

## **N - PILING WORK**

### **1.0 GENERAL REQUIREMENTS**

#### **1.1 *General***

Unless otherwise specified, all pilings shall comply in all respects to CP 2004. All materials and workmanship for piling shall be in accordance with the appropriate sections of this specification.

#### **1.2 *Soil Investigation Reports***

Any information and reports on site investigations for the works made available to Tenderers are intended for guidance only. The S.O. shall not be responsible for the scope, completeness or accuracy of the information, or for any opinions or conclusions given in the reports.

#### **1.3 *Handling of Piles***

All piles shall be handled with great care. Any piles cracked or damaged during handling shall not be used in the works and shall be replaced by the Contractor at no extra cost to the Government.

#### **1.4 *Pitching and Driving of Piles***

Piles shall be pitched accurately and driven to the lines and levels as shown on the drawing. During and after completion of piling, the pile head shall not be more than 75mm off-centre in any one direction from its required position. Piles deflected from vertical with an eccentricity larger than this shall, where ordered by S.O. be extracted or re-pitched until the proper line is obtained. No forcible method of correction will be permitted. The cost of such extraction or re-driving, or any extra cost in a modified foundation shall be borne by the Contractor if the opinion of the S.O. such extra works has been occasioned by the negligence of the Contractor.

During driving, the Contractor must ensure that the piles head are properly protected.

The head of pile shall at all times be central with the hammer and normal to the length of the pile and the pile shall not run out of position relative to the leaders.

Where cracks or fissures appear in pile while it is being driven, the pile shall be rejected.

#### **1.5 *Pile Driving Plant***

The weight of hammer, height of drop and set to be achieved shall be approved by the S.O. In general, for heavy piles the weight of the hammer shall be at least equal to the weight of the pile for hard driving conditions and not less than half of the weight of the pile for easy driving.

The plant used for pile driving shall be of such type and capacity with the approval of the S.O.

## **1.6 Extension of Piles**

As the result of measurements of the driving resistance or load bearing capacity of piles driven, the S.O. may order the lengths of piles to be modified either by lengthening in-situ or by providing a longer initial length of pile.

Where piles have to be further extended with extension piles, they shall be brought up to the required length by addition of an extension pile as shown on the Drawing. The extension pile shall be placed in alignment and jointed as shown on the Drawing.

## **1.7 Piling Programme**

The Contractor shall submit to the S.O. his proposed programme for the execution of the piling work at least seven days before commencement of the work. In addition, the Contractor shall inform the S.O. daily of the programme of the piling for the following working day and shall give adequate notice of this intention to work outside working hours, if this has already been approved by the S.O.

## **1.8 Records**

The Contractor shall maintain a record of driving of all piles giving sets and other data listed below or as required by the S.O. to whom the records shall be submitted. All piles shall be driven to such final sets or depths as may be approved by the S.O.

Piling Records shall include the following details:

- Contract particulars.
- \*\*Pile type.
- Pile reference number (location).
- Nominal cross-sectional dimensions or diameter.
- Length of preformed pile.
- Date and time of starting and finishing and redriving.
- Ground level at commencement of installation of pile.
- Cut - off level
- Type, weight, drop and mechanical condition of hammer and equivalent information for other equipment.
- Number of types of packing used and type and condition of dolly used during driving of the pile.
- \*\*Pile driving log.
- \*Set of pile in mm per blows or number of blows per 25mm of penetration.
- \*If required, the sets taken at intervals during the driving.
- \*If required, temporary compression of ground and pile from time of marked increase in driving resistance until pile reaches its final level.
- All information regarding obstructions, delays and other interruptions to be sequence of work.

# SYABAS' STANDARD SPECIFICATION FOR PIPE LAYING WOKS

First Edition : May 2007

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\*\* e.g. *Pre-cast concrete, timber or bakau; vertical or rake; compression or tension; friction or and bearing or both.*

\* *Not applicable to Bakau piles*

Immediately after a pile has been completely driven a record shall be made of the reduced level of the pile head and further checks shall be made on the level of the pile head and further checks shall be made on the level of each pile head after the driving of adjacent piles. Should any pile heave upwards it shall be re-driven to its original level or, if necessary, until its specified set is again obtained.

Any unexpected driving conditions shall be noted in the records.

## **1.9 Nuisance and Damage**

The Contractor shall take all necessary precaution in carrying out the work to minimize noise and disturbance during driving.

The Contractor is deemed to have familiarized himself with the risks likely to be imposed on adjacent structures and all utilities by the proposed method of piling.

Before commencing any piling work, the contractor shall accompany the S.O on a site inspection in order to consider any circumstances which may indicate the presence of underground mains at or in the vicinity of the site. If, during execution of the works damage is, or is likely to be caused to any utilities or adjacent structures, the Contractor shall submit to the S.O. his proposal for repair or avoidance of such damage.

## **1.10 Safety Precaution**

The Contractor shall take safety precautions throughout the piling operations in accordance with the requirements of the relevant laws and by-laws and to the approval of the S.O.

## **1.11 Definition**

A preliminary pile is a pile installed before the commencement of the main piling works for the purpose of establishing the driving criteria for subsequent working piles and for conforming the adequacy of the design, dimensions, and bearing capacity. The pile shall be treated as a working pile unless otherwise directed by the S.O.

A working pile is a pile which is installed as part of the permanent foundation works.

Where a pile test is carried out, the ultimate load is defined as the constant load at which the pile continue to settle at a steady rate or the load at which the maximum settlement of the pile test during one continuous loading cycle is one tenth of the pile base diameter or least dimensions, which ever is the lesser.

# SYABAS' STANDARD SPECIFICATION FOR PIPE LAYING WOKS

First Edition : May 2007

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Where a pile test is not carried out, the ultimate load is defined as the calculated ultimate load, derived from appropriate static bearing capacity calculations. The design load shall be defined in relation to pile loaded in isolation, without nearby piles being loaded except those providing test reaction.

Where the ultimate load is measured by means of pile tests, the design load is the ultimate load divided by the specified factor of safety.

Where the ultimate load is not measured by means of pile tests, the design load is the lesser of the following:

- The calculated ultimate load for the pile divided by the specified factor of safety.
- The calculated load of the pile base together with the calculated shaft adhesion, as derived from appropriate static bearing capacity calculations divided by a factor of safety of 3.0

Unless otherwise specified, the factor of safety shall be taken as not less than 2.0 for piles in compression and not less than 3.0 for piles in tension.

The working load is the design load modified to allow for group effect, pile spacing or any other factors changing the efficiency of the total foundation from that of a single isolated pile and is at least equal to the dead plus imposed loads on the pile together with down drag or up lift loads appropriate.

## **2.0 PRE-CAST REINFORCED CONCRETE PILES**

### **2.1 *General***

The materials to be used and workmanship for pre-cast reinforced concrete piles shall be as specified under concrete works. The type of mix used shall be as those shown in the Drawings.

### **2.2 *Reinforcement***

The main reinforcing bars in piles not exceeding 12m in length shall be in one continuous length unless otherwise approved by the S.O.

In the piles exceeding 12m long, joints will be permitted in main longitudinal bars at 12m nominal intervals. Joints in adjacent bars shall be staggered at least 1m apart along the length of the pile. Joint shall be butt-welded as specified in concrete work. Other means of jointing reinforcement, such as by means of mechanical couplings shall be to the approval of the S.O.

### **2.3 *Pile Shoes***

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

- “Chilled-hardened” cast iron shoes as used for making grey iron casting to BS 1452, Grade 10; or
- Mild steel to BS 4360, Grade 50B; or
- Cast steel to BS 3100, Grade A.

Mild steel straps cast into the shoes shall be as shown in 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 in the Drawings.

## **2.4 Formwork and Casting of Pile**

Pile units shall be cast in one continuous operation on a horizontal platform in approved moulds to the dimensions as shown in the Drawings. The moulds shall be thoroughly cleaned before casting and the assembled reinforcement lowered into the mould and held in position from top. Lifting holes shall be formed during casting in the positions and in accordance with the details shown in the Drawings.

After casting the piles, shuttering shall be removed in the presence of the S.O. Failure by the Contractor to observe this requirement may result in rejection of the pile concerned. Any pile showing signs of honey combing or other defects on removal of the shuttering shall be repaired to the approval of the S.O. before it is used in the works.

## **2.5 Curing, Stripping, Handling and Storage of Piles**

Piles shall be kept damp for a period of at least 10 days after casting. Side shuttering may be stripped after 4 days and bottom boards 14 days after casting, provided the piles are kept supported on level blocks spaced not more than 2 metres apart. After 14 days the piles may be lifted and removed to a suitable stacking point, but no pile shall be driven until it is at least 28 days old.

Each pile shall be clearly marked with date of casting and graduated in 300mm by painting. All stacks shall be arranged to facilitate the removal of piles for driving in their correct age order.

The method and sequence of lifting, handling, transporting and storing piles shall be such that piles are not damaged. 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.

## **2.6 Tolerance in Piles Dimension**

The cross-sectional dimensions of the pile shall not be less than those shown in the Drawings and not exceed them by more than 6mm.

Any face of the pile shall not deviate by more than 6mm from a straight edge 3m long laid on the face, and the centroid of any cross-section of the pile shall not

deviate by more than 12mm from the straight line connecting the centroids of the end faces of the pile.

## **2.7**      ***Length of piles***

The length of a pile shall be taken to the mean overall length measured from the tip of the shoes to the top of the head. The length of the piles to be cast shall be to the approval of the S.O. Based on the results of piles 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.

## **2.8.**      ***Pitching and Driving***

The equipment to be used shall be of such type and capacity to the approval of the S.O. If drop hammer is used, it shall be of a free fall type and the weight of the hammer shall be as specified in of CP 2004.

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 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.

Each pile shall be driven continuously until the specified set and/or depth has been reached. However, the S.O. may permit the suspension of driving if he is satisfied that the rate of penetration prior to the cessation of driving will be substantially re-established on its resumption or he is satisfied that the suspension of driving is beyond the control of the Contractor.

A follower (long dolly) shall not be used for driving end bearing piles. It may be used for driving frictional piles with prior approval of the S.O.

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 behavior of the piles. A set shall be taken only in the presence of the S.O. The Contractor shall provide all facilitate to enable the S.O to check driving resistances.

Redrive checks, if required, shall be carried out in accordance with an approved procedure.

A detail 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 300mm of pile penetration.

The final set of a pile other than as friction pile, shall be recorded either as the penetration in millimetres per 10 blows or as the number of blows required to produce a penetration of 25mm.

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

# SYABAS' STANDARD SPECIFICATION FOR PIPE LAYING WOKS

First Edition : May 2007

- The exposed part of the pile shall be in good condition, without damage or distortion;
- The dolly and packing shall be in sound condition;
- The hammer blow shall be in line with the pile axis and the impact surfaces shall be flat and at right angle to the pile and the hammer axis.
- The hammer shall be in good condition and operating correctly;
- The temporary compression of the pile shall be recorded if required.

Piles shall be driven in an approved sequence to minimize the detrimental effect of heave and lateral displacement of the ground. When required, levels and measurement shall be taken to determine the movement of the ground or any pile resulting from the driving process. If any pile rise occurs as a result of adjacent piles being driven, the contractor shall submit to the S.O. his proposal for correcting this and to avoid the same in subsequent work.

If preboring is specified the pile shall be pitched into a hole prebored to the depth shown on the Drawings, unless otherwise instructed by the S.O.

Jetting shall be carried out only when the Contractor's detailed proposals have been approved and not for the last 3m of the required depth of penetration.

## **2.9 Repair and Lengthening of Piles**

Any damage pile heads shall be cut of square at sound concrete and all loose particles shall be removed by wire brushing, followed by washing with water. If the pile is to be subjected to further driving, the head shall be replaced with concrete of an approved mix. 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 sound concrete of the pile is below cut-off level, the pile shall be made good to the cut-off level with concrete of a mix not inferior to that of the concrete of the pile.

Where piles have to be lengthened, other than by means of welding of steel plates as detailed in the Drawing, the reinforcement shall be stripped-off all surrounding concrete for a distance equal to thirty times the diameter of the main reinforcement measured from the pile head for spliced joints and 300mm for butt welded joints and all lateral reinforcement shall be removed. The lengthening bars shall butt on the exposed bars of the same diameter as the main pile bars, 60 diameters in length

and lapping the main bars for a distance of 30 diameters above and below the joint, and shall be securely bound with 1.63mm soft annealed iron wire. New binders of similar size shall be provided and spaced at half the centre 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 correcting in properly constructed moulds to the length required. Care shall be taken to form the joint between the old and new concrete as specified, hereinbefore. The extension shall be 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.

Pile which has been repaired/lengthened by adding cast-in-situ concrete as described in 2.9 and shall not be driven until the added concrete has reached the specified strength of the concrete for the pile.

## **2.10 *Cutting and Stripping Pile Head***

When a pile has been driven to the required set of depth and after load test has been carried out, the head of the pile shall be cut off to the level specified or shown in the Drawings. The length of the reinforcing bars projecting above this level shall be as shown or specified in the Drawings.

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 bounded to the old.

## **3.0 STEEL H-BEARING PILES**

### **3.1 *Pile Sections and Dimensions***

All steel H-bearing pile shall comply with BS 4 with regards to sectional dimensions and the steel shall comply with the requirements of BS 4360. The section and grade to be used are as specified or as shown in the Drawings.

### **3.2 *Straightness of Piles***

For standard rolled sections the deviation from straightness in millimetres shall not exceed  $1.04(L - 4.5)$  where L is the length of pile in metres.

For proprietary sections made up from rolled sections the deviation from straightness shall not exceed 1/1000 of the length of the pile.

### **3.3 *Strengthening of Piles***

Unless otherwise approved by the S.O. the strengthening of the toe of the pile in lieu of the 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 in the Drawings.

### **3.4 *Marking of Piles***

Each pile shall be clearly marked with indeletable marking at the flanged head showing the following:

- Reference Number
- Overall Length

In addition, each pile shall be marked at interval of 300mm along its length before being driven.

## **3.5**      ***Handling and Storage of Piles***

All operations such as handling and transporting of piles shall be carried out in such a manner that damage of piles and their coatings are 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.

## **3.6**      ***Pitching and Driving of Piles***

Pitching and driving of piles shall in accordance with Clause 2.8 as described herein before under "Pre-cast Reinforced Concrete Piles".

## **3.7**      ***Lengthening of Piles***

Where lengthening of piles are required, the piles shall be joined by butt-welding stiffened with plates fillet-welded on all four sides as detailed in the Drawings. All welding shall be continuous and complying with BS 4449. The type and size of welding shall be detailed in the Drawings.

## **3.8**      ***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 21mm of the levels shown in the Drawings, and protective coatings if any shall be removed from the surface of the pile heads down to a level 150mm above soffit of the concrete. Pile heads shall be constructed to the details as shown in the Drawings.

## **4.0**      **PRESSURE – TREATED TIMBER PILES.**

### **4.1**      ***Species of Timber***

Unless otherwise approved by the S.O only Kempas (Keempassla Malaccensis) of approved manufacture shall be used for the Works.

### **4.2**      ***Definitions***

The timber terms used in this specification shall have the meaning assigned to them in CP 112:1967 on Malayan Grading Rules for Sawn Hardwood Timber (2168) whichever is applicable.

### **4.3**      ***Quality***

The timber used for the piles shall not be of a lesser quality than the selected Structural Grades Specified in section J (Stress Grading) of part III of the Malayan Grading Rules for Sawn Hardwood Timber. The timber shall be free from rot, fungal or pest attack and any other defects not permitted for its grade.

## **4.4**      **Sizes**

The tolerance allowed for the pile shall be as for U.K Standard of CP 112:1967. The dimension of sawn timber piles shall be within the range of 2mm less and 6mm greater than their specified cross sectional dimensions. The centroid of any cross-section of sawn timber pile shall not deviate by more than 25mm from the straight line connecting the centroids of the end faces of the standard length of pile.

## **4.5**      **Workmanship**

The standard of workmanship shall comply with CP 112:1967 where applicable.

## **4.6**      **Preservative Treatment**

The method of treatment shall be the full-cell process as described in MS 3.38. The composition of preservative shall be Type 2 of MS 3.38. The depth of penetration of preservative when determined by the method described in Appendix "H" of MS 3.38, shall be a minimum of 25mm. The net dry salt retention in the treated part of the timber as determined by the method described in Appendix "K" of MS 3.38 shall be a minimum of 16kg/cu.metre.

## **4.7**      **Inspecting and Testing**

The S.O. may require inspection of treatment plant and control testing described in MS 3.38. Each pile shall be inspected for compliance with this specification before installation.

## **4.8**      **Marking**

The treated timber piles shall be permanently marked with an identification which indicates that they comply with this specification, manufacturer's trade mark, charge number and date of treatment, and the length of the pile.

## **4.9**      **Warranty**

Before commencement of work the Contractor shall nominate the supplier who shall be approved by the S.O.

The supplier of the treated piles shall issue a warranty which provides that for ten years period the treated piles shall be free from, such fungus and insect attack which may render the supported structure structurally unsound. If it is established that the defects in the supported structure are due to wood destroying organisms in the pile, the supplier shall remedy the defect in the structure and its foundation at his own cost. Subject to the provision of this clause, the actual form of the warranty shall be approved by the S.O. before the treated piles are accepted for the incorporation work.

## **4.10      *Delivery and Stacking***

The Contractor shall notify the S.O. of the delivery of timber piles to the site, and provide the necessary facilities to enable the S.O. to inspect each pile and take random sampling for net dry salt retention.

Accepted pile shall be marked and stacked in lengths on paving of drained hard ground. Each piece of pile shall be stacked clear of the ground and have an air space around it. The pile shall be separated by sticks or blocks placed horizontally to avoid sagging of the piles. All rejected piles shall be removed from the site promptly.

## **4.11      *Pile Head***

The pile head shall be adequately protected during driving, so that "brooming" does not occur.

The pile head shall be fitted with toothed metal plates as approved by the S.O. for protection against "brooming" and splitting during normal driving.

In case of hard driving, unless otherwise approved by the S.O. a metal helmet shall be fitted to the top of the pile. The top of the pile shall first be trimmed to fit closely into recess of underside of the helmet. A hardwood dolly and, if necessary, a packing piece shall be used above the helmet.

If during driving the head of the pile becomes excessively broomed or otherwise damaged, the damaged part shall be cut off, and the helmet refitted.

## **4.12      *Pitching and Driving of Piles***

Driving of piles shall in accordance with clauses 2.8 on Section 2.0

## **4.13      *Lengthening of Piles***

Piles shall be provided in one single length of 6.0m each unless otherwise approved. Any pile driven to the required set at a depth of 6.0m or less shall be one continuous length.

If jointing is required, piles joints shall be made by using mild steel welded boxes 450mm long fabricated from 5mm thick plates unless otherwise shown in the Drawings. The internal dimensions of the box shall be 3mm undersize of the pile cross-sectional dimensions. The joints and the ends of the piles to be jointed shall be constructed, so that the necessary strength and stiffness are developed at the joint.

## **4.14      *Defects on Piles while Driving***

When fissures appear in a pile during driving, which in opinion of the S.O. will affect its strength, the pile shall be rejected and replaced at the Contractor's own expense.

## **4.15**      ***Preparation of Pile Heads***

When a pile has been driven to the required set or depth, the head of the piles shall be cut off square to sound wood and treated with an approved preservative and waterproof coating to the approval of the S.O.

The pile head shall be embedded for a depth of not less than 150mm in the concrete cap which shall be at least 150mm thick round the piles.

## **5.0**            **PILE TESTING**

### **5.1**            ***General***

#### **5.1.1**        **Type of Tests Necessary**

The "Maintained Load Test" shall be carried out on a test pile. The Contractor shall, if required by the S.O. carry out the "Constant Rate of Penetration Test" on completion of the "Maintained Load Test".

#### **5.1.2**        **Safety Precautions**

When preparing, conducting and dismantling a pile test the Contractor shall carry out the work in a safe manner and shall in addition make such other provisions as may be necessary to safeguard against any likely hazards.

### **5.2**            ***Definitions***

#### **5.2.1.**        **Compression Pile**

A pile which is designed to resist an axial force such as would cause it to penetrate into the ground.

#### **5.2.2**        **Anchor Pile**

A pile which is designed to resist an axial force such as would tend to cause it to be extracted from the ground.

#### **5.2.3**        **Test Pile**

Compression pile to which a load is applied to determine the load versus settlement characteristics of the pile and the surrounding ground.

#### **5.2.4**        **Reaction System**

The system of kentledge, piles or anchors that provides a resistance against which the pile is tested.

#### **5.2.5**        **Kentledge**

The dead weight used in loading test.

## 5.2.6 **Maintained Load Test**

A loading test in which each increment or decrement of load is held constant either for a defined period of time or until the rate of settlement or rebound falls to a specified value.

## 5.2.7 **Constant Rate of Penetration Test (CRP)**

A loading test in which the pile is made to penetrate the soil from its position at a constant speed while the force applied at the top of the pile to maintain the rate of penetration is continuously measured. The force versus penetration relationship obtain does not represent an equilibrium condition between load and settlement.

## 5.3 **Supervision**

All tests shall be carried out only under the direction of an experienced and competent Contractor's Supervisor with approved test equipment and test procedure as specified hereinafter.

All Contractor's personnel operating the test equipment shall have been trained in its use. Test shall be carried out only in the presence of the S.O.

## 5.4 **Reaction System**

### 5.4.1 **General**

Compression test shall be carried out using a kentledge, anchor piles or specially constructed anchorages as reaction system. The reaction system used shall be designed to transfer safely to the test pile the maximum load required for testing. Full details of the reaction shall be submitted to the S.O. prior to any work related to the testing process being carried out on the Site.

### 5.4.2 **Kentledge**

Where kentledge is to be used it shall have adequate weight to resist load up to 1.2 times the maximum test load. The kentledge shall be supported on cribwork, beams or other supporting structures disposed around the test pile so that its centre of gravity is on the axis of the pile. Kentledge shall not rest directly on the pile head. The bearing pressure under the supports shall be such as to ensure stability of the kentledge stacks and shall not impair the efficiency of the testing operations. The distance from the edge of the test pile to the nearest part of the support to the kentledge stack in contact with the ground shall not be less than 1.3m.

### 5.4.3 **Anchor Pile and Ground Anchor**

Where anchor piles or ground anchors are to be used, they shall be of adequate strength to resist load up to 1.2 times the maximum test load on the ground in a safe manner without excessive movement or influence on the test pile. The method employed in the installation shall be such to prevent damage to any test pile or working pile.

The Contractor shall ensure that when the test load is applied, the load is correctly transmitted to all the bolts and tie rods. The extension of rods by welding shall not

be permitted unless it is known that the steel will not be reduced in strength by welding. The bond stress of the rod in tension shall not exceed normal permissible bond stresses of the type of the steel and mix of concrete used.

Where anchor piles are used the centre to centre spacing of the piles from the test pile shall be not less than three (3) times the diameter of the test pile or the anchor piles or 2m whichever is the greater. Under-reamed tension piles shall not be used. Where permanent working piles are approved by the S.O. to be used as anchor piles, their levels shall be observed during application of the test load to ensure that there is no residual uplift.

Where ground anchors are used, no part of the section of the anchor transferring load to the ground shall be closer to the test pile than three (3) times the diameter of the test pile. Furthermore, no part of the ground anchor shall be closer to a working pile than one-and-a-half times the diameter of the test pile along the unbounded length of the anchor, and three (3) times the diameter of the test pile along the bonded length of the anchor. Under-reams on ground anchors shall not exceed 180mm in diameter.

## **5.5 Testing Equipment**

The Contractor shall ensure that when the hydraulic jack and load measuring device are mounted on the pile heads, the whole system will be stable up to the maximum load to be applied.

The test loads shall be applied by means of a hydraulic jack of adequate capacity fitted with a load measuring device.

The hydraulic jack, pump, hoses, pipes, couplings and other apparatus to be operated under hydraulic pressure shall be capable of withstanding and test pressure equivalent to one and a half times the maximum test load without leakage.

Where the C.R.P test is required the jack pump capacity shall be adequate to maintain the required rate of penetration. The permissible extension of the jack shall be such that the pile can be moved continuously and without repacking for distance of at least 50mm.

The measuring device shall be of the type approved by the S.O. capable of registering loads in increments not exceeding 21KN.

The hydraulic jack and measuring device shall be calibrated together to the approval of the S.O. before and after each series of test whenever adjustments are made to device or at intervals appropriate for the type of equipment used. Certificates of calibration shall be submitted to the S.O.

The loading equipment shall be capable of adjustment throughout the test to obtain a smooth increase of load or to maintain each load constant at the required stages of maintained loading test.

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## **5.6 Preparation of a Working Pile to be Tested**

### **5.6.1 General**

If a test is required on a working pile the Contractor shall prepare the pile for testing to the approval of the S.O.

### **5.6.2 Driving Records**

For each working pile which is to be tested a detailed records of driving shall be made and submitted to the S.O. daily not later than noon on the next working day.

### **5.6.3 Cut-off Level**

The pile shall terminate at the normal cut-off level or at a level required by the S.O. However, where necessary the pile shall be extended above the cut-off level of working piles so that gauges and other apparatus to be used in the testing process will not be damaged by water or falling debris. If the cut-off level is below ground level, the pile is not extend and there is a risk of the borehole collapsing, a sleeve shall be left in place or inserted above the pile, or other approved action shall be taken.

Adequate clearance shall be given between the top of the pile and the bottom of the sleeve to permit unrestricted movement of the pile.

### **5.6.4 Pile Head of Compression Test**

For a pile that is tested in compression, the pile head or cap shall be formed to give a plane surface which is normal to the axis of the pile. An approved mild steel bearing plate shall be mounted on top of the pile head or cap to accommodate the loading and settlement measuring equipment and to prevent damage from the concentrated application of load from the loading equipment.

### **5.6.5 Notice of Test**

The Contractor shall give the S.O. at least 24 hours notice of the commencement of test.

## **5.7 Settlement Measurement**

An independent reference frame shall be set up to permit measurement of the vertical movement of the test pile. The support for the frame shall be located not closer than 2m from the test pile, and shall be rigidly fixed to the ground to a depth of not less than 1m of concrete surround. In addition, the elevation of the supports shall be checked frequently with reference to fixed benchmark.

The entire measuring assembly shall be protected against rain, direct sunlight and other disturbances that might affect its reliability. Temperature readings shall be taken when requested by the S.O. The measurement of pile movement shall be made by four dial gauges rigidly mounted on the reference frame that bear on machined metal or glass surfaces normal to the pile axis fixed to the pile cap or head. Alternatively the gauges may be fixed to the pile and bear on surfaces on the

reference frame. The dial gauges shall be placed in diametrically opposite positions and be equidistant from the pile axis. The dial gauges shall enable readings to be made to within an accuracy of 0.1mm and shall have minimum travel of not less than 50mm.

The Contractor may submit other methods of measuring the movement of pile heads for approval.

## **5.8 Test Procedure**

### **5.8.1 General**

Throughout the test period all equipment for measuring load and movement shall be protected from the effects of weather. Construction equipment and persons who are not involved in the testing process shall be kept at sufficient distance from the test to avoid disturbance to the measurement apparatus.

### **5.8.2 Maintained Load Test**

The load shall be applied in increments of 25% of the working load and appropriately smaller thereafter, until a maximum test load of twice the working load is reached. Each increment of load shall be applied as smoothly and as expeditiously as possible. Settlement readings and time observations shall be taken before and after each new load increment.

A time-settlement graph shall be plotted to indicate when the rate of settlement of 0.05mm in 15 minutes is reached. A further increment of load shall be applied when this rate of settlement is achieved or until a minimum time of 2 hours has elapsed, whichever is later. The process shall be repeated until the maximum test load is reached.

The maximum test load shall then be maintained for a minimum of 24 hours, and time-settlement readings shall be taken at regular intervals as for the earlier load stages.

The test load shall then be decreased in four equal stages and time-settlement reading shall be as described aforesaid until the movement ceases. At least 60 minutes interval shall be allowed between the unloading decrements.

### **5.8.3 Constant Rate of Penetration Test**

The load shall be applied to achieve a constant rate of penetration value varying between 0.75mm per minute to 1.5mm per minute. The rate chosen shall suit the jacking equipment used.

Both settlement and time reading shall be recorded at every minute period. Further loading shall be discontinued when the loading varies indirectly as the penetration in the case of end bearing piles in sand or gravel, or when the rate of penetration is constant without further increase in the load in the case of friction piles in clay. Loading shall then be released gradually and rebound readings taken.

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## **5.9 Presentation of Results**

### **5.9.1 Submission of Results**

Result shall be submitted as a signed summary in duplicate to the S.O. immediately on completion of the test, which shall give:

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.

For the CRP test, the maximum load reached and a graph of load against penetration.

### **5.9.2 Schedule of Recorded Data**

The Contractor shall provide information about the tested pile in accordance with the following schedule where applicable:

#### **General**

- Site Location
- Contractor Identification
- Proposed Structure
- Main Contractor
- Piling Sub-contractor (if any)
- Site Office
- Client's Name
- Maintained Load or CRP Test
- Date of Test

#### **Test Procedure**

- Weight of Kentledge
- Tension of Pile, Group Anchor Details
- Plan of Test Arrangement showing position and distance of Kentledge Supports, Tension Piles and reference frame to Test Piles
- Jack Capacity
- Method of Load Measurement
- Method(s) of Penetration Measurement
- Relevant Dates and Times

#### **Test Results**

- In Tabular Form
- In Graphical Form : Load Plotted against Settlement, with Times
- Ground Heave (if any)
- Effect on Adjacent Structure (if any)

## **Site Investigation**

- Site investigation Drawing Number
- Borehole Reference nearest to Test Pile.

### **5.10 Interpretation of Test Results**

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

- The residual settlement after removal of the test load exceeds 6.50mm: or
- The total settlement under the Design Load exceeds 12.50mm;

or

- The total settlement under twice the Design Load exceeds 38.0mm, or 10% of pile diameter/width whichever is the lower value.

### **5.11 Completion of Test**

#### **5.11.1 Measuring Equipment**

On completion of a test all equipment and measuring devices shall be dismantled, checked and either stored so that they are available for use in further tests, or removed from the Site.

#### **5.11.2 Kentledge**

Kentledge and its supporting structure shall be removed forthwith from the Site on completion of all tests.

#### **5.11.3 Ground Anchors and Temporary Piles**

On completion of a pile test, tension piles or ground anchors shall be cut off below ground level, and the ground made good with approved material.

### **5.12 Load Testing of Bakau Piles**

#### **5.12.1 General**

In general, all relevant clauses stated herein before shall apply to the load testing of bakau piles, except that what is understood as single test pile in these clauses shall mean a group of test piles for bakau piles.

#### **5.12.2 Arrangement of Test Piles**

The load testing of bakau piles shall be carried out on a group of nine bakau piles, made up of three rows of piles and of three in a row.

## **5.12.3 Pile Cap**

An approved reinforced concrete pile cap with a column stump shall be cast centrally over the group of piles to be tested. The column stump shall be short to ensure stability, and it shall have an approved mild steel bearing plate cast on top. The loads shall be applied centrally on to the steel plate.

## **5.12.4 Test Procedure.**

The bakau pile shall be tested to failure by the Maintained Load Test as described herein before. The load on the pile group shall be applied in 6 to 8 equal increments until failure load is reached. Failure load (i.e. ultimate load) is that load at which the piles continue to settle at a constant rate without further increase of load.

For each increment of load, the settlement readings shall be recorded at various time intervals until the rate of the settlement is less than 0.25mm per hour. The load at each increment shall be maintained at a constant value throughout the test.

*(Note : for a group of 9 (nine) bakau piles, the increment of load is generally about 4 tonnes).*

The process of applying the next increment of load and taking the settlement readings against various times intervals shall be repeated until the ultimate load for the pile group is reached. The test load shall than be gradually released. No further settlement readings or rebound readings need to be taken on release of load.

## **5.12.5 Interpretation of Results**

The allowable load on the pile group shall be obtained by applying an appropriate factor of safety to the ultimate load determined from the load test. The factor of safety is applied chiefly to offset against the possibility of settlement due to consolidation. A factor of safety from 3 to 6 shall be applied depending on the strength of the soil. As a guide, a factor of safety of 6 shall be applied to very soft soil and a factor of safety of 3 shall be applied to medium strength soil.