Indian Standard

CODE OF PRACTICE FOR DETERMINATION OF BEARING CAPACITY OF SHALLOW FOUNDATIONS

(First Revision)

Seventh Reprint AUGUST 2004

UDC 624.151.5 : 624.131.52 : 006.76

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Gr 4

November 1981

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(First Revision)

Foundation Engineering Sectional Committee, BDC 43

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0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 30 January 1981, after the draft finalized by the Foundation Engineering Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 The bearing capacity of foundations is needed for dimensioning the foundation for any structure. Several methods are available for the determination of bearing capacity of shallow foundations and this standard gives some of the methods which are commonly used for the purpose. Comparison of the results shows that when each of the various methods is applied to different problems no one method consistently gives higher or lower values of allowable bearing pressure. The designer must therefore regard the methods as aids to design which cannot replace the critical role of engineering judgement.

0.2.1 This standard was first published in 1971. The principal modifications made in this revision are: (a) keeping its terminology in line with that of other related Indian Standards, (b) giving generalized equations for calculation of ultimate bearing capacity, (c) including cone penetration methods and (d) deleting adjustment for fine sand and silt.

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 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.

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

1. SCOPE

1.1 This standard covers the procedure for determining the ultimate bearing capacity and allowable bearing pressure of shallow foundations based on shear and allowable settlement criteria.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

2.1 Terms Relating to Bearing Capacity

2.1.1 *Net Loading Intensity* — The net loading intensity on the foundation is the gross intensity of loading minus the weight of displaced soil above the foundation base.

2.1.2 *Ultimate Bearing Capacity* — The intensity of loading at the base of the foundation which would cause shear failure of the soil support.

2.1.3 *Safe Bearing Capacity* — Maximum intensity of loading that the foundation will safely carry without the risk of shear failure of soil irrespective of any settlement that may occur.

2.1.4 *Safe Bearing Pressure or Net Soil Pressure for Specified Settlement* — The intensity of loading that will cause a permissible settlement or specified settlement of the structure.

2.1.5 *Allowable Bearing Capacity* — The net intensity of loading which the foundation will carry without undergoing settlement in excess of the permissible value for the structure under consideration but not exceeding net safe bearing capacity.

2.2 General Terms

2.2.1 *Density Index (Relative Density)* — The ratio of the difference between the void ratios of cohesionless soil in the loosest state and any given state to the difference between its void ratios at the loosest and densest states.

2.2.2 *Effective Surcharge at the Base Level of Foundation* — The intensity of vertical pressure at the base level of foundation, computed assuming total unit weight for the portion of soil above the water table and submerged unit weight for the portion below the water table.

2.2.3 *Footing* — A structure constructed in brickwork, masonry or concrete under the base of a wall or column for the purpose of distributing the load over a larger area.

2.2.4 *Foundation* — That part of a structure which is in direct contact with soil and transmits loads into it.

2.2.5 *Shallow Foundation* — A foundation whose width is greater than its depth. The shearing resistance of the soil in the sides of the foundation is generally neglected.

3. SYMBOLS

3.1 For the purpose of this code and unless otherwise defined in the text, the following letter symbols shall have the meaning indicated against each:

A = Area of footing in cm^2

A' = Effective area of footing in cm^2

B = Width of strip footing, width of footing, side of square footing, diameter of circular footing in cm

B' = Effective width of footing in cm

b = Half of B

c = Cohesion in kgf/cm^2

c_1 = Undrained cohesion of the top layer in kgf/cm^2

c_2 = Undrained cohesion of the lower clay layer in kgf/cm^2

D_f = Depth of foundation in cm

D_w = Depth to water table in cm

d = Depth of top clay layer with undrained cohesion c_1

$d_c, d_q, d\gamma$ = Depth factors

e = Eccentricity of loading in cm

e_B = Eccentricity of loading along the width in cm

e_L = Eccentricity of loading along the length in cm

H = Horizontal component of loading in kgf

$i_c, i_q, i\gamma$ = Inclination factors

K_d = Depth factor (varies linearly from 1 for depth D_f = 0 to 1·33 for depth D_f = B)

L = Length of footing in cm

L' = Effective length of footing in cm

N = Corrected standard penetration value

$N_c, N'_c, N_q, N'_q, N\gamma, N'\gamma$ = Bearing capacity factors

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$$N\phi = \tan^2 (\pi/4 + \phi/2)$$

q = Effective surcharge at the base level of foundation in kgf/cm²

q_a = Net soil pressure for a specified settlement of 25 mm in kgf/cm²

q_c = Static cone penetration resistance in kgf/cm²

q_d = Net ultimate bearing capacity based on general shear failure in kgf/cm²

q'_d = Net ultimate bearing capacity based on local shear failure in kgf/cm²

R = Relative density of soil

W' = Correction factor for location of water table

s_c, s_q, s_γ = Shape factors

α = Inclination of the load to the vertical in degrees

ϕ = Angle of shearing resistance of soil in degrees

γ = Bulk unit weight of foundation soil kgf/cm²

4. GENERAL

4.1 Sufficient number of undisturbed samples, about 40 to 100 mm in diameter or more or block samples should be obtained, where possible. These samples are for the determination of field density of soil and conducting tests for determining the relevant shear and consolidation parameters of the soil. Tests on soils should be conducted in accordance with relevant parts of IS : 2720*.

4.2 Position and fluctuation of water table should be ascertained. Reference may be made to IS : 1892-1979† and IS : 2132-1972‡ for guidance regarding investigations and collection of data.

5. ULTIMATE NET BEARING CAPACITY

5.0 General — Three types of failure of soil support beneath the foundations have been recognized, depending upon the deformations associated with the load and the extent of development of failure surface.

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*Methods of test for soils.
†Code of practice for subsurface investigations for foundations (*first revision*).
‡Code of practice for thin-walled tube sampling of soils (*first revision*).

They are: a) general shear failure, b) local shear failure and c) punching shear. The choice of which method of analysis is best suited in a given situation is difficult to make, because only limited test data are available on full sized foundations to verify the reliability of the computed bearing capacity. However, guidelines given in relevant clauses may be used for guidance. Wherever possible bearing capacity calculations shall be made on the basis of shear strength parameters ϕ and c obtained from appropriate shear tests [see IS : 2720 (Parts XI and XIII)*] or from plate load test results as given in IS : 1888-1981† or from static cone penetration resistance q_c obtained from static cone penetration test as given in IS : 4968 (Part III)-1976‡.

5.0.1 *Effect of Eccentricity*

a) *Single Eccentricity* — If the load has an eccentricity e, with respect to the centroid of the foundation in only one direction, then the dimension of the footing in the direction of eccentricity shall be reduced by a length equal to $2 e$. The modified dimension shall be used in the bearing capacity equation and in determining the effective area of the footing in resisting the load.

b) *Double Eccentricity* — If the load has double eccentricity (e_L and e_B) with respect to the centroid of the footing then the effective dimensions of the footing to be used in determining the bearing capacity as well as in computing the effective area of the footing in resisting the load shall be determined as given below:

$$L' = L - 2 e_L$$
$$B' = B - 2 e_B$$
$$A' = L' \times B'$$

5.1 Soils with Cohesion and Angle of Shearing Resistance

5.1.1 The following formulæ shall be used for calculating ultimate net bearing capacity in the case of strip footings:

a) In case of general shear failure $q_d = cN_c + q (N_q - 1) + \frac{1}{2}B\gamma N\gamma$

b) In case of local shear failure $q'_d = \frac{2}{3} cN'_c + q (N'_q - 1) + \frac{1}{2} B\gamma N'\gamma$

The values of N_c, N'_c, N_q, N'_q, $N\gamma$ and $N'\gamma$ may be obtained from Table 1.

*Methods of test for soils: Part XI Determination of shear strength parameters of a specimen tested in unconsolidated undrained triaxial compression without the measurement of pore water pressure, and Part XIII Direct shear test (*first revision*).

†Method of load test on soils (*second revision*).

‡Method for subsurface sounding for soils: Part III Static cone penetration test (*first revision*).

TABLE 1 BEARING CAPACITY FACTORS

(*Clause* 5.1.1)

ϕ (Degrees)	BEARING CAPACITY FACTORS		
	N_c	N_q	$N\gamma$
0	5·14	1·00	0·00
5	6·49	1·57	0·45
10	8·35	2·47	1·22
15	10·98	3·94	2·65
20	14·83	6·40	5·39
25	20·72	10·66	10·88
30	30·14	18·40	22·40
35	46·12	33·30	48·03
40	75·31	64·20	109·41
45	138·88	134·88	271·76
50	266·89	319·07	762·89

NOTE — For obtaining values of N'_c, N'_q and $N'\gamma$, calculate $\phi' = \tan^{-1}$ (0·67 $\tan \phi$). Read N_c, N_q, and $N\gamma$, from the Table corresponding to the value of ϕ' instead of ϕ which are values of N'_c, N'_q, $N'\gamma$ respectively.

5.1.2 The ultimate net bearing capacity obtained in **5.1.1** for strip footing shall be modified to take into account, the shape of the footing, inclination of loading, depth of embedment and effect of water table. The modified bearing capacity formulæ are given as under:

a) In case of general shear failure q_d $\left.\right\} = cN_c s_c d_c i_c + q(N_q - 1) s_q d_q i_q + \frac{1}{2} B\gamma N\gamma s_\gamma d_\gamma i_\gamma W'$

b) In case of local shear failure q'_d $\left.\right\} = \frac{2}{3} cN'_c s_c d_c i_c + q(N'_q - 1) s_q d_q i_q + \frac{1}{2} B\gamma N'\gamma s_\gamma d_\gamma i_\gamma W'$

5.1.2.1 The shape factors shall be as given in Table 2.

TABLE 2 SHAPE FACTORS

Sl No.	SHAPE OF BASE	SHAPE FACTOR		
		s_c	s_q	$s\gamma$
i)	Continuous strip	1·00	1·00	1·00
ii)	Rectangle	1+0·2 B/L	1+0·2 B/L	1−0·4 B/L
iii)	Square	1·3	1·2	0·8
iv)	Circle	1·3	1·2	0·6

Use *B* as the diameter in the bearing capacity formula.

5.1.2.2 The depth factors shall be as under:

$d_c = 1 + 0.2 \, D_f/B \, \sqrt{N\phi}$

$d_q = d\gamma = 1$ for $\phi < 10°$

$d_q = d\gamma = 1 + 0.1 \, D_f/B\sqrt{N\phi}$ for $\phi > 10°$

NOTE — The correction is to be applied only when back filling is done with proper compaction.

5.1.2.3 The inclination factor shall be as under:

$$i_c = i_q = \left(1 - \frac{\alpha}{90}\right)^2$$

$$i\gamma = \left(1 - \frac{\alpha}{\phi}\right)^2$$

5.1.2.4 *Effect of water table*

a) If the water table is likely to permanently remain at or below a depth of ($D_f + B$) beneath the ground level surrounding the footing then $W' = 1$.

b) If the water table is located at a depth D_f or likely to rise to the base of the footing or above then the value of W' shall be taken as 0.5.

c) If the water table is likely to permanently got located at depth $D_f < D_w < (D_f + B)$, then the value of W' be obtained by linear interpolation.

5.2 Cohesionless Soil ($c = 0$) — The ultimate net bearing capacity shall be calculated as given in **5.2.1** and **5.2.2**.

5.2.1 *Based on Relative Density* — The formulæ given in **5.1.1** and **5.1.2** shall be used, together with relevant shear strength parameter.

5.2.1.1 The relative density as given in Table 3 shall be used as a guide to determine the method of analysis.

TABLE 3 METHOD OF ANALYSIS BASED ON RELATIVE DENSITY

SL No.	RELATIVE DENSITY (DENSITY INDEX)	VOID RATIO	CONDITION	METHOD OF ANALYSIS
i)	Greater than 70 percent	Less than 0.55	Dense	General shear
ii)	Less than 20 percent	Greater than 0.75	Loose	Local shear (as well as punching shear)
iii)	20 to 70 percent	0.55 to 0.75	Medium	Interpolate between i) and ii)

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5.2.2 *Based on Standard Penetration Resistance Value* — The standard penetration resistance shall be determined as per IS : 2131-1981* at a number of selected points at intervals of 75 cm in the vertical direction or change of strata if it takes place earlier and the average value beneath each point shall be determined between the level of the base of the footing and the depth equal to 1·5 to 2 times the width of foundation. In computing the average any individual value more than 50 percent greater than the average shall be neglected, but the values for all loose seams shall be included.

5.2.2.1 The ultimate net bearing capacity shall be calculated from following formula (covering effect of other factors as mentioned in **5.1.2**):

$$q_d = q(N_q - 1) s_q d_q i_q + \tfrac{1}{2} B\gamma N\gamma s\gamma d\gamma i\gamma W'$$

Where ϕ may be read from Fig. 1, $N\gamma$, N_q may be read from Table 1, S_q, d_q, i_q, $s\gamma$, $d\gamma$, $i\gamma$, and W' may be obtained as in **5.1**.

5.2.3 *Method Based on Static Cone Penetration Test* — The static cone point resistance 'q_c' shall be determined as per IS : 4968 (Part III)-1976† at number of selected points at intervals of 10 to 15 cm. The observed values shall be corrected for the dead weight of sounding rods. Then the average value at each one of the location shall be determined between the level of the base of the footing and the depth equal to $1\tfrac{1}{2}$ to 2 times the width of the footing. The average of the static cone point resistance values shall be determined for each one of the location and minimum of the average values shall be used in the design. The ultimate bearing capacity of shallow strip footings on cohesionless soil deposits shall be determined from Fig. 2.

5.3 Cohesive Soil (when $\phi = 0$)

5.3.1 *Homogeneous Layer*

5.3.1.1 The net ultimate bearing capacity immediately after construction on fairly saturated homogeneous cohesive soils shall be calculated from following formula:

$$q_d = c N_c s_c d_c i_c$$

where

$$N_c = 5·14.$$

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*Method for standard penetration test for soils (*first revision*).
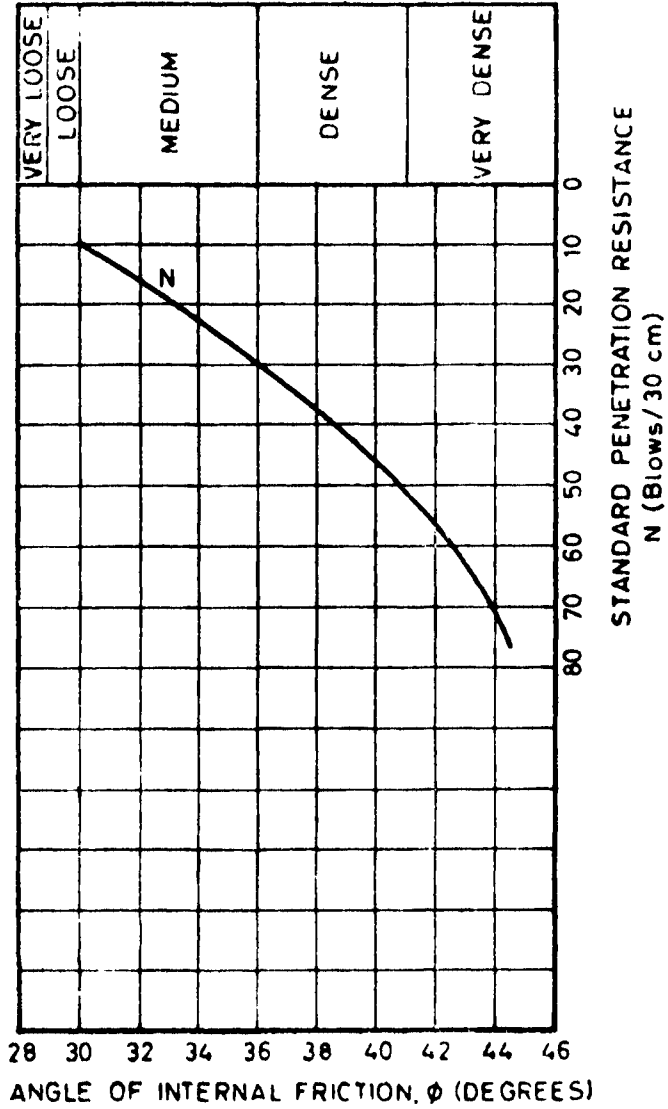†Method for subsurface sounding for soils: Part III Static cone penetration test (*first revision*).

FIG. 1 RELATIONSHIP BETWEEN ϕ AND N
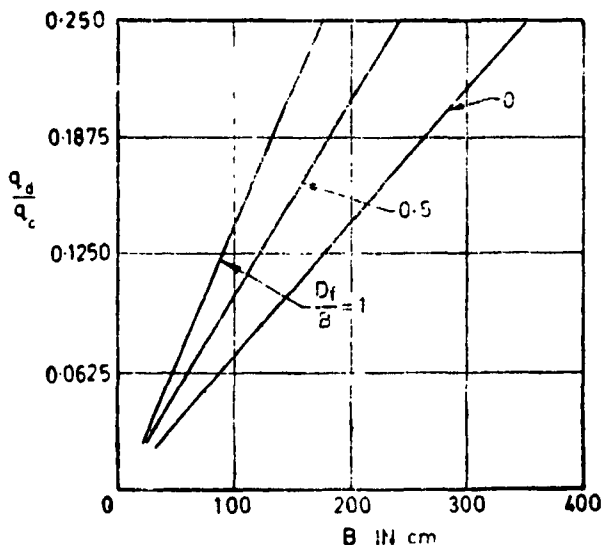
FIG. 2 CHART FOR STATIC CONE TEST

The value of c shall be obtained from unconfined compressive strength test. Alternatively, it can also be derived from static cone test (see 5.3.1.2). The values of s_c, d_c and i_c may be obtained as in 5.1 If the shear strength for a depth of $\frac{2}{3}B$ beneath the foundation does not depart from the average by more than 50 percent, the average may be used in the calculation.

5.3.1.2 Alternately, cohesion c shall be determined from the static cone point resistance q_c using the empirical relationship shown below:

Soil Type	Point Resistance Values (q_c) kgf/cm^2	Range of Undrained Cohesion (kgf/cm^2)
Normally consolidated clays	$q_c < 20$	$q_c/18$ to $q_c/15$
Over consolidated clays	$q_c > 20$	$\left.\dfrac{q_c}{26}\right\}$ to $\left\{\dfrac{q_c}{22}\right.$

5.3.2 *Two Layered System* — In the case of two layered cohesive soil system which do not exhibit marked anisotropy the ultimate net bearing capacity of a strip footing can be calculated by using the formula given below:

$$q_d = c_1 N_c$$

where N_c may be obtained from Fig. 3.

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5.3.3 *Desiccated Soil* — In the case of desiccated cohesive soils, the undrained cohesion is likely to decrease along with depth and is likely to get stabilized at some depth below ground level, usually 3·5 m, if other factors do not influence. If a plot of undrained cohesion, values as shown in Fig. 4 is obtained, and where the pressure bulb falls within the desiccated top soil the ultimate net bearing capacity shall be obtained from Table 4.
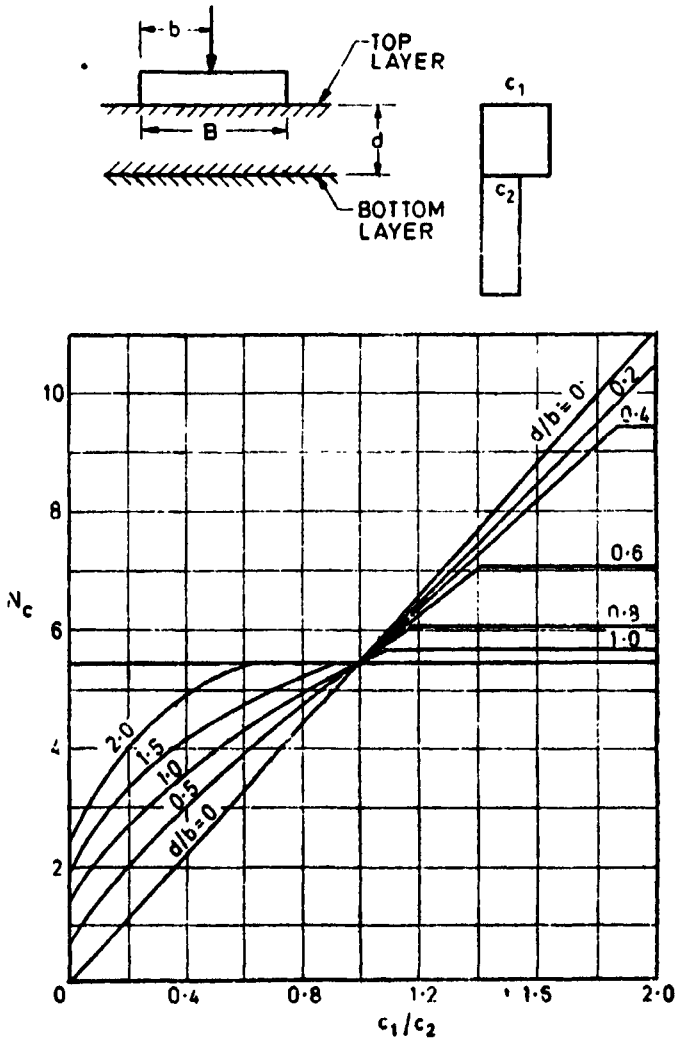
FIG. 3 BEARING CAPACITY FACTORS FOR LAYERED
COHESIVE SOIL DEPOSITS

λ - DECREASE IN COHESION .c
IN kgf/cm² PER UNIT DEPTH OF
FOUNDATION SOIL IN cm
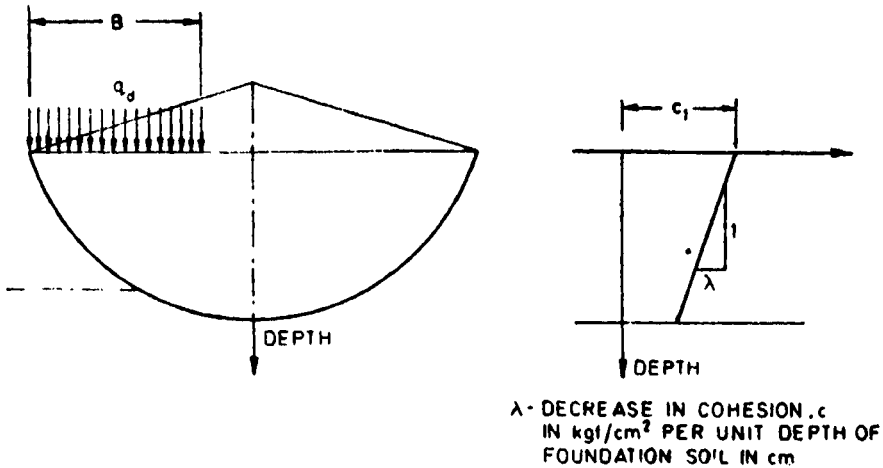
FIG. 4 BEARING CAPACITY FACTORS FOR DESICCATED COHESIVE SOIL

TABLE 4 DATA FOR DETERMINING ULTIMATE NET
BEARING CAPACITY

$\dfrac{8\lambda B}{q_d}$	$\dfrac{q_d}{c_1}$
0·0	5·7
0·2	5·0
0·4	4·5
0·6	4·0
0·8	3·6
1·0	3·2

λ, c_1 shall be obtained from the borehole data, and for a known value of the width of the strip footing 'B', by trial and error q_d can be estimated by matching $\dfrac{8\lambda B}{q_d}$ with $\dfrac{q_d}{c_1}$.

6. ALLOWABLE BEARING CAPACITY

6.1 The allowable bearing capacity shall be taken as either of the following, whichever is less:

    a) Net ultimate bearing capacity as obtained in 5 divided by suitable factor of safety, that is, net safe bearing capacity.

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b) The net soil pressure (*see* **6.1.1**) that can be imposed on the base without the settlement exceeding the permissible values as given in IS : 1904-1978* to be determined for each structure and type of soil, that is, safe bearing pressure.

6.1.1 *Safe Bearing Pressure* — The permissible settlements for different types of soil formations are specified in IS : 1904-1978*. The methods for calculations of settlements for assumed pressure are specified in IS : 8009 (Part I)-1976†; by calculating the settlements for two or three probable soil pressures and interpolating, the net soil pressure for permissible settlement may be estimated.

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*Code of practice for structural safety of buildings: Shallow foundation (*second revision*).

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

Bearing Capacity of Foundation Subcommittee, BDC 43 : 4

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AMENDMENT NO. 1   MAY 1984

TO

IS:6403-1981 CODE OF PRACTICE FOR DETERMINATION
OF BEARING CAPACITY OF SHALLOW FOUNDATIONS

(First Revision)

Alterations

(Page 10, clause 5.2.2, last sentence)
Substitute the following for the existing sentence:

'In computing the value, any individual value more
than 50 percent of the average calculated shall be
neglected and average re-calculated (the values for
all loose seams shall however be included).'

(Page 13, clause 5.3.3):

    a) *Line 3* - Substitute 'around' *for* 'usually'

    b) *Line 6* - Add the words 'with the assumption
       of cylindrical failure surface' after
       'obtained'

(Page 13, Fig. 3) - Substitute 'c_2/c_1' *for* 'c_1/c_2'

(Page 14, Fig. 4, caption) - Substitute the
following for the existing caption:

'Decreasing Cohesion with Depth in Case of Desiccated
  Cohesive Soil'

(Page 14, Table 4 and clause 5.3.3) - Substitute
'$\dfrac{4 \lambda B}{q_d}$' *for* '$\dfrac{8 \lambda B}{q_d}$'

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(Page 15, clause 6.1.1, line 3) - Add the words 'from standard penetration resistance' after 'pressure'.

(Page 15, clause 6.1.1) - Add the following sentence in the end:

'This safe bearing pressure can also be calculated based on plate load test *(see* IS:1888-1982§).'

(Page 15, foot-note with '†' mark) - Add the words 'of settlement' after 'calculation'.

(Page 15, foot-note) - Add the following additional foot-note:

'§Method of load test on soils *(second revision)*'.

(BDC 43)

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AMENDMENT NO. 2 APRIL 2018
TO
IS 6403 : 1981 CODE OF PRACTICE FOR DETERMINATION OF BEARING CAPACITY OF SHALLOW FOUNDATIONS

(First Revision)

(*Page* 6, *clause* **4.2**, *line* 2) ― Substitute 'IS 2132 : 1986‡' *for* 'IS : 2132-1972‡' and substitute the following for the corresponding footnote:

'‡Code of practice for thin-walled tube sampling of soils (*second revision*).'

(*Page* 6, *clause* **5.0**, *line* 11) ― Substitute 'IS 2720 (Part 11) : 1993* and IS 2720 (Part 13) : 1986$' *for* 'IS : 2720 (Parts XI and XIII)*' and substitute the following for the corresponding footnote marked with '*':

'*Methods of test for soils: Part 11 Determination of the shear strength parameters of a specimen tested in unconsolidated undrained triaxial compression without the measurement of pore water pressure (*first revision*).

$Methods of test for soils: Part 13 Direct shear test (*second revision*).'

(*Page* 6, *clause* **5.0**, *line* 12) ― Substitute 'IS 1888 : 1982†' *for* 'IS : 1888-1981†'.

[*Page* 14, *clause* **6.1** (a)] ― Insert the following sentence at the end:

'The minimum factor of safety against shear failure shall be 2.5 on the net ultimate bearing capacity.'

(*Page* 15, *clauses* **6.1** (b) *and* **6.1.1**) ― Substitute 'IS 1904 : 1986*' *for* 'IS : 1904-1978*' and substitute the following for the corresponding footnote:

'*Code of practice for design and construction of foundations in soils: General requirements (*third revision*).'

(CED 43)