of the base width of foundation and also more than one metre. Otherwise piles, bearing on hard strata, shall be provided (*see* Fig. 13).

8.9 Foundation on Different Rock Masses

If a building is so located that part of it rests on hard rock and remaining part on soft rock

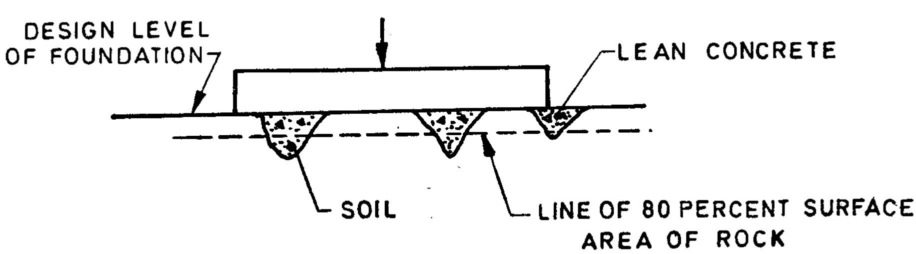


FIG. 12 FOUNDATION ON UNDULATING ROCK SURFACE

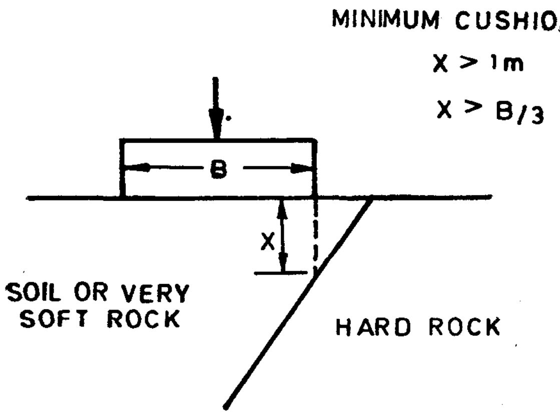


FIG. 13 STEEPLY DIPPING JOINT PLANE

(*see* Fig. 14), then a settlement joint shall be provided in the foundation at such location that the minimum depth of soft rock under the base of one footing is not less than one third of the width of the footing and the other footing rest solely on the hard rock.

8.10 Stepped Foundation for Multistorey Frames

In case a multistorey building is to be constructed on hill slope (*see* Fig. 15) the following criteria shall be adopted:

a) The stability of the rock slopes alongwith the load on it due to the building shall be ensured;

b) The building frame shall be so planned that column points are located on inner side of the rock benches;

c) The columns shall be well anchored into the foundation rocks to provide complete fixity at base. The minimum depth of

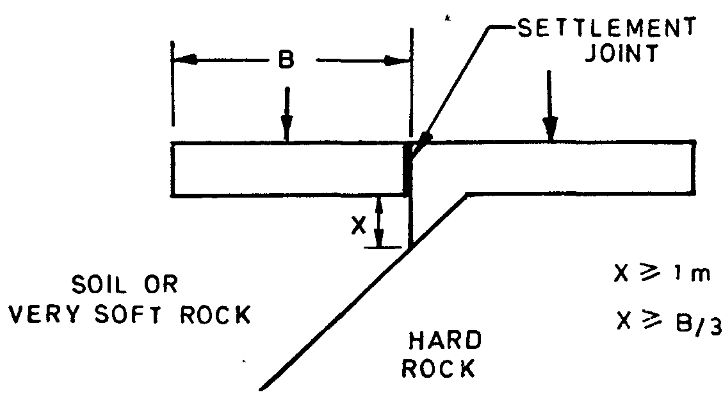


FIG. 14 FOUNDATION ON DIFFERENT ROCK MASSES

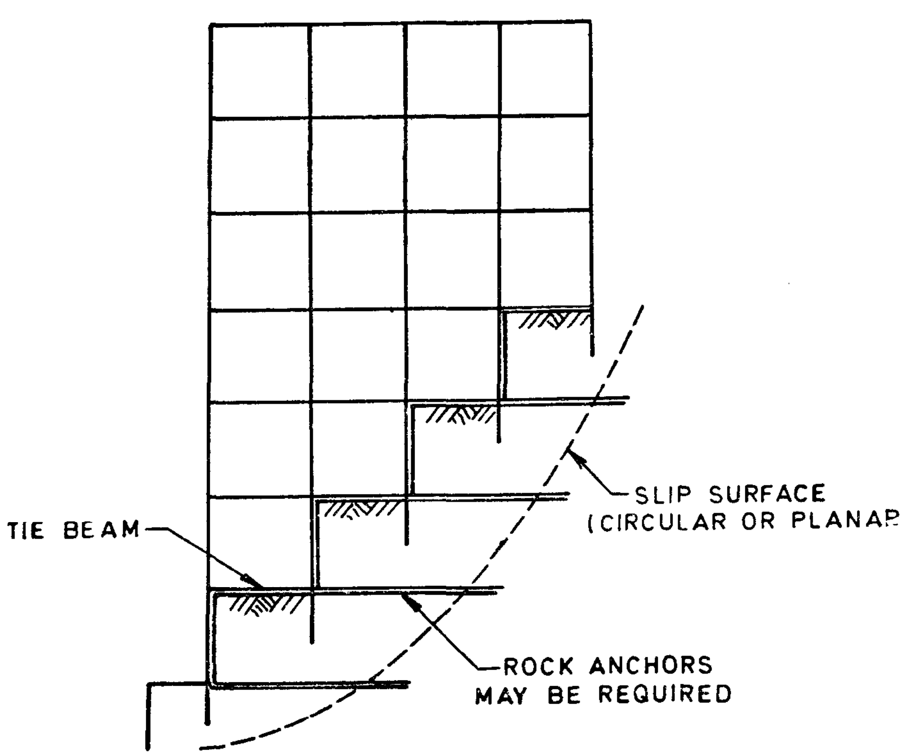


FIG. 15 MULTISTOREY BUILDING ON ROCK SLOPE

column foundation shall be at least one metre below the excavated terrace level;

d) The beams shall be provided between the columns at plinth level as to increase the stiffness of the RCC frame of the building;

e) The frame may be anchored to rock mass with the help of horizontal anchors at each beam level, if required, to stabilize the terraces or the frame itself; and

f) The building frame shall be designed for the probable differential settlement due to non-uniformity of foundation rock. The common practice in such cases is to provide stiff column with slender beams so that the beam column joints behaves as hinge joints.

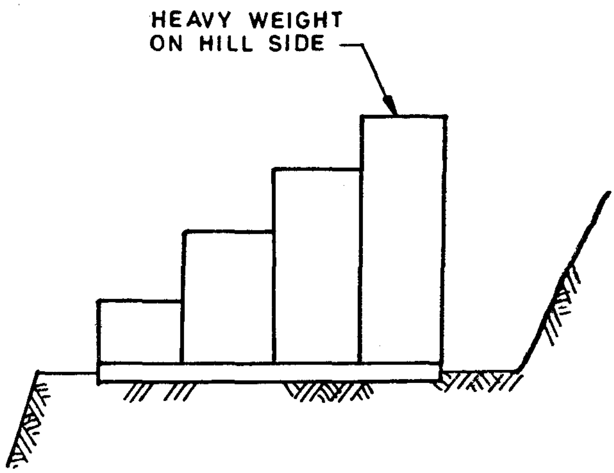


FIG. 16 RAFT FOUNDATION ADJACENT TO HILL SLOPES

8.11 Raft Foundations Adjacent to Hill Slope

If a raft foundation is to be constructed adjacent to hill slope, if possible, the building shall be so planned that heavier part of the building are located on the up hill side part of the raft to provide better stability (*see* Fig. 16).

8.12 Foundations on Slopes of Tallus Deposits

In case of buildings up to two storeys are required to be built on steep hill slopes dipping more than 15, wall and column construction will not be possible. At such sites, flexible structure which can withstand small ground movements is best suited. Still type foundation shown in Fig. 17 is one of that type. These consist of wooden or steel framed structures with fibre glass, aluminium or G.C. steel roofing and walls clad with PVC sheets. The roofs are constructed of wooden planks. The depth of foundation in loose tallus deposit shall be at least 2 m.

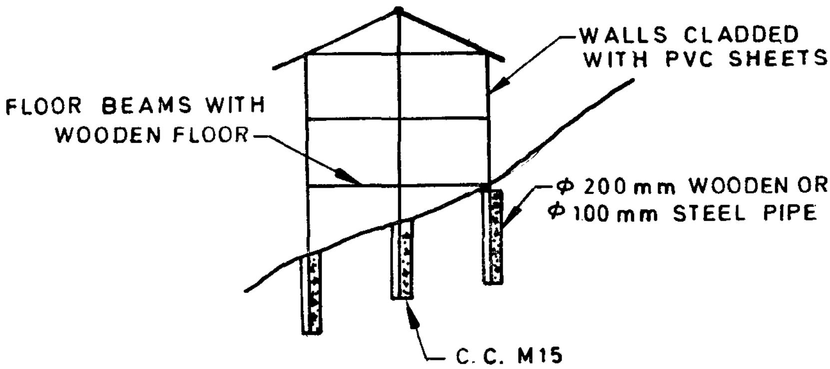


FIG. 17 STILL FOUNDATION

ANNEX A
(*Item* 2)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*
456 : 1978	Code of practice for plain and reinforced concrete (*third revision*)
875 : 1964	Code of practice for design loads (other than earthquake) for building and structures: Part 2 Imposed loads (*second revision*)
1888 : 1982	Method of load test on soils (*second revision*)
1892 : 1979	Code of practice for subsurface investigation for foundations (*first revision*)
1904 : 1986	Code of practice for design and construction of foundations in soils: general requirements (*third revision*)
2809 : 1972	Glossary of terms and symbols relating to soil enginnering (*first revision*)
6066 : 1984	Recommendations for pressure grouting of rock foundations in river valley projects (*first revision*)
7317 : 1974	Code of practice for uniaxial jacking test for deformation moulds of rock
7746 : 1975	Code of practice for *in situ* shear test on rock
8764 : 1978	Method of determination of point load strength index of rocks
9143 : 1979	Method for the determination of unconfined compressive strength of rock materials
9179 : 1979	Method of preparation of rock specimen for laboratory testing
10082 : 1981	Method of test for determination of tensile strength by indirect tests on rock specimens
11315	Methods for the quantitative description of discontinuities in rock mass
11315 (Part 1) : 1987	Orientation
11315 (Part 2) : 1987	Spacing
11315 (Part 3) : 1987	Persistence
11315 (Part 4) : 1987	Roughness
11315 (Part 5) : 1987	Wall strength
11315 (Part 6) : 1987	Aperture
11315 (Part 7) : 1987	Filling
11315 (Part 8) : 1987	Seepage
11315 (Part 9) : 1987	Number of sets
11315 (Part 10) : 1987	Block size
11315 (Part 11) : 1985	Core recovery and rock quality designation
12070 : 1987	Code of practice for design and construction of shallow foundation on rocks

Standard Mark

The use of the Standard Mark is governed by the provisions of the *Bureau of Indian Standards Act, 1986* and the Rules and Regulations made thereunder. The Standard Mark on products covered by an Indian Standard conveys the assurance that they have been produced to comply with the requirements of that standard under a well defined system of inspection, testing and quality control which is devised and supervised by BIS and operated by the producer. Standard marked products are also continuously checked by BIS for conformity to that standard as a further safeguard. Details of conditions under which a licence for the use of the Standard Mark may be granted to manufacturers or producers may be obtained from the Bureau of Indian Standards.

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Indian Standards are reviewed periodically and revised, when necessary and amendments, if any, are issued from time to time. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition. Comments on this Indian Standard may be sent to BIS giving the following reference :

Doc : No. CED 48 (4463)

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Amend No.	Date of Issue	Text Affected

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