1100

Pile Foundations

1101. DESCRIPTION

1101.1. This work shall consist of construction of all types of piles for structures in accordance with the details shown on the drawings and conforming to the requirements of these specifications.

1101.2. The construction of pile foundations requires a careful choice of the piling system depending upon sub-soil conditions and loading characteristics and type of structure. The permissible limits of total and differential settlements, unsupported length of pile under scour, impact/ entanglement of floating bodies and any other special requirements of project are also equally important criteria for selection of the piling system. The method of installing the piles, including details of the equipment shall be submitted by the Contractor and got approved from the Engineer.

1101.3. The work shall be done as per IS:2911 except as modified herein.

1102. SUB-SURFACE INVESTIGATION

1102.1. The complete sub-surface investigation of strata in which pile foundations are proposed shall be carried out in advance and by in-situ pile tests. For details of geotechnical sub-surface explorations reference may be made to Section 2400. At least one bore-hole for every foundation of the bridge shall be executed. Borings should be carried upto sufficient depths so as to ascertain the nature of strata around the pile shaft and below the pile tip. However, depth of boring shall not be less than :

i) 1.5 times estimated length of pile in soil but not less than 15 m beyond the probable length of pile

ii) 15 times diameter of pile in weak/jointed rock but minimum 15 m in such rock

iii) 4 times diameter of pile in sound, hard rock but minimum 3 m in such rock

1102.2. The sub-surface investigation shall define adequately stratification of sub-strata including the nature and type of strata, its variation and extent and specific properties of the same. The investigation shall be adequate for the purpose of selection of appropriate piling system and for estimating design capacities for different diameters and length of piles.

1102.3. Pressure meter tests may be used in the case of rock, gravel or soil for direct evaluation of strength and compressibility characteristics. Though these tests are of specialised nature they are most appropriate for difficult/uncertain sub-strata especially for important projects.

1102.4. For piles socketed into rocks, it is necessary to determine the uniaxial compressive strength of the rock and its quality.

The investigation shall also include location of ground water table and other parameters including results of chemical tests showing sulphate and chloride content and any other deleterious chemical content in soil and/or ground water, likely to affect durability.

1103. TYPE OF PILES

The piles may be of reinforced concrete, prestressed concrete, steel or timber. The piles may be of solid or hollow sections or steel cased piles filled with concrete. Concrete piles may be driven cast-in-situ or precast or bored cast-in-situ or precast piles driven into preformed bores. The shape of piles may be circular, square, hexagonal, octagonal, "H" or "I" Section.

1104. MATERIALS

1104.1. The basic materials shall conform to the specifications for materials given in Section 1000. The specifications for steel reinforcement, structural concrete, prestressed concrete and structural steel to be used in pile foundations shall be as given in the relevant sections.

1104.2. Concrete in Piles

Grade of concrete to be used in cast-in-situ piles shall not be less than M 20 and the cement content shall not be less than 400 kg per cubic meter of concrete. Grades of concrete for precast reinforced and prestressed concrete piles shall not be less than M 25 and M 35 respectively. Maximum water cement ratio shall be 0.5 for cast-in-situ piles and 0.45 for precast piles.

The minimum slump of concrete for driven cast-in-situ piles shall be 100 mm to 150 mm and that of bored cast-in-situ piles 150 mm to 200 mm. The slump should not exceed 200 mm in any case.

Concrete mix should have homogeneous mixture with required workability for the system of piling adopted. Suitable and approved admixtures may be used in concrete mix where necessary.

Where piles are exposed to action of harmful chemicals or severe conditions of exposure due to presence of sulphate, chloride etc, it may be preferable to opt for higher grades of concrete restricting water cement ratio to 0.45. Special types of cement, such as sulphate resistant cement may be used where considered appropriate.

1105. TEST PILES

1105.1. Test piles which are shown on the drawings or specified in the contract or installed by the Contractor on his own to determine the lengths of piles to be furnished shall conform to the requirements for piling as indicated in these specifications, if they are to be incorporated in the completed structure.

Test piles that are to become a part of the completed structure shall be installed with the same type of equipment that is proposed to be used for piling in the actual structure.

Test piles which are not to be incorporated in the completed structure shall be removed to at least 600 mm below the proposed soffit level of pile cap and the remaining hole shall be backfilled with earth or other suitable material.

The piles shall be load tested in accordance with provisions laid down in this section.

1106. PRECAST CONCRETE PILES

1106.1. General

Precast concrete piles shall be of the size and shape as shown in the approved drawings. If a square section is employed, the corners shall be chamfered at least 25 mm unless otherwise specified on the drawings. The length of pile shall not normally exceed 25 metres. However, where special equipments for handling and installation are available to the satisfaction of the Engineer, longer length could be permitted.

Piles shall be cast with a driving point and for hard driving, shall be shod with a metal shoe approved by the Engineer.

1106.2. Stacking, Storing and Handling

Care shall be taken that at all stages of transporting, lifting and handling, piles are not damaged or cracked. During transport and stacking of piles, they shall be supported at the same points as those provided for lifting purposes. If the piles are put down temporarily during handling, they shall be placed on trestles or blocks located at the same points.

Piles shall be stored at least 300 mm above firm level ground which is not liable to unequal subsidence or settlement under the weight of the stack of piles. They shall be placed on timber supports which are level and spaced so as to avoid bending. The supports shall be verti cally 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 without disturbing newer piles. Separate stacks shall be provided for different lengths of piles. Where piles are stacked in layers, the number of layers shall not exceed three. Whenever curing is needed during storage, arrangements shall be made to enable the piles to be watered. For detailed precautions with regard to curing operations specifications for structural concrete given in Section 1700 shall apply.

Before the operation of handling and driving the piles, the minimum periods counted from the time of casting shall be allowed for as indicated in Table 1100-1. Prestressed piles shall not be lifted or handled until fully stressed.

TABLE 1100-1 TIME FOR CURING PRECAST PILES

Type of cement used in casting 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	24	7	10	28
Rapid hardening Portland	12	7	7	10

1106.3. Lengthening of Piles

Where a pile is to have another length cast on it during driving, the longitudinal reinforcement shall preferably be joined by full penetration butt welding. The concrete at the top of the original pile shall be cut down to expose not less than 200 mm of the bars to avoid spalling of the concrete by heat. The added bars have to be held accurately and rigidly in position during welding. Where facilities on site are insufficient to make proper butt welding practicable, the joint may be made by lapping. The reinforcement at the head of pile will need to be exposed for full anchorage length or 600 mm whichever is greater and the new bars over-lapped for this distance. Unless otherwise specified, the extension of the pile shall be formed to the same cross-sectional profile and with concrete of at least the same strength as that specified for the original pile. The stirrup spacing shall in no case be greater than

150 mm. Not more than one extension shall be permitted. In case more than one extension is permitted by the Engineer, only approved mechanical couplers shall be used.

Driving shall not be resumed until :

(i) The strength of the concrete in the extension is at least equal to the specified characteristic strength of concrete in pile, and

(ii) The approval of the Engineer has been obtained.

1106.4. Removal of Surplus Length

Any length of pile surplus to that required for incorporation in the structure shall be cut off neatly and removed. During the process of cutting off, it shall be ensured that projecting reinforcement to be anchored into the pile cap and the prestressing strands/wires are not damaged. When stripping prestressed concrete piles, shock release of tendons shall be avoided. Reference may also be made to clause 7.7.1. of IS:2911 (Part I Section 3) in this connection.

1106.5. Risen Piles

Level reading should be taken on each pile after driving and again after all the piles are driven. Piles which are found to have risen due to ground heave or as a result of driving adjacent piles, shall be re-driven to the original depth or resistance unless re-driving tests on adjacent piles have shown this to be unnecessary.

1106.6. Manufacture

The pile should be cast in one continuous operation from end to end of each pile. Manufacture of precast concrete piles shall conform to the guidelines contained in clause Nos. 7.1,7.2 and 7.3 of IS:2911 (Part I, Section 3).

Pile shall be provided with suitable shoe for protecting the point of the pile during driving in hard ground.

Piles shall not be moved from casting bed until the concrete has hardened sufficiently.

Piles shall not be driven in less than 28 days after casting or unless their strength at the time of driving is at least that specified for 28 days.

1106.7. Prestressed Concrete Piles

Additional specifications for precast prestressed concrete piles shall conform to those contained in clause 8 of IS:2911 (Part I Section 3).

1107. CAST-IN-SITU CONCRETE PILES

Cast-in-situ concrete piles may be either installed by making a bore into the ground by removal of material or by driving a metal casing with a shoe at the tip and displacing the material laterally. The two types of piles are termed as "bored piles" and "driven piles" respectively. Cast-in-situ concrete piles may be cast in metal shells which may remain permanently in place. However, other types of cast-in-situ concrete piles, plain or reinforced, cased or uncased, may be used if in the opinion of the Engineer the soil conditions permit their use and if their design and the methods of placing are satisfactory.

The metal casing shall be of sufficient thickness and strength to hold its original form and show no harmful distortion after it and adjacent casings have been driven and the driving core, if any, has been withdrawn.

Cast-in-situ concrete driven piles shall be installed using a properly designed detachable shoe at the bottom of the casing. Certain specific requirements of cast-in-situ driven piles shall be as per Clauses 1110 and 1111.

Any liner or bore-hole which is improperly located or shows partial collapse that would affect the load carrying capacity of the pile, shall be rejected or repaired as directed by the Engineer at the cost of the Contractor.

Wherever practicable, concrete should be placed in a clean dry hole. Where concrete is placed in dry and there is casing present, the top 3 m of the pile shall be compacted using internal vibrators. The concrete should invariably be poured through a tremie with a funnel so that the flow is directed and concrete can be deposited in the hole without segregation.

Where the casing is withdrawn from cohesive soils for the formation of cast-in-situ pile, the concreting should be done with necessary precautions to minimise the softening of the soil by excess water. Where mud flow conditions exist, the casing of cast-in-situ piles shall not be allowed to be withdrawn.

Care shall be taken during concreting to prevent as far as possible the segregation of the ingredients. The displacement or distortion of reinforcement during concreting and also while extracting the tube shall be avoided.

If the concrete is placed inside precast concrete tubes or consists of precast sections, these shall be free from cracks or other damage before being installed.

The concrete shall be properly graded, shall be self-compacting and shall not get mixed with soil, excess water, or other extraneous matter. Special care shall be taken in silty clays and other soils with the tendency to squeeze into the newly deposited concrete and cause necking. Sufficient head of green concrete shall be maintained to prevent inflow of soil or water into the concrete.

The placing of concrete shall be a continuous process from the toe level to the top of the pile. To prevent segregation, a tube or tremie pipe as appropriate shall be used to place concrete in all piles.

To ensure compaction by hydraulic static heads, rate of placing concrete in the pile shaft shall not be less than 6 m (length of pile) per hour.

Bored cast-in-situ piles in soils which are stable, may often be installed with only a small casing length at the top. A minimum of 2.0 m length of top of bore shall invariably be provided with casing to ensure against loose soil falling into the bore. In cases in which the side soil can fall into the hole, it is necessary to stabilise the side of the bore hole with drilling mud, or a suitable steel casing. The casing may be left in position permanently specially in cases where the aggressive action of the ground water is to be avoided, or in the cases of piles built in water or in cases where significant length of piles could be exposed due to scour.

For bored cast-in-situ piles, casing/liner shall be driven open ended with a pile driving hammer capable of achieving penetration of the liner to the length shown on the drawing or as approved by the Engineer. Materials inside the casing shall be removed progressively by air lift, grab or percussion equipment or other approved means.

Where bored cast-in-situ piles are used in soils liable to flow, the bottom of the casing shall be kept enough in advance of the boring tool to prevent the entry of soil into the casing, thus preventing the formation of cavities and settlements in the adjoining ground. The water level in the casing should generally be maintained at the natural ground water level for the same reasons. The joints of the casing shall be made as tight as possible to minimise inflow of water or leakage of slurry during concreting.

Boring shall be carried out using rotary or percussion type equipment. Unless otherwise approved by the Engineer, the diameter of the bore-holes shall be not more than the inside diameter of the liner.

Prior to the lowering of the reinforcement cage into the pile shaft, the shaft shall be cleaned of all loose materials. Cover to reinforcing steel shall be maintained by suitable spacers.

The diameter of the finished pile shall not be less than that specified and a continuous record shall be kept by the Engineer as to the volume of concrete placed in relation to the pile length cast.

Before concreting under water, the bottom of the hole shall be cleaned of drilling mud and all soft or loose material very carefully. In case a hole is bored with use of drilling mud, concreting should not be taken up when the specific gravity of bottom slurry is more than 1.2. The drilling mud should be maintained at 1.5m above the ground water level.

Concreting under water for cast-in-situ concrete piles may be done either with the use of tremie method or by the use of an approved method specially designed to permit under water placement of concrete.

General requirements and precautions for concreting under water are as follows :

(a) The concreting of a pile must be completed in one continuous operation. Also, for bored holes, the finishing of the bore, cleaning of the bore, lowering of reinforcement cage and concreting of pile for full height must be accomplished in one continuous operation without any stoppage.

(b) The concrete should be coherent, rich in cement with high slump and restricted water cement ratio.

(c) The tremie pipe will have to be large enough with due regard to the size of aggregate. For 20 mm aggregate the tremie pipe should be of diameter not less than 150 mm and for larger aggregate, larger diameter tremie pipes may be necessary.

(d) The first charge of concrete should be placed with a sliding plug pushed down the tube ahead of it to prevent mixing of water and concrete.

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

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

(g) All tremie tubes should be scrupulously cleaned after use.

The minimum embedment of cast-in-situ concrete piles into pile cap shall be 150 mm. Any defective concrete at the head of the completed pile shall be cut away and made good with new concrete. The clear cover between the bottom reinforcement in pile cap from the top of the pile shall be not less than 25 mm. The reinforcement in the pile shall be exposed for full anchorage length to permit it to be adequately bonded into the pile cap. Exposing such length shall be done carefully to avoid damaging the rest of the pile. In cases where the pile cap is to be laid on ground, a levelling course of M 15 nominal mix concrete 100 mm thick shall be provided. Defective piles shall be removed or left in place as judged convenient without affecting the performance of adjacent piles or pile cap. Additional piles shall be provided to replace the defective piles.

1108. STEEL PILES

Steel piles shall be "H" or "I" sections as shown on the drawings and shall be of structural steel conforming to the specifications given in Section 1000.

Steel piles shall be protected by suitable anti-corrosive painting as specified on the drawing. Piles shall be stored above the ground using protective packing to minimise damage to surface coating. Each pile shall be supplied preferably in one piece without splices.

At the option of the Contractor, steel piling consisting of structural steel plates welded together may be substituted for the rolled sections specified, provided that the depth, width and average thicknesses are at least equal to those of the rolled sections, the steel plates conform to specification given in Section 1000, the flanges are welded to the web with continuous fillet welds on either side of the web, and the welding conforms to Clause 1904.8 of these specifications.

The length of the steel pile may be built up in sections either before or during driving operations. The sections shall be of identical cross-section. Pile splices shall be made with full penetration butt welds over the whole cross-section. Pile splices shall develop at least the yield strength of pile.

The connections shall be nade by butt-welding the entire cross-section in accordance with the provisions in Clause 1904.8 of these specifications. Care shall be taken to properly align the sections connected so that the axis of the pile will be straight. The number of welded connections in the length of pile shall be as few as possible.

1109. TIMBER PILES

The Engineer shall stamp each pile on the butt with a stamp which shall make an impression that is readily legible. Treated timber piles will be inspected by the Engineer after treatment.

Untreated timber may be used as test piles.

Untreated timber piles and treated timber piles shall be of approved quality.

Treated timber piles shall be driven within 6 months after treatment.

Timber piles shall be furnished with tip protection and shall be protected by the use of steel straps as hereinafter specified. Tip protection shall be suitable for use on timber piling of the size to be driven. Details of tip protection shall be furnished to the Engineer for review and approval before driving piles. Not less than 2 separate steel straps shall be placed within 600 mm of the butt of each pile after the pile is square cut. Not less than 2 separate steel straps shall be placed within 300 mm of the tip of each pile. Additional intermediate steel straps shall be placed at not more than 3 metres centre measured along the length of the pile.

Timber piles which are to be capped shall be separately cut off so that true bearing is obtained on every pile. Piles inaccurately cut off shall be replaced. Splicing of timber piles shall not be permitted except by written permission of the Engineer.

1110. DRIVING EQUIPMENT

Piles or their casings may be driven with any type of drop hammer, diesel hammer or single-acting steam or compressed air hammer, provided they penetrate to the prescribed depth or attain the designed resistance without being damaged. The weight or power of the hammer should be sufficient to ensure a penetration of at least 5 mm per blow, unless rock has been reached. It is always preferable to employ the heaviest hammer practicable and to limit the stroke, so as not to damage the pile. The minimum weight of the hammer shall be 2.5 t. In the case of precast concrete piles the mass of the hammer shall be not less than 30 times the mass of 300 mm length of pile.

Steam or air hammers shall be furnished along with boiler or air compressor of capacity at least equal to that specified by the manufacturer of the hammers. The boiler or air compressor shall be equipped with

an accurate pressure gauge at all times. The valve mechanism and other parts of steam, air or diesel hammers shall be maintained in first class condition so that the length of stroke and number of blows per minute for which the hammer is designed, will be obtained. Inefficient steam, air or diesel hammers shall be removed from the work.

1111. DRIVING

1111.1. General Procedure

Details of the equipment and the method proposed for driving the piles shall be submitted with the tender for scrutiny and approval of the Engineer. Piles shall be installed from firm ground or from temporary supports or from fixed platform. The arrangement shall provide sufficient rigidity to ensure accuracy of pile driving under all conditions of tide, stream flow or hammer drop.

During driving the top of pile shall be protected by a suitable helmet of substantial steel construction. The helmet shall provide uniform bearing across the top of the pile and shall hold the pile centrally under the hammer. No pile shall be driven unless inspected and approved by the Engineer.

Piles shall be driven from a fixed frame of sufficient rigidity to ensure accuracy of driving within specified tolerances. Forces producing undue bending or torsional stresses in piles shall not be applied during driving. The force of the hammer shall be directed centrally and axially during driving.

The stroke of a single acting or drop hammer shall be limited to 1.2 m unless otherwise permitted by the Engineer. A shorter stroke may be necessary when there is danger of damaging the pile.

Piles shall not be bent or sprung into position but shall be effectively guided and held on-line during the initial stages of driving. Attempts to correct any tendency for the pile to run off-line by the application of significant horizontal restraint will not be permitted. Shortly after the commencement of driving and at regular intervals throughout the driving operation, checks shall be made to ensure that the pile frame does not exert any undue lateral force on the pile due to restraint within the helmet.

If the indications are that a pile will finish outside the specified tolerances, driving operations on that pile will cease. The pile shall be withdrawn, the hole filled and the pile re-driven at no extra cost.

To avoid the possibility of premature "set-up" pile driving shall be continuous in the later stages, without any deliberate stops. (Delays of an hour or less may lead to significant "set-up" in piles i.e. resistance to further driving increases after driving is stopped).

If any pile is damaged in any way during driving, it shall be repaired or replaced as directed by the Engineer, at no extra cost. If during driving, the head of a pile is damaged to the extent that further driving is not possible, the head shall be cut off and driving continued. The cost of cutting off shall be borne by the Contractor and where, as a result of such cutting off the head, the pile is too short, the Contractor, shall, at his own cost, supply and splice on sufficient length of pile to restore the pile to its correct length.

Piles should be driven to the minimum acceptable penetration shown on the drawings. This may require preboring and/or jetting as indicated in these specifications with the full approval of the Engineer.

Piles shall be driven to nominal refusal or the required ultimate dynamic capacity nominated on the drawings or until the top of the pile is at the level required and specified on the drawing whichever gives the lowest toe elevation. The Engineer's decision in these matters shall be final. Nominal refusal shall be taken as equivalent to 25 mm total penetration for the final 20 blows using a hammer of driving energy as specified and shall be used as the criterion for acceptance for piles founded on rock. Severe driving which results in an average set per blow less than 0.5 mm will not be permitted.

Where hard drilling is encountered because of dense strata or obstructions located above the predetermined pile tip level, nominal refusal shall not be considered to have been achieved unless the Engineer is satisfied that the total number of blows, as the average driving resistance specified for nominal refusal, indicates that further driving will not advance the pile through dense strata or obstructions.

The pile shall be driven as accurately as possible to the vertical or to specified batter. Straining the pile into position can damage it and the driving equipment should be adjusted as much as possible to follow the position of the pile. Any deviation from the proper alignment shall be noted and promptly reported to the Engineer. If the deviation is to such an extent that the resulting eccentricity cannot be taken care of by strengthening the pile cap or pile ties, such a pile shall, at the discretion of the Engineer, be replaced or supplemented by an additional pile. Unless otherwise specified, the permissible

positional deviation for piles shall be limited to those indicated in Clause 1116.

Care shall be taken not to damage the pile by over-driving. Any sudden change in the rate of penetration which cannot be ascribed to the nature of the ground shall be noted and its cause ascertained, if possible, before driving is continued.

When employing a tube which is subsequently withdrawn for the formation of cast-in-situ pile, consideration shall be given to the possibility of doing harm to a pile recently formed by driving the tube nearby before the concrete has sufficiently set. The danger of doing harm is greater in compact soils than loose soils. No pile shall be bored or driven within 3 m of a newly cast pile until at least 24 hours after completion of its installation.

Driving piles in loose sand tends to compact the sand which in turn increases the skin friction. Therefore, driving a number of friction piles in a group shall proceed outward from the centre as otherwise it will be difficult to drive the inner piles to the same depth as the others.

In the case of stiff clay also, the driving for a group of piles shall proceed outward from the centre. However, in case of very soft soil, the driving may proceed from outside to inside, so that the soil is restrained from flowing out during driving operations.

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

1111.2. Preboring and Jetting

Driving of the piles may be assisted by preboring holes or by the use of jets or both subject to the approval of the Engineer. These may be used essentially to achieve the minimum penetration shown on the drawings where such penetration is not reached under normal conditions of driving indicated in Clause 1111.1.

The diameter of the hole shall not be greater than the diagonal dimension of the pile less 100 mm.

The maximum depth of the preboring shall be such that the

specified set (or less) is obtained when the toe of the pile is at founding level. Preboring shall be as approved by the Engineer and shall not extend below one metre above the founding level and the pile shall be driven to at least one metre below the prebored hole. To ensure that the pile is properly supported laterally in the hole, any space remaining around the pile at the ground level after driving is finished shall be backfilled with approved granular material.

When water jetting is used, at least two jets shall be attached to the pile symmetrically when this type of technique is used. The volume and pressure of water at the outlet nozzles shall be sufficient to freely erode material adjacent to the toe of the pile. The maximum depth of jetting shall be such that the specified set (or less) is obtained when the toe of the pile is at founding level. Jetting shall cease as directed by the Engineer and shall not proceed below one metre above the founding level and the pile shall be driven at least one metre below the pre-bored hole.

To avoid very hard driving and vibration in materials such as sand, jetting of piles by means of water may be carried out only by express permission of the Engineer and in such a manner as not to impair the bearing capacity of piles already in place, the stability of the soil or the safety of any adjoining buildings. Details of the arrangement for jetting shall be got approved from the Engineer in advance.

If, for jetting, large quantities of water are used, it may be necessary to make provision for collection of water when it comes to the ground surface, so that the stability of the piling plant is not endangered by the softening of the ground.

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

1112. RAKER (INCLINED) PILES

The maximum rake to be permitted in piles shall not exceed the following :

i) 1 in 8 for large diameter cast-in-situ piles viz 0.75 m diameter and above

ii) 1 in 5 for smaller diameter cast-in-situ piles

iii) 1 in 4 for precast driven piles

1113. PILE TESTS

1113.1. General

The bearing capacity of a single pile may be determined from test loading a pile. The load test on a concrete pile may not be carried out earlier than 28 days from the time of casting of the pile.

There shall be two categories of tests on piles, namely, initial tests and routine tests. Initial tests should be carried out on test piles which are not to be incorporated in the work. Routine tests shall be carried out as a check on working piles. The number of initial and routine tests on piles shall be as determined by the Engineer depending upon the number of foundations, span length, type of superstructure and uncertainties of founding strata. In any case, the initial load tests shall not be less than 2 in number, while the routine load tests shall not be less than 2 per cent of the total number of piles in the structure nor less than 2 in number.

The above stipulations hold good for both vertical as well as lateral load tests on pile foundations.

However, both initial and routine tests may be suitably increased for important structures or cases with large variation in the sub-surface strata.

The methodology of carrying out load tests and of arriving at safe load on piles shall conform to IS:2911 (Part IV).

In case of any doubt of workmanship or load carrying capacity of working piles not subjected to routine tests, or when ordered by the Engineer, or when provided in the contract, load tests on working piles may be supplemented by non-destructive testing. Such tests may include "Integrity Testing" of concrete in the installed pile and utilisation of "Pile Driving Analyser" which gives an indication of pile capacity in end bearing and side friction.

1114. PILE CAP

Pile Caps shall be of reinforced concrete. A minimum offset of 150 mm shall be provided beyond the outer faces of the outer most piles in the group. If the pile cap is in contact with earth at the bottom, a levelling course of minimum 100 mm thickness of M 15 nominal mix concrete shall be provided.

The attachment of the pile head to the cap shall be adequate for the transmission of loads and forces. A portion of pile top may be

stripped of concrete and the reinforcement anchored into the cap. Manual chipping may be permitted after three days of pile casting, while pneumatic tools for chipping shall not be used before seven days after pile casting. The top of pile after stripping shall project at least 150 mm into the pile cap. A layer of surface reinforcement may be provided with a cover of 25 mm to retain the integrity of concrete below the main cap reinforcement which is to be laid 25 mm above the pile top.

Concreting of the pile cap shall be carried out in dry conditions. The bottom of the pile cap shall be laid preferably as low as possible taking account of the water level prevalent at the time of casting.

The top of concrete in a pile shall be brought above cut-off level to permit removal of all laitance and weak concrete before pile cap is laid. This will ensure good concrete at the cut-off level.

1115. IMPORTANT CONSIDERATIONS, INSPECTION/ PRECAUTIONS FOR DIFFERENT TYPES OF PILES

1115.1. Driven Cast-in-Situ Piles

1115.1.1. Specialist literature and the guidelines from the pile construction industry shall be consulted regarding the method of installation, equipment and accessories for pile driving and recording of data.

1115.1.2. During installation of piles the final "set" of penetration of pile per blow of hammer shall be checked taking an average of last 10 blows.

1115.1.3. The pile shoes which may be of either cast iron conical type or mild steel flat type shall have double reams for proper seating of the removable casing tube inside the space between the reams.

1115.1.4. Before commencement of pouring of concrete, it shall be ensured that there is no ingress of water in the casing tube from the bottom. Further adequate control during withdrawal of the casing tube is essential so as to maintain sufficient head of concrete inside the casing tube at all stages of withdrawal.

1115.1.5. Concrete in piles shall be cast upto a minimum height of 600 mm above the designed top level of pile, which shall be stripped off at the time of construction of pile cap.

1115.2. Bored Cast-in-Situ Piles

1115.2.1. While concreting uncased piles, voids in concrete shall be avoided and sufficient head of concrete is to be maintained to prevent inflow of soil or water into the concrete. It is also necessary to take precautions during concreting to minimise the softening of the soil by excess water. Uncased cast-in-situ piles shall not be allowed where mudflow conditions exist.

1115.2.2. The drilling mud such as bentonite suspension shall be maintained at a level sufficiently above the surrounding ground water level to ensure the stability of the strata which is being penetrated throughout the boring process until the pile has been concreted.

1115.2.3. Where bentonite suspension is used to maintain the stability of the bore-hole, it is essential that the properties of the material be carefully controlled at stages of mixing, supply to the bore-hole and immediately before concrete is placed. It is usual to limit :

i) The density of bentonite suspension to 1.05 g/cc

ii) The marsh cone viscosity between 30 and 40

iii) The pH value between 9.5 and 12

iv) The silt content less than 1 per cent

v) The liquid limit of bentonite not less than 400 per cent

These aspects shall act as controlling factors for preventing contamination of bentonite slurry for clay and silt.

1115.2.4. The bores shall be washed by bentonite flushing to ensure clean bottom at two stages viz. after completion of boring and prior to concreting after placing of reinforcement cage. Flushing of bentonite shall be done continuously with fresh bentonite slurry till the consistency of inflowing and out-flowing slurry is similar.

1115.2.5. Tremie of 150 mm to 200 mm diameter shall be used for concreting. The tremie should have uniform and smooth cross-section inside, and shall be withdrawn slowly ensuring adequate height of concrete outside the tremie pipe at all stages of withdrawal. Other recommendations for tremie concreting are :

(i) The sides of the bore-hole have to be stable throughout.

(ii) The tremie shall be water-tight throughout its length and have a hopper attached at its head by a water-tight connection

(iii) The tremie pipe shall be large enough in relation to the size of aggregates. For 20 mm aggregate the tremie pipe shall be of diameter not less than 150 mm and for larger size aggregate tremie pipe of larger diameter is required.

(iv) The tremie pipe shall be lowered to the bottom of the bore-hole, allowing water or drilling mud to rise inside it before pouring concrete.

(v) The tremie pipe shall always be kept full of concrete and shall penetrate well into the concrete in the bore-hole with adequate margin of safety against accidental withdrawal if the pipe is surged to discharge the concrete.

1115.2.6. For very long or large diameter piles, use of retarding plasticiser in concrete is desirable.

1115.2.7. For large diameter piles, it may be essential to conduct non-destructive pile integrity tests to evaluate integrity of the pile.

1115.2.8. Where possible, it may be desirable to grout the base of pile with cement slurry under suitable pressure after concrete in the pile attains the desired strength. For this purpose, conduit pipes with easily removable plugs at the bottom end should be placed in the bore alongwith reinforcement cage before concreting.

1116. TOLERANCES

1116.1. Permissible Tolerances for Pile

i)	Precast Concrete Piles :		
	a)	Variation in cross-sectional dimensions	: ± 5 mm
	b)	Variation in length	: ± 25 mm
	c)	Surface irregularities measured with 3 m straight edge	: 5 mm
	d)	Bow for length in mm	Pile Length in mm / 1000
ii)	Driven Piles		
	a)	Variation in cross-sectional dimensions	: +50 mm, -10 mm
	b)	Variation from vertical or specified rake	: 1 in 50
	c)	Variation in the final position of the head in plan	: 75 mm
	d)	Variation of level of top of piles	: ± 25 mm
iii)	Bored Piles		
	a)	Variation in cross-sectional dimensions	: + 50 mm, -10 mm
	b)	Variation from vertical or specified rake	: 1 in 50
	c)	Variation in the final position of the head in plan	: 50 mm
	d)	Variation of level of top of piles	: ± 25 mm

1116.2. Permissible Tolerances for Pile Caps

(a)	Variation in dimensions	: +50 mm - 10 mm
(b)	Misplacement from specified position in plan	: 15 mm
(c)	Surface irregularities measured with 3 m straight edge	: 5 mm
(d)	Variation of levels at the top	: ± 25 mm

1117. TESTS AND STANDARDS OF ACCEPTANCE

The materials shall be tested in accordance with these Specifications and shall meet the prescribed criteria.

The work shall conform to these Specifications and shall meet the prescribed standards of acceptance.

1118. MEASUREMENTS FOR PAYMENT

For supply of precast concrete, timber or steel piles of specified cross-section, the measurement shall be in metres of the length of piles ordered in writing by the Engineer measured from the head to the butt of the shoe or the tapered point. Reinforcement in precast concrete piles shall not be measured for payment.

For cast-in-situ driven and bored concrete piles of specified cross-section, the measurement shall be the length in metres of the accepted pile that remains in the finished structure complete in place. Reinforcement in cast-in-situ driven and bored concrete piles shall be measured for payment as per Section 1600.

Routine and Initial Pile Load Tests shall not be measured for payment.

For installation of the pile, i.e. by driving in the case of precast concrete, timber, steel and cast-in-situ driven piles, and by boring in the case of cast-in-situ bored piles the measurement shall be the length in metres that remains in the finished structure complete in place, limited to that shown on drawings or ordered by the Engineer. No distinction shall be made for penetration through hard strata or rock and socketing into rock.

For steel liners/casing shown on the drawings to be permanently left in place, the measurement shall be by weight in tonnes that remains in the finished structure complete in place, limited to that shown on drawings or ordered by the Engineer.

For the pile cap, the quantity of concrete shall be measured in cubic metres as per Section 1700. While reinforcement in pile cap

shall be measured in tonnes as per Section 1600.

1119. RATE

The contract unit rate for supplying precast concrete, timber or steel piles shall include cost of all labour, materials, tools and equipment, and other work involved in making or fabricating the pile complete as shown on the drawing, and where required its loading, transport, delivery to site unloading and stacking it at the place indicated by the Engineer. The cost of reinforcement as per Seciton 1600 in precast concrete piles shall be deemed to be included in the quoted rate for supply of piles.

The contract unit rate for cast-in-situ driven and bored piles shall include the cost of concrete and all other items as per Section 1700. The contract unit rate shall also include costs of all labour, materials, equipments and all other incidentals involved in conducting routine and initial pile load tests including installation of piles for initial load tests.

The contract unit rate for reinforcement in cast-in-situ driven and bored piles shall be as per Section 1600.

The contract unit rate for installation of piles shall include full compensation for furnishing all labour, materials, tools and equipment, and incidentals for doing all the works involved in driving timber, precast concrete and steel piles, driving or making bores for cast-in-situ driven and bored concrete piles, cutting off pile heads, all complete in place to the specified penetration of piles. Providing temporary liner/casing and its withdrawal and placing reinforcement in position shall also be deemed to be included in the rate for installation of piles and no additional payment shall be made for the same.

The contract unit rate for permanent steel liners shall incude cost of all labour, fabrication and placing the steel liner to the required depth as shown on the drawings and as ordered by the Engineer.

The contract unit rate for concrete in pile cap shall cover all costs of labour, materials, tools, plant and equipment, formwork and staging including placing in position, sampling and testing and supervision, all as per Section 1700. Reinforcement in the pile cap shall be paid for separately as per Section 1600
