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JABATAN KERJA RAYA MALAYSIA

STANDARD SPECIFICATION FOR ROAD WORKS

Section 10: Piling Works



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FOREWORD

As practices in road construction change over time, it is imperative for Jabatan Kerja Raya (JKR) to continuously update and improve their standard specifications. These new specifications are not only aimed at keeping abreast with current technologies but also helping in improving the quality of constructed product. In unison, these new specifications have a significant positive impact on the construction industry especially with the incorporation of new products and technologies.

Standard Specification for Road Works is an essential component in the road infrastructure construction industry. This specification provides an improved guidance in the material selection and the production of good quality workmanship and products, based on current best practices. The purpose of this standard specification is to establish uniformity in road works to be used by road designers, road authorities, manufacturers and suppliers of road related products.

This document "Standard Specification for Road Works - Section 10: Piling Works" is a part of a series of improved specifications in the Standard Specification for Road Works. The compilation of this document was carried out through many discussions by the technical committee members. Additionally it has been reviewed by a group of independent consultants and presented at a technical workshop held on 16th July 2008. Feedbacks and comments received were carefully considered and incorporated in the specification where appropriate.

This Specification also had been presented in Mesyuarat Ketua Sektor (MKS) JKR on 2nd September 2010 and Mesyuarat Pengarah JKR Malaysia Bil 3/2011 on 15th August 2011.

ACKNOWLEDGEMENT

This **Standard Specification for Road Works - Section 10: Piling Works** has been prepared by a technical committee consisting of engineers from Cawangan Kejuruteraan Awam, Struktur dan Jambatan (CKASJ), Cawangan Jalan & Geoteknik (CKJG), Cawangan Jalan (CJ) and Cawangan Pengurusan Projek Kompleks (CPPK). The members of the committee involved in preparing this Standard Specification for Road Works - Section 10: Piling Works are:-

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SECTION 10 – PILING WORKS

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10.1 DESCRIPTION

This work shall consist of the supply, installation and testing of piles in accordance with this Specification and the lines, levels, grades and cross-sections shown on the Drawings and as directed by the S.O.

10.2 GENERAL REQUIREMENTS AND TOLERANCES

10.2.1 Setting Out

Setting out shall be carried out using the data and reference points as shown on the Drawings. The pile position shall be marked with suitable identifiable pins, pegs or markers at least 300mm length. The pins, pegs or markers should be driven to ground level and the location marked with contrasting material. If raking piles are to be installed then the setting out pins, pegs or markers is located in an offset position at piling platform level taking into account of depth to cut-off level and rake value of the pile. In addition, the alignment of pins, pegs or markers shall indicate the direction of the rake. Immediately before installation of the pile, the pile positions shall be checked by the Contractor again.

10.2.2 Position

For a pile cut off at or above ground level the maximum permitted deviation of the pile centre from the centre points shown on the Drawings shall not exceed 75 mm in any direction. For a pile cut off below ground level an increase in this tolerance of 150mm is permitted in accordance with Sub-Sections 10.2.3 and 10.2.4 herein below.

No pile edge shall be nearer than 150mm from the edge of any pile cap.

10.2.3 Verticality

The maximum permitted deviation of the finished pile from the vertical is 1 in 75.

10.2.4 Rake

The piling rig shall be set and maintained to attain the required rake. The maximum permitted deviation of the finished pile from the specified rake or the rake shown on the Drawings is 1 in 25.

10.2.5 Forcible Corrections

Forcible corrections to concrete piles shall not be permitted. Forcible corrections may be permitted to specific types of piles if approved by the S.O. However, no forcible corrections shall be made to piles which have deviated

beyond the permissible limits specified in Sub-Sections 10.2.2, 10.2.3 and 10.2.4 above.

10.2.6 Piles Out of Alignment or Position

The Contractor shall, if ordered by the S.O., extract and reinstall any pile which has deviated out of position or alignment by more than the specified limit, or alternatively the substructure shall be modified to the approval of the S.O. The cost of such extraction and reinstallation or any extra cost in the design and construction of a modified foundation shall be borne by the Contractor if, such extra works have been made necessary due to the error and/or negligence of the Contractor.

10.2.7 Records

The Contractor shall keep records of the installation of each pile as required by the S.O. and shall submit two signed copies of these records to the S.O not later than at noon of the next working day after the pile has been installed. The signed records shall form part of the records for the Works. Any unexpected driving or boring conditions shall be noted in the records.

10.2.8 Soil Investigation Report

A soil investigation report shall be made available at the S.O.'s office for the Contractors information. The report is intended solely as a preliminary guide and the completeness nor the accuracy of the information provided is not guaranteed. No responsibility is assumed by the S.O for any opinion or conclusion given in the soil report.

The Contractor shall study the given soil report in detail and oblige to place his own interpretation on the information provided and to make due allowance for the effect of site conditions on his construction operations.

10.2.9 Unexpected Ground Conditions

The Contractor shall report immediately to the S.O any circumstances which, in the Contractor's opinion, indicate ground conditions that may differ from those expected by him from interpretation of the soil investigation report. The Contractor's report shall be in the form of written notice of which shall be given to the S.O at the earliest possible time after encountering such conditions and obstructions. The report shall be accompanied by all information available to the Contractor which will materially assist the S.O in verifying the conditions reported, and in determining the cause and reasonableness of any claim relating thereto in accordance with the Conditions of Contract.

If unexpected ground conditions require the permanent substructure works to be constructed to a modified design, the S.O shall issue instruction for a variation to the permanent works in the contract.

10.2.10 Adjacent Structures

The Contractor shall pay very careful attention to the construction constraints imposed by adjacent structures. The Contractor shall exercise extra care and implement adequate monitoring measures when carrying out his piling operations so as not to disturb or damage existing adjacent properties and foundations. The Contractor shall provide a proposal for monitoring adjacent properties for any detrimental effects arising out in execution of the piling works, so that appropriate and timely preventive action can be taken to minimise damage. The Contractor's proposal and monitoring program shall be certified by his Professional Engineer.

The Contractor shall also carry out a condition survey of adjacent properties to establish the condition of the existing structures and facilities prior to commencement of piling work. Condition Surveys shall be conducted by a registered building surveyor and the result of the survey shall be submitted to the S.O. for record.

The Contractor shall be responsible for and shall bear the cost of such works and any claims for damage to adjacent structure and facilities arising from his execution of the piling works.

10.2.11 Existing Services

The Contractor shall give all required notices to the appropriate utility authorities before commencement of piling works. The Contractor shall also locate existing services by piloting, protect existing services, rectify any damage or interference to them and provide temporary support while repairs are being carried out if so required.

10.2.12 Method Statement for Construction Operations

Two weeks before the commencement of piling works, the Contractor shall submit to the S.O. a detailed method statement for the installation of piles. For the purpose of this clause, a method statement shall be a document containing:

i) A detailed construction sequence.
ii) Shop drawings showing details of all special requirements for the construction activities such as hoisting of piles, reinforcement cages, cast in fixing etc.
iii) Design calculation of key temporary works endorsed by his Professional Engineer.
iv) Material, plant and labour requirement at each construction stage.
v) Rate of production output based on resources allocated.
vi) Other information relevant to the piling works.

If requested by the S.O, the Contractor shall submit additional information pertaining to the method of construction (including temporary works and the use of the construction plant), calculation of the stresses, strain and deflection that will arise in the permanent works of any part thereof during construction.

The Contractor shall not change the methods which have been approved by the S.O. Approval by the S.O. of the Contractor's proposed methods of construction in accordance with the clause shall not in anyway relieve the Contractor of any of his duties or responsibilities under the contract.

10.2.13 <u>Alternative Piling System by Contractor</u>

The Contractor may submit his proposed alternative piling system, excluding timber and bakau piles, other than that specified in the drawings for the S.O's review. The Contractor's submission shall be endorsed by his Professional Engineer, an Independent Check Engineer (ICE) and shall include the following information: -

i) Calculation demonstrating the single pile and group working capacity and pile lengths of the pile system proposed stating clearly the underlying assumptions adopted.
ii) Specification for the proposed system, including type of piling equipment, maximum length of piles that can be satisfactorily installed and average output in linear metres of installed pile per piling frame per normal working day of 8 working hours per day.
iii) Pile layout arrangements.
iv) Method of construction, including method of jointing.
v) Design drawing and quantities of pile cap.
vi) Guarantee of pile capacity for all piles installed, regardless whether or not the capacity of a pile is proven by test.
vii) Any other information required by the engineer in his review of the alternative system.
viii) Cost savings to the Government.

The system put forward by the Contractor shall have good records of successful installation and performance in local projects of comparably project size and ground conditions.

The Contractor's design calculation and specification shall comply fully with the relevant recommendations of the British Standard BS 8004, the requirement of the specification and the Condition of Contract. In matters not specifically covered by the British Standard BS 8004 and the specification, the Contractor's proposal shall also be subject to the S.O's approval. It shall be the Contractors responsibility to clearly itemise any departure from British Standard BS 8004 and piling specification provided.

Prior to the acceptance of the alternative pile design and the installation of any working pile, the Contractor shall be required to carry out failure load tests to confirm his design. Based on the results of the tests, the Contractor shall be required to modify his design of piles where necessary to the satisfaction of the S.O at no extra cost.

10.2.14 As-Built Locations

After construction, actual pile locations shall be certified by a Licensed Surveyor employed by the Contractor for this purpose. The Contractor shall submit an as-built pile plan to the S.O within 7 (seven) working days of completion of the last pile. Partial as-built may be submitted throughout construction of the foundation for verification by the S.O.

10.3 PRECAST REINFORCED CONCRETE PILES

10.3.1 Description

This work shall comprise the supply and installation of precast reinforced concrete piles, inclusive of pitching and driving, lengthening and cutting and preparation of pile heads, all in accordance with this Specification and to the details shown on the Drawings. The classification and definition of Precast Concrete Pile shall be in accordance with Table 10.1 of this Specification.

10.3.2 Materials

10.3.2.1 Concrete

Unless otherwise specified, Portland cement shall be used for the casting of piles. The materials and workmanship shall be as specified under Section 9 of this Specification. The grade of concrete and the details of reinforcement to be used shall be as shown on the Drawings and shall comply with the specification as stated in Table 10.1 of this Specification.

10.3.2.2 Reinforcement

The main reinforcing bars in piles not exceeding 12 m in length shall be in one continuous length unless otherwise approved by the S.O. In piles exceeding 12 m long, joints shall be permitted in main longitudinal bars at 12 m nominal intervals. Joints in adjacent bars shall be staggered at least 1 m apart along the length of the pile. Joints shall be butt welded as specified in Sub-Section 9.7.3.5 of this Specification. Jointing at reinforcement, by means of mechanical couplings shall not be permitted.

10.3.2.3 Pile Shoes

The type of pile shoes to be used shall be as shown on the Drawings and shall comply with the following as relevant: -

i) "Chilled-hardened" cast iron shoes as used for making grey iron castings to BS EN 1561, Grade 10; or
ii) Mild steel to B.S EN 10025 or equivalent, Grade 50B; or
iii) Cast steel to BS EN 10293, Grade A.

Mild steel straps cast into the shoes shall be as shown on the Drawings. Rock shoes where required shall consist of wrought iron shoes and mild steel straps cast into "Chilled-hardened" cast iron blocks, as shown on the Drawings.

The shoes shall be truly coaxial and firmly embedded on to end of the pile.

10.3.3 Manufacture and Storage of Precast Reinforced Concrete Piles

10.3.3.1 Casting

The length of piles to be cast shall be as shown on the Drawings, subject to revision by the S.O. The concrete shall be compacted by approved means against the face of the mould and in between reinforcements.

Based on the results of pile driving resistance and/or load tests carried out on piles driven on the site, the S.O. may from time to time order the lengths of piles to be modified.

Piles shall be cast on a horizontal platform in approved moulds to the dimensions as shown on the Drawings. The moulds used in manufacture shall be sufficiently rigid and accurate to maintain the pile dimension within the tolerance stated in the following paragraph. The concreting of each pile shall be completed in one continuous operation and no interruptions will be permitted. Lifting holes shall be formed during casting in the positions and in accordance with the details shown on the Drawings. The piles shall be cured in accordance with Section 9 of this Specification.

The cross-sectional dimensions of the pile shall not be less than those shown on the Drawings and shall not exceed by more than 6 mm. Any face of a pile shall not deviate by more than 6 mm from a straight edge 3 m long laid on the face, and the centroid of any cross-sections of the pile shall not deviate by more than 12 mm from the straight line connecting the centroid of the end faces of the pile.

After a pile has been cast, the date of casting, reference number and the length shall be clearly marked with undeletable marker on the top surface and on the head of the pile. Each pile shall be marked at intervals of 0.5 m along its length before being driven.

10.3.3.2 Handling and Storage

The method and sequence of lifting, handling, transporting and storing piles shall be such that piles are not damaged or having crack width greater than 0.1mm. Only the designed lifting and support points shall be used. During transport and storage, piles shall be placed on adequate supports located under the lifting points of the piles. Piles shall be stored and stacked on firm ground not liable to settlement under the weight of piles. The supports shall be vertically above one another. All piles within a stack shall be in groups of the same length. Packings of uniform thicknesses shall be provided between piles at the lifting points.

No piles shall be allowed for transportation before achieving concrete strength of 30 N/mm^2.

No pile shall be driven before the specified characteristic strength of appropriate grade of concrete has been achieved.

10.3.4 Installation of Precast Reinforced Concrete Piles

10.3.4.1 Pitching of Piles

Piles shall be pitched accurately in the positions as shown on the Drawings. At all stages during driving and until the pile has set or been driven to the required length, all exposed piles shall be adequately supported and restrained by means of leaders, trestles, temporary supports or other guide arrangements to maintain position and alignment and to prevent buckling and damage to the piles.

10.3.4.2 Driving of Piles

Each pile shall be driven continuously until the specified set and/or depth has been reached, unless otherwise approved by the S.O. The driving equipment used shall be of such type and capacity to the approval of the S.O. A follower (long dolly) shall not be used unless otherwise meet the following requirement and approved by the S.O.

i) The first pile in each pile system and every tenth pile driven thereafter shall be driven full length, without a follower, to verify that adequate pile length is being attained to develop the desired pile capacity.
ii) The follower and pile shall be held and maintained in equal and proper alignment during driving.
iii) The follower shall be of such material and dimension to permit the piles to be driven to the length determined necessary from the driving of the full length piles.
iv) The final position and alignment of the first two piles installed with follower in each substructure unit shall be verified to be in accordance with the location tolerances specified in Sub-Section 10.2 before additional piles are installed.

Follower shall not be used in driving of raked pile.

A detailed record of the driving resistance over the full length of each pile shall be kept. The log shall record the number of blows for every 0.5 m of pile penetration. The Contractor shall inform the S.O. without delay if an unexpected change in driving characteristics is encountered. Where required by the S.O. set shall be taken at approved intervals during the driving to establish the behaviour of the piles.

A set shall be taken only in the presence of the S.O. unless otherwise approved. The Contractor shall provide all facilities to enable the S.O. to check driving resistances. The final set of a pile other than as friction pile,

shall be recorded as the penetration in millimetres per 10 blows. The temporary compression of the pile shall be recorded if required.

When a set is being measured, the following requirements shall be met:

i) The pile shall be in good condition, without damage or distortion.
ii) The hammer blow shall be in line with the axis of the pile and the impact surface shall be flat and perpendicular to the hammer axis.
iii) The hammer shall be in good condition, delivering the required energy per blow and operating correctly.
iv) The rebound shall be measured and recorded accordingly.

When an acceptable resistance or set appears to have been reached, the driving of pile should be suspended for an interval sufficient to permit the soil to recover from the disturbance of pile driving, and then resumed to determine whether there is any increase or decrease in resistance.

In soils that dilate when disturbed e.g. silts and some shales, negative pore pressure can be set up temporarily and the driving resistance may fall as these pore pressure return to normal. In clays disturbance can cause positive pore pressure to develop and the strength of the soil may increase as these dissipate. The necessary time interval before redriving may vary from 1 hour to 2 hours for non-cohesive soils or to 2 days or more for clays.

The resistance at the start of redriving is more likely to be representative of the true bearing value of the pile, and each redriving result should be taken into consideration when deciding the pile penetration length.

Piles shall be driven in an approved sequence to minimise the detrimental effects of heave and lateral displacement of the ground. When required, careful levelling from a datum unaffected by the piling shall be made on the pile heads already driven, before and after driving subsequent piles. Piles which have been displaced vertically by more than 3mm as a result of driving adjacent piles shall be redriven to the required resistance.

10.3.4.3 <u>Preboring and Jetting of Piles</u>

Piles shall not be prebored without the written approval of the S.O. Preboring of piles may be allowed for the following reasons:

i) To ease pile drivability by breaking through soil layers.
ii) To reduce lateral soil displacement where this could cause damage to nearby structure.
iii) To investigate and possibly deal with obstruction in the ground.

The piles shall remain in intimate contact with surrounding soil and the completed piles shall comply with the requirements of this Specification. Diameter of preboring shall be in accordance with Section 10.5.3.1 of this Specification. If boring is oversize, any gap between the tube and ground shall be filled with compacted sand prior driving the pile.

In some soils, jetting may lift adjacent structure or cause undermining of nearby foundations. Pile shall not be jetted without the written approval of the S.O. Prior to jetting any pile, the Contractor shall submit to the S.O. details of the equipment to be used and the proposed method to be adopted.

10.3.4.4 Repair of Damaged Pile Heads

If a pile is to be subjected to further driving, concrete in the damaged pile head shall be cut off square at sound concrete, and all loose particles shall be removed by wire brushing, followed by washing with water. Care shall be exercised to ensure that the reinforcement in the pile head is not in any way damaged. Any damaged reinforcement shall be made good to the satisfaction of the S.O. The head shall be replaced with concrete of similar grade or higher.

The new head shall be cast truly in line with the remainder of the pile and be properly cured and allowed to harden sufficiently to develop the strength necessary for further driving. If a pile has been driven to the required set or depth but the level of sound concrete of the pile is below cut-off level, the pile shall be made good to the cut-off level as described above so that the completed foundation will safely withstand the specified ultimate load.

10.3.4.5 Lengthening of Piles

Where piles have to be lengthened, other than by means of welding of steel plates as detailed on the Drawings, the reinforcement shall be stripped of all surrounding concrete for a distance equal to forty (40) times the diameter of the main reinforcement measured from the pile head for spliced joints and 300 mm for butt welded joints and all lateral reinforcement shall be removed.

The new concrete shall be of the same grade or higher as the original concrete on pile and shall be adequately compacted.

The lengthening bars shall butt on the exposed bars in true alignment and shall be butt welded as specified or shall be spliced with bars of the same diameter as the main pile bars, 60 diameters in length and lapping the main bars for a distance of 40 diameters above and below the joint, and shall be securely bound with 1.63 mm soft annealed iron wire.

New binders of similar size shall be provided and spaced at half the centers of the binders in the main body of the pile and shall be securely bound with 1.63 mm soft annealed iron wire and the pile extended by concreting in properly constructed mounds to the length required.

Care shall be taken to form the joint between the old and new concrete as specified hereinbefore. The old concrete shall be adequately roughened and all loose particles shall be removed by wire brushing, followed by washing with clean water. The extension shall be truly in line at all stages of handling and driving with the remainder of the pile and be properly cured and allowed to harden sufficiently to develop the strength necessary for further driving.

10.3.4.6 Pile Joint

The bending strength test of pile joint shall be done for laterally loaded pile only to determine the bending capacity at each respective joint. The test shall be done as in 10.3.4.7 provided that the joint is positioned at the centre of the span. The bending capacity at the pile joint shall be greater than the bending capacity of the pile body by 10%. The result shall be submitted to S.O for approval prior to driving of any pile.

10.3.4.7 Pile Bending Strength Test

Pile bending strength test shall be performed in accordance with Appendix A/1 of this Specification.

10.3.4.8 Cutting and Preparation of Pile Heads

When a pile has been driven to the required set or depth, the head of the pile shall be cut off to the level specified or shown on the Drawings. This shall be done carefully to avoid shattering or otherwise damaging the rest of the pile. Any cracked or defective concrete shall be cut away and made good with new concrete properly bonded to the old. The length of reinforcing bars projecting above this level shall be as shown or specified on the Drawings. If the length of reinforcing bars left projecting is insufficient, then they shall be extended by either of the following methods: -

(a) Butt Welding

The extension bars shall butt on the projecting bars in true alignment and shall be butt welded in accordance with Sub-Section 10.7.4 of this Specification.

Redriving of the piles shall only be allowed after the welded joints have sufficiently air cooled to 100°C or below.

(b) Splicing

The projecting bars shall be stripped of all surrounding concrete as necessary to allow splices of length 60 diameters with extension bars. The extension bars shall be securely bound to the projecting bars with 1.63 mm soft annealed iron wire. The concrete of the pile shall be made good either before or together with the casting of the pile cap, all to the satisfaction of the S.O. Care shall be taken to avoid cracking or otherwise damaging the rest of the pile. Any cracked or defective concrete shall be cut away and made good with new concrete properly bonded to the old.

10.4 PRESTRESSED SPUN CONCRETE PILES

10.4.1 Description

This work shall comprise the supply and installation of prestressed spun concrete piles, inclusive of pitching and driving, lengthening and cutting and preparation of pile heads, all in accordance with this Specification and to the details shown on the Drawings and shall comply with the specification as stated in Table 10.1 of this Specification.

10.4.2 Materials

10.4.2.1 Concrete

Unless otherwise specified, Portland cement shall be used for the casting of piles. The materials and workmanship shall be as specified under Section 9 of this Specification. The grade of concrete to be used shall be as shown on the Drawings.

10.4.2.2 Reinforcement

The prestressing tendons and the non-prestressing reinforcement of the piles including workmanship shall be as specified under Sections 9 and 11 respectively of this Specification and to the details as shown on the Drawings.

Prestressing steel shall comply with JIS G3137 or BS 4486 or BS 5896 or ASTM A416 or equivalent.

A certificate of conformance is required for every delivery of reinforcement.

10.4.2.3 Transfer of Prestress

The minimum concrete cube strength at transfer should be 30 N/mm^2. All test cubes should be stored under same conditions as the piles.

10.4.2.4 End Plates

Details of end plates of each length of pile shall be as shown on the Drawings. Each end plate shall be machine-finished and provided with a chamfer to accommodate the welding when two lengths of pile are jointed.

10.4.2.5 Pile Shoes

If specified, the type of pile shoes to be used shall be as shown on the Drawings and shall be in accordance with Sub-Section 10.3.2.3.

10.4.3 Manufacture and Storage of Prestressed Spun Concrete Piles

10.4.3.1 Casting

The length of piles to be cast shall be as shown on the Drawings, subject to revision by the S.O. Based on the results of pile driving resistance and/or load tests carried out on piles driven on the site, the S.O. may from time to time order the lengths of piles to be modified.

Piles shall be hollow cylinders manufactured by the centrifugal casting process. Moulds shall be of metal, well braced and stiffened against deformations caused by the hydrostatic pressure of the wet concrete while spinning. The mould used in manufacture and casting shall be in accordance with Sub-Section 10.3.3.1.

The metal forms shall have smooth joints and inside surfaces. The forms shall be accessible for adequate cleaning. The spiral reinforcement shall be securely held to the longitudinal reinforcement during casting and spinning. Any welding used shall not affect the strength of the pre-stressing tendons.

The pile shall not be removed from the moulds until after the specified transfer strength is achieved.

The external diameter and the thickness of the pile shall not be less than that shown on the Drawings and shall be constant over the entire length of the pile and coaxial with the end plate at each end.

After a pile has been cast, the date of casting, reference number and length shall be clearly marked with undeletable marking on the top surface and on the head of the pile. In addition, each pile shall be marked at intervals of 0.5 m along its length before being driven.

10.4.3.2 Handling and Storage

The method and sequence of lifting, handling, transporting and storing piles shall be in accordance with Sub-Section 10.3.3.2.

10.4.4 Installation of Prestressed Spun Concrete Piles

10.4.4.1 Pitching and Driving of Piles

Pitching and driving of piles shall be in accordance with Sub-Sections 10.3.4.1 and 10.3.4.2. Piles shall not be driven until the concrete has achieved the specified characteristic strength.

10.4.4.2 Lengthening of Piles

Where lengthening of piles is required, the details of the joint shall be as shown on the Drawings and in accordance with Sub-Section 10.7.4. When

two lengths of pile are jointed, the end plates shall bear over their complete areas. Shims for packing shall not be accepted. For laterally loaded pile, the pile joint shall be in accordance with Sub-Section 10.3.4.5.

10.4.4.3 Cutting and Preparation of Pile Heads

When a pile has been driven to the required set or depth, the head of the pile shall be cut off to the level specified or shown on the Drawings using a diamond cutter. Pile heads shall be constructed to details as shown on the Drawings.

10.5 BORED CAST-IN-SITU PILES

10.5.1 Description

This work shall comprise the boring or grabbing, with or without casing, and subsequently filling the hole with plain or reinforced concrete to form bored cast-in-situ piles, all in accordance with this Specification and to the details shown on the Drawings.

10.5.2 Materials

10.5.2.1 Concrete and Reinforcement

The concrete and reinforcement to be used and workmanship for bored cast-in-situ piles shall be as specified under Section 9 of this Specification. The grade of concrete and the details of reinforcement to be used shall be as shown on the Drawings.

10.5.2.2 Permanent Casings

Permanent casings which form part of the designed pile shall be as specified on the Drawings.

10.5.2.3 Support Fluid

Support fluid material, bentonite, shall comply with the manufacturer's certificate and mix proportion. A certificate shall be obtained by the Contractor from the manufacturer of the bentonite powder, showing the properties of each consignment delivered to the site. This certificate shall be made available to the S.O. Test should be carried out at regular interval to ensure consistency of the batching process.

Polymer can be used as an alternative to bentonite to maintain stability of the bores with the approval of the S.O.

Bentonite or polymer shall be mixed thoroughly with water complying with MS 28 to make a suspension which will maintain the stability of the pile excavation for the period necessary to place concrete and complete

construction. Preparation of the suspension shall comply with the manufacturer's instructions.

Where saline or chemically contaminated ground water occurs, special precautions shall be taken to modify the bentonite suspension or prehydrate the bentonite in fresh water to render it suitable in all respects for the construction of piles.

10.5.3 Boring Operations

10.5.3.1 Diameter of Piles

The diameter of piles shall not be less than the specified designed diameter at any level throughout its length.

The auger width shall be checked as necessary and recorded for each pile to ensure the specified diameter is achieved. A tolerance of +5% to 0% on the auger width is permissible.

10.5.3.2 Boring

Boring shall be carried down to the depth as required and directed by the S.O. When deemed necessary by the S.O., the Contractor shall take undisturbed soil samples while the pile is being bored. The samples shall be taken to an approved Laboratory for testing.

Sampling and all subsequent handling and testing shall be carried out in accordance with BS EN ISO 1997, BS EN ISO 14688, BS EN ISO 14689, BS EN ISO 22475 and BS EN ISO 22476.

Piles shall not be bored at a distance less than 3 times diameter close to other piles which have recently been cast and which contain workable or unset concrete.

10.5.3.3 Drilling In Rock

The Contactor shall submit a method statement when drilling in rock. Chiselling of rock may cause micro cracks in surrounding rock and is not allowed.

10.5.3.4 Temporary Casings

Temporary casings of approved quality or an approved alternative method shall be used to maintain the stability of pile excavations which might otherwise collapse.

Temporary casings shall be free from significant distortion. They shall be of uniform cross-section throughout each continuous length. During concreting they shall be free from internal projections and encrusted concrete which might prevent the proper formation of the piles being cast.

10.5.3.5 Stability of Piling Excavations Using Support Fluid

Where the use of support fluid or a column of water is approved for maintaining the stability of boring, the level of fluid or column of water in the excavation shall be maintained such that the fluid pressure always exceeds the pressure exerted by the soil and external ground water and an adequate temporary casing shall be used in conjunction with the method to ensure the stability of the strata near ground level until concrete has been placed. The fluid water level shall be maintained at a level not less than 1 metre above the level of the external ground water. In the event of a rapid loss of bentonite suspension, polymeric fluids or water from the piling excavation, the excavation shall be backfilled with lean concrete or well compacted sand as specified in Section 9 of this Specification without delay and the instructions of the S.O. shall be obtained prior to resuming boring at that location.

10.5.3.6 Spillage and Disposal

All reasonable steps shall be taken to prevent the spillage of bentonite suspension or water on the site in areas outside the immediate vicinity of the boring operations. Discarded bentonite water shall be removed from the site without delay. The disposal of bentonite water shall comply with the regulations of the Local Authorities.

Entrained solids shall be removed from the polymeric fluid by use of flocculants before disposal of the remaining fluid to the environmentally acceptable area.

10.5.3.7 Pumping of Boreholes

Pumping from the borehole shall not be permitted unless a casing has been placed into the stable stratum to prevent the further ingress of water in significant quantities from other strata into the boring, or, unless it can be shown that pumping will not have a detrimental effect on the surrounding soil or its properties.

10.5.3.8 Continuity of Construction

A pile constructed in stable soil, without the use of temporary casings or other support, shall be bored and concreted without delay to ensure that the soil characteristics are not significantly altered. Sandy clays or clayey silts may soften significantly in less than 12 hours. Where prolonged delay in construction arises, the bore may have to be backfilled with lean concrete as specified in Section 9 of this Specification or well compacted sand to minimise deterioration of the shaft. The time interval between completion of boring and placing of concrete should be preferably within 6 hours.

If the pile excavation is carried out using permanent or temporary casing, the time period between completion of pile excavation and completion of concreting is recommended not to exceed 24 hours.

10.5.3.9 Enlarged Pile Bases

The enlarged pile base shall not be smaller than the dimensions specified and shall be concentric with the pile shaft to within 10% of the shaft diameter. A sloping surface of the frustum forming the enlargement shall make an angle to the horizontal of not less than 55°. At the specified diameter of the under ream at the perimeter of the base there shall be a minimum height of 150mm.

10.5.3.10 Cleanliness of Pile Bases

On completion of boring, loose, disturbed or remoulded soil or fragments of rock shall be removed from the base of the pile.

10.5.3.11 Inspection

For dry boreholes, each hole shall be inspected prior to the placing of concrete in it. The inspection shall be carried out from the ground surface in the case where the borehole diameter is less than 1500 mm. Where the borehole diameter exceeds 1500 mm, adequate equipment shall be provided to enable the Contractor and the S.O. to descend into the borehole for the purpose of inspection. All works shall conform to the requirement of BS 5537: Safety Precaution in the Construction of Large Diameter Borehole for Piling and Other Purposes. For wet boreholes, i.e. holes filled with drilling fluid or water, a suitable probe shall be provided to ascertain the evenness and cleanliness of the pile base.

10.5.4 Placing of Reinforcement

10.5.4.1 Joints in Longitudinal Bars

Reinforcement shall be such that the full strength of the bar is effective across the joint and the joint shall be made so that there is no relative displacement of the reinforcement during the construction of the pile and the spacing of the reinforcing bars shall be maintained in such a way that proper concreting shall not be impeded.

10.5.4.2 Positions of Reinforcement

Adequate spacer blocks, guide tubes, and lifting wires shall be provided so as to maintain the reinforcing steel in the positions as specified.

Where temporary casings are employed, the longitudinal reinforcement shall extend at least 1.0 metre below the bottom of the casing so that movement of the reinforcement during extraction of the casing is minimised.

10.5.5 Concreting Operations

10.5.5.1 Placing Concrete

The method of placing and the workability of concrete shall be such that a continuous monolithic concrete shaft of the full cross-section is formed.

10.5.5.2 Workability of Concrete

The workability of the concrete shall be determined by the slump test as described in M.S. 26.

The suggested slump details for typical concreting situations shall be as specified in Table 10.2 of this Specification. The slump shall be measured at the time of discharge into the borehole.

10.5.5.3 Compaction

Internal vibrators shall not be used to compact concrete unless it can be satisfied that they will not cause segregation or arching of the concrete.

10.5.5.4 Placing Concrete In Dry Borings

Approved measures shall be taken to avoid segregation and bleeding and to ensure that the concrete at the bottom of the pile is not deficient in grout.

Where piles are vertical, concrete may be poured through a funnel with a length of tube so that the flow is directed and does not hit reinforcement bars or the side of the hole. Chutes extending to near the base shall be employed for raking piles of large diameter. For raking piles of small diameter, an enriched mix of 20% more cement shall be used in the first few batches of concrete to minimise segregation.

10.5.5.5 Placing Concrete Under Water or Support Fluid

The concrete mix shall be 20% more cement content when placing is done under water.

Concrete to be placed under water or support fluid shall be placed by tremie unless otherwise approved and shall not be discharged freely into the water or support fluid. Before placing concrete, measures shall be taken to ensure that there is no accumulation of silt or other material at the base of the boring.

The hopper and pipe of the tremie shall be clean and watertight throughout. The pipe shall extend to the base of the boring and a sliding plug or barrier shall be placed in the pipe to prevent direct contact between the first charge of concrete in the pipe of the tremie and the water or support fluid. The tremie pipe shall at all times penetrate the concrete which has previously been placed and shall not be withdrawn from the concrete until the completion of

concreting.

At all times, a sufficient quantity of concrete shall be maintained within the tremie pipe to ensure that the pressure from it exceeds that from the water or support fluid. The internal diameter of the tremie pipe shall not be less than 150 mm for concrete made with 20 mm aggregate and not less than 200 mm for concrete made with 40 mm aggregate.

The tremie pipe shall be so designed that external projections are minimised, allowing the tremie pipe to pass through the reinforcing cage without causing damage or uplifting. The internal face of the tremie pipe shall be from projections.

10.5.6 Extraction of Casing

10.5.6.1 Workability of Concrete

Temporary casings shall be extracted while the concrete within them remains sufficiently workable to ensure that the concrete is not lifted.

10.5.6.2 Concrete Level

When the casing is being extracted, a sufficient quantity of concrete shall be maintained within it to ensure that the pressure from external water, drilling fluid or soil is exceeded and that the pile is neither reduced in section nor contaminated.

No concrete shall be placed in the bore once the bottom of the casing has been lifted above the top of the concrete. It shall be placed continuously as the casing is extracted until the desired head of concrete is obtained.

Adequate precautions shall be taken in all cases where excess heads of water or drilling fluid could be caused as the casing is withdrawn because of the displacement of water or fluid by the concrete as it flows into its final position against the wall of the pile shaft. Where double casings are used in the boring, the proposed method of working shall be with the approval of the S.O.

10.5.6.3 Vibrating Extractors

The use of vibrating extractors shall be permitted subject to the condition that work shall be carried out in such a manner and at such times as to minimise nuisance and disturbance.

10.5.7 Construction of Pile Heads

10.5.7.1 Water Levels

In the event of the ground water level being higher than the required pile head casting level shown on the Drawings, the Contractor shall submit his proposals for approval prior to placing concrete. The pile head shall not be left below the ground water level unless approved precautions are taken.

10.5.7.2 Cutting and Preparation of Pile Heads

The top of the pile shall be brought at least 300 mm or more as specified in the drawings above the cut-off level of the pile to permit all laitance and weak concrete to be removed and to ensure that it can be properly keyed into the pile cap. Only hand held cutting equipment or hydraulic splitters shall be used. Pile heads shall be constructed to the details shown on the Drawings.

10.5.7.3 Temporary Backfilling Above Pile Casting Level

After each pile has been cast, any empty bore remaining shall be protected and shall be carefully backfilled as soon as possible with well compacted sand.

10.5.7.4 Piling Records

Complete piling records shall be kept by the Contractor during pile installation. The Contractor shall submit in duplicate the following information to the S.O:

i) Signed records of all piles as the work proceeds. Individual pile record shall be submitted not later than noon of the next working day after the pile was installed. The signed records shall form record of the work. Any unexpected installation condition shall be noted in the record.
ii) Upon completion, compile a record of the work as carried out and provide as-build drawings. The Drawings shall be prepared and endorsed by the Licensed Surveyor.

The format of the record shall be approved by the S.O. and shall contain but not be limited to the following information where applicable: -

- Date of concreting
- Concrete mix
- Method of concreting
- Standing ground water level
- Length of temporary casing
- Length of permanent casing
- Details of soil strata penetrated.
- Soil samples taken and in-situ tests carried out.
- Length and details of reinforcement.
- Estimated and actual volume of concrete required to form the pile shaft.

All record shall bear the names of person who records and person who checks.

10.5.8 Pressure Grouting of Piles

Post grouting of piles in sand shall be constructed to details as shown in the drawings if encounter any base disturbance to ensure compatible performance of piles. Method of grouting shall be carefully controlled to prevent pile uplift and avoid other potential problems with prior approval of the S.O.

Pressure grouting shall not be used to compensate for poor pile construction practice.

10.6 STEEL H-SECTION PILES

10.6.1 Description

This work shall comprise the supply and installation of steel H-section piles, inclusive of pitching and driving, lengthening and preparation of pile heads, all in accordance with this Specification and to the details shown on the Drawings.

10.6.2 Materials

All steel H-bearing piles shall comply with the requirement of BS EN 10025 and or BS EN 10029, BS EN 10210, BS EN 10113, BS 7668 or JIS A5526. The profile and grade to be used are as specified or as shown on the Drawings.

10.6.3 Manufacture and Storage of Steel H-Section Piles

10.6.3.1 Manufacturing Tolerances

All piles shall be of the type and cross-sectional dimensions as designed. For standard rolled sections the dimensional tolerances and weight shall comply with the relevant standard. Length tolerance of H-section steel bearing piles shall be ± 50 mm in accordance with BS EN 10034.

The rolling or proprietary tolerances for H-section steel bearing piles shall be such that the actual weight of the section does not differ from the theoretical weight by more than ± 2.5%.

10.6.3.2 Straightness of Sections

For standard rolled sections the deviation from straightness shall be within the compliance provisions of BS EN 10034. When two or more rolled sections are joined by butt-jointing, the deviation from straightness shall not exceed 1/600 of the overall length of the pile.

For proprietary sections made up from rolled sections and for tubular piles, the deviation from straightness on any longitudinal face shall not exceed 1/600 of the length of the pile nor 5 mm in any 3 m length.

Based on the results of pile driving resistance and/or load tests carried out on piles driven on the Site, the S.O. may from time to time order the lengths of piles to be modified.

10.6.3.3 Strengthening of Piles

Unless otherwise approved by the S.O., the strengthening of the toe of the pile in lieu of a shoe or the strengthening of the head of a pile shall be made from material of the same grade as the pile and to the details as shown on the Drawings.

10.6.3.4 Marking of Piles

Each pile shall be clearly marked with white undeletable marking at the flanged head showing its reference number and overall length. In addition, each pile shall be marked at intervals of 500 mm along its length before being driven. The length of piles to be supplied shall be as shown on the Drawings subject to revision by the S.O

10.6.3.5 Handling and Storage

All operations such as handling and transporting of piles shall be carried out in such a manner that damage to piles and their coatings is minimized. Piles that are damaged during handling and transporting shall be replaced by the Contractor at his own expense. All damaged and rejected piles shall be removed from the Site forthwith.

Piles within a stack shall be in groups of the same length and on approved supports.

10.6.4 Installation of Steel H-Section Piles

10.6.4.1 Pitching and Driving of Piles

Pitching and driving of piles shall be in accordance with Sub-Sections 10.3.4.1 and 10.3.4.2.

10.6.4.2 Lengthening of Piles

Where lengthening of piles is required, the piles shall be jointed by butt welding. Butt welded joints shall be stiffened with plates fillet welded on all four sides as detailed on the Drawings. All welding shall be continuous and complying with BS 638, BS EN 1011 and BS EN 1993 for arc welding and BS EN ISO 4577 for resistance welding as appropriate. The type and size of weld shall be as detailed on the Drawings.

Weld tests shall be performed by radiographic or ultrasonic methods as specified. Provided that satisfactory results are being obtained, one test of a length of 300 mm shall be made for 10% or more of the number of welded splices.

Redriving of the piles shall only be allowed after the welded joints have sufficiently air cooled to 100ºC or below.

10.6.4.3 Cutting and Preparation of Pile Heads

When a pile has been driven to the required set or depth and before encasing in concrete, the piles shall be cut to within 20 mm of the levels shown on the Drawings. Pile heads shall be constructed to the details as shown on the Drawings.

The remaining section which can be reused for lengthening of piles shall be stored and protected as directed by the S.O.

10.7 STEEL PIPE PILES

10.7.1 Description

This work shall comprise the supply and installation of steel pipe piles, inclusive of pitching and driving, lengthening and preparation of pile heads, all in accordance with this Specification and to the details shown on the Drawings.

10.7.2 Materials

All steel pipes shall comply with BS EN 10296, BS EN 10297 and BS EN 10305 with regard to sectional dimensions and the steel shall comply with the requirements of BS EN 10113 or BS EN 10025.

10.7.3 Manufacture and Storage of Steel Pipe Piles

10.7.3.1 Welding

Unless otherwise specified, all welds shall be full penetration butt welds complying with the requirements of BS EN 12334.

10.7.3.2 Fabrication of Piles

Pile lengths shall be set up so that the differences in dimensions are matched as evenly as possible. The length of piles to be supplied shall be as shown on the Drawings subject to revision by the S.O.

Based on the results of pile driving resistance and/or load tests carried out on piles driven on the Site, the S.O. may from time to time order the lengths of piles to be modified.

For tubular piles where the load will be carried by the wall of the pile, and if the pile will be subjected to loads that induce reversal of stress during or after construction, the external diameter at any section as measured by using a steel

tape on the circumference shall not differ from the theoretical diameter by more than ± 1%.

The ends of all tubular piles as manufactured shall be within a tolerance on ovality of ± 1% as measured by a ring gauge for a distance of 100 mm at each end of the pile length.

The root edges or root faces of lengths of piles that are to be shop butt-welded shall not differ by more than 25% of the thickness of pile walls not exceeding 12 mm thick or by more than 3 mm for piles where the wall is thicker than 12 mm. When piles of unequal wall thickness are to be butt-welded, the thickness of the thinner material shall be the criterion.

Pile lengths shall be set up so that the differences in dimensions are matched as evenly as possible.

10.7.3.3 Matching of Pile Lengths

Longitudinal shop seam welds and spiral seam welds of lengths of pipe piles forming a completed pile shall, whenever possible, be evenly staggered. However, if in order to obtain a satisfactory match of the ends of piles or the specified straightness, the longitudinal seams or spiral seams are brought closely to one alignment at the joint, then they shall be staggered by at least 100 mm.

10.7.3.4 Straightness of Piles

For standard rolled sections the deviation from straightness shall be within the compliance provisions of BS EN 10034 and in accordance with Sub-section 10.6.3.2.

10.7.3.5 Fabrication of Piles on Site

When pile lengths are to be made up on Site, all test procedures and dimensional tolerances shall conform to the Specification for the supply of pipe materials. Adequate facilities shall be provided for supporting and aligning the lengths of pile.

10.7.3.6 Handling and Storage

All piles within a stack shall be in groups of the same length and on approved supports. All operations such as handling, transporting and pitching of piles shall be carried out in a manner such that no damage occurs to piles and their coatings. Piles that are damaged during handling and transporting shall be replaced by the Contractor at his own expense. All damaged and rejected piles shall be removed from the Site forthwith.

10.7.3.7 Marking of Piles

Each pile shall be clearly marked with white undeletable marking near the pile head showing its reference number and overall length. In addition, each pile shall be marked at intervals of 500 mm along its length before being driven. The length of piles to be supplied shall be as shown on the Drawings subject to revision by the S.O.

10.7.4 Workmanship

10.7.4.1 Welding Procedures

The Contractor shall submit for approval, full details of the welding procedures and electrodes with drawings and schedules as may be necessary. Tests shall be undertaken as may be required by the S.O. and shall be in accordance with the requirements of BS EN 288.

All welding procedures shall have been qualified to BS EN ISO 15607, BS EN ISO 15609-1, BS EN ISO 15613 and BS EN ISO 15614-1 and the Contractor shall make available full details of the welding procedures and electrodes, with drawings and schedules as may be necessary. Tests shall be undertaken as may be required by the S.O.

10.7.4.2 Welders' Qualifications

All welding works shall be executed by qualified welders with valid certificate issued by approved Authorities such as Pusat Latihan Pengajar & Kemahiran Lanjutan (CIAST).

Only welders who are qualified to BS EN 287-1 or who have attained a similar standard shall be employed on the Works. Proof of welders' proficiency shall be made available on request by the S.O.

10.7.4.3 Weld Tests

During production of welded tube piles, at least one radiograph approximately 300 mm long shall be required on each completed length as a spot check on weld quality. This shall be taken on a circumferential or longitudinal weld and its position shall be as directed by the S.O.

For spirally welded piles, one of the following tests shall be carried out :-

i) For tubes of wall thickness 12 mm or less, three spot check radiographs, one at each end of each length of the tube as manufactured and one at a position to be chosen at the time of testing by the S.O.; and spot check radiographs as required by the S.O. on the weld joints between strip lengths;

ii) For tubes of any wall thickness, continuous ultra-sonic examination over the whole weld, supplemented where necessary by radiographs to investigate defects revealed by the ultrasonic examination.

Weld tests shall be performed by radiographic or ultrasonic methods as specified. Provided that satisfactory results are being obtained, one test of a length of 300 mm shall be made for 10% or more of the number of welded splices in the case where the load will be carried by the wall or section of the pile will not normally exceed 10%.

Results shall be made available to the S.O. within 10 days of completion of the tests.

10.7.4.4 Standards for Welds

Longitudinal welds in tubular piles

For piles of longitudinal or spiral weld manufacture where the load will be carried by the wall of the pile, and if the pile will be subject to loads which induce reversal of stress during or after construction other than driving stresses, the standard for interpretation of non-destructive testing shall be the American Petroleum Institute Specification 5L. The maximum permissible height of weld reinforcement shall not exceed 3.2 mm for wall thicknesses not exceeding 12.7 mm and 4.8 mm for wall thicknesses greater than 12.7 mm.

Circumferential welds

For circumferential welds in tubular piles the same maximum height of weld reinforcement as specified above for longitudinal welds in tubular piles shall apply, the standard for interpretation of non-destructive testing shall be the American Petroleum Institute Specification 5L.

If the results of any weld test do not conform to the specified requirements, two additional specimens from the same length of pile shall be tested. In the case of failure of one or both of these additional tests, the length of pile covered by the test shall be rejected.

10.7.5 Protective Coatings

The term ‘coating’ shall include the primer and the coats specified.

If protective coatings are specified, the preparation of surfaces and the application of the coatings shall be carried out by skilled labour having experience in the preparation of the coatings specified.

Corrosion protection of permanent steel structure in accordance with environment classified as C4 according to BS EN ISO 12944-2 shall require durability resistance of 25 years.

The protective coating system shall comply with BS EN ISO 12944-5 and shall comprise of at least:

i) First Coating or Prime Coat Zinc Epoxy of 0.08 mm thick
ii) 2 layers of Intermediate coating of 0.08 mm thick epoxy each layer
iii) Top coating of Polyurethane of 0.08 mm thick

10.7.5.1 Surface Preparation

Surface preparation to cleanliness SA 2 ½ in accordance with BS EN ISO 12944-4 and BS EN ISO 8501-1.

Blast-cleaning shall be done after fabrication. Unless an instantaneous-recovery blasting machine is used, the cleaned steel surface shall be air-blasted with clean dry air and vacuum-cleaned or otherwise freed from abrasive residues and dust immediately after cleaning.

10.7.5.2 Application and Type of Primer

Immediately after surface preparation, the surface shall be coated with an approved primer or the specified coating to avoid recontamination. No primer coat shall be applied to a metal surface which is not thoroughly dry. Within 4 hours after surface preparation, before visible deterioration takes place, the surface shall be coated with an appropriate primer or the specified coating.

The primer shall be compatible with the specified coating and shall be such that if subsequent welding or cutting is to be carried out it shall not emit noxious fumes or be detrimental to the welding.

10.7.5.3 Control of Humidity During Coating

No coating shall be applied when the surface metal temperature is less than 3°C above the dew point temperature or when the humidity could have an adverse effect on the coat.

When heating or ventilation is used to secure suitable conditions to allow coating to proceed, care shall be taken to ensure the heating or ventilation of a local surface does not have an adverse effect on adjacent surfaces or work already done.

10.7.5.4 Part to be Welded

The coating within 200 mm of a weld shall be applied after welding. The method of application shall comply with the manufacturer's recommendations.

10.7.5.5 Thickness, Number and Colour of Coats

The minimum dry film thickness of the finished coating, including the minimum dry film thickness of each coat and the minimum number of coats that are to be applied, shall be as specified and shown on the Drawings. Coatings shall be applied in accordance with the manufacturer's instructions.

The nominal thickness of the finished coating and each coat shall be as specified. The average coat or finished coating thickness shall be equal to or greater than the specified nominal thickness. In no case shall any coat or finished coating be less than 75% of the nominal thickness. Each coat shall be applied after an interval that ensures the proper hardening or curing of the previous coat.

Where more than one coat is applied to a surface, each coat shall be different colour from the previous coat. The colour sequence and final coating colour shall be established prior to application of coatings.

10.7.5.6 Inspection of Coatings and Acceptability

The finished coating shall be generally smooth, of a dense and uniform texture and free from sharp protuberances or pin holes.

Any coat damaged by subsequent processes or which has deteriorated to an extent such that proper adhesion of the coating may not be obtained or maintained, shall be recleaned to the original standard and recoated with the specified sequence of coats.

The completed coating shall be checked for thickness and continuity by an approved magnetic gauge or detector. Areas where the thickness is less than that specified shall receive approved additional treatment.

When specified, the completed coating shall be checked for adhesion by means of an adhesion test to BS EN ISO 2409, BS 3900-E6, carried out on 10% of the piles. The adhesion of any completed coating shall not be worse than Classification 2. If adhesion tests on the initial batch are satisfactory, then on further batches 1% of the piles shall be tested. Adhesion tests shall not be carried out until seven (7) days after coating.

10.7.6 Installation of Steel Pipe Piles

10.7.6.1 Pitching and Driving of Piles

Pitching and driving of piles shall be in accordance with Sub-Sections 10.3.4.1 and 10.3.4.2.

10.7.6.2 Lengthening of Piles

Unless otherwise approved, where lengthening of piles is required, the piles shall be jointed by butt welding along the entire periphery as detailed on the Drawings.

Redriving of the piles shall only be allowed after the welded joints have sufficiently air cooled to 100ºC or below.

10.7.6.3 Cutting and Preparation of Pile Heads

When a pile has been driven to the required set or depth and before encasing in concrete, the pile shall be cut to within 20 mm of the levels shown on the Drawings and protective coatings shall be removed from the surfaces of the pile head 100 mm above the soffit of the concrete. Pile heads shall be constructed to details as shown on the Drawings.

10.7.6.4 Concreting of Pile Shaft

If concreting is specified or shown on the Drawings after the pile has been cut off to the specified level, the shaft shall be filled with concrete in a continuous operation. The method of placing shall be approved by the S.O.

The reinforcement cage in the pile shall be made sufficiently rigid and kept in its correct position during concreting.

The length of the reinforcing bars projecting above the pile cut off level shall be as shown on the Drawings.

10.8 MICROPILES

10.8.1 Description

This work shall comprise the drilling of a hole, placing of reinforcement unit and subsequently filling the hole with grout to form micropiles, all in accordance with this Specification and to the details shown on the Drawings.

10.8.2 Materials

10.8.2.1 Reinforcement Unit

The type of reinforcement unit to be used, the diameter and/or thickness, grade, yield strength and working stress shall be as specified or as shown on the Drawings.

10.8.2.2 Grout

Unless otherwise specified, the grout shall be non-shrink cement grout. The grout mix design such as the water-cement ratio, the minimum cement and grout strength at 7 and 28 days shall be as specified and shown on the Drawings.

If admixtures are used, details of admixtures shall be submitted to the S.O. for approval before commencement of works. The use of the admixture shall fully comply with the manufacturer's instructions.

10.8.3 Drilling Operations

10.8.3.1 Diameter of Piles

The diameter of piles shall not be less than the specified/designed diameter at any level throughout its length and shall be in accordance with Sub-Section 10.5.3.1.

10.8.3.2 Drilling

The Contractor shall submit to the S.O. details of drilling equipment and drilling procedure for approval before commencement of works. Drilling operations shall be carried out in accordance with the relevant requirements of Sub-Section 10.5.3.

10.8.4 Grouting Operations

10.8.4.1 Mixing and Placing Grout

The Contractor shall provide details of the method and equipment used in grout mixing. Further information such as grouting pressure, grouting procedure, grouting equipment and techniques employed in grouting underwater shall also be furnished for approval.

Grout shall be mixed on Site and shall be free from segregation, slumping and bleeding. Grout shall be pumped into its final position in one continuous operation as soon as possible and in no case more than half an hour after mixing.

10.8.4.2 Testing Grout

Grout shall be tested in accordance with BS EN 12390 and BS EN 196.

Maximum bleed shall be limited to 5%.

If the grout cube as tested failed to satisfy the criteria as prescribed in specification and drawings, the pile constructed using this batch of grout shall be rejected. The contractor shall undertake all necessary additional

and consequential remedial works to the approval of S.O.

10.8.5 Construction of Pile Heads

10.8.5.1 Lengthening of Piles

Where lengthening is required, the pile reinforcement unit shall be connected on Site to the details shown on the Drawings. Other means of jointing reinforcement shall be to the approval of the S.O.

10.8.5.2 Cutting and Preparation of Pile Heads

Pile heads shall be constructed to the details as shown on the Drawings.

10.9 PILE TESTING

10.9.1 General

In order to verify the working load, the Contractor shall carry out pile load test as shown on the Drawings and / or as instructed by the S.O. The Contractor shall give at least 48 hours notice of the commencement of construction of any preliminary pile which is to be test-loaded.

The design and construction of the load application system shall be satisfactory for the required test. These details shall be made available prior to the commencement testing.

10.9.2 Construction of Pile to be Tested

10.9.2.1 Notice of Construction

The Contractor shall give at least 48 hours notice of commencement of construction of any preliminary pile which is to be tested.

10.9.2.2 Method of Construction

Each preliminary test pile shall be constructed in a manner similar to that to be used for the construction of the working piles and by the used of similar equipment and material. Extra reinforcement and concrete of increase strength will be permitted in the shafts of preliminary piles where necessary for carrying out the testing.

10.9.2.3 Boring or Driving Record

For each preliminary pile which is to be tested, a detailed record of the conditions experienced during boring or of the progress during driving, shall be made available daily, not later than noon on the next working day. Where soil samples are required to be taken or in-situ tests to be made, the Contractor shall present the results without delay.

10.9.2.4 Concrete Test Cube

Three (3) test cubes shall be made from the concrete used in the preliminary test pile and from the concrete used for building up the working pile. If the concrete pile is extended or capped for the purpose of testing, a further three (3) cubes shall be made from the corresponding batch of concrete. The cube shall be made and tested in accordance with Section 9 of this Specification.

The pile test shall not be started until the strength of the cubes taken from the pile exceed twice the average direct stress in any pile section under the maximum required test load and the strength of the cubes taken from the pile head or cap exceed twice the average stress at any point in the pile head or cap under the same load.

10.9.2.5 Cut-off Level

The cut-off level for the preliminary test pile/working piles shall be as specified on the Drawings or as directed by the S.O.

Where the cut-off level of working piles is below the ground level at the time of pile installation and where it is required to carry out a load test from that installation level, either allowance shall be made in the determination of the twice working load for friction which may be developed between the cut-off level and the existing ground level, or the piling may be sleeved appropriately or otherwise protected to eliminate friction which develop over the extended length.

10.9.2.6 Preparation for Pile Head for Testing

For a pile that is tested in compression, the pile head or cap shall be formed to give the plane surface which is normal to the axis of the pile, sufficiently large to accommodate the loading and settlement measuring equipment and adequately reinforced or protected to prevent damage from the concentrated application of load from the loading equipment.

For a pile that is tested in tension, means shall be provided for transmitting the test load axially without inducing moments in the pile. The connection between the pile and the loading equipment shall be constructed in such a manner as to provide strength equal to the maximum load which is to be applied to the pile during the test with an appropriate factor of safety on the structural design.

10.9.2.7 Supervision

The setting up of pile testing equipment shall be carried out under competent supervision and the equipment shall be checked to ensure that the setting-up is satisfactory before the commencement of load test.

All tests shall be carried out only under the direction of an experience and competent supervisor conversant with the test equipment and test procedures. All personal operating the test equipment shall have been trained in its use. The Curriculum Vitae of Tester(s) shall be submitted 48 hours prior testing works.

10.9.3 Protection of Testing Equipment

10.9.3.1 Protection from Weather

Throughout the test period, all equipment for measuring load and movement and beams shall be protected from adverse effects of sun, wind and precipitation. Temperature reading shall be taken at the start, end and at the maximum load of each loading cycle.

10.9.3.2 Prevention of Disturbance

Construction activities and person who are not involved in the testing processes shall be kept at a sufficient distance from the test to avoid disturbance to any unavoidable activity and its effects.

10.9.3.3 Notice of Test

The Contractor shall give at least 24 hours notice of the commencement of the test. No load shall be applied to the test pile before the commencement of the specified test procedure.

10.9.4 Method of Loading

10.9.4.1 Test Load

The test load shall be applied in one of the following ways: -

i) By means of a jack which obtains its reaction from kentledge heavier than the required load;
ii) By means of a jack which obtains its reaction from tension piles or other suitable anchors.

In all cases the Contractor shall ensure that when the hydraulic jack and load measuring device are mounted on the pile head, the whole system shall be stable up to the maximum load to be applied.

If in the course of carrying out a test, any unforeseen occurrence should take place, further loading shall not be applied until a proper engineering assessment of the conditions has been made and steps have been taken to rectify any fault.

Where an inadequacy in any part of the system might constitute a hazard, means shall be provided to enable the test to be controlled from a position clear of the kentledge stack or test frame.

The hydraulic jack, pump, hoses, pipes, couplings and other apparatus to be operated under hydraulic pressure shall be capable of withstanding a pressure of 1.5 times the maximum pressure used in the test without leaking. Test certificate shall be submitted before carrying the test.

The maximum test load expressed as a reading on the gauge in use shall be displayed and all operators shall be made aware of this limit.

When method (i) is used, care shall be taken to ensure that the centre of gravity of the kentledge is on the axis of the pile. The nearest edge of the crib supporting the kentledge stack shall not be closer than 1300 mm to the surface of the test pile. Kentledge shall not be used for testing raked piles.

When method (ii) is used, all anchor piles shall be at a distance of at least three (3) pile shaft diameters from the test pile, centre to centre, and in no case shall they be less than 2000 mm from the test pile.

If the anchor piles are to be permanent working piles, their levels shall be observed during application of the test load to ensure no residual uplift occurs.

Alternatively, the Contractor may propose the use of other types, patented or otherwise, in which case the requirements as below shall be fully complied with.

10.9.4.2 Contractor's Load Test System

The Contractor may propose to use other different types from those specified. The proposal shall be submitted to the S.O. at least 90 days before the date of testing. The suitability or adequacy of any system shall be determined by the S.O. In the event that the testing system proposed by the Contractor is acceptable, the Contractor shall obtain a Professional Engineer's endorsement on load settlement results.

10.9.4.3 Measuring Apparatus

The Contractor shall provide apparatus for measuring settlement consisting of a primary system, at least one auxiliary system, and a network of settlement reference points. Two fixed independent benchmarks at least 15 metre from the test site to monitor the settlement reference point shall be established. If desired, the auxiliary system may also be referenced to these benchmarks. All measuring devices, scales and reference points with numbers or letters to ensure accurate data recording shall be clearly identified.

10.9.4.4 Reference Beams and Displacement Measuring Devices

At least three (3) Linear Variable Differential Transformers (LVDT) and a Readout Unit are to be used for measuring the displacement. DC/DC–type displacement transducer having at least 75 mm of travel and a linearity of 0.5 % or less shall be used. A Readout Unit having a minimum display of 3 digits, capable of monitoring output from DC/DC – Type LVDT shall be provided.

The measurement devices parallel to the longitudinal axis of the test pile and the axis of load application shall be aligned.

An independent reference beam or beams shall be set up to enable measurement of the movement of the pile to be made to the required accuracy. The supports for beam shall be founded in such a manner and at such a distance from the test pile and reaction system that movement of the ground do not cause movement of the reference beam or beams which will affect the accuracy of the test. Embedded

the references beam supports at least 3000 mm into the crown at a horizontal distance of not less than 3000 mm or 10 times pile diameters (whichever is greater) from the closest face of the test pile and from any reaction piles or supports for the weighted box of platform shall be provided. The beam must be free to move horizontally at one end.

A clear distance of 150 mm to 300 mm from the test pile to the references beam or any projection used to support LVDT shall be maintained. The beam and projections should be at about the same elevation as the attachments to the pile on which the measuring devices will bear. The LVDT supports to references beam shall be attached so as to allow the stem of each device to rest on a attachment to the pile sides. Hardway and pile attachment for LVDT devices shall be mounted using such materials as brass, aluminium or 303 series stainless steel, to avoid magnetic interference which the instruments. The pile attachments are angles, about 75 mm x 100 mm with the 100 mm dimension projecting from the pile. For round pile, these attachments shall be placed on the perimeter of the pile at a 120 degrees and an equal radial distance. For pile of other cross section, the attachments shall be placed at a convenient location as approved by the S.O.

Observation of any movements of the reference beam or beams shall be made and checking of the movement of the pile head relative to a remote reference datum shall be made and stopped at maximum load for each loading.

10.9.4.5 <u>Auxiliary Systems</u>

This measuring system shall consist of one or more of the following: wire, mirror and scale; surveyor's level and target road; or, as alternatives, electrical or optical levels.

i) Wire, mirror and scale

Pile movement shall be determined by means of a single strand of wire drawn in front of graduated scale mounted on a mirror. This scale, at least 150 mm long and machine-divided in graduations of 250 μm, is mounted on a 75 mm x 150 mm mirror with metal and glass bonding adhesive or electrical tape. The mirror shall be attached directly to the pile oriented so that the mirror face is parallel to the reference beam. The mirror shall be mounted to the wire between the ends of the reference beam, with one end fixed and the other is placed over a pulley with a weight in order to maintain tension. The wire shall be located so that it is level and within 20 mm of the mirror face.

ii) Optical levelling method

An optical levelling method by reference to a remote datum may be used.

Where a level and levelling rod are used, the level and scale of the levelling rod shall be chosen to enable readings to be made to within an accuracy of 0.5 mm. A scale attached to the pile or pile cap may be used instead of levelling rod. At least two (2) reliable independent datum

points shall be established. Each datum point shall be so situated as to permit a single setting up position of the level for all readings.

No datum point shall be located where it can be affected by the test loading or other operations on or off the Site.

iii) Alternative Systems

Any other type of electrical or optical gauge yielding a precision equivalent to the primary system is acceptable as and alternative, provided prior written approval is obtained from the S.O.

10.9.4.6 Measurement of Load

The test load shall be measured by a single load cell or proving ring calibrated in divisions not exceeding 1% of the maximum load to be applied. If an electronic transducer is used, each reading shall be immediately saved so that in case of power failure the readings are not lost.

The load cell or proving ring shall be calibrated immediately prior to the test and a Certificate of Calibration shall be made available.

All increments of load shall be maintained to within 1% of the specified load.

A spherical seating of appropriate size shall be used to avoid eccentric loading. Care shall be taken to avoid any risk of buckling of the load application and measuring system. Load measuring and application devices shall be in short axial length in order to secure stability. The Contractor shall ensure that axial loading is maintained.

The loading equipment shall enable the load to be increased or decreased smoothly or to be held constant at any required value.

10.9.4.7 Measurement of Settlement

Settlements shall be measured by use of a reference beam or wire supported independently of the load test pile, reaction pile or piles supporting reaction loads. Settlements shall be measured to the nearest 0.1 mm for reference beams or 0.5 mm for reference wires. The reference beam supports shall be located at least 3 mm from the load test pile, reaction pile or pile supporting reaction loads. The reference beams or wires shall be protected from the effects of temperature changes.

10.9.5 Testing Procedure

10.9.5.1 General

Maintained Load Tests shall be conducted on test piles as selected by the S.O. The loading tests shall be carried out in accordance with Sub-Section 10.9.5.2.

Prior to the performance of any load test, the Contractor shall submit to the S.O. for his approval, working drawings showing the method and equipment he proposes to use in the performance of the load test and the measurement of settlements. Such submission shall include design calculations of lateral supports or other methods to be used in ensuring against buckling. Horizontal supports to ensure bucking stability shall be provided to the pile to be loaded whenever the ratio of the unsupported height to the least cross-sectional dimension is 20 or more. Horizontal supports shall provide full support without restraining the vertical movement of the pile in any way.

10.9.5.2 Maintained Load Test

The Maintained Load Test shall be carried out as follows: -

i) The Full Test Load (FTL) on a pile shall be twice the Working Load (WL) noted on the Drawings and it shall be as specified in Table 10.3 of this Specification.

Following each application of an increment of load, the load shall be maintained at the specified value for not less than the period shown in Table 10.3 and until the measured rate of settlement in a period of 30 minutes is less than 0.5% of the current cumulative settlement which has occurred, subject to a minimum settlement rate of 0.05 mm in 30 minutes. The rate of settlement shall be calculated from the slope of the line obtained by plotting values of settlement versus time and drawing a smooth curve through the points.

During testing, if the result from the each LVDT differs by more than 20%, the Contractor shall release the load and recheck the arrangement of the load cell and redo the load test.

ii) Settlement readings shall be made immediately after and before every load increment is applied or removed.

10.9.6 Submission of Results

Full test data and results from the readout unit shall be jointly signed by the S.O.'s representative and the Contractor's authorised agent immediately upon completion of the maintain load test, and shall consist of the following: -

i) Stage of Loading
ii) Period for which the load was held
iii) Final load and load increment
iii) Maximum settlement

These are to be plotted as time-settlement graphs: -

i) For the Maintained Load Test, for each stage of loading, the period for which the load was held, the load and the maximum settlement. These are to be plotted as time-settlement graphs.

10.9.6.1 Interpretation of Test Results

The S.O.'s interpretation and conclusions on the test results shall be final. Unless otherwise specified, the pile so tested shall be deemed to have failed if: -

i) The residual settlement after removal of the test load at working load exceeds [(diameter of pile or diagonal width for non-circular pile / 120) + 4] mm or 12.50 mm whichever is the lower value; or
ii) The total settlement under the Working Load exceeds 12.50 mm; or
iii) The total settlement under twice the Working Load exceeds 38.0 mm, or 10% of pile diameter / width whichever is the lower value.

10.9.7 Completion of a Test

10.9.7.1 Removal of Test Equipment

On completion of a test, all measuring equipment and load application devices shall be dismantled and checked. All other test equipment, including kentledge, beams and supporting structures shall be removed from the test pile location. Measuring and other demountable equipment shall be stored in a safe manner so that it is available for further tests, if required, or removed from site.

Temporary tension piles and ground anchorages shall be cut off below ground level and off-cut materials removed from the site. The ground shall be made good to the original commencing surface level.

10.9.7.2 Preliminary Test Pile Head

Unless otherwise specified, the head of each preliminary test pile shall be cut off below ground level, and off-cut materials removed from the site. The ground shall be made good to the original commencing surface level.

Table 10.1 - Specification of Precast Concrete Piles

Piles		Minimum Concrete Strength (N/mm^2)	Minimum Longitudinal Reinforcement	Minimum Cement Content (kg/m^3)	Type of Driving
Type	**Class**				
RC	M	45	1.2 % of cross sectional area	400	Hammer driven
	J	45	1.0 % of cross sectional area	400	Hammer driven
Spun pile	A	60	Minimum effective prestressed of 4 N/mm^2	420	Hammer driven
	B	60	Minimum effective prestressed of 5 N/mm^2	420	Hammer driven
	C	60	Minimum effective prestressed of 7 N/mm^2	420	Hammer driven
PC	X	60	Minimum effective prestressed of 5 N/mm^2	420	Hammer driven
	Y	60	Minimum effective prestressed of 7 N/mm^2	420	Hammer driven
PCS	1	60	Minimum effective prestressed of 3.5 N/mm^2	420	Hammer driven
	2	55	Minimum effective prestressed of 3.5 N/mm^2	420	Jacked-in
RCS	1	45	1.0 % of cross sectional area	400	Hammer driven
	2	45	0.8 % of cross sectional area	400	Jacked-in

NOTES:
1. Concrete strength means *characteristic compressive strength* at 28 days.
2. The nominal sizes and length for each class of piles are specified in Parts 3, 4, 5 or 6 of Malaysian Standard, whichever relevant.

Definitions:
1 Precast reinforced concrete square pile (RC pile)
A pile made of concrete cast in a uniform four-sided cross section before driving into the ground. It shall be suitably reinforced mainly with steel bars.
2 Precast prestressed concrete square pile (PC pile)
A pile described in definition No. 1 but suitably reinforced mainly with prestressing steel.
3 Precast pretensioned spun concrete pile (Spun pile)
A hollow cylindrical pile made of concrete cast by centrifugal spinning before driving into the ground. It shall be suitably reinforced mainly with pretensioned prestressing steel.
4 Small prestressed concrete square pile (PCS pile)
A small PC pile for sizes 200mm and less.
5 Small reinforced concrete square pile (RCS pile)
A small RC pile for sizes less than 200mm.

Table 10.2 - Slump Range for Typical Concreting Situations

Typical Conditions of Use	Slump Range (mm)
Placed into water-free unlined bore. Widely spaced reinforcement leaving room for free movement between bars.	75 to 125
Where reinforcement is not spaced widely enough to give free movement between bars. Where casting level of concrete is within the casing. Where pile diameter is less than 600 mm.	100 to 175
Where concrete is to be placed by tremie under water or drilling fluid.	150 to collapse

Table 10.3 – Minimum Holding Time for Pile Test

Load	Minimum Time of Holding Load
25% WL	30 minutes
50% WL	30 minutes
75% WL	30 minutes
100% WL	6 hours
75% WL	10 minutes
50% WL	10 minutes
25% WL	10 minutes
0	1 hours
100% WL	1 hour
125% WL	1 hour
150% WL	1 hour
175% WL	1 hour
200% WL	6 hours
150% WL	10 minutes
100% WL	10 minutes
50% WL	10 minutes
0	1 hour

WL = Working Load

APPENDIX

Appendix A/1

Bending Strength for Precast Concrete Piles

Pile Body Strength Test

General

Bending strength test on the pile body shall be done to determine the ability of the pile to withstand the cracking bending moment (*M*c) and the ultimate bending strength (*M*u). The bending strength test of pile body shall be made by the application of vertical load *P* to the centre of the span, on the pile laid on two supports which has a span equal to 3/5 of its length.

The applied bending moment shall be calculated from the following equation: -

$$M = \frac{1}{40}WL + \frac{P}{4}\left(\frac{3L}{5} - 1\right)$$

Where,

M is the applied bending moment (kNm);
W is the weight of pile (kN);
L is the length of pile (m); and
P is the applied load (kN)

The cracking bending moment (M_c)

The pile shall be designed to withstand the cracking bending moment calculated based on the maximum allowable crack width as shown in Table 1. The pile is considered to have passed the requirement to withstand the cracking bending moment if when subjected to a test load equal to the cracking load (P_c) corresponding to the appropriate M_c, no crack exceeding the values in Table 1 occurs. The calculated values of M_c are given in Table 2, Table 3 and Table 4.

Table 1- Maximum Allowable Crack Width

	Types of pile	Maximum crack width (mm)
1	RC pile	0.20
2	Spun pile	0.05
3	PC and PCS pile	0.10
4	RCS pile	0.20

The ultimate bending moment (M_u)

The pile shall be tested to the largest applied load (P_{max}) until the pile failure occurs or until the applied load slightly exceeds the minimum ultimate load ($P_{min\text{-}u}$) which corresponds to the minimum ultimate bending strength, whichever comes first.

The minimum ultimate bending strength ($P_{min\text{-}u}$) is obtained by multiplying the cracking bending moment (M_c) by the factor *'f'* as given in.

The pile is considered to have passed the bend test if the pile does not fail when subjected to $P_{\mathbf{min\text{-}u}}$ load.

Testing

Apparatus setup

The pile manufacturer shall design and fabricate a suitable set-up for carrying out the bend test. The test shall be carried out using any suitable equipment of sufficient capacity and capable of applying the loads continuously and vertically.

The loading arrangement and the device for applying the loads shall consist of two supporting rollers and two load-applying rollers as in Figure 1.

All rollers shall be manufactured from steel and shall have a circular cross-section with a diameter of 20 mm to 120 mm; the rollers shall be at least 20 mm longer than the width of the test specimen. All rollers except one shall be capable of rotating around their axes and of being inclined in a plane normal to the longitudinal axis of the test specimen. All rollers shall be adjusted in their correct positions with all distances having an accuracy of ± 5 mm. Suitable safety precaution should be taken to ensure that the rollers do not fall off while adjustment is made and during the testing.

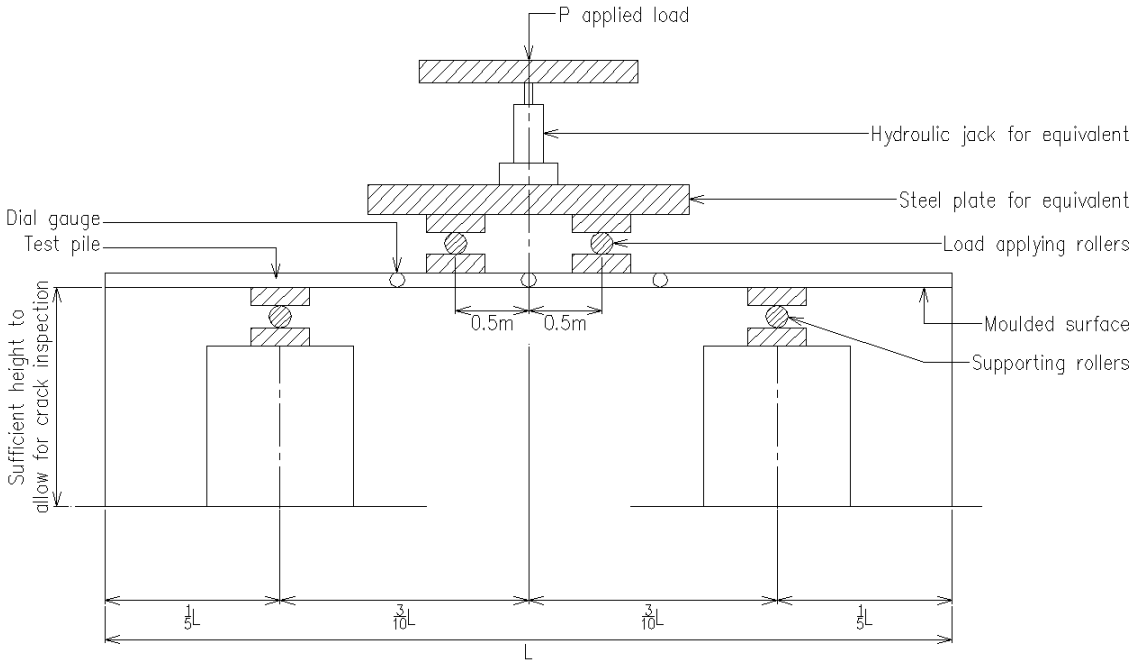

Figure 1- Loading Method

Rate of loading

The load shall be applied at the rate of (0.06 ± 0.04) N/mm^{2}s using suitable equipment which shall be capable of applying the load uniformly without shock using manual or automatic control.

Load pacers

If the equipment is not equipped with a device to maintain, automatically, the specified rate of increase of load on the specimen, a load pacer shall be fitted or alternatively the control shall be done by manual method to ensure the rate of loading as describe in the paragraph above is complied. If the pacer has a scale, this scale shall be basically linear such that 1 mm represents not more than 100 N/s.

Over the operating range of the scale the accuracy shall be within ± 5 %.

NOTE. The pacer may incorporate a scale with an indicator or alternatively, it may be, for example, a marked disc or pointer, which rotates at the rate at which, the load pointer should move on the load scale being used. If the pacer is fitted with a variable speed control or has preset speeds, then once the variable speed control has been set, or preset speed has been chosen, the pacer speed shall remain within ± 5 % of the specified speed over the operating range.

Alternatively if the rate of loading is controlled manually then the manufacturer shall prepare the table of loading application against time.

Load scale indicators or digital displays

The equipment shall be provided with either: -
a) Easily read dials or scales; or
b) Electrical load indicators, which shall include a visual display.

These load scale indicators or digital displays shall be calibrated by an accredited laboratory.

Test specimens

Test specimens shall be selected randomly from piles casted and results shall be properly documented for inspection. The number of piles to be sampled is to be decided in accordance with the agreement between the parties concerned.

Procedure

1. Prior to testing, select a suitable load and time increment for a selected loading rate for particular hydraulic equipment such that it will facilitate inspection of the pile at the calculated crack load and at the required minimum ultimate load.

2. Check the specimens thoroughly for initial crack before testing. Wipe clean the bearing surfaces of the supporting and loading rollers.

3. Place the test specimen on the support rollers, correctly centred with the longitudinal axis of the specimen at right angles to the rollers. The trowelled surface direction shall be normal to the direction of loading and the moulded surface is in tension (see Figure 1). The moulded surface may not therefore be orientated with its position in the structure. For Spun piles, the test specimen can be placed at any surface position. Do not use packing between the specimen and the rollers.

4. Place the loading equipment and the load applying rollers correctly in the testing setup. Do not begin to apply the load until all loading and supporting rollers are in even contact with the test specimen.

5. Apply the load steadily and without shock at a rate of (0.06 ± 0.04) N/mm^2s. Choose the lower loading rates for low strength concrete and the higher loading rates for high strength concrete (i.e. for RC Piles, f_{cu} more than 45 N/mm^2).

6. Once the loading rate has been adjusted, maintain the rate of loading without change until the applied crack load (P_c) corresponding to crack moment (M_c) from the respective tables 2, 3 and 4 as shown below is reached. Then hold the load for a sufficient time to inspect the pile for possible cracking. If crack is present, it shall be checked by means of the test crack measuring gauge and crack width and the location shall be recorded.

7. After step 5.6, continue the loading at the same uniform rate until failure occurs or when the applied load is slightly greater than the minimum ultimate load (P_{min-u}), whichever comes first. The minimum ultimate load (P_{min-u}) is a value corresponding to the value of M_c multiplied by the factor *f* from the respective tables 2, 3 and 4 as shown below.

8. If pile failure comes first, the test specimen is considered fail. Record the maximum load (P_{max}) applied. P_{max} is the maximum applied load (kN), if and when pile failure occurs during the bend test.

9. If the pile does not fail, and when the applied load is slightly greater than P_{min-u} is reached, then hold the load for sufficient time to allow for inspection of pile body for cracking. If crack is present, it shall be checked by means of the test crack-measuring gauge and crack width and location shall be recorded.

10. For record purposes, record all the deflection of test specimen shown by dial gauge during loading and unloading.

Table 2 - Cracking Bending Moment (M_c) and Factor *'f'* for Precast Reinforced Concrete Square Piles (RC Piles)

Nominal Pile Size (mm x mm)	Cracking Bending Moment, Mc (kN-m)		*'f'*	
	Class M	Class J	Class M	Class J
200 x 200	8.3	7.3	1.5	
225 x 225	-	-		
250 x 250	13.1	11.6	1.8	
275 x 275	-	-		
300 x 300	22.1	19.6	2.0	
325 x 325	-	-		
350 x 350	33.7	29.8		
375 x 375	-	-		
400 x 400	47.9	42.5		
450 x 450	65.0	57.8		

Table 3 - Cracking Bending Moment (M_c) and Factor *'f'* for Precast Pretensioned Spun Concrete Piles (Spun Piles)

Nominal Diameter (mm)	Class	Minimum Concrete Strength (N/mm^2)	Cracking Bending Moment (M_c) (kNm)	Factor *'f'*	Effective Prestress (N/mm^2)
250	B	60	12	1.5	5.0
300	A	60	17	1.5	4.0
	B	60	20	1.5	5.0
350	A	60	26	1.5	4.0
	B	60	30	1.5	5.0
400	A	60	38	1.5	4.0
	B	60	43	1.5	5.0
	C	60	54	1.8	7.0
450	A	60	53	1.5	4.0
	B	60	60	1.5	5.0
	C	60	76	1.8	7.0
500	A	60	74	1.5	4.0
	B	60	84	1.5	5.0
	C	60	106	1.8	7.0
600	A	60	123	1.5	4.0
	B	60	141	1.5	5.0
	C	60	177	1.8	7.0
700	A	60	191	1.5	4.0
	B	60	218	1.5	5.0
	C	60	273	1.8	7.0
800	A	60	278	1.5	4.0
	B	60	318	1.5	5.0
	C	60	399	1.8	7.0
900	A	60	390	1.5	4.0
	B	60	445	1.5	5.0
	C	60	558	1.8	7.0
1000	A	60	527	1.5	4.0
	B	60	601	1.5	5.0
	C	60	755	1.8	7.0
1200	A	60	853	1.5	4.0
	B	60	973	1.5	5.0
	C	60	1217	1.8	7.0

Table 4 - Cracking Bending Moment (M_c) and Factor *'f'* for Precast Prestressed Concrete Square Piles –Class PC-X, Class PC-Y, Small Piles

Size (mm)	Class of Pile	Minimum Concrete Strength (N/mm^2)	Minimum Effective Prestress (N/mm^2)	Cracking Bending Moment, M_c (kNm)	Factor *'f'*
125	PCS-1	60	3.5	2.9	1.5
	PCS-2	55	3.5	2.9	1.5
150	PCS-1	60	3.5	4.9	1.5
	PCS-2	55	3.5	1.5	1.5
175	PCS-1	60	3.5	7.8	1.5
	PCS-2	55	3.5	7.8	1.5
200	PCS-2	55	3.5	11.7	1.5
	PC-X	60	5.0	13.7	1.5
	PC-Y	60	7.0	16.4	1.7
250	PC-X	60	5.0	26.5	1.5
	PC-Y	60	7.0	31.7	1.7
300	PC-X	60	5.0	45.2	1.5
	PC-Y	60	7.0	54.2	1.7
350	PC-X	60	5.0	70.9	1.5
	PC-Y	60	7.0	85.2	1.7
400	PC-X	60	5.0	104.5	1.5
	PC-Y	60	7.0	125.9	1.7
450	PC-X	60	5.0	147.0	1.5
	PC-Y	60	7.0	177.4	1.7