IS 12070 (1987): Code of Practice for Design and Construction of Shallow Foundations on Rocks [CED 48: Rock Mechanics]

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Indian Standard

CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF SHALLOW FOUNDATIONS ON ROCKS

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BUREAU OF INDIAN STANDARDS
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CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF SHALLOW FOUNDATIONS ON ROCKS

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AMENDMENT NO. 1 NOVEMBER 2008
TO
IS 12070 : 1987 CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF SHALLOW FOUNDATIONS ON ROCKS

(*Page* 6, *Table* 2) — Substitute '30' *for* '40' *for* value of 'q_{ns} (t/m^2)' against 'Soft shale'.

(*Page* 6, *Table* 3) — Substitute the following for the existing values of 'q_{ns} (t/m^2)':

600-448 440-288 280-141 135-48 45-30

(CED 48)

Reprography Unit, BIS, New Delhi, India

Indian Standard

CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF SHALLOW FOUNDATIONS ON ROCKS

0. FOREWORD

0.1 This Indian Standard was adopted by the Bureau of Indian Standards on 30 April 1987, after the draft finalized by the Rock Mechanics Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 Shallow foundation cover such type of foundation in which load transfering is through direct bearing pressure of bearing strata and is normally up to 3 m from natural ground level. Rock is usually recognised as the best foundation material. However, design engineers should be aware of the dangers associated with hetrogeneity and unfavourable rock conditions since over stressing a rock foundation may result in large differential settlements or perhaps sudden failure. Therefore, a separate code covering shallow foundation on rock has been formulated.

0.3 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 of 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 design, construction and methods of estimating the safe bearing pressures of rocks for shallow foundations based on strength, allowable settlement and classification criteria.

2. TERMINOLOGY

2.0 For the purpose of this standard, the definitions of terms given in IS : 2809-1972† and IS : 11358-1986‡ shall apply.

*Rules for rounding off numerical values (*revised*).
†Glossary of terms and symbols relating to soil engineering (*first revision*).
‡Glossary of terms and symbols relating to rock mechanics.

3. GENERAL

3.1 The design of a foundation unit normally requires that both bearing capacity and settlement are checked. While either bearing capacity or settlement criteria may provide the limiting condition, it is normal for settlement to govern. Structural distress from settlement as evidenced by such occurrences as cracking and distortion of doors and window frames, is common experience in hills.

3.2 The calculation of bearing capacity, the distribution of stresses, and the prediction of settlement and the choice of allowable load will depend on the following factors, which should be fully considered during design:

i) *Occurrences During Excavation*

a) Undulating rock surface below a level ground;

b) Hetrogeneity of rock mass (the bearing capacity may vary up to 10 times in apparently the same rock mass because of presence of localized fractures/shear zones/clay gauge/clay weathering/alternate hard and soft beds, etc.

c) Solution and gas cavities;

d) Wetting, swelling and softening of shales/phyllite and expansive clays;

e) Bottom heave;

f) Potential unstable conditions of the slope; and

g) High *in situ* horizontal stresses.

ii) *Adjacent Construction Activities*

a) Blasting (Controlled blasting techniques such as line drilling, cushion blasting and presplitting are available if it is necessary to protect the integrity of the work just outside the excavation);

b) Excavation: and

c) Ground water lowering (excepting in highly pervious sedimentary rock, this phenomenon is rare in most of igneous and metamorphic rocks); and

d) Undesirable seismic response of the foundation.

iii) *Other Effects*

a) Scour and erosion (in case of abutments and piers);

b) Frost action;

c) Flooding (only erodible rocks like sale and phyllite); and

d) Undesirable seismic response of the foundation.

3.3 The permissible settlement for calculation of safe bearing pressure from plate load test should be taken as 12 mm even for large loaded areas. The low value for settlement of foundation is due to hetrogeneity of rocks. In case of rigid structures like R.C.C. silos, the permissible settlement may be increased judiciously, if required.

3.4 Where site is covered partly by rocks and partly by talus deposits or soil, care should be taken to account for hetrogeneity in deformability of soil and rocks. It is recommended that plate load tests be conducted on talus or soil and bearing pressure be recommended considering 12 mm settlement, as is for rock.

4. APPLICABILITY OF METHODS FOR THE DETERMINATION OF SAFE BEARING PRESSURE ON ROCK

4.1 The methods proposed in this standard for the determination of the safe bearing pressure on rock apply for various ranges of rock quality, guidance on the applicability of the proposed methods is outlined in Table 1.

TABLE 1 APPLICABILITY OF METHODS FOR THE DETERMINATION OF SAFE BEARING PRESSURE ON ROCK

Basis of Design Method	Rock Quality	Clause No.
Rock mass classification	Good rock with wide (1 m to 3 m) or very wide (>3 m) spacing of discontinuities	5
Core strength	Rock mass with closed discontinuities at moderately close (0·3 to 1 m) spacing	6
Pressure meter	Rock of low to very low strength (<500 kg/cm^2): rock mass with discontinuities at close (5 to 30 cm) or very close (<5 cm) spacing, fragmented or weathered rock	7
Plate load test	Rock of very low strength (<250 kg/cm^2): rock mass with discontinuities at very close spacing; fragmented or weathered rock	9

Note — Although specific approaches have been outlined for various qualities of rock masses but each approach may be used for all qualities of rock, if required.

5. ESTIMATES OF SAFE BEARING PRESSURES FROM CLASSIFICATION TABLES

5.1 Universally applicable values of safe bearing pressure cannot be given. Many factors influence the safe bearing pressure and it will frequently be controlled by settlement criteria. Nevertheless, it is often useful to estimate the safe bearing pressure for preliminary design on the basis of the classification although such values should be checked or treated with caution for final design.

5.2 The classification of rock mass for assessing safe bearing pressure is listed in Table 2.

TABLE 2 NET SAFE BEARING PRESSURE (q_{ns}) BASED ON CLASSIFICATION

Material	q_{ns} (t/m^2)
Massive crystalline bedrock including granite, diorite, gneiss, trap rock	1 000
Foliated rocks such as schist or slate in sound condition	400
Bedded limestone in sound condition	400
Sedimentary rock, including hard shales and sandstones	250
Soft or broken bedrock (excluding shale), and soft limestone	100
Soft shale	40

5.3 Rock Mass Rating (**RMR**) —may also be used to give net allowable pressure as per Table 3. This will ensure settlement of raft foundation up to 6 m thickness to be less than 12 mm.

5.3.1 The RMR for use in Table 3 should be the average within a depth below foundation level equal to the width of the foundation, provided the RMR is fairly uniform within the depth. If the upper part of the rock, within a depth of about one fourth of the width of foundation, is of lower quality the value of this part should be used or the inferior rock should be removed. Since the values in Table 3 are based on limiting the settlement, they should not be increased if the foundation is embedded into the rock.

TABLE 3 NET SAFE BEARING PRESSURES BASED ON RMR

Classification No.	I	II	III	IV	V
Description of rock	Very good	good	Fair	Poor	Very Poor
R M R	100-81	80-61	60-41	40-21	20-0
q_{ns} (t/m^2)	600-448	440-288	280-151	145-90-58	55-45-40

6. ESTIMATE OF SAFE BEARING PRESSURE FROM THE CORE STRENGTH

6.1 Where the rock is sound the strength of the foundation rock is generally much in excess of the design requirements, provided the walls of the discontinuities are closed and they are favourably oriented (*see* Fig. 1) with respect to the applied forces. The investigations should, therefore, be concentrated on:

i) The identification and mapping of all discontinuities in the rock mass within the zone of influence of the foundation including the determination of the aperture (opening) of discontinuities;

ii) An evaluation of the mechanical properties of these discontinuities, frictional resistance, compressibility and strength of infilling material ; and

iii) The identification and evaluation of the strength of the rock material according to relevant Indian Standard.

6.2 In case of rock mass with favourable characteristics that is, rock surface is parallel to the base of the foundation, the load has no tangential component, the rock mass has no open discontinuities). The safe bearing pressure should be estimated from the equation :

$$q_s = q_c N_j$$

where

q_s = safe bearing pressure (gross),

q_c = average uniaxial compressive strength of rock cores,

N_j = empirical coefficient depending on the spacing of discontinuities (*see* Table 4 and Fig. 1)

$$= \frac{3 + S/B_f}{10\sqrt{(1 + 300\,\delta/S)}},$$

δ = thickness of discontinuities in cm,

S = spacing of discontinuities in cm, and

B_f = footing width in cm.

NOTE 1 — Equation includes a factor of safety of 3.

The relationship given is valid for a rock mass with a spacing of discontinuities greater than 0·3 m, aperture (opening) of discontinuities less than 10 mm (15 mm if filled with soil or rock debris) and a foundation width of greater than 0·3 m.

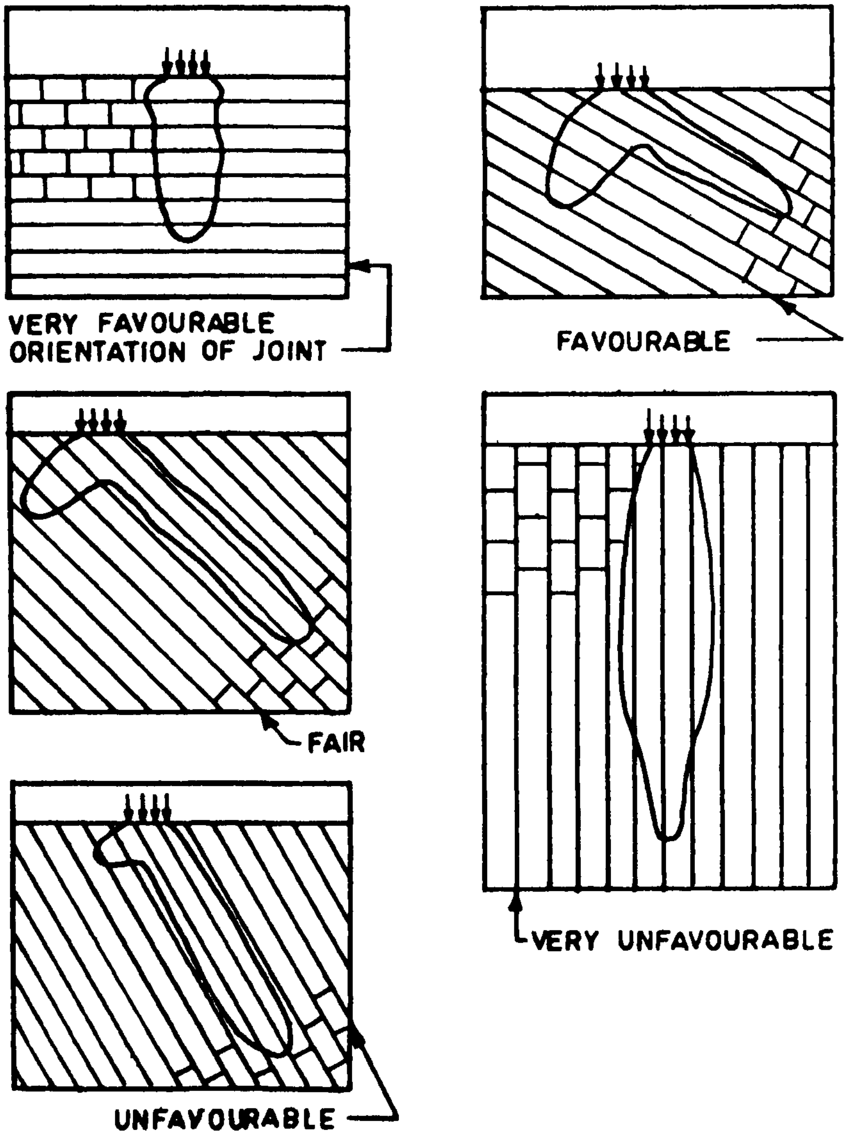

FIG. 1 THEORETICAL PRESSURE BULBS (10% INTENSITY) BELOW STRIP LOAD ON A MEDIUM OF ROCK MASS HAVING LOW SHEAR MODULUS

TABLE 4 VALUE OF N_j
(*Clause* 6.2)

SPACING OF DISCONTINUITIES cm	N_j
300	0·4
100-300	0·25
30-100	0·1

7. DETERMINATION OF SAFE BEARING PRESSURE FROM PRESSURE METER TEST

7.1 Conditions are frequently encountered where the rock is of very low strength and has discontinuities at a very close spacing, or is weathered or fragmented. It is common practice in such cases to consider the rock as a grannular mass and to design the foundation on the basis of conventional soil mechanics.

7.2 The pressure meter allows for a direct determination of the strength of a rock mass including the effect of discontinuities and weathering for the design of foundations on poor rock. Using an approximate factor of safety of 3 the following equation shall be used:

$$q_{ns} = \frac{1}{3} [\gamma D_f + K_d (P_L - \gamma D_f)]$$

where

q_{ns} = net safe bearing pressure (t/m²),
P_L = limit pressure determined by the pressure meter (t/m²),
γ = unit weight of soil or rock (t/m³),
D_f = depth of foundation (m).
γD_f = overburden pressure (t/m²), and
K_d = constant given in Table 5.

TABLE 5 VALUE OF K_d

DEPTH OF FOOTING	K_d
Load at rock surface (zero depth)	0·8
Radius* of foundation unit	2·0
4 × radius of foundation unit	3·6
10 × radius of foundation unit	5·0

*Equivalent radial dimensions.

8. DETERMINATION OF SAFE BEARING PRESSURE FROM PLATE LOAD TEST

8.1 Plate load test is still the most practical and proven test for recommending bearing pressures inspite of many limitations.

8.2 It is recommended that plate load tests be conducted on poor rocks where safe bearing pressure is suspected to be less than 100 t/m^2. A frequent mistake is committed in ignoring the fact that rock mass is very hetrogeneous material as compared to soil. So a large number rof observation pits be made at a rate of at least three per important ısucture and tests be conducted in the pit representing poorer rock qualitise. The final trimming of rock surface should be done according to IS : 7317-1974*.

8.3 Plate load test should be performed according to IS : 1888-1982† and safe pressures be obtained for settlements of plate. For a given settlement of footing, the settlement of plate is obtained by using the following formulae:

i) For massive or sound rocks $\dfrac{S_p}{S_f} = \dfrac{B_p}{B_f}$

ii) For laminated or poor rocks $\dfrac{S_p}{S_f} = \left[\dfrac{B_p}{B_f} \times \dfrac{(B_f + 30)}{(B_p + 30)} \right]^2$

where

S_p = settlement of plate (mm),
S_f = settlement of footing (mm),
B_p = width of plate (cm), and
B_f = width of footing (cm).

From pressure-settlement curve, the safe bearing pressure is read for the calculated settlement of the plate.

8.4 It is recommended that three plate load tests on different sizes of plates be conducted on the rock mass of same quality and the validity of equations be checked when desired.

8.5 From the pressure-settlement curve, if failure point can be obtained, the footing may be checked in shear failure also.

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*Code of practice for uniaxial jacking test for deformation modulus of rock.
†Method of load test on soils (*second revision*).

9. OTHER FACTORS

9.1 For getting the allowable bearing pressure the safe bearing pressure obtained from the Table 2 or from 6, 7 or 8 should be multiplied with the correction factor(s) given below according to the geological conditions. These corrections are not applicable for the classification of RMR method given in Table 5.

9.2 Allowances should be made for submerged conditions, cavities and slopes as given below:

i) *Submerged Condition Under Water Table*

a) Rock with discontinuous joints with opening less than 1 mm wide ; $\frac{3}{4}$

b) Rock with continuous joints with opening 1 to 5 mm wide and filled with clay; and $\frac{3}{4}$ to $\frac{1}{2}$

c) Limestone/Dolomite deposit with major cavities filled with soil $\frac{2}{3}$ to $\frac{1}{2}$

ii) *Cavities*

Major cavities inside limestone (core recovery less than 70 percent) $\frac{1}{2}$

NOTE 1 — If the solution cavities can be converted into equivalent seams, equation given in **6.2** can be used considering S/Bf as ratio of thickness of all solution cavities to the drill hole depth; and

NOTE 2 — All rocks with solution features are highly pervious, ground water control is essential where excavation below water level. If dewatering is impracticable, under water concrete should be placed only in static water by carefully supervised techniques.

iii) *Slopi*

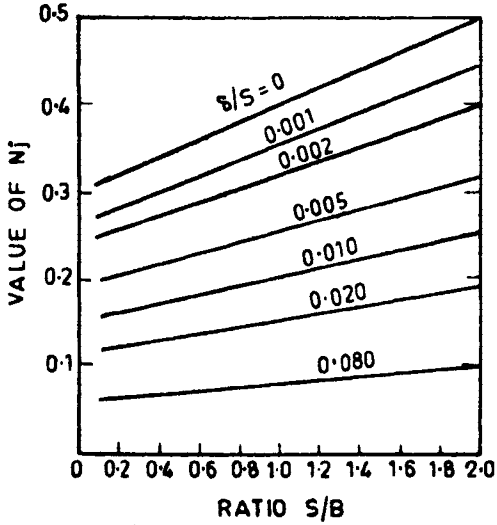
a) Fair orientation of continuous joints in the slope 1 to $\frac{1}{2}$

b) Unfavourable orientation of continuous joints in slope $\frac{1}{2}$ to $\frac{1}{3}$

NOTE — Factor of safety of slope should be at least 1·20.

9.3 Safe bearing pressure should be recommended always less than the safe uniaxial compressive strength of lean concrete levelling course of the individual foundations, otherwise richer plain concrete layer should be laid to prepare smooth surface for laying R.C.C. foundations. Care should be taken to remove loosened pieces of rock from the foundation after blasting and washing and air jetting has been done so that foundation rests on practically undisturbed rock mass.

9.4 Effect of Orientation of Joints on Pressure Bulb — The orientation of the continuous joints has a profound effect on the pressure bulb. It is seen that normal stresses are transmitted mainly in two directions, parallel to the joints and perpendicular to the major joints (*see* Fig. 2). When the major joints are gently sloping, the extent of the pressure bulb across major joints is more than that along the joints. The converse is true for steeply inclined major joints. The practical implications are serious, for example, the elongated stress bulb may act as an imaginary impervious curtain below a concrete dam founded on stratified rocks. Further the rock mass rating will be reduced considerably in case of unfavourably orientation of continuous joints. Accordingly the bearing pressure will also be reduced.



$$N_j = \frac{3 + S/B}{10\sqrt{1 + 300\,\delta/S}}$$

FIG. 2 BEARING PRESSURE COEFFICIENT N_j

9.5 Horizontal stiffness of foundations on rock is too small compared to its vertical stiffness. Due consideration should be given in selecting minimum size of footings.

9.6 In case rock is available in small area of the raft, Inverted-T-beam of raft foundation be allowed to rest on the rock and soil, as the confinement effect of T-beams will improve the stiffness of soil, thereby reducing the hetrogeneity in deformability of soil and rock.

9.7 In case of R C.C. strip foundation on hetrogeneous soil and rock deposit, longitudinal reinforcement (along wall) should also be provided to take care possible bending moments.

9.8 For similar reasons, circumferential reinforcement should be provided in ring foundation on hetrogeneous soil and rock deposit.

10. TREATMENT OF FOUNDATIONS

10.1 If at the time of actual excavation, major solution cavities have been found which have rendered the ground surface uneven, the depth of foundation should be taken to a level such that 80 percent rock area is available. It must be ensured that the raft does not over hang at any corner.

10.2 Otherwise excavate the filled up soil up to 80 percent area level and backfill it by lean concrete of required strength. However, the rock has to be excavated up to the pre-selected foundation level.

10.3 If after excavation, loose pockets of talus deposit are found out at a few places, the same should be cleaned and backfilled with lean concrete.

10.4 If very deep observation pits have been made at the site, the same should be backfilled by lean concrete up to the foundation level.

10.5 Due attention should be paid to problems of foundation on hetrogeneous rocks particularly foundations on rock slopes and neces ary remedial measures should be taken.

11. REPORTING OF RESULTS

These should include the following:

a) Geology of the site;

b) Table giving unaxial compressive strength, RMR, various geological parameters and unit weights;

c) Safe bearing pressure from various methods;

d) Correction factors;

e) Recommended net allowable bearing pressure; and

f) Recommended gross allowable bearing pressure.

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	*Unit*	*Symbol*
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	*Unit*	*Symbol*
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	*Unit*	*Symbol*	*Definition*
Force	newton	N	1 N = 1 kg.m/s^2
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1 c/s (s^{-1})
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2

BUREAU OF INDIAN STANDARDS

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