Indian Standard

CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF PILE FOUNDATIONS

PART I CONCRETE PILES

Section 2 Bored Cast *In-Situ* Piles

(First Revision)

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Indian Standard

CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF PILE FOUNDATIONS

PART I CONCRETE PILES

Section 2 Bored Cast *in-Situ* Piles

(First Revision)

0. FOREWORD

0.1 This Indian Standard (Part I/Sec 2) (First Revision) was adopted by the Indian Standards Institution on 10 August 1979, after the draft finalized by the Foundation Engineering Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 Piles find application in foundation to transfer loads from a structure to competent sub-surface strata having adequate load bearing capacity. The load transfer mechanism from a pile to the surrounding ground is complicated and could not yet be fully determined, although application of piled foundations is in practice over many decades. Broadly, piles transfer axial loads either substantially by friction along its shaft and/or substantially by the end bearing. Piles are used where either of the above load transfer mechanism is possible depending upon the subsoil stratification at a particular site. Construction of pile foundations require a careful choice of piling system depending upon the subsoil conditions, the load characteristics of a structure and the limitations of total settlement, the differential settlement and any other special requirement of a project. The installation of piles demands careful control on position, alignment and depth and involve specialised skill and experience.

0.3 This standard (Part I) was originally published in 1964 and included provisions regarding driven cast-in-situ piles, precast concrete piles, bored piles and under-reamed piles including load testing of piles. Subsequently, portion pertaining to under-reamed pile foundations were deleted and now covered in IS : 2911 (Part III)-1980*. At that time it was decided that the provisions regarding other types of piles should also be published separately for ease of reference and to take into account the recent developments in

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

this field. This revision has been brought out to incorporate these decisions. Consequently, this standard has been revised in the following sections:

Section 1 Driven cast-in-situ concrete piles

Section 2 Bored cast-in-situ piles

Section 3 Driven precast concrete piles

0.3.1 The portion relating to load test on piles has been covered by a separate part, namely, IS : 2911 (Part IV) - 1979*. This section deals with bored cast-in-situ piles. Bored cast-in-situ pile is formed within the ground by excavating or boring a hole within it, with or without the aid of a temporary casing (to keep the hole stabilized) and subsequently filling it with plain or reinforced concrete. These piles are particularly applicable in certain subsoil conditions where penetration to a pre-determined depth is essential. In this revision, an appendix on the determination of load carrying capacity of piles by static formula has been added. Provisions regarding minimum quantity of cement and reinforcement and curtailment of reinforcement have been modified.

0.4 The technical committee responsible for this standard, has while formulating this standard given due consideration to the available experience in this country in pile construction and also the limitations regarding the availability of piling plant and equipment.

0.4.1 The information furnished by the various construction agencies and specialist firms doing piling work in this country and the technical discussions thereon considerably assisted the committee in formulation of this code.

0.4.2 The committee has also consulted several standards and publications from different countries and of the world, of which special mention can be made of the following:

BSCP : 2004-1972 Code of practice for foundations;

Recommendation of British Piling Specialist Committee; and

New York City Building Code.

0.5 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.

*Code of practice for design and construction of pile foundations: Part IV Load test on piles.

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

1. SCOPE

1.1 This standard (Part I/Sec 2) covers the design and construction of load bearing concrete bored cast-in-situ piles of diameter less than or equal to 2 500 mm which transmit the load of the structure to the soil by resistance developed either at the tip by end-bearing or along the surface of the shaft by friction or by both. This also covers piles having non-circular cross-sections.

1.2 This standard does not cover the use of bored cast-in-situ piles for any other purpose, for example, temporary or permanent retaining-stiuctures, etc. The bored cast-in-situ piles having bulb(s) known as under-reamed piles are covered in IS : 2911 (Part III)-1980*.

2. TERMINOLOGY

2.0 For the purpose of this code the following definitions shall apply.

2.1 Allowable Load — The load which may be applied to a pile after taking into account its ultimate load capacity, pile spacing, overall bearing capacity of the ground below the pile, the allowable settlement, negative skin friction and the loading conditions including reversal of loads, etc.

2.2 Batter Pile (or Raker Pile) — The pile which is installed at an angle to the vertical.

2.3 Bearing Pile — A pile formed in the ground for transmitting the load of structure to the soil by the resistance developed at its tip and/or along its surface. It may be formed either vertically or at an inclination (Batter Pile) and may be required to take uplift. If the pile supports the load primarily by resistance developed at the pile point or base it is referred to as 'End Bearing Pile': if primarily by friction along its surface, the as 'Friction Pile'.

2.4 Bored Cast-in-situ Pile — The pile formed within the ground by excavating or boring a pile within it, with or without the use of a temporary casing and subsequently filling it with plain or reinforced concrete. When the casing is left permanently it is termed as cased pile and when the casing is taken out it is termed as uncased pile.

In installing a bored pile the sides of the borehole (when it does not stand by itself) is required to be stabilized with the aid of a temporary casing, or with the aid of drilling mud of suitable consistency. For marine situations such piles are formed with permanent casing (liner).

2.5 Cut-Off Level — It is the level where the installed pile is cut-off to support the pile caps or beams or any other structural components at that level.

2.6 Factor of Safety — It is the ratio of the ultimate load capacity of a pile, to the safe load of a pile.

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

2.7 Nett Displacement — The nett movement of the pile top after the pile has been subjected to a test load and subsequently released.

2.8 Safe Load — It is the load derived by applying a factor of safety on the ultimate load capacity of the pile or as determined in the pile load test.

2.9 Test Pile — A pile which is selected for load testing and which is subsequently loaded for that purpose. The test pile may form working pile itself, if subjected to routine load test with loads up to one and one half times the safe load.

2.10 Trial Pile — Initially one or more piles, which are not working piles, may be installed to assess load carrying capacity of a pile. Pile of this category is tested either to its ultimate load capacity or to twice the estimated safe load.

2.11 Total Elastic Displacement — This is the magnitude of the displacement of the pile due to rebound caused at the top after removal of a given test load. This comprises two components:

a) Elastic displacement of the soil participating in the load transfer.

b) Elastic displacement of the pile shaft.

2.12 Total Displacement (Gross) — The total movement of the pile top under a given load.

2.13 Ultimate Load Capacity — The maximum load which a pile can carry before failure of ground (when the soil fails by shear).

2.14 Working Load — The load assigned to a pile as per design.

2.15 Working Pile — A pile forming part of foundation of a structural system.

3. NECESSARY INFORMATION

3.1 For the satisfactory design and construction of bored cast-in-situ piles and pile foundation, the following information are necessary :

a) Site investigation data as laid down in IS : 1892 - 1979* or any other relevant IS code.

Sections of trial borings, supplemented, wherever appropriate, by penetration tests, should incorporate data/information sufficiently below the anticipated level of pile tip; the boring below the pile tip should generally be not less than 10 metres unless bed rock or firm strata has been encountered earlier.

The nature of the subsoil both around and beneath the proposed pile should be indicated on the basis of appropriate tests of strength, compressibility, etc. Ground water levels and conditions (such as

*Code of practice for sub-surface investigations for foundations (*first revision*) artesian conditions) should be indicated. Results of chemical tests to ascertain the sulphate and chloride content and/or any other deleterious chemical content of soil and/or ground water should be indicated particularly in areas where large scale piling is envisaged or where such information is not generally available.

b) In case of bridge foundations data on high flood level, maximum scouring depth, normal water level during working season, etc. In case of marine construction necessary information, as listed in IS : 4651 (Part I) - 1974* should be provided.

c) In case rock is encountered, adequate description of the rock to convey its physical conditions as well as its strength characteristics should be indicated.

In case of weathered rock adequate physical description and its expected physical behaviour on boring should be indicated.

d) General plan and cross section of the building showing type of structural frame, including basement, if any, in relation to the proposed pile cap top levels.

e) The general layout of the structure showing estimated loads, vertical and horizontal, moments and torque at the top of pile caps, but excluding the weight of the piles and caps. The top levels of finished pile caps shall be clearly indicated.

f) It is preferably to have the dead load, equipment and live loads separately indicated. Loads and moments for wind/earthquake should be separately indicated.

g) Sufficient information structures existing nearby should be provided.

3.2 As far as possible, all information in **3.1** shall be made available to the agency responsible for the design and/or construction of piles and/or foundation work.

3.3 The design details of pile foundation shall indicate the information necessary for setting out, the layout of each pile within a cap, cut-off levels, finished cap levels, orientation of cap, in the foundation plan and the safe capacity of each type of piles, etc.

4. EQUIPMENT AND ACCESSORIES

4.1 The equipment and accessories would depend upon the type of bored cast-in-situ piles chosen in a job and would be selected giving due

*Code of practice for design and construction of ports and harbours: Part I Site investigation (*first revision*).

consideration to the subsoil strata, ground water conditions, type of founding material and the required penetration therein wherever applicable.

4.2 Among the commonly used plants, tools and accessories, there exist a large variety; suitability of which depends on the subsoil conditions and manner of operations, etc.

Boring operations are generally done by rotary or percussion type drilling rigs using direct mud circulation or reverse mud circulation methods to bring the cuttings out. In soft clays and loose sands bailer and chisel method, if used, should be used with caution to avoid the effect of suction. Rope operated grabbing tool or kelly mounted hydraulically operated grab are also used. The grab method of advancing the hole avoids suction. Rope operated grabbing tool or kelly mounted hydraulically operated grab are used. The grab method of advancing hole avoids suction.

The size of the cutting tool should not be less than the diameter of the pile by more than 75 mm.

4.3 Use of drilling mud in stabilizing sides of boreholes is also made where appropriate or necessary. Drilling mud should have certain basic properties which are defined in Appendix A.

4.4 Permanent liner may be used to avoid the aggressive action of ground water or otherwise. In case, liner is used and the bore is filled with water or drilling fluid, the bottom part may be concreted using tremie method, so that the liner is effectively sealed against ingress of ground water and then upper part may be concreted in dry after proper inspection of the top surface of the concrete so placed under water.

5. DESIGN CONSIDERATIONS

5.1 General — Pile foundations shall be designed in such a way that the load from the structure it supports, can be transmitted to the soil without causing any soil failure and without causing such settlement differential or total under permanent transient loading as may result in structural damage and/or functional distress. The pile shaft should have adequate structural capacity to withstand all loads (vertical, axial or otherwise) and moments which are to be transmitted to the subsoil.

5.2 Adjacent Structures

5.2.1 When working near existing structures care shall be taken to avoid any damage to such structures. In the case of cased bored pile care shall be taken to avoid effect due to loss of ground.

5.2.2 In case of deep excavations adjacent to piles, proper shoring or other suitable arrangement shall be done to guard against the lateral movement of soil stratum or releasing the confining soil stress.

5.3 Soil Resistance — The bearing capacity of a pile is dependent on the properties of the soil in which it is embedded. Axial load from a pile is normally transmitted to the soil through skin friction along the shaft and end bearing at its tip. A horizontal load on a vertical pile is transmitted to the subsoil primarily by horizontal subgrade reaction generated in the upper part of the shaft. A single pile is normally designed to carry load along its axis. Transverse load bearing capacity of a single pile depends on the soil reaction developed and the structural capacity of the shaft under bending. In case the horizontal loads are of higher magnitude, it is essential to investigate the phenomena using principles of horizontal subsoil reaction adopting appropriate values for horizontal modulus of the soil. Alternatively piles may be installed in rake. The feasibility of constructing bored piles in rake under a given subsoil condition should, however, be examined critically.

5.3.1 The ultimate load capacity of a pile may be estimated using a suitable static formula. However, it should preferably be determined by an initial load test on a trial pile [*see* IS : 2911 (Part IV) - 1979*].

The settlement of pile obtained at safe load/working load from load test results on a single pile shall not be directly used in forecasting the settlement of a structure unless experience from similar foundations on its settlement behaviour is available.

The average settlement may be assessed. It would be more appropriate to assess the average settlement on the basis of subsoil data and loading details of the structure as a whole using the principles of soil mechanics.

5.3.1.1 *Static formula* — By using static formulae, the estimated value of ultimate load capacity of a typical pile is obtained, the accuracy being dependent on the reliability of the formula and the reliability of the available soil properties for various strata. The soil properties to be adopted in such formulae may be assigned from results of laboratory tests and field tests like standard penetration tests (IS : 2131-1963 †). Results of cone penetration tests can also be utilized where, necessary correlation with soil data has been established. Two separate static formulae commonly applicable for cohesive and non-cohesive soil respectively are indicated in Appendix B, to serve only as a guide. Other alternative formulae may also be applicable depending on the subsoil characteristics and method of installation of piles.

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*Code of practice for design and construction of pile foundations: Part IV Load test on piles.

†Method for standard penetration test for soils.

5.3.1.2 *Load test results* — An initial load test [*see* IS : 2911 (Part IV) - 1979*] should be conducted on a trial pile, particularly in any locality where experience of piling is not available.

5.4 Negative Skin Friction or Dragdown Force — When a soil stratum through which a pile shaft has penetrated into an underlying hard stratum, compresses as a result of either it being unconsolidated or it being under a newly placed fill or as a result of remoulding during driving of the pile, a dragdown force is generated along the pile shaft up to a point in depth where the surrounding soil does not move downward relative to the pile shaft.

NOTE — Estimation of this dragdown force is still under research studies and considerations, although a few empirical approaches are in use for the same. The concept is constantly under revision and therefore, no definite proposal is embodied in this standard. Recognition of the existence of such a phenomenon shall be made and suitable reduction shall be made to the allowable load where appropriate. There is no evidence to show that the use of drilling fluids for the construction of piles effects the skin friction.

5.5 Structural Capacity — The piles shall have necessary structural strength to transmit the loads imposed on it, ultimately to the soil.

5.5.1 *Axial Capacity* — Where a pile is wholely embedded in the soil (having a undrained shear strength not less than 0·1 kgf/cm²) its axial carrying capacity is not limited by its strength as a long column. Where piles are installed through very weak soils (having an undrained shear strength less than 0·1 kgf/cm²) special considerations shall be made to determine whether the shaft would behave as long column or not; if necessary suitable reductions shall be made for its structural strength following the normal structural principles covering the buckling phenomenon. When the finished pile projects above ground level and is not secured against buckling by adequate bracing the effective length will be governed by the fixity conditions imposed on it by the structure it supports and by the nature of the soil into which it is installed. The depth below the ground surface to the lower point of contraflexure varies with the type of the soil. In good soil the lower point of contraflexure may be taken at a depth of one metre below ground surface subject to a minimum of three times the diameter of the shaft. In weak soil (less than 0·1 kgf/cm²) such as soft clay, soft silt, this point may be taken at about half the depth of penetration into such stratum but not more than three metres or 10 times the diameter of the shaft whichever is less. A stratum of liquid mud should be treated as if it was water. The degree of fixity of the position and inclination of the pile top and the restraint provided by any bracing shall be estimated following accepted structural principles. The permissible stress shall be reduced in accordance with similar provisions for reinforced concrete columns as laid down in IS : 456 - 1978†.

5.5.2 *Lateral Load Capacity* — A pile may be subjected to transverse force from a number of causes, such as wind, earthquake, water current, earth

*Code of practice for design and construction of pile foundations: Part IV Load test on piles.

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

pressure, effect of moving vehicles or ships, plant and equipment, etc. The lateral load carrying capacity of a single pile depends not only on the horizontal subgrade modulus of the surrounding soil but also on the structural strength of the pile shaft against bending consequent upon application of a lateral load. While considering lateral load on piles, effect of other co-existent loads including the axial load on the pile should be taken into consideration for checking the structural capacity of the shaft. A recommended method wherever possible for the determination of the depth of fixity of piles required for design is given in Appendix C. Other accepted methods such as the method of Reese and Matlock may also be used.

5.5.2.1 Because of limited information on horizontal modulus of soil, and refinements in the theoretical analysis, it is suggested that the adequacy of a design may be checked by an actual field load test.

5.5.3 *Raker Piles* — Raker piles are normally provided where vertical piles cannot resist the required applied horizontal forces. In the preliminary design the load on a raker pile is generally considered to be axial. The distribution of load between raker and vertical piles in a group may be determined by graphical or analytical methods. Where necessary, due consideration should be made for secondary bending induced as a result of the pile cap movement, particularly when the cap is rigid. Free-standing raker piles are subjected to bending moments due to their own weight, or external forces from other causes. Raker piles embedded in fill or consolidating deposits, may become laterally loaded owing to the settlement of the surrounding soil. In consolidating clay special precautions like provision of permanent casing, should be taken for raker piles.

5.6 Spacing of Piles — The centre to centre spacing of piles should be considered from two aspects:

a) Practical aspects of installing the piles, and

b) The nature of the load transfer to the soil and possible reduction in the bearing capacity of a group of piles thereby.

The choice of the spacing is normally made on semi-empirical approach.

5.6.1 In case of piles founded on a very hard stratum and deriving their capacity mainly from end bearing, the spacing will be governed by the competency of the end bearing strata. The minimum spacing in such cases, shall be 2·5 times the diameter of the shaft. In case of piles resting on rock, the spacing of two times the diameter may be adopted.

5.6.2 Piles deriving their bearing capacity mainly from friction shall be sufficiently apart to ensure that the zones of soils from which the piles derive their support do not overlap to such an extent that their bearing values are reduced. Generally the spacing in such cases shall not be less than three times the diameter of the shaft.

NOTE — In case of piles of non-circular cross section, the word 'diameter' shall be taken as minimum dimension of section adopted.

5.6.3 The spacing should not be so close as to cause direct contact between two adjacent piles in a group, at depths arising out of the tolerance allowed in the installation. This would mean the minimum spacing would, to some extent, depend on the length of piles installed.

5.7 Pile Grouping — In order to determine the bearing capacity of a group of piles, a number of efficiency equations are in use. However, it is very difficult to establish the accuracy of these efficiency equations as the behaviour of pile group is dependent on many complex factors. It is desirable to consider each case separately on its own merit.

5.7.1 The bearing capacity of a pile group may be either:

a) equal to the bearing capacity of individual piles multiplied by the number of piles in the group; or

b) it may be less.

In case of bored piles founded on bed rocks or that installed in a progressively stiffer materials, condition (a) as above may be valid.

5.7.2 In case of piles deriving their support mainly from friction and connected by a pile cap, the group may be visualized to transmit load to the soil, as if from a column of soil enclosed by the piles. The ultimate capacity of the group may be computed following this concept, taking into account the frictional capacity along the perimeter of the column of soil as above and the end bearing of the said column using the accepted principles of soil mechanics.

5.7.2.1 When the cap of the pile group is cast directly on reasonably firm stratum which supports the piles it may contribute to the bearing capacity of the group. This additional capacity along with the individual capacity of the piles multiplied by the number of piles in the group should not be more than the capacity worked out.

5.7.3 When a moment is applied on the pile group either from super structure of as a consequence of unavoidable inaccuracies of installation, the adequacy of the pile group in resisting the applied moment should be checked. In case of a single pile subjected to moments due to lateral forces or eccentric loading ground beams may be provided to restrain the pile cap effectively from lateral or rotational movement.

5.7.4 In case of structure supported on single pile/group of piles, resulting into large variation in the number of piles from column to column, it is likely, depending on the type of subsoil supporting the piles to result in a high order of differential settlement. Such high order of differential settlement may be either catered for in the structural design or it may be suitably reduced by judicious choice of variations in the actual pile loadings. For example, a single pile cap may be loaded to a level higher than that of a pile in a group in order to achieve reduced differential settlement between two adjacent pile cap supported on different number of piles.

5.8 Factor of Safety

5.8.1 Factor of safety should be judiciously chosen after considering:

a) the reliability of the value of ultimate load capacity of a pile.

b) the type of super structure and the type of loading.

c) allowable total/differential settlement of the structure.

5.8.2 The ultimate load capacity may be obtained whenever practicable from a load test (initial) [*see* IS : 2911 (Part IV)-1979*].

5.8.3 When the ultimate load capacity is computed from static formula the factor of safety would depend on the reliability of the formulae depending on a particular site and locality and the reliability of the subsoil parameters employed in such computation. The minimum factor of safety on static formula shall be 2·5. The final selection of factor of safety shall take into consideration the load settlement characteristics of the structure as whole at a given site.

5.8.4 Factors of safety for assessing safe load on piles from load test data should be increased in unfavourable conditions where:

a) settlement is to be limited or unequal settlement avoided as in the case of accurately aligned machinery or a superstructure with fragile finishings;

b) large impact or vibrating loads are expected;

c) the properties of the soil may be expected to deteriorate with time; and

d) the live load on a structure carried by friction piles is a considerable portion of the total load and approximates to the dead load in its duration.

5.9 Transient Loading — The maximum permissible increase over the safe load of a pile as arising out of wind loading, is 25 percent. In case of loads and moments arising out of earthquake effects, the increase of safeload on a single pile may be limited to the provisions contained in IS : 1893-1975†. For transient loading arising out of superimposed loads no increase may be generally allowed.

*Code of practice for design and construction of pile foundations: Part IV Load test on piles.

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

5.10 Overloading — When a pile in a group, designed for a certain safe load is found, during or after execution, to fall just short of the load required to be carried by it, an overload up to 10 percent of the pile capacity may be allowed on each pile. The total overloading on the group should not be more than 10 percent of the capacity of the group nor more than 40 percent of the allowable load on a single pile. This is subject to the increase of the load on any pile not exceeding 10 percent of its capacity.

5.11 Reinforcement — The design of the reinforcing cage vary depending upon installation conditions, the nature of the subsoil and the nature of load to be transmitted by the shaft, axial or otherwise.

5.11.1 The minimum area of longitudinal reinforcement within the pile shaft should be 0·4 percent of the sectional area calculated on the basis of outside area of the casing or the shaft.

5.11.2 The curtailment of reinforcement along the depth of the pile, in general depends on the type of loading and subsoil strata. In case of piles subject to compressive load only, the designed quantity of reinforcement may be curtailed at appropriate level as per the design requirements. For piles subjected to uplift load, lateral load and moments, separately or with compressive loads, it may be necessary to provide reinforcement for the full depth of the pile. In soft clays or loose sands the reinforcement should be provided up to the full pile depth regardless of whether or not it is required from uplift and lateral load considerations. However in all cases, the minimum reinforcement specified in **5.11.1** should be provided in the full length of the pile.

Piles shall always be reinforced with minimum reinforcement as dowels, keeping the minimum bond length into the pile shaft below its cut off level and with adequate projection into the pile cap irrespective of design requirement.

5.11.3 The minimum clear cover to all main reinforcement in pile shaft shall be not less than 40 mm. The minimum clear distance between two adjacent main reinforcement should normally be 100 mm for the full depth of the cage. The laterals of a reinforcing cage may be in the form of links or spirals. The diameter and spacing of the same is chosen to impart adequate rigidity of the reinforcing cage during its handling and installation. The minimum diameter of the links or spirals shall be 6 mm and the spacing of the links or spirals shall be not less than 150 mm.

5.12 Design of Pile Cap

5.12.1 The pile caps may be designed by assuming that the load from column is dispersed at 45° from the top of the cap up to the mid-depth of the pile cap from the base of the column or pedestal. The reaction from piles may also be taken to be distributed at 45° from the edge of the pile, up to the mid-depth of the pile cap. On this basis the maximum bending moment and shear forces should be worked out at critical sections. The methods of analysis and allowable stresses should be in accordance with IS : 456-1978* other suitable rational methods may also be used.

5.12.2 Pile cap shall be deep enough to allow for necessary anchorage of the column and pile reinforcement.

5.12.3 The pile cap should normally be rigid enough so that the imposed load could be distributed on the piles in a group equitably.

5.12.4 In case of a large cap, where differential settlement may be imposed between piles under the same cap, due consideration for the consequential moments should be given.

5.12.5 The clear overhang of the pile cap beyond the outermost pile in the group shall normally be 100 to 150 mm depending upon the pile size.

5.12.6 The cap is generally cast over a 75 mm thick levelling course of concrete. The clear cover for main reinforcement in the cap slab shall not be less than 60 mm.

5.12.7 The pile should project 50 mm into the cap concrete.

5.13 The design of grade beam shall be as per IS : 2911 (Part III)-1980†.

6. MATERIALS AND STRESSES

6.1 Cement — The cement used shall conform to the requirements of IS : 269-1976‡, IS : 455-1976§, IS : 8841-1978|| and IS : 6909-1973¶ as the case may be.

6.2 Steel — Reinforcement steel shall conform to IS : 432 (Part I)-1966** or IS : 1139-1966†† or IS : 786-1966‡‡ or IS : 226-1975§§. The stresses allowed in steel should conform to IS : 456-1978||||.

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

†Code of practice for design and construction of pile foundations: Part III Under reamed pile foundations (*first revision*).

‡Specification for ordinary and low heat portland cement (*third revision*).

§Specification for portland slag cement (*third revision*).

||Specification for rapid hardening portland cement.

¶Specification for supersulphated cement.

**Specification for mild steel and medium tensile steel bars and hard drawn steel wire for concrete reinforcement: Part I Mild steel and medium tensile steel bars (*second revision*).

††Specification for hot rolled mild steel, medium tensile steel and high yield strength steel deformed bars for concrete reinforcement (*revised*).

‡‡Specification lor cold twisted steel bars for concrete reinforcement (*revised*).

§§Specification for structural steel (standard quality) (*fifth revision*).

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

6.3 Concrete

6.3.1 Materials and methods of manufacture for cement concrete shall in general be in accordance with the method of concreting under the conditions of pile installation.

6.3.2 Consistency of concrete for cast-in-situ piles shall be suitable to the method of installation of piles. Concrete shall be so designed or chosen as to have homogeneous mix having a flowable character consistent with the method of concreting under the given conditions of pile installation. In achieving these results, minor deviations in the mix proportions used in structural concrete may be necessary.

6.3.3 For pile of smaller diameter and depth of up to 10 m, the minimum cement content should be 350 kg/m³ of concrete. For piles of large diameter and/or deeper piles, the minimum cement content should be 400 kg/m³ of concrete. For design purposes, the strength of concrete mix using the quantities of cement mentioned above, may be taken equivalent to M 15 and M 20 respectively for concrete with cement content of 350 kg/m³ and 400 kg/m³. Where concrete of higher strength is needed, richer concrete mix with greater cement content may be designed. In case of piles subsequently exposed to free water or in case of piles where concreting is done under water or drilling mud using methods other than the tremie, 10 percent extra cement over that required for the design grade of concrete at the specified slump shall be used subject to a minimum quantities of cement specified above.

6.3.4 Slump of concrete shall range between 100 to 180 mm depending on the manner of concreting. The table below gives the general guidance:

Piling	*Slump*		*Typical Conditions of Use*
	Min	*Max*	
A	100	180	Poured into water-free unlined bore having widely spaced reinforcement. Where reinforcement is not spaced widely enough, cut-off level of pile is within the casing and diameter of pile is less than or equal to 600 mm, higher order of slump within this range may be used
B	150	180	Where concrete is to be placed under water or drilling mud, by tremie or by placer

6.3.5 Clean water, free from acids and other impurities, shall be used in the manufacture of concrete.

6.3.6 The average compressive stress under working load should not exceed 25 percent of the specified works cube strength at 28 days calculated on the total cross sectional area of the pile. When concreting is done using a tremie, allowable stress in concrete may be 33·33 percent of the specified works cube strength at 28 days and aggregates more than 20 mm shall not be used.

7. WORKMANSHIP

7.1 Control of Piling Installation

7.1.1 Bored cast-in-situ piles may be adopted by suitable choice of installation techniques; covering the manner of soil stabilization, that is use of casing and/or use of drilling mud; manner of concreting that is direct pouring and placing or by use of tremie and choice of boring tools in order to permit a satisfactory installation of a pile at a given site. Sufficient detailed information about the subsoil conditions is essential to predetermine the details of the installation technique.

7.1.2 *Control of Alignment* — Piles shall be installed as accurately as possible as per the designs and drawings either vertically or to the specified batter. Greater care should be exercised in respect of installation of single pile or piles in two pile groups. As a guide, for vertical piles a deviation of 1·5 percent and for raker piles a deviation of 4 percent should not normally be exceeded although in special cases a closer tolerance may be necessary. Piles should not deviate more than 75 mm or $D/10$ whichever is more in case of piles having diameter more than 600 mm from their designed positions at the working level of the piling rig. In the case of a single pile in a column positional tolerance should not be more than 50 mm (100 mm in case of piles having diameter more than 600 mm). Greater tolerance may be prescribed for piles driven over water and for raking piles. For piles to be cut-off at a substantial depth, the design should provide for the worst combination of the above tolerances in position and inclination. In case of piles deviating beyond these limits and to such an extent that the resulting eccentricity cannot be taken care of by a redesign of the pile cap of pile ties, the piles should be replaced or supplemented by one or more additional piles. In case of piles, with non-circular cross section 'D' should be taken as the dimensions of pile, along which the deviation is computed. In such cases the permissible deviation in each direction should be different depending upon the dimension of the pile along that direction.

NOTE — In case of raker piles up to a rake of 1 in 6, there may be no reduction in the capacity of the pile unless otherwise stated.

7.1.2.1 Any deviation from the designed location, alignment or load capacity of any pile shall be noted and adequate measures taken well before the concreting of the pile cap and plinth beam.

7.1.3 A minimum length of one metre of temporary casing shall be inserted in each bored pile unless otherwise specifically desired. Additional length of temporary casing may be used depending on the condition of the strata, ground water level, etc.

Drilling mud of suitable consistency may also be used instead of temporary casings for stabilizing sides of the holes.

7.1.3.1 For marine situations such piles may be formed with permanent casing (liner) (*see* **4.4**).

7.2 In case, a bored pile is stabilized by drilling mud or by maintaining water heads within the hole, the bottom of the hole shall be cleaned very carefully before concreting work is taken up. The cleaning of the hole may be ensured by careful operation of boring tool and/or flushing of the drilling mud through the bottom of the hole. Flushing of bore holes before concreting with fresh drilling fluid/mud is preferred.

7.3 In case a hole is bored by use of drilling mud, the specific gravity of the mud suspension near about the bottom of the hole shall, whenever practicable, be determined by suitable slurry sampler in a first few piles and at suitable interval of piles and recorded. Consistency of the drilling mud suspension shall be controlled throughout the boring as well as concreting operations in order to keep the hole stabilized as well as to avoid concrete getting mixed up with the thicker suspension of the mud.

The concreting operations should not be taken up when the specific gravity of bottom slurry is more than 1·2. Concreting shall be done by tremie method in all such cases. The slurry should be maintained at 1·5 m above the ground water level if casing is not used.

7.4 Concreting under water may be done either with the use of tremie method or by the use of specially designed underwater placer to permit deposition of concrete in successive layers, without permitting the concrete within the placer to fall through free water.

7.5 Tremie Method — In addition to the normal precautions to be taken in tremie concreting, the following requirements are particularly applicable to the use of tremie concrete in pipes.

a) The concrete should be coherent, rich in cement (not less than 370 kg/m^3) and of slump not less than 150 mm.

b) When concreting is carried out under water a temporary casing should be installed to the full depth of the bore hole or 2 m into non-collapsible stratum, so that fragments of ground cannot drop from the sides of the hole into the concrete as it is placed. The temporary casing may not be required except near the top when concreting under drilling mud.

e) The hopper and tremie should be a closed system embedded in the placed concrete, through which water cannot pass.

d) The tremie should be large enough with due regard to the size of the aggregate. For 20 mm aggregate the tremie pile should be of diameter not less than 200 mm, aggregates more than 20 mm shall not be used.

e) The first charge of concrete should be placed with a sliding plug pushed down the tube ahead of it or with a steel plate of adequate charge to prevent mixing of concrete and water. However, the plug should not be left in the concrete as a lump.

f) The tremie pipe should always penetrate well into the concrete with an adequate margin if safety against accidental withdrawal of the pipe is surged to discharge the concrete.

g) The pile should be concreted wholly by tremie and the method of deposition should not be changed part way up the pile, to prevent the laitance from being entrapped within the pile.

h) All tremie tubes should be scrupulously cleaned after use.

7.5.1 Normally concreting of the piles should be uninterrupted. In the exceptional case of interruption of concreting; but which can be resumed within 1 or 2 hours, the tremie shall not be taken out of the concrete. Instead it shall be raised and lowered slowly, from time to time to prevent the concrete around the tremie from selting. Concreting should be resumed by introducing a little richer concrete with a slump of about 200 mm for easy displacement of the partly set concrete.

If the concreting cannot be resumed before final set up concrete already placed, the pile so cast may be rejected or accepted with modifications.

7.5.2 In case of withdrawal of tremie out of the concrete, either accidentally or to remove a choke in the tremie, the tremie may be re-introduced in the following manner to prevent impregnation of laitance or scum lying on the top of the concrete already deposited in the bore.

7.5.2.1 The tremie shall be gently lowered on to the old concrete with very little penetration initially. A vermiculite plug should be introduced in the tremie. Fresh concrete of slump between 150 mm and 175 mm should be filled in the tremie which will push the plug forward and will emerge out of the tremie displacing the laitance/scum. The tremie will be pushed further in steps making fresh concrete sweep away laitance/scum in its way. When tremie is burried by about 60 to 100 cm, concreting may be resumed.

7.6 During installation of bored cast-in-situ piles, the convenience of installation may be taken into account while determining the sequence of pilling in a group.

7.7 The top of concrete in a pile shall be brought above the cut-off level to permit removal of all laitance and weak concrete before capping and to ensure good concrete at the cut-off level for proper embedment into the pile cap.

7.8 Where cut-off level is less than 1·5 metre below the working level concrete shall be cast to a minimum of 300 mm above cut-off level. For each additional 0·3 m increase in cut-off level below the working level additional coverage of 50 mm minimum shall be allowed. Higher allowance may be necessary depending on the length of the pile. When concrete is placed by tremie method, concrete shall be cast to the piling platform level to permit overflow of concrete for visual inspection or to a minimum of one metre above cut-off level. In the circumstance where cut-off level is below ground water level the need to maintain a pressure on the unset concrete equal to or greater than water pressure should be observed and accordingly length of extra concrete above cut-off level shall be determined.

7.9 Defective Pile — In case, defective piles are formed, they shall be removed or left in place whichever is convenient without affecting performance of the adjacent piles or the cap as a whole. Additional piles shall be provided to replace them as directed.

7.10 Any deviation from the designed location alignment or load capacity of any pile shall be noted and adequate measures taken well before the concreting of the pile cap and plinth beam if the deviations are beyond the permissible limit.

7.11 During chipping of the pile top manual chipping may be permitted after three days of pile casting; pneumatic tools for chipping shall not be used before seven days after pile casting.

7.12 After concreting the actual quantity of concrete shall be compared with the average obtained from observations actually made in the case of a few piles initially cast. If the actual quantity is found to be considerably less, special investigations shall be conducted and appropriate measures taken.

7.13 Recording of Data

7.13.1 A competent inspector shall be maintained at site to record necessary information during installation of piles and the data to be recorded shall include:

a) Sequence of installation of piles in a group;

b) Dimensions of the pile, including the reinforcement details and mark of the pile;

c) Depth bored;

d) Time taken for concreting;

e) Cut off level/working level;

f) When drilling mud is used, the specific gravity of the fresh supply and contaminated mud in the hole before concreting is taken up, shall be recorded in case of first ten piles, and subsequently at an approximate interval of 10 piles or earlier; and

g) Any other important observation.

7.13.2 Typical data sheet for facility of recording piling data are shown in Appendix D.

APPENDIX A

(*Clause* 4.3)

BASIC PROPERTIES OF DRILLING MUD (BENTONITE)

A-1. PROPERTIES

A-1.1 The bentonite suspension used in bore holes is basically a clay of montmorillonite group having exchangeable sodium cations. Because of the presence of sodium cations, bentonite on dispersion will break down into small plate like particles having a negative charge on the surfaces and positive charge on the edges. When the dispersion is left to stand undisturbed, the particles become oriented building up a mechanical structure at its own. This mechanical structure held by electrical bonds is observable as a jelly like mass or jell material. When the jell is agitated, the weak electrical bonds are broken and the dispersion becomes fluid.

A-2. FUNCTIONS

A-2.1 The action of bentonite in stabilizing the sides of bore holes is primarily due to the thixotropic property of bentonite suspension. The thixotropic property of bentonite suspension permits the material to have the consistency of a fluid when introduced into the excavation and when undisturbed forms a jelly which when agitated becomes a fluid again.

A-2.2 In the case of a granular soil, the bentonite suspension penetrates into the sides under positive pressure and after a while forms a jelly. The bentonite suspension gets deposited on the sides of the hole and makes the surface impervious and imparts a plastering effect. In impervious clay, the bentonite does not penetrate into the soil, but deposits only a thin film on the surface of the hole. Under such condition stability is derived from the hydrostatic head of the suspension.

A-3. SPECIFICATION

A-3.1 The bentonite suspension used for piling work shall satisfy the following requirements:

a) The liquid limit of bentonite when tested in accordance with IS : 2720 (Part V) - 1965* shall be more than 300 percent and less than 450 percent.

b) The sand content of the bentonite powder shall not be greater than 7 percent.

NOTE — The purpose of limiting the sand content is mainly to control and reduce the wear and tear of the pumping equipment.

c) Bentonite solution should be made by mixing it with fresh water using pump for circulation. The density of the bentonite solution should be about 1·12.

d) The Marsh viscosity when tested by a Marsh cone should be about 37 seconds.

e) The swelling index as measured by the swelled volume after 12 hours in abundent quantity of water shall be at least 2 times its dry volume.

f) The *p*H value of the bentonite suspension shall be less than 11·5.

APPENDIX B

(*Clause* 5.3.1.1)

LOAD CARRYING CAPACITY — STATIC FORMULA

B-1. PILES IN GRANULAR SOILS

B-1.1 The ultimate bearing capacity (Q_u) of piles in granular soils is given by the following formula:

$$Q_u = A_p \left(\tfrac{1}{2} D \gamma N_\gamma + P_D N_q \right) + \sum_{i=1}^{D} K\, P_{Di} \tan \delta\, A_{si}$$

where

A_p = cross-sectional area of pile toe in cm²;

D = stem diameter in cm;

γ = effective unit weight of soil at pile toe in kgf/cm³;

*Methods of test for soils: Part V Determination of liquid and plastic limits (*first revision*).

P_D = effective overburden pressure at pile toe in kgf/cm²;

N_γ and N_q = bearing capacity factors depending upon the angle of internal friction ϕ at toe;

$\sum_{i=1}^{n}$ = summation for n layers in which pile is installed;

K = coefficient of earth pressure;

P_{Di} = effective overburden pressure in kg/cm² for the i^{th} layer where i varies from 1 to n;

δ = angle of wall friction between pile and soil, in degrees (may be taken equal to ϕ); and

A_{si} = surface area of pile stem in cm² in the i^{th} layer where i varies from 1 to n.

NOTE 1 — N_γ factor can be taken for general shear failure as per IS : 6403-1971*.

NOTE 2 — N_q factor will depend, apart from nature of soil on the type of pile and its method of construction, for bored piles, the value of N_q corresponding to angle of shearing resistance ϕ are given in Fig. 1. This is based on Berezantseu's curve for D/B of 20 up to $\phi = 35°$ and Vesic's curves beyond $\phi = 35°$.

NOTE 3 — The earth pressure coefficient K depends on the nature of soil strata, type of pile and its method of construction. For bored piles in loose medium sands, K values between 1 and 2 should be used.

NOTE 4 — The angle of wall friction may be taken equal to angle of shear resistance of soil.

NOTE 5 — In working out pile capacities using static formula, for piles longer than 15 to 20 pile diameter, maximum effective overburden at the pile tip should correspond to pile length equal to 15 to 20 diameters.

B-2. PILES IN COHESIVE SOILS

B-2.1 The ultimate bearing capacity of piles (Q_u) in cohesive soil is given by the following:

$$Q_u = A_p . N_c . C_p + \alpha . \bar{C} . A_s$$

where

A_p = cross sectional area of pile toe in cm²,

N_c = bearing capacity factor usually taken as 9,

C_p = average cohesion at pile tip in kg/cm²,

α = reduction factor,

*Code of practice for determination of allowable bearing pressure on shallow foundations.

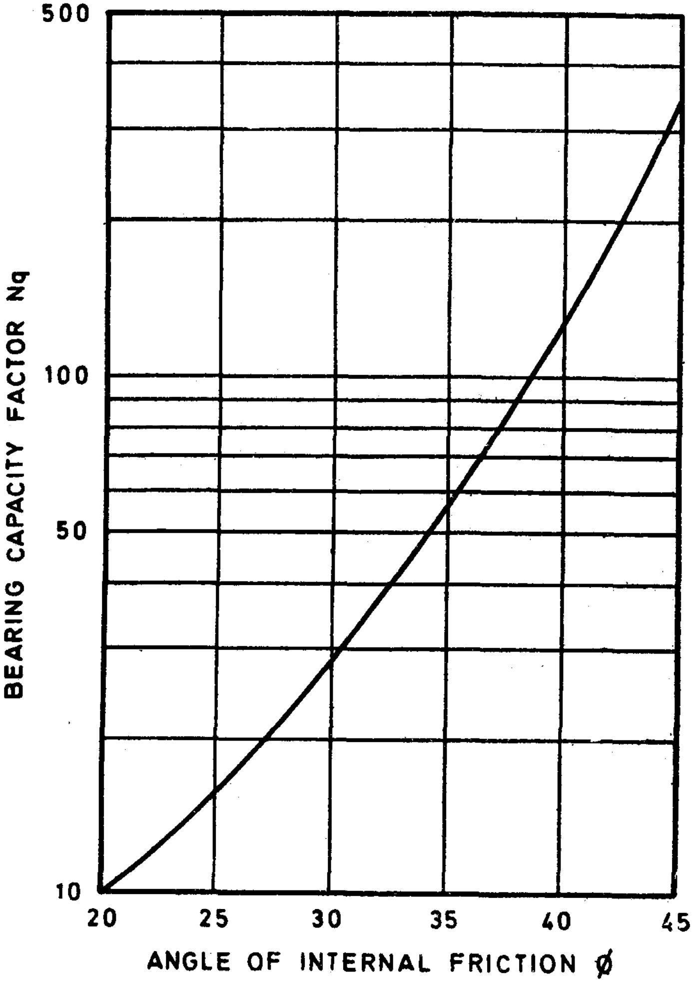


FIG. 1 BEARING CAPACITY FACTOR N_q FOR BORED PILES

C = average cohesion throughout the length of pile in kg/cm², and

A_s = surface area of pile shaft in cm².

NOTE 1 — The following values of α may be taken depending upon the consistency of the soils:

Consistency	*N Value*	*Value of α*	
		Bored Piles	Driven Cast-in-situ
Soft to very soft	<4	0·7	1
Medium	4 to 8	0·5	0·7
Stiff	8 to 15	0·4	0·4
Stiff to hard	>15	0·3	0·3

NOTE 2 — (a) Static formula may be used as a guide only for bearing capacity estimates. Better reliance may be put on load test on piles.

(b) For working out safe load a minimum factor of safety 2·5 should be used on the ultimate bearing capacity estimated by static formulae.

NOTE 3 — α may be taken to vary from 0·5 to 0·3 depending upon the consistency of the soil. Higher values of up to one may be used for softer soils, provided the soil is not sensitive.

B-2.2 When full static penetration data is available for the entired epth, the following correlations may be used as a guide for the determination of shaft resistance of a pile.

Type of Soil	*Local Side Friction* f_s
Clays and peats where $q_c < 10$	$\frac{q_c}{30} < f_s < \frac{q_c}{10}$
Clays	$\frac{q_c}{25} < f_s < \frac{q_c}{25}$
Silty clays and silty sands	$\frac{q_c}{100} < f_s < \frac{q_c}{25}$
Sands	$\frac{q_c}{100} < f_s < \frac{q_c}{100}$
Coarse sands and gravels	$f_s < \frac{q_c}{150}$

where

q_c = static point resistance, and

f_s = local side friction.

For non-homogeneous soils the ultimate point bearing capacity may be calculated using the following relationships:

$$q_u = \frac{\frac{q_{c0} + q_{c1}}{2} + q_{c2}}{2}$$

where

q_u = ultimate point bearing capacity,

q_{c0} = average static cone resistance over adepth of 2 d below the base level of the pile,

q_{c1} = minimum static cone resistance over the same 2 d below the pile tip,

q_{c2} = average of the minimum cone resistance values in the diagram over a height of 8 d above the base level of the pile, and

d = diameter of the pile base or the equivalent diameter for a non-circular cross section.

B-2.3 The correlation between standard penetration test value N and static point resistance q_c given below may be used for working the shaft resistance and skin friction of piles.

Soil Type	q_c/N
Clavs	2·0
Silts, sandy silts and slightly cohesive silt sand mixtures	2·0
Clean fine to medium sands and slightly silty sands	3-4
Course sands and sands with little gravel	5-6
Sandy gravels and gravel	8-10

APPENDIX C

(*Clause* 5.5.2)

DETERMINATION OF DEPTH OF FIXITY OF PILES

C-1. For determining the depth of fixity for calculating the bending moment induced by horizontal load, the following procedure may be followed.

Estimate the value of the constant of modulus of horizontal subgrade reaction n_h, or the modulus of subgrade reaction K of soil from Table 1 or Table 2.

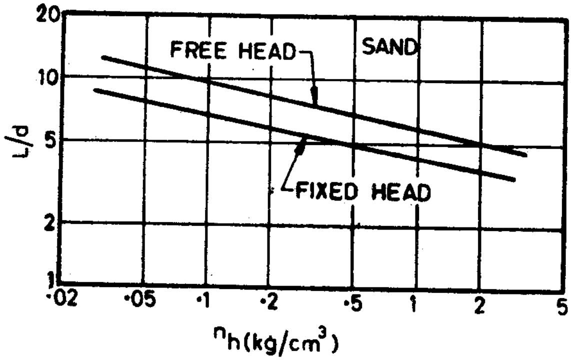
Determine from appropriate graphs given in Fig. 2 and Fig. 3 the value of L, the equivalent length of cantilever giving the same deflection at ground level as the actual pile.

TABLE 1 TYPICAL VALUES OF n_h

Soil Type	n_h in kg/cm^3	
	Dry	Submerged
Loose sand	0·260	0·146
Medium sand	0·775	0·526
Dense sand	2·076	1·245
Very loose sand under repeated loading		0·041

TABLE 2 TYPICAL VALUES OF K FOR PRELOADED CLAYS

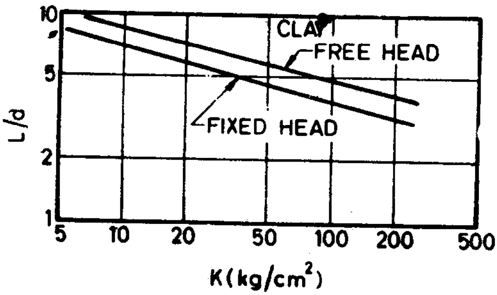
Unconfined Compression Strength	Range of Values of K	Probable Value of K
kg/cm^2	kg/cm^2	kg/cm^2
0·2 to 0·4	7 to 42	7·73
1 to 2	32 to 65	48·79
2 to 4	65 to 130	97·73
4	—	195·46



L — Equivalent length of cantilever giving the same deflection at ground level as the actual pile.

d — Diameter of the pile.

FIG. 2 *L*/*d* VERSUS n_h FOR EQUIVALENT CANTILEVER LENGTH IN SAND



L — Equivalent length of cantilever giving the same deflection at ground level as the actual pile.

d — Diameter of the pile.

FIG. 3 *L*/*d* VERSUS *K* FOR EQUIVALENT CANTILEVER LENGTH IN CLAY

APPENDIX D

(*Clause* 7.13.2)

DATA SHEETS

Site ....

Title ....

Date of enquiry ....

Date piling commenced ....

Actual or anticipated date for completion of piling work ....

Number of pile ....

TEST PILE DATA

Pile:	Pile test commenced .... Pile test completed ....
Pile type:	.... (Mention proprietary system, if any) ....
Pile specification:	Shape — round/square .... Size — shaft ....toe .... Reinforcement......No.......dia for.........(depth) (....)
Sequence of piling (for Groups):	From centre towards the periphery or from periphery towards the centre
Concrete:	Mix ratio 1 :........... : ....by volume/weight or strength after...........days..............kgf/cm² Quantity of cement per m³ :.............................. Extra cement added if any :..............................

Details of drilling mud used: ....

Time taken for concreting: ....

Quantity of concrete — Actual: ....

— Theoretical: ....

Test loading:

Maintained load/Cyclic loading/C.R.P. ....

....

Capacity of jack..

If anchor piles used, give.......................No., Length.......................

Distance of test pile from nearest anchor pile................ ....

Test pile and anchor piles were/were not working piles.

Method of taking observations:

Dial gauges/Engineers level...

Reduced level of pile toe...

General Remarks:

....

....

....

....

....

Special difficulties encountered:

....

....

....

Results:

Working load specified for the test pile..................................

Settlement specified for the test pile.....................................

Settlement specified for the structure.....................................

Working load accepted for a single pile as a result of the test...........

....

....

Working load in a group of piles accepted as a result of the test........

....

....

General description of the structure to be founded on piles.............

....

....

....

....

....

Name of the constructing agency..

....

Name of person conducting the test...

....

Name of the party for whom the test was conducted......................

....

BORE-HOLE LOG

1. Site of bore hole relative to test pile position..............................

....

2. NOTE — If no bore hole, give best available ground conditions..........................

....

....

Soil Properties	Soil Description	Reduced Level	Soil Legend	Depth Below G.L.	Thickness of Strata
	Position of the toe of pile to be indicated thus→ Standing ground water level indicated thus ∇				

METHOD OF SITE INVESTIGATION

Trial pit/post-hole auger/shell and auger boring/Percussion/Probing/ Wash borings/Mud-rotary drilling/Core-drilling/ Shot drilling/ Sub-surface sounding by cones or standard sampler.......................

....

....

NOTE — Graphs, showing the following relations, shall be prepared and added to the report:

1) Load *vs* Time
2) Settlement *vs* Load

(*Continued from page* 2)

Pile Foundations Subcommittee, BDC 43 : 5

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Gangotri Complex, 5th Floor, Bhadbhada Road, T.T. Nagar, BHOPAL 462003	55 40 21
Plot No. 62-63, Unit VI, Ganga Nagar, BHUBANESHWAR 751001	40 36 27
Kalaikathir Buildings, 670 Avinashi Road, COIMBATORE 641037	21 01 41
Plot No. 43, Sector 16 A, Mathura Road, FARIDABAD 121001	8-28 88 01
Savitri Complex, 116 G.T. Road, GHAZIABAD 201001	8-71 19 96
53/5 Ward No. 29, R.G. Barua Road, 5th By-lane, GUWAHATI 781003	54 11 37
5-8-56C, L.N. Gupta Marg, Nampally Station Road, HYDERABAD 500001	20 10 83
E-52, Chitaranjan Marg, C-Scheme, JAIPUR 302001	37 29 25
117/418 B, Sarvodaya Nagar, KANPUR 208005	21 68 76
Seth Bhawan, 2nd Floor, Behind Leela Cinema, Naval Kishore Road, LUCKNOW 226001	23 89 23
NIT Building, Second Floor, Gokulpat Market, NAGPUR 440010	52 51 71
Patliputra Industrial Estate, PATNA 800013	26 23 05
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AMENDMENT NO. 1 AUGUST 1982

TO

IS : 2911 (Part I/Sec 2)-1979 CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF PILE FOUNDATIONS

PART I CONCRETE PILES

Section 2 Bored Cast-*in-Situ* Piles

(First Revision)

Alterations

(*Page* 15, *clause* **6.1**) — Substitute the following for the existing clause:

'**6.1 Cement** — The cement used shall conform to the requirements of IS : 269-1976‡, IS : 455-1976§, IS : 8041-1978||, IS : 1489-1976¶¶ and IS : 6909-1973 as the case may be. '

(*Page* 15, *clause* **6.2**, *line* 2) —Substitute ' IS : 1786-1979‡‡ ' *for* ' IS : 786-1966‡‡ '.

(*Page* 15, *foot-note with* ' ‡‡ ' *mark*) — Substitute the following for the existing foot-note:

' ‡‡Specification for cold worked steel high strength deformed bars for concrete reinforcement (*second revision*). '

[(*Page* 22, *clause* **A-3.1** (c) *to* (f)] — Substitute the following for the existing matter:

c) The density of the freshly prepared bentonite suspension shall be between 1·034 and 1·10 g/ml depending upon the pile dimensions and type of soil in which the pile is to be met. However, the density of bentonite suspension after mixing with deleterious materials in the bore hole may be up to 1·25 g/ml.

d) The marsh viscosity when tested by a marsh cone shall be between 30 to 60 seconds; in special cases it may be allowed up to 90. It may be noted that in the latter case, special methods of pumpings shall have to be used.

e) The differential free swell shall be more than 540 percent.

f) The *p*H value shall be between 9 and 11·5. '

(*Page* 23, *clause* **B-1.1,** *Note* 1, *line* 2) — Substitute ' IS: 6403-1981*' *for* ' IS: 6403-1971* '.

(*Page* 23, *foot-note* with ' * ' *mark*) — Substitute with the following for the existing foot-note:

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

(*Page* 24, Fig. 1) — Substitute the following for the existing figure:

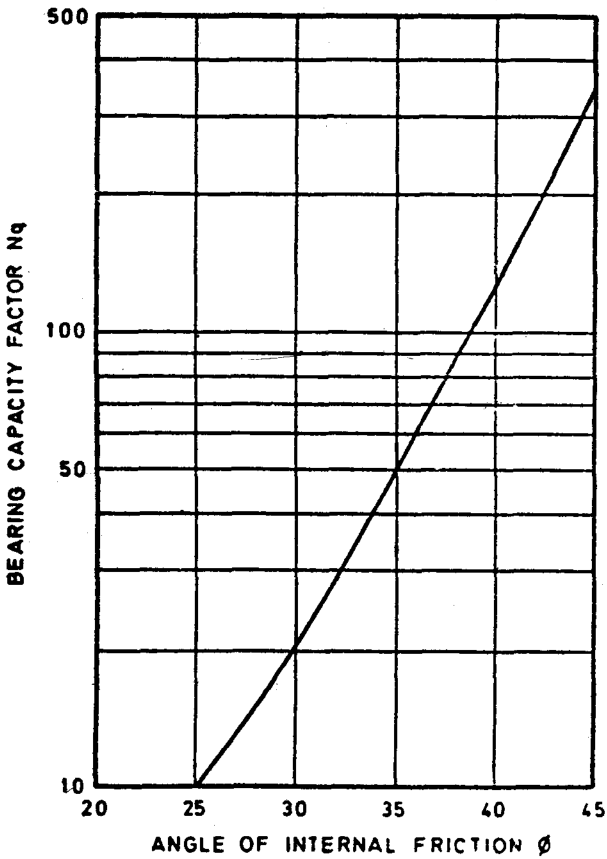

FIG. 1 BEARING CAPACITY FACTOR N_q FOR BORED PILES

(*Page* 25, *clause* **B-2.2**, *informal table*) — Substitute the following for the existing matter:

Clays and peats where $q_c < 10$	$\frac{q_c}{30} < fs < \frac{q_c}{10}$
Clays	$\frac{q_c}{25} < fs < \frac{2q_c}{25}$
Silty clays and silty sands	$\frac{q_c}{100} < fs < \frac{2q_c}{25}$
Sands	$\frac{q_c}{100} < fs < \frac{2q_c}{100}$
Coarse sands and gravels	$fs < \frac{q_c}{150}$

Addenda

(*Page* 14, *clause* **5.11.1**) — Add the following new Note after **5.11.1**:

'NOTE — Where deformed bars are used, a minimum reinforcement of 0·4 percent of sectional area should be the equivalent area of the bars used, compared to plain mild steel bars. '

(*Page* 15, *foot-note with* ' |||| ' *mark*) — Add the following new foot-note after ' |||| ' mark:

' ¶¶ Specification for Portland pozzolana cement (*second revision*). '

(BDC 43)

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AMENDMENT NO. 2 SEPTEMBER 1984
TO
IS : 2911 (Part I/Sec 2) - 1979 CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF PILE FOUNDATIONS

PART I CONCRETE PILES

Section 2 Bored Cast-*in-Situ* Piles

(First Revision)

Alterations

(*Page* 6, *clause* **2.13**) — Substitute the following for the words 'by shear:

'by shear as evidenced from the load settlement curves) or failure of pile materials.'

(*Page* 9, *clause* **5.3.1.1**, *line* 6) — Substitute 'IS : 2131-1981†' *for* 'IS : 2131-1963†'.

(*Page* 9, *foot-note with* '†' *mark*) — Substitute the following for the existing foot-note:

'†Method for standard penetration test for soils (*first revision*).

(*Page* 10, *clause* **5.3.1.2**) — Delete.

(*Page* 10, *clause* **5.4**, *line* 4) — Delete the words 'during driving of the pile'.

(*Page* 10, *clause* **5.4**, *Note, lines* 4 *to* 6) — Delete.

(*Page* 10, *foot-note with* '*' *mark*) — Delete.

(*Page* 12, *clause* **5.7.3**, *line* 2) — Substitute 'or' *for* first 'of'

(*Page* 14, *clause* **5.11.1** *read with Amendment No.* 1) — Delete the Note.

(*Page* 15, *clause* **6.2**, *line* 1) — Substitute 'IS : 432 (Part I) - 1982**' *for* 'IS : 432 (Part I)-1966**'.

(*Page* 15, *foot-note with* '**' *mark*) — Substitute the following for the existing foot-note:

'**Specification for mild steel and medium tensile steel bars and hard drawn steel wire for concrete reinforcement: Part I Mild steel and medium tensile steel bars (*third revision*).'

(*Page* 17, *clause* **6.3.6**, *second sentence*) — Delete.

(*Page* 17, *clause* **7.1.2**, 4th *to* 7th *sentences*) — Substitute the following for the existing:

'Piles should not deviate more than 75 mm or D/4 whichever is less (75 mm or D/10 whichever is more in case of piles having diameter more than 600 mm) from their designed positions at the working level. In the case of single pile under a column the positional deviation should not be more than 50 mm or D/4 whichever is less (100 mm in case of piles having diameter more than 600 mm). Greater tolerance may be prescribed for piles driven over water and for raking piles. For piles to be cut-off at a substantial depth (below ground level) or height (above ground level) the design should provide for the worst combination of the above tolerances in position and inclination.'

(*Page* 17, *clause* **7.1.2.1**) — Delete.

[*Page* 19, *clause* **7.5**(d), *line* 2] — Substitute 'pipe' *for* 'pile'.

[*Page* 19, *clause* **7.5**(f), *line* 2] — Substitute 'of' *for* 'if'.

(*Page* 19, *clause* **7.5.1**, *line* 5) — Substitute 'setting' *for* 'selting'.

(*Page* 22, *clause* **B-1.1**, *value of* Q_u *second term*) — Substitute '$\sum_i^n K P_{Di} \tan \delta A_{si}$' for the existing term.

(*Page* 25, *clause* **B-2.1**, *informal table*) — Delete the matter appearing in column 4.

(*Page* 25, *clause* **B-2.2**, *informal table read with Amendment No.* 1, *line* 3, *col* 4) — Substitute '$\frac{q_c}{25}$' *for* '$\frac{2q_c}{25}$'

(*Page* 27, *Table* 2) — Substitute 'kgf/cm³' *for* 'kg/cm²'. in columns 2 and 3.

(*Page* 28, *figure* 3) — Substitute 'kgf/cm³' *for* 'kg/cm²'.

Addenda

(*Page* 5, *clause* **1.2**) — Add the following Note after **1.2**:

'NOTE — In case of group of element piles or diaphragam wall units the grouping effect shall be examined considering the total load carried by a group of elements and the area enclosed in the group of elements.'

(*Page* 8, *clause* **5.1**, *line* 7) — Add the following in the end:

'and shall be designed according to IS : 456-1978*'.

(*Page* 8) — Add the following foot-note:

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

(*Page* 9, *clause* **5.3.1.1**, *line* 7) — Add the following words after the word ‘ tests ’:

‘ [*see* IS : 4968 (Parts I, II and III)-1976‡] ’.

(*Page* 9, *foot-notes*) — Add the following foot-note in the end:

‘ ‡Method for subsurface rounding for soils (*first revision*). ’

(*Page* 14, *clause* **5.11.1**, *line* 1) — Add the following words after the word ‘ reinforcement ’:

‘ of any type or grade ’

(*Page* 14, *clause* **5.11.2**) — Add the following Note after **5.11.2**:

‘ NOTE — In some cases the cage may lift at bottom or at the laps during withdrawal of casing. This can be minimized by making the reinforcement ‘ U ’ shaped at the bottom and providing well secured joints. Also the lifting up to 5 percent of the length should be considered not to affect the quality of pile. ’

(BDC 43)

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AMENDMENT NO. 3 AUGUST 1987

TO

IS : 2911 (Part 1/Sec 2)-1979 CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF PILE FOUNDATIONS

PART 1 CONCRETE PILES

Section 2 Bored Cast *in-Situ* Piles

(*First Revision*)

(*Page* 11, *clause* **5.5.2**, *last two sentences*) — Substitute the following for the existing matter:

'A recommended method for the determination of depth of fixity, lateral deflection and maximum bending moment, required for design is given in Appendix C for fully or partially embedded piles. Other accepted methods such as the method of Reese and Matlok for fully embedded piles may also be used.'

(*Page* 16, *clauses* **6.3.3** *and* **6.3.5**) — Substitute the following for the existing:

'**6.3.3** The minimum grade of concrete to be used for piling shall be M-20 and the minimum cement content shall be 400 kg/m³ in all conditions. For piles up to 6 m deep M-15 concrete with minimum cement content 350 kg/m³ without provision for under water concreting may be used under favourable non-aggressive sub-soil condition and where concrete of higher strength is not needed structurally or due to aggressive site conditions. The concrete in aggressive surroundings due to presence of sulphates, etc, shall conform to provisions given in IS : 456-1978 Code of practice for plain and reinforced concrete (*third revision*).

6.3.5 For the concrete, water and aggregates specifications laid down in IS : 456-1978 Code of practice for plain and reinforced concrete (*third revision*), shall be followed in general. Natural rounded shingle of appropriate size may also be used as coarse aggregate. It helps to give high slump with less water-cement ratio. For tremie concreting aggregates having nominal size more than 20 mm should not be used.'

(*Page* 17, *clause* **7.1.1**) — Add the following new clause after **7.1.1**:

'**7.1.1.1** For piles penetrating through soft rock and resting on hard rock, care should be taken to ensure that sufficient contact between the founding strata and pile is available. The socket length may be suitably designed for this purpose. In the first few piles careful study should be made about physical efforts to create the length of the socket as required from design or practical considerations and further monitoring at the site should be carried in terms of the chiselling time criteria established in the initial trials. The criteria shall vary from site to site, from strata to strata and for different equipment and as such is required to be established by each site in the initial working period.'

[*Page* 17 *Clause* **7.1.2**, *fourth and fifth sentences* (see also *Ammendment No. 2*)] — Substitute 'D/6' *for* 'D/4'.

(*Pages* 26 *to* 28, *Appendix* C *and Fig.* 2 *and* 3) — Substitute the following for the existing appendix and figures:

'APPENDIX C

(*Clause* 5.5.2)

DETERMINATION OF DEPTH OF FIXITY, LATERAL DEFLECTION AND MAXIMUM MOMENT OF LATERALLY LOADED PILES

C-1. DETERMINATION OF LATERAL DEFLECTION AT THE PILE HEAD AND DEPTH OF FIXITY

C-1.1 The long flexible pile, fully or partially embedded, is treated as a cantilever fixed at some depth below the ground level (*see* Fig. 2).

C-1.2 Determine the depth of fixity and hence the equivalent length of the cantilever using the plots given in Fig. 2.

where

$T = \sqrt[5]{\frac{EI}{K_1}}$ and $R = \sqrt[4]{\frac{EI}{K_2}}$ (K_1 and K_2 are constants given in Tables 1 and 2 below, E is the Young's modulus of the pile material in kg/cm^2 and I is the moment of inertia of the pile cross-section in cm^4).

NOTE — Fig. 2 is valid for long flexible piles where the embedded length L_e is $\geqslant 4R$ or $4T$.

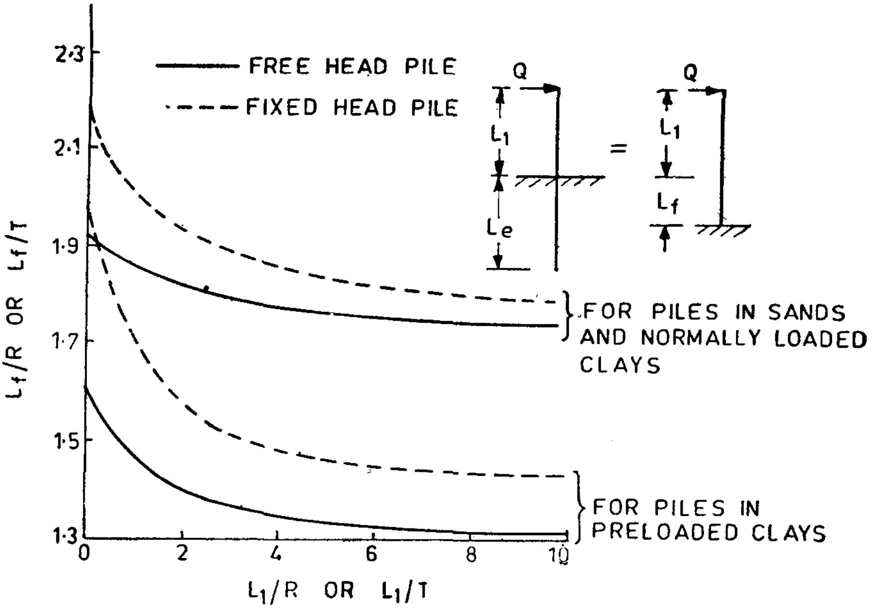


FIG. 2 DETERMINATION OF DEPTH FIXITY

C-1.3 Knowing the length of the equivalent cantilever the pile head deflection (Y) shall be computed using the following equations:

$$Y = \frac{Q(L_1 + L_F)^3}{3EI} \quad \text{...for free head pile}$$

(cm)

$$= \frac{Q(L_1 + L_F)^3}{12\,EI} \quad \text{...for fixed head pile}$$

where Q is the lateral load in kg.

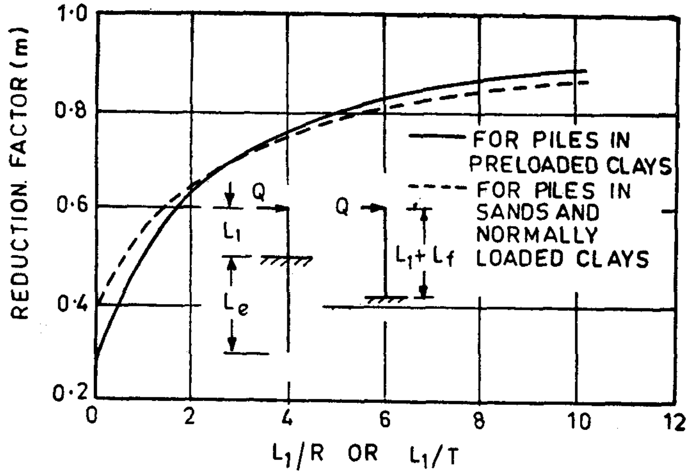
C-2. DETERMINATION OF MAXIMUM MOMENT IN THE PILE

C-2.1 The fixed end moment (M_F) of the equivalent cantilever is higher than the actual maximum moment (M) of the pile. The actual maximum moment is obtained by multiplying the fixed end moment of the equivalent cantilever by a reduction factor, m given in Fig. 3. The fixed end moment of the equivalent cantilever is given by:

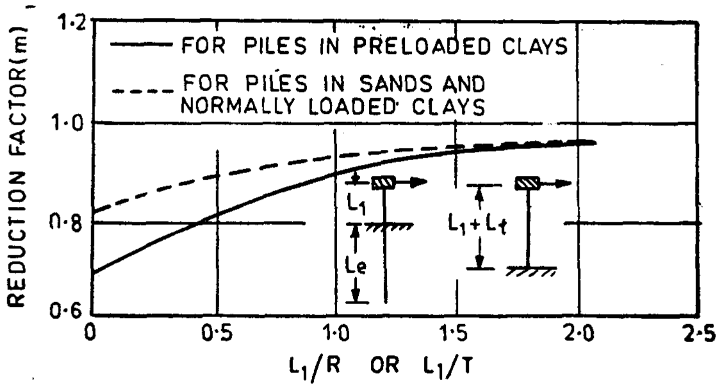
$$M_F = Q(L_1 + L_f) \quad \text{...for free head pile}$$

$$= \frac{Q(L_1 + L_f)}{2} \quad \text{.. for fixed head pile}$$

The actual maximum moment (M) = m (M_F).



3A FOR FREE HEAD PILE



3B FOR FIXED HEAD PILE

FIG. 3 DETERMINATION OF REDUCTION FACTORS FOR COMPUTATION OF MAXIMUM MOMENT IN PILE

TABLE 1 VALUES OF CONSTANT K_1 (kg/cm³)

TYPE OF SOIL	VALUE	
	Dry	Submerged
Loose sand	0·260	0·146
Medium sand	0·775	0·525
Dense sand	2·075	1·245
Very loose sand under repeated loading or normally loading clays	—	0·040

TABLE 2 VALUES OF CONSTANT K_2 (kg/cm²)

UNCONFINED COMPRESSIVE STRENGTH IN kg/cm²	VALUE
0·2 to 0·4	7·75
1 to 2	48·80
2 to 4	97·75
More than 4	195·50

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