IS : 2911 (Part 1/Sec 3) - 1979

(Reaffirmed 1997)

Indian Standard

CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF PILE FOUNDATIONS

PART 1 CONCRETE PILES

Section 3 Driven Precast Concrete Piles

(First Revision)

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Section 3 Driven Precast Concrete Piles
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(*Continued on page* 2)

(*Continued from page* 1)

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(*Continued on page* 42)

Indian Standard
CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF PILE FOUNDATIONS
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(First Revision)

0. FOREWORD

0.1 This Indian Standard (Part I/Sec 3) (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 requires 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 and under-reamed piles including load testing. Subsequently, portions pertaining to under-reamed pile foundations were deleted and which are 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 the 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 IS : 2911 (Part I) - 1964* 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 covers the driven precast 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 Precast Concrete Pile is a pile constructed in a casting yard and subsequently driven in the ground with or without jetting, or other technics like preboring (depending on the conditions of soil) when the pile has attained sufficient strength. By driving, the subsoil is displaced and remain in direct contact with the pile. These piles find wide application particularly for structures such as wharves, jetties, etc, to act as a free standing piles above the soil/water level or where conditions are unfavourable for use of cast-in-situ piles.

0.5 The technical committee, responsible for this standard, while formulating this standard has given due consideration to the available experience in this country in pile construction and also to 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 formulation of this code.

0.5.2 The committee has also consulted several standards and publications from different countries 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.

0.6 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.

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*Code of practice for design and construction of pile foundations: Part I Load-bearing concrete piles.

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

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

1. SCOPE

1.1 This standard (Part I/Sec 3) covers the design and construction of load-bearing driven precast concrete piles 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.

1.2 This standard does not cover the use of driven precast concrete piles for any other purpose, for example, temporary or permanent retaining structure.

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, etc.

2.2 Batter Pile (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 then as '*Friction Pile*'.

2.4 Driven Precast Pile — A pile constructed in concrete (Reinforced or Prestressed) in a casting yard and subsequently driven in the ground when it has attained sufficient strength.

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 Drop or Stroke — The distance through which the driving weight is allowed to fall for driving the pile.

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

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

2.9 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 load test.

2.10 Set — The net distance by which the pile penetrates in the ground due to a stated number of blows of the hammer.

2.11 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 one-half times the safe load.

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

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

a) Elastic displacement of the soil participating in the load transfer, and

b) Elastic displacement of the pile shaft.

2.14 Trial Pile — Initially one or more piles, which are not working piles, may be installed if required to assess the load-carrying capacity of a pile. These piles are tested either to their ultimate load capacity or to twice the estimated safe load.

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

2.16 Working Load -- The load assigned to a pile as per design.

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

3. NECESSARY INFORMATION

3.1 For the satisfactory design and construction of driven precast piles and pile foundation, the following information is necessary:

a) Site investigation data as laid down under IS : 1892-1979*, or any other relevant IS Code. Sections of trial boring, supplemented, wherever appropriate, by penetration tests, should incorporate data/information sufficiently below the anticipated level of the 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 soil 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 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 piling is envisaged or where such information is not generally available.

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

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

c) In case rock is encountered, adequate description of 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 driving 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 should be provided.

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 should be provided. The top levels of finished pile caps shall be clearly indicated.

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

g) Sufficient information of structures existing near by and the experience of driving piles in the area close to the proposed site and boring report thereof for assessing the founding level of piles 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 level 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 will have to be selected depending upon the hardness of driving, the capacity suitable for the size and weight of the pile to be handled and the location of work.

4.2 Generally, the equipment for installation of piles consists of a movable steel or timber structure designed for handling, pitching and driving the piles in the correct position and alignment. Additional equipment, tackles, etc, may be necessary to handle the piles from the casting/stacking yard.

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

4.3 A hammer, operating in the guides (leaders) of the movable structure, is used for driving the piles. A temporary steel driving cap, often termed as ' drive-cap ' is placed on top of a pile to distribute the blow over the cross-section of the pile and prevent the head of the same from being damaged during driving. The upper portion of the cap (helmet) is designed to hold in position a pad, block or packing of hardwood or some suitable resilient material (termed as ' Dolly ') for preventing the shock from the hammer.

A hammer may be ' single-acting ' or ' double-acting ' depending upon whether the same is allowed to fall under gravity alone or it derives the energy of blow mainly from the source of a motive power.

In practice, the piles may often be required to be driven down below the pile frame leaders out of reach of the hammer. In that even a removable extension piece known as ' Follower ' or ' long dolly ' is used to transmit the hammer blows on to the pile head.

4.4 Where soil/driving conditions so warrant, equipment for jetting, preboring, etc, are used for installation of piles.

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

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

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

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.

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 data obtained during driving the pile or by test loading.

The settlement of pile obtained at safe load/working load from load-test results on a single pile shall not be directly used for casting 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 principles of soil mechanics.

5.3.1.1 *Static formula* — By using static formula, 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 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 test, like standard penetration tests (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. The two separate static formulae, commonly applicable for cohesive and non-cohesive soil respectively, are indicated in Appendix A, to serve only as a guide. Other alternative formulae may also be applicable 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 one of the more reliable and is most commonly used (*see* Appendix B). 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 data obtained during driving the pile or by test loading. Dynamic formulae are not directly applicable to cohesive soil deposits such as saturated silts and clays as the resistance to impact of the toe

*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 one penetration test (*first revision*) of the casing will be exaggerated by their low permeability while the frictional resistance on the 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 bearing 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 four weeks from the time of installation of the pile.

5.4 Negative Skin Friction or Dragdown Force — When a soil stratum, through which a pile shaft has penetrated into a 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. Recognition of the existence of such a phenomenon shall be made and suitable reduction shall be 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 wholely 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 varies with the type of the soil. In good soil the lower point of contraflexure may be taken at a depth of 1 metre 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 or soft silt, this point may be taken at about half the depth of penetration into such stratum but not more than 3 metres or 10 times the diameter of the shaft whichever is less. A stratum of liquid mud

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

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 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 force for 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 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 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 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.

5.6 Spacing of Piles — The centre to centre spacing of pile is considered from two aspects, namley:

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,

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

shall be 2·5 times the diameter of the circumscribing circle corresponding to the cross-section of the shaft. In case of piles resting on rock, the spacing of two times the said 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 3 times the diameter of the shaft.

5.6.3 In 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 two times the diameter of the shaft.

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 merits.

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.

The former holds true in case of friction piles, cast or driven into progressively stiffer materials or in end-bearing piles. In friction piles 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 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 sides 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 above.

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 ground beams may be provided to restrain the pile cap effectively from lateral or rotational movement.

5.7.4 In case of a structure supported on single piles/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 loading. For example, a single pile cap may be loaded to a level higher than that of the 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:

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

b) the types 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 super-structure 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 time 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.

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

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 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 and not 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 Design of Pile

5.11.1 Design of pile section shall be such as to ensure the strength and soundness of the pile against lifting from the casting bed, transporting, handling, driving stresses without damage.

5.11.2 Any shape having radial symmetry will be satisfactory for precast piles. The most common cross-sections used are square and octagonal.

5.11.3 Square piles are easy to concrete. These require simple formwork and compared to other shape have more surface area per unit volume of concrete. Square piles usually have chamfered corners.

Octagonal or hexagonal piles are adoptable to metal forms and they do not require any special chamfering of the edges. Their strength in flexure is almost the same in all directions. The lateral ties may be in the form of continuous spirals. The impact of lateral force on these shapes by flowing water will be less than in the case of square piles.

Besides the above sections H or I section piles are also common for particular requirements.

5.11.4 Where exceptionally long lengths of piles are required, hollow sections may advantageously be used. If the final conditions require larger cross-sectional area, the hollow sections may be filled with concrete after driving in position.

5.11.5 Excessive whippiness in handling precast pile may generally be avoided by limiting the length of pile to a maximum of 50 times the least width.

5.11.6 Stresses induced by bending in the cross-section of a precast pile during lifting and handling may be estimated just as for any reinforced

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

concrete section in accordance with relevant provisions of IS : 456-1978*. The calculations with regard to moments depending on the method of support during handling will be as given below:

Number of Points of Pick Up	*Location of Point of Support from and in Terms of Length of Pile for Minimum Moments*	*Bending Moment to be Allowed for Design*
Two	$0{\cdot}207\,L$	$\frac{WL}{46{\cdot}6}$
Three	$0{\cdot}145\,L$, the middle point will be at the centre	$\frac{WL}{95}$

where

W = weight of pile in kg, and

L = length in metres.

During hoisting the pile will be suspended at one point near the head and the bending moment will be the least when it is pulled at a distance of $0{\cdot}293\,L$, and the value of bending moment will be

$$\frac{WL}{23{\cdot}3}$$

5.11.6.1 The driving stresses on a pile may be estimated by the following formula:

$$\frac{\text{Driving resistance}}{\text{Cross-sectional area of the pile}} \times \left[\frac{2}{\sqrt{n}} - 1\right]$$

where

n is the efficiency of the blow.

NOTE — For the purpose of this formula, cross-sectional area of the pile shall be calculated as the overall sectional area of the pile including the equivalent area for reinforcement.

5.11.7 *Reinforcement*

5.11.7.1 The longitudinal reinforcement shall be provided in precast reinforced concrete piles for the entire length. All the main longitudinal bars shall be of the same length and should fit tightly into the pile shoe if there is one. Shorter rods to resist local bending moments may be added but the same should be carefully detailed to avoid any sudden discontinuity of the steel which may lead to cracks during heavy driving. The area of main longitudinal reinforcement shall not be less than the following percentages of the cross-sectional area of the piles:

a) For piles with a length less than 30 times the least width — 1·25 percent,

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

b) For piles with a length 30 to 40 times the least width — 1·5 percent, and

c) For piles with a length greater than 40 times the least width — 2 percent.

5.11.7.2 The lateral reinforcement is of particular importance in resisting the driving stresses induced in the piles and should be in the form of hoops or links and of a diameter not less than 6 mm. The volume of lateral reinforcement shall not be less than the following:

a) At each end of the pile for a distance of about 3 times the least width — not less than 0·6 percent of the gross volume of piles, and

b) In the body of the pile — not less than 0·2 percent of the gross volume of piles.

The spacing shall be such as to permit free flow of concrete around it. The transition between the close spacing of lateral reinforcement near the ends and the maximum spacing shall be gradually over a length of 3 times the least width of the pile.

5.11.7.3 While adopting deformed medium tensile steel as per IS : 1139-1966* or IS : 1786-1966† as reinforcement in the piles, suitable grade of concrete shall be used keeping in view the stresses which will be induced during driving of the piles.

5.11.7.4 The cover of concrete over all the reinforcement including binding wire should not be less than 40 mm, but where the piles are exposed to sea-water or water having other corrosive content, the cover should be nowhere less than 50 mm. Cover should be measured clear from the main or longitudinal reinforcement.

NOTE — Where concrete of the pile is liable to be exposed to the attack of sulphates and chlorides present in the ground water, the piles may be coated with a suitable material.

5.11.8 Piles should be provided with flat or pointed co-axial shoes if they are driven into or through ground such as rock, coarse gravel, clay with cobbles and other soils liable to damage the concrete at the tip of the pile. The shoe can be of steel or cast iron. In uniform clay or sand the shoe may be omitted and in these circumstances there may be no advantage in tapering the tip of the pile.

Where jetting is necessary for concrete piles a jet tube may be cast into the pile, the tube being connected to the pile shoe which is provided with jet holes. Generally, a central jet is inadvisable, as it is liable to become choked. At least two jet holes will be necessary on opposite sides of the shoe,

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

†Specification for cold-twisted steel bars for concrete reinforcement (*revised*).

four holes giving the best result. Alternatively two or more jet pipes may be attached to the sides of the pile. A balanced arrangement of jets is essential or the pile is liable to load off.

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 as agreed between the concerned parties 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 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 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 beams if used shall be as given in IS : 2911 (Part III)-1980†.

6. MATERIALS

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.

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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.

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§.

6.3 Concrete

6.3.1 Materials and method of manufacture for cement concrete of precast piles shall in general be in accordance with the relevant requirements given in IS : 456-1978‖. The stresses in concrete due to working load and during handling, pitching and driving of the pile should not exceed those stipulated in IS : 456-1978‖ according to the grade of concrete used and having due regard to the age of piles at the time of handling.

6.3.2 The grade of concrete shall be as follows:

Situation	*Grade of Concrete*
For hard driving (where driving stress exceeds 100 kgf/cm^2)	Not less than M 20
For easy driving (where the driving stress is less than 100 kgf/cm^2)	Not less than M 15

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

7. WORKMANSHIP

7.1 The casting yard for all concrete piles shall preferably be so arranged that they can be lifted directly from their beds and transported to the piling frame with a minimum of handling. The casting yard should have a well-drained surface to prevent excessive or uneven settlement due to softening during manufacture and curing.

7.2 As far as practicable each longitudinal reinforcement shall be in one length. In cases where joints in reinforcing bars cannot be avoided, the joints in bars shall be staggered and preferably be made by butt welding. The hoops and links for reinforcement or by tying with mild steel wire, the free ends of which should be turned into the interior of the pile. The longitudinal bars may be held apart by temporary or permanent spreader forks not more than 1·5 metres apart. The reinforcement shall be checked for tightness and position immediately before concreting.

*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 reinforcements (*revised*).

‡Specification for 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*).

7.3 Casting and Curing

7.3.1 The piles should be cast in a continuous operation from end to end of each pile. The concrete should be thoroughly compacted against the forms and around the reinforcement by means of immersion and/or shutter vibrators. The faces of the pile including those exposed at the top of pile should be dense as far as possible. Immediately on completion of the casting the top surface should be finished level without excessive trowelling. Care should be taken to ensure that vibration from adjoining work does not affect the previously placed concrete for piles during the setting period.

7.3.2 Where Portland cement concrete with ordinary or rapid-hardening cement is used, piles shall be kept continuously wet for at least 7 days, but longer curing shall be applied when hard driving is expected and in all cases where it is practicable to do so. When piles are stacked between the period of wet curing and driving, they shall be protected from rapid drying by sheltering them from the wind and direct sunlight by covering the stacks.

7.3.3 Though from consideration of speed and economy precast concrete piles will have to be driven with the least possible delay after casting, it shall be kept in mind that a thorough curing and hardening is necessary before the piles are driven and proper schedule to take care of this shall be decided for the operations of casting, stacking and driving. The most important factors affecting the time of curing are the method of curing, weather during hardening, probable hardness of driving and the method of lifting and pitching.

7.3.4 Before the operation of handling and driving the piles, the minimum periods counted from the time of casting shall be as in Table 1.

TABLE 1 TIME FOR CURING PRECAST PILES

Type of Cement Used in the Casting of the Pile	Minimum Periods from Time of Casting			
	Strike Side Shutters (hours)	End of Wet Curing (days)	Lift from Casting Bed (days)	Drive (days)
Ordinary Portland cement	24	7	10	28
Rapid-hardening Portland cement	12	7	7	10

7.4 Storing and Handling

7.4.1 Piles shall be stored on firm ground free from liability to unequal subsidence or settlement under the weight of the stack of piles. The piles shall be placed on timber supports which are truly level and spaced so as to avoid undue bending in the piles. The supports shall be vertically one above the other. Spaces shall be left round the piles to enable them to be lifted without difficulty. The order of stacking shall be such that the older piles can be withdrawn for driving without disturbing the newer piles. Separate stacks shall be provided for different lengths of piles. Wherever curing is needed during storage, arrangements shall be made to enable the piles to be watered if weather conditions so require. For detailed precautions with regard to curing operations reference may be made to IS : 456-1978*.

7.4.2 Care shall be taken at all stages of transporting, lifting and handling of the piles that they are not damaged or cracked. During transportation the piles shall be supported at the appropriate lifting holes provided for the purpose. If the piles are put down temporarily after being lifted, they shall be placed on trestles or blocks located at the lifting points.

7.5 Control of Pile Driving

7.5.1 The hammer blow generates a stress wave which traverses the length of the pile, and failure, whether by compression or tension, may occur anywhere along the pile.

7.5.2 Failure due to excessive compressive stress most commonly occurs at the head. Head stresses, which in general are independent of ground conditions, depend upon the weight of the hammer, its drop and the stiffness of head cushion.

7.5.2.1 The maximum set for a given stress is obtained by using the heaviest hammer and the softest packing, the hammer drop being adjusted to suit the allowable stress in the concrete.

7.5.2.2 Since head-packing materials increase in stiffness with repeated use, optimum driving conditions can be maintained only by regular replacement of the packing.

7.5.2.3 Failure in the lower sections of a pile can only occur in exceptionally hard driving where in theory the compressive stresses of toe can reach twice the head stresses. In practice, however, this rarely occurs and more than the maximum compressive stress tends to be fairly uniform over a considerable length of the pile.

7.5.3 Longitudinal tension is caused by reflection of the compressive wave at a ' free ' end. Tensile stresses, therefore, may arise when the ground resistance is low and/or when the head conditions result in hammer rebound that is, with hard packing and light hammer.

7.5.3.1 In addition, a relatively long length of pile unsupported above a hard stratum may encourage transverse or flexural vibrations which may be set up if the hammer blow becomes non-axial or the pile is not restrained.

7.5.4 Piles may be driven with any type of hammer, provided they penetrate to the prescribed depth or attain the specific resistance without being

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

damaged. The hammer, helmet, dolly and pile should be coaxial and should sit squarely one upon the other. It is always preferable to employ the heaviest hammer practicable and to limit the stroke so as not to damage the pile. When choosing the size of the hammer, regard should be given to whether the pile is to be driven to a given resistance or to a given depth. The stroke of a single acting or drop hammer should be limited to 1·2 m, preferably 1 m. A shorter stroke with particular care should be used when there is a danger of damaging the pile. The following are examples of such conditions:

a) Where in the early stages of driving a long pile, a hard layer near the ground surface has to be penetrated.
b) Where there is a very soft ground up to a considerable depth, so that a large penetration is achieved at each hammer blow.
c) Where the pile is expected suddenly to reach refusal on rock or other virtually impenetrable soil.

When a satisfactory set with an appropriate hammer and drop for the last 10 blows has been achieved, repeat sets should only be carried out with caution and long-continued driving, after the pile has almost ceased to penetrate, should be avoided, especially when a hammer of moderate weight is used. It is desirable that a full driving record be taken on one pile in every hundred driven, and on the first few piles in a new area.

7.5.4.1 Any sudden change in the rate of penetration which cannot be ascribed to normal changes in the nature of the ground should be noted and the cause ascertained, if possible, before driving is continued.

7.5.4.2 When the acceptance of piling is determined by driving to a set, the driving conditions when taking the set should be the same as those used when the sets of test piles were obtained.

7.5.5 The head of precast concrete pile should be protected with packing of resilient material, care being taken to ensure that it is evenly spread and held securely in place. A helmet should be placed over the packing and provided with a dolly of hardwood or other material not thicker than the width of the pile.

7.5.6 Jetting may be used as a means of minimizing or eliminating the resistance at the toe; frictional resistance along the surface of the pile shaft may also be reduced. By reducing the toe resistance very hard driving and vibration can be avoided and greater rates and depths of penetration can be achieved than by percussive methods. Jetting is effective in cohesionless soils such as sand, gravel and fine-grained soils provided the percentage of clay is small; it is not effective in clay soils.

7.5.6.1 Jetting of piles should be carried out only when it is desired and in such a manner as not to impair the bearing capacity of the piles already in place, the stability of the ground or the safety of any adjoining buildings.

7.5.6.2 The quantity of water required for effective jetting is directly related to the cross-sectional area of the piles (including external jet piles); up to 2 litres per minute per square centimetre of pile cross-section may be required at the pile in dense cohesionless soils; loosely compacted soils may require less water. The pressure should be from 5·6 kgf/cm² to 10·6 kgf/cm² or more. If large quantities of water are used, it may be necessary to make provision for leading away the water that emerges at the ground surface so that the stability of the piling equipment is not endangered by the softening of the ground.

7.5.6.3 The arrangement of the jets should be balanced to ensure that the pile penetrates vertically. Independent piles surged down or two pipes attached to the opposite sides of the pile may be used. To minimize the risk of blockages the nozzles should not be positioned at the point of the toe. Acceptable verticality may be achieved by the use of rigid leaders and allowing the pile to enter the ground gradually, after operating the water under weight of the pile and hammer, the rate of penetration being controlled by the pile winch. Once maximum apparent penetration is achieved by this method, further penetration may generally be obtained in cohesionless soils by light driving whilst the water jets are running. When jetting is completed the piles should be driven to the final penetration or set.

7.5.6.4 Jetting should be stopped before completing the driving, which should always be finished by ordinary methods. Jetting should be stopped if there is any tendency for the pile tips to be drawn towards the piles already driven owing to disturbance to the ground.

7.5.6.5 Jets shall be tested before driving commences. If it becomes necessary to jet a pile which is not provided with built-in-jet, satisfactory results can be obtained by working on independent jet pipes down the outside of the pile, the jet being worked alternatively down the several faces of the pile to assist verticality.

7.5.7 *Control of Alignment* — Piles shall be installed as accurately as possible as per the designs and drawings either vertically or to the specified better. 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 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 re-design of the pile cap or pile 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.

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

7.6 Recording of Data

7.6.1 A competent inspector shall be present to record the necessary information during installation of piles and the data to be recorded shall include:

a) the sequence of installation of piles in a group;

b) the dimensions of the pile including the reinforcement details and mark of the pile;

c) the depth driven;

d) the final set for the last ten blows or as may be specified;

e) cut off level/working level;

f) the type and size of hammer and its stroke, or with double-acting hammers, the number of blows per minute;

g) the type and condition of the packing on the pile head and the dolly in the helmet; and

h) any other important observation.

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

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

7.7 Stripping Pile Heads

7.7.1 The concrete should be stripped to a level such that the remaining concrete of a pile will project minimum 50 mm into the pile cap. The effect of this projection on the position of any reinforcement in the pile cap should be considered in design. The pile reinforcement should be left with adequate projecting length above the cut off level for proper embedment into the pile cap. Exposing such length should be done carefully to avoid shattering or otherwise damaging the rest of the pile. Any cracked or defective concrete should be cut away and made good with new concrete properly bonded to the old.

7.8 Lengthening Piles — Where a pile is to have another length cast on to it before or during driving the longitudinal reinforcement should preferably be joined by full penetration butt welding. The concrete at the top of the original pile should be cut down to expose not less than 200 mm of the bars. The bars should be held accurately and rigidly in position during welding. Where facilities to site are insufficient to make good butt welding practicable, the joint may be made by lapping. The reinforcement at the head of the pile will need to be exposed for a distance of 40 times the bar diameter and the new bars overlapped for this distance. If the bonds are lapped, spot welding shall be done. As an alternative special bottle nut joints may be provided.

7.9 Risen Piles — In ground where there is a possibility of piles rising due to ground heave, levels of the tops of the piles should be measured at interval while nearby piles are being installed. Piles which have risen as a result of driving adjacent piles should be redriven to the original depth or resistance, unless redriving tests on neighbouring piles have shown this to be unnecessary.

7.10 Defective piles 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.

8. ADDITIONAL PROVISION FOR PRESTRESSED CONCRETE PILES

8.1 General — The stresses set up when handling prestressed piles of given length can be resisted by smaller cross-section and thus economy in materials may be achieved. The small cross-section may permit or necessitate greater penetration. The bearing capacity may govern the cross-section of a pile and could preclude the use of the smaller sizes that would be possible from strength considerations alone. The tensile stresses caused by the action of stress waves when driving can be reduced by the prestress. The reduction of tensile cracks may give greater durability to the pile, particularly if the pile is submerged. The piles are better able to resist, without cracking, any tensile forces set up by the working loads, whether direct or due to bending, or by accidental loads.

8.2 Concrete

8.2.1 The maximum axial stress that may be applied to a pile acting as a short strut should be 25 percent of the specified works cube strength at 28 days less the prestress after losses.

8.2.2 The static stresses produced during lifting and pitching should not exceed the values given in IS : 1343-1960*, the values relating to loads of short duration. To allow for impact, the tensile stresses during transport, calculated as static stresses, should not exceed one-third of the values calculated as above.

*Code of practice for prestressed concrete.

8.3 Prestresses

8.3.1 The prestress after allowing for losses of prestress should satisfy the following conditions:

a) Prestress to cover handling, transporting and lifting conditions. For this purpose it may be assumed that only 75 percent of the full loss of prestress will have occured within two months of casting.

b) Prestress in N/mm² of not less than 0·07 times the ratio of the length of the pile to its least lateral dimensions.

c) Minimum prestress related to the ratio of effective weight of hammer to weight of pile to be as follows:

Ratio of hammer to pile weight not less than	0·9	0·8	0·7	0·6
Minimum prestress for normal driving, kgf/cm²	20	35	50	60
Minimum prestress for easy driving, kgf/cm²	35	40	50	60

8.3.1.1 For diesel hammers the minimum prestress should be 5 N/mm² (50 kgf/cm²).

8.3.2 A considerably greater prestress may be required for raking piles, particularly if these are driven in ground which may tend to deflect the piles from their true alignments.

8.3.3 Loss of prestress should be calculated in accordance with IS : 1343-1960*.

8.4 Prestressing Wires and Stirrups

8.4.1 The prestressing wires should be evenly spaced parallel to faces of the pile.

8.4.2 Mild steel stirrups of not less than 6 mm diameter should be placed at a pitch of not more than the side dimension less 50 mm. At the top and bottom, for a length of three times the side dimensions, the stirrup volume should be not less than 0·6 percent of the pile volume. The concrete cover to reinforcement should be in accordance with **5.11.7.4**.

8.4.3 *Pile Shoes* — If pile shoes are required, they may be as described in **5.11.4** with sufficient space round them to pass the prestressing wire. Alternatively they may be light shoes drilled to pass the ends of the prestressing wires.

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*Code of practice for prestressed concrete.

8.5 Materials and Stresses

8.5.1 *Reinforcement* — Where ordinary reinforcement is introduced into prestressed piles, it should be in accordance with IS : 1139-1966* or IS : 1786-1966† as in **6.2**.

8.5.2 *Prestressing Steel* — Prestressing steel should be in accordance with IS : 2090-1962‡.

8.5.3 *Concrete* — The materials should, in general, be in accordance with IS : 1343-1960§.

8.6 Workmanship

8.6.1 *Manufacture Curing and Transfer of Prestress* — Prestressed piles require high strength concrete and careful control during manufacture, usually this means casting in a factory where the curing conditions can be strictly regulated. Where piles have to be lengthened the procedure is more elaborate (*see* **8.7**).

8.6.2 *Manufacture* — Prestressed concrete piles are normally cast by the 'long-line' method in a factory under conditions of close control. Where piles are cast other than in factory, casting should take place in an enclosed space at an air temperature of not less than 10°C (50°F). Piles should not be removed from the place of casting until after the transfer of prestress.

The piles should be cast in one operation using internal and external vibrators to assist compaction of the concrete.

Care should be taken to ensure that vibration from adjoining work does not affect the placed concrete during the setting period. Care should be taken that the head of the piles is finished plane and normal to the axis of the pile. Each pile should be marked with a reference number and rate of casting. Curing should be carried out as described in **7.3.3** or the piles may be steam cured.

8.6.3 *Transfer of Prestress* — Whenever a batch of piles is cast, four test cubes should be cast and stored in close proximity to and under the same conditions of temperature and humidity as the piles.

The minimum cube strength of the concrete at transfer of prestress should be 2·5 times the stress in the concrete at transfer, or 28 N/mm^2 (280 kgf/cm^2) for strand or crimped wire or 35 N/mm^2 (350 kgf/cm^2) for plain or indented wire, whichever is the greater. The attainment of this strength may be checked either by testing the relevant test cubes or by allowing sufficient times to elapse after casting, provided this period can be shown to be

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

†Specification for cold-twisted steel bars for concrete reinforcement (*revised*).

‡Specification for high tensile steel bars used in prestressed concrete.

§Code of practice for prestressed concrete.

adequate on the basis of previous test cube results and strictly controlled curing conditions. After transfer of prestress, the prestressing wires should be cut off flush with the face of the concrete or pile shoe.

8.6.4 *Stacking and Storing* — For stacking and storing, **7.4.1** may be referred to.

8.7 Driving — There is some evidence to suggest that a larger ratio of hammer weight to pile weight is required to avoid damaging the pile. Driving of prestressed concrete piles should follow the recommendations for reinforced concrete piles as in **7.5**. Although the effect of prestressing is to reduce tension cracks induced by stress waves, such cracking may still occur, particularly when driving is ' light ', or if too light a hammer is used. A careful check for tension cracks should be made during the driving of the first pile and, if these occur, the hammer drop should be reduced. If the cracks persist or recur when the full drop has to be used, then a heavier hammer should be substituted.

8.8 Bonding of Head of Pile into Pile Cap — The concrete of the pile may be stripped to expose the prestressing wires. The concrete should be stripped to such a level that the remaining concrete projects 50 mm to 75 mm into the pile cap. Where tension has to be developed between the cap and pile, the exposed prestressing wires should extend at least 600 mm into the cap. An alternative method is to incorporate mild steel reinforcement in the upper part of the pile. After stripping the concrete this reinforcement should be bonded into the cap.

8.9 Lengthening of Piles — Where piles have to be lengthened during driving, this may be done by one of the following methods:

a) Where mild steel reinforcement is incorporated in the head of the pile, lengthening may be as described in **7.8**.

b) By using a mild steel splicing sleeve together with a precast extension piece. The sleeve should be bedded on to the top of the pile with an earth-dry sand/cement mortar or other compound, and the extension piece similarly bedded on to the sleeve.

   It should be noted that piles lengthened in this way have a limited resistance to bending at the splice.

c) By means of dowel bars inserted into drilled holes the connection being made with grout or epoxy resin.

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 kgf/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 value are given in Fig. 1.

NOTE 3 — The earth pressure coefficient K depends on the nature of soil strata, type of pile and its method of construction. For driven piles 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.

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

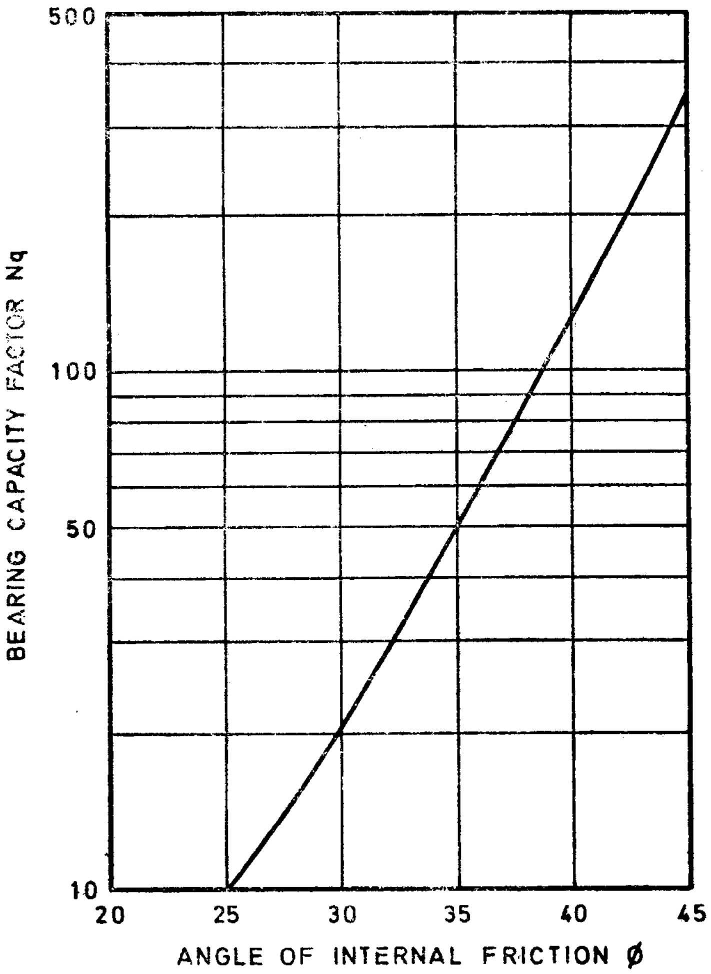


FIG. 1 BEARING CAPACITY FACTOR N_q FOR DRIVEN PILES

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

A-2. PILES IN COHESIVE SOILS

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

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

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 kgf/cm²,

α = reduction factor,

$\overline{C}$ = average cohesion throughout the length of pile in kgf/cm², and

A_s = surface area of pile shaft in cm².

NOTE 1 — The following values of α may be piles 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 — In case of soft to very soft soils which are not sensitive, the value of α can be taken up to 1.

NOTE 3 — 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.

A-2.2 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	$\frac{q_c}{25} < f_s < \frac{q_c}{25}$
Silty clays and silty sands	$\frac{q_c}{100} < f_s < \frac{q_c}{1}$

Sands $\frac{q_c}{100} < f_s < \frac{2q_c}{100}$

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 :

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

where

q_u = ultimate point bearing capacity,

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

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

q_{c2} = average of the minimum cone resistance values in the diagram over a height of $8d$ 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-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 sink 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 gravels	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 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 P_e and the pile is driven into penetrable ground,

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

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

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

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 weight of the pile, anvil, helmet, and follower (if any) in tonnes.

Where the pile finds refusal in rock, $0·5P$ 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 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 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:

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

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

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

$$C_3 = 3{\cdot}55\ \frac{R}{A}$$

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 cm².

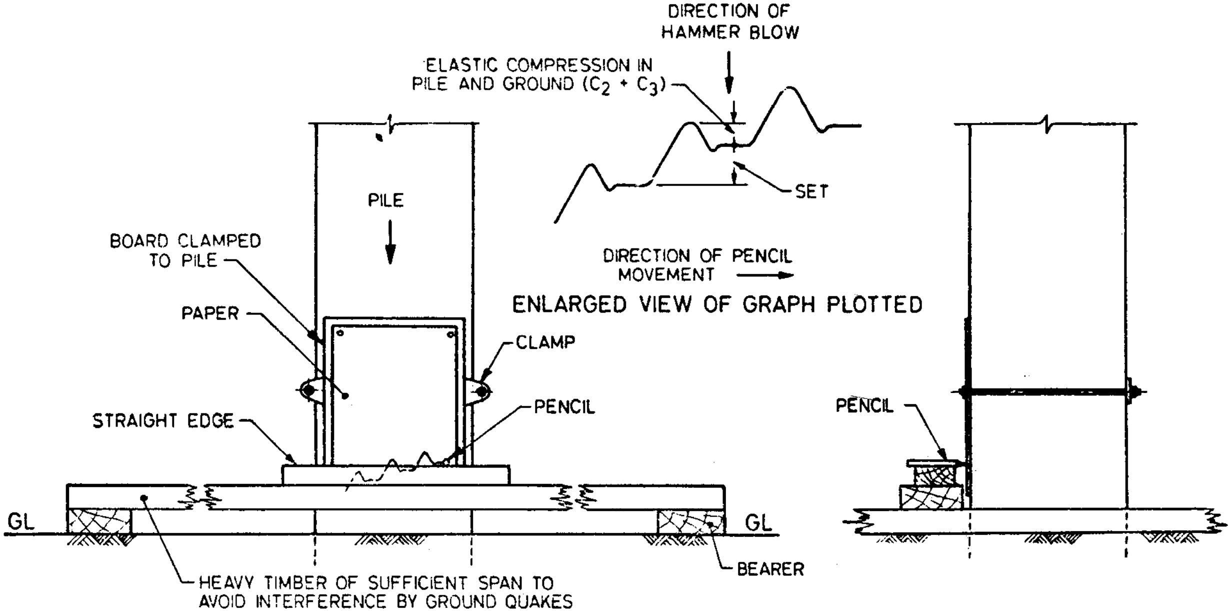


FIG. 2 TYPICAL ARRANGEMENT FOR A SET RECORDER

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 2 or Table 3.

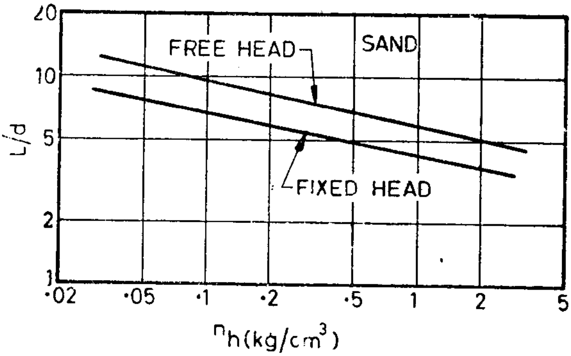
Determine from appropriate graphs given in Fig. 3 and Fig. 4 the value of L, the equivalent length of cantilever giving the same deflection at ground level as the actual pile.

TABLE 2 TYPICAL VALUES OF n_h

Soil Type	n_h in kg/cm³	
	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 3 TYPICAL VALUES OF K FOR PRELOADED CLAYS

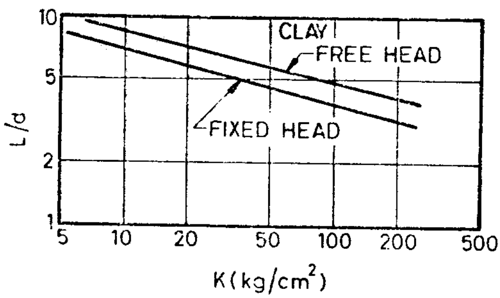
Unconfined Compression Strength	Range of Values of K	Probable Value of K
kgf/cm²	kgf/cm²	kgf/cm²
0·2 to 0·4	7 to 42	7·73
1 to 2	32 to 65	48·79
2 to 4	65 to 130	97·73
4	—	195·46



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* 7.6.3)

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:	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/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

Trait 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 — Graph, showing the following relations, shall be prepared and added to the report:

1) Load vs Time, and
2) Settlement vs Load.

(*Continued from page* 2)

Pile Foundations Subcommittee, BDC 43 : 5

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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
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AMENDMENT NO. 1 AUGUST 1982

TO

IS : 2911 (Part I/Sec 3) - 1979 CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF PILE FOUNDATIONS

PART I CONCRETE PILES

Section 3 Driven Precast Concrete Piles

(First Revision)

Alterations

(*Page* 18, *clause* **6.2**, *line* 2) — Substitute ' IS : 1786-1979‡ ' *for* ' IS : 1786-1966‡ '.

(*Page* 18, *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* **7.5.7**, *line* 3) — Substitute ' batter ' *for* ' better '.

(*Page* 28, *clause* **A-1.1**):

a) *Formula* — Substitute ' P_D ' for ' P '.

b) (*Note* 1, *lines* 1 *and* 2) — Substitute ' IS : 6403-1981* ' *for* ' IS : 6403-1971* '.

(*Page* 28, *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* 29, *Fig.* 1) — Substitute the following for the existing figure:

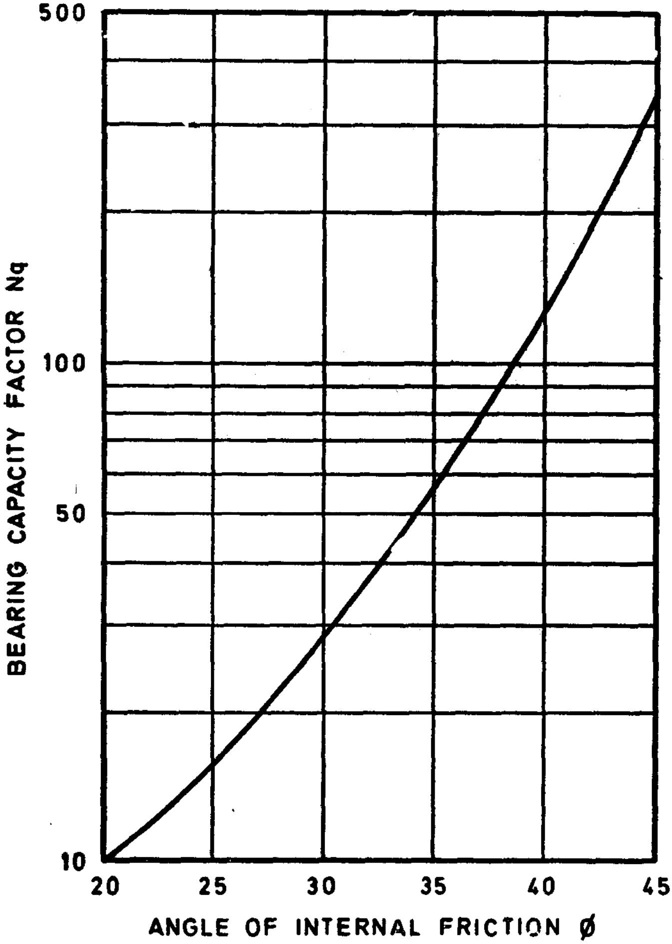

FIG. 1 BEARING CAPACITY FACTORS N_q FOR DRIVEN PILES

(*Page* 30, *clause* **A-2.2**, *informal table, first three entries*) — Substitute the following for the existing matter:

Clays and peats where $q_c < 10$	$\frac{q_c}{30} < f_s < \frac{q_c}{10}$
Clays	$\frac{q_c}{25} < f_s < \frac{2q_c}{25}$
Silty clays and silty sands	$\frac{q_c}{100} < f_s < \frac{2q_c}{25}$

(*Page* 31, *clause* **A-2.3**, *line* 3) — Substitute ' skin ' *for* ' sink '.

Addenda

(*Page* 8, *clause* **5.1**, *line* 6) — Add the words ' handling and driving stresses and ' after the word ' withstand '.

(*Page* 15, *clause* **5.11.6.1**, *line* 6) — Add the words ' (*see* Appendix B for probable value of *n*) ' after the word ' blow '.

(*Page* 16, *clause* **5.11.7.1**) — Add the following new Note after **5.11.7.1**:

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

(*Page* 17, *clause* **6.1**) — Add ' IS : 1489-1976** ' after ' IS : 8041-1978|| '.

(*Page* 17, *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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TO

IS : 2911 (Part 1/Sec 3)-1979 CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF PILE FOUNDATIONS

PART 1 CONCRETE PILES

Section 3 Driven Precast Concrete Piles

(First Revision)

Alterations

(*Page* 6, *clause* **2.15**) — 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, *clause* **5.3.1.1**, *lines* 7 *and* 8) — Substitute ' IS : 4968 (Parts 1, 2, 3)-1976 Method for subsurface for sounding of soils ' for the existing references of Indian Standards.

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

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

†Code of practice for design and construction of pile foundations: Part 4 Load test on piles.'

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

(*Page* 10, *foot-note*) — Delete.

(*Page* 16, *clause* **5.11.7.1** *read with Amendment No.* 1, *Note*) — Delete.

(*Page* 16, *clause* **5.11.7.3**, *line* 2) — Substitute ' IS : 1786-1979† ' *for* ' IS : 1786-1966† '.

(*Page* 16, *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* 18, *clause* **6.2**, *line* 1) — Substitute ' IS : 432 (Part 1)-1982*' *for* ' IS : 432 (Part 1)-1966*'.

(*Page* 18, *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 1 Mild steel and medium tensile steel bars (*third revision*). '

(*Page* 22, *clause* **7.5.7**, 4th *and* 5th *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.'

(*Pages* 24, 25 *and* 26, *clauses* **8.2.2, 8.3.3** *and* **8.5.3**) — Substitute 'IS : 1343-1980' *for* ' IS . 1343-1960 '.

(*Pages* 24, 25 *and* 26, *foot-note for* IS : 1343) — Substitute the following for the existing foot-note:

' Code of practice for prestressed concrete (*first revision*). '

(*Page* 26, *clause* **8.5.1**, *line* 3) — Substitute ' IS : 1786-1979† ' *for* ' IS : 1786-1966† '.

(*Page* 26, *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* 30, *clause* **A-2.2**, *informal table read with Amendment No.* 1, *third entry*) — Substitute ' $\frac{q_0}{25}$ ' *for* ' $\frac{2q_0}{25}$ '

(*Page* 32, *clause* **B-1.2**) — Substitute the equation for ' n ' as under:

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

(*Page* 33, *clause* **B-1.2**, *equation after line* 1) — Substitute the equation for ' n ' as under:

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

(*Page* 36, *Table* 3) — Substitute ' kgf/cm³ ' *for* ' kg/cm² ' in columns 2 and 3.

(*Page* 37, *Fig*. 4) — Substitute ' kgf/cm³ ' *for* ' kg/cm² '.

Addenda

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

' and shall be designed according to IS : 456-1978 ' Code of practice for plain and reinforced concrete (*third revision*).'

(*Page* 9, *clause* **5.3.1**, *line* 4) — Add '[*see* IS : 2911 (Part IV)-1979†]'

(*Page* 15, *clause* **5.11.7.1**, *line* 1) — Add the following words after the word ' reinforcement ':

' of any type or grade '

(*Page* 18, *clause* **7.2**, *line* 4) — Add the following after the word ' reinforcement ':

' shall fit tightly against longitudinal bars and be bound to them by welding.'

(BDC 43)

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AMENDMENT NO. 3 AUGUST 1987
TO
IS : 2911 (Part 1/Sec 3)-1979 CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF PILE FOUNDATIONS

PART 1 CONCRETE PILES

Section 3 Driven Precast Concrete Piles

(First Revision)

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

(*Page* 11, *clause* **5.2.2**, *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* 16, *clause* **5.11.7.3**, *lines* 1 *and* 2 (see also *Amendment No. 2*)] — Substitute 'According to IS : 1786-1985* ' *for* ' as per IS : 1139-1966* or IS : 1786-1966 †'.

(*Page* 16, *foot-notes*) — Substitute the following for the existing foot-notes:

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

[(*Page* 18, *clause* **6.2**, *line* 2 (see also *Amendment No. 1*)] — Substitute ' IS : 1786-1985† ' *for* ' IS : 1139-1966† or IS : 1786-1979‡ '.

(*Page* 18, *clause* **6.3**) — Sustitute the following for the existing matter:

"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* 18, *foot-notes with* ' † ' *and* ' ‡ ' *marks*) — Substitute the following for the existing foot-notes:

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

Gr 1

[*Page* 22, *clause* **7.5.7**, *fourth and fifth sentences* (*see also Amendment No.* 2)] — Substitute ' D/6 ' *for* ' D/4 ' at both the places.

(*Pages* 24 *and* 25, *clauses* **8.2.2** *and* **8.3.3**) — Substitute 'IS : 1343-1980*' *for* 'IS : 1343-1960*'.

(*Pages* 24 *and* 25, *foot-note*)— Substitute the following for the existing foot-note:

'*Code of practice for prestressed concrete (*first revision*).'

[(*Page* 26, *clause* **8.5.1**, *lines* 2 *and* 3 (*see also Amendment No.* 2)] — Substitute 'IS : 1786-1985*' *for* 'IS : 1139-1966‡ or IS : 1786-1966† ')].

(*Page* 26 *clause* **8.5.2**) — Substitute 'IS : 2090-1983‡' *for* 'IS : 2090-1962‡.'

(*Page* 26, *clause* **8.5.3**) — Substitute 'IS : 1343-1980§' *for* 'IS : 1343-1960§'.

(*Page* 26, *foot-notes*) — Substitute the following for the existing foot-notes:

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

‡Specification for high tensile steel bars used in prestressed concrete (*first revision*).

§Code of practice for prestressed concrete (*first revision*).'

(*Pages* 32 *to* 35, *Appendix B*, *including Fig.* 2) — Delete.

(*Pages* 36 *to* 37, *Appendix C*, *including Fig.* 3 *and* 4) — Substitute the following for the existing appendix and figures.

'APPENDIX B

(*Clause* 5.2.2)

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

$$T = \sqrt[5]{\frac{EI}{K_1}} \text{ and } R = \sqrt[4]{\frac{EI}{K_2}}$$ (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 $4T$.

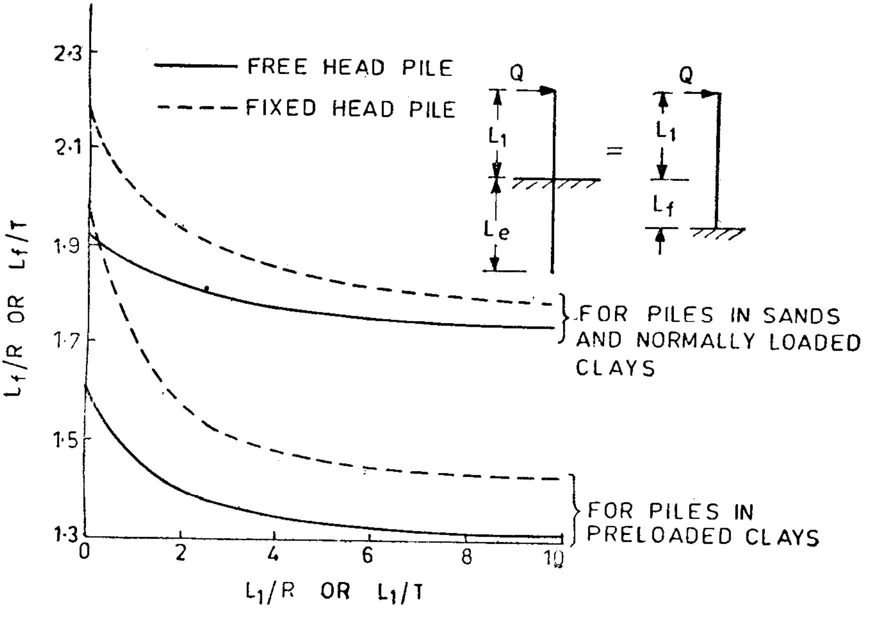


FIG. 2 DETERMINATION OF DEPTH FIXITY

TABLE 2 VALUES OF CONSTANT K_1 (kg/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 3 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

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.

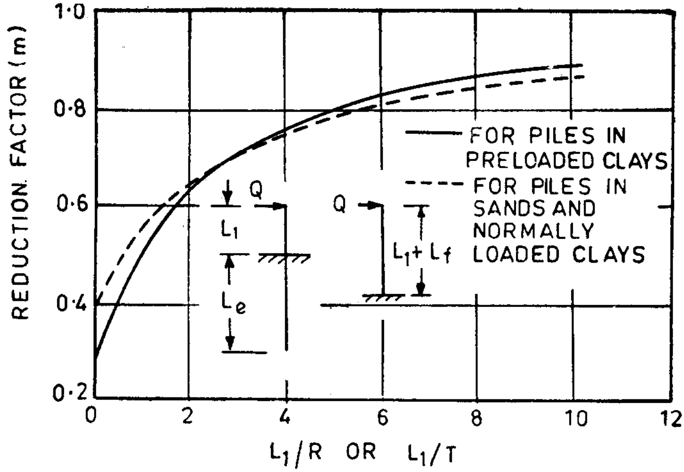
B-2. DETERMINATION OF MAXIMUM MOMENT IN THE PILE

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:

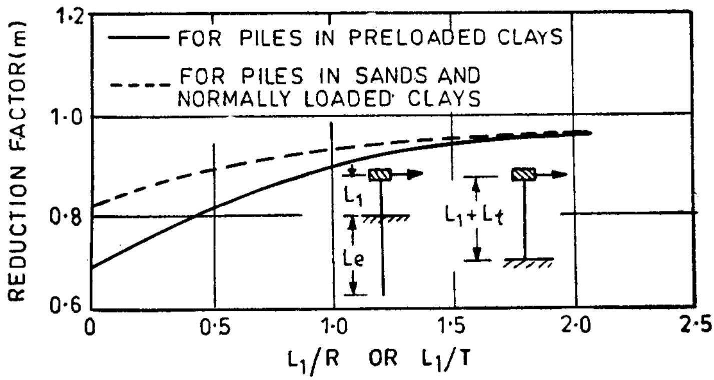
$$M_F = Q(L_1 + L_f) \quad \text{...for free head pile}$$

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

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



3A FOR FRFE HEAD PILE



3B FOR FIXED HEAD PILE

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

(BDC 43)

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