Indian Standard

CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF PILE FOUNDATIONS

PART I CONCRETE PILES

Section 1 Driven Cast *in-Situ* Concrete Piles

(First Revision)

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Indian Standard
CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF PILE FOUNDATIONS
PART I CONCRETE PILES
Section I Driven Cast *In-Situ* Concrete Piles
(*First Revision*)

0. FOREWORD

0.1 This Indian Standard (Part I/Sec 1) (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 foundations to transfer loads from a structure to competent subsurface strata having adequate load-bearing capacity. The load transfer mechanism from a pile to the surrounding ground is complicated and is not yet fully understood, 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 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, differential settlement and any other special requirement of a project. The installation of piles demands careful control on position, alignment and depth, and involve specialized 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 the portion pertaining to under-reamed pile foundations was 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

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

for ease of reference and to take into account the recent developments in 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 driven cast *in-situ* concrete piles. 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 Driven cast *in-situ* pile is formed in the ground by driving a casing, permanent or temporary, and subsequently filling in the hole with plain or reinforced concrete. For this type of pile the subsoil is displaced by the driving of the casing, which is installed with a plug or a shoe at the bottom. In case of the piles driven with temporary casings, known as uncased, the concrete poured *in-situ* comes in direct contact with the soil. The concrete may be rammed, vibrated or just poured, depending upon the particular system of piling adopted. This type of piles find wide application where the pile is required to be taken to a greater depth to find adequate bearing strata or to develop adequate skin friction and also when the length of individual piles cannot be predetermined.

0.5 The Sectional 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.

0.5.1 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 formulating this code.

0.5.2 The Committee has also consulted several standards and publications from different countries of the world, of which special mention may be made of the following:

BSCP : 2004-1972 Code of practice for foundations. British Standards Institution

Recommendation of British Piling Specialist Committee

New York City Building Code

0.6 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing

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

the result of a test, shall be rounded off in accordance with IS : 2 - 1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard (Part I/Sec 1) covers the design and construction of reinforced concrete driven cast *in-situ* load-bearing piles which transmit the load of a structure to the soil by resistance developed at the toe of the piles by end bearing or by friction along their surface or by both.

1.2 This standard does not cover the use of driven cast *in-situ* piles for any other purpose, for example, temporary or permanent retaining structure, etc.

2. TERMINOLOGY

2.0 For the purpose of this standard, 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.

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 a 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, as a '*Friction pile*'.

2.4 Driven Cast *in-Situ* Pile — The pile formed within the ground by driving a casing of uniform diameter, permanent or temporary, and subsequently filling in the hole so formed with plain or reinforced concrete. For displacing the subsoil the casing is installed with a plug or a shoe at the bottom end. 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.

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.

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

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

2.7 Nett Displacement — 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 a working pile itself if subjected to routine load test with up to one and a half times the safe load.

2.10 Trial Pile — One or more piles, which are not working piles, that may be installed initially to assess the load-carrying capacity of the piles are called trial piles. These piles are tested either to their ultimate bearing 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 as follows:

a) Elastic displacement of the soil participating in load transfer, and
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 Follower Tube — A tube which is used following the main casing tube when adequate set is not obtained with the main casing tube and it requires to be extended further. The inner diameter of the follower tube should be the same as the inner diameter of the casing. The follower tube shall preferably be an outside guide and should be water-tight when driven in water-bearing strata or soft clays.

2.14 Ultimate Load Capacity — The maximum load which a pile can carry before failure of ground (when the soil fails by shear as evidenced from the load settlement curves) or failure of pile materials.

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

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

3. NECESSARY INFORMATION

3.1 For the satisfactory design and construction of driven cast *in-situ* piles and pile foundation the following information is necessary:

a) Site investigation data as laid down in IS : 1892-1979* or any other relevant Indian Standard code. Sections of trial boring,

*Code of practice for sub-surface investigations for foundations (*first revision*).

supplemented where appropriate by penetration tests, should incorporate data/information sufficiently below the anticipated level of founding of piles but this should generally be not less than 10 m unless bed rock or firm strata has been encountered. The nature of soil, both around and beneath the proposed piles, should be indicated on the basis of appropriate tests of strength and compressibility. Ground-water level and conditions (such as artesian conditions) should also be recorded. Results of chemical tests to ascertain the sulphate chloride and other deleterious chemical content of soil and water should be indicated. This is particularly required in a job when extensive piling is to be undertaken.

b) The experience of driving cast *in-situ* piles in the area close to the proposed site and any boring report thereof for assessing the founding level of piles.

c) For piling work in water, as in the case of bridge construction, data on high flood levels, water level during the working season, maximum depth of scour, etc, and in the case of marine construction, data on high and low tide level, corrosive action of chemical present and data regarding flow of water.

d) The general layout of the structure showing the estimated loads, vertical and lateral, including moments and torques at the top of the pile caps, but excluding the weight of the pile caps and piles. The level of pile caps should also be indicated.

e) All transient loads due to seismic and wind conditions and force due to water should be indicated separately.

f) Sufficient information of structures existing near by 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 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.

4. EQUIPMENT AND ACCESSORIES

4.1 The equipment and accessories would depend upon the type of driven cast *in-situ* piles, job by job, and would be selected giving due 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 exists a large variety; suitability of which depends on the subsoil conditions, manner of operations, etc. Brief definitions of some commonly used equipment are given below:

Dolly — A cushion of hardwood or some suitable material placed on the top of the casing to receive the blows of the hammer.

Drop Hammer (or Monkey) — Hammer, ram or monkey raised by a winch and allowed to fall under gravity.

Single- or Double-Acting Hammer — A hammer operated by steam compressed air or internal combustion, the energy of its blows being derived mainly from the source of motive power and not from gravity alone.

Kentledge — Dead weight used for applying a test load to a pile.

Pile Frame (or Pile Rig) — A movable steel structure for deriving piles in the correct position and alignment by means of a hammer operating in the guides or (leaders) of the frame.

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 which 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. Figure 1 of IS : 2974 (Part I)-1969* may be used as a guide for qualitatively studying the effect of vibration of persons and structures.

5.2.2 In case of deep excavations adjacent to piles, proper shoring or other suitable arrangements 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 the load along its axis. Transverse load bearing capacity of a single pile depends on soil

*Code of practice for design and construction of machine foundations: Part I Foundations for reciprocating type machines (*first revision*).

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 and adopting appropriate values for horizontal modulus of the soil. Alternatively, piles may be installed in rake.

5.3.1 The ultimate bearing capacity of a pile may be estimated approximately by means of a static formula on the basis of soil test results, or by using a dynamic pile formula using the data obtained during driving in the pile or by test loading. However, it should preferably be determined by an initial load test on a trial pile tested to its ultimate level particularly in any locality where experience of piling is not available.

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 on the basis of subsoil data and loading details of the structure as a whole using the principle of soil mechanics.

5.3.1.1 *Static formula* — By using the static formula the estimated value of ultimate bearing capacity of a typical pile is obtained, the accuracy being dependent on the reliability of the formula and the reliability of the soil properties for various strata available. The soil properties to be adopted in such formula may be assigned from the results of laboratory tests and field tests like standard penetration tests (*see* IS : 2131-1963*). Results of cone penetration tests [*see* IS : 4968 (Part I)-1968†, IS : 4968 (Part II)-1968‡ and IS : 4968 (Part III)-1971§] may also be utilized where necessary correlation with soil data has been established. Two separate static formulae, commonly applicable for cohesive and non-cohesive soils, are indicated in Appendix A to serve only as a guide. Other alternative formulae may be applied depending on the subsoil characteristics and method of installation of piles.

5.3.1.2 *Dynamic formula* — In non-cohesive soils, such as gravels, coarse sand and similar deposits an approximate value of the bearing capacity may be determined by a dynamic pile formula. The Hiley formula is more reliable and is most commonly used (*see* Appendix B). Dynamic formulae are not directly applicable to cohesive soil deposits such as saturated silts and clays as the resistance to impact of the toe of the casing will be exaggerated by their low permeability while the frictional resistance on the

*Method for standard penetration test for soils.

†Method for subsurface sounding for soils: Part I Dynamic method using 50 mm cone without bentonite slurry (*first revision*).

‡Method for subsurface sounding for soils: Part II Dynamic method using cone and bentonite slurry (*first revision*).

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

sides is reduced by lubrication. If as a result of test loadings on a given area a suitable coefficient can be applied to a dynamic formula, the results may then be considered of reasonable reliability for that particular area.

5.3.1.3 *Load test results* — The ultimate load capacity of a single pile is, with reasonable accuracy, determined from test loading [*see* IS : 2911 (Part IV)-1979*]. The load test on a pile shall not be carried out earlier than 4 weeks from the time of casting the pile.

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 downwards relative to the pile shaft. The existence of such phenomenon shall be recognized and suitable reduction made to the allowable load where appropriate.

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.

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 wholly embedded in the soil (having an undrained shear strength not less than 0·1 kgf/cm^2), 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/cm^2), special considerations shall be made to determine whether the shaft would behave as a 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 may be taken as a depth of 1 m below ground surface subject to a minimum of 3 times the diameter of the shaft. In weak soil (undrained shear strength less than 0·1 kgf/cm^2) such as soft clay and soft silt, this point may be taken at about half the depth of penetration into such stratum but not more than 3 m or 10 times the dia meter 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 the accepted structural principles.

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

The permissible stress shall be reduced in accordance with similar provision for reinforced concrete columns as laid down in IS : 456-1978*.

5.5.2 *Lateral Load Capacity* — A pile may be subjected to transverse forces from a number of causes, such as wind, earthquake, water current, earth 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 coexistent loads including the axial load on the pile, should be taken into consideration for checking the structural capacity of the shaft. A recommended method 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.

Because of limited information on horizontal modulus of soil and refinements in the theoretical analysis, it is suggested that the adequacy of a design should 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 graphically or by 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 loose fill or consolidating deposit 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 pile is considered from two aspects as follows:

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 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.

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

5.6.2 Piles deriving their bearing capacity mainly from friction shall be sufficiently apart to ensure that the zones of soil 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 3 times the diameter of the shaft.

5.6.3 In the case of loose sand or filling, closer spacing than in dense sand may be possible since displacement during the piling may be absorbed by vertical and horizontal compaction of the strata. Minimum spacing in such strata may be twice the diameter of the shaft.

NOTE — In the case of piles of non-circular cross-section, diameter of the circumscribing circle shall be adopted.

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 the pile group is dependent on many complex factors. It is desirable to consider each case separately on its own merits.

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

a) Equal to the bearing capacity of individual piles multiplied by the number of piles in the group, or

b) It may be less.

The former holds true in case of friction piles, cast or driven into progressively stiffer materials or in end-bearing piles. In friction piles installed in soft and clayey soils it is normally smaller. For driven piles in loose sandy soils the group value may be higher due to the effect of compaction. In such a case, a load test should be made on a pile from the group after all the piles in the group have been installed.

5.7.2 In case of piles deriving their support mainly from friction and connected by a rigid pile cap, the group may be visualized to transmit the 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, shall not be more than the capacity worked out according to **5.7.2**.

5.7.3 When a moment is applied on the pile group either from superstructure or 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, beams may be provided to restrain the pile caps effectively from lateral or rotational movement.

5.7.4 In case of a structure supported on single piles/group of piles, resulting in 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 caps supported on different number of piles.

5.8 Factor of Safety

5.8.1 Factor of safety should be judiciously chosen after considering the following:

a) The reliability of the value of ultimate bearing capacity of a pile,

b) The type of superstructure and the type of loading, and

c) Allowable total/differential settlement of the structure.

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

5.8.3 When the ultimate bearing capacity is computed from either static formula or dynamic 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 a factor of safety shall take into consideration the load settlement characteristics of the structure as a whole on a given site.

5.8.4 Factor 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 safe load on a

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

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.

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

5.11.1 The design of the reinforcing cage varies depending upon the driving and installation conditions, the nature of the subsoil and the nature of load to be transmitted by the shaft, axial, or otherwise. The minimum area of longitudinal reinforcement within the pile shaft shall be 0·4 percent of the sectional area calculated on the basis of outside area of the casing of the shaft.

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.

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 according to 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 pile. In soft clays or loose sands, or where there is likelihood of danger to green concrete due to driving of adjacent piles, 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 a minimum amount of 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 requirements.

5.11.3 Clear cover to all main reinforcement in pile shaft shall be not less than 50 mm. 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 installations. 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.

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

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 method 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 moment 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 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 according to 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 : 8041-1978¶ 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 : 1786-1966‡‡ 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 reinforced 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 for cold-twisted steel bars for concrete reinforcement (*revised*).

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

6.3 Concrete

6.3.1 Consistency of concrete to be used for driven cast *in-situ* piles shall be suitable to the method of installation of piles. Concrete shall be so designed or chosen as to have a homogeneous mix having a slump/workability consistent with the method of concreting under the given conditions of pile installation.

6.3.2 The minimum slump should be 100 mm when the concrete in the pile is not compacted. The slump should not exceed 180 mm in any case.

6.3.3 The minimum grade of concrete to be used for piling shall be M-15. For conditions under which the concrete is not exposed to sulphate attack, the minimum cement content shall be 300 kgf/m^3. For concrete exposed to sulphate attack the minimum cement content shall be in accordance with IS : 456-1978*. When concreting under water or drilling mud 10 percent additional cement over that required for the designed mix of concrete for the required slump shall be used subject to a minimum of 370 kgf/m^3. For subaqueous concrete the requirements specified in IS : 456-1978* shall be followed.

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

6.3.5 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. Where the casing of the pile is permanent, of adequate thickness and of suitable shape, the allowable compressive stress may be increased.

7. CONTROL OF PILE DRIVING

7.1 Control of Alignment — Piles shall be installed as accurately as possible according to the designs and drawings either vertically or to the specified batter. Greater care should be exercised in respect of installation of single piles 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 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. 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 or pile

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

ties, the piles should be replaced or supplemented by one or more additional piles.

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.

7.2 Sequence of Piling

7.2.1 In a pile group the sequence of installation of piles shall normally be from the centre to the periphery of the group or from one side to the other.

7.2.2 Consideration should be given to the possibility of doing harm to a pile recently formed by driving the tube near by before the concrete has sufficiently set. The danger of doing harm is greater in compact soils than in loose soils.

7.2.3 *Driving a Group of Friction Piles* — Driving piles in loose sand tends to compact the sand which, in turn, increases the skin friction. Therefore, the order of installing of such a pile in a group should avoid creating a compacting block of ground into which further piles cannot be driven.

In case where stiff clay or compact sand layers have to be penetrated, similar precautions need be taken. This may be overcome by driving the piles from the centre outwards or by beginning at a selected edge or working across the group. However, in the case of very soft soils, the driving may have to proceed from outside to inside so that the soil is restrained from flowing out during operations.

7.3 Jetting — Jetting of casings by means of water shall be carried out, if required, in such a manner as not to impair the bearing capacity of piles already in place, the stability of the soil or the safety of any adjoining buildings.

7.4 The top of concrete in a pile shall be brought above the cut-off level to permit removal of all latiance and weak concrete before capping and to ensure good concrete at the cut-off level. The reinforcing cages shall be left with adequate protruding length above the cut-off level for proper embediment into the pile cap.

7.5 Where cut-off level is less than 1·5 m below working level, the 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 working level, an additional coverage a minimum of 50 mm shall be allowed. Higher allowance may be necessary, depending on the length of the pile. In the circumstances, pressure on the unset concrete equal to or greater than the water pressure should be observed and accordingly length of extra concrete above cut-off level shall be determined.

7.6 Defective Pile

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

7.6.2 If there is a major variation between the depths at which adjacent foundation piles in a group meet refusal, a boring shall be made near by to ascertain the cause of this difference. If the boring shows that the soil contains pockets of highly compressive material below the level of the shorter pile, it may be necessary to take all the piles to a level below the bottom of the zone which shows such pockets.

7.7 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.

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

7.9 Recording of Data

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

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 driven;
d) Time taken for driving and for concreting;
e) Cut-off level/working level; and
f) Any other important observations.

7.9.2 Typical data sheets for facility of recording piling data are shown in Appendix D.

APPENDIX A

(*Clause* 5.3.1.1)

LOAD CARRYING CAPACITY — STATIC FORMULA

A-1. PILES IN GRANULAR SOILS

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

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

where

A_p = cross-sectional area of pile toe in cm^2;

D = stem diameter in cm;

γ = effective unit weight of soil at pile toe in kg/cm^3;

P_D = effective overburden pressure at pile toe in kgf/cm^2;

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 kgf/cm^2 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 cm^2 in the i^{th} layer where i varies from 1 to n.

NOTE 1 — N_γ factor can be taken for general shear failure according to 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, and the values are given in Fig. 1 which are based on recommendation of Vesic.

NOTE 3 — The earth pressure coefficient K depends on the nature of soil strata, type of pile and its method of construction. In loose to medium sands, K values of 1 to 3 should be used.

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

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

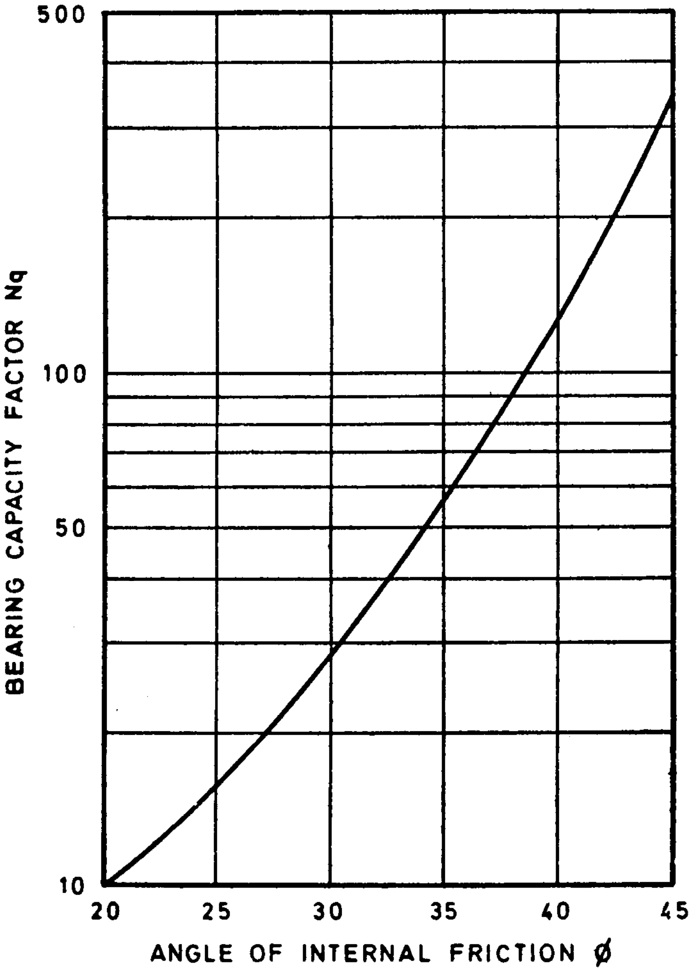


FIG. 1 BEARING CAPACITY FACTOR N_q FOR DRIVEN PILES

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

A-2. PILES IN COHESIVE SOILS

A-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 cm^2,

N_c = bearing capacity factor usually taken as 9,

C_p = average cohesion at pile tip in kgf/cm^2,

α = reduction factor,

$\bar{C}$ = average cohesion throughout the length of pile in kgf/cm^2, and

A_s = surface area of pile shaft in cm^2.

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

Consistency	*N Value*	*Value of* α
Soft to very soft	<4	1
Medium	4 to 8	0·7
Stiff	8 to 15	0·4
Stiff to hard	>15	0·3

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

NOTE 3 — 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 4 — α may be taken to vary from 0·5 to 0·3, depending upon the consistency of the soil. Higher values of up to 1 may be used for softer soils, provided the soil is not sensitive.

A-3. PILES IN NON-COHESIVE SOILS

A-3.1 When full static penetration data are available for the entire depth, 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	$\frac{q_c}{25} < f_s < \frac{q_c}{25}$

Type of Soil	*Local Side Friction* f_s
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:

$$q_u = \frac{\frac{q_{c_0} + q_{c_1}}{2} + q_{c_2}}{2}$$

where

q_u = ultimate point bearing capacity,

q_{c_0} = average static cone resistance over a depth of 2 d below the base level of the pile,

q_{c_1} = minimum static cone resistance over the same 2 d below the pile tip,

q_{c_2} = 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.

A-3.2 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
Clays	2·0
Silts, sandy silts and slightly cohesive silt sand mixtures	2·00
Clean fine to medium sands and slightly silty sands	3-4
Coarse sands and sands with little gravel	5-6
Sandy gravels and gravel	8-10

APPENDIX B

(*Clause* 5.3.1.2)

DYNAMIC PILE FORMULAE

B-1. GENERAL

B-1.1 These are based on the laws governing the dynamic impact of elastic bodies. They equate the energy of the hammer blow to the work done in overcoming the resistance of the ground to the penetration of the pile. Allowance is made for losses of energy due to the elastic contractions of the pile, cap and subsoil as well as the losses caused by the inertia of the pile. One of the most used of these formulae is the Hiley formula.

B-1.2 The modified Hiley formula is:

$$R = \frac{Whn}{S + C/2}$$

where

R = ultimate driving resistance in tonnes. The safe load shall be worked out by dividing it with a factor of safety of 2.5;

W = mass of the ram in tonnes;

h = height of the free fall of the ram or hammer in cm taken at its full value for trigger-operated drop hammers, 80 percent of the fall of normally proportioned winch-operated drop hammers, and 90 percent of the stroke for single-acting hammers. When using the McKiernan-Terry type of double-acting hammers, 90 percent of the maker's rated energy in tonne-centimetre per blow should be substituted for the product (Wh) in the formula. The hammer should be operated at its maximum speed whilst the set is being taken;

n = efficiency of the blow, representing the ratio of energy after impact to the striking energy of ram;

S = final set or penetration per blow in cm; and

C = sum of the temporary elastic compressions in cm of the pile, dolly, packings and ground calculated or measured as prescribed in **B-1.4**.

Where W is greater than Pe and the pile is driven into penetrable ground,

$$n = \frac{W + Pe^2}{W + P}$$

Where W is less than Pe and the pile is driven into penetrable ground

$$n = \frac{W + Pe^2}{W + P} - \left(\frac{W - Pe}{W + P} \right)^2$$

The following are the values of n in relation to e and to the ratio of P/W:

Ratio of P/W	$e = 0·5$	$e = 0·4$	$e = 0·32$	$e = 0·25$	$e = 0$
½	0·75	0·72	0·70	0·69	0·67
1	0·63	0·58	0·55	0·53	0·50
1½	0·55	0·50	0·47	0·44	0·40
2	0·50	0·44	0·40	0·37	0·33
2½	0·45	0·40	0·36	0·33	0·28
3	0·42	0·36	0·33	0·30	0·25
3½	0·39	0·33	0·30	0·27	0·22
4	0·36	0·31	0·28	0·25	0·20
5	0·31	0·27	0·24	0·21	0·16
6	0·27	0·24	0·21	0·19	0·14
7	0·24	0·21	0·19	0·17	0·12
8	0·22	0·20	0·17	0·15	0·11

P is the mass of the pile, anvil, helmet, and follower (if any) in tonnes.

Where the pile finds refusal in rock, 0·5 P should be substituted for P in the above expressions for n.

e is the coefficient of restitution of the materials under impact as tabulated below:

a) For steel ram of double-acting hammer striking on steel anvil and driving reinforced concrete pile, $e = 0·5$.

b) For cast iron ram of single-acting or drop hammer striking on the head of reinforced concrete pile, $e = 0·4$.

c) Single-acting or drop hammer striking a well-conditioned driving cap and helmet with hard wood dolly in driving reinforced concrete piles or directly on the head of timber pile, $e = 0·25$.

d) For a deteriorated condition of the head of pile or of dolly, $e = 0$.

B-1.3 Deduction for Raking — Where single-acting or drop hammers work in leader guides inclined on a batter, the percentages given in the following table should be deducted from the calculated bearing value in the axial direction of the pile.

Rake	*Percent Deduction*
1 in 12	1·0
1 in 10	1·5
1 in 8	2·0
1 in 6	3·0
1 in 5	4·0
1 in 4	5·5
1 in 3	8·5
1 in 2	14·0

B-1.4 Value of Temporary Compression — The temporary compression of the pile and ground occurring during driving shall be determined from site measurements whenever possible, especially when the set is small. A typical arrangement for setting up of the set recorder is shown in Fig. 2. To the measured compression, the value of the compression of the dolly and packing (C_1) shall be added.

The value C may be obtained by calculations (*see* **B-1.4.2**).

B-1.4.1 Where measurement cannot be taken, the temporary compression of the pile C_2 and of the ground C_3 may also be obtained by calculations (*see* **B-1.4.2**).

B-1.4.2 *Calculation for Temporary Compression* — The value of C (*see* formula in **B-1.2**) is equal to $C_1 + C_2 + C_3$,

where

C_1 = temporary compression of dolly and packing,

C_2 = temporary compression of pile, and

C_3 = temporary compression of ground.

The values of C_1, C_2 and C_3 may be computed using the following formulae:

$C_1 = 1{\cdot}77 \dfrac{R}{A}$, where the driving is without dolly or helmet, and cushion about 2·5 cm thick;

or $= 9{\cdot}05 \dfrac{R}{A}$, where the driving is with short dolly up to 60 cm long, helmet and cushion up to 7·5 cm thick.

$$C_2 = 0{\cdot}657 \frac{RL}{A}$$

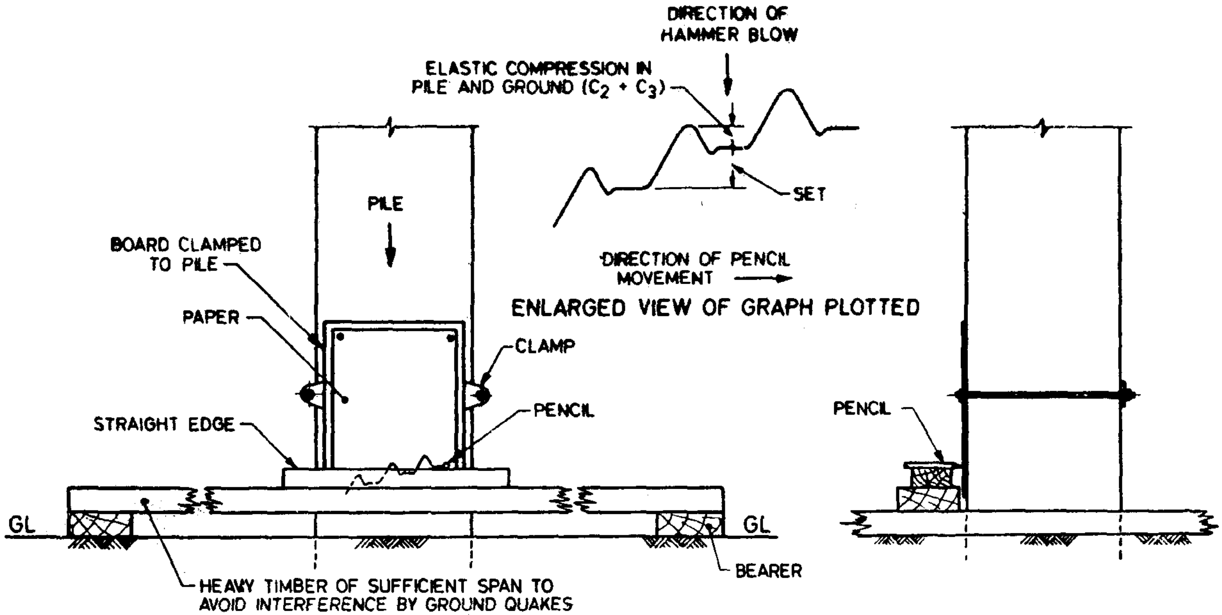


Fig. 2 Typical Arrangement for a Set Recorder

$$C_8 = 3.55 \frac{R}{A}$$

where

R = ultimate driving resistance calculated as in **B-1.2** in tonnes,
L = length of the pile in metres, and
A = area of the pile in cm^2.

APPENDIX C

(*Clause* 5.5.2)

DETERMINATION OF DEPTH OF FIXITY OF PILES

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.

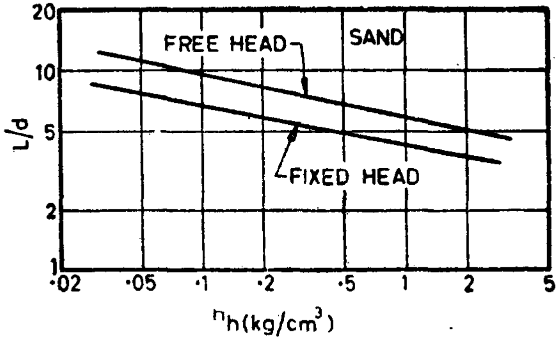
Determine from appropriate graphs given in Fig. 3 and 4 the value of L, the equivalent length of cantilever, giving the same deflection at ground level as the actual pile.

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

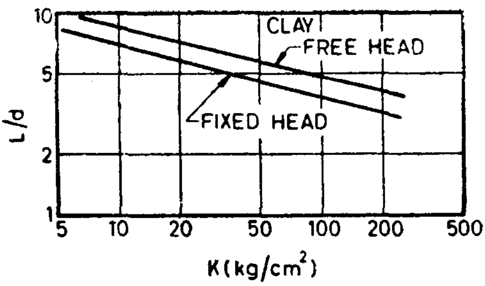
Unconfined Compression Strength kgf/cm^2	Range of Values of K kgf/cm^2	Probable Value of K kgf/cm^2
0·2 to 0·4	7 to 42	7·73
1 to 2	32 to 65	48·79
2 to 4	65 to 130	97·73
4	—	195·46



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

d = Diameter of the pile.

FIG. 3 L/d VERSUS n_h FOR EQUIVALENT CANTILEVER LENGTH



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

d = Diameter of the pile.

FIG. 4 L/d VERSUS K FOR EQUIVALENT CANTILEVER LENGTH

APPENDIX D

(*Clause* 7.9.2)

DATA SHEETS

Site ....

Title ....

Date for 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 :	R Shape — ound/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/cm^2
	Quantity of cement per m^3 : ....
	Extra cement added, if any : ....

Weight of hammer........................Type of hammer.......................
(Specify rated energy, if any)

Fall of hammer....................Length finally driven...........................

No. of blows during last inch of driving...

Dynamic formula used, if any..

Calculated value of working load...
(Calculations may be included)

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 piling 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

Trail 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)

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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
Institution of Engineers (India) Building 1332 Shivaji Nagar, PUNE 411005	32 36 35
T.C. No. 14/1421, University P.O. Palayam, THIRUVANANTHAPURAM 695034	6 21 17

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AMENDMENT NO. 1 AUGUST 1982

TO

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

PART I CONCRETE PILES

Section 1 Driven Cast *In-situ* Concrete Piles

(*First Revision*)

Alterations

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

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

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

(*Page* 19, *clause* **A-1.1**, *Note* 1, *lines* 1 *and* 2) — Substitute 'IS : 6403-1981*' *for* 'IS : 6403-1971*'.

(*Page* 19, *foot-note with* ' * ' *mark*) — Substitute the following for the existing foot-note:

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

(*Page* 21, *clause* **A-3.1**, *informal table, first column, first entry*) — Substitute ' $q_c < 10$ ' for the existing matter.

(*Page* 21, *clause* **A-3.1**, *informal table, second column, second entry*) — Substitute the following for the existing matter:

$$`\frac{q_c}{25} < f_s < \frac{2q_c}{25}'$$

(*Page* 22, *clause* **A-3.1**, *informal table, second column, second entry*) — Substitute the following for the existing matter:

$$`\frac{q_c}{100} < f_s < \frac{2q_c}{100}'$$

Addenda

(*Page* 15, *clause* **6.1**, *line* 2) — Add ', IS : 1489-1976¶¶' after 'IS : 8041-1978¶'.

(*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 DECEMBER 1984
TO
IS : 2911 (Part I/Sec 1)-1979 CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF PILE FOUNDATIONS

PART I CONCRETE PILES

Section 1 Driven Cast *In-Situ* Concrete Piles

(First Revision)

Alterations

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

(*Page* 9, *clause* **5.3.1.1**, *lines* 7 *and* 8) — Substitute the following for the existing reference to Indian Standards:

' [IS : 4968 (Parts I, II *and* III) - 1976†]. '

(*Page* 9, *foot-notes*) — Substitute the following for the existing oot-notes:

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

†Method for subsurface sounding for soils .'

(*Page* 10, *clause* **5.3.1.3**) — Delete.

(*Page* 10, *foot-note*) — Delete.

(*Page* 14, *clause* **5.11.1**, *line* 4) — Add the following words after the word ' reinforcement ':

' of any type or grade '

(*Page* 14, *clause* **5.11.1**, *Note*) — Delete.

(*Page* 15, *clause* **6.2**, *line* 1) — Substitute ' IS : 432 (Part I) - 1983**' *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* 16, *clause* **7.1**, *4th to 7th sentences*) — Substitute the following for the existing sentences:

'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* 22, *clause* **A-3.1**, *second column, first entry*) — Substitute '$\frac{q_0}{25}$' *for* '$\frac{2q_0}{25}$'

(*Page* 27, *Table* 2) S— ubstitute 'kgf/cm^3' *for* 'kgf/cm^2' in columns 2 and 3.

(*Page* 28,.*Fig.* 4) — Substitute 'kgf/cm^3' *for* 'kg/cm^2'.

Addenda

(*Page* 8, *clause* **5.1**, *line* 7) — Add the following in the end:
'and shall be designed according to IS : 456-1978†.'

(*Page* 8, *foot-note*) — Add the following foot-note in the end:
'†Code of practice for plain and reinforced concrete (*third revision*).'

(*Page* 9, *clouse* **5.3.1**, *line* 6) — Add the following in the end:
'[*see* IS : 2911 (Part IV)-1979‡]'

(*Page* 9, *foot-notes*) — Add the following foot-note in the end:
'‡Code of practice for design and construction of pile foundation: Part IV Load test on piles.'

(*Page* 14, *clause* **5.11.2**) —Add the following note under this clause:

'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 up to well secured joints. Also the lifting 5 percent of the length should be considered not to affect the quality of pile.'

(*Page* 18, *clause* **7.7**) — Add the following in the end:
'if the deviations are beyond the permissible limit.'

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AMENDMENT NO. 3 SEPTEMBER 1987 TO

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

PART 1 CONCRETE PILES

Section 1 Driven Cast *in-Situ* Concrete Piles

(First Revision)

(*Page* 9, *clause* **5.3.1.2**, *line* 4) — Delete the words '(*see* Appendix B)'.

(*Page* 11, *clause* **5.5.2**, *fourth and fifth 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 B for fully or partially embedded piles. Other accepted methods, such as the method of Reese and Matlock for fully embedded piles may also be used.'

[*Page* 15, *clause* **6.2** (see also *Amendments No. 1 and 2*)] — Substitute 'IS : 1786-1985††' *for* 'IS : 1139-1966†† *or* IS : 1786-1979‡‡.'

[*Page* 15, *foot-notes marked with* '††' *and* '‡‡' *marks* (see also *Amendments No. 1 and 2*)] — Substitute the following for these foot-notes:

'†† Specification for high strength deformed steel bars and wires for concrete reinforcement (*third revision*).'

(*Page* 16, *clauses* **6.3.3** *and* **6.3.4**) — Substitute the following for the existing clauses:

'**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 provisions 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*.

6.3.4 For the concrete, water and aggregates specifications laid down in IS : 456-1978* shall be followed in general. Natural rounded shingle of appropriate size may also be used as coarse aggregate. It helps to

Gr 1

give high slump with less water-cement ratio. For tremie concreting aggregates having nominal size more than 20 mm should not be used.'

[*Page* 16, *clause* **7.1**, *fourth and fifth sentences* (see also *Amendment No. 2*)] — Substitute ' D/6 ' *for* ' D/4 ' at both the places.

(*Pages* 23 *to* 27, *Appendix B, including Fig.* 2) — Delete.

(*Pages* 27 *and* 28, *Appendix C, including Fig.* 3 *and* 4) — Substitute the following for the existing appendix and figures:

'APPENDIX B

(*Clause* 5.5.2)

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

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

B-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).

B-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 2 and 3 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.

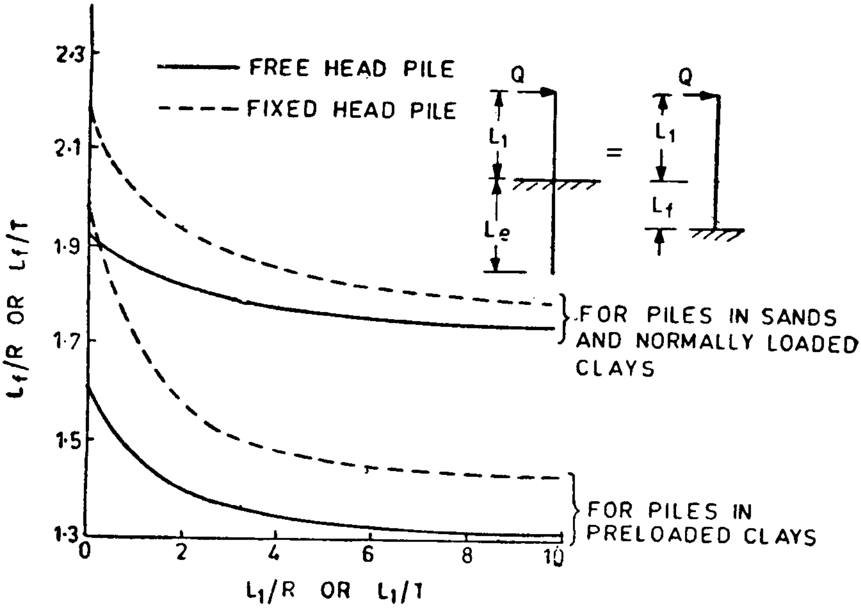


FIG. 2 DETERMINATION OF DEPTH FIXITY

TABLE 2 VALUES OF CONSTANT K_1 (kg/cm^2)
(*Clause* B-1.2)

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 3 VALUES OF CONSTANT K_2 (kg/cm^2)
(*Clause* B-1.2)

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

B-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.

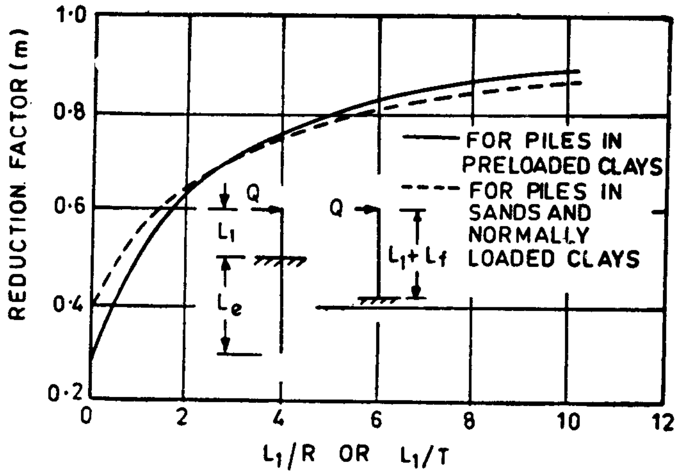
B-2. DETERMINATION OF MAXIMUM MOMENT IN THE PILE

B-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:

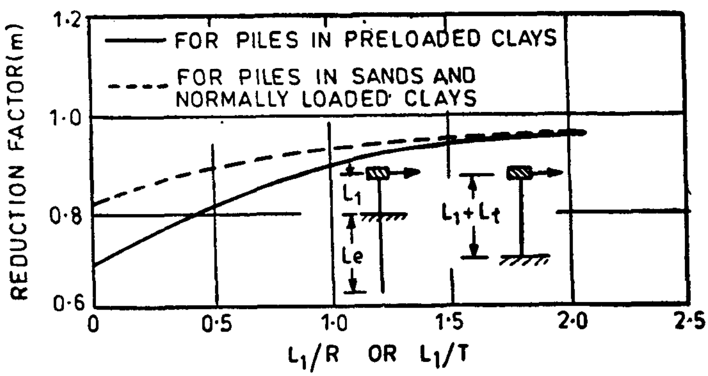
$$M_F = Q\,(L_1 + L_f) \quad \text{...for free head pile}$$

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

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

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