SERIES 1600
PILING AND EMBEDDED RETAINING WALLS

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PILING AND EMBEDDED RETAINING WALLS

1601 General Requirements for Piling and Embedded Retaining Walls

Definitions

1 "Allowable pile capacity": a capacity which takes into account the pile's bearing capacity, the materials from which the pile is made, the required load factor, settlement, pile spacing, downdrag, the overall bearing capacity of the ground beneath the piles and other relevant factors.

2 "Commencing surface": the level at which the piling equipment first enters the ground.

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

4 "Constant rate of penetration (CRP) test": a test in which the pile is made to penetrate the ground at a constant controlled speed, while the force applied at the top of the pile to maintain the rate of penetration is continuously measured.

5 "Constant rate of uplift (CRU) test": a test in which the pile is made to lift out of the ground at a constant controlled speed, while the force applied at the top of the pile to maintain the rate of extraction is continuously measured.

6 "Cut-off level": the level to which the pile is trimmed.

7 "Design Verification Load (DVL)": a load which will be substituted for the Specified Working Load for the purpose of a test.

8 "Kentledge": dead load used in a loading test.

9 "Load factor": the ratio between the pile's ultimate bearing capacity and maximum safe bearing capacity.

10 "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.

11 "Preliminary pile": a pile installed before the commencement of the main piling works or specific part of the Works.

12 "Proof load": a load applied to a selected working pile to confirm that it is suitable for the load at the settlement specified.

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

14 "Reaction system": the arrangement of the kentledge, piles, anchorages or spread foundations that provide a resistance against which the pile is tested.

15 "Pile settlement": the axial movement at the top of the pile. The value of pile settlement specified for a given load refers to the value reached at the end of the first cycle of loading. Where piles are to be loaded and unloaded through a number of cycles settlement shall be the cumulative vertical movement.

16 "Specified Working Load (SWL)": the specified load on the head of the pile as stated in the relevant Appendix.

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

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

19 "Ultimate bearing capacity": the maximum resistance offered by the pile when the strength of the soil is fully mobilised.

20 "Working pile": one of the piles forming the foundation of a structure.

21 "Embedded retaining wall": retaining wall with shuttering provided either by the surrounding ground (ie. cast against an excavated soil face) or sheet piles inserted into the ground.

22 "Embedded retaining wall element": an individual component utilised in a particular embedded retaining walling system eg. diaphragm wall panel, or primary or secondary pile in a secant wall which can be constructed in isolation.

General

23 (11/03) Piles and embedded retaining walls shall be constructed from one of the permitted options described in Appendix 16/1 and in compliance with this Series and appropriate Clauses of Series 1700, 1800, and 1900 unless otherwise described in Appendix 16/1.

Layout, design and construction

24 Where applicable Appendices 1/10 and 1/11 in Series 100 list structures and elements which the

Contractor has to design in accordance with the Specification and relevant Appendices 16/1 to 16/18. Where required in Appendix 16/1, the Contractor shall also submit design calculations, details of materials to be used, and a schedule of dimensions.

Pile tolerances

25 Piles shall be installed within the following maximum permitted tolerances:

Position:	75 mm in any direction at commencing level.
Verticality:	1 in 75 deviation from the vertical
Rake:	1 in 25 deviation from the specified rake for piles raking up to 1:6 and 1 in 15 for piles raking more than 1:6.

No method of forcible correction will be permitted unless it can be proved that the integrity, durability and performance of the piles will not be adversely affected.

Piling method

26 Where required in Appendix 16/1, the Contractor shall supply all relevant details of the method of piling, the plant and monitoring equipment he plans to adopt. Alternative piling methods may be used provided that they satisfy the requirements of the Specification.

Records

27 The Contractor shall keep records as indicated by an asterisk in Table 16/1 for the installation of each pile, or for each element in embedded retaining walls, or as listed in Clause 1615 for sheet pile walls. The signed records will form a record of the work. Copies of these records shall be provided where required in Appendix 16/1.

Any unexpected driving or boring conditions shall be noted in the records.

Damage

Damage criteria for adjacent structures or services

28 Damage criteria for adjacent structures or services are given in Appendix 16/1. Where required in Appendix 16/1, the Contractor shall submit his plans for making surveys and monitoring movements or vibration before the commencement of the piling works.

Damage to piles or completed wall elements

29 The Contractor shall ensure that during the course of the work, displacement or damage which would impair either performance or durability does not occur to completed piles or wall elements.

Where required in Appendix 16/1, the Contractor shall submit his planned sequence and timing for driving or boring piles, or for installing wall elements having regard to the avoidance of damage to adjacent piles or wall elements.

Temporary support

30 The Contractor shall ensure that where required, any permanently free-standing piles are temporarily braced or stayed immediately after driving to prevent loosening of the piles in the ground and to ensure that no damage resulting from oscillation, vibration or movement can occur.

Ordering of piles

31 The Contractor shall ensure that the piles are available in time for incorporation in the Works. All piles and production facilities shall be made available for inspection at any time. Piles shall be examined by the Contractor at the time of delivery and any faulty units replaced. Where required in Appendix 16/1, the records of testing of the concrete and steel used in the piles shall be provided.

Testing of materials shall be in accordance with Appendix 1/5. For steel piles the Contractor shall submit details of all preliminary test results at least 5 working days prior to ordering piles for the main works other than temporary works.

1602 Precast Reinforced and Prestressed Concrete Piles and Precast Reinforced Concrete Segmental Piles

Materials and components

Steel and iron components

1 (11/05) In the manufacture of precast concrete piles and jointed precast concrete segmental piles, fabricated steel components shall comply with BS EN 10025-1 and BS EN 10025-2, Grades S275 or S355, cast steel components with BS 3100, grade A (A1, A2 or A3) and ductile iron components with BS EN 1563 material designation symbol EN-GJS-350-22, EN-GJS-400-15, EN-GJS-400-10.

Pile joints for segmental piles

2 The joints shall be close-fitting face to face and the locking method shall be such as to hold the faces in intimate contact. Where required in Appendix 16/2, details of the design, manufacture and tests of the jointing system shall be submitted prior to the commencement of the piling works.

A jointed pile shall be capable of withstanding the same driving stresses as a single unjointed pile of the same cross-sectional dimensions and materials.

The welding of a joint to main reinforcement in lieu of a lapped connection with projecting bars affixed to the joint shall not be permitted.

Each pile joint shall be square to the axis of the pile within a tolerance of 1 in 150. The centroid of the pile joint shall lie within 5 mm of the true axis of the pile element.

Pile toes

3 Pile toes shall be constructed so as to ensure that damage is not caused to the pile during installation.

Pile head reinforcement

4 Pile heads shall be so reinforced or banded as to prevent bursting of the pile under driving.

TABLE 16/1: Records to be kept (indicated by an asterisk)

Data	Driven precast concrete and steel bearing piles	Driven segmental concrete piles	Driven cast-in-place concrete piles	Bored cast-in-place concrete piles	Continuous flight auger concrete or grout piles
Contract	*	*	*	*	*
Pile reference number (location)	*	*	*	*	*
Pile type	*	*	*	*	*
Nominal cross-sectional dimensions or diameter	*	*	*	*	*
Nominal diameter of underream/base	-	-	-	*	-
Length of preformed pile	*	*	-	-	-
Standing groundwater level from direct observation or given site investigation data	-	-	*	*	*
Date and time of driving, redriving or boring	*	*	*	*	*
Date of concreting	-	-	*	*	*
Ground level at pile position at commencement of installation of pile (commencing surface)	*	*	*	*	*
Working level on which piling base machine stands	*	*	*	*	*
Depth from ground level at pile position to pile toe	*	*	*	*	*
Toe level	*	*	*	*	*
Pile head level as constructed	*	*	*	*	*
Pile cut-off level	*	*	*	*	*
Length of temporary casing	-	-	*	*	-
Length of permanent casing	-	-	*	*	-
Type, weight, drop and mechanical condition of hammer and equivalent information for other equipment	*	*	*	-	-
Number and type of packing used and type and conditions of dolly used during driving of the pile	*	*	*	-	-
Set of pile or pile tube in millimetres per 10 blows or number of blows per 25 mm of penetration	*	*	*	-	-
Temporary compression of ground and pile	*	*	*	-	-
Driving resistance taken at 0.25 m intervals	*	*	*	-	-
Soil samples taken and in situ tests carried out during pile formation or adjacent to pile position	*	*	*	*	*
Length and details of and cover to reinforcement	-	-	*	*	*
Concrete mix	-	-	*	*	*
Volume of concrete supplied to pile where this is practical	-	-	*	*	*
All information regarding obstructions delays and other interruptions to the sequence of work	*	*	*	*	*
Pile forming equipment including rig no.	*	*	*	*	*
Description of ground excavated	-	-	-	*	*
Depth from commencing surface to changes in strata and to standing ground water and any fluctuations	-	-	-	*	*

TABLE 16/1: Records to be kept (cont'd)

Data	Driven precast concrete and steel bearing piles	Driven segmental concrete piles	Driven cast-in-place concrete piles	Bored cast-in-place concrete piles	Continuous flight auger concrete or grout piles
Depth to average levels of concrete surface before and after withdrawing temporary lining	-	-	-	*	-
Type, torque, assessed efficiency of motor	-	-	-	-	*
Depth to concrete surface after every concrete load	-	-	*	*	*
For raking piles, angle of rake	*	*	*	*	-
Support fluid tests	-	-	-	*	*
Monitoring information referred to in Clause 1604 sub-Clause 15	-	-	-	-	*
Level of top of reinforcement cage, as constructed	-	-	*	*	*
Contract	*	*	*	*	*
Element reference number (location)	*	*	*	*	*
Element type	*	*	*	*	*
Nominal cross-sectional dimensions	*	*	*	*	*
Top and bottom of guidewall level (as appropriate)	*	*	*	-	-
Length of preformed element (as appropriate)	*	-	-	-	*
Groundwater level from direct observation	*	*	*	*	*
Date and time of excavation	*	*	*	*	*
Date of concreting	*	*	*	*	*
Details of material samples taken	*	*	*	*	*
Ground level at element position at commencement of element installation (commencing surface)	*	*	*	*	*
Working level on which base machine stands	*	*	*	*	*
Depth from ground level or guide wall, as appropriate, at element position to element toe	*	*	*	*	*
Toe level	*	*	*	*	*
Element head level as constructed	*	*	*	*	*
Element cut-off level	*	*	*	*	*
Stop end details	*	-	-	-	-
Length of temporary casing (as appropriate)	-	*	*	*	*
Length of permanent casing (as appropriate)	-	-	*	*	*
Soil samples taken and in situ tests carried out during element formation or adjacent to element position	*	*	*	*	*
Tests on support fluid (as appropriate)	*	*	*	*	*
Length and details of steel reinforcement (as appropriate)	*	*	*	*	*
Concrete mix or grout (as appropriate)	*	*	*	*	*
Volume of concrete supplied to element	*	*	*	*	*
Graph of top of concrete or grout level vs volume placed by batch (as appropriate)	*	*	*	*	*
All information regarding obstructions, delays and other interruptions to the sequence of work	*	*	*	*	*
As constructed positional records vertical and horizontal, as required	*	*	*	*	*
Movements of ground and structures and services as specified	*	*	*	*	*

NOTES
1. All levels shall be relative to the Datum specified in Appendix 1/12.
2. All times shall be given in 24-hour format.

Tolerances in pile dimensions

5 The cross-sectional dimensions of the pile shall be not less than those specified and shall not exceed them by more than 6 mm. Each face of a pile shall not deviate by more than 6 mm from any straight line 3 m long joining two points on that face, nor shall the centre of area of the pile at any cross-section along its length deviate by more than 1/500 of the pile length from a line joining the centres of area at the ends of the pile. Where a pile is less than 3 m long the permitted deviation from straightness shall be reduced below 6 mm on a pro rata basis in accordance with actual length.

The head of a pile element or the end of the pile upon which the hammer acts shall be square to the pile axis within a tolerance of 1 in 150.

Reinforcement for precast reinforced and prestressed concrete piles

6 (11/03) Steel reinforcement shall be as described in Appendix 16/2 and in accordance with Series 1700.

The main longitudinal reinforcing bars in piles not exceeding 12 m in length shall be in one continuous length. In piles more than 12 m long, joints will be permitted in main longitudinal bars so that the number of joints is minimised. Joints in reinforcement shall be such that the full strength of the bar is effective across the joint.

Lap or splice joints shall be provided with link bars designed to resist eccentric forces. Reinforcement shall be incorporated for lifting and handling purposes.

Spacers shall be designed and manufactured using durable materials which shall not lead to corrosion of the reinforcement or spalling of the concrete cover. Where required in Appendix 16/2, details of the means by which the Contractor plans to ensure the correct cover to and position of the reinforcement shall be submitted.

Reinforcement for precast reinforced concrete segmental piles

7 (11/03) Steel reinforcement shall be as described in Appendix 16/2 and in accordance with Series 1700.

The main longitudinal reinforcing bars shall be in one continuous length. Reinforcement shall be incorporated for lifting and handling purposes.

Spacers shall be designed and manufactured using durable materials which shall not lead to corrosion of the reinforcement or spalling of the concrete cover. Where required in Appendix 16/2, details of the means by which the Contractor plans to ensure the correct cover to and position of the reinforcement shall be submitted.

Formwork

8 If a pile is constructed with a shaped point or shoe, then the end of the pile shall be symmetrical about the longitudinal axis of the pile. Holes for handling or pitching, where provided in the pile, shall be lined with steel tubes; alternatively, inserts may be cast in.

Formwork shall be robust, clean and so constructed as to prevent loss of grout or aggregate from the wet concrete and ensure the production of uniform pile sections, free from defects. The piles shall be removed from the formwork in such a manner that damage to the pile is prevented.

Concrete

General

9 Cement materials, aggregates, admixtures and water shall be in accordance with Series 1700.

The method of placing and compacting the concrete shall be such as to ensure that the concrete in its final position is dense and homogeneous.

Protecting and curing concrete

10 Immediately after compaction, concrete shall be adequately protected from the harmful effects of the weather, including wind, rain, rapid temperature changes and freezing. Curing and accelerated curing shall comply with Clause 1710.

Piles shall not be removed from formwork until a sufficient pile concrete strength has been achieved to allow the pile to be handled without damage.

Prestressing

General

11 Prestressing operations shall be carried out only under the direction of an experienced and competent supervisor. All personnel operating the stressing equipment shall have been trained in its use.

The extensions and total forces, including allowance for losses, shall be calculated before stressing commences.

Stressing of tendons and transfer of prestress shall be carried out at a gradual and steady rate. The force in the tendons shall be obtained from readings on a recently calibrated load cell or pressure gauge incorporated in the equipment. The extension of the tendons under the total forces shall be within 5% of the calculated extension.

Concrete strength

12 The Contractor shall cast sufficient cubes, cured in the same manner as the piles, to be able to demonstrate by testing two cubes at a time, with appropriate intervals between pairs of cubes, that the necessary in situ strength of the concrete has been reached.

Concrete in the piles shall not be stressed until two test cubes attain the necessary strength.

Records

13 The Contractor shall keep detailed records of times of tensioning, measured extensions, pressure gauge readings or load cell readings and the amount of pull-in at each anchorage. The Contractor shall also check the cover to reinforcement of each pile and shall ensure it is at least that specified. Copies of these records shall be provided where required in Appendix 16/2.

Post-tensioned piles

14 Apart from the requirement for ducts and vents in post-tensioned piles to be grouted after the transfer of prestress, the requirements for pre-stressed piles apply.

Grouting procedure

15 Grout shall be mixed for a minimum of 2 minutes and until a uniform consistency is obtained.

Ducts shall not be grouted when the air temperature in the shade is lower than 3°C.

Before grouting is started all ducts shall be thoroughly cleaned by means of compressed air which shall be free of oils.

Grout shall be injected near the lowest point in the duct in one continuous operation and allowed to flow from the outlet until the consistency is equivalent to that of the grout being injected.

Vents in ducts shall be provided in accordance with Clause 1711.

Grout

16 Grout for prestressing shall have the following properties:

a) (11/03) The design and consistence of grout to be used in the formation of piles shall produce a mix which is suitable for pumping.

b) (11/03) Grout shall consist only of Portland cement CEM I to BS EN 197-1, water and admixtures. Admixtures are only to be used in accordance with the Manufacturer's instructions and shall comply with Clause 1703.

c) (11/03) Grout shall have a water/cement ratio as low as possible consistent with the necessary consistence, and the water cement ratio shall not exceed 0.40.

d) Grout shall not bleed in excess of 2% after 3 hours, or a maximum of 4%, when measured at 18°C in a covered glass cylinder approximately 100 mm in diameter with a height of grout of approximately 100 mm, and the water shall be reabsorbed after 24 hours.

Testing works grout

17 (11/03) Cube strength testing shall be carried out in accordance with BS EN 12390-1. A sample shall consist of a set of six 100 mm cubes. Three cubes shall be tested at seven days and the remaining three at 28 days after casting.

Batching grout

18 The weighing and water-dispensing mechanisms shall be maintained at all times to within the limits of accuracy described in BS 1305.

The weights of each component of the mix shall be within 2% of the respective weights per batch.

Mixing grout

19 Cement grouts shall be mechanically mixed using:

a) high speed colloidal mixer (minimum speed = 1000 revs/minute); or

b) paddle mixer (minimum speed = 150 revs/minute)

or other suitable mixer subject to satisfactory evidence of performance.

The grout shall be mixed on site until a homogenous grout is obtained and shall be kept in continuous movement until it is used. It shall be used within 30 minutes from the start of mixing. Following mixing the grout shall be passed through a 5 mm aperture sieve and shall be remixed if lumps are retained.

Transporting grout

20 Grout shall be transported from the mixer to the position of the pile in such a manner that segregation of the mix does not occur.

Placing grout in cold weather

21 Grout shall have a minimum temperature of 5°C when placed. No frozen material or material containing ice shall be used for making grout. All plant and equipment used in the transporting and placing of grout shall be free of ice that could enter the grout.

Records

22 The Contractor shall keep records of grouting, including the date, the proportions of the grout and any admixtures used, the pressure, details of interruption and topping up required. Copies of these records shall be provided where required in Appendix 16/2.

Pile quality

23 A certificate of quality from the pile manufacturer shall be provided where required in Appendix 16/2 stating that the requirements of this Specification have been fulfilled during manufacture.

Marking of piles

24 (11/03) Each pile shall be marked in such a manner that it can be identified with the records of manufacture which shall state the date of casting, the cement type, concrete strength class, element length, the prestressing force where appropriate and any other relevant data. On delivery the piles shall be accompanied by records of manufacture. Lifting positions shall be marked on each pile in accordance with the requirements of design.

Handling, transportation and storage of piles

25 The method and sequence of lifting, handling, transporting and storing piles shall be such as to avoid shock loading and to ensure that the piles are not damaged. Only designed lifting and support points shall be used. During transport and storage, piles shall be appropriately supported under the marked lifting points or fully supported along their length.

All piles within a stack shall be in groups of the same length. Packing of uniform thickness shall be provided between piles at the lifting points.

Concrete shall at no time be subjected to loading, including its own weight, which will induce a compressive stress in it exceeding 0.33 of its strength at the time of loading or of the specified strength, whichever is the lesser. For this purpose an assessment of the strength of the concrete and of the stresses produced by the loads shall be carried out.

A pile shall be rejected when the width of any transverse crack exceeds the value given in Table 1 of BS 5400 : Part 4. The measurement shall be made with the pile in its working attitude.

Driving piles

Strength of piles

26 Piles shall not be driven until the concrete cubes have achieved the specified characteristic strength or the pile has attained the strength to resist driving stresses, whichever is the greater.

Leaders and trestles

27 At all stages during driving and until incorporation into the structure the pile 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 damage to the pile.

Performance of driving equipment

28 Where required in Appendix 16/2, the Contractor shall provide information on the efficiency and energy of the driving equipment including when followers are used. Where required in Appendix 16/2, (or 16/6 as appropriate), dynamic evaluation and analysis shall be provided.

Where a drop hammer is used, the mass of the hammer shall be at least half that of the pile or pile segment. For other types of hammer the energy delivered to the pile per blow shall be at least equivalent to that of a drop hammer of the stated mass. Drop hammers shall not be used from floating craft in such a manner as to cause instability of the craft or damage to the pile.

Length of piles

29 The length of pile to be driven in any position shall be as specified in Appendix 16/2. During the execution of the Works any amendments to the scheduled lengths shall be recorded by the Contractor and a full statement of the reasons included in the pile record.

Driving procedure and redrive checks

30 The driving procedure shall be such as to avoid damage to the piles.

The Contractor shall comply with all the particular requirements of Appendix 16/2 on driving resistances and characteristics.

The driving of each pile shall be continuous until the depth or set as required by the design has been reached. In the event of unavoidable interruption to driving, the pile may be redriven provided it can subsequently be driven to the designed depth and/or resistance or set without damage. A follower shall not be used unless the set is revised where applicable in order to take into account reduction in the effectiveness of the hammer blow.

Driving records shall be made for every pile. This record shall contain the weight and fall of the hammer or ram and the number of blows for each 0.25 m of penetration, unless otherwise specified in Appendix 16/2, (or 16/5 or 16/6 as appropriate).

Any unexpected change in driving characteristics shall be included in the pile record.

Set

31 The set and temporary compression shall be measured and recorded for each pile at the completion of driving unless otherwise stated in Appendix 16/2, (or 16/6 as appropriate).

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

(a) The exposed part of the pile shall be in good condition without damage or distortion.

(b) The helmet, dolly and any packing shall be in sound condition.

(c) The hammer blow shall be in line with the pile axis and the impact surfaces shall be flat and at right angles to the pile and hammer axis.

(d) The hammer shall be in good condition, delivering adequate energy per blow, and operating correctly.

(e) The temporary compression of the pile shall be recorded if required in Appendix 16/2, (or 16/6 as appropriate).

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

Driving sequence and risen piles

32 Piles shall be driven in a sequence to minimise any detrimental effects of heave and lateral displacement of the ground. The sequence and method of piling including preboring shall limit uplift and lateral movement so that the final position of each pile is within the specified tolerances. At all times the deflections of each pile from its axis as driven shall not be such as to cause damage or impair durability of the piles or any structures or services.

The maximum permitted uplift of each pile due to any one pile driven within a pile centre to centre radius of eight pile diameters is 3 mm or such figure as shall be specified unless it can be demonstrated by static load testing that uplift exceeding this amount does not affect the ability of the pile to meet the requirements of this Specification.

Even if during the installation of preliminary piles uplift is shown to be within the permitted maximum and the preliminary piles tested meet the requirements of the Specification, checks of uplift on working piles shall be made by the Contractor at least once a week throughout the period of the piling work and the results recorded.

If preliminary piles are not installed the Contractor shall commence installation of working piles taking measures to reduce or eliminate uplift until it can be established by site measurements that such measures are no longer necessary. Thereafter checks on uplift shall be made by the Contractor at least once a week and the results recorded.

If a static load test shows that a pile which uplifted more than the maximum permitted amount due to any pile driven within a radius of eight pile diameters does not comply with the requirements of the Specification all such piles that may have been uplifted shall be redriven.

If records and measurements show that piles have been laterally displaced so as to be outside the permitted tolerance or damaged the measures the Contractor plans to adopt to enable the piles to comply with the Specification shall be provided in accordance with Appendix 16/2.

Laterally displaced piles shall not be corrected by forcible correction at the heads.

Preboring

33 If preboring is specified, the diameter and depth of prebore shall be as stipulated in Appendix 16/2.

Other means to ease pile drivability may be used provided the completed piles meet the requirements of the Specification.

Repair and lengthening of piles

Repair of damaged pile heads

34 If it is necessary to repair the head of a pile before it has been driven to its final level, the Contractor shall carry out such repair in a way which allows the pile-driving to be completed without further damage. If the driving of a pile has been completed but the level of sound concrete of the pile is below the required cut-off level, the pile shall be made good to the cut-off level, or the pile cap or substructure may be locally deepened, so that the completed foundation will safely withstand the specified working load.

Lengthening of precast reinforced and prestressed concrete piles

35 Any provision for lengthening piles incorporated at the time of manufacture shall be designed by the Contractor to resist all stresses to which it may be subjected.

If no provision for lengthening piles was incorporated at the time of manufacture, any method for lengthening shall be such that the extended pile including any joints is capable of taking safely the stresses during driving and under load.

Lengthening of segmental piles

36 Where piles are driven to depths exceeding those expected, leaving insufficient projection for penetration into the following works, the piles shall be extended or replaced so that the completed piles are capable of meeting the requirements of the Specification.

Driving repaired or lengthened piles

37 Repaired or lengthened piles shall not be driven until cubes for the added concrete have reached the specified characteristic strength of the concrete of the pile.

Cutting off pile heads

38 When the driving of a pile has satisfied the Specification requirements the concrete at the head of the pile shall be cut off to the level specified. Reinforcing bars projecting above this level shall be as specified.

Care shall be taken to avoid shattering or otherwise damaging the rest of the pile. Any cracked or defective concrete shall be cut away and the pile repaired to provide a full and sound section to cut-off level.

1603 Bored Cast-in-Place Piles

Support fluid

1 Where support fluid is used to maintain the stability of the excavation it shall be in accordance with Clause 1618.

Diameter of piles

2 The diameter of a pile shall be not less than the specified diameter.

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

Boring

Boring near recently cast piles

3 Piles shall be bored in an order and in such a manner that no damage is sustained by previously formed piles.

Casings

4 (11/03) Temporary casings shall be of quality of material, length and thickness adequate for the purpose of preventing water and unstable soil from entering the pile excavations. A short length of temporary casing shall be provided for all piles to provide an upstand of at least 1 m above surrounding ground level for safety and to prevent contamination of the concrete in the bore.

Temporary casings shall maintain the excavations to their full dimensions and ensure that piles are completed to their full cross-sectional dimensions.

The use of a vibrator to insert and withdraw temporary casings is subject to compliance with Clause 109 (Control of Noise and Vibration) and sub-Clause 1601.28 and to the method not causing disturbance of the ground which would adversely affect the construction or the capacity of piles.

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

Where piles are bored under water or support fluid in an unlined state, the insertion of a full-length loosely fitting casing to the bottom of the bore prior to placing concrete will not be permitted.

If required, permanent casings shall be specified in Appendix 16/3.

Stability of pile bore

5 Where boring takes place through unstable water-bearing strata, the process of excavation and the support fluid and depth of temporary casing where employed shall be such that soil from outside the area of the pile is not drawn into the pile section and cavities are not created outside the temporary casing as it is advanced.

Where a support fluid is used for maintaining the stability of a bore, an adequate temporary casing shall be used in conjunction with the support fluid so as to ensure stability of the strata near ground level until concrete has been placed. During construction the level of drilling fluid in the pile excavation shall be maintained within the cased or stable bore so that it is not less than 2 m above the level of external standing groundwater at all times, unless stated otherwise in Appendix 16/3.

Pumping from pile bores

6 Pumping from pile bores shall not be permitted unless the bore has been sealed against further water

entry by casing or unless the soil is stable and will allow pumping to take place without ground disturbance below or around the pile.

Continuity of construction

7 The pile shall be bored and the concrete shall be placed without such delay as would lead to impairment of the performance of the pile.

The time period during which each pile is excavated and the concrete is placed shall not exceed 12 hours. The time period shall start when excavation below the temporary lining tubes commences. Where the construction sequence is such that the time period of 12 hours will be exceeded even if no delays are taken into account, a realistic time period during which the pile is excavated and concrete placed shall be stated in the Contractor's method statement. The Contractor shall advise on the likely effect of this extended pile construction period on the performance and capacity of the pile.

Enlarged pile bases

8 A mechanically formed enlarged base shall be no smaller than the dimensions specified and shall be concentric with the pile shaft to within a tolerance of 10% of the shaft diameter. The sloping surface of the frustum forming the enlargement shall make an angle to the axis of the pile of not more than 35°.

At the specified diameter of the underream at the perimeter of the base there shall be a minimum height of 150 mm.

Inspection

9 Each pile bore which does not contain standing water or support fluid shall be inspected from the ground surface prior to concrete being placed in it to ensure the base is clean. Adequate means of lighting, measuring tapes and a means of measuring verticality shall be used. For piles of 750 mm diameter or larger and where manned inspection of the pile base is specified in Appendix 16/3, equipment shall be provided by the Contractor to enable his representatives to descend into the bore for the purpose of inspection. The Contractor shall provide all necessary facilities to enable an inspection of any pile excavation to be made including facilities to check the depth, verticality and position. The full requirements of BS 8008 shall be followed.

The Contractor shall designate a Supervisor to supervise each inspection. The Supervisor shall have a copy of BS 8008 and shall ensure that every person involved in the descent of piles is familiar with its requirements.

Cleanliness of pile bases

10 On completion of boring loose, disturbed or softened soil shall be removed from the bore using appropriate methods, which shall be designed to clean while at the same time minimizing ground disturbance below the pile bases. Water or support fluid shall be maintained at such levels throughout and following the cleaning operation that stability of the bore is preserved. At all times when the pile head is unattended, the bore shall be clearly marked and fenced off so as not to cause a safety hazard.

Reinforcement

11 (11/03) Steel reinforcement shall be as described in Appendix 16/3 and in accordance with Series 1700. Where steel sections are used for reinforcement, they shall be in accordance with Series 1800.

The number of joints in longitudinal steel bars shall be kept to a minimum. Joints in steel reinforcement shall be such that the full strength of each bar is effective across the joint and shall be made so that there is no detrimental displacement of the reinforcement during the construction of the pile. Reinforcement shall be maintained in its correct position during concreting of the pile, to allow a vertical tolerance of +150/-50 mm on the level of the reinforcement projecting above the final cut off level. Where reinforcement is made up into cages, they shall be sufficiently rigid to enable them to be handled, placed and concreted without damage. If the cage is to be welded together, welding shall be carried out to the requirements of BS 7123.

Unless otherwise specified, reinforcement shall extend to the base of the pile or to at least 3 m below the bottom of the temporary casing, whichever is the lesser.

Spacers shall be designed and manufactured using durable materials which shall not lead to corrosion of the reinforcement or spalling of the concrete cover. Where required in Appendix 16/3, details of the means by which the Contractor plans to ensure the correct cover to and position of the reinforcement shall be submitted.

Concrete

General

12 (11/03) Cement materials, aggregates, admixtures and water shall be in accordance with Series 1700.

The consistence and method of placing of the concrete shall be such that a continuous monolithic concrete or grout shaft of the full cross-section is formed. Concrete shall be transported from the mixer to the position of the pile in such a manner that segregation of the concrete constituents does not occur.

The concrete shall be placed without such interruption as would allow the previously placed batch to have achieved a stiffness which prevents proper amalgamation of the two concrete batches.

The Contractor shall take all precautions in the design of the concrete mix and placing of the concrete to avoid arching of the concrete. No soil, liquid, or other foreign matter shall be permitted to contaminate the concrete.

(11/03) **Consistence of concrete**

13 Consistence measured at the time of discharge into the pile bore shall be in accordance with the limits shown in Table 16/2

Compaction

14 Internal vibrators shall not be used to compact concrete.

Placing concrete in dry borings

15 Measures shall be taken to ensure that the structural strength of the concrete placed in all piles is not impaired through grout loss, segregation or bleeding.

The method of placing shall be such as to ensure that the concrete or grout in its final position is dense and homogeneous. Concrete shall be introduced into the pile via a hopper and suitable length of rigid delivery tube to ensure that the concrete falls vertically and centrally down the shaft. The tube shall be at least 3 m long.

Placing concrete under water or support fluid

16 (11/03) Before placing concrete, measures shall be taken in accordance with sub-Clause 1603.10 to ensure there is no accumulation of silt or other material at the base of the boring, and the Contractor shall ensure that heavily contaminated support fluid, which could impair the free flow of concrete from the tremie pipe, has not accumulated in the bottom of the hole.

A sample of support fluid shall be taken from the top and bottom of the boring using an appropriate device. The fluid shall be prepared, sampled and tested as stated in the Contractor's submission. If tests show the fluid does not comply with the limits stated by the Contractor for the particular type of support fluid, the fluid shall be wholly or partly replaced as appropriate before concrete is placed.

Concrete to be placed under water or support fluid shall be placed by tremie in one continuous operation and shall not be discharged freely into the water or support fluid. Pumping of concrete may be used where appropriate. The bottom end of the tremie must be square to the axis of the tremie and its circumference must be continuous. The tremie must be fully charged with concrete before it is lifted off the base of the pile.

The concrete shall be of high consistence and cement content in accordance with Series 1700 and Table 16/2 mix C.

The concrete shall be placed in a manner that shall not cause segregation of the constituents of concrete mix.

TABLE 16/2: (11/03) **Piling Mix Consistence**

Piling mix Consistence	**Consistence**		**Typical conditions of use (The concrete and aggregate size must be compatible with the reinforcement spacing)**
	Flow class Range mm	**Slump class Range mm**	
A	Not	S2-S4 applicable	Placed into water-free unlined or permanently lined bore of 600 mm diameter or over, or where casting level lies below temporary casing; reinforcement spaced at 100 mm centres or greater, leaving ample room for free movement of concrete between bars.
B	F3-F4	*S3-S5b**	Where reinforcement is spaced at less than 100 mm centres; where cut-off level of concrete is within temporary casing; where pile bore is water-free and the diameter is less than 600mm.
C	F4-F5	*S4 or more	Where concrete is to be placed by tremie under water or support fluid or by pumping or by continuous flight auger.

Notes: 1. (11/03) *The slump test method is not suited to these very high consistence and the flow test is to be preferred.
2. (11/03) **The test method may lack sensitivity with this class.

The depths to the surface of the concrete shall be measured and the length of the tremie tubes recorded at regular intervals corresponding to the placing of each batch of concrete. The depths measured and volumes placed shall be plotted immediately on a graph and compared with the theoretical relationship of depth against volume.

The hopper and pipe of the tremie shall be clean and watertight throughout. The pipe shall extend to the base of the bore and a sliding plug or barrier shall be placed in the pipe to prevent direct contact between the first charge of concrete in the tremie and the water or support fluid. The pipe shall at all times penetrate the concrete which has previously been placed with a minimum embedment of 3 m and shall not be withdrawn from the concrete until completion of concreting. A sufficient quantity of concrete shall be maintained within the pipe to ensure that the pressure from it exceeds that from the water or support fluid. The internal diameter of the pipe of the tremie shall be not less than the greater of 150 mm or six times the maximum aggregate size. It shall be so designed that external projections are minimized, allowing the tremie to pass within reinforcing cages without causing damage. The internal face of the pipe of the tremie shall be free from projections.

Extraction of casing

(11/03) **Consistence of concrete**

17 (11/03) Temporary casings shall be extracted while the concrete within them remains sufficient consistence to ensure that the concrete is not lifted. During extraction the motion of the casing shall be maintained in an axial direction relative to the pile.

Concrete level

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

TABLE 16/3: Casting Tolerance above Cut-off Level for Piles cast in Dry Bores using Temporary Casing and without the use of Permanent Lining

Cut-off distance below commencing surface, H, m+	Casting tolerance above cut-off level, m
0.15 - 10.00	0.3 + H/12+C/8 where C = length of temporary casing below the commencing surface*

+ Beyond H = 10 m, the casting tolerance applying to H = 10 m shall apply.
* If H is greater than C, then this tolerance is no longer applicable and the tolerances in Table 16/4 will apply.

TABLE 16/4: Casting Tolerance above Cut-off Level for Piles cast in Dry Bores within Permanent Lining tubes or Permanent casings, or where their Cut-off Levels are in Stable Ground below the Base of any Casing used

Cut-off distance below commencing surface, H, m+	Casting tolerance above cut-off level, m
0.15 - 10.00	0.3 + H/10

+ Beyond H = 10 m, the casting tolerance applying to H = 10 m shall apply.

TABLE 16/5: Casting Tolerance above Cut-off Level for Piles cast under Water or Support Fluid*

Cut-off distance below commencing surface, H, m+	Casting tolerance above cut-off level, m
0.15 - 10.00	1.0 + H/12 + C/8 where C = length of temporary casing below the commencing surface*

+ Beyond H = 10 m, the casting tolerance applying to H = 10 m shall apply.
* In cases where a pile is cast so that the cut-off is within a permanent lining tube, the appropriate tolerance is given by deletion of the casing term C/8 in the table.

The concrete level within a temporary casing in a dry bore may be topped up where necessary during the course of casing extraction so that the base of the casing is always below the concrete surface until the casting of the pile has been completed.

Adequate precautions shall be taken in all cases where excess heads of water or support fluid could occur as the casing is withdrawn because of the displacement of water or fluid by the concrete as it flows into its final position against the walls of the pile bore. Where two or more discontinuous lengths of casing (double casing) are used in the construction the Contractor's method of working shall produce piles to their full designed cross-sections. The depth to the average levels of the concrete surface of the pile shall be measured before and after each temporary casing is removed. These measurements shall be recorded on the pile record.

Pile head casting level tolerances

19 For piles cast in dry bores using temporary casing and without the use of a permanent casing, piles heads shall be cast to a level above the specified cut-off so that, after trimming, a sound concrete connection with the pile can be made. The casting level shall be above the cut-off level and within the tolerance shown in Table 16/3, but shall not be above the commencing surface level. No pile shall be cast with its cut-off level below standing water level unless appropriate measures

are taken to prevent inflow of water causing segregation of the concrete as temporary casing is extracted.

For piles cast in dry bores within permanent lining tubes or permanent casings to where their cut-off levels are in stable ground below the base of any casing used, pile heads shall be cast to a level above the specified cut-off so that, after trimming, a sound concrete connection with the pile can be made. The casting level shall be above the cut-off level and within the tolerance shown in Table 16/4, but shall not be above the commencing surface level.

For piles cast under water or support fluid, the pile heads shall be cast to a level above the specified cut-off so that, after trimming to remove all debris and contaminated concrete, a sound concrete connection with the pile can be made. The casting level shall be above the cut-off level and within the tolerance shown in Table 16/5, but shall not be above the commencing surface level. Cut-off levels may be specified below the standing groundwater level, and where this condition applies the borehole fluid level shall not be reduced below the standing groundwater level until the concrete has set.

Where either support fluid or water is mixed in the ground by the drilling equipment to assist with the installation of temporary casings the casting level shall be coincident with the commencing surface.

Temporary backfilling above pile casting level

20 After each pile has been cast, any empty bore remaining shall be carefully backfilled as soon as possible with inert spoil.

Cutting off pile heads

21 When cutting off and trimming piles to the specified cut-off level, the Contractor shall take care to avoid shattering or otherwise damaging the rest of the pile. Any cracked or defective concrete shall be cut away and the pile repaired in a manner to provide a full and sound section at the cut-off level.

Grout

22 (11/03) The use of grout containing fine aggregate is permitted in place of concrete specified elsewhere in this Clause. The requirements of Clause 1602, sub-Clauses 15 to 22 shall apply. The sand shall be in accordance with the limits of 0/4 (CP) or 0/2 (MP) of BS EN 12620.

The moisture content of aggregates shall be measured immediately before mixing and as frequently thereafter as is necessary to maintain consistency of the mix. Allowance shall be made for the aggregate moisture when assessing batch weights.

Where the word "concrete" is used elsewhere in this Clause then "grout" shall be read in its place. In particular sub-Clauses 14 to 18 shall also apply to grout, except the requirement for grout consistence shall be that in Clause 1602, sub-Clause 16.

Pressure grouting

Grouting of piles

23 Where bases or sides of piles are to be pressure grouted, as detailed in Appendix 16/3, the Contractor shall construct the piles with grout tubes and any other necessary equipment pre-installed so that piles may subsequently be grouted.

Method of grouting

24 The method of grouting shall be such that the completed pile meets the requirements of the Specification for load-settlement behaviour and that during grouting pile uplift is within the limits specified. Where required in Appendix 16/3, the Contractor shall submit full descriptions of the equipment, materials and methods that he plans to use before commencing grouting. The method statement shall comprise at least the following information:

i) Details of specialist contractor for grouting (if applicable), names of key personnel and their curricula vitae and previous experience on similar types of work.

ii) Details of grout pump, mixer, agitator and any other equipment used for mixing and injection of grout.

iii) Full details of grout to be used, including admixtures.

iv) Method of quality control on grout, including details of number of cubes taken and checks on density, flow and bleed of the grout.

v) (11/03) Method of measuring grout take, which shall be automatic and include a physical method of checking grout take at the end of injection of each circuit.

vi) (11/03) Method of measuring grout pressures which shall include a continuous record. Calibration certificates for pressure gauges.

vii) Typical record sheet for grouting, which shall include records of grout take, grout pressure, residual pressure, times of grouting and pile uplift for each grouting circuit. Typical continuous records of grout pressure and pile uplift shall also be included.

viii) Target minimum, maximum and residual grout pressures for each grout injection.

ix) Method of grout injection, including full details of any packers. Target grout volumes for each injection.

x) Method of measuring friction losses in the tubes/packers.

Grout tubes

25 The grouting tubes shall be tested to determine any grout leakage in joints under pressure prior to installation into the piles. The grout tubes must be capable of withstanding the pressures to which they will be subjected.

Robust threaded caps shall be provided to protect the top of the grouting tubes during concreting and afterwards.

The grouting tubes shall be flushed with water after each grouting operation.

If the target volumes or grout pressures are not achieved, or the specified uplift is not achieved, then the pile shall be regrouted within 24 hours.

The Contractor shall provide an engineer to monitor grout pressures and grout takes.

Pile uplift

26 During base grouting, the pile uplift shall be not less than 0.2 mm and shall not exceed 2.0 mm.

The Contractor shall provide an engineer to monitor the uplift of the piles during grouting.

The pile uplift shall be monitored with an appropriate level reading off a graduated scale attached to the pile head and by a dial gauge attached to a reference frame. A continuous record of pile uplift shall be made using a displacement transducer also attached to the reference frame. The accuracy of measurement shall be a minimum of 0.1 mm for each monitoring device. The design of the reference frame shall be made available on request.

Grout testing

27 Close control of the mixing of the grout shall be carried out. The Contractor shall provide and maintain on site all test facilities required to test and control the grout mixes.

Records

28 In accordance with Appendix 16/3, the Contractor shall provide duplicate copies of all grouting records for each pile within 24 hours of the completion of grouting that pile.

The records shall comprise the following information:

a) Pile number.

b) Date.

c) Leakage test on grout pipes.

d) Grout mix.

e) Continuous records of grout pressure and pile uplift to the same timescale. The records shall be annotated at regular intervals with physical measurements from pressure gauges and dial gauges including times of such measurements. Circuit number and pile number are also to be included.

f) For each circuit the peak and residual grout pressures including times and sequence of grouting.

g) The total pile uplift and the uplift after each circuit is grouted.

h) For each circuit the physical and automatic measurements for grout volume injected and derived injected volumes. The total grout volume.

i) All tests made on grout.

1604 Bored Piles Constructed Using Continuous Flight Augers and Concrete or Grout Injection Through Hollow Auger Stems

Diameter of piles

1 The diameter of a pile shall be not less than the specified diameter.

The cutting head width shall be checked as necessary and recorded for each pile to ensure the specified diameter is achieved and that the width is greater than the diameter of the following flight. A tolerance of +5% -0 on the cutting head width is permissible.

Boring

Boring near recently cast piles

2 Piles shall be formed in an order and in such a manner that no damage is sustained by previously formed piles.

Removal of augers from the ground

3 The auger shall not be extracted from the ground during the boring or construction of a pile in such a way that an open unsupported bore or inflow of water into

the pile section would result. As the auger is withdrawn from the ground it shall be cleaned of all rising.

Suitability of boring equipment

4 The piles shall be bored using equipment capable of penetrating the ground without drawing surrounding soils laterally into the pile bore.

The Contractor shall record the fact if flighting of soil up the auger is excessive.

The verticality of the auger shall be checked at the commencement of boring. Should it deviate during boring so that the pile verticality is outside the specified tolerance the fact shall be recorded on the pile record.

Sealing the base of the auger

5 The base of the auger stem shall be fitted with a suitable means of sealing it against ingress of water and soil during boring.

Depth of piles

6 Any failure of a pile to reach the required depth, as given in Appendix 16/4, shall be recorded by the Contractor and a full statement of the reasons included in the pile record.

Placing of concrete or grout

(11/03) **Mix design and consistence; concrete**

7 (11/03) Where not otherwise stated in this section, the concrete shall comply with Series 1700. The design and consistence of concrete to be used in the formation of a pile shall produce a concrete mix which is suitable for pumping. It shall have a slump classs S4 or greater or flow classes F4 to F5 and a minimum cement content of 340 kg/m³. The concrete shall be designed so that segregation does not occur during the placing process, and bleeding of the concrete shall be minimized.

The consistence of concrete mixes shall be measured by the method described in Appendix 16/4.

Equipment for supply of concrete or grout to piles

8 Grout or concrete shall be supplied to the pile through suitable concrete pump, tubing and the hollow auger stem. All pipe fitments and connections shall be so constructed that grout does not leak during the injection process.

Commencement of concrete or grout supply to each pile

9 At the beginning of concrete or grout placing the sealing device at the base of the auger stem shall be removed by the application of concrete or grout pressure. Care shall be taken to ensure that the auger is lifted only the minimum distance necessary to initiate the flow of concrete or grout, and that water inflow and soil movement at the base of the auger are minimized. The technique and equipment used to initiate and maintain the concrete or grout flow shall be such that a pile of the full specified cross-section is obtained from the maximum depth of boring to the final pile cut-off level.

Rate of supply of concrete or grout

10 The concrete or grout shall be supplied to the pile at a sufficient rate during auger withdrawal to ensure that a continuous monolithic shaft of at least the full specified cross-section is formed, free from debris or any segregated concrete or grout.

Completion of concreting or grouting of piles

11 If the concrete or grout placing in any pile cannot be completed in the normal manner, then the pile shall be rebored to a safe level below the position of interruption in supply before the concrete or grout has achieved initial set and before further concrete or grout is injected. The method statement shall set out the procedure.

Casting level of pile head

12 Concrete or grout shall be cast to the commencing surface level in all cases. The pile position shall be clearly marked and fenced off so as not to cause a safety hazard.

(11/03) **Mix design and consistence; grout**

13 (11/03) Where not otherwise stated in this section, the grout shall comply with Clause 1602 sub-Clauses 15 to 22 with the exception that sand may be used. The sand shall be in accordance with the limits of 0/4 (CP) or 0/2 (MP) of BS EN 12620.

The moisture content of aggregates shall be measured immediately before mixing and as frequently thereafter as is necessary to maintain consistency of the mix. Allowance shall be made for the aggregate moisture content when assessing batch weights.

The procedure for monitoring the suitability of grout throughout the Works shall be established prior to commencement of the Works.

Reinforcement

14 (11/03) Steel reinforcement shall be as described in Appendix 16/4 and in accordance with Series 1700. Where steel sections are used for reinforcement, they shall be in accordance with Series 1800.

All reinforcement shall be placed with the minimum delay after the completion of the concreting or grouting operation. It shall be fabricated in cages or bundles of bars fixed securely to permit it to be placed in the correct position and to the depth specified through the concrete or grout of the pile. Suitable spacers shall be provided to maintain the specified concrete or grout cover to steel.

The transverse reinforcement of any reinforcing cage shall meet the design requirements and shall maintain the longitudinal bars in position when the cage is inserted into the wet concrete or grout.

Longitudinal main steel reinforcement shall be continuous over the specified length. Where joints are necessary, no more than one joint shall be used and then only if the reinforcement cage length exceeds 12 m. Joints in steel reinforcement shall be such that the full strength of each bar is effective across the joint and shall be made so that there is no detrimental displacement of the reinforcement during placing in the pile. At the joint bars shall be welded to the requirement of BS 7123 or joined together in a suitable manner.

Reinforcement shall be placed and maintained in position to provide the specified projection of reinforcement above the final cut-off level. A vertical tolerance of +150/-50 mm on the level of reinforcement projecting above the final cut-off level shall be met.

The Contractor shall provide such additional reinforcement as he may require to suit his method of placing the reinforcing steel cage.

Monitoring system for pile construction

15 An automated system shall be provided for monitoring the construction of the piles. It shall provide the operator with information on the depth of the auger tip, flow of concrete and relative pressure of concrete as a minimum. In addition the automatic monitoring equipment shall monitor continuously with depth the following parameters.

a) During boring:
   i) auger penetration rate
b) During concreting:
   i) rate of extraction of the auger
   ii) relative injection pressure of concrete or grout
   iii) rate of supply of concrete or grout

Equipment used for monitoring shall be calibrated at the start of the piling works and calibration certificates issued before commencing piling. After the commencement of works, the monitoring equipment shall be calibrated at the frequency specified below or at any time where there is reason to suspect malfunction.

Depth shall be calibrated once a week. At full auger length the tolerance is ± 0.1 m.

Concrete flow rate shall be calibrated once during the progress of the works by passing a known volume of concrete through the flow meter. The tolerance on flow is ± 5%.

The pressure transducer shall have a calibration certificate. The tolerance on pressure shall be stated in bars.

The automated monitoring system must be operational at the start of every pile. The following information shall be recorded during the construction of each pile:

i) the incremental time of auger penetration during boring
ii) final depth of the bore
iii) time for each 0.5 m increment of auger extraction during concreting
iv) the volume of concrete or grout pumped for each 0.5 m increment of auger extraction during concreting
v) total volume of concrete or grout for completion of the pile
vi) the time at the start and end of boring, concreting and insertion of the reinforcement cage and any time intervals for delays or stoppages
vii) relative concrete pressure during concreting
viii) the direction of rotation of the auger during concreting

If the number of auger revolutions relative to auger penetration becomes abnormally high at any stage during boring, the fact shall be recorded, as shall the occurrence of excessive flighting.

The rig operator shall be competent and experienced in the construction of continuous flight auger piles and a full time supervisor shall be devoted to pile construction. Where required in Appendix 16/4, details of their relevant experience shall be submitted prior to work commencing.

In accordance with Appendix 16/4, the Contractor shall submit proposals on how he shall complete a pile in the event of failure of all or part of the rig instrumentation system prior to work commencing. This proposal shall include the recording of the depth at which failure occurred, the time for auger extraction during concreting, and the total volume of concrete or grout

delivered. Any pile which was subject to an instrumentation failure during construction shall be integrity tested in accordance with Clause 1608.

The monitoring results must be available immediately on completion of every pile.

Cutting off pile heads

16 When cutting off and trimming piles to the specified cut-off level, the Contractor shall take care to avoid shattering or otherwise damaging the rest of the pile. Any laitence, or contaminated, cracked or defective concrete shall be cut away and the pile made good in a manner to provide a full and sound section up to the cut-off level.

1605 Driven Cast-in-Place Piles

Materials

Permanent casings

1 Permanent casings shall be as specified in Appendix 16/5. Where a permanent casing is to be made from a series of short sections it shall be watertight. The dimensions and quality of the casing shall be adequate to withstand the stresses caused by handling and driving without damage or distortion.

Pile shoes

2 Pile shoes shall be manufactured from durable material capable of withstanding the stresses caused by driving without damage, and shall be designed to give a watertight joint during construction.

Diameter of piles

3 The diameter of a pile shall be not less than the specified diameter.

Temporary casings

4 Temporary casings shall be free from significant distortion. They shall be of uniform external cross-section throughout each continuous length and shall be of sufficient strength to withstand driving and ground forces without deformation. During concreting they shall be free from internal projections and encrusted concrete which might prevent the proper formation of piles.

Enlarged pile bases

5 Where the Contractor wishes to form a pile with an enlarged base or where such a base is specified in Appendix 16/5, details of the method of forming the base and the materials to be used shall be included in the Contractor's method statement.

Driving piles

Piling near recently cast piles

6 Casings shall not be driven or piles formed so close to other piles which have recently been cast and which contain workable or unset concrete that a flow of concrete could be induced from or damage caused to any of the piles.

Performance of driving equipment

7 Where required in Appendix 16/5, the Contractor shall provide information on the efficiency and energy of the driving equipment including when followers are used. Where required in Appendix 16/5, dynamic evaluation and analysis shall be provided.

Drop hammers shall not be used from floating craft in such a manner as to cause instability of the craft or damage to the pile.

Length of piles

8 The length of pile to be driven in any position shall be as specified in Appendix 16/5. During the execution of the Works any amendments to the scheduled lengths shall be recorded by the Contractor and a full statement of the reasons included in the pile record.

Driving procedure and redrive checks

9 Driving procedure and redrive checks shall be in accordance with sub-Clause 1602.30.

Set

10 The set shall be measured and recorded for each pile at the completion of driving unless otherwise stated in Appendix 16/5.

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

(a) The exposed part of the pile casing shall be in good condition, without damage or distortion.

(b) The dolly, helmet and packing, if any, shall be in sound condition.

(c) The hammer blow shall be in line with the pile axis and the impact surfaces shall be flat and at right angles to the pile and hammer axis.

(d) The hammer shall be in good condition, delivering adequate energy per blow, and operating correctly.

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

Driving sequence and risen piles

11 Requirements for the driving sequence and risen piles shall be in accordance with sub-Clause 1602.32.

Laterally displaced piles shall not be corrected by forceable correction at the heads.

Preboring

12 If preboring is specified the pile casing shall be pitched after preboring to the depth and diameter stipulated in Appendix 16/5.

Other means to ease pile driveability may be used provided the completed piles meet their specified requirements.

Internal drop hammer

13 (11/03) Where a casing for a pile without an enlarged base is to be driven by an internal drop hammer, a plug consisting of concrete strength class C16/20 with a water/cement ratio not exceeding 0.25 shall be placed in the pile. This plug shall have a compacted height of not less than 2½ times the diameter of the pile. Fresh concrete shall be added to ensure that this height of driving plug is maintained in the casing throughout the period of driving, and in any event a plug of fresh concrete shall be added after 1½ hours of normal driving or after 45 minutes of hard driving, or, should the pile-driving be interrupted for 30 minutes or longer, fresh concrete shall be added prior to driving being resumed.

Repair of damaged pile heads and extending of piles to the cut-off level

14 (11/03) When repairing or extending the head of a pile, the head shall be cut off square at sound concrete, and all loose particles shall be removed by wire-brushing, followed by washing with water.

If the level of sound concrete of the pile is below the cut-off level, the pile shall be extended to the cut-off level with concrete of a strength class not inferior to that of the concrete of the pile so that it will safely withstand the specified working load.

Lengthening of permanent pile casings during construction

15 The lengthening of permanent steel pile casings by adding an additional length of steel casing during construction shall be carried out in accordance with Clause 1606.

Inspection and remedial work

16 Prior to placing concrete in a pile casing, the Contractor shall check that the casing is undamaged, and free from water or other foreign matter. In the event of water or foreign matter having entered the pile casing, the casing shall be withdrawn, repaired if necessary and redriven, or other action taken to continue the construction of the pile to meet the requirements of the Specification.

Reinforcement

17 (11/03) Steel reinforcement shall be as described in Appendix 16/5 and in accordance with Series 1700.

The number of joints in longitudinal steel bars shall be kept to a minimum. The full strength of each bar shall be effective across each joint, which shall be made so that there is no detrimental displacement of the reinforcement during the construction of the pile. Reinforcement shall be maintained in its correct position during concreting of the pile to allow a vertical tolerance of +150/-50 mm on the level of the reinforcement projecting above the final cut-off level to be met. Where reinforcement is made up into cages, they shall be sufficiently rigid to enable them to be placed, handled and concreted without damage. If the cage is to be welded together, welding shall be carried out to the requirements of BS 7123.

Spacers shall be designed and manufactured using durable materials which shall not lead to corrosion of the reinforcement or spalling of the concrete cover. Where required in Appendix 16/5, details of the means by which the Contractor plans to ensure the correct cover to and position of the reinforcement shall be submitted.

Concrete

General

18 (11/03) Cement materials, aggregates, admixtures and water shall be in accordance with Series 1700.

The consistence and method of placing of the concrete shall be such that a continuous monolithic concrete shaft of the full cross-section is formed. Concrete shall be transported from the mixer to the position of the pile in such a manner that segregation of the constituents of concrete mix does not occur.

The concrete shall be placed without such interruption as would allow the previously placed batch to have hardened.

The Contractor shall take all precautions in the design of the concrete mix and placing of the concrete to avoid arching of the concrete in the casing. No spoil, liquid or

other foreign matter shall be permitted to contaminate the concrete.

(11/03) **Consistence of concrete**

19 (11/03) Consistence measured at the time of discharge into the pile casing shall be in accordance with the requirement shown in Table 16/2, except that these standards shall not apply to piling systems which use semi-dry concrete and employ special means for its compaction. The concrete shall be of the consistence specified when in its final position and until all construction procedures in forming the pile have been completed.

Compaction

20 Internal vibrators shall not be used to compact concrete cast-in-place.

Placing concrete

21 (11/03) Measures shall be taken as necessary in all piles to ensure that the structural strength of the placed concrete is not impaired through grout loss, segregation, or bleeding.

Extraction of casing

(11/03) **Consistence of concrete**

22 (11/03) Temporary casings shall be extracted while the concrete within them remains sufficiently workable to ensure that the concrete is not lifted. Should a semi-dry concrete mix have been used, the Contractor shall ensure the concrete shall not lift during extraction of the casing.

Concrete level

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

Concrete shall be topped up as necessary while the casing is extracted until the required head of concrete to complete the pile in a sound and proper manner has been provided. No concrete is to be placed once the bottom of the casing has been lifted above the top of the concrete.

Vibrating extractors

24 The use of vibrating casing extractors will be permitted subject to Clause 109 and Clause 1601 sub-Clause 28.

Concrete casting tolerances

25 For piles constructed without the use of a rigid permanent lining, pile concrete shall be cast to the commencing surface level.

Where piles are constructed inside rigid permanent lining tubes or permanent casings, pile heads shall be cast to a level above the specified cut-off so that, after trimming, a sound concrete connection with the pile can be made. In this case the tolerance of casting above the cut-off level shall be determined according to Table 16/4.

Temporary backfilling above pile casting level

26 After each pile has been cast, any hole remaining shall be protected and shall be carefully backfilled as soon as possible with appropriate materials.

Cutting off pile heads

27 When cutting off and trimming piles to the specified cut-off level, the Contractor shall take care to avoid shattering or otherwise damaging the rest of the pile. Any cracked or defective concrete shall be cut away and the pile repaired to provide a full and sound section to the cut-off level.

1606 Steel Bearing Piles

Materials

1 (11/05) Steel for bearing piles shall be in accordance with Series 1800.

Cast steel shoes shall be of steel to BS EN 10293, Grade A1.

Strengthening of piles

2 (11/03) The strengthening to the toe of a pile in lieu of a shoe or the strengthening of the head of a pile shall be made using material of the same strength class as the pile.

Manufacturing tolerances

3 All piles shall be of the type and cross-sectional dimensions as designed. For standard rolled sections the dimensional tolerances and weight shall comply with the relevant standard. Length tolerance of H-section steel bearing piles shall be ± 50 mm in accordance with BS EN 10034. The tolerance on length of other steel bearing piles shall be -0 and +75 mm unless otherwise specified. For proprietary sections the dimensional tolerances shall comply with the manufacturer's standards. The rolling or manufacturing tolerances for proprietary sections shall be such that the actual weight

of section does not differ from the theoretical weight by more than +4% or -2.5%. The rolling or manufacturing tolerances for steel tubular piles shall be such that the actual weight of section does not differ from the theoretical weight by more than ± 5%. The rolling or proprietary tolerances for H-section steel bearing piles shall be such that the actual weight of the section does not differ from the theoretical weight by more than ± 2.5%.

Straightness of sections

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

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

Fabrication of piles

5 For tubular piles where the load will be carried by the wall of the pile, and if the pile will be subject to loads that induce reversal of stress during or after construction, the external diameter at any section as measured by using a steel tape on the circumference shall not differ from the theoretical diameter by more than ± 1%.

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

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

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

Matching of pile lengths

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

Welding

7 (11/03) All welding shall be to BS EN 1011-1 and BS EN 1011-2 and when appropriate shall be in accordance with Clause 1801.

For a tubular pile where the load will be compressive and non-reversible and will be carried by the wall of the pile or by a concrete core, the welding shall be to BS EN 1011-1 and BS EN 1011-2 or BS 6265.

Welders' qualifications

8 (11/05) Only welders who are qualified to BS EN 287-1 or who have attained a similar standard, shall be employed on the Works. Proof of welders' proficiency shall be made available on request.

Welding procedures

9 (11/05) All welding procedures shall have been qualified to BS EN ISO 15607, BS EN ISO 15609-1, BS EN ISO 15613 and BS EN ISO 15614-1 and the Contractor shall make available full details of the welding procedures and electrodes, with drawings and schedules as may be necessary. Tests shall be undertaken as may be required by the relevant British Standard or as may be required in Appendix 16/6.

Manufacturing processes

Welded tube piles

10 Where required in Appendix 16/6, the Contractor shall submit details of the manufacturing and welding procedures before commencement of manufacture.

Welded box piles and proprietary sections

11 Welded box piles or proprietary sections made up from two or more hot-rolled sections shall be welded in accordance with the manufacturer's standards.

Non-destructive testing of welds

12 During production of welded tube piles, one radiograph or ultrasonic test of a length of approximately 300 mm shall be made at each end of a length as manufactured at the mill to provide a spot check on weld quality. In addition, on a spirally welded tube pile, a further check shall be made on welded joints between strip lengths.

All the circumferential welds shall be fully radiographed or ultrasonically tested by the method specified in Appendix 16/6.

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

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

Standards for welds

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

Longitudinal welds in proprietary box piles and proprietary sections. Longitudinal welds joining the constituent parts of the box or proprietary section shall be in accordance with the manufacturer's specification.

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

Site-welded butt splices

Support and alignment

14 When lengths of pile are to be butt-spliced on site, adequate facilities shall be provided for supporting and aligning them prior to welding such that the specified straightness criterion can be achieved.

Weld tests

15 Weld tests shall be performed by radiographic or ultrasonic methods as specified. Provided that satisfactory results are being obtained, one test of a length of 300 mm shall be made for 10% or more of the number of welded splices in the case where the load will be carried by the wall or section of the pile. Where the load will be carried by the concrete core of a pile the number of tests will be as specified in Appendix 16/6, but will not normally exceed 10% of the number of butt splices.

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

Any defective weld shall be cut out, replaced and reinspected.

Standards for site butt welds

16 Welds shall comply with the requirements of the weld quality standards for site butt welds, given in Series 1800.

Protection during welding

17 All work associated with welding shall be protected from the weather so that the quality of work meets the requirements of the Specification.

Coating piles for protection against corrosion

Durability of coatings

18 Where coatings are specified they shall be provided in accordance with Appendix 16/6.

Definition

19 The term 'coating' shall include the primer and the coats specified.

Specialist labour

20 The preparation of surfaces and the application of the coats to form the coating shall be carried out by specialist labour having experience in the preparation of the surface and the application of the coating specified.

Protection during coating

21 All work associated with surface preparation and coating shall be undertaken inside a waterproof structure.

Surface preparation

22 All surfaces to be coated shall be clean and dry and prepared as follows:

Degreasing with detergent wash compatible with the coating shall be carried out where necessary.

All surfaces shall be blast cleaned to Sa 2.5 of BS 7079 Part A1. Blast-cleaning shall be done after fabrication. Unless an instantaneous-recovery blasting machine is used, the cleaned steel surface shall be air-blasted with clean dry air and vacuum-cleaned or otherwise freed from abrasive residues and dust immediately after cleaning.

Application and type of primer

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

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

Control of humidity during coating

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

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

Parts to be welded

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

Thickness, number and colour of coats

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

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

Inspection of coatings

27 (11/05) The finished coating shall be generally smooth, of dense and uniform texture and free from sharp protuberances or pin-holes. Excessive sags, dimpling or curtaining shall be retreated.

Any coat damaged by subsequent processes or which has deteriorated to an extent such that proper adhesion of the coating is in doubt shall be removed, and the surface shall be cleaned to the original standard and recoated to provide the specified number of coats.

The completed coating shall be checked for thickness by a magnetic thickness gauge. Areas where the thickness is less than that specified shall receive additional treatment.

When specified, the completed coating shall be checked for adhesion by means of an adhesion test to 'BS EN ISO 2409, BS 3900-E6', carried out on 10% of the piles. The adhesion of any completed coating shall not be worse than Classification 2. If adhesion tests on the initial batch are satisfactory, then on further batches 1% of the piles shall be tested. Adhesion tests shall not be carried out until seven days after coating. On completion of testing the test area shall be made good to the standard specified in Appendix 16/6. Areas where the adhesion is defective shall be repaired and reinspected.

Marking, handling and storage of piles

Marking of piles

28 Each pile shall be clearly numbered and its length shown near the pile head using white paint. In addition, before being driven, each pile shall be graduated along its length at intervals of 250 mm.

Handling and storage of piles

29 All piles within a stack shall be in groups of the same length and on appropriate supports. All operations such as handling, transporting and pitching of piles shall be carried out in a manner such that no damage occurs to piles and their coatings.

Driving of piles

Leaders and trestles

30 At all stages during driving and until incorporation in the structure the free length of the pile 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. In marine works, lengths which remain unsupported after driving shall be adequately restrained until incorporated into the Permanent Works. These constraint arrangements shall be such that no damage occurs to piles or their coatings.

Performance of driving equipment

31 Performance of driving equipment shall be in accordance with sub-Clause 1602.28 of this Specification.

Length of piles

32 The length of pile to be driven and any additional lengths of pile to be added during driving shall be as specified in Appendix 16/6. During the execution of the Works any amendments to the scheduled lengths shall be recorded by the Contractor and a full statement of the reasons included in the pile record.

Driving procedure and redrive checks

33 Driving procedure and redrive checks shall be in accordance with sub-Clause 1602.30.

Set

34 Requirements for set shall be in accordance with sub-Clause 1602.31.

Driving sequence and risen piles

35 Requirements for driving sequence and risen piles shall be in accordance with sub-Clause 1602.32.

Laterally displaced piles shall not be corrected by forceable correction at the heads, unless the Contractor can demonstrate that the integrity, durability and performance of the piles has not been adversely affected.

Preboring

36 If preboring is specified the pile shall be pitched after preboring to the depth and diameter stipulated in Appendix 16/6.

Other means to ease pile drivability may be used provided the completed piles meet the requirements of the Specification.

Preparation of pile heads

37 If a steel structure is to be welded to piles, the piles shall be cut square and to within ± 5 mm of the levels specified. If pile heads are to be encased in concrete they shall be cut to within ± 20 mm of the levels specified, and protective coatings shall be removed from the surfaces of the pile heads down to a level 100 mm above the soffit of the concrete.

1607 Reduction of Friction on Piles

General

1 Where the particular method of reducing friction is not specified, the Contractor shall provide full details of the method which he plans to employ. The Contractor shall ensure that any product used will be compatible with the ground conditions into which it will be installed. Particular requirements are detailed in Appendix 16/7.

Pre-applied bituminous or other friction-reducing coating materials

General

2 Where a proprietary product is used, the process of cleaning pile surfaces, and the conditions and methods of application shall conform with the manufacturer's current instructions. All materials shall conform with the manufacturer's specification, which shall be made available before any coating is applied.

Protection from damage

3 Where a friction-reducing material has been applied to a preformed pile prior to installation, it shall be protected from damage during handling and transportation. In the event of damage to the coating, it shall be made good on site to the same specification as the original coating prior to the pile being driven.

Where bituminous materials are involved, precautions shall be taken as necessary in hot weather to prevent excessive flow or displacement of the coating. The coated piles shall be adequately protected against direct sunlight and, if stacked, they shall be separated to prevent their coatings sticking together.

Pile driving

4 In the case of applied coatings, the piles shall not be driven when the air temperature is such that the coating will crack, flake or otherwise be damaged prior to entry into the ground. Where bituminous materials are involved, driving shall be carried out while the temperature is at or above 5°C or as called for in the manufacturer's instructions.

Pre-applied low-friction sleeving

5 Where required in Appendix 16/7, detailed design of the pre-applied low-friction sleeving shall be submitted prior to driving the piles. All materials shall conform with the manufacturer's specification, which shall be made available before the material is used.

Formed-in-place low-friction surround

6 Where required in Appendix 16/7, detailed design of the formed-in-place low-friction surround shall be submitted prior to driving or forming the piles. All materials shall conform with the manufacturer's specification, which shall be made available before the material is used.

Pre-installed low-friction sleeving

7 Where required in Appendix 16/7, detailed design of the pre-installed low-friction sleeving shall be

submitted prior to driving or forming the piles. All materials shall conform with the manufacturer's specification, which shall be made available before the material is used.

Inspection

8 Where required in Appendix 16/7, piles shall be partially exposed or extracted. Where significant damage to the coating is found to have occurred the Contractor shall prepare a method statement for the repair or replacement of the coating prior to carrying out the work.

1608 Non-Destructive Methods for Testing Piles

Integrity testing of piles

Method of testing

1 Where integrity testing is called for, the method to be adopted shall be one of the following, as specified:

(a) impulse method;

(b) Sonic Echo, Frequency Response or Transient Dynamic steady state vibration method;

(c) sonic logging method.

Other methods may be considered subject to satisfactory evidence of performance. Particular requirements are detailed in Appendix 16/8.

Age of piles at time of testing

2 In the case of cast-in-place concrete piles, integrity tests shall not be carried out until the number of days specified in Appendix 16/8 have elapsed since pile casting.

Preparation of pile heads

3 Where the method of testing requires the positioning of sensing equipment on the pile head, the head shall be broken down to expose sound concrete and shall be clean, free from water, laitence, loose concrete, overspilled concrete and blinding concrete and shall be readily accessible for the purpose of testing.

Specialist Sub-contractor

4 The testing shall be carried out by a specialist firm, subject to demonstration of satisfactory performance on other similar contracts before the commencement of testing.

Where required in Appendix 16/8, the Contractor shall submit the name of the specialist integrity testing firm, a description of the test equipment, a test method statement and a programme for executing the specified tests prior to commencement of the Works.

Interpretation of tests

5 The interpretation of tests shall be carried out by competent and experienced persons.

The Contractor shall give all available details of the ground conditions, pile dimensions and construction method to the specialist firm before the commencement of integrity testing in order to facilitate interpretation of the tests.

Report

6 Preliminary results of the tests shall be made available within 24 hours of carrying out the tests.

The test results and findings shall be recorded and made available within 10 days of the completion of each phase of testing.

The report shall contain a summary of the method of interpretation including all assumptions, calibrations, corrections, algorithms and derivations used in the analyses. If the results are presented in a graphical form, the same scales shall be used consistently throughout the report. The units on all scales shall be clearly marked.

Anomalous results

7 In the event that any anomaly in the acoustic signal is found in the results indicating a possible defect in the pile the Contractor shall demonstrate that the pile is satisfactory for its intended use or shall carry out remedial works to make it so. Sonic logging tubes shall be grouted up after the Contractor has demonstrated that the pile is satisfactory.

Dynamic pile-testing

General

8 Particular requirements are detailed in Appendix 16/8.

Measuring instruments

9 Current calibration certificates shall be made available for all instruments and monitoring equipment before testing commences.

Hammer

10 The hammer and all other equipment used shall be capable of delivering an impact force sufficient to mobilize the equivalent specified dynamic test load without damaging the pile.

Preparation of the pile head

11 The preparation of the pile head for the application of the dynamic test load shall involve trimming the head, cleaning and building up the pile using materials which will at the time of testing safely withstand the impact stresses. The impact surface shall be flat and at right angles to the pile axis. Where pile preparation requires drilling holes or welding, this preparation shall not adversely affect the performance of the pile when in service.

Interpretation of tests

12 The interpretation of the tests shall be carried out by competent and experienced persons.

The Contractor shall give all available details of the ground conditions, pile dimensions and construction method to the specialist firm carrying out the testing in order to facilitate interpretation of tests.

Time of testing

13 The time between the completion of installation and testing for a preformed pile shall be more than 12 hours, and in the case of a cast-in-place pile shall be such that the pile is not damaged under the impact stresses.

Measurement of set

14 If specified, the permanent penetration per blow and temporary compression of the pile and soil system shall be measured independently of the instruments being used to record the dynamic test data from a fixed reference point unaffected by the piling operations.

Results

15 Initial results shall be made available within 24 hours of the completion of a test. These shall include:

(a) the maximum force applied to the pile head

(b) the maximum pile head velocity

(c) the maximum energy imparted to the pile.

Subsequently a full report shall be made available, within 10 days of the completion of testing, including:

(a) date of pile installation

(b) date of test

(c) pile identification number and location

(d) length of pile below commencing surface

(e) total pile length, including projection above commencing surface at time of test

(f) length of pile from instrumentation position to toe

(g) hammer type, drop and other relevant details

(h) blow selected for analysis

(i) test load achieved (ie. total mobilised deduced static load)

(j) pile head movement at equivalent Design Verification Load

(k) pile head movement at equivalent Design Verification Load plus 50% of Specified Working Load

(l) pile head movement at maximum applied test load

(m) permanent residual movement of pile head after each blow

(n) temporary compression.

For all piles tested the following information shall be provided for typical blows:

(a) date of pile installation

(b) date of test

(c) pile identification number and location

(d) length of pile below commencing surface

(e) total pile length, including projection above commencing surface at time of test

(f) length of pile from instrumentation position to toe

(g) hammer type, drop and other relevant details

(h) permanent set per blow

(i) maximum force at pile head

(j) maximum velocity at pile head

(k) maximum downward energy imparted to the pile

(l) dynamic soil resistance mobilised during the blow

(m) static soil resistance mobilised during the blow assuming that soil damping is proportional to pile velocity

(n) magnitude and location of possible pile damage.

Where required in Appendix 16/8, an analysis of measurements from selected blows shall be carried out using a numerical model of the pile and soil to provide the following information.

(a) Magnitude and distribution of mobilised static soil resistance

(b) Magnitude and distribution of soil stiffness and damping

(c) Deduced static load deflection behaviour of the pile at the head and toe

(d) Assumptions made in the analysis

(e) Limitations of the method.

1609 Static Load Testing of Piles

General

1 The design and construction of the load application system shall be satisfactory for the required test. These details shall be made available prior to the commencement of testing. Particular requirements are detailed in Appendix 16/9.

Construction of a pile to be tested

Notice of construction

2 The Contractor shall give at least 48 hours notice of the commencement of construction of any preliminary pile which is to be test-loaded.

Method of construction

3 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. Extra reinforcement and concrete of increased strength will be permitted in the shafts of preliminary piles where necessary for carrying out the testing.

Boring or driving record

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

Concrete test cubes

5 (11/03) Four test cubes shall be made from the concrete used in the preliminary test pile and from the concrete used for building up a working pile. If a concrete pile is extended or capped for the purpose of testing, a further four cubes shall be made from the corresponding batch of concrete. The cubes shall be made and tested in accordance with BS EN ISO 12390-2.

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

Preparation of working pile to be tested

6 If a test is required on a working pile the Contractor shall cut down or otherwise prepare the pile for testing in accordance with Appendix 16/9 and sub-Clauses 13 and 14.

Cut-off level

7 The cut-off level for a preliminary test pile shall be as specified in Appendix 16/9.

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

Supervision

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

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.

Safety precautions

General

9 Design, erection and dismantling of the pile test reaction system and the application of load shall be carried out according to the requirements of the various applicable statutory regulations concerned with lifting and handling heavy equipment and shall safeguard operatives and others who may from time to time be in the vicinity of a test from all avoidable hazards.

Kentledge

10 Where kentledge is used the Contractor shall construct the foundations for the kentledge and any cribwork, beams or other supporting structure 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 becoming unstable because of deflection of the supports or for any other reason.

The weight of kentledge for each test shall be greater than the maximum test load for that test, 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. Additional kentledge required shall be determined taking into account the accuracy of positioning of the centre of gravity of the stack.

Tension piles, reaction piles and ground anchorages

11 Where tension piles, reaction piles or ground anchorages are used to provide the necessary load reaction, they shall be so designed that they will resist the forces applied to them safely and without excessive deformation which could cause a safety hazard during the work. Such piles or anchorages shall be placed in the specified positions, and bars, tendons or links shall be aligned to give a stable reaction in the direction required. Any welding employed to extend or to fix anchorages to a reaction frame shall be carried out so that the full strength of the system is adequate and unimpaired.

Testing equipment

12 (11/03) In all cases the Contractor shall ensure that when the hydraulic jack and load-measuring device are mounted on the pile head the whole system will be stable up to the maximum load to be applied.

If in the course of carrying out a test any unforeseen occurrence should take place, further loading shall not be applied until a proper engineering assessment of the condition has been made and steps have been taken to rectify any fault. Reading of gauges shall, however, be continued where possible and if it is safe to do so.

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

The hydraulic jack, pump, hoses, pipes, couplings and other apparatus to be operated under hydraulic pressure shall be capable of withstanding a pressure of 1½ times the maximum pressure used in the test without leaking. The maximum test load expressed as a reading on the gauge in use shall be displayed and all operators shall be made aware of this limit.

Pile head for compression test

13 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.

Any pile cap shall be concentric with the test 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 and around any part of the cap projecting beyond the section of the pile so that, at the maximum expected settlement, load is not transmitted to the ground by the cap.

Pile connection for tension test

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

Reaction systems

Compression tests

15 Compression tests shall be carried out using kentledge, tension piles or specially constructed anchorages. Kentledge shall not be used for tests on raking piles.

Where kentledge is to be used, it shall be supported on cribwork and positioned so that the centre of gravity of the load is as close as possible to the axis of the pile. The bearing pressure under supporting cribs shall be such as to ensure stability of the kentledge stack.

Tension tests

16 Tension tests may be carried out using compression piles, rafts or grillages constructed on the ground to provide the necessary reaction. In all cases the resultant force of the reaction system shall be coaxial with the test pile.

Where inclined piles or reactions are specified or their use is planned by the Contractor, full details shall be made available prior to the commencement of testing.

Working piles

17 If the Contractor plans to use working piles as reaction piles, he shall notify his intention prior to commencement of work. Working reaction piles shall not uplift by more than half their specified permissable settlement at working load. The integrity of all working piles used as reaction piles shall be checked on completion of static load testing.

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

Spacing

18 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 1.3 m.

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 three times the diameter of the test pile or the reaction piles or 2 m 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 one half of the enlarged base diameter. Where vertical reaction piles penetrate deeper than the test pile, the centre-to-centre spacing of the reaction piles from the test pile shall be not less than five times the diameter of the test pile or the reaction piles whichever is the greatest unless the base capacity of the test pile is less than 20% of the total ultimate capacity.

Where ground anchorages are used to provide a test reaction for loading in compression, no section of fixed anchor length 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 the additional requirement that no section of the fixed anchor transferring load to the ground shall be closer to the pile base than a distance equal to the base diameter.

Adequate reaction

19 The reaction frame support system shall be adequate to transmit the maximum test load in a safe manner without excessive movement or influence on the test pile. Calculations shall be provided when required to justify the design of the reaction system.

Care of piles

20 The method employed in the installation of the reaction system shall be such as to prevent damage to any test pile or working pile.

Equipment for applying load

21 The equipment used for applying load shall consist of a hydraulic ram or jack. The jacking system shall be arranged in conjunction with the reaction system to deliver an axial load to the test pile and maintain it constant when required. The complete system shall be capable of safely transferring the maximum load required for the test. The length of stroke of a ram shall be sufficient to cater for deflection of the reaction system under load plus a deflection of the pile head up to 15% of the pile shaft diameter unless otherwise specified in Appendix 16/9.

Measurement of load

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

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

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

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

Control of loading

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

Measuring pile head movement

Maintained load test

24 In a maintained load test, movement of the pile head shall be measured by the method in sub-Clause 26 and by one of the methods in sub-Clauses 27, 28 and 29 in the case of vertical piles, or by one of the methods in sub-Clauses 27, 28 and 29 in the case of the raking piles, as required.

CRP and CRU test

25 In a constant rate of penetration (CRP) or a constant rate of uplift (CRU) test the method in sub-Clause 26 shall be used. Check-levelling of the reference frame or the pile head shall not be required. The dial gauge shall be graduated in divisions of 0.02 mm or less.

Optical levelling method

26 An optical levelling method by reference to a remote 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 to within an accuracy of 0.5 mm. A scale attached to the pile or pile cap may be used instead of a levelling staff. At least two reliable independent datum points shall be established. Each datum point shall be so situated as to permit a single setting-up position of the level for all readings.

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

Reference beams and dial gauges

27 An independent reference beam or beams shall be set up to enable measurement of the movement of the pile to be made to the required accuracy. The supports for a beam shall be founded in such a manner and at such a distance from the test pile and reaction system that movements of the ground do not cause movement of the reference beam or beams which will affect the accuracy of the test. The supports of the beam or beams shall be at least three test pile diameters or 2 m from the centre of the test pile, whichever distance is the greater. The beam must be free to move horizontally at one end.

Check observations of any movements of the reference beam or beams shall be made and a check shall be made of the movement of the pile head relative to a remote reference datum at the start and end and at maximum load for each loading cycle.

The measurement of pile movement shall be made by four dial gauges rigidly mounted on the reference beam or beams, bearing on prepared flat surfaces fixed to the pile cap or head and normal to the pile axis. Alternatively, the gauges may be fixed to the pile and bear on prepared surfaces on the reference beam or beams. The dial gauges shall be placed equidistant from the pile axis and from each other. The dial gauges shall enable readings to be made to an accuracy of at least 0.1 mm and have a stem travel of at least 25 mm. Machined spacer blocks may be used to extend the range of reading. Equivalent electrical displacement-measuring devices may be substituted.

Reference wires and scales

28 Two parallel reference wires, one on either side of the pile, shall be held under constant tension at right angles to the test pile axis between supports formed as in the method in sub-Clause 27. The wires shall be positioned against scales fixed to the test pile head in an axial direction and the movements of the scales relative to the wires shall be determined.

Check observations of any movements of the supports of the wires shall be made and a check shall be made on the movement of the pile head at appropriate time intervals. Readings shall be taken to within an accuracy of 0.5 mm.

Other methods

29 Where appropriate the Contractor may use an alternative method of measuring the movement of the test pile head. The method shall be accurate to within 0.5 mm of the pile head movement.

Protection of testing equipment

Protection from weather

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

Prevention of disturbance

31 Construction activity and persons who are not involved in the testing process shall be kept at a sufficient distance from the test to avoid disturbance to the measuring apparatus. Full records shall be kept of any unavoidable activity and its effects.

Notice of test

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

Test procedure

Proof load test procedure (working compression piles)

33 The maximum load which shall be applied in a proof test shall normally be the sum of the design verification load (DVL) plus 50% of the specified working load (SWL). The loading and unloading shall

TABLE 16/6: Minimum Loading Times for Pile Test

Load*	Minimum Time of Holding Load
25% DVL	30 minutes
50% DVL	30 minutes
75% DVL	30 minutes
100% DVL	6 hours
75% DVL	10 minutes
50% DVL	10 minutes
25% DVL	10 minutes
0	1 hour
100% DVL	1 hour
100% DVL + 25% SWL	1 hour
100% DVL + 50% SWL	6 hours
100% DVL + 25% SWL	10 minutes
100% DVL	10 minutes
75% DVL	10 minutes
50% DVL	10 minutes
25% DVL	10 minutes
0	1 hour

*SWL denotes specified working load; DVL denotes design verification load.be carried out in stages as shown in Table 16/6.

Any particular requirements given in Appendix 16/9 shall be complied with.

Following each application of an increment of load, the load shall be maintained at the specified value for not less than the period shown in Table 16/6 and until the measured rate of settlement in a period of 30 minutes is less than 0.5% of the current cumulative settlement which has occurred, subject to a minimum settlement rate of 0.05 mm in 30 minutes. The rate of settlement shall be calculated from the slope of the line obtained by plotting values of settlement versus time and drawing a smooth curve through the points.

Each stage of unloading shall proceed after the expiry of the period shown in Table 16/6.

For any period when the load is constant, time and settlement shall be recorded immediately on reaching the load, at not more than five minute intervals up to 15 minutes, at approximately 15 minutes intervals up to one hour, at 30 minute intervals between one hour and four hours, and 1 hour intervals between four hours and 12 hours after the application of the increment of load.

Where the methods of measuring pile head movement given in sub-Clauses 26, 28 and 29 are used, the periods of time for which loads must be held constant to achieve the specified rates of settlement shall be extended as necessary to take into account the lower levels of accuracy available from these methods and to allow correct assessment of the settlement rate.

Test procedure for preliminary compression piles

34 The procedure to be adopted for carrying out preliminary load tests on compression piles shall be in accordance with the requirements specified in Appendix 16/9 and either the extended proof load test procedure or the constant rate of penetration testing procedure given below. A normal proof load test will constitute the first stage of such a preliminary test unless otherwise specified.

Extended proof load test procedure

Where verification of the required minimum load factor is called for, the loading procedure may be carried out as a continuation of the proof load testing procedure given in sub-Clause 33.

Following the completion of the proof load test, the load shall be restored in two stages (DVL, DVL + 50% SWL), and shall subsequently be increased by stages of 25% of the specified working load or other specified amount until the maximum specified load for the test is reached. Following each application of an increment of load, the load shall be maintained at the specified value for not less than 30 minutes and until the additional measured settlement in a period of 30 minutes is less than 0.5% of the current cumulative settlement which has occurred since the start of the current load increment, subject to a minimum settlement rate of 0.05 mm in 30 minutes. The rate of settlement shall be calculated from the slope of the line obtained by plotting values of settlement versus time and drawing a smooth curve through the points. Reduction of load at the end of the test shall be gradual as required by sub-Clause 36 and the final recovery of the pile head shall be recorded.

Permissible settlement at the load corresponding to the required minimum factor of safety called for in the design will not normally be specified. (The mobilization of ultimate load for compression piles normally involves settlements of at least 10% of the pile base diameter in clay and more in granular soils. The settlement of piles bearing on rock requires special consideration, and failure of pile materials may precede failure of the rock).

Constant rate of penetration (CRP) testing procedure

The rate of movement of the pile head shall be maintained constant in so far as is practicable and shall be approximately 0.01 mm/s for piles in predominantly cohesive soils and 0.02 mm/s for piles in predominantly cohesionless soils.

Readings of loads, penetration and time shall be made simultaneously at regular intervals; the interval chosen shall be such that a curve of load versus penetration can be plotted without ambiguity.

Loading shall be continued until one of the following results is obtained:

a) the maximum required test load as specified in accordance with Appendix 16/9 is reached

b) a constant or reducing load has been recorded for an interval of penetration of 10 mm

c) a total movement of the pile base equal to 10% of the base diameter, or any other greater value of movement specified in Appendix 16/9, has been reached.

The load shall then be reduced in five approximately equal stages to zero load, penetration and load at each stage and at zero load being recorded.

Testing of piles designed to carry load in tension

35 The testing of piles designed to carry load in tension shall follow the same procedure as specified in sub-Clauses 33 and 34.

The rate of movement of the pile head shall be maintained at approximately 0.005 mm/s in so far as is practicable.

Presentation of results

Results to be submitted

36 During the progress of a test, all records taken shall be available for inspection.

Results shall be made available as follows:

a) a preliminary copy of the test records, unless otherwise directed, within 24 hours of the completion of the test, which shall show

   i) for a test by maintained load: for each stage of loading, the period for which the load was held, the load and the maximum pile movement at the end of the stage

   ii) for a CRP or CRU test: the maximum load reached and a graph of load against penetration or load against uplift

b) the completed schedule of recorded data as prescribed in sub-Clause 37 within 10 days of the completion of the test.

Schedule of recorded data

37 The Contractor shall provide information about the test pile in accordance with the following schedule where applicable.

(a) (11/03) **General**
Site location
Contract identification
Proposed structure
Main contractor
Piling contractor
Client/Overseeing Organisation
Date and time of test

(b) (11/03) **Pile details**
All types of pile
Identification (number and location)
Specified working load (SWL)
Design verification load (DVL)
Commencing surface level at pile position
Head level at which test load was applied
Type of pile
Vertical or raking, compression or tension
Shape and size of cross-section of pile, and position of any change in cross-section
Shoe or base details
Head details
Length in ground
Level of toe
Dimensions of any permanent casing

Concrete Piles
Concrete mix/strength class
Aggregate type and source
Cement type and cement replacement and type where used
Admixtures
Slump class
Cube test results for pile and cap
Date of casting of precast pile
Reinforcement

Steel piles
Steel quality
Coating
Filling or core materials - type and quality

(c) **Installation details**

All piles
Dates and times of boring, driving and concreting of test pile
Difficulties and delays encountered
Date and time of casting concrete pile cap

Bored piles
Type of equipment used and method of boring
Temporary casing - diameter, type and length
Full log of pile borehole
Method of placing concrete
Volume of concrete placed

Driven preformed and driven cast-in-place piles
Method of support of hammer and pile
Driven length of pile or temporary casing at final set
Hammer type, and size or weight
Dolly and packing, type and condition
Driving log (depth, hammer drop, blows per 250 mm, interruptions or breaks in driving)
Final set in number of blows to produce penetration of 25 mm
Redrive check, time interval and set in number of blows to produce penetration of 25 mm
At final set and at redrive set, for a drophammer or for a single acting hammer the length of the drop or stroke, for a diesel hammer the length of the stroke and the blows per minute, for a double acting hammer the operating pressure and the number of blows per minute.
Condition of pile head or temporary casing after driving
Use of a follower
Use of preboring
Use of jetting
Lengthening
Method of placing concrete

(d) **Test procedure**

Mass of kentledge
Tension pile, ground anchorage or compression pile details
Plan of test arrangement showing position and distances of kentledge supports, rafts, tension or compression pile or ground anchorages, and supports to pile movement reference system
Jack capacity
Method of load measurement
Method(s) of penetration or uplift measurement
Calibration certificates
Temperature readings

(e) **Test results**

In tabular form
In graphical form: load plotted against pile head movement, load plotted against time
Ambient temperature records during test

Completion of a test

Removal of test equipment

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

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

Preliminary test pile head

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

Proof test pile head

40 On completion of a test on a proof pile, the test pile head shall be prepared as specified and left in a state ready for incorporation into the Permanent Works.

1610 Diaphragm Walls

Guide walls

1 The design and construction of the guide walls shall be the responsibility of the Contractor and shall take into account the actual site and ground conditions and the equipment to be used on site to ensure stability and avoid undercutting. Guide walls shall be constructed in reinforced concrete or other suitable materials. The minimum depth of guide wall shall be 1.0 m.

Materials

Concrete : supply, mixing and testing

2 Cement materials, aggregates, admixtures and water shall be in accordance with Series 1700.

Steel reinforcement : supply, fixing and welding

3 (11/03) Steel reinforcement shall be as described in Appendix 16/10 and in accordance with Series 1700. Where steel sections are used for reinforcement, they shall be in accordance with Series 1800.

Support fluid

4 Bentonite and/or alternative fluid support materials, admixtures, mixing and testing and clean water shall be in accordance with Clause 1618.

Dimensions of panels

5 The thickness of a panel shall be not less than the specified thickness. The length of panel may be varied to suit an individual Contractor's equipment but any upper limits on length because of geological or other external factors shall be specified in Appendix 16/10. Within these constraints the Contractor shall be responsible for selecting panel dimensions which ensure stability and that movements remain within the criteria set in Appendices 16/1 and 16/10.

Excavation

Excavation near recently cast panel

6 Panels shall not be excavated so close to other panels which have recently been cast and which contain workable or unset concrete that a flow of concrete or instability could be induced from or damage caused to any panel. The Contractor's sequence of construction shall be submitted prior to work commencing in accordance with Clause 1601.

Stability of the excavation

7 Support fluid for maintaining the stability of an excavation shall be in accordance with Clause 1618 of this Specification. A suitable guide wall shall be used in conjunction with the method to ensure stability of the strata near ground level until concrete has been placed. During construction the level of support fluid in the excavation shall be maintained within the guide wall or stable ground so that it is not less than 1.5 m above the level of external standing groundwater at all times.

In the event of a loss of support fluid from an excavation, the Contractor shall include a full statement of the reasons in the pile record.

Cleanliness of base

8 Prior to placing steel or concrete the Contractor shall clean the base of the excavation of as much loose, disturbed and remoulded materials as practical and in accordance with the method of construction and shall wholly or partly remove and replace support fluid while maintaining the fluid head if it does not comply with the Contractor's stated limits for support fluid prior to concreting.

Steel reinforcement

9 The number of joints in longitudinal steel bars shall be kept to a minimum. Joints in steel reinforcement shall be such that the full strength of each bar is effective across the joint and shall be made so that there is no detrimental displacement of the reinforcement during the construction of the panel. Reinforcement shall be maintained in its correct position during concreting of the panel. Where it is made up into cages, they shall be sufficiently rigid to enable them to be handled, placed and concreted without damage. If the cage is to be welded together, welding shall be carried out to the requirements of BS 7123.

Spacers shall be designed and manufactured using durable materials which shall not lead to corrosion of the reinforcement or spalling of the concrete cover. Where required in Appendix 16/10, details of the means by which the Contractor plans to ensure the correct cover to and position of the reinforcement shall be submitted.

The minimum projecting bond lengths required by Appendix 16/10 shall be observed.

The Contractor shall prepare reinforcement detail construction drawings for each panel and these shall be made available.

Placing concrete

General

10 (11/03) The consistence and method of placing of the concrete shall be such that a continuous monolithic concrete panel of the full cross-section is formed, and that the concrete in its final position is dense and homogenous. Concrete shall be transported from the mixer to the position of the wall in such a manner that segregation of the concrete mix does not occur.

Before commencement of concreting of a panel, the Contractor shall satisfy himself that the supplier will have available sufficient quantity of concrete to construct the panel in one continuous operation.

The concrete shall be placed without such interruption as would allow the previously placed batch to have achieved a stiffness which prevents proper amalgamation of the two concrete batches.

No spoil, liquid or other foreign matter shall be allowed to contaminate the concrete.

(11/03) **Consistence of concrete**

11 (11/03) The concrete consistence shall be determined using the slump or flow classes in accordance with BS EN 12390-2 and BS EN 12390-5 respectively. The slump or flow classes for concrete placed through support fluid using a tremie pipe shall be class S4 or greater or classes F4 to F5 respectively or as specified in Appendix 16/10.

Compaction

12 Internal vibrators shall not be used to compact concrete within a cast in place panel.

Placing concrete

13 The concrete shall be placed through a tremie pipe in one continuous operation. Where two or more pipes are used in the same panel simultaneously, care shall be taken to ensure that the concrete level at each pipe position is maintained nearly equal.

The hopper and pipe of the tremie shall be clean and watertight throughout. The pipe shall extend to the base of the panel and a sliding plug or barrier shall be placed in the pipe to prevent direct contact between the first charge of concrete in the tremie and the support fluid.

The pipe shall at all times penetrate the concrete which has previously been placed with a minimum embedment of 3 m and shall not be withdrawn from the concrete until completion of concreting. At all times a sufficient quantity of concrete shall be maintained within the pipe to ensure that the pressure from it exceeds that from the support fluid and workable concrete above the tremie base. The internal diameter of the pipe of the tremie shall be not less than the greater of 150 mm or six times the maximum aggregate size. It shall be so designed that external projections are minimised, allowing the tremie to pass within reinforcing cages without causing damage. The internal face of the pipe of the tremie shall be free from projections.

The depth of the surface of the concrete shall be measured and the embedded length of the tremie pipe recorded at regular intervals corresponding to each batch of concrete. The depths measured and volumes placed shall be plotted immediately on a graph and compared with the theoretical relationship of depth against volume.

Tolerances

Guide wall

14 The finished face of the guide wall towards the excavation and on the side of the excavation nearest to any subsequent main excavation shall be vertical to within a tolerance of 1 in 200 and the top edge of the wall shall represent the reference line. There shall be no ridges or abrupt changes on the face and its variation from its specified position shall not exceed ± 15 mm in 3 m.

The minimum clear distance between the guide walls shall be the specified diaphragm wall thickness plus 25 mm and the maximum distance shall be the specified diaphragm wall thickness plus 50 mm.

Diaphragm wall

15 At cut-off level the maximum deviation of the centre line of each panel from the specified position shall be 15 mm and an additional tolerance of 8 mm for each 1.0 m that the cut-off level is below the top of the guide wall shall be permitted unless otherwise stated in Appendix 16/10.

The exposed wall face and the ends of panels shall be vertical within a tolerance of 1:120 for walls constructed using grabs. A tolerance of 1:200 may be specified if there is a special need and an expectation of reverse circulation cutters being used. An additional tolerance of 100 mm will be allowed for concrete protrusions resulting from cavities formed by overbreak in the ground. Where very soft clay layers or peat layers are anticipated or obstructions are to be removed during trench excavation, an additional overbreak tolerance shall be stated in Appendix 16/10.

Recesses

16 Where recesses are to be formed by inserts in the wall, the vertical tolerance shall be that of sub-Clause 17 and the horizontal tolerance shall be that of sub-Clause 17 plus the horizontal tolerance resulting from sub-Clause 15.

Steel reinforcement

17 The longitudinal tolerance of the cage head at the top of the guide wall measured along the excavation shall be ± 75 mm.

The vertical tolerance of the cage head measured relative to the guide wall shall be +150/-50 mm. The reinforcement shall be maintained in position during concreting of a panel.

Temporary stop-ends in diaphragm panels

18 Temporary stop-ends shall be of the length, thickness and quality of material adequate for the purpose of preventing water and soil from entering the panel excavations.

Each temporary stop-end shall be straight and true throughout. The external surface shall be clean and free from distortions that may affect panel integrity during removal of the temporary stop-end.

Stop-ends shall be rigid and adequately restrained to prevent horizontal movement during concreting.

Concrete level

19 If the cut off level for the panel is less than 1 m below the top level of the guide walls, uncontaminated concrete shall be brought to the top of the guide walls. If the cut off level is greater than 1m below the top level of the guide walls, concrete shall be brought to 1 m above the cut off level specified, with a tolerance of ±150 mm. An additional tolerance of + 150 mm over the above tolerances shall be permitted for each 1.0 m

of depth by which the cut off level is below the top of the guide wall.

Where more than one tremie pipe is used the concrete shall be brought up to 1000 mm above the cut off level specified with a tolerance of ± 250 mm.

Temporary backfilling above panel casting level

20 After each panel has been cast, it shall be protected and shall be carefully backfilled as soon as possible, with material in accordance with Appendix 16/10. All panels shall be clearly marked and fenced off so as not to cause a safety hazard.

Water retention

21 The complete retaining wall shall be considered to have satisfactory water retaining properties if overall the leakage of water per square metre of exposed wall does not exceed the volume stated in Appendix 16/10. The Contractor shall be responsible for the repair of any joint, defect or panel where on exposure of the wall visible water leaks are found. Any leak which results in water flow emanating from the surface of the retaining wall shall be sealed.

Instrumentation

22 Movement of the wall, the surrounding ground and existing structures shall be monitored in accordance with Appendix 16/10 and Clause 1617.

Preparation of wall surfaces

23 All surfaces buried or constructed as buried during execution of the Works but which subsequently are to be partially or totally uncovered as part of the construction shall be cleaned, trimmed of all detritus and obstructions to the appropriate line and level as described in Appendix 16/10 (or 16/11, 16/12, 16/13 as appropriate).

1611 Hard/Hard Secant Pile Walls

Guide walls

1 The design and construction of guide walls, if the use of guide walls is specified in Appendix 16/11 or is required by the Contractor, shall be the responsibility of the Contractor and shall take into account the actual site and ground conditions and the equipment to be used on site to ensure stability and avoid undercutting as appropriate. Guide walls shall be constructed in reinforced concrete (or other suitable materials). The minimum depth of guide wall shall be 0.5 m, and the minimum shoulder width shall be 0.3 m for walls in reinforced concrete.

Materials

Concrete : supply, mixing and testing

2 Cement materials, aggregates, admixtures and water shall be in accordance with Series 1700.

Steel reinforcement : supply, fixing and welding

3 (11/03) Steel reinforcement shall be as described in Appendix 16/11 and in accordance with Series 1700. Where steel sections are used for reinforcement, they shall be in accordance with Series 1800.

Support fluid

4 Where support fluid is used to maintain the stability of the pile bore it shall be in accordance with Clause 1618.

Boring

Boring near recently cast piles

5 Piles shall not be bored so close to other piles which have recently been cast and which contain workable or partially set concrete that a flow of concrete or instability could be induced or damage caused to any installed piles. The Contractor's sequence of construction shall be submitted prior to work commencing in accordance with Clause 1601.

Stability of bore

6 Temporary casing shall be used in unstable ground with or without support fluid to maintain the stability of the bore unless continuous flight augers are used. The casing shall extend to the full depth of each bore or to the depth to which the minimum overlap has to be provided. The process of advancing the bore and the temporary casing shall be such that soil is not drawn into the bore from outside the area of the pile and cavities are not created outside the temporary casing.

Cleanliness of pile base

7 Prior to placing steel or concrete, the Contractor shall remove from the base of the pile as much loose disturbed and remoulded materials as practical and in accordance with the method of construction.

Cleaning of support fluid

8 Prior to placing steel or concrete, any support fluid including water shall be wholly or partly removed and replaced while maintaining the fluid head if it does not comply with the Contractor's stated limits for support fluid prior to concreting.

Steel reinforcement

9 The number of joints in longitudinal steel bars shall be kept to a minimum. Joints in steel reinforcement shall be such that the full strength of each bar is effective across the joint and shall be made so that there is no detrimental displacement during the construction of the pile. Reinforcement shall be maintained in its correct position during concreting of the pile or wall element. Where reinforcement is made up into cages, they shall be sufficiently rigid to enable them to be handled, placed and concreted without damage. If the cage is to be welded together, welding shall be carried out to the requirements of BS 7123.

Spacers shall be designed and manufactured using durable materials which shall not lead to corrosion of the reinforcement or spalling of the concrete cover. Where required in Appendix 16/11, details of the means by which the Contractor plans to ensure the correct cover to and position of the reinforcement shall be submitted.

The minimum projecting bond lengths required by Appendix 16/11 (and 16/12, 16/13 or 16/14 as appropriate) shall be maintained.

For continuous flight auger piles steel reinforcement cages shall be inserted into the pile shaft immediately after completion of concreting. The method of insertion of reinforcement cages shall avoid distortion or damage to the steel reinforcement and ensure accurate positioning of the cage within the pile shaft.

Placing and compacting concrete

General

10 (11/03) The consistence and method of placing of the concrete shall be such that a continuous monolithic concrete shaft of the full cross section is formed, and that the concrete in its final position is dense and homogenous. Concrete shall be transported from the mixer to the position of the pile in such a manner that it does not cause segregation of the constituents of the concrete mix.

Before commencement of concreting of a pile, the Contractor shall satisfy himself that the Supplier will have available a sufficient quantity of concrete to construct the pile in one continuous operation.

Each batch of concrete in a pile shall be placed before the previous batch has achieved a stiffness which prevents proper amalgamation of the two concrete batches. Removal of temporary casings, when used, shall be completed before the concrete within the casing loses its consistence.

For continuous flight auger piles injection of concrete shall continue up to the commencing surface or above so that free discharge from the delivery pipe can be observed to be taking place, and reinforcement placed after concreting.

No spoil, liquid or other foreign matter shall be allowed to contaminate the concrete.

(11/03) **Consistence of concrete**

11 (11/03) The concrete consistence shall be determined using the slump or flow classes in accordance with BS EN 12350-2 and BS EN 12350-5 respectively. The slump or flow shall be measured at the time of discharge into the pile boring and shall be in accordance with the limits shown in Table 16/2, or as specified in Appendix 16/11 (and 16/12, 16/13 or 16/14 as appropriate).

Compaction

12 Internal vibrators shall not be used to compact concrete.

Placing concrete in dry boreholes

13 (11/03) The concrete shall be placed through a hopper attached to a length of tremie pipe and in such a way that the flow is directed and does not hit reinforcing bars or the side of the bore.

The tremie pipe shall be at least 3 m long.

Placing concrete under water or support fluid

14 Concrete to be placed under water or support fluid shall be placed through a tremie pipe in one continuous operation.

The hopper and pipe of the tremie shall be clean and watertight throughout. The pipe shall extend to the base of the boring and a sliding plug or barrier shall be placed in the pipe to prevent direct contact between the first charge of concrete in the pipe of the tremie and the water or support fluid. The pipe shall at all times penetrate the concrete which has previously been placed with a minimum penetration of 3 m and shall not be withdrawn from the concrete until completion of concreting.

At all times a sufficient quantity of concrete shall be maintained within the tremie pipe to ensure that the pressure from it exceeds that from the water or support fluid and workable concrete above the tremie base.

The internal diameter of the pipe of the tremie shall be not less than the greater of 150 mm or six times the maximum aggregate size. It shall be so designed that external projections are minimised, allowing the tremie to pass through reinforcing cages without causing

damage. The internal face of the pipe of the tremie shall be free from projections.

The depths to the surface of the concrete shall be measured and the embedded length of the tremie pipe recorded at regular intervals corresponding to the placing of each load of concrete. The depth measured and volumes of concrete placed shall be plotted immediately on a graph and compared with the theoretical relationship of depth against volume.

The foregoing is not applicable to piles constructed using continuous flight augers. For such piles the full monitoring requirements of Clause 1604 shall be met.

Time period for excavation and placing concrete

15 The time period after a pile is excavated and before the concrete is placed shall not exceed 12 hours unless otherwise specified in Appendix 16/11 (and 16/12, 16/13 or 16/14 as appropriate).

If temporary casing is used, this period shall start when excavation below the temporary casing commences.

Tolerances

Guide wall

16 The finished face of each guide wall towards the excavation shall be vertical to a tolerance of 1 in 200 and shall represent the reference line. There shall be no ridges on the face and the centre line of the guide wall shall not deviate from its specified position by more than ± 15 mm in 3 m.

The minimum clear distance between the guide walls shall be the pile diameter plus 25 mm and the maximum distance shall be the pile diameter plus 50 mm.

Secant piles

17 At cut-off level the maximum permitted deviation of the pile centre from the centre point shown on the setting out drawings shall be 25 mm in any direction except that an additional tolerance of 5 mm shall be permitted for each 1.0 m that the cut-off level is below the top of the guide wall unless otherwise specified in Appendix 16/11.

In the case of construction by continuous flight augers the additional tolerance shall be 8 mm for each 1.0 m below top of guide wall.

The exposed face of the pile shall be vertical within a tolerance of 1:200 for secant walls constructed with temporary casings and 1:120 for secant walls constructed with continuous flight augers in any direction.

An additional tolerance of 100 mm will be allowed for concrete protrusions resulting from cavities formed by overbreak in the ground. Where very soft clay layers or peat layers are anticipated or obstructions are to be removed prior to or during boring, an additional overbreak tolerance shall be stated in Appendix 16/11.

Recesses

18 If recesses in the form of box outs are to be formed within a pile shaft, the vertical tolerance shall be in accordance with sub-Clause 19 and rotational tolerance shall be 10 degrees.

Steel reinforcement

19 A vertical tolerance of +150 mm/-50 mm shall generally be permitted on the level of steel projecting from a pile cut off, except where a pile is constructed to a higher level for reasons associated with ground conditions, or technique (continuous flight auger), where additional steel projection may be necessary.

Concrete level

20 No pile shall be cast with its final cut off level below standing water level unless the Contractor's method of construction includes measures to prevent inflow of water that may cause segregation of the concrete as temporary casing is withdrawn. The standing water level will be treated as the cut off level for the purpose of calculating casting level.

For piles cast in dry bores using temporary casing, and for piles cast under water the casting level shall be above the cut off level and within the tolerances shown in Table 16/7 except for continuous flight auger piles which shall be cast to ground level.

Backfilling of empty bore

21 Where concrete is not brought to the top of the guide wall, the empty pile bore shall be backfilled as soon as possible with material in accordance with Appendix 16/11 (and 16/12 or 16/13 as appropriate). Prior to backfilling the bore shall be clearly marked and fenced off so as not to cause a safety hazard.

Water retention

22 The completed retaining wall shall be considered to have satisfactory water retaining properties if the leakage of water per square metre of exposed wall does not exceed the volume specified in Appendix 16/11 or 16/12. The Contractor shall be responsible for the repair of any joint, defect or pile where on exposure of the wall visible water leaks are found. Any leak which results in water flow emanating from the surface of the retaining wall shall be sealed.

TABLE 16/7: Casting Tolerance Above Cut Off Levels for Specified Conditions

Cut off Level Below Commencing Surface, H, m*	Casting Tolerance Above Cut off Level, m	Condition
0.15 to any depth	0.3 + H/10	Permanent casing and dry bore
0.15 - 10.00	0.3 + H/12 + C/8	Piles cast in dry bore using temporary casing
0.15 - 10.00	1.0 + H/12 + C/8 Where C = length of temporary casing below the commencing surface	Pile cast under water or support fluid

* Beyond H = 10 m, the casting tolerance applying to H = 10 m shall apply.

Instrumentation

23 Movement of the wall, the surrounding ground and existing structures shall be monitored in accordance with Appendix 16/11 (and 16/12 or 16/13 as appropriate) and Clause 1617.

Preparation of wall surfaces

24 Preparation of wall surfaces shall be in accordance with sub-Clause 1610.23.

1612 Hard/Soft Secant Pile Walls

Guide walls

1 The design and construction of guide walls shall be in accordance with Appendix 16/12 and sub-Clause 1611.1.

Materials

General

2 (11/03) Concrete, steel reinforcement and support fluid shall be in accordance with sub-Clauses 1611.2, 3 and 4 and as described in Appendix 16/12.

Self hardening slurry mixes

3 (11/03) The Contractor shall submit details for the self hardening slurry mix (soft pile) proportions to be used as required by Clause 1601.

Cement materials, aggregates (if used), admixtures and water shall be in accordance with Series 1700.

Trial concrete mixes shall be prepared for each mix unless there are existing data showing that the concrete mix proportions and method of manufacture will produce hardened material of the strength, permeability, shrinkage properties and durability required, having adequate consistence for compaction by the method to be used in placing. The performance requirements are set out in Appendix 16/12. Limits on consistence and time for placement are included. The requirements for testing will be set out in Appendix 16/12.

Where a trial concrete mix is required after commencement of the works the above procedure shall be adopted.

The consistence of each batch of a trial concrete mix shall be determined by the method as specified in Appendix 16/12.

Trial concrete mix proportions shall be regarded as satisfactory if the compliance requirements set out in Appendix 16/12 are met.

No variations outside the limits set out in the proportions shall be made nor in the original source of the materials without demonstrating compliance with this Specification.

Self hardening concrete mixes shall be checked for compliance with the mix proportions. Cylindrical samples shall be made at the rate of four samples for each 50 m^3 of self hardening slurry or part thereof in each day's work. Testing will be made in accordance with the requirements of Appendix 16/12. The results shall comply with Appendix 16/12.

The Contractor shall keep a detailed record of the results of all tests on self hardening mixes and their ingredients. Each test shall be clearly identified with the pile to which it relates and the date it was carried out.

Boring

General

4 Boring near recently cast piles, cleanliness of pile base, and cleaning of support fluid shall be in accordance with sub-Clauses 1611.5, 7 and 8.

Stability of bore

5 Temporary casing shall be used in unstable ground with or without support fluid to maintain the stability of the bore unless continuous flight augers are used. The process of advancing the bore and the temporary casing shall be such that soil is not drawn into the bore from outside the area of the pile and cavities are not created outside the temporary casing.

Steel reinforcement

6 (11/03) Steel reinforcement shall be in accordance with sub-Clause 1611.9 and as described in Appendix 16/12.

Placing and compacting concrete

7 Placing and compacting concrete shall be in accordance with sub-Clauses 1611.10 to 15 inclusive.

Placing and compacting self hardening slurry mixes

General

8 The method of placing and the workability of a self hardening slurry mix shall be such that a continuous monolithic shaft of the full cross section is formed and that it shall be homogeneous in its final position.

Before commencing the filling of the pile the Contractor shall plan and reasonably demonstrate that a sufficient quantity of self hardening mix is available to construct the pile in one continuous operation.

Removal of temporary casing, when used, shall be completed before the self hardening mix within the casing loses its workability.

For continuous flight auger piles injection of self hardening mix shall continue up to the commencing surface or above so that free discharge from the delivery pipe can be observed to be taking place.

No spoil, liquid or other foreign matter shall be allowed to contaminate the mix.

(11/03) **Consistence of self hardening concrete mix**

9 (11/03) Self hardening concretes shall be coherent and of a consistence such that when in its final position and after all constructional procedures in forming the pile have been completed it shall remain sufficient consistence.

(11/03) **Placing self hardening concrete**

10 (11/03) The self hardening concrete mix shall be placed using methods appropriate to the composition of the concrete mix. These may include placing through a hopper attached to a length of tremie pipe and tremie methods in which case placement shall be in accordance with sub-Clauses 1611.14 and 15. Other self hardening concrete mixes use proprietary methods which shall be set out by the Contractor in his method of construction. Continuous flight auger piles shall use an appropriate pump which shall be kept charged continuously throughout pile construction.

Time period for excavation and placing self hardening mix

11 (11/03) The time period after a pile is excavated and before the self hardening concrete mix is placed shall not exceed 12 hours unless otherwise specified in Appendix 16/12. If temporary casing is used, this period shall start when excavation below the temporary casing commences.

Tolerances

General

12 Guide wall, recesses and steel reinforcement tolerances shall be in accordance with sub-Clauses 1611.16, 18 and 19.

Secant piles

13 At cut-off level the maximum permitted deviation of the pile centre from the centre point shown on the setting out drawings shall be 25 mm in any direction except that an additional tolerance of 10 mm shall be permitted for each 1.0 m that the cut-off level is below the top of the guide wall unless otherwise specified in Appendix 16/12.

The exposed face of the pile shall be vertical within a tolerance of 1:100 in any direction.

An additional tolerance of 100 mm will be allowed for concrete protrusions resulting from cavities formed by overbreak in the ground. Where very soft clay layers or peat layers are anticipated or obstructions are to be removed prior to or during boring, an additional overbreak tolerance will be stated in Appendix 16/12.

General

14 Concrete level, backfilling of empty bore, water retention, instrumentation and preparation of wall surfaces shall be in accordance with sub-Clauses 1611.20, 21, 22, 23 and 24.

1613 Contiguous Bored Pile Walls

Guide walls

1 The design and construction of guide walls shall be in accordance with Appendix 16/13 and sub-Clause 1611.1.

Materials

2 (11/03) Concrete, steel reinforcement and support fluid shall be in accordance with sub-Clauses 1611, 2, 3 and 4 and as described in Appendix 16/13.

Boring

General

3 Boring near recently cast piles, cleanliness of pile base and cleaning of support fluid shall be in accordance with sub-Clauses 1611.5, 7 and 8.

Stability of bore

4 Temporary casings shall be used in unstable ground with or without support fluid to maintain the stability of the bore unless continuous flight augers are used. The process of advancing the bore and the temporary casing shall be such that soil is not drawn into the bore from outside the area of the pile and cavities are not created outside the temporary casing.

Temporary casings shall be extracted immediately on completion of concreting.

Steel reinforcement

5 Steel reinforcement shall be in accordance with sub-Clause 1611.9.

Placing and compacting concrete

6 Placing and compacting concrete shall be in accordance with sub-Clauses 1611.10 to 15 inclusive.

Tolerances

General

7 Guide wall, recesses and steel reinforcement tolerances shall be in accordance with sub-Clauses 1611.16, 18 and 19.

Contiguous piles

8 At cut-off level the maximum permitted deviation of the pile centre from the centre point shown on the setting out drawings shall be 50 mm in any direction except that an additional tolerance of 13 mm shall be permitted for each 1.0 m that the cut-off level is below working level or top of the guide wall unless otherwise specified in Appendix 16/13.

The exposed face of the pile shall be vertical within a tolerance of 1:75 in any direction for contiguous walls.

An additional tolerance of 100 mm will be allowed for concrete protrusions resulting from cavities formed by overbreak in the ground. Where very soft clay layers or peat layers are anticipated or obstructions are to be removed prior to or during boring, an additional overbreak tolerance shall be stated in Appendix 16/13.

General

9 Concrete level, backfilling of empty bore, instrumentation and preparation of wall surfaces shall be in accordance with sub-Clauses 1611.20, 21, 23 and 24.

1614 King Post Walls

Materials

General

1 (11/03) Concrete, steel reinforcement and support fluid shall be in accordance with sub-Clauses 1611.2, 3 and 4 and as described in Appendix 16/14.

Structural steelwork

2 Structural steelwork shall be in accordance with Series 1800.

Boring

General

3 Boring near recently cast piles, cleanliness of pile base, and cleaning of support fluid shall be in accordance with sub-Clauses 1611.5, 7 and 8.

Stability of bore

4 Temporary casings shall be used in unstable soils with or without support fluid to maintain the stability of the bore unless continuous flight augers are used. Care shall be taken not to undermine or destabilise ground by boring too far ahead of the temporary casing. Temporary casings shall be extracted immediately on completion of concreting.

The method of construction shall be submitted in accordance with Clause 1601.

Placement of King Post members

5 The method of handling and placing King Post members shall be set out in the Contractor's method of construction, submitted in accordance with Clause 1601.

In appropriate conditions, the member may be plunged into concrete already placed in the pile bore immediately after the concrete placement and before the concrete has achieved its initial set. Guides or hole spacers shall be used so that the specified tolerances of the King Post member are achieved.

Where the King Post member is installed prior to concreting, the Contractor shall ensure that it is not disturbed, displaced or disoriented during concreting.

Steel reinforcement

6 (11/03) Steel reinforcement shall be in accordance with sub-Clause 1611.9 and as described in Appendix 16/14.

Placing and compacting concrete

General

7 Placing and compacting concrete shall be in accordance with sub-Clauses 1611.10 to 15 inclusive. The method of placing concrete shall avoid disturbance of King Post members.

Tolerances

8 The required tolerances depend on the application and are set out in Appendix 16/14.

Concrete level

9 No pile shall be cast with its final concreted level below standing water level unless the Contractor's method of construction includes measures to prevent inflow of water that may cause segregation of the concrete as the temporary casing is withdrawn. The standing water level will be treated as the cut off level for the purpose of calculating tolerance.

For piles cast in dry bores using temporary casing and for piles cast under water or support fluid the casting level above cut off level shall be within the casing tolerance above the cut off level shown in Table 16/7.

Backfilling

10 The concrete will usually be below the working level and the pile bore containing the King Post member shall be backfilled once the concrete has sufficient strength or after such time as specified in Appendix 16/14.

The backfill material in accordance with Appendix 16/14 shall be evenly placed on either side of the King Post member to avoid uneven loading. Prior to backfilling, bores shall be clearly marked and fenced off so as not to cause a safety hazard.

Instrumentation

11 Movement of the wall, the surrounding ground and existing structures shall be monitored in accordance with Appendix 16/14 and Clause 1617.

1615 Steel Sheet Piles

General

1 Only new piles shall be used for permanent works. Piles shall be carefully examined by the Contractor at the time of delivery and damaged piles repaired or replaced. The records of testing of the steel used in the piles shall be made available.

Materials

Standard sheet piles

2 Unless specified otherwise, all steel for sheet piles shall be manufactured to BS EN 10248 Grade S270GP or S355GP.

Fabricated sheet piles

3 All fabricated piles eg. corners, junctions, box sections, high modulus sections, shall be fabricated and supplied to the sheet pile manufacturer's recommendations.

Storage

4 If sheet piles of different grade steel are stored on site, each pile shall be clearly marked as to its grade and piles of different grade shall be stored separately.

Clutch sealant

5 If specified in Appendix 16/15, the Contractor shall apply a clutch sealant to the piles prior to pitching in accordance with the manufacturer's recommendations.

Pile handling and driving

Pile handling

6 When assembling piles before pitching the Contractor shall ensure that the interlocks are clean and free from distortion. All storage, handling, transporting and pitching of piles shall be carried out in such a way that no significant damage occurs to piles and their coatings.

Pile installation and extraction

7 (11/03) In the event of a Contractor's design he shall demonstrate that the sheet piles can be installed adequately to the correct depths through the reported or anticipated soil conditions.

The Contractor shall give at least 24 hours notice before the commencement of driving.

The piles shall be guided and held in position by temporary gates with each pile properly interlocked

with its neighbour. Piles shall not by-pass one another in place of interlocking.

Where sheet piles are driven in panels, the end piles to each panel shall be driven in advance of the general run of piles. After allowing for initial penetration, no pile in the panel shall be driven to an excessive lead in comparison with the toe level of the panel in general and where hard driving is encountered this lead shall not exceed 1 m.

At all stages during driving the free length of the sheet pile shall be adequately supported and restrained. The Contractor shall ensure that the sheet panels are driven without significant damage or declutching, where possible.

The selection of driving and extracting plant shall be made having due regard to the ground conditions and pile type. The sheet piles shall be driven to the specified level and/or resistance or if hard driving is experienced, to practical refusal (which shall be defined as when the rate of penetration is below 100 mm per minute when hammering continuously or 12 blows per 25 mm movement when using the appropriate equipment), or when visible damage to the pile occurs. Practical refusal for pile extraction shall be defined generally as when the rate of extraction of a pile is below 100 mm per minute when back-hammering or pulling (with equipment normally capable of withdrawing a pile) continuously (after an initial effort of 10 minutes), or when damage to the pile head occurs. If the piles have not penetrated to the levels specified in Appendix 16/15, or have encountered obstructions, a full statement of the reasons shall be recorded by the Contractor and included in the pile record.

If required in Appendix 16/15, the Contractor shall install the sheet piles using a vibrationless jacking system.

Pile driving hammers shall be correctly positioned on the pile so that the hammer will be aligned as near to the axis of the pile as is practically possible. Freely suspended piling hammers shall be equipped with correctly adjusted leg guides and inserts. Where a hammer is mounted in a rigid leader, the leader shall be stable. The anvil block or driving plate shall be of sufficient size to cover as much as possible of the cross section of the pile.

Piles previously driven shall not be used until the Contractor can demonstrate that they can meet all the requirements of the Specification.

The Contractor may provide each pile in more than one length. Spliced joints shall be designed to cater for the combined effects of bearing, shear and bending stresses imposed upon the sheet piles. Splices shall be located to avoid maximum stress positions. If splices are to be welded, then these shall be designed in accordance with the guidelines given in BS EN 1011-1 and BS EN 1011-2 and the manufacturer's recommendations. Weld metal shall not encroach within the interlock areas so as to interfere with the interlocking of the piles.

Piling records

8 The following records shall be kept where appropriate:

(a) pile reference number or location

(b) pile type and grade of steel

(c) pile length

(d) type of hammer

(e) date of driving

(f) commencing surface level

(g) depth driven

(h) length of offcuts

(i) length of pile extensions

(j) if required, the measurement of driving resistance at appropriate depths.

(k) all information regarding interruptions, unexpected changes in driving characteristics, obstructions and times taken in overcoming them.

Positional and alignment tolerance

9 Unless deflected by obstructions, sheet piles shall be installed within the following tolerances:

In plan ±75 mm of the given sheet pile line at commencing surface.

Vertical 1 in 75

Level ±50 mm of required top level

Pile line dimensions shall be based on the nominal size of piles. Creep or shrinkage of the pile lines shall not exceed the manufacturer's rolling tolerances.

Welding

Welders qualification

10 (11/05) Only welders who are qualified to BS EN 287-1 or who have attained a similar standard, shall be employed on the Works. Proof of welder's proficiency shall be made available on request.

Welding standard

11 (11/03) For manual metal arc and semi-automatic welding of carbon and carbon manganese steels,

welding of piles and steel framework shall be carried out in accordance with BS EN 1011-1 and BS EN 1011-2. Defective welds shall be cut out and replaced. Where steel piles are to be spliced by butt welding the interlocks shall not be welded unless a sealing weld is required.

Durability and protection

12 Protective coating shall be applied, if specified, following the procedures set out in Clause 1606.

Preparation of pile heads

13 If a steel structure is to be welded to piles, the piles shall be cut square and to within ± 5 mm of the levels specified. If pile heads are to be encased in concrete they shall be cut to within ± 20 mm of the levels specified, and protective coatings shall be removed from the surfaces of the pile heads down to a level 100 mm above the soffit of the concrete.

1616 Integrity Testing of Wall Elements

Method of testing

1 Where integrity-testing of wall elements is specified the sonic logging method normally shall be used. Other methods may be considered subject to satisfactory evidence of performance.

Age of wall elements at time of testing

2 Integrity tests shall not be carried out until the number of days specified in Appendix 16/16 have elapsed since casting of the wall element.

Preparation of heads or tops of wall elements

3 Where the method of testing requires the positioning of sensing equipment on the wall element head or top, it shall be broken down to expose sound concrete and shall be clean, free from water, laitence, loose concrete, overspilled concrete and blinding concrete and shall be readily accessible for the purpose of testing.

Specialist Sub-contractor

4 The requirements of sub-Clause 1608.4 shall apply.

Interpretation of tests

5 The interpretation of tests shall be carried out by competent and experienced persons.

The Contractor shall give all available details of the ground conditions, element dimensions and construction method to the specialist firm before the commencement of testing in order to facilitate interpretation of the tests.

Report

6 The requirements of sub-Clause 1608.6 shall apply.

Anomalous results

7 In the event that any anomaly in the acoustic signal is found in the results indicating a possible defect in the wall element the Contractor shall demonstrate that the wall element is satisfactory for its intended use or shall carry out remedial works to make it so. Sonic logging tubes shall be grouted up after the Contractor has demonstrated that the wall element is satisfactory.

1617 Instrumentation for Piles and Embedded Walls

General

1 All materials and work shall be in accordance with this Clause and Appendix 16/17.

Type of instrumentation

2 Where the installation of instrumentation is called for, the type of instrumentation shall be one of the following, as specified in Appendix 16/17.

a) extensometer (rod or magnetic)

b) inclinometer

c) load cell

d) pressure cell

e) strain gauge (to be attached to steel or precast concrete or embedded in cast in situ concrete).

Other methods may be considered subject to satisfactory evidence of performance. All equipment used shall be suitable for its specified purpose.

The instrumentation shall be robust and shall be a proprietary system supplied by a reputable supplier. Where required in Appendix 16/17, the Contractor shall submit details of the Supplier, the instrumentation and curricula vitae for the staff who will install the instrumentation on site, monitor it and analyse the readings. The Contractor shall also submit details of projects where the Specialist Instrumentation Contractor has successfully installed and monitored the specified type of instrumentation.

Extensometers

3 The instrumentation shall be securely attached to the reinforcement cage so that no component is displaced during placing of the reinforcement cage or concreting. During concreting, the tubing shall be adequately covered at both ends to prevent the ingress of concrete. Compression or extension couplings shall be installed as necessary for the movement range specified in Appendix 16/17.

The system will be such that the anchor and reference blocks shall be securely cast into the pile concrete. The rod shall be made of fibreglass or similar material so that it will not corrode or distort nor change its length due to heat or water changes.

The top of the rod shall incorporate a range adjuster with a travel of 25 mm.

If direct measurements are specified the displacement measuring device shall consist of a rechargeable digital dial gauge with 240 V. mains battery charger or analogue dial gauge. The orientation of the dial gauge relative to the top of the tube shall be constant for every reading. If remote reading is specified the readings shall be made by a linear potentiometer or other suitable device, securely held in place.

Inclinometers

4 (11/03) The access tubing shall be securely attached to the reinforcement cage so that no component is displaced during placing of the reinforcement cage or concreting. During concreting, the tubing shall be adequately covered at both ends to prevent the ingress of concrete. Alternatively, a nominal 100 mm steel duct sealed at the lower end and fitted with a removable screw cap at the upper end, shall be attached to the reinforcement cage. The inclinometer access tube can then be installed afterwards using a cementitious grout containing a non-shrink admixture.

The system shall consist of 60 mm nominal diameter corrosion-proof access tubing which shall have four longitudinal internal keyways on two orthogonal axes. The keyways shall be continuous over the length of the access tubing so that the wheels of the torpedoes can pass freely along it. For embedded walls, the keyways shall be oriented so that one set are parallel to the face of the wall. The coupling between sections of the access tube shall ensure that the correct alignment of keyways is maintained through a joint. Jointing rivets to connect the tube sections shall be located midway between keyways. Sealing mastic shall be applied to each rivet head and to the points where the tubing enters a coupling. All joints shall be sealed by liberally wrapping with a fabric tape impregnated with a waterproofing compound. This procedure shall also be carried out for the end-caps.

The inclinometer readout equipment shall comprise a uniaxial or biaxial torpedo complete with operating cable, cable reel, grip, carrying case, cartridge readout unit and battery charger. The torpedo shall be fully waterproof, stainless steel and incorporate two robust force servo accelerators aligned at right angles to each other. The torpedo shall be fitted with two orthogonal pairs of centre sprung wheels and shall have a gauge length of 0.5 m and be capable of negotiating a tube curvature of 3 m. The cable shall be of an appropriate length. The readout unit shall have an alphanumeric LCD and rechargeable battery with sufficient power for 20 hours continuous use. The Contractor shall supply a calibration frame for checking the readout equipment.

Alternatively a string of electrolevels may be used. Sufficient electrolevels shall be incorporated to provide an accurate deformation profile.

The “azimuth deviation” shall be recorded for each inclinometer access tube and shall be taken into account when processing the data. Where azimuth correction is necessary, the Contractor shall make available details of the method used.

Readings shall be taken for the full length of each inclinometer access tube for faces A, B, C and D. The top wheel of the torpedo will travel up face A first followed by faces B, C and D when using a uniaxial torpedo. With a biaxial torpedo, only faces A and B are travelled.

If a full set of readings cannot be obtained due to accumulation of debris in the access tubes, the Contractor shall flush the tubes with water to remove the debris until readings can be taken.

The readings shall be taken in increments of 0.5 m starting from the base of the access tube. All readings shall be recorded and reported to the nearest 0.1 mm. The readings are considered to be sufficiently accurate only if the “face errors” in the A/B plane and the C/D plane are less than 1.5 mm.

The datum readings to be used in the calculations for each inclinometer shall be made available.

The data shall be processed assuming a fixed base. The surveyed cumulative horizontal movement of the top of the access tube shall be reported to an accuracy of 0.5 mm. When required, the data shall also be processed assuming a specified offset at the top of the access tube.

The processed data for faces A, B, C and D shall be tabulated to show the following:

a) deviations and face errors

b) mean deviation

c) change in mean deviation

d) cumulative mean deviation

e) displacement profiles.

Items (c) and (e) shall also be presented graphically to show the deviation or displacement plotted against depth.

Load cells

5 (11/03) The loads to be measured may be either compressive or tensile, as specified in Appendix 16/17. The load cells shall have a response time of two seconds or less in response to monotonically increasing or decreasing loading.

The monitoring system shall provide a stable signal and any temperature or cable length or other effects on the load signal shall be included in the permissible tolerance. If a hydraulic or pneumatic system is used it shall be rated for and have been tested to twice the anticipated maximum pressure. The load cells and cabling shall be compatible with their intended position within a pile and shall be unaffected by the presence of water or fluid concrete. They shall be sufficiently strong to withstand additional loading due to placing of the reinforcement cage and concreting.

As the cell will give a direct reading of load, it shall be positioned so that all the load passes through it without any eccentricity. The loading system shall be safe and stable.

Pressure cells

6 The pressure cells shall have a response time of 2 seconds or less in response to monotonically increasing or decreasing loading.

The monitoring system shall provide a stable signal and any temperature or cable length or other effects on the pressure signal shall be included in the permissible tolerance. If a hydraulic oil, pneumatic or mercury-based system is used it shall be rated for and have been tested to twice the anticipated maximum pressure. The pressure cells and cabling shall be compatible with their intended position within a pile and shall be unaffected by the presence of water or fluid concrete. They shall be sufficiently strong to withstand additional loading due to placing of the reinforcement cage and concreting.

If the pressure cell is to be placed against concrete on one or both sides, it shall be provided with a mercury filled re-pressurising tube to ensure that no gap occurs between the hardened concrete and the pressure cell.

Strain gauges

General

7 The strain gauges shall have a response time of 10 seconds or less. The monitoring systems shall provide a stable signal and any temperature or cable length or other effects on the signal shall be included in the permissible tolerance. The strain gauges and cabling shall be compatible with their intended position within a pile and shall be unaffected by the presence of water or fluid concrete. They shall be sufficiently strong to withstand additional loading due to placing of the reinforcing cage and concreting or pile driving.

Strain gauges attached to steel or precast concrete piles

8 The strain gauges shall be securely attached to a mounting plate welded to the steel for steel piles, or securely attached to the reinforced concrete for precast concrete piles. The welding procedures of Clause 1606 shall be followed. The method of attachment shall be sufficiently strong so the gauge is not displaced, nor the wires or cables damaged by driving.

Strain gauges embedded in concrete

9 Strain gauges for cast in situ piles shall be either the embedment variety or shall be securely attached to reinforcement bars or to ‘sister’ bars which shall be attached to the reinforcement cage. The methods of attachment shall be such that the gauge is not displaced, nor the wires or cables damaged by placing of the reinforcement, concreting, driving or other processes.

Readings

General

10 Readings shall be reported in terms of the basic property measured (eg. volts, hertz, mm of Mercury) and shall be converted to SI or derivative units by means of a calibration constant. The calibration constant and the range over which it is applicable shall be clearly stated.

Readings shall be taken at the times or time intervals specified in Appendix 16/17.

Calibration and data checking

11 The instrumentation shall be calibrated prior to incorporation into the works and a certificate of calibration shall be made available. For strain gauges a calibration constant can be provided if evidence is available showing that the variation in calibration constant will not vary maximum readings outside the specified tolerance.

The instrumentation shall be calibrated so that its behaviour has been monitored over the range specified in Appendix 16/17. The Contractor shall demonstrate that the type of instrumentation can provide a stable, reproducible and repeatable calibration.

All data shall be checked by the Contractor for errors prior to submission. If erroneous data are discovered (eg. face errors for inclinometer readings greater than 1.5 mm), the Contractor shall take a second set of readings immediately. If the errors are repeated, the Contractor shall determine the cause of the error. Both sets of readings shall be processed and submitted, together with the reasons for the errors and details of remedial works. The Contractor shall rectify any faults found in the instrumentation system for the duration of the specified monitoring period.

All computer data files and calculation sheets used in processing the data shall be preserved until the end of the contract. They shall be made available for inspection on request.

Tolerances

12 For load or pressure, a tolerance of ± 1% of the range specified in Appendix 16/17 is permissible. For strain, a tolerance of ± 2 x 10^{-6} is permissible. For displacement, a tolerance of ± 0.1 mm is permissible.

Except where explicitly specified in Appendix 16/17, no instrumentation device, tubing or cable shall be placed in the concrete cover zone.

Report

13 The results shall be made available within five working days of the completion of each phase of testing.

The report shall contain the following:

a) the date and time of each reading

b) the weather

c) the name of the person who made the reading on site and the name of the person who analysed the readings together with their company affiliations

d) the pile or wall element reference number and the depth and identity number of the instrumentation

e) any damage to the instrumentation or difficulties in reading

f) the condition of the pile (eg. if the reading is being made during a load test, the stage of the test; if a wall is being excavated alongside, the depth of the excavation, etc)

g) the calibration constants or equations that are being applied and the dates they were determined

h) a table comparing the specified results with any previous readings and with the base readings

i) (11/03) a graph showing variation of load or pressure or vertical movement or strain with time or horizontal movement with depth. Key dates shall be marked with a brief explanation of their significance.

Columns of numbers shall be clearly labelled together with units. Numbers shall not be reported to a greater accuracy than is appropriate. Graph axes shall be linear and clearly labelled together with units.

Specialist Instrumentation Contractor

14 The installation, monitoring and analysis shall be carried out by a specialist Contractor, subject to demonstration of satisfactory performance before the commencement of monitoring.

The staff carrying out the monitoring and interpretation of the results shall be competent and experienced with the type of instrumentation used.

Monitoring equipment

15 (11/03) The monitoring equipment shall become the property of the Overseeing Organisation, if so specified in Appendix 16/17. Monitoring shall be carried out either directly at the pile head, or remotely from a monitoring cabin as specified in Appendix 16/17.

The monitoring equipment shall be appropriate for the situation in which it is to be used. The manufacturer's guidelines for its use shall be followed. Where it has not been possible to follow the manufacturer's guidelines, the fact shall be reported together with the reason and details of the alternative procedure.

The monitoring equipment shall remain on site for the duration of the monitoring programme, except when necessary for it to be calibrated, after which it shall be returned to site. The same monitoring equipment shall be used at each position. Where this is not possible the fact shall be reported together with the reason.

Protection

16 Terminal boxes at the head of the pile shall be protected by a lockable robust steel cap. The pile head shall then be fenced off with clearly visible barriers which shall be maintained for the duration of the monitoring programme.

Any cable running along the ground shall be clearly marked and adequately protected to prevent the cable posing a safety hazard or becoming damaged.

Surveying

17 The pile or element head terminal (top of access tubing or as specified in Appendix 16/17) shall be surveyed, if specified in Appendix 16/17. The level will be determined to an accuracy of 1 mm relative to the datum specified in Appendix 16/17. The grid coordinates will be determined to an accuracy of ± 2 mm relative to the grid specified in Appendix 16/17. Other measurements shall be to the specified accuracy.

1618 Support Fluid

General requirements

1 Where a support fluid is used for maintaining the stability of an excavation the properties and use of the fluid shall be such that the following requirements are achieved:

i) continuous support of the excavation

ii) solid particles are kept in suspension

iii) the fluid can be easily displaced during concreting

iv) the fluid does not coat the reinforcement to such an extent that the bond between the concrete and reinforcement is impaired

v) the fluid shall not cause pollution of the ground and groundwater before, during or after use.

Where required in Appendix 16/18, details of the type of support fluid, manufacturer's certificates for the constituents and mix proportions shall be submitted.

Support fluids shall be in accordance with Appendix 16/18 and this Clause, except where there may be a conflict of requirements, in which case those in Appendix 16/18 shall take precedence.

Evidence of suitability of support fluid

2 The Contractor shall make available details of the properties and use of the support fluid to demonstrate it will meet the specified requirements. These details shall be prepared at least 21 days prior to the commencement of work and shall include:

i) (11/03) evidence from previous work with this support fluid and justification for its suitability for these ground conditions and method of construction. Particular issues, which shall be addressed, are the types and sources of the support fluid constituents, time of construction of the piles, ambient temperature, soil and groundwater chemistry.

ii) results of representative laboratory or field mixing trials with the support fluid to demonstrate compliance with the Specification.

iii) details of the tests to be used for monitoring the support fluid during the works and the compliance values for these tests, presented in the form of Table 16/8.

Materials

Water

3 (11/03) If water for the Works is not available from a water company's supply, the Contractor shall ensure that the water complies with the guidance given in BS EN 1008. Water from the sea or tidal rivers shall not be used.

When required in Appendix 16/18, the Contractor shall arrange for tests of the water for the Works to be carried out in accordance with the specified schedule before and during the progress of the work. The frequency of testing shall be as stated in Appendix 16/18.

Additives to the water

4 All solid additives shall be stored in separate waterproof stores with a raised floor or in waterproof silos which shall not allow the material to become contaminated.

Additives shall generally be used in accordance with the manufacturer's recommendations unless demonstrated otherwise. Bentonite shall be of a quality that shall accord with Publication 163 "Drilling Fluid Materials" of the Engineering Equipment and Material Users Association.

Mixing of support fluid

5 The constituents of the fluid shall be mixed thoroughly to produce a homogeneous mix. The temperature of the water used in mixing, and of the support fluid at the time of commencing concrete placement shall not be less than 5°C.

Compliance testing of support fluid

6 The Contractor shall carry out testing of the support fluid in accordance with his regime and this Specification to demonstrate compliance with his limits for each test. The Contractor shall establish a suitably equipped and properly maintained site laboratory for this sole purpose and provide skilled staff and all necessary apparatus to undertake the sampling and testing.

Each batch of freshly prepared or reconditioned slurry shall be proven by sampling and testing to be within the compliance values before the batch is used in excavations. Details of the method, frequency and locations for sampling and testing slurry from the excavations shall be prepared at least 21 days prior to the commencement of work. At least one sample immediately prior to placing steel and concrete shall be taken and tested from the base of the excavation and one from the top.

If tests show the support fluid does not comply with the Specification it shall be replaced.

Spillage and disposal of support fluid

7 All reasonable steps shall be taken to prevent the spillage of support fluid on the site in areas outside the immediate vicinity of boring. Discarded fluid shall be removed from the site without undue delay. Any disposal of fluid shall comply with the requirements of current legislation and all relevant authorities.

TABLE 16/8: Test and Compliance Values for Support Fluid

Compliance Values Measured at 20°C				
Property to be Measured	**Test Method and Apparatus**	**Specification for test**	**Freshly Mixed Fluid**	**Sample from bore prior to placing steel and concrete**
Density	Mud balance			
Rheological properties - over appropriate range of shear rates and temperature (a) Plastic viscosity (b) Yield stress (c) Consistency index, K (d) Flow index, n (e) Marsh cone viscosity (f) Gel strength - for appropriate range of times	 Fann viscometer Fann viscometer Fann viscometer Fann viscometer Marsh cone Fann viscometer			
Sand Content	Sand Screen Set			
Fluid loss - for appropriate range of temperatures times and pressures	Fluid loss test			
Filtercake thickness	Fluid loss test			
pH	Electrical pH meter to BS 3145, range pH 7 to 14			