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# मानक

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IS 11089 (1984): Code of practice for design and construction of ring foundation [CED 43: Soil and Foundation Engineering]



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IS : 11089 - 1984

*Indian Standard*

"पुनर्पुष्टि १९९०"

"REAFFIRMED 1990"

CODE OF

PRACTICE FOR DESIGN AND  
CONSTRUCTION OF RING FOUNDATION

UDC 624.153.525 : 006.76



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**INDIAN STANDARDS INSTITUTION**

MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG

NEW DELHI 110002



# Indian Standard

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# *Indian Standard*

## CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF RING FOUNDATION

### 0. FOREWORD

**0.1** This Indian Standard was adopted by the Indian Standards Institution on 30 May 1984, after the draft finalized by the Foundation Engineering Sectional Committee had been approved by the Civil Engineering Division Council.

**0.2** Ring foundation is a substructure supporting on arrangement of columns or walls and transmitting the loads to the soil by means of a continuous slab. In this code guidelines have been given to choose particular type of methods in particular situations and giving reference to finite element method which will be covered at a later stage.

**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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### 1. SCOPE

**1.1** This standard covers the design of ring foundation based on conventional method for tall structures, such as, silos, chimneys and water tanks, which have vertical and non-uniform distributed loads.

### 2. TERMINOLOGY

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

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

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

### 3. NECESSARY INFORMATION

**3.1** For satisfactory design and construction of ring foundation, the following information is necessary:

- a) *Site Plan* — Site plan showing the location of proposed as well as neighbouring structure.
- b) *Building Plan* — Showing the details of height, staging, columns, etc.
- c) *Loading Conditions* — Dead load, wind or earthquake loads, shown on a schematic plan indicating design combination of loads transmitted to the foundation.
- d) *Environmental Factors* — Information relating to geologic history of the area, seismicity of the region, hydrological information indicating ground water conditions and its seasonal variations, climatic factors like vulnerability of the site to sudden flooding by surface run-off, erosion, etc.
- e) *Geotechnical Information* — Subsurface profile with stratification details ( see IS : 1892-1979\* ) engineering properties of the founding strata, index properties, effective shear parameters determined under appropriate drainage conditions, compressibility characteristics, swelling properties, results of field tests like static and dynamic penetration tests, pressure meter test, etc.
- f) *Modulus of Elasticity and Modulus of Subgrade Reaction* — [ see IS : 2950 ( Part 1 )-1981† ].
- g) Limiting values of the angular distortion and differential settlement, the super structure can withstand.
- h) A review of the performance of similar structure, if any, in the locality.
- j) Information necessary to assess the possible effects of the new structure on existing structures in the neighbourhood.
- k) Proximity of mines or major storage reservoir to the site.

**3.2 Parameters for the Analysis** — These are obtained by averaging the parameters ( see 3.1 ) which can be determined only for relatively less number of points of the foundation soil. The accuracy with which the average values represent the actual conditions is of decisive importance for the final results.

\*Code of practice for subsurface investigations for foundations ( *first revision* ).

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



## 4. DESIGN CONSIDERATIONS

### 4.1 Choice of Ring Foundations

**4.1.1** For fairly small and uniform column spacing and when the supporting soil is not too compressible a flat concrete slab having uniform thickness throughout is most suitable. Under the effects of dead loads foundations are subjected to uniform pressure but under the effect of lateral loads caused by earthquake and wind, the pressure becomes non-uniform. If there is sufficient bending due to lateral forces (say  $P_2 > P_1$ ) it is more economical to adopt annual raft ( see Fig. 1A ).

**4.1.2** Annual circular slab with a ring beam type of raft is likely to be more economical for large column spacing and when the soil is very compressible ( see Fig. 1B ).

**4.2 Allowable Bearing Pressure** — The allowable bearing pressure shall be determined in accordance with IS : 6403-1981\*.

**4.2.1** In granular soils, the ultimate bearing capacity of rafts is generally very large. However, for rafts placed at depth possibility of punching code of failure should be investigated. The influence of soil compressibility and related scale effects should also be assessed.

**4.2.2** For rafts on cohesive soils stability against deep seated failures shall be analyzed.

**4.2.3** In cohesive soils, the effects of long term settlements shall be taken into consideration.

**4.3 Depth of Foundation** — The depth of foundation shall be in accordance with IS : 1904-1978†.

**4.4** The uplift due to subsoil water shall be considered in the design.

**4.4.1** All construction below the ground water level shall be checked for floatation.

## 5. METHODS OF ANALYSIS

**5.1 Rigid Foundation ( Conventional Method )** — This is based on the assumption of linear distribution of contact pressure. The basic assumptions of this method are:

- a) The foundation is rigid relative to the supporting soil and the compressible soil layer is relatively shallow; and

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

†Code of practice for structural safety of buildings: Shallow foundations ( second revision ).

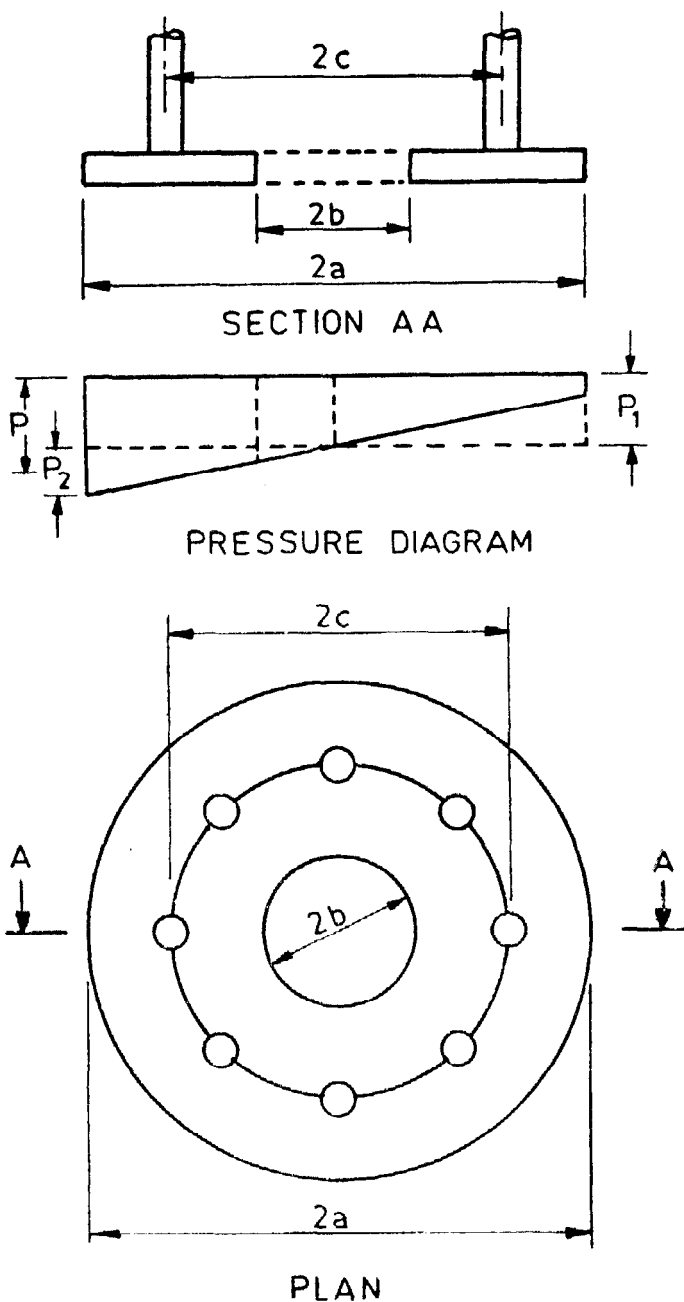


FIG. 1A SHOWING THE NON UNIFORM PRESSURES UNDER A CIRCULAR FOOTING DUE TO HORIZONTAL FORCES SUCH AS WIND AND EARTHQUAKE WHICH CAN BE APPROXIMATED TO A UNIFORM PRESSURE OF VALUE  $(P = P_1 + 0.5 P_2)$

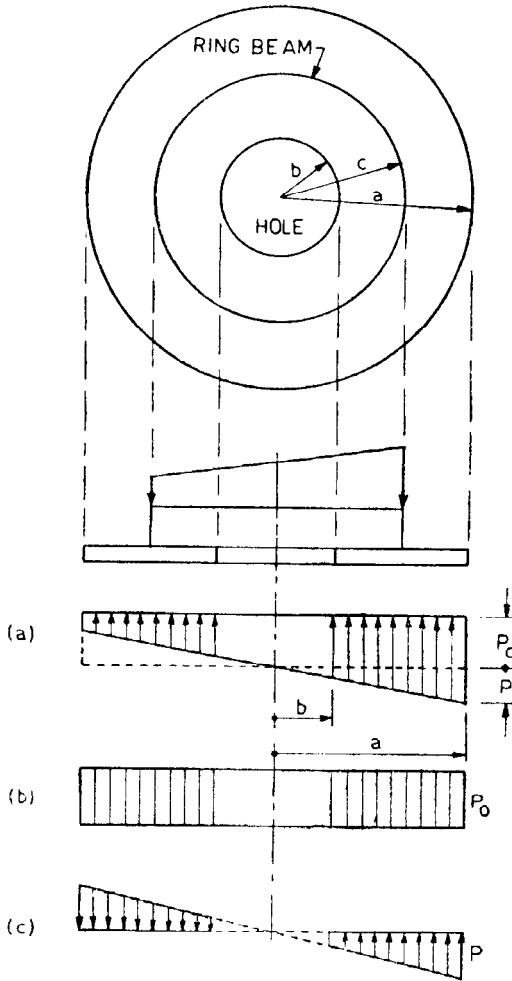


FIG. 1B PRESSURE DISTRIBUTION UNDER A RAFT

- b) The contact pressure distribution is assumed to vary linearly throughout the foundation.

**5.1.1** This method may be used when either of the following conditions are satisfied:

- a) The structure behaves as rigid ( due to the combined action of the superstructure and the foundation ) with a relative stiffness

factor  $K > 0.5$  [ for evaluation of  $K$ , see Appendix C of IS : 2950 ( Part 1 )-1981\* ]; and

- b) The column spacing is less than  $1.75 \lambda$  [ see Appendix C of IS : 2950 ( Part 1 )-1981\* ].

**5.1.2** The ring annular raft is analyzed from approximately non-uniform pressure distribution to uniform pressure distribution ( see Fig. 1A ). The modified uniform pressure intensity  $p$  is given by  $p_1 + 0.5 p_2$ , where  $p_1$  is uniform pressure due to dead loads and  $p_2$  is pressure due to bending effects.

The formulae for circumferential and radial moments  $M_t$  and  $M_r$  respectively are as follows:

For  $r < c$

$$M_t = \frac{pa^2}{16} \left[ \left\{ 4 \left( 1 + \frac{b^2}{r^2} \right) \left( \log_e \frac{a}{c} + \frac{1}{2} - \frac{c^2}{2a^2} \right) \right\} \right. \\ \left. + \frac{r^2}{a^2} - \frac{4b^2}{a^2} \left\{ \log_e \frac{r}{a} + \frac{3}{4} \left( \frac{1}{3} + \frac{a^2}{b^2} + \frac{a^2}{r^2} \right) - \frac{a^2 + r^2}{a^2 - b^2} \cdot \frac{b^2}{r^2} \log_e \frac{a}{b} \right\} \right] \\ M_r = \frac{pa^2}{16} \left[ \left\{ 4 \left( 1 - \frac{b^2}{r^2} \right) \left( \log_e \frac{a}{c} + \frac{1}{2} - \frac{c^2}{2a^2} \right) \right\} \right. \\ \left. + \frac{3r^2}{a^2} - \frac{4b^2}{a^2} \left\{ \log_e \frac{r}{a} + \frac{3}{4} \left( 1 + \frac{a^2}{b^2} - \frac{a^2}{r^2} \right) + \frac{a^2 - r^2}{a^2 - b^2} \cdot \frac{b^2}{r^2} \log_e \frac{a}{b} \right\} \right]$$

For  $r > c$

$$M_t = (M_t)_{r < c} + \frac{pa^2}{16} \left[ 4 \left( 1 - \frac{b^2}{a^2} \right) \left( \log_e \frac{c}{r} + \frac{1}{2} - \frac{c^2}{2r^2} \right) \right] \\ M_r = (M_r)_{r < c} + \frac{pa^2}{16} \left[ 4 \left( 1 - \frac{b^2}{a^2} \right) \left( \log_e \frac{c}{r} - \frac{1}{2} + \frac{c^2}{2r^2} \right) \right]$$

where

$r$  is the radial distance.

The ratio  $b/a$  will depend on the bearing area and the moment of inertia required for footing such that the maximum stress developed does not exceed the safe allowable bearing pressure specified for the soil. For a particular  $b/a$  ratio, the value of  $c/a$  at which the maximum moments are minimum could be obtained from Fig. 1C.

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

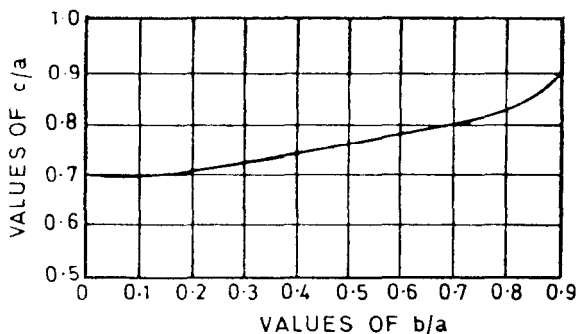


FIG. 1C POSITION OF RING BEAM FOR MINIMUM VALUE OF THE MAXIMUM MOMENTS

**5.2** In case the annular circular raft with a ring beam, two conditions are generally to be satisfied. The maximum pressure under foundation should not exceed the safe allowable bearing pressure of the soil. The minimum pressure shall be zero or of a compressive nature. To satisfy these, the dimensions of rafts shall be determined as follows:

$$a = ex \sqrt{(ex)^2 + \frac{A}{2\pi}}$$

$$b = \sqrt{a^2 - \frac{A}{\pi}}$$

where

$$x = \frac{q_{all} - (P_0 - P_1)}{q_{all} + (P_0 - P_1)}$$

$$A = \frac{2W}{q_{all} - (P_0 - P_1)}$$

where

$W$  = total weight of the structure above ground

$e$  = eccentricity of the vertical load on base due to overturning moment of lateral loads of wind or earthquake

$a$  = outer radius of annular raft or radius of solid raft

$b$  = inner radius of annular raft

$A$  = area of raft

$$= \pi (a^2 - b^2)$$

$q_{all}$  = net safe bearing capacity of soil at base

$P_0$  = overburden pressure due to depth of foundation

$P_1$  = net pressure desired at base.

**5.2.1** For a given number of columns, the ring beam will have less moment when the ring perimeter is small. The curves *A* and *B* shown in Fig. 1E give the most economical locations of the ring beam on the raft when the soil pressures are uniform and when they vary linearly as shown at *b* and *c* in Fig. 1D respectively. The radial and tangential moments in annular circular plates can be determined for uniform and linear distribution of pressure for expression.

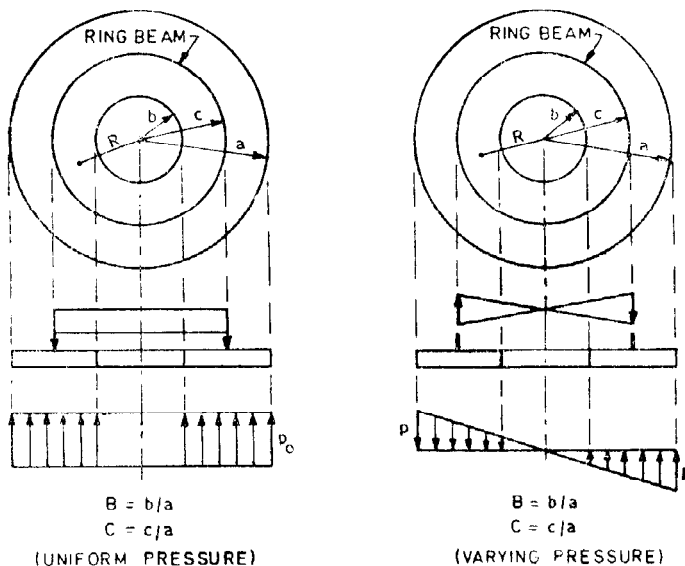


FIG. 1D RADIAL AND TANGENTIAL MOMENT IN ANNULAR CIRCULAR PLATES

The critical sections for finding the tangential moments are the inner edge, under bearing and outer edge. The critical section for radial moments is under the ring beam for sagging moments and at some point in the raft for hogging moment.

The formulae for radial and tangential moments  $M_r$ , and  $M_t$  respectively are as follows:

*Radial*

For  $R < C$

$$M_r = \frac{p_0 a^2}{16} \left[ 4 \left( 1 + \frac{B^2}{R^2} \right) \left( \frac{1}{2} - \log_e C - \frac{C^2}{2} \right) + R^2 \right. \\ \left. - 4B^2 \left\{ \log_e R + \frac{3}{4} \left( -\frac{1}{3} + \frac{1}{B^2} + \frac{1}{R^2} \right) + \frac{1}{1 - B^2 R^2} \log_e B \right\} \right]$$

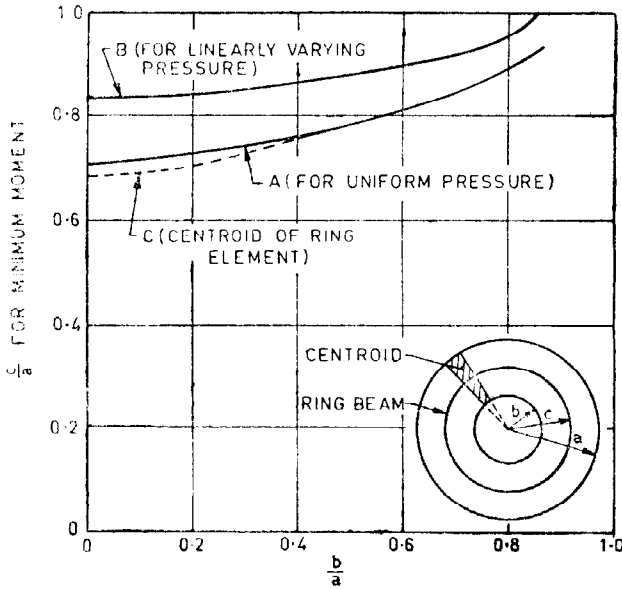


FIG. 1E POSITION OF RING BEAM FOR MINIMUM MOMENTS

$$M_r = \frac{p_0 a^2}{16} \left[ 4 \left( 1 - \frac{B^2}{R^2} \right) \left( \frac{1}{2} - \log_e \frac{C}{e} - \frac{C^2}{2} \right) + 3R^2 \right. \\ \left. - 4B^2 \left\{ \log_e R + \frac{3}{4} \left( 1 + \frac{1}{B^2} - \frac{1}{R^2} \right) - \frac{1 - R^2 B^2}{1 - B^2 R^2} \log_e B \right\} \right]$$

For  $R > C$ 

$$M_t = (M_t) R < C + \frac{p_0 a^2}{16} \left[ 4 \left( 1 - B^2 \right) \left( \frac{1}{2} - \log_e \frac{R}{C} - \frac{C^2}{2R^2} \right) \right]$$

$$M_r = (M_r) R < C - \frac{p_0 a^2}{16} \left[ 4 \left( 1 - B^2 \right) \left( \frac{1}{2} + \log_e \frac{R}{C} - \frac{C^2}{2R^2} \right) \right]$$

*Tangential*For  $R < C$ 

$$M_t = \frac{p a^2}{96 R^3} \left[ \frac{2B^4}{B^2 + 1} \left( -5 + 3B^2 - \frac{8}{3} R^4 \right) + 2R^2 \left( -\frac{5}{3} R^2 + \right. \right. \\ \left. \left. R^4 + 3B^4 \right) + \frac{(3 + C^2)(1 - C^2)(R^4 + 3B^4)}{C^2} \right] \cos \theta$$



$$M_r = \frac{pa^2}{96R^3} \left[ \frac{2B^4}{B^2 + 1} \left( 5 - 3B^2 - 8R^4 \right) - 2R^2 (5R^2 - 5R^4 - 3B^4) + \frac{3(3 + C^2)(1 - C^2)(R^4 - B^4)}{C^2} \right] \cos \theta$$

For  $R > C$

$$M_t = \frac{pa^2}{96R^3} \left[ \frac{2B^4}{B^2 + 1} \left( -5 + 3B^2 - \frac{8}{3} R^4 \right) + 2R^2 \left( -\frac{5}{3} R^2 + R^4 + 3B^4 \right) + (R^4 + 3) \left( \frac{3B^4}{C^2} - C^2 \right) - 2(R^4 + 3B^4 - 3R^2 + 3R^2B^4) \right] \cos \theta$$

$$M_r = \frac{pa^2}{96R^3} \left[ \frac{2B^4}{B^2 + 1} (5 - 3B^2 - 8R^4) - 2R^2 (5R^2 - 5R^4 - 3B^4) + 3(1 - R^4) \left( C^2 - \frac{3B^4}{C^2} \right) + 6(1 - R^2)(R^2 + B^4) \right] \cos \theta$$

### 5.3 Flexible Ring Foundation

**5.3.1** In this method, it is assumed that the subgrade consists of an infinite array of individual elastic springs. The spring constant  $B$  equal to modulus of subgrade reaction ( $K$ ). The contact pressure at any point is therefore linearly proportional to the settlement at the point. This method may be used when all the following conditions are satisfied:

- The structure (combined action of super structure and raft) may be considered as flexible relative stiffness factors  $K < 0.5$  (see Appendix C).
- Variation in adjacent column load does not exceed 20 percent of the higher value.

**5.3.2** A circular slab on elastic media is the usual form of solution to evaluate bending and shear at various points within the slab. The differential equation governing is fourth order differential equation.

$$\left( \frac{d^2}{dr^2} + \frac{1}{r} \frac{d}{dr} \right) \left( \frac{d^2 w}{dr^2} + \frac{1}{r} \frac{dw}{dr} \right) = \frac{q - K_w}{D}$$

where

$$D = \frac{Et^3}{12(1 - \nu^2)}$$

$w$  = plate deflection

$q$  = uniform load

$\gamma$  = Poisson's ratio

This equation can be solved using finite difference solutions.

NOTE — One of the recent methods based on the above theory is numerical analysis by either finite difference method or finite element method. This method is used for accurate analysis of annular raft foundation.

## 6. STRUCTURAL DESIGN AND CONSTRUCTION ASPECTS

**6.1** The general designs of loads, wind, loads, shrinkage, creep and temperature effects and provision of reinforcement and detailing and other constructional aspects shall conform to IS : 456-1978\* and IS : 1893-1975†, the foundation being considered as an inverted beam or slab.

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

†Specification for criteria for earthquake resistant design of structures ( *third revision* ).

( Continued from page 2 )

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# AMENDMENT NO. 1      MARCH 1989

TO

## IS : 11089 - 1984   CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF RING FOUNDATION

( Page 3, clause 0.2, line 3 ) — Add the word ‘ circular ’ after the word ‘ continuous ’.

( Page 5, clause 4.3, line 2 ) — Substitute ‘ IS : 1904-1986† ’ for ‘ IS : 1904-1978† ’.

( Page 5, foot-note marked with ‘ † ’ mark ) — Substitute the following for the existing foot-note:

‘ †Code of practice for design and construction of foundation in soils: General requirements ( third revision ). ’

( Page 10, clause 5.2.1, caption of formulae ) — Substitute ‘ Uniform Pressure ’ for the word ‘ Radial ’.

( Page 10, last line ) — Substitute the following for the existing line:

$$- 4B^2 \left\{ \log_e R + \frac{3}{4} \left( -\frac{1}{3} + \frac{1}{B^2} + \frac{1}{R^2} \right) + \left( \frac{1 + R^2}{1 - B^2} \right) \frac{B^2}{R^2} \log_e B \right\}$$

( Page 11, lines 1 and 2 of the formulae ) — Substitute the following for the existing lines:

$$M_r = \frac{p_0 q^2}{16} \left[ 4 \left( 1 - \frac{B^2}{R^2} \right) \left( \frac{1}{2} \log_e G - \frac{C^2}{2} \right) + 3R^2 \right. \\ \left. - 4B^2 \left\{ \log_e R + \frac{3}{4} \left( 1 + \frac{1}{B^2} - \frac{1}{R^2} \right) - \left( \frac{1 - R^2}{1 - B^2} \right) \frac{B^2}{R^2} \log_e B \right\} \right]$$

( Page 11, line 6 ) — Substitute ‘ Varying Pressure ’ for the word ‘ Tangential ’.

( Page 13, clause 6.1, line 4 ) — Substitute ‘ IS : 1893-1984† ’ for ‘ 1893-1975† ’.

( Page 13, foot-note marked with ‘ † ’ mark ) — Substitute the following for the existing foot-note:

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