भारतीय मानक ब्यूरो
(उपभोक्ता मामले, खाद्य एवं सार्वजनिक वितरण मंत्रालय, भारत सरकार)
BUREAU OF INDIAN STANDARDS
(Ministry of Consumer Affairs, Food & Public Distribution, Govt. of India)

मानक भवन, 9, बहादुर शाह ज़फर मार्ग, नई दिल्ली – 110002
Manak Bhawan, 9, Bahadur Shah Zafar Marg, New Delhi – 110002
Phones: 23230131 / 2323375 / 23239402
Website: www.bis.gov.in, www.manakonlin.in

व्यापक परिचालन मसौदा

हमारा संदर्भ : सीईडी 43/टी-108 **23 अगस्त 2024**

तकनीकी समिति : मृदा एवं नींव इंजीनियरिंग अनुभागीय समिति 43

प्राप्तकर्ता :

1. **सिविल अभियांत्रिकी विभाग परिषद, सीईडीसी के सभी सदस्य**
2. **मृदा एवं नींव इंजीनियरिंग अनुभागीय समिति 43 और इसकी उपसमितियों के सभी सदस्य**
3. **रुचि रखने वाले अन्य निकाय।**

महोदय/महोदया,

निम्नलिखित मानक का मसौदा संलग्न हैं:

प्रलेख संख्या	शीर्षक
सीईडी 43 (26416)	भारतीय मानक मसौदा रडार और सैटेलाइट ट्रैकिंग एंटेना एवं माइक्रोवेव, मोबाइल और टेलीविजन टॉवर के नींव का डिजाइन और निर्माण — रीति संहिता (*आईएस 11233 का पहला पुनरीक्षण*) (आई सी एस संख्या: 93.020)

कृपया इस मसौदे का अवलोकन करें और अपनी सम्मतियाँ यह बताते हुए भेजे कि यह मसौदा प्रकाशित हो तो इन पर अमल करने में आपको व्यवसाय अथवा कारोबार में क्या कठिनाइयां आ सकती हैं।

सम्मतियाँ भेजने की अंतिम तिथि: 27 सितंबर 2024

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यह प्रालेख भारतीय मानक ब्यूरो की वेबसाइट **www.bis.gov.in** पर भी उपलब्ध हैं।

धन्यवाद।

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ह/-
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वैज्ञानिक ई एवं प्रमुख
सिविल अभियांत्रिकी विभाग
ई-मेल: ced43@bis.gov.in
फोन: +91-11 2323 5529

संलग्न: उपरलिखित

भारतीय मानक ब्यूरो
(उपभोक्ता मामले, खाद्य एवं सार्वजनिक वितरण मंत्रालय, भारत सरकार)
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WIDE CIRCULATION DRAFT

Our Reference: CED 43/T-108 **23 August 2024**

TECHNICAL COMMITTEE: Soil and Foundation Engineering Sectional Committee, CED 43

ADDRESSED TO:

1. All Members of Civil Engineering Division Council, CEDC
2. All Members of Soil and Foundation Engineering Sectional Committee, CED 43 and its Subcommittees
3. All others interested.

Dear Sir/Madam,

Please find enclosed the following draft:

Doc No.	Title
CED 43(26416)	Draft Indian Standard of Design and Construction of Foundations for Radar and Satellite Tracking Antennas and Microwave, Mobile and Television Towers — Code of Practice *(First Revision of IS 11233)* ICS No.: 93.020

Kindly examine the attached draft and forward your views stating any difficulties which you are likely to experience in your business or profession, if this is finally adopted as National Standard.

Last Date for comments: 27 September 2024

Comments if any, may please be made in the enclosed format and emailed at ced43@bis.gov.in or sent at the above address. Additionally, comments may be sent online through the BIS e-governance portal, www.manakonline.in.

In case no comments are received or comments received are of editorial nature, kindly permit us to presume your approval for the above document as finalized. However, in case comments, technical in nature are received, then it may be finalized either in consultation with the Chairman, Sectional Committee or referred to the Sectional Committee for further necessary action if so desired by the Chairman, Sectional Committee.

The document is also hosted on BIS website www.bis.gov.in.

Thanking you,

Yours faithfully,

Sd/-

Dwaipayan Bhadra
Scientist 'E' & Head
Civil Engineering Department
Email: ced43@bis.gov.in
Phone: +91-11 2323 5529

Encl: As above

FORMAT FOR SENDING COMMENTS ON THE DOCUMENT

[Please use A4 size sheet of paper only and type within fields indicated. Comments on each clause/sub-clause/ table/figure, etc, be stated on a fresh row. Information/comments should include reasons for comments, technical references and suggestions for modified wordings of the clause. **Comments through e-mail to ced43@bis.gov.in shall be appreciated**.]

Doc. No.: **CED 43(26416)**

BIS Letter Ref: CED 43/T-108

Title: Draft Indian Standard of Design and Construction of Foundations for Radar and Satellite Tracking Antennas and Microwave, Mobile and Television Towers — Code of Practice (*First Revision of* IS 11233)
ICS No.: 93.020

Last date of comments: **27 September 2024**

Name of the Commentator/ Organization: ____

Sl No.	Clause/ Para/ Table/ Figure No. commented	Type of Comment (General/ Technical/ Editorial)	Comments/ Modified Wordings	Justification of Proposed Change
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BUREAU OF INDIAN STANDARDS

DRAFT FOR COMMENTS ONLY

Draft Indian Standard

DESIGN AND CONSTRUCTION OF FOUNDATIONS FOR RADAR AND SATELLITE TRACKING ANTENNAS AND MICROWAVE, MOBILE AND TELEVISION TOWERS — CODE OF PRACTICE

(*First Revision of IS 11233*)

Soil and Foundation Engineering Sectional Committee, CED 43	Last date for Comment: **27 September 2024**

FOREWORD

(*Formal clauses to be added later*)

Radar antenna, microwave and television towers are widely used for the communication systems in defence, postal department, railways and for television stations. Dish-type antennas are used by space research organizations, for satellite tracking and various other purposes. Foundations for such antennas and towers are covered by this standard. Foundation required for these types of antennas and towers have to be designed based on several known and assumed factors. Therefore, this standard on the subject was first formulated in 1985 based on the experience gained till that time so as to help various organizations to standardize the design procedures and assumed factors.

With the increased use of mobiles for communication during normal conditions and natural calamities, foundations for mobile signal towers have also been now covered in this standard, and the various stipulations in the standard would be applicable for such towers also. These towers are considered as life-line structures, hence, their functionality during and after extreme conditions, such as, floods, severe earthquakes and landslides are to be ensured.

Similarly, foundation for all types of antennas (dish type and others) used by various government agencies and private institutions, for satellite tracking, signal reception by ground stations and similar applications have also been covered in this standard.

Satellite tracking antennas need high accuracy in their positioning and pointing during normal operation. Hence, wherever large absolute or differential settlements are expected due to poor subsoil conditions, foundation design should incorporate provisions to account for such settlements and re-alignment of the antennas during design life, as needed by the user.

Present revision of the standard incorporates the experience gained with the use of this standard and brings the standard in line with the latest developments in the field. Accordingly, in this revision of the standard the following major modifications have been incorporated:

a) New terms and their definitions have been incorporated. Some of the existing definitions have also been modified.
b) The scope of the standard has been extended to cover foundations of mobile communication towers and satellite tracking antennas. Title of the standard has been accordingly modified.
c) The provisions on necessary information to be provided for design and construction of foundations have been modified.
d) Provisions relating to design, construction and materials have also been modified.
e) Provisions on foundation drawings and anchor bolt template have been included.
f) Block foundations are included, for those superstructures transmitting vibrations from superstructure to the foundation.
g) Uncertainty analysis for estimating settlements in soft soil, has been incorporated.

Further, in the design and construction of foundations for all the structures mentioned earlier, a proper coordination between different branches of engineering, including those dealing with erection and commissioning is essential. Coordinated efforts by the different branches would result in satisfactory performance, convenience of operation, economy and a good appearance of complete unit.

The main unit with all its auxiliaries and adjacent structures/components, if any shall be provided for, when making the foundation plans and all the details should be well worked out, before going ahead with the design.

In the formulation of this standard due weightage has been given to international coordination among the standards and practices prevailing in different countries in addition to relating it to the practices in this field in the country. Considerable assistance has been derived from the following International Standards:

ISO 23469 : 2005	Bases for design of structures – Seismic actions for designing geotechnical works
CAN/CSA-S37-18	Antennas, towers and antenna-supporting structures

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: 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

BUREAU OF INDIAN STANDARDS

DRAFT FOR COMMENTS ONLY

Draft Indian Standard

DESIGN AND CONSTRUCTION OF FOUNDATIONS FOR RADAR AND SATELLITE TRACKING ANTENNAS AND MICROWAVE, MOBILE AND TELEVISION TOWERS — CODE OF PRACTICE

(*First Revision of* IS 11233)

Soil and Foundation Engineering Sectional Committee, CED 43	Last date for Comment: **27 September 2024**

1 SCOPE

1.1 This standard provides guidelines for the design and construction of reinforced concrete foundations for self-supporting type radio communication, radar and satellite tracking antennas, dish antennas, mobile communication towers (including mono-poles), microwave towers and television towers.

NOTE — Grillage, brick and massive footings of prestressed concrete are not covered in this standard. Specialist literature may be consulted for such foundations.

1.2 This standard does not cover mobile communication towers installed on top of existing buildings, and, infrastructure facilities, etc.

NOTE — Concerned local/municipal authorities giving permission for mobile communication towers installed on top of existing building, and infrastructure facilities should review such installations, separately, in consultation with experts.

2 REFERENCES

The standards listed in Annex A contain provisions, which through reference in this text constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standard indicated in Annex A.

3 TERMINOLOGY

For the purpose of this standard, the terms and definitions given in IS 2809 shall apply in addition to those given below.

3.1 Foundations — That part of the structure which is in direct contact with the ground and transmits the loads to the ground.

3.2 Footing — A type of shallow foundation that are normally constructed by making open excavations, they may have enlarged base provided either in the open excavation or by under-cutting the soil by suitable devices for the purpose of distributing the load over a larger area of the ground. A spread footing (or isolated or pad) is provided to support an individual column. Sometimes, it is stepped or haunched to spread the load over a large area.

3.3 Raft Foundation — A substructure supporting an arrangement of columns or walls in a row or rows transmitting the loads to the soil by means of a continuous slab, with or without depressions or openings.

3.4 Pile Foundation — A particular type of precast or cast in-situ foundation normally provided by driving or boring, and having uniform, bulbed, tapered or corrugated section along its length.

3.5 Rock — Foundation supporting material other than soil which is possible to excavate; in the case of soft rocks with pick axe and shovels and in case of hard rocks by special methods like blasting.

3.6 Soil, Black Cotton Soil — Clayey soil, not necessarily black in colour, which shrinks when dry and swells when wet, resulting in differential movement of ground. In deep deposits of these soil, generally there is no appreciable ground movement due to seasonal moisture changes beyond 3.5 m [*see* IS 2720 (Part 40)].

3.7 Liquefaction — Large drop in soil shear strength and/or stiffness caused by an increase in pore water pressure that may cause significant reduction.

3.8 Liquefaction Potential — Susceptibility of the soil to the onset of liquefaction under a reference earthquake motion.

4 NECESSARY INFORMATION AND DESIGN DATA

For the design and construction of foundations, the information as given in **4.1** to **4.3** shall be required.

4.1 General

a) The location map showing the layout of the existing towers and structures with the general topography of the area.
b) The geometrical details of the tower like height and details of antenna and its / their sizes configuration.
c) The resulting forces acting at the base of the tower (or at the base of the antenna, at the level of anchor bolts) like downward loads, uplift forces,horizontal shears, overturning, torsional moments from analysis of antenna/tower structure.
d) Maximum total settlement of/and differential settlement between the legs allowed at the foundation level for the tower. This information shall be supplied by the tower user.

NOTE — For foundations of satellite communication antenna, in addition to settlement/differential settlement, horizontal deformation at foundation top (at the base of anchor bolts) shall be as specified by the user.

e) 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 to a depth of hard/firm stratum to finalize the type of foundation for the tower, 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 a depth of not less than 10 m below ground level and consolidation test data (coefficient of compression necessarily in clayey and silty soils along with results of other tests carried out on soil samples). A report on water table and its seasonal variations should be included. Suggested geotechnical investigations are given in Annex C.
f) Special information like the wind data including cyclones/tornado, etc, depth of frost and penetration, and earthquake data [see IS 875 (Part 3) and IS 1893 (Part 1)].
g) A review of the performance of tower like structures, if any, in the locality.
h) In case of rocky subgrade, it should be ensured that rocky strata are of sufficient thickness (up to 1.5 to 2.0 times width of the foundation) 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.
j) Sections of trial borings or pits showing soil profile at the site of work.

4.2 Design Forces

The design forces shall include the following:

a) Total weight of the structure;
b) Overturning and torsional moments due to wind forces;
c) Horizontal shear forces at tower base level;
d) Earthquake generated forces as per IS 1893 (Part 1);
e) Pulsating forces due to the vibrations caused in the tower by the wind;
f) Transient forces due to rotation of dish antennas in vertical and horizontal planes, (a) whether directly mounted at ground level, or, (b) transferred to the top of foundation, in case they are mounted at certain height above the foundation; and
g) Thermal loads arising out of diurnal variations should be included for analysis and design check, for their adverse affects, and resultants forces transmitted to the foundation.

4.3 Vertical Settlements and Lateral Displacements

4.3.1 For the allowable settlements for these structures, the following guidelines shallbe considered:

a) The allowable total settlements and rotations should be restricted as follows, or as given by the equipment manufacturer, whichever is stringent:

1) Radar antenna towers : 12 mm;

2) Microwave towers with dish type antenna : 16 mm;
3) Towers and towers with Yagi type antenna : 50 mm; and
4) Maximum rotation at antenna foundation : 1 milli-degree.

In addition, satellite tracking antennas are sensitive to displacements under lateral loads, like, seismic and wind loads. Realistic estimate of lateral displacements of foundations shall be made, to ensure functionality of the superstructure, under worst possible environmental conditions. These stipulations are primarily governed by the user requirements.

b) The maximum allowable differential vertical settlement should be restricted to 6 mm for foundations of satellite tracking antennas and radar antenna towers, 20 mm for television towers and 12 mm for microwave towers. These values are basic requirements; equipment manufacturer/user may specify stringent values, based on functional requirements.

c) In case of foundations resting partially on rock and partially on soil, the allowable differential settlements should be restricted 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 concrete piles of end bearing type.

NOTE — If option exists, foundations at such locations may be avoided, as far as possible.

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.

In case of block foundations for specialized rotary type of antenna towers/disc towers, while determining the bearing capacity of the foundation, the total permissible settlement shall be taken as the least of the following, for calculating the net allowable bearing pressure:

1) 25 mm in case of soil/12 mm in case of rock; or
2) As specified by the equipment/tower manufacturer.

Reference can be made to IS 2974 (Part 2).

f) For subsoil conditions where seasonal variation in water table depth is large, or the founding medium is clay or black cotton soil or other types of expansive soils, settlements may be monitored for 4 to 5 years, or till settlement are stabilized, to understand the behaviour of foundation and superstructure, for important towers, to ensure functionality during service life.

g) Provisions should be made in the foundation design, to correct large differential settlements with associated effect on the structure so as to make the towers functional, after such incidences.

h) Range analysis as given in Annex B for estimation of short-term and long-term settlements may be carried out, to envelope the uncertainties in geotechnical design parameters, and ensure durability of foundation and superstructure, during the service life of structure.

5 TYPES OF FOUNDATIONS

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

a) Isolated footings under each leg of the tower (with or without connecting beams);
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;
g) Shell foundations, especially for circular section RCC towers; and
h) Block foundations with adequate mass, where continuous vibrations or transient loads are predominant during operation of rotating type dish antennas.

5.1.1 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.

5.2 Bearing against Undisturbed Soil

Where possible, the sides of tower foundations and the front face of guy anchors shall be placed against undisturbed soil. Where this is not possible, the engineer shall specify the type of material required for the backfill and compaction effort used to provide the necessary resistance against sliding, uplift, and overturning.

TABLE 1 LOADING AND FOOTING CLASSIFICATION
(*Clause* 5.1.1)

Sl No.	**Class of Footings**	**Type of Loads**	**Type of Structure**	**Type of Footing Recommended**	**Type of Soil Reaction**
(1)	(2)	(3)	(4)	(5)	(6)
i)	A	Heavy uplift withlight shear	Wide base towers or individual footing under each leg	With enlarged (under-cut) type base or under reamed or group of piles	Weight of earth on enlarged base or pull-out resistance

ii)	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 based and soil pressure on bottom of the base
iii)	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
iv)	D	Heavy shear, uplift with light vertical load	Lack of self-weight of structure to give stability	Wide base with foundation anchors to resist the sliding shear and uplift forces	Uplift may be restricted to one-third base area of foundation, neglecting projections from the regular shape.

5.3 Base of Foundation Below Frost Line or into Permafrost

Tower foundations and guy anchors in soil shall extend below the frost line, except in permafrost areas, unless frost action is considered in the design of the foundations and guy anchors.

5.4 Ultimate Load Effects for Overturning and Sliding

Factored loads for ultimate limit states, including overturning and sliding, shall be determined. Where resistance to movement is provided by dead load alone, the factored loads shall be determined using a dead load factor of 0.9. The mount shall be proportioned so that sliding occurs before overturning, and movement shall be limited to the extent that it does not endanger people, the building, or any other attachment.

5.5 Serviceability Load Effects for Sliding

Where loss of service is considered acceptable, sliding of the antenna may be considered as serviceability limit state. Serviceability loads shall be determined, with a resistance factor of 0.8 applied to the coefficient of friction, or, with a factor of 0.9 for dead loads resisting sliding.

6 GENERAL DESIGN CRITERIA

6.1 Design Loads and Forces

6.1.1 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.

6.1.2 Inclined loads should be split into lateral/shear and vertical loads at the top ofthe foundations.

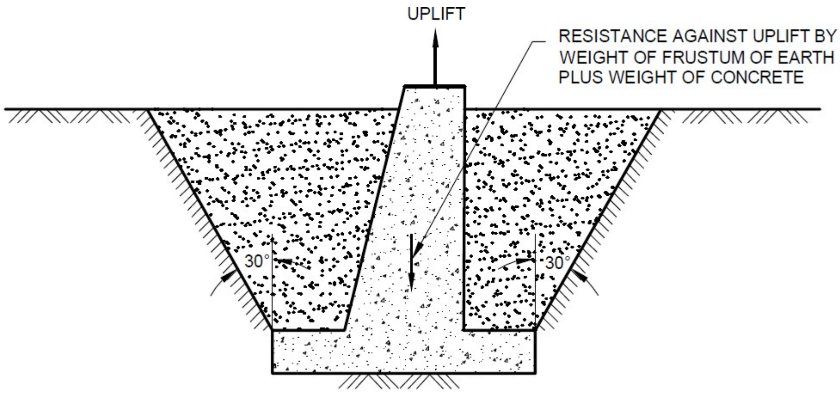
6.2 Design Criteria for Various Types of Design Loads

6.2.1 *Uplift Loads and Horizontal Thrusts* (*Stability Considerations*).

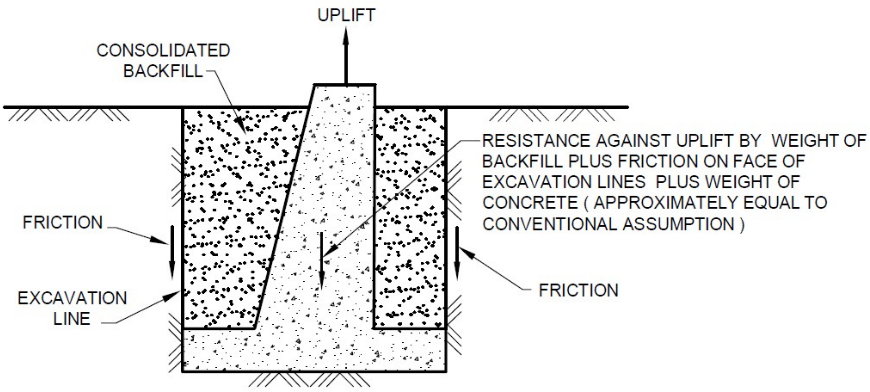
6.2.1.1 In tall self-supporting type of towers, monopoles (microwave and television), and often in short towers (radar antenna) uplift load becomes an important governing criteria for selection and design of type of foundations for structure and foundation stability. General consideration and criteria are given in **6.2.1.2** to **6.2.1.14**.

6.2.1.2 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 20 ° to 30 ° with the vertical, as per **6.2.1.4**.

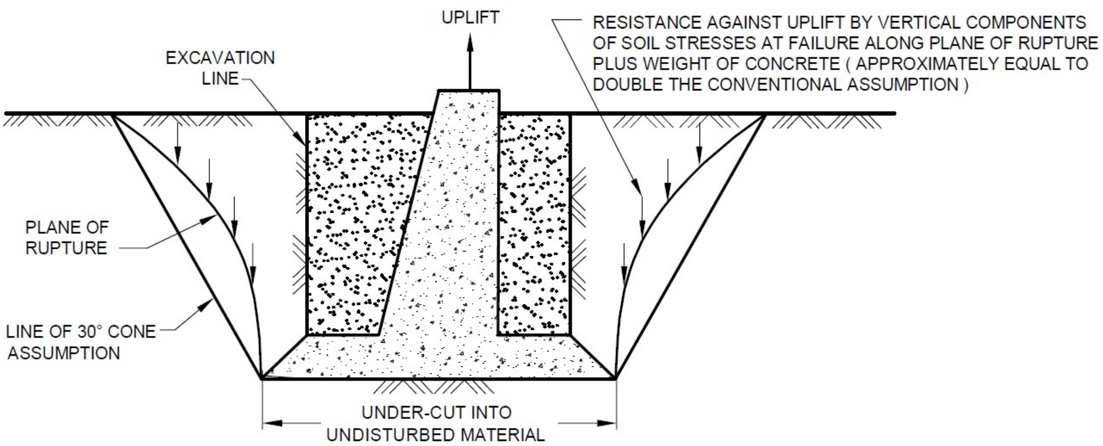
6.2.1.3 A footing with an under-cut generally develops uplift resistance that is higher than that of an identical footing without an under-cut (*see* Fig. 1) for which reason, reduced factors of safety (*see* **6.5.1**) can be adopted.



1 A CONVENTIONAL ASSUMPTION



1 B ACTUAL ACTION WITHOUT UNDER-CUT



1 C ACTUAL ACTION WITH UNDER-CUT

FIG. 1 SOIL RESISTANCE TO UPLIFT

6.2.1.4 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 shall be done for in between soil classifications.

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

6.2.1.6 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 one sixth of its width from the toes;
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.

6.2.1.7 The uplift forces in case of pile foundation should be counteracted by the uplift resistance of piles and weight of the pile caps and the earth cone above it (wherever applicable) with factors of safety as in **6.5.1**.

6.2.1.8 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 **6.5.1**.

6.2.1.9 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 **6.5.1**.

6.2.1.10 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) and (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 **6.5.1** shall be used.

6.2.1.11 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 or more as needed by the design of uplift forces, under the footing be provided to achieve additional uplift resistance, instead of increasing the size of footing. Economy considerations should, however, govern the design.

6.2.1.12 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 analysing the stability of the foundation.

Checks for floatation shall be carried out, when the basement is empty (fully or partly), and ground water table is at natural ground level, due to external flooding or excessive rainfall, or blocking of natural drainage in surrounding areas, leading to stagnation of water at ground level, or similar other conditions). A minimum factor of safety of 1.1 against floatation shall be ensured under worst possible scenario.

6.2.1.13 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 eases, the dead weight of the footing (cap in cases of piles) and the earth fill above the footing of pile cap in accordance with **6.2.1.1** should be considered for balancing the tension providing factor of safety as in **6.5.1**.

For unavoidable conditions, under most unfavourable load combinations, limited tension at the edges of the foundation may be permitted. Tension area to the extent of 33 percent of plan area of the foundation may be permitted. Any smaller projections from standard shape of foundation shall be ignored for calculating tension/compression areas. Under such cases, compressive stress at the other edges shall be limited, in line with geotechnical considerations.

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

6.2.2 *Downward Loads and Overturning Moments*

6.2.2.1 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 **6.6.3.1**.

6.2.2.2 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.

6.2.2.3 Combination of shallow foundations and pile foundations should ensure that differential settlement of tower legs is within permissible limits as in **4.3.1**.

6.3 Criteria for Selection of Type of Foundation and its Design

6.3.1 Amongst other considerations, the safe bearing capacity, founding depth, and, settlement characteristics of soil should govern the selection of the type of foundation. Amongst various alternatives, cost economics may become one of the decisive factors in many cases. However, functionality, safety and stability of foundation and super structure should be the governing factor, for life line structures.

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

The provisions provided in IS 13094 can be followed for weak soils. Ground improvement refers to enhancement of the in-place properties of the ground by controlled application of technique suited to the subsoil conditions. These techniques are used to improve the load bearing capacity and settlement potential of the loose or soft soil lying close to the surface or at depths.

6.3.3 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 shall be as per IS 1080.

6.3.4 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 shall follow IS 11089 and that of shell type foundation shall be as per IS 9456. For other non-standard shapes of foundation, specialist literature may be referred, and rigorous analysis may be needed, for optimum design.

6.3.5 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, structural safety and functionality.

6.3.6 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.

6.3.7 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.

6.3.8 *Concrete Piles*

In case of concrete piles (other than under-reamed) the provisions of IS 2911 (Part 1/Sec 1), IS 2911 (Part 1/Sec 2), IS 2911 (Part 1/Sec 3) or IS 2911 (Part 1/ Sec 4) as applicable shall apply.

6.3.9 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.

6.3.10 The load carrying capacity of an under-reamed pile shall be determined as per the provisions of IS 2911 (Part 3).

6.3.10.1 The safe loads given in IS 2911 (Part 3) for under- reamed piles apply to both, medium compact sandy soils and clayey soils of medium consistency. For dense sandy (N>30) and stiff clayey (N>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<10) and soft clayey (N<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.

6.3.10.2 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.

6.4 Footing on Rock

For footings resting on rock, the uplift and horizontal loads, may be considered to develop strength by the dead load of the concrete (framed structure, foundation block, or pile and pile cap, as the case may be) 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).

6.4.1 The depth of embedment of the bars below the bottom of the footing should notbe less than the following:

$$D = 45 \times d$$

Where,

D = minimum depth of embedment, in mm; and
d = diameter of anchor bar, in mm.

6.4.2 The spacing of embedded bars should not to exceed one-half of the normal depth of embedment as given in **6.4.1**. In exceptional cases, suitable provisions should be adopted.

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

6.4.4 For design aspects of foundations on tip of hills, possibility of land/slope sliding, soil erosion due to rain, snow fall, etc may be reviewed. Specialist literature and guidelines of local or state authorities may be consulted for detailed design aspects, wherever required.

6.5 Factor of Safety and Permissible Stresses

6.5.1 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 1.5 may be adopted while 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.

6.5.2 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.

6.5.3 The permissible stresses in concrete and reinforcement shall be as given in IS 456. Where stresses due to wind, temperature and shrinkage effects are combined with those due to dead, imposed and impact loads, permissible stresses specified in IS 456 for these conditions shall be used in the design.

For the other materials, the relevant Indian Standards shall be followed. Under earthquake forces, the permissible stress in all the materials may be exceeded up to a limit of 33 percent [*see* IS 1893 (Part 1)]. However, the influence of fatigue under vibration generated forces during winds and earthquakes may also be considered suitably, while selecting permissible stresses. For the case of foundations supporting life-line structures, this increase in permissible stress may not be applicable, based on the user requirements.

For foundations of satellite and other communication antenna towers (ground stations), under the actions of uplift, sliding, overturning and buoyancy (or flotation), the factor of safety shall not be less than 1.5 in case of design load combinations of wind load [*see* IS 875 (Part 3)] and seismic force [*see* IS 1893 (Part 1)], and, shall not be less than 1.1 for extreme load conditions.

6.6 Bearing Capacity and Other Sub-soil Parameters

6.6.1 The safe bearing capacity should be determined in accordance with provisions in IS 6403, and permissible total and differential settlements as in **4.3**.

6.6.1.1 The allowable bearing pressure of the foundation where the towers are founded shall be based on adequate subsoil exploration and testing carried out in accordance with IS 1888, IS 1892 and IS 1904.

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

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

6.6.3.1 The permissible bearing pressures arrived at as in **6.6.1** 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.

6.6.4 Rock anchor pull-out tests should be carried out on 75 mm diameter 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.

6.6.4.1 For guidance on data on rock anchors used to counteract uplift in tower,IS 10270 shall be referred.

6.6.5 The bearing pressure and subgrade modulus of the founding soil should be determined using field plate load test as per IS 1888.

6.7 The general structural requirements are given in IS 1905.

6.8 Construction

6.8.1 *Excavation Drilling and Blasting*

6.8.1.1 These operations shall conform to IS 3764 and IS 4081.

6.8.1.2 Drilled foundations present certain challenges and the following guidelines may be followed:

a) Foundations can be drilled in any type of soil formation including sandy soils where drilling is, however, not straight-forward due to the likelihood of hole cave-in;
b) Where drilling is in sandy soil, a casing may be used and pulled out as the concrete is being placed so that the concrete is in contact with the sides of the hole; and
c) Alternatively, drilling slurry could be used. The hole is filled with mud and as the concrete is pumped into the bottom of the hole, the mud is pumped out atthe top. The concrete likewise makes immediate contact with the soil and the foundation provides the support, that is required.

6.8.1.3 Foundation in swamps can be done more effectively,

a) With modified construction techniques and an alternative method for anchoring;
b) The 'simple marsh anchor' method which is a technology that employs square rods with screw helices at one metre intervals on the initial three to six metre length may be used;
c) Use of the screw anchors requires only the availability of an auger machine to screw the anchors into the ground thus avoiding the digging of holes, forming, and pouring concrete;

d) The anchors are simply screwed into the ground until a layer of earth is encountered that offers sufficient resistance to achieve the required installation torque;
e) In order to shorten the depth to which anchors are to be screwed, the use of multiple anchors with load-distributing linkages is advisable; and
f) The advantage of this method is the ease with which extensions or additional anchors can later be added in the event that capacity needs to be increased for additional load requirements or for the addition of torque arms.

6.8.2 *Concreting*

Concreting, shall be done in accordance with the relevant requirements given in IS 456.

6.9 MATERIALS

6.9.1 Cement

The cement used shall be any of the following:

a) Ordinary Portland cement conforming to IS 269;
b) Rapid hardening Portland cement conforming to IS 8041;
c) Portland slag cement conforming to IS 455;
d) Portland pozzolana cement (fly ash based) conforming to IS 1489 (Part 1);
e) Portland pozzolana cement (calcined clay based) conforming to IS 1489 (Part 2); and
f) Super sulphated cement conforming to IS 6909.

6.9.2 Steel

Reinforcement steel shall be any of the following:

a) Mild steel and medium tensile steel bars conforming to IS 432 (Part 1);
b) High strength deformed steel bars conforming to IS 1786; and
c) Stainless steel conforming to IS 16651 or any other special steel(s) as per user requirement and as per site conditions.

6.9.3 Concrete

In general, materials mixing and quality control for concrete shall be in accordance with relevant requirements given in IS 456.

7 STRUCTURAL SAFETY

7.1 For the structural safety against sliding, overturning and for the footings atdifferent levels, provisions laid down in IS 1904 shall apply.

7.2 The depth of foundation shall conform to the provisions laid down in the relevant Indian Standards depending on the type of foundation [*see* IS 1080, IS 1904, IS 2950 (Part 1), IS 2911 (Part 1/Sec 1), IS 2911 (Part 1/Sec 2), IS 2911 (Part 1/ Sec 3), IS 2911 (Part 1/Sec 4), IS 2911 (Part 3) and IS 9456].

8 SPECIAL CONSIDERATIONS

8.1 Foundations in Seismic Zones

In designing foundations in seismic zones, the provisions of IS 1893 (Part 1) to evaluate the seismic forces shall also apply.

Susceptibility of the soils to the onset of liquefaction under a reference earthquake motion, specially for cohesionless sands and similar other coarse grained soils, in the regions of high seismicity.

Where, founding medium is susceptible to liquefaction, ground improvement can be carried out, in line with the guidelines of IS 15284 (Parts 1 and 2) or any other suitable methods. Provisions given in IS 1893 (Part 1) or any other suitable method may be followed for evaluating liquefaction potential.

To minimize higher amplification under seismic conditions, it is preferable to keep the natural frequency of antenna foundations above 8 Hz. Foundation stiffness may be adjusted and incorporated in design accordingly.

Wherever applicable, effects of soil liquefaction and induced ground displacement may be analysed by incorporating the stiffness and strength reduction in the liquefied soils, either through:

a) The use of equivalent shear modulus in the linear analysis, or,
b) Through the use of reduced stiffness and residual strength in the non-linear analysis. Allowance shall be made for differential settlements caused by site heterogeneity, taking into account the characteristics of the structure and the simplifications in the analysis.

NOTE — Specialist literature, such as, ISO 23469 : 2005 'Bases for design of structures — Seismic actions for designing geotechnical works' or any other state of the art research work may be consulted for detailed and rigorous analyses to estimate liquefaction potential.

8.2 Foundations in Sulphate Bearing Clays

Suitable precautions as laid down in IS 1904 shall be taken in the case of foundations in sulphate bearing clays.

8.3 Foundation Drawings

Foundation drawings shall indicate dimensions, material strengths, reinforcing steel and embedded anchorage material type, size and location. Every foundation that is designed for normal soil conditions shall duly be noted and every foundation design shall include site soil data as a footnote.

8.4 Anchor Bolts Template

Templates which provide proper anchor bolt orientation at the time of foundation forming shall be used to eliminate problems associated with misalignment. Templates shall be precisely fabricated and used in constructing tower foundations in accordance with design specifications.

ANNEX A
(*Clause* 2)

LIST OF REFERRED INDIAN STANDARDS

IS No	*Title*
269 : 2015	Ordinary Portland cement — Specification (*sixth revision*)
432 (Part 1) : 1982	Specification for mild steel and medium tensile steel bars and hard-drawn steel wire for concrete reinforcement: Part 1 Mild steel and medium tensile steel bars (*third revision*)
455 : 2015	Portland slag cement — Specification (*fifth revision*)
456 : 2000	Plain and reinforced concrete — Code of practice (*fourth revision*)
875 (Part 3) : 2015	Design loads (other than earthquake) for buildings and structures — Code of practice Part 3 Wind loads (*third revision*)
1080 : 1985	Code of practice for design and construction of shallow foundations in soils (other than raft, ring and shell) (*second revision*)
1489	Portland pozzolana cement — Specification
(Part 1) : 2015	Part 1 Fly ash based (*fourth revision*)
(Part 2) : 2015	Part 2 Calcined clay based (*fourth revision*)
1786 : 2008	High strength deformed steel bars and wires for concrete reinforcement — Specification (*fourth revision*)
1888 : 1982	Method of load test on soils (*second revision*)
1892 : 2021	Subsurface investigation for foundations — Code of practice (*second revision*)
1893 (Part 1) : 2016	Criteria for earthquake resistant design of structures: Part 1 General provisions and buildings (*sixth revision*)
1904 : 2021	General requirements for design and construction of foundations in soils — Code of practice (*fourth revision*)
2062: 2011	Hot rolled medium and high tensile structural steel — Specification (*seventh revision*)
2131: 1981	Method for standard penetration test for soils (*first revision*)
2720 (Part 40) : 1977	Methods of test for soils: Part 40 Determination of free swell index of soils
2809 : 1972	Glossary of terms and symbols relating to soil engineering (*first revision*)
2911	Design and construction of pile foundations — Code of practice

(Part 1/Sec 1) : 2010	Part 1 Concrete piles, Section 1 Driven cast *in-situ* concrete piles (*second revision*)
(Part 1/Sec 2) : 2010	Part 1 Concrete piles, Section 2 Bored cast *in-situ* concrete piles (*second revision*)
(Part 1/Sec 3) : 2010	Part 1 Concrete piles, Section 3 Driven precast concretepiles (*second revision*)
(Part 1/Sec 4) : 2010	Part 1 Concrete piles, Section 4 Precast concrete piles in prebored holes (*first revision*)
(Part 3) : 2021	Part 3 Under-reamed piles
2974 (Part 2) : XXXX	Design and construction of machine foundations: Part 2 Block foundations (*second revision*) (under preparation)
3764 : 1992	Excavation work — Code of safety (*first revision*)
4081 : 2013	Blasting and related drilling operations — Code of safety
4091 : 1979	Code of practice for design and construction of foundations for transmission line towers and poles
6403 : 1981	Code of practice for determination of bearing capacity of shallow foundations (*first revision*)
6909 : 1990	Super sulphated cement — Specification (*first revision*)
8041 : 1990	Rapid hardening Portland cement — Specification (*second revision*)
9456 : 1980	Code of practice for design and construction of conical and hyperbolic paraboloidal types of shell foundations
11089 : 1984	Code of practice for design and construction of ring foundation
12070 : 1987	Code of practice for design and construction of shallow foundations on rocks
13094 : 2021	Selection of ground improvement techniques for weak soils — Guidelines
15284	Design and construction for ground improvement — Guidelines
(Part 1) : 2003	Part 1 Stone Columns
(Part 2) : 2004	Part 2 Preconsolidation using vertical drains
16651 : 2017	High strength deformed stainless steel bars and wires for concrete reinforcement — Specification

ANNEX B

[*Foreword and* 4.3.1 (*h*)]

ANALYSIS OF SOIL STRUCTURE INTERACTION FOR UNCERTAINTIES IN FOUNDATION DESIGN PARAMETERS

B-1 Uncertainties in the Soil Structure Interaction (SSI) analysis may be considered for analysis and design, as follows.

For the chosen sites where detailed and thorough subsoil investigations are not possible, range analysis for estimation of absolute and differential settlements may be carried out. Often, such results from the analyses may govern the design of superstructure.

a) The preferred treatment of uncertainties in the SSI analysis is the use of probabilistic techniques. In such an approach, the resulting design quantities would be established at a non-exceedance probability of approximately 80 percent to meet the goal of this standard.
b) If the input motion for SSI analysis has been developed using IS 1893 (Part 1), the variation of the soil properties for SSI analysis shall be consistentwith the soil properties used in the generation of input motion.
c) In lieu of a probabilistic analysis, an acceptable method to account for uncertainties in SSI analysis is to vary the strain-compatible (high-strain) soil shear modulus.
d) High-strain soil shear modulus shall be varied between the best-estimate value times $(1+C_v)$ and the best estimate value divided by $(1+C_v)$, where C_v is a factor that accounts for uncertainties in the SSI analysis and soil properties. If sufficient and adequate soil investigation data are available, the mean and standard deviation of the high-strain shear modulus shall be established for every soil layer. The factor C_v shall then be established as the coefficient of variation so that it covers the mean plus or minus one standard deviation for every layer.
e) For deterministic SSI analysis, a minimum variation of strain-compatible soil shear modulus, with C_v as 0.50 shall be used. If insufficient data are available to address uncertainties in soil properties, C_v shall be taken as no less than 1.0.
f) Range analysis for settlements may be carried out with two enveloping cases (upper bound and lower bound), as indicated above, by varying the soil modulus, that is, multiplying with $(1+C_v)$ and dividing with $(1+C_v)$.

ANNEX C
(*Clause* 4.1.5)

GEOTECHNICAL SITE INVESTIGATIONS

C-1 GENERAL

A geotechnical report should be provided for all sites and should include, as a minimum, the following information in accordance with recommendations of relevant Indian Standards.

C-2 SOIL SITES

For soil sites, the geotechnical report should include, but not limited to the following:

a) Ultimate and serviceability bearing resistances;
b) Coefficients of lateral at rest, active and passive soil pressure;
c) Angle of internal friction for coarse grained soils;
d) Soil cohesion for fine grained soils;
e) Water table level for the worst expected condition or recommended design level, whichever governs;
f) Density of soil to at least 4 m below grade but to a greater depth, if required for the foundation or anchor design. Values should be provided for both dry and submerged conditions;
g) Depth of seasonal frost penetration;
h) Ultimate end bearing and skin friction (tension and compression) capacities for driven piles and poured caissons;
j) Soil resistivity and corrosive nature of the soil; and
k) Site category for seismic response in accordance with IS 1893 (Part 1).

C-3 ROCK SITES

For rock sites, the geotechnical report should include, but not limited to the following:

a) Type and condition of rock, including fracture frequency and spacing;
b) Depth to sound rock, including thickness of weathered rock. If significant overburden is present, the information as per **C-2** should also be provided for the overburden;
c) Rock density;
d) Ultimate and serviceability bearing resistances;
e) Unconfined compressive strength;
f) Water table level for the worst expected condition or the recommended design level, whichever governs;
g) Recommended anchoring procedure;
h) Rock quality designation (RQD); and
j) Site category for seismic response in accordance with IS 1893 (Part 1).

C-4 PERMAFROST SITES

For permafrost sites, the geotechnical report should include, but not limited to the following:

a) Lithology, ice content, and temperature of permafrost;
b) Thickness of the active layer and depth to base of permafrost;
c) Recommended type of foundation;
d) Recommended foundation resting level; and
e) Analysis and recommendation on material sensitivity and construction impact related to mechanical and thermal disturbance.

C-5 GEOTECHNICAL SITE INVESTIGATIONS

C-5.1 General

A geotechnical investigation, carried out by or under the direction of an engineer having sufficient knowledge and experience in planning and executing such investigations, shall be provided for the site. Geotechnical investigation for sites located in permafrost areas shall be carried out under the direction of an engineer with sufficient knowledge and experience in permafrost geotechnical investigation.

C-5.2 Information Required

The geotechnical report shall include all necessary information for the design and/or design review of the foundations and anchorages in soil, rock, or permafrost. The information provided in the geotechnical report shall be based on or compatible with limit states design methodology.

C-5.3 Failure Mechanisms

The geotechnical report shall specify all failure mechanisms that could involve any geotechnical component. For each failure mechanism, the geotechnical report shall specify either the ultimate geotechnical resistance or the method of calculating the ultimate geotechnical resistance when the resistance varies according to the foundations' and/or the anchorages' geometry and depth. The geotechnical report shall specify the information required to associate applied pressure with corresponding displacement over a range up to the limit values specified in the geotechnical report.

C-5.4 Sensitivity of Soil

The geotechnical report shall address the sensitivity of the soil or rock to earthquakes and other design considerations as they apply to the site and, if required, identify the site class for seismic site response as defined in IS 1893 (Part 1).

C-5.5 Pre-Existing Report

If a pre-existing geotechnical report is available and values provided in the report are 'allowable values' only, the safety factors used in arriving at these allowable values shall be used to determine the ultimate resistance. In cases where the safety factors are not specified, a safety factor of 2.0 shall be used.