PILE TESTING SPECIFICATION

1.0 GENERAL

This specification deals with the testing of a pile by the application of an axial load or force. It covers vertical and raking piles tested in compression (i.e. subjected to loads or forces in a direction such as would cause the pile to penetrate further into the ground) and vertical or raking piles tested in tension (i.e. subjected to forces in a direction such as would cause the piles to be extracted from the ground).

This specification also covers proof logging of pile shafts, and integrity testing of installed working piles by the vibration testing method and the sonic coring method.

This specification shall be used for driven piles only. Clauses relevant to other pile types are for information only. The Contractor may use this specification as a reference to develop his piling specification for the alternative pile system he proposed.

2.0 DEFINITIONS

Compression pile : a pile which is designed to resist an axial force such as would cause it to penetrate further into the ground.

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

Raking pile : a pile installed at an inclination to the vertical.

Preliminary pile (for failure load test) : a pile installed before the commencement of the main piling works or specific pile of the Works for the purpose of establishing the suitability of pile and for confirming its design dimension and bearing capacity.

Test pile : any pile to which a test is, or is to be applied.

Kentledge : the dead weight used in a loading test.

Reaction system : the arrangement of kentledge, piles, anchors or rafts that provides a resistance against which the pile is tested.

Maintained load test : a loading test in which each increment of load is held constant either for a defined period of time or until the rate of movement (settlement or uplift) falls to a specified value.

Failure load test : a load test applied to a preliminary pile. Maximum test load for this test should not normally be less than 300% of the estimated working load. This test serves as a design check for soil parameters used to determine the lengths of subsequent working piles.

Working load test : a load test applied to a selected working pile to confirm that it is suitable for the load at the settlement specified. Maximum test load for this test should not normally exceed 200% of the working load on a pile. This test serves as a quality control check on working piles.

Ultimate bearing capacity : the load at which the resistance of the soil becomes fully mobilized.

Allowable load : the load which may be safely applied to a pile after taking into account its ultimate bearing capacity, negative skin friction, pile spacing, overall bearing capacity of the ground below and allowable settlement.

Working load : the load which the pile is designed to carry without exceeding the allowable settlement requirement.

3.0 SAFETY PRECAUTIONS

3.1 General

When preparing for, conducting and dismantling a pile test, the Contractor shall carry out the requirements of the various Acts, orders, regulations and other statutory instruments that are applicable to the work for the provision and maintenance of safe working conditions, and shall in addition make such other provision as may be necessary to safeguard against any hazards that are involved in the testing or preparations for testing.

3.2 Personnel

All tests shall be carried out only under the direction of an experienced and competent supervisor conversant with the test equipment and test procedure. All personnel operating the test equipment shall have been trained in its use.

3.3 Kentledge

Where kentledge is used, the Contractor shall construct the foundations for the kentledge and any cribwork, beams or other supporting structures in such a manner that there will not be differential settlement, bending or deflection of an amount that constitutes a hazard to safety or impairs the efficiency of the operation. The kentledge shall be adequately bonded, tied or otherwise held together to prevent it from falling apart, or becoming unstable because of deflection of the supports.

The weight of kentledge shall be at least 1.2 times the maximum test load and if the weight is estimated from the density and volume of the constituent materials, an adequate factor of safety against error shall be allowed. The Contractor shall take all reasonable steps to ensure that sufficient excess load capacity is at all times available for the uninterrupted execution of a load test.

3.4 Tension Piles and Ground Anchors

Where tension piles or ground anchors are used, the Contractor shall ensure that the load is correctly transmitted to all the tie rods or bolts. The extension of rods by welding shall not be permitted unless it is that the steel will not be reduced in strength by welding. The bond stresses of the rods in tension shall not exceed normal permissible bond stresses for the type of steel and grade of concrete used.

3.5 Testing Equipment

In all cases the Contractor shall ensure when the hydraulic jack and load measuring device are mounted on the pile head, the whole system will be stable up to the maximum test load to be applied. Means shall be provided to enable dial gauges to be read from a position clear of the kentledge stack or test frame in conditions where failure in any part of the system due to overloading, buckling, loss of hydraulic pressure or any other cause might constitute a hazard to personnel.

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

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

4.0 NUMBER OF PILE TESTS

Total number of pile tests on working piles shall be as specified in the Bill of Quantities.

5.0 MATERIALS AND LABOUR

The Contractor shall supply all labour, materials and all other equipment necessary for the performance, recording and measurements of the test loads and settlement including the supply and placing in position of kentledge used in the tests. The Contractor shall subsequently dismantle and remove all the material and equipment used.

Throughout the duration and operation of the test loading the Contractor shall place competent men to operate, watch and record the test.

6.0 WORKING PILES

Pile tests shall be carried out on working piles as directed by the Engineer at any time before the pile is built into the structure.

A pile test shall be taken to mean test on a pile installed as part of the foundation and tested to ensure that standards of materials, workmanship and performance are being maintained in accordance with this Specification. The displacement (and recovery) of the pile are determined for a maximum test load equal to twice the design working load.

The use of working piles as tension reaction piles for the purpose of these tests will not be permitted.

7.0 MEASURING DEVICES

Load measuring devices shall be calibrated before and after each series of tests, whenever adjustments or replacements are made to the devices or at the intervals recommended by the manufacturer of the equipment. All measuring equipment and gauges shall be calibrated together. Certificates of calibration from approved laboratory shall be supplied to the Engineer for acceptance.

The Contractor's proposed method of measuring the movement of pile heads and load shall be submitted to the Engineer for approval.

8.0 SUPERVISION

All tests shall be carried out under the direction of an experienced and competent supervisor conversant with the test equipment and test procedure. All personnel operating the test equipment shall have been trained in its use. Load testing shall be carried out in the presence of the Engineer.

9.0 LOADING ON TEST PILES

The rate of application and the rate of removal of the load may be altered or modified solely by the Engineer. Unless otherwise decided by the Engineer the load steps and duration are as indicated in item Test Procedure.

10.0 READINGS

Take readings of time, load and settlement and record immediately before and after the application of each load increment or decrement or as directed by the Engineer. A minimum of another two readings shall be recorded at intermediate intervals.

11.0 PREPARATION OF A WORKING PILE TO BE TESTED

11.1 Inclusive Works

The works for the load tests shall include the construction and subsequent demolition of all necessary pile caps built in rapid hardening cement to the contractor's design which shall be subjected to the Engineer's approval.

11.2 Notice Of Construction

The Contractor shall give the Engineer at least 48 hours notice of commencement of construction of any preliminary pile.

11.3 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 use of similar equipment and materials. Any variation will only be permitted with prior agreement.

11.4 Duration

Once any load test is carried out, it shall be continued until the whole test load is completed and all measurements of settlements taken and recorded. Under no circumstances should a load test on piles stop unless the pile has failed. The Engineer shall be informed immediately in the event of a pile failure.

11.5 Time Lapse For Testing

Driven pile selected for testing shall not be loaded after the installation. The minimum required time lapse is at least 14 days.

11.6 Driving Record

For each preliminary pile, a detailed record of the progress during driving shall be made and submitted to the Engineer.

11.7 Pile Head For 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, 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.

The pilecap shall be concentric with the best pile. The joint between the cap and the pile shall have a strength equivalent to that of the pile.

Sufficient clear space shall be made under any part of the cap projecting beyond the section of the pile so that, at maximum expected settlement, load is not transmitted to the ground except through the pile.

11.8 Pile Connection For Tension Pile

For a pile that is tested in tension, means shall be provided for transmitting the test load axially to the pile.

The connection between the pile and the loading equipment shall be constructed in such a manner as to provide a strength equal to the maximum load which is to be applied to the pile during the test with an appropriated factor of safety on the structural design.

12.0 CONCRETE TEST CUBES

Three test cubes shall be made from the concrete used in the preliminary test pile and from working piles as directed by the Engineer. If a concrete cap is cast separately from a preliminary pile or a working pile a further three cubes shall be made from this concrete. The cubes shall be made and tested in accordance with BS 1881.

The test pile shall not be started until the sample cubes have acquired strength such that the applied direct stress is less than 0.5 times the cube strength. This requirement shall apply to both pile and pile head or cap.

13.0 REACTION SYSTEMS

13.1 Compression Tests

Compression tests shall be carried out using kentledge, tension piles, ground anchors or otherwise specially constructed anchorage. Use of kentledge is preferred for load tests on vertical piles; use of tension reaction piles, ground anchors or other tension reaction systems shall be permitted only when use of kentledge proves impractical. Kentledge shall not be used for tests on raking piles.

Where kentledge is to be used, it shall be supported on cribwork, disposed around the pilehead so that its center of gravity is on the axis of the pile. The bearing pressure under supporting cribs shall be such as to ensure stability of the kentledge stack. Kentledge shall not be carried directly on the pile head, except when directed by the Engineer.

The kentledge may consist of concrete blocks, steel piles etc, but must be of uniform size so that weight of the kentledge can be easily calculated.

13.2 Tension Tests

Tension tests shall be carried out using compression piles or rafts constructed on the ground. The use of inclined reaction piles, anchors or rafts is not precluded, subject to agreement. In all cases the resultant force of the reaction system shall be co-axial with the test pile.

13.3 Working Piles

Working piles shall not be used as reaction piles without agreement from the Engineer.

Where working piles are used as reaction piles their movement shall be measured to within an accuracy of 0.5mm.

13.4 Ground Anchors

Ground anchors shall be pre-loaded to provide reaction greater than the specified capacity of the test assembly so that sufficient contact stress is maintained throughout the pile test between the loading beam and the loading beam support to prevent unrestrained lateral movement. The ground anchor pre-load shall be approved.

Each ground anchor shall be loaded to 1.2 times the approved pre-load and the load held for 5 minutes while measurements of tendon extension are recorded at 1 minute intervals. If these measurements indicate that the ground anchor is satisfactory, it may be locked off at an accepted load in excess of the pre-load to allow for loss due to creep.

If anchor piles or ground anchors are used, they shall not be closer to the test pile than 2.5m, measured centre to centre, or such greater distance as the Engineer may direct having regard to the nature of the ground and the piles. There shall be a factor of safety of at least 2.0 against failure of the anchorage by pull-out. The soil and rock properties used to determine this safety factor shall be to the approval of the Engineer.

13.5 Spacing

Where kentledge is used for loading vertical piles in compression, the distance from the edge of the test pile to the nearest part of the crib supporting the kentledge stack in contact with the ground shall be not less than 1.3m.

The centre to centre spacing of vertical reaction piles, including working piles used as reaction piles, from a test pile shall be not less than five times the diameter of the test pile or the reaction piles or 2 metres, whichever is the greatest. Where a pile to be tested has an enlarged base, the same criterion shall apply with regard to the pile shaft, with the additional requirement that no surface of a reaction pile shall be closer to the base of the test pile than a distance of one half of the enlarged base diameter. The pile spacing requirement may be varied by the Engineer to suit site conditions at no extra costs.

Where ground anchors are used to provide a test reaction for loading in compression, no part of the section of the anchor transferring load to the ground shall be closer to the test pile than three times the diameter of the test pile. Where the pile to be tested has an enlarged base, the same criterion shall apply with regard to the pile shaft, with additional requirement that no section of the anchor transferring load to the ground shall be closer to the pile base than a distance equal to the base diameter. The pile spacing requirement may be varied by the Engineer to suit site conditions at no extra costs.

13.6 Adequate Reaction

The size, length and number of reaction piles or anchors, or the area of the rafts, shall be adequate to transmit the maximum test load to the ground in a safe manner without excessive movement or influence in the test pile.

13.7 Care Of Piles

The method employed in the installation of any reaction piles, anchors or rafts shall be such as to prevent damage to any test pile or working pile.

13.8 Loading Arrangement

The loading arrangement used shall be designed to transfer safely to the test pile the maximum load required in testing. Full details shall be submitted to the Engineer prior to any work related to the testing process being carried out on the Site.

13.9 Pilecaps and Structural Elements

Temporary pilecaps and other structural elements forming part of the reaction system proposed by the Contractor shall be designed and built by the Contractor, and to the approval of the Engineer. The cost of building and demolishing such pilecaps and structural elements shall be borne by the Contractor.

14.0 EQUIPMENT FOR APPLYING LOAD

14.1 General

The equipment used for applying load shall consist of one or more hydraulic rams or jacks. The rams or jacks shall be arranged in conjunction with the reaction system to deliver an axial load to the test pile. The complete system shall be capable of transferring the maximum load required for the test.

14.2 Jack Capacity

The total capacity of the jacks shall exceed by 20% or more the required maximum test load, thereby avoiding heavy manual pumping effort when nearing maximum load and minimizing the risks of any leakage of oil through the seals.

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 a maintained load test.

15.0 MEASUREMENT OF LOAD

15.1 Load Measurement Procedure

The load shall be measure by a load measuring device and by a calibrated pressure gauge included in the hydraulic system. Readings of both the load measuring device and the pressure gauge shall be recorded. In interpreting the test data, the values given by the load

measuring device shall normally be used. The pressure gauge readings are required as a check for gross error. The pressure gauge shall have been recently calibrated.
The load measuring device may consist of a proving ring, load measuring column, pressure cell or other appropriate system. A spherical seating shall be used in conjunction with any devices that are sensitive to eccentric loadings; care must be taken to avoid any risk of buckling. Load measuring devices and jacks shall be short in axial length in order to achieve the best possible stability. The Contractor shall pay attention to details in order to ensure that axial loading is maintained.

Any increments of load shall not be allowed to fall below 1% of the specified load.

The Engineer's agreement shall be obtained in writing prior to any modification of this procedure.

15.2 Calibration Of Load Measurement Devices

The load measuring device shall be calibrated before and after each series of tests, whenever adjustments are made to the device or at intervals appropriate to the type of equipment. The pressure gauge and hydraulic jack shall be calibrated together.

Certificates of calibration performed by an approved testing laboratory shall be supplied to the Engineer prior to carrying out the load test.

15.3 Measurement of Settlement

Settlement shall be measured by use of a reference beam or wire supported independently of' the test pile, reaction pile or piles supporting reaction loads. Settlements shall be measured to the nearest 0.1mm for reference beams or 0.5mm for reference wires. A precise optical level shall be used to check movements of the reference frame against an independent datum. The reference beam supports shall be located at least 3m from the test pile, reaction pile or piles supporting reaction loads. The reference beams or wires shall be protected from the effects of temperature changes. Construction equipment and persons not involved in the test shall be kept well clear to avoid disturbance of the measuring system. Pile driving or similar operations will not be permitted in the vicinity of the test unless the Engineer is satisfied that the measuring system will not be affected.

Deflections shall be precisely measured by four dial gauges equally spaced around the pile head to an accuracy of 0.01mm to give useful information on pile bending as well as axial movement. These dial gauges shall be firmly attached to the reference beams, so that the plungers are parallel to the pile axis. The plunger points shall bear onto reference plates by means of machined plates or glass slides attached to the pile head. The reference plates shall be equidistant from the centre of the pile, diametrically opposed, and carefully aligned so that they are perpendicular to the pile axis in order that sideways movements do not produce any axial components.

15.4 Initial Zero Load Readings

Before the first increment of test load is applied, all gauges shall be read at 30 minute intervals over a period of 24 hours under zero load to determine the effect of variable site conditions on the test pile. Air temperature shall be recorded with each set of readings. The test set-up shall be exactly as during the test proper, with the loading jack in position but clear of the loading frame.

16.0 MEASURING MOVEMENT OF PILE HEADS

16.1 Maintained Load Test

In a maintained load test, movement of the pile head shall be measured by one of the primary systems and one of the secondary systems described in this section.

16.2 Primary System

An optical or any other leveling method by reference to an external datum may be used.

Where a level and staff are used, the level and scale of the staff shall be chosen to enable readings to be made within an accuracy of 0.5mm. A scale attached to the pile or pilecap may be used instead of a leveling staff. At least two datum points shall be established on permanent objects or other well-founded structures, or deep datum points shall be installed, so that any one datum point can be re-established in case it is inadvertently demolished. Each datum point shall be situated so that only one setting of the level is needed.

No datum point shall be affected by the test loading or other operations on the Site. Where another method of leveling is proposed, this shall be agreed in writing.

16.3 Independent Reference Frame

An independent reference frame may be set up to permit measurement of the movement of the pile. The supports for the frame shall be founded in such a manner and at such a distance from the test pile, kentledge support cribs, reaction piles, anchorages and rafts that movements of the ground in vicinity of the equipment do not cause movement of the reference frame during the test which will effect the required accuracy of the test.

Observations of any movements of the reference frame shall be made and a check shall be made of the movement of the pile head relative to an external datum during the progress of the test. Supports for the reference frame shall be placed not less than three test pile diameters or 2 metres, whichever is the greater, from the center of the test pile, and not less than I metre from the nearest corner of the kentledge support crib.

The measurement of pile movement shall be made by at least 3 but preferably 4 dial gauges equally spaced around the pile and equidistant from the pile axis. Dial gauges shall be rigidly mounted on the reference frame that bears on surfaces which are normal to the pile axis and 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 have a travel of 50mm and shall be accurate to 0.025mm.

The reference frame shall be protected from direct sunlight, wind and rain.

16.4 Secondary Systems

16.4.1 Reference Wire

A reference wire shall be held under constant tension between two rigid supports founded as in the method used for the primary Reference Frame system. The wire shall be positioned against a scale fixed to the pile and the movement of the scale relative to the wire shall be measured.

Observations of any movements of the supports of the wire shall be made or a check shall be made of the movement of the pile head as in the method used for primary Reference Frame systems. Readings shall be taken to within an accuracy of 0.5mm. The reference wire shall be protected from direct sunlight, wind and rain.

16.4.2 Other Methods

The Contractor may propose and implement any other suitable and adequate method of measuring the movement of pile heads subject to the prior agreement of the Engineer.

16.4.3 Instrument Calibration

Prior to carrying out the load test, the Contractor shall submit to the Engineer the calibration certificates of dial gauges performed by an approved testing laboratory.

16.4.4 Night Readings

The entire test area shall be adequately lighted up during the night to facilitate taking readings.

17.0 PROTECTION OF TESTING EQUIPMENT

17.1 Protection From Weather

Throughout the test period, all equipment for measuring load and movement shall be protected from direct exposure to sunlight, wind and rain.

17.2 Prevention of Disturbance

Construction equipment and persons who are involved in the testing process shall be kept at a sufficient distance from the test to avoid disturbance to the measurement apparatus.

18.0 SUPERVISION

18.1 Notice of Test

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

18.2 Records

During the progress of a test, the testing equipment and all records of the test as required under the section headed "Presentation Of Results" in this specification shall be available for inspection by the Engineer.

19.0 TEST PROCEDURE

19.1 Working Load Test

A number of working load tests on 2.0 times the working capacity of the pile shall be carried out on working piles to be designated by the Engineer, and in accordance with BS 8004: 1986 Clause 7.5.5. In case of discrepancies the provision of this specification shall take precedence. The Contractor shall submit a detailed proposal of load tests to the Engineer, and shall obtain his approval in writing before carrying them out. On completion of the test, the Contractor shall submit to the Engineer the test results, including graphs showing load and settlement versus time and settlement versus load.

The provisional number of working load tests to be carried out shall be specified. The Engineer may reduce the number of tests if a consistent high quality of workmanship and pile material is well established and if the nature of soil conditions encountered does not vary substantially, Conversely, the Engineer reserves the right to increase the number of tests either to verify the quality of workmanship and pile material or in response to variable subsoil conditions.

Unless otherwise specified by the Engineer, the test procedure shall be as follows, with the percentage for loading and unloading operations given in terms of the working load, taken as 100%:

TABLE 1: LOADING CYCLES FOR WORKING PILES

Load. Percentage Of Working Load	Time Of Holding Load (minutes)
0	10
10	10
20	10
30	10
40	10
50	10
60	10
70	10
80	10
90	10
100	60 min or settlement rate less than 0.25min/hr (whichever is longer)
75	10
75	10
5O	10
25	10
0	30
25	10
50	10
75	10
100	10
110	10
120	10
130	10
140	10
150	10
160	10
170	10
180	10
190	10
200	60 min or longer as instructed by the Engineer
150	10
150	10
50	10
0	10

The test schedule for compression test is for guidance only. It is subject to variation by the Engineer to meet site conditions.

The procedure for working load tension pile tests shall be exactly as described in this section for compression pile tests; for tension test, the words "settlement" and "rebound" should be read "displacement" in the column "action to be taken after Load Stage".

All loading and unloading operations shall take place during the day. Minimum three (3) sets of readings shall be taken in each loading stage: one set each at the beginning, middle and end of each loading or unloading stage. When a test load is maintained for more than 30 minutes, readings shall be taken at maximum half-hourly intervals thereafter unless otherwise specified by the Engineer.

If large discrepancies occur between different measurement systems, the test shall be halted and the cause for the discrepancy corrected. The test shall be restarted from the beginning in this instance.

20.0 ABANDONMENT OF PILE TEST

Test shall have to be discontinued if any of the following occurs:

- faulty jack or gauge,
- instability of kentledge,
- improper setting of datum,
- unstable Bench Marks or Scales,
- measuring instruments used are found to have been tampered with by anyone, or
- pre-jacking or pre-loading before commencement of the test.

Should any test be abandoned due to any of the above causes, the Contractor shall carry out further tests to the Engineer instructions after rectification of the errors.

21.0 PRESENTATION OF RESULTS

21.1 Results to be Submitted

A written summary to the Engineer within 24 hours (or unless otherwise directed) of the test, which shall give:

(i) For each stage of loading, the period for which the load was held, the load and the maximum settlement or uplift recorded.

(ii) Load vs Settlement curve.

The completed schedule of recorded data as described hereunder in this section together with interpretation of test results within seven days of completion of the test. Interpretation of test results shall be carried out in a manner approved by the Engineer.

21.2 Schedule of Recorded Data

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

21.2.1 General

* Site location
* Contract identification
* Proposed structure
* Main Contractor
* Piling Contractor
* Engineer
* Client
* Date of test

21.2.2 Pile Details

All piles

* Identification (no. and location).
* Position relative to adjacent piles.
* Brief description of location (e.g. in cofferdam, in cutting, over water)
* Ground level at pile location.
* Head level at which test load is applied.
* Type of pile (e.g. precast reinforced concrete. steel H, bored in place, driven in place, composite type).
* Vertical or raking, compression or tension.
* Shape and size of cross-section of pile, position of change in cross-section
* Shoe or base details.
* Head details.
* Length in ground
* Level of toe
* Any permanent casing or core,

Concrete piles

* Pile reference
* Concrete mix
* Aggregate type and source
* Cement type.
* Slump
* Cube test results for pile and cap.
* Date of casting of precast pile
* Reinforcement.
* Complete pile record (as per requirement in the General Piling Specification)

Steel piles

* Steel quality.
* Coating.
* Filling.

21.2.3 Installation Details

All piles

* Dates and times of boring, driving and concreting of test pile and adjacent pile.
* Unexpected circumstances and difficulties.
* Date and time of casting concrete pile cap.
* Start and finish of each operation during driving or installation of a pile and subsequent testing.
* Difficulties in boring, handling, pitching and driving pile.
* Delays due to sea, water and weather conditions.

Bored Pile

* Pile diameter
* RL of top of pile
* RL of bottom of pile
* All instruments reading
* Concrete strength when tested
* Date cast
* Date tested
* Length of reinforcement cage
* Water table below ground level
* Length of casing
* Description of soil for the length of pile *(for* bored piles and pre-drilling only)
* Unusual events or data and movements of the test pile
* Any other relevant information requested by the Engineer
* All of the above information shall be recorded in 3.5" PC diskettes in approved software format

Test procedure

* Weight of kentledge.
* Tension pile, ground anchor or compression pile details.
* Plan of test arrangement showing position and distances of kentledge support, rafts, tension or compression piles and reference frame to test pile.
* Jack capacity.
* Calibration certificates of pressure gauges and dial gauges.
* Method of load measurement.
* Method(s) of penetration or uplift measurement.
* Proof test by maintained loading.
* Relevant dates and times.

Test results

* In tabular form.
* In graphical form : log P plotted against log S (only for Failure Load Tests), load plotted against settlement (or uplift load and settlement or uplift) plotted against time
* Ground heave.

Site investigation

* Site Investigation report number
* Borehole reference

21.3 Presentation of Graphical Results

The scales used for plotting load against settlement (or uplift) curves shall be such that a settlement of 10mm is equivalent to a load of 100 tonnes. The same scales shall be used for the load and settlement (or uplift) against time curves.

22.0 COMPLETION OF A TEST

22.1 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 future tests or removed from the Site.

22.2 Kentledge

Kentledge and its supporting structure shall be removed from the test pile and stored so that they are available for use in further tests or removed from the Site.

22.3 Ground Anchors and Temporary Piles

On completion of a Failure Load Test, temporary piles and ground anchors shall be cut off below ground level, removed from the Site and the ground made good with approved material.

On completion of a Working Load Test, temporary piles and ground anchors shall either be removed by cutting off below ground level and making good the ground with approved material or, if agreed, incorporated into the permanent works.

The pile cap, if formed in concrete, shall be broken up and removed from the Site. If the pile cap is made of steel, it shall be cut off and either stored so that it is available for use in further tests or removed from the Site.

22.4 Working Load Test Pile Cap

On completion of a Working Load Test on a working pile, the test pile cap, if in concrete, shall be stripped down and removed from Site. The pile shall be left in a state ready for incorporation into the permanent works.

If the pile cap is made of steel, it shall be cut off and either stored so that it is available for further tests or removed from the Site as required.

23.0 FAILURE OF WORKING LOAD TEST

A pile or pile group shall be deemed to have failed the load test if any one of the following observations is recorded:

a. The maximum settlement under test load of one working load exceeds 12mm.

b. The residual settlement after removal of the test load of one working load exceeds 6mm.

c. The total settlement under twice the working load exceeds 10% of the least width or diameter of the pile or the ultimate capacity of the pile has been reached in the opinion of the Engineer.

d. The test could not be completed due to instability of the kentledge.

e. The test could not be completed due to failure of the pile cap through whatever cause.

f. The scales and/or measuring instrument used are found to have been tampered with.

g. The pile is found to have cracked, crumbled, distorted from its original shape, deflected from its original position and the like.

The Contractor shall not be paid for pile test which has failed. The Contractor shall bear the cost for redesign and enlargement of pilecaps or, if necessary, for replacement piles. Successful test will be paid for as specified.

24.0 SCOPE OF PILE LOAD TEST

Load tests shall be carried out for compression or tension piles. The numbers and types of load tests for this contract shall be as shown in Bill of Quantities.

Generally, preliminary piles for compression failure tests shall be installed in the vicinity of soil investigation report. The approximate positions in plan of boreholes are indicated in the soil investigation report. The results of pile load tests shall be interpreted against the soil stratification identified by the corresponding boreholes near the preliminary piles. In all cases, the final positions of preliminary piles shall be decided by the Engineer to suit site conditions.

The Engineer reserves the right to order, prior to the installation of a preliminary pile, the execution of a borehole to establish if the soil stratification at the location selected for the preliminary pile can be considered suitably representative of the subsurface ground conditions found over the rest of the Site. The Contractor shall not be entitled to extra time for his compliance with the Engineer's instruction either for the execution of the exploratory borehole or for relocating the preliminary pile on the basis of the results from the investigation.

If for any reason, the Engineer is not satisfied with the performance of working piles, he may instruct the Contractor to increase the number of working load tests Conversely, the number of working load tests may be reduced by the Engineer when consistent high quality has been established.

The maximum test load in a working load test shall be 200 % of the working load of a pile. The test load in a failure load test shall be at least but not necessarily limited to 300 % of the working load of a pile. It is held that the Contractor is fully aware of the preliminary nature of the pile design prior to execution of failure load tests and that underestimation of pile failure load, among other things, may occur. Under these circumstances, it is for the Contractor to make all necessary allowance for the proper execution of a failure load test and to provide a reaction system with sufficient capacity to ensure continuity of loading sequences when performing a test. In this respect, the Contractor shall not be entitled to extra time and cost.

A pile or pile group which has passed the working load test may, if the Engineer so decides, be selected for re-test. In a group of piles, which have been tested together, the Engineer may select one or more piles from the group for re-test.

25.0 COMPENSATING PILES

Any pile or pile group which fails under the working load test shall be replaced by one or more piles to be installed as directed by the Engineer, and at no extra cost to the Employer. If, in the opinion of the Engineer, it is impractical or unadvisable to install substitute piles in place of a failed pile, the Contractor shall make his proposals for solving the problem to the Engineer for his consideration and approval. Notwithstanding the Engineer's approval, the Contractor shall be held fully responsible for all costs incurred and any loss to the Employer due to changes in the design of the structure and/or delay to the contract arising from the Contractor's proposal.

For each working load test which has failed, the Contractor is required to carry out at no extra cost to the Employer, an additional working load test on a pile selected by the Engineer as a replacement to the working load test on the pile which has failed. If the additional working load test on the selected pile also shows that this pile is unable to satisfy the acceptance requirements, then all the piled installed in a similar condition will be considered as failed. The capacity of piles installed shall be suitably downgraded based on the working load test results. Any additional piles required as a result of such reduction in pile capacity, including the cost for amending pilecaps and ground beams, shall be entirely at the Contractor's expense. The Engineer's decision on this matter shall be final.

26.0 INTEGRITY TESTING OF PILES

26.1 General

Piles shall be selected by the Engineer for testing and detection of major faults, necking, discontinuities in pile lengths and cross sectional areas of the piles. Integrity testing of piles shall be carried out by an independent testing organisation approved by the Engineer.

If the results of the tests show that the pile or piles are defective, the pile or piles shall be treated as fault and shall be rejected unless the Contractor can demonstrate to the approval of the Engineer effective remedial measures that will be carried out.

The Engineer's interpretations and conclusions arrived at on the test results shall be final.

All preliminary piles shall be subject to high strain dynamic test. Working pile integrity tests is defined in the Bill of Quantities.

26.2 High Strain Dynamic Test

High Strain Dynamic Test shall be conducted on working piles to be selected by the Engineer as the work progresses.

Dynamic Pile Testing is carried out for any of the following:
- determination of pile bearing capacity
- determination of pile integrity

In the case of driven piles:
- determination of pile stress during driving
- determination of hammer efficiency

All tasks require measurement of both axial pile forces and accelerations under at least one hammer blow. A permanent pile set of more than 1.2mm per blow is recommended for activation of soil resistance. Smaller sets may under-predict static capacity. For integrity, permanent set is not required, but the blow should cause motion of the pile toe.

i) Apparatus For Applying Impact Force
The apparatus for applying the impact force shall be either a conventional pile driving hammer or a similar device acceptable for applying the impact force provided it is capable of generating a net measurable pile penetration, or an estimated mobilised static resistance in the bearing strata which, for a minimum period of 3 milliseconds, exceeds the working load assigned to the pile. The driving apparatus shall be positioned so that the impact is applied axially to the head of the pile and concentric with the pile.

ii) Apparatus For Obtaining Dynamic Measurements
The apparatus shall include transducers, which are capable of independently measuring strain and acceleration versus time at a specific location along the pile axis from the moment of impact until the pile comes to rest. The transducers shall be placed at the same location diametrically opposed and on equal distances from the longitudinal axis of the pile so that the measurements are not affected by bending of the pile. At the upper end of the pile they shall be attached at least one and one-half

to three pile diameters from the pile head. Care shall be taken to ensure that the apparatus is securely attached to the pile so that slippage is prevented. The apparatus shall be calibrated to an accuracy of 2 percent throughout the applicable measurement range. If damaged is suspected during use, the transducers shall be recalibrated or replaced.

Force measurements shall be made by strain transducers. A minimum of two of these devices shall be securely attached to the pile on opposite sides of the pile so that they do not slip. Bolt-on, glue-on or weld-on transducers are acceptable. The strain transducers shall have a linear output over entire range of possible pile strains.

Velocity data shall be obtained with accelerometers. A minimum of two accelerometers with a resonant frequency above 10,000 Hertz shall be attached to the pile securely on diametrically opposite sides of the pile so that they do not slip and at equal distances from the pile axis. Bolt-on, glue-on or weld-on transducers are acceptable. The accelerometers shall be linear to a least 1,000 g and 10,000 Hertz for satisfactory result on concrete piles. For steel piles, the accelerometers shall be linear up to 5,000 g. Either a.c. or d.c. accelerometers shall be used. If a.c. devices are used, the time constant shall be a least one second.

iii) Apparatus For Recording, Reducing And Displaying Data

The signals from the transducers during the impact event, shall be transmitted to an apparatus for recording, reducing and displaying data to allow determination of the force and velocity versus time. The acceleration and displacement of the pile head, and the energy transferred to the pile shall be determined. The apparatus shall include an oscilloscope or screen for displaying the force and velocity, a tape recorder for obtaining a record for future analysis, and a means to reduce the data. The apparatus for recording, reducing and displaying data shall have the capability of making an internal calibration check of force, velocity and time scales. No error shall exceed 2 percent of the maximum signal expected.

Signals from the transducers shall be displayed by means of an apparatus on which the force and velocity versus time can be observed for each hammer blow such as an oscilloscope or oscillograph. Both the force and velocity data shall be reproduced for each blow and the apparatus shall be capable of holding and displaying the signal from each selected blow for a minimum period of 30 seconds.

iv) Dynamic Measurements

Dynamic properties shall be determined from a minimum of ten impact records during initial driving. Soil resistance computations shall be determined from one or two representative blows at the beginning of restriking. The force and velocity versus time signals shall be reduced by computer or manually to calculate the developed force, velocity, acceleration, displacement, and energy over the impact event. The number of impact for a specific penetration ram travel length and the number of blows per minute delivered by the hammer shall be recorded. The testing shall be performed by an experienced Civil Engineer in the field of dynamic testing.

v) Submission Of Test Records

The Contractor shall submit all records of results and any other information to the Engineer within three days (3) from the completion of the test.

The result shall consist of the stresses in piles, pile integrity, hammer performance, pile bearing capacity, and whatever information deemed necessary for the report.

For preliminary test and complicated cases, CAPWAP laboratory analysis shall be carried out.

The Engineer's interpretation and conclusion arrived at on the test result shall be final.

vi) CAPWAP Computer Analysis programme

The outputs shall consist of matches of forces and velocities, resistance distribution, static simulation and complete tables of numeric values.
The specialist Contractor shall complete and provide the following:

- Static capacity of pile including the toe resistance and shaft friction
- Hammer Efficiency
- Integrity of Pile
- Case Damping Factor Jc
- Predicted Load Vs Settlement Plots

CAPWAP computer analysis report shall be submitted to the Engineer within seven days (7) from the issuance of instruction. The report shall contain complete analysis, result and their interpretation.

27.0 SHOCK METHOD

27.1 Preparation of the Pile Head

The pile head shall be clearly exposed, free from debris, etc. and not more than 1.0 metre above or below ground level, otherwise the surrounding soil shall be built up or excavated to meet this condition. The pile head shall be smooth over its complete cross-section, free from irregularities and perpendicular to the vertical axis of the pile.

The pile head shall consist of sound concrete. This shall be achieved during the concreting of the pile by flushing out all weak mortar, etc. from the top of the pile head and carefully screeding off to provide a smooth level surface in sound concrete. Alternatively, if the pile head is prepared after concreting, all weak mortar, broken concrete, etc. shall be removed form the pile head to expose sound concrete over its complete cross-section. After cleaning it off to ensure a sound bond, a very thin screed (maximum 1cm) of strong sand/cement mortar, rapid hardening compound, shall be spread to provide a smooth working surface for the shock test equipment. The mortar shall be allowed to harden before testing. The soundness shall be tested by means of light blows from a small hammer.

Any reinforcement or other inclusions protruding from the pile head shall not prevent the testing team from giving the pile the required impact force over the centre of the pile and the placing of a 5cm diameter (approx.) electronic pick-up at about 10cm from the periphery of the pile. Access shall be provided for the service van within 30 metres of the pile.

27.2 Shock Test Equipment

The shock which is to be imparted onto the pile head shall be carried out using a suitable hammer or any approved method which is capable of transmitting vibration to the base of the pile shaft. The electronic pick-ups located on the pile head shall be approved velocity transducers or accelerometers connected through an approved frequency analysed to any X-Y plotter. The mechanical admittance shall be plotted on a vertical scale and the frequency on the horizontal scale. Both the horizontal and vertical scales shall be varied as required. The equipment shall have an independent power supply.

27.3 Shock Test

The Contractor shall provide the testing team with a site plan showing the pile layout and a list of the piles to be tested.

Before testing, the heads of the piles shall be inspected by the testing team for regularity and soundness and any unsatisfactory pile heads reported to the Engineer. They shall be made good to the satisfaction of the Engineer and smoothed off using a suitable epoxy mortar if necessary. Preliminary tests shall be carried out to establish the appropriate scales and to check the electronic circuit.

28.0 SONIC LOGGING METHOD

For the purpose of carrying out sonic logging, the Contractor shall be required to install the necessary tubing for the tests at all pier location or as directed by the Engineer.

The tubes shall be of internal diameter not less than 50mm with no internal projections or couplings. They can be of mild steel pipes or PVC pipes. Four (4) nos. of tubes are required for each pile greater than 700mm diameter while two (2) nos. are required for each smaller diameter pile.

The tubes shall be fixed to the longitudinal bars with equal spacing on the inside perimeter of the links. The tubes shall be watertight with the bottom of the tube sealed and suitably weighted to prevent floating. The tubes shall be secured to the internal face of the reinforcement cage at equal distance from each other on the circumference.

The tubes shall extend the full depth of the pile and project 300mm above the top of the concrete and not lower than 300mm below the surface of the ground. All joints shall be made watertight. The tubes shall be filled with water to provide the necessary acoustic coupling, and then plugged or capped before concreting. The type of tube and condition of sealing shall be checked and approved by the Engineer before installation.

The rate of logging for increments of depth shall be approved by the Engineer.

After conducting the tests, all metal tubes shall be grouted and water in the tubes displaced. The grout shall be dense cement grout with an approved expanding agent.

Prior to testing, the necessary equipment shall be thoroughly checked to ensure that all parts are functioning satisfactorily. During sonic logging testing, where any irregularities are detected, the tests shall be repeated at a smaller scale to allow a "close-up view" of the irregularities.

29.0 PRESENTATION OF TEST RESULTS

The time required to carry out the test for each pile must be recorded along with records of starting time and finishing time.

The results of the tests shall be presented in report form by the testing firm and must be signed by a professional engineer. The report shall include comprehensive engineering analysis of the test results for each pile taking into consideration the soil condition and any other relevant factors. Interim reports of each pile or group of piles tested in one day shall be submitted to the Engineer within 3 days of the completion of the test or tests. A final comprehensive report shall be submitted to the Engineer within 10 days of the completion of the last test or tests.

30.0 PROOF CORING OF PILE SHAFTS

The Contractor shall check the quality of the concrete in the shafts of working piles as directed by the Engineer. This shall be achieved by a vertical diamond core hole drilled through the centre region of the pile from pile head to required depth. The location of the drill hole and depth shall be approved by the Engineer. Full core recovery shall be attempted. The core so produced shall not be less than 50mm in diameter. The minimum number of piles for proof coring test shall not be less than 1% of the total number of working piles.

For each pile to be cored, the coring work shall be completed before the concrete in the pile has reached an age of 28 days to allow the cores to be tested for unconfined compression tests at 28 days. The Engineer shall mark the sections of the core to be tested and the Contractor shall arrange for testing in an approved laboratory. A minimum of six (6) unconfined compression tests shall be conducted on cores obtained from a pile. Additional number of the unconfined compression tests may be requested by the Engineer if in the opinion of the Engineer the quality of the concrete of the pile is suspicious.

The cored hole in the pile shall be grouted after testing. The grout shall be an approved dense cement grout with a minimum 28 days strength of 30N/mm2. If the pile is found to be faulty in the opinion of the Engineer because of defects such as cracks, overbreaks, necking, cavity, inclusion of foreign deleterious materials, poor quality concrete, etc., the pile shall be rejected and the Contractor shall undertake all necessary remedial measures to the approval of the Engineer.

In conjunction to core testing, the Engineer may request sonic logging test to be conducted in the cored holes or pre-installed tubings to determine the in-situ density of the pile and their integrity continuously along the pile length in correlation with core samples.

31.0 INSTRUMENTATION FOR PRELIMINARY PILES

31.1 Strain Gauges

Vibrating wire type strain gauges shall be installed in preliminary pile. The following vibrating wire strain gauges and equipment or equivalent to the approval of the Engineer shall be used:

i) Vibrating wire type weldable strain gauge. Steel wire of length 62mm, and frequency range 0.8 to 2.4 kHz and associated connections, cables and read out device.
ii) 3M Scotchcast Insulating Resin 4.
iii) Miscellaneous small tools and materials for making concrete.

All strain gauges shall be mounted on major longitudinal steel bars of the steel cage of the preliminary pile. The strain gauges shall be installed in sets of four and equally spaced on the steel cage at levels directed by the Engineer. A total of 6 sets of strain gauges shall be installed.

The steel bars shall be polished using a hand held electrical grinder to obtain a flat surface for the strain gauges to be placed on. Polishing shall be completed by hand using silicon carbide paper. The surfaces of the polished bars shall be cleaned using acetone.

The weldable strain gauges shall then be bonded to the steel bars using a microbond welder. Next, the strain gauge sensors shall be placed on the strain gauges and tied firmly to the steel bars with wires. Short lengths of PVC protective pipe shall be placed over the strain gauge locations, and filled with insulating resin.

The electrical lead wires from the sensors shall be brought to the top of the pile through PVC pipes tied to the steel cage.

The gauges shall be checked before and after microwelding, after installation, after placement of the steel cage in the borehole, and after concreting.

31.2 Rod Extensometers

A system of sleeved rods to the approval of the Engineer shall be installed in each preliminary pile to determine the movement under testing loads. A minimum of three (3) levels within the pile shaft shall be measured as shown in the drawings. The rod extensometers shall have the capability of measuring movements both mechanically and electronically.

31.3 Instrumentation Installation

The Contractor shall follow the manufacturer recommended procedures for instruments installations and shall provide a method statement for approval prior to installation. The work shall be carried out by persons experienced in this type of work. A data logging system shall be provided for all automatic recording instruments.

31.4 Instruments Identification and Recording

The leads of various instruments shall be probably identified to facilitate easy hook-up and recording. All instrument readings shall be recorded as directed by the Engineer in approved forms. Any sort of calibration or conversion charts shall be available on site at all times.

31.5 Monitoring

The nominated testing agency shall submit a method statement on pile instrumentation for the Engineer's agreement before the conduct of the tests. The method statement shall give full details of the proposed methods, equipments, specifications and precautions to be taken for the proper installation and monitoring of pile instrumentation, and the criterion and procedure for interpretation of results obtained, including any other relevant information required by the Engineer. Prior to the tests, the instruments and necessary monitoring equipment shall be checked to ensure all parts are functioning satisfactorily.

The results of the pile instrumentation and monitoring programme shall be presented in a report prepared by the testing agency and signed by a qualified engineer. The report shall include a comprehensive engineering analysis of the test data, taking into consideration the soil condition and any other relevant factors. An interim report shall be submitted to the Engineer within 3 working days after the completion of each Failure Load Test, and a final comprehensive report shall follow 7 days later. The testing agency shall be required to correlate the results of pile instrumentation with that of the Failure Load Test and against the soil information available in the soil report from exploratory boreholes located in the vicinity of preliminary test piles.

The Contractor shall make every necessary allowance for the proper execution of the instrumentation programme. Full cooperation shall be given to the nominated agency carrying out the tests. The Contractor shall not be allowed to claim for extra time to the contract on all matter arising from the execution of pile instrumentation, and on any consequences arising out of such instrumentation.

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