IS 11233 (1985): Code of practice for design and construction of radar antenna, microwave and TV tower foundations [CED 43: Soil and Foundation Engineering]

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(Reaffirmed 2002)

Indian Standard

CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF RADAR ANTENNA, MICROWAVE AND TV TOWER FOUNDATIONS

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BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

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Indian Standard
CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF RADAR ANTENNA, MICROWAVE AND TV TOWER FOUNDATIONS

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Indian Standard

CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF RADAR ANTENNA, MICROWAVE AND TV TOWER FOUNDATIONS

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 20 February 1985, after the draft finalized by the Foundation Engineering Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 Radar antenna, microwave and TV towers are widely used for the communication system in Defence, Posts and Telegraph Department, Railways and for TV stations. The foundation required for these types of towers have to be designed based on several known and assumed factors. Based on the experience gained so far, this standard on the subject has been formulated so that it will help various organizations to standardize the design procedures and assumed factors.

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, 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 provides guidelines for the design and construction of reinforced concrete foundations for self-supporting type radar antenna towers, microwave towers and TV towers.

NOTE—Grillage, brick and massive footings prestressed concrete are not covered in this Code.

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

2. TERMINOLOGY

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

3. NECESSARY INFORMATION AND DESIGN DATA

3.0 For the design and construction of foundations the information as given in **3.1** to **3.3** would be needed.

3.1 General

3.1.1 The location map showing the layout of the existing towers and structures with the general topography of the area.

3.1.2 The geometrical details of the tower like height and details of antenna and its/their sizes configuration.

3.1.3 The resulting forces acting at the base of the tower like downward loads, uplift forces, the horizontal shears, overturning moments, torsional moments (if not included) obtained from the analysis of tower structure.

3.1.4 Maximum total settlement of/and differential settlement between the legs allowed at the foundation level for the tower. (This information is to be supplied by the tower user.)

3.1.5 A detailed geotechnical report depicting clearly the sub-soil profile, the physical and strength properties of the various strata, etc, the sub-soil profile to a depth of 10 m or to a depth equal to twice the width of the tower foundation at the founding level or any other information required for the design. Information on the ground water table and its seasonal variations, aggressive characteristics of sub-soil and surroundings should be available. The soil test report should indicate the bore log with classification of soil, standard penetration test values in full depth, dynamic core penetration test value up to at least 10 m depth below ground level and consolidation test data (coefficient of compression necessarily in clayey and silty soils alongwith results of other tests carried out on soil samples). A report on water table and its seasonal variations should be included.

3.1.6 Special information like the wind data including cyclones/tornado, etc, depth of frost and penetration, and earthquake data.

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

3.1.7 A review of the performance of tower like structures, if any, in the locality.

3.1.8 In case of rocky subgrades, it should be ensured that rocky strata is of sufficient thickness and not just a sheet rock under laid by compressible or poor soil strata. In such cases the data like compressive strength of rock, rock core recovery and deterioration, if any, on submergence or saturation should be invariably made available.

3.2 Design Forces

3.2.1 Total weight of the structure.

3.2.2 Overturning and torsional comments due to wind forces.

3.2.3 Horizontal shear forces at tower base level.

3.2.4 Earthquake generated forces (*see* IS : 1893-1975*).

3.2.5 Pulsating forces due to the vibrations caused in the tower by the wind.

3.3 Settlements

3.3.1 For the allowable settlements for these structures, the following guidelines may be considered:

a) The allowable total settlement should be restricted as follows:

   1) Radar antenna towers—12 mm;
   2) Microwave towers with dish type antenna—16 mm; and
   3) Towers and towers with yagi type antenna—50 mm.

b) The maximum allowable differential settlement should be restricted to 6 mm for radar antenna towers, 20 mm for TV towers and 12 mm for microwave towers.

c) In case of foundations resting partially on rock and partially on soil, the allowable differential settlements should be restricted to as per (b) above. There is likelihood of large differential settlements and large variations in estimation of settlements. In such situations, the foundation portion in compressible soil should be taken to a base on which settlement is comparable to that on rocky portion, using even concrete piles of end bearing type.

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

d) The possible differential settlement due to eccentric loading should also be evaluated during the analysis.

e) While deciding the allowable settlement, the seasonal variation of water table should be duly taken into account.

4. TYPES OF FOUNDATIONS

4.1 The following types of foundations can be considered as alternatives:

a) Isolated footings under each leg of the tower;
b) A combined raft foundation (with or without beams);
c) Annular or ring foundation, specially for circular section RCC towers;
d) Pile foundations;
e) Rock anchors in case of towers resting on rocks;
f) Combination of (a) with (d) or (e) above; and
g) Shell foundations, specially for circular section RCC towers.

4.1.1 Depending upon the relative magnitude of upward or downward vertical loads, lateral load and overturning moments, footings in soil should be as classified in Table 1 according to their suitability.

TABLE 1 LOADING AND FOOTING CLASSIFICATION

CLASS OF FOOTINGS	TYPE OF LOADS	TYPE OF STRUCTURE	TYPE OF FOOTING RECOMMENDED	TYPE OF SOIL REACTION
(1)	(2)	(3)	(4)	(5)
A	Heavy uplift with light shear	Wide base towers or individual footing under each leg	With enlarged (under-cut) type base or under-reamed	Weight of earth on enlarged base or pull-out resistance
B	Heavy over-turning moments with light shear and vertical loads	Poles or columns with narrow footings	a) With or without an enlarged base b) Piles	Lateral resistance or weight of cone of earth on half of the enlarged base and soil pressure on bottom of the base
C	Heavy downward load	Heavy electrical equipment mounted directly on footings	a) With base b) Under-reamed or group of piles	Allowable soil pressure on bottom of footing shaft resistance and point bearing

5. GENERAL DESIGN CRITERIA

5.0 Design Loads and Forces — The following loads and forces should be used for design of tower foundations:

a) Downward load;

b) Uplift load;

c) Horizontal thrust (base shear); and

d) Overturning moments.

5.0.1 Inclined loads should be split into lateral/shear and vertical loads at the top of footings.

5.1 Design Criteria for Various Types of Design Loads

5.1.1 Uplift loads and horizontal thrusts (stability considerations).

5.1.1.1 In tall self-supporting type of towers (M/W and TV), and often in short towers (radar antenna) uplift load becomes an important governing criteria for selection and design of type of foundations due to structure and foundation stability. General consideration and criteria are given in from **5.1.1.12** to **5.1.1.14**.

5.1.1.2 The uplift loads are assumed to be counteracted in case of shallow foundations by the weight of the footing plus the weight of an inverted frustum of a pyramid of earth, on the footing pad, with sides inclined at an angle of up to 30° with the vertical.

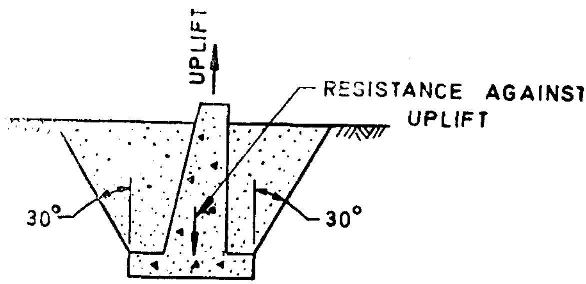
5.1.1.3 A footing with an under-cut generally develops uplift resistance that is higher than that of an identical footing without an under-cut (*see* Fig. 1) for which reason reduced factors of safety (*see* **5.4.1**) can be adopted.

5.1.1.4 A 30° cone shall be taken for an average firm cohesive material while a 20° cone shall be taken for non-cohesive materials, such as sand and gravelly soils. Interpolation can be done for in between soil classifications.

5.1.1.5 Alternative footing designs with or without under-cut should be provided where field investigations have not been made to determine feasibility of undercutting.

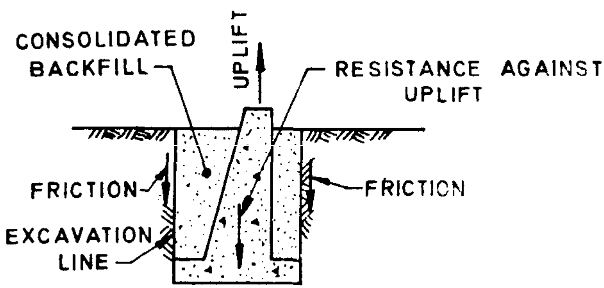
5.1.1.6 In enlarged footings without an under-cut where individual footing is not provided under each leg and where a combination of uplift loads with lateral loads occurs, the suitability should be checked by the following criteria:

a) The resultant of forces acting vertically and laterally should act at a point in its base at a distance of onesixth of its width from the toes;



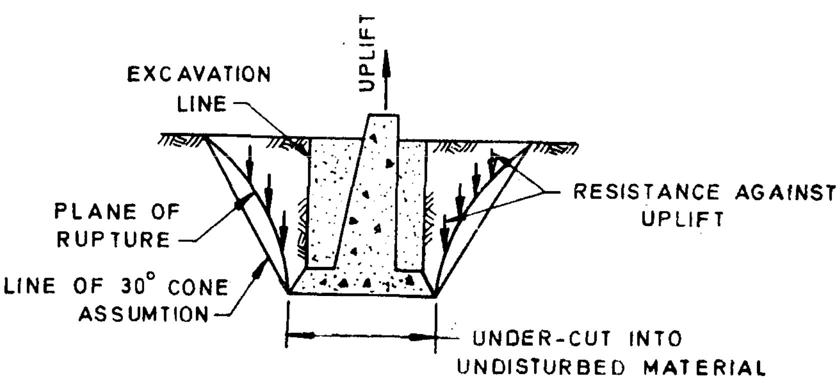
Conventional Assumption—Resistance Against Uplift by Weight of Frustum of Earth Plus Weight of Concrete

1 A



Actual Action Without Under-Cut Resistance Against Uplift by Weight of Backfill Plus Friction on Face of Excavation Lines Plus Weight of Concrete (Approximately Equal to Conventional Assumption)

1 B



Actual Action with Under-Cut Resistance Against Uplift by Vertical Components of Soil Stresses at Failure Along Plane of Rupture Plus Weight of Concrete (Approximately Equal to Double the Conventional Assumption)

1 C

FIG. 1 SOIL RESISTANCE TO UPLIFT

b) The weight of the footing acting at the centre of the base; and

c) Mainly that part of the cone which stands over the heel causes a stabilizing moment. However, for design purposes, this may be taken equal to half the total weight of the cone of earth acting over the base. It should be assumed to act through the tip of the heel.

5.1.1.7 The uplift forces in case of pile foundation should be counteracted by the uplift resistance of piles and weight of pile caps and the earth-cone above it with factors of safety as in **5.4.1**.

5.1.1.8 The horizontal forces, in case of shallow foundations are resisted by passive soil pressure on the edges of the footings and the drag resistance with soil at the base of footing with factors of safety as in **5.4.1**.

5.1.1.9 In case of pile foundations the horizontal load capacity of all piles with passive earth pressure of footings (pile caps) should be equal to horizontal base shear multiplied by factor of safety as in **5.4.1**.

5.1.1.10 A footing on rock, for uplift and horizontal loads, may be considered to develop strength by the dead load of the concrete and the least of (a) strength of all the bars anchored under the footing (the pull out bond resistance of anchor bars grouted or embedded in concrete in drilled holes) or (b) the pull out resistance (frictional resistance of concrete in anchor holes with rock) of all the rock anchors in the footing area. The factors of safety as in **5.4.1** should be used.

5.1.1.11 In case of good soils where the size of footing designed on downward load considerations is considerably smaller than the size of footing required with uplift criterion, short under-reamed piles of 3·5 m length under the footing be provided to achieve additional uplift resistance, instead of increasing the size of footing. Economy considerations should, however, govern the design.

5.1.1.12 If a basement is provided, active earth pressure on the walls should be considered. The passive resistance of the soil on the basement wall during earthquake and horizontal forces should be neglected while analyzing the stability of the foundation.

5.1.1.13 When shallow foundations are adopted, tension should not be allowed on the edges of the foundation under horizontal forces. In cases of pile foundation, however, uplift resistance of the piles, and in case of rock anchors the pull-out resistance of the anchor should be three times the tension. In all the other cases the dead weight of the footing (cap in cases of piles) and the earth fill above the footing of pile cap in accordance with **5.1.1.1** should be considered for balancing the tension providing factor of safety as in **5.4.1**.

5.1.1.14 All the isolated/individual footings should be inter-connected at ground level or below, by beams inter-connecting columns/stems, to be designed for a maximum differential settlement in addition to the other design considerations.

5.1.2 Downward loads and overturning moments.

5.1.2.1 For downward force, the shallow foundations are to be designed such that the pressure on sub-grade at any point does not exceed the safe bearing capacity. In case of pressure variation caused by moments due to lateral (horizontal forces) on tower, permissible increase in bearing pressure should be in accordance with **5.5.3.1**.

5.1.2.2 The pile foundations system should be so designed that load shared by a pile does not exceed its safe load carrying capacity in vertical (downward as well uplift) as well as horizontal direction. Group action for number of piles more than 2 should be considered.

5.1.2.3 Combination of shallow foundations and pile foundations should ensure that differential settlement of tower legs is within permissible limits as in **3.3.1**.

5.2 Criteria for selection of type of foundation and its design.

5.2.1 Amongst other consideration, the safe bearing capacity and settlement characteristics of soil should govern the selection of the type foundation. Amongst various alternatives, cost economics should be the decisive factor.

5.2.2 The raft foundations may become good choice if basements are provided in case of high towers or if the soils are weak with low settlement values. The raft should be sufficiently stiff to withstand the differential settlement and also the flexural vibrations cause due to wind/earthquake. It is generally preferable to go in for beam type raft system. The raft design may be as per IS : 2950 (Part 1)-1981*.

5.2.3 The isolated footings may become a good choice in case of lattice towers resting on good soils with medium to high bearing capacity and when tower legs are spaced far apart. The design of isolated footings should be as per IS : 1080-1980†.

*Code of practice for design and construction of raft foundations : Part 1 Design.

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

5.2.4 For RCC towers of circular shape, the ring type or annular or shell type of foundations can be adopted. The design of annular ring type foundation should follow IS : 11089-1984* and that of shell type foundation should follow IS : 9456-1980†.

5.2.5 The combination of isolated footings and pile foundations should be used with utmost caution due to greater chances of high and unanticipated differential settlements between legs. In case the footings under the same tower structure happen to rest such that some of them are in soil and while others on rock, then due consideration should be given for differential settlement and the structural safety.

5.2.6 Bored piles with enlarged bases usually provide an economical type of footing in many soils where under-reaming is possible. In expansive type of soils such as black cotton soils, they have to be carried down to a depth of 3·5 m below the cut-off level in deep layers of these soils to counteract the effect of upthrust due to swelling pressure introduced in the soil. Normal type of independent spread footing carried down to shallow depth will not be suitable in such soils.

5.2.7 Different types of piles can be used depending upon the location and sub-soil characteristics in case of heavy uplift forces and moments multiple under-reamed piles or anchors may be used. In case of loose to medium sandy soils bored compaction under-reamed piles may be used.

5.2.8 *Concrete Piles* — In case concrete piles (other than under reamed) the provisions of IS : 2911 (Part 1/Sec 1)-1979‡, IS : 2911 (Part 1/Sec 2)-1979‡, IS : 2911 (Part 1/Sec 3)-1979‡ and IS : 2911 (Part 1/Sec 4)-1984‡ should apply.

5.2.9 The piles in uplift should be designed by the usual considerations of the friction on stem and bearings on the annular projections. A factor of safety of 3 may be applied for safe uplift.

5.2.10 The load carrying capacity of an under-reamed pile may be determined from a load test as given in IS : 2911 (Part 4)-1985§. In the

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*Code of practice for design and construction of ring foundations.

†Code of practice for design and construction of conical and hyperbolic paraboloidal types of shell foundations.

‡Code of practice for design and construction of pile foundations : Part 1 Concrete piles, Section 1 Driven cast *in-situ* concrete piles (*first revision*;) Section 2 Bored cast *in-situ* piles (*first revision*); Section 3 Driven precast concrete piles (*first revision*); Section 4 Pre-cast bored piles.

§Code of practice for design and construction of pile foundations : Part 4 Load test on piles (*first revision*).

absence of actual tests, the safe loads allowed on piles can be taken from IS : 2911 (Part 3)-1980*

5.2.10.1 The safe loads given in IS : 2911 (Part 3) - 1980* for under-reamed piles apply to both, medium compact sandy soils and clayey soils of medium consistency. For dense sandy ($N \geqslant 30$) and stiff clayey ($N \geqslant 8$) soils the loads may be increased by 25 percent. However, the values of lateral thrust should not be increased unless stability of top soil (strata to a depth of about three times the stem diameter) is ascertained. On the other hand a 25 percent reduction should be made in case of loose sandy ($N \leqslant 10$) and soft clayey ($N \leqslant 4$) soils.

NOTE — For determining the average 'N' values (the standard penetration test values) a weighted average shall be taken and correction for fineness under water table shall be applied where applicable.

5.2.10.2 In case of piles resting on rock bearing the component should be obtained by multiplying the safe capacity of rock with the bearing area of pile stem plus the bearing provided by the under-ream portion.

5.3 Footing on Rock — A rock footing, the uplift and horizontal loads, may be considered to develop strength by the dead load of the concrete and the strength of bar anchorage (the pull-out value of anchor bars grouted in drill holes or the failure strength of rock engaged by bars).

5.3.1 The depth of embedment of the bars below the bottom of the footing should not be less than the following:

$$D = 45\,d$$

where

D = the minimum depth of embedment in mm; and

d = diameter of anchor bar in mm.

5.3.2 The spacing of embedded bars should normally be one-half of the normal depth of embedment as given in **5.3.1**.

5.3.3 The size of the bar should be governed by the criterion that combined stressed do not exceed the permissible limits.

5.4 Factor of Safety and Permissible Stresses

5.4.1 While calculating the stability of the foundations, the factor of safety 2·0 should be provided at every stage. However, in case of foundations with an under-cut, the factor of safety of 1·25 may be adopted while

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

calculating the uplift resistance. A factor of safety of 3 should be provided for safe uplift resistance in case of piles and rock pull out anchors.

5.4.2 If the foundations are resting on saturated non-cohesive strata, no increase in the allowable bearing pressure should be considered for the stability analysis under eccentric loadings.

5.4.3 The permissible stresses in concrete and reinforcement should be as given in IS : 456-1978*. For the other materials, the relevant Indian Standards should be followed. Under earthquake forces, the permissible stress in all the materials can be exceeded up to a limit of 33 percent (*see* IS : 1893-1975†). However, the influence of fatigue under vibration generated forces during winds and earthquakes may also be considered suitably, while selecting permissible stresses.

5.5 Bearing Capacity and Other Sub-soil Parameters

5.5.1 The safe bearing capacity should be determined in accordance with provisions in IS : 6403-1981‡ and permissible total and differential settlements as in **3.3**.

5.5.2 Except when towers are constructed on hillocks, the sub-soil saturation effect due to flooding should be considered while recommending safe bearing capacity.

5.5.3 No increase in allowable bearing pressure on soil or on piles shall be considered under wind or earthquake forces.

5.5.3.1 The permissible bearing pressures arrived at as in **5.5.1** may be exceeded at the edge of the footings by 25 percent when variation in intensity of the reaction caused by the transmission of moments to the footing is taken into account.

5.5.4 Rock anchor pull-out tests should be carried out on 75 mm dia and 1 000 mm deep drilled holes, in case of hard rocks, on at least 3 holes, in determining average value of rock anchor strength.

5.5.4.1 For guidance on data on rock anchors used to counteract uplift in tower, refer IS : 10270 - 1982§.

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

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

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

§Guidelines for design and construction of prestressed rock anchors.

5.6 The general structural requirements are given in IS : 1905 - 1985*.

5.7 Construction

5.7.1 *Excavation Drilling and Blasting* - These operations shall conform to IS : 3764-1966† and IS : 4081-1967‡.

5.7.2 *Concreting*—Concreting shall be done in accordance with the relevant requirements given in IS : 456-1978§.

*Code of practice for general structural requirements of foundations (*third revision*).

†Safety code for excavation work.

‡Safety code for blasting and related drilling operations.

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

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INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	*Unit*	*Symbol*
Lehgth	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*
Plan 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 Wa/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

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Telelphones : 331 01 31
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