PILING AND DIAPHRAGM WALLING

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Piling and Diaphragm Walling

NG 1601 General

1 British Standard 8004 : 'Code of Practice for Foundations' provides guidance on preliminary investigation, design, materials, workmanship and control of piling.

2 The Specification has been prepared on the assumption that the information from a site investigation report/ground investigation report will enable the Engineer to consider the type of pile, e.g. precast or cast-in-place, to estimate the lengths and to decide whether there are any special requirements, e.g. permanent casings or sulphate-resisting cement.

3 Generally, in cohesive soils, all types of friction pile should be driven or excavated to length and, in non-cohesive soils, all types other than bored piles should be driven to a set. Should ground conditions vary from those predicted in the site investigations then the set should be used for determination of founding level and then only after further investigation.

4 For a scheme requiring a considerable expenditure on piling, the construction and proof loading of trial piles is recommended either in advance of the Contract (where a non-proprietary system is envisaged), as an aid to its preparation, or at an early stage of the Works, to prove their suitability. Trial piles should be located so that they do not interfere with the Works.

5 Where the Engineer prepares a design, the piling type he has selected must be based upon the use of a non-proprietary system.

6 Where piles are designed by the Contractor, the Engineer should consider the need for pile proof loading. For example, driven piling in non-cohesive soil may not require proof loading whereas it may be necessary for bored cast-in-place piling.

7 The Instructions for Tendering require the Contractor to submit with the Tender the name of any piling sub-contractor he proposes to employ. This is to enable the Engineer to assess the suitability of the sub-contractor's method of installation. In general, if the Contractor wishes to change his sub-contractor after the Contract has been awarded, the Engineer should be prepared to agree if he is satisfied that the alternative method of installation is technically acceptable.

8 Some specialist piling sub-contractors will install their type of pile to a performance specification. In this event details should be agreed (see 9 below). The minimum length of pile shown on the Drawings may subsequently be adjusted in the light of information from a trial pile.

9 Where piling is offered to meet a performance specification, the Engineer should obtain from the Contractor full details of the type of pile offered, the standards of control he intends to use, how the calculation and checking of the load-carrying capacity and settlement of the piles will be carried out and the proof loading or other testing he proposes to undertake on the Site.

10 Completed piles may be subjected to lateral loading due to consolidation of sub-soil because of adjacent earthworks operations.

11 The purpose of requiring the Contractor to give early warning of ground conditions different from those expected from his interpretation of the ground investigation report is to enable the Engineer to determine without delay the need for changes in design or construction or for any remedial measures. When such differences are reported during work on bored cast-in-place piles, the Engineer should obtain confirmation, if possible by, having soil tests made in accordance with BS 5930.

12 The following information should be shown on the Drawings, as appropriate (cross-referenced in Appendix 16/1):

- Location of trial piles.
- Timing of installation and testing of trial piles.
- Working load.
- Class of concrete.
- Minimum cement content.
- Cross-sectional dimensions and tolerances.
- Estimated length.
- Minimum length of pile.
- Reinforcement, including pile shoe.
- Prestress and cube strength at transfer.
- Handling points.
- Concrete cube strength to be attained before lifting.

- Proof loading details:
  - Proof load;
  - Number of increments;
  - Limits of permissible movement and recovery.
- Method of lengthening piles.
- Method of incorporating the pile head into the substructure (e.g. a minimum of 75 mm of pile and an anchorage length of prestressing tendon or reinforcement might be incorporated).
- Details of permanent casings.
- Any other information (see NG 1602.5 and NG 1605.11).

This information should not be based upon any proprietary system.

13 Timber bearing piles are seldom used in Permanent Works and are not specially mentioned. Where they are required and sufficient description cannot be included on the Drawings, Substitute or Additional Clauses should be based on 'Piling - Model procedures and Specifications' published by ICE.

14 The Engineer should complete Appendix 16/1 and include cross-references to Drawings which give further information.

NG 1602 Precast Concrete Piles

1 The concrete should be not inferior to Grade 30 for normal reinforced precast concrete piles and Grade 50 for prestressed precast concrete piles.

2 Sub-contracting of the manufacture of precast concrete piles requires the Engineers written consent under Clause 4 of the Conditions of Contract. If their manufacture differs in any respect from that described in Appendix 16/1, the Contractor should be asked for complete details of his proposed alternative if these were not submitted at tender stage.

3 When sides of piles are used as formwork for casting adjacent piles, the method used to prevent adhesion between concrete surfaces should be to the approval of the Engineer.

4 The Engineer should require the Contractor to submit his detailed proposals for pile driving for approval in compliance with Clause 14 of the Conditions of Contract. When the plant and procedure have been agreed, the Engineer should state any particular requirements such as the set or length to be obtained.

The Engineer may permit the suspension of driving if he is satisfied that the rate of penetration before the suspension of driving will be substantially re-established on its resumption.

5 In certain types of soil, the set obtained using a diesel hammer may not reliably indicate the bearing capacity of the pile. Any limitations on the type of driving should be stated on the Drawings.

6 The length of pile required should be shown on the Drawings. Any variation in length should be approved only after the installation and, where necessary, testing of a trial pile.

7 During installation of the piles the Engineer should ensure that the Contractor records pile head levels. The Engineer should look for any signs of rising of, or damage to, completed piles resulting from ground heave. If uplift or damage does occur, the Engineer should agree appropriate remedial measures.

8 Where prestressed concrete piles may require lengthening, splicing steel should be included in the pile head. Welding of reinforcement in prestressed concrete piles is subject to the prior approval of the Engineer to comply with sub-Clause 1716.1. Guidance on various methods of lengthening can be found in Concrete Society Technical Report No. 12, 'Segmental Precast Prestressed Concrete Piles'.

NG 1603 Cast-in-place Piles

1 For cast-in-place piles the slump values of fresh concrete measured at the time of discharge shown in Table NG 16/1 are given to guide the Engineer in his assessment of the Contractor's proposals. After agreement, they may be varied at the discretion of the Engineer following due consideration of conditions of mixing, transport and placing.

2 As it is seldom possible to vibrate the concrete in small diameter cast-in-place piles, workability is of equal importance to cube strength. A 28-day cube strength of 20 N/mm^2 is adequate in most cases, but a minimum cement content of 375 kg/m^3 should be maintained. It may be desirable to vibrate the concrete in large diameter piles but, as this may involve special heavy vibrational equipment, the Engineer should satisfy himself that this will not cause segregation.

3 Any type of cast-in-place pile which is considered unsatisfactory for the particular site should be excluded but otherwise the Contractor's freedom to propose an alternative piling system should not be inhibited.

4 If the proposed system is a cast-in-place pile where a casing is driven and subsequently withdrawn, the Engineer should ensure that the Contractor's proposals to avoid damage to unfilled pile excavations or completed piles are acceptable having regard to the ground conditions, sequence of piling and the time interval between the construction of successive piles.

The Engineer may permit the suspension of driving if he is satisfied that the rate of penetration before the suspension of driving will be substantially re-established on its resumption.

5 Piles which are formed with zero slump concrete and hammered into place (especially those with enlarged bases) should not be driven in an alternate sequence because the increased resistance to driving might result in the infilling piles being founded at a higher level. The risk of damage from driving in sequence is less for these types of piles than for driven cast-in-place piles.

6 With all driven piles there is a risk, especially for closely spaced piles in stiff clays, that the upward displacement of soil may tend to lift adjacent piles. Recently placed concrete in driven cast-in-place piles can also be damaged by horizontal and vertical soil movements due to the installation of nearby piles. It has not been found possible to give firm rules regarding the sequence and distance between piles as the correct procedure will vary for different types of pile and ground conditions. In some circumstances a spacing of 3 pile diameters may be satisfactory while in others it may be as much as 6 pile diameters. Because redriving of cast-in-place piles is generally impracticable, it is essential that the Engineer should require the Contractor to satisfy him that the working procedure will avoid these difficulties.

7 During installation of the piles the Engineer should ensure that the Contractor records pile head levels. The Engineer should look for any signs of rising of, or damage to, completed piles resulting from ground heave. If uplift or damage does occur the Engineer should agree appropriate remedial measures.

8 Reinforcement should be openly spaced to facilitate the placing of concrete, lateral or spiral binding should be spaced no closer than 150 mm and spacer blocks should be used to ensure correct cover throughout the length of the pile.

TABLE NG 16/1: PELING CONCRETE MDC WORKABILITY

Piling Mix Workability	*Slump*		*Typical Conditions of Use*
	Minimum mm	*Maximum mm*	
A	75	125	Placed into water-free unlined hole. Widely spaced reinforcement leaving ample room for free movement between bars.
B	100	175	Where reinforcement is not spaced widely enough to give free movement between bars. Where casting level of concrete is within the casing. Where pile diameter is less than 600 mm.
C	150	—	Where concrete is to be placed by tremie under water or drilling fluid.

9 Inspection of pile borings and/or casings should be carried out immediately before concrete is placed. The method and type of apparatus proposed to be used should be agreed by the Engineer. It will normally be sufficient to lower a light down the shaft to check that the alignment and full cross-section are maintained within acceptable limits, but if more sophisticated methods are required they should be described in Appendix 16/1. In the case of large diameter bored piles, adequate safety precautions to comply with the codes and statutory regulations must be taken to protect personnel lowered into the shaft.

10 Where casings are damaged, or water or other foreign matter has entered the casing, the casing should be withdrawn and repaired or other action taken to ensure the soundness of the pile. Any damaged permanent casings should be assessed as to their acceptability as part of the working piles. Should water in the excavations be unpolluted then the pile may be concreted using a tremie pipe.

11 Pumping from a boring, or dewatering operations should not be permitted unless the Contractor has satisfied the Engineer that these operations will not have a detrimental effect on the surrounding soil or property, or cause damage to concrete during and after concreting operations.

12 Where standing groundwater level is higher than the required pile head level shown on the Drawings, the Contractor should submit his proposals for the approval of the Engineer before placing concrete. The pile head should not be left below groundwater level unless approved precautions are taken.

13 Temporary casings should be extracted while the concrete within remains sufficiently workable to ensure that it is not lifted.

14 Should the Contractor propose to drive any specialist type of pile to carry a specified load, the details of how this is to be achieved should be submitted to and receive the consent of the Engineer. The pile lengths shown on the Drawings may be adjusted in the light of information from a trial pile.

15 If the Engineer wishes to design on the basis of continuous flight auger cast-in-place piles, he should insert an appropriate additional clause.

NG 1604 Steel Piles

1 Radiographic tests on steel casings and piles may be carried out. While satisfactory results are being obtained, one radiograph 300 mm long should be made for not less than 10% of the number of welded connections in the case of a pile where the load is carried by the wall or section of a pile, and for not greater than 10% of the number of welded connections in the case of a pile where the load is to be carried by a concrete core.

2 For a pile where the load will be carried by the wall or section of the pile, and where the pile will be subjected to loads that induce reversal of stress during or after construction, the acceptance standard for radiographs should comply with ASME Boiler and Pressure Vessel Code, Section VIII. Division 1, Part UW-51. For a pile where the loads will be static and will not be carried by the wall of the pile, and where the pile will have a long length without lateral support, the acceptance standard for radiographs should comply with API 1104. For a pile where the loads will be static and where the pile will receive lateral support or where the load will be carried by a concrete core, radiographs will not normally be required, but welds must be capable of withstanding handling, driving and design load stresses.

3 Where radiographic testing is to be carried out, full details should be included in an Additional Clause and scheduled in Appendix 1/5.

4 Where the Contractor proposes to use proprietary steel pile sections for which there are no requirements in Series 1800, the Engineer should ensure that the manufacturers materials specification and rolling and fabrication tolerances are adequate for the purpose.

5 Reference should be made to NG 1602.4 to 1602.7 inclusive, as these are also applicable to steel piles.

6 The Engineer may permit the suspension of driving if he is satisfied that the rate of penetration before the suspension of driving will be substantially re-established on its resumption.

NG 1605 Proof Loading of Piles

1 The Specification deals with the proof loading of a pile by the application of an axial force, and covers the testing of both vertical and raking piles loaded in compression or tension.

2 Where trial piles are required, the object should be to have them constructed prior to the installation of working piles and to allow time for the test and the adoption of modifications if these prove necessary. If it is necessary to specify a more precise timing for the construction and testing of trial piles this should be included as an alteration to sub-Clause 1605.3 in Appendix 0/2.

3 Subject to the approval of the Engineer, main piles may be tested at any time. Although a more favourable result will often be obtained by delaying the testing of any pile, this should be balanced against the risk of delaying the remainder of the Works if the pile proves to be unsatisfactory. However, for some strata, e.g. soft chalk, it is essential to delay the testing for up to 28 days after pile construction.

4 The method of loading, i.e. under kentledge, against anchor piles or against ground anchors, should not be specified but is subject to the Engineer's approval.

5 The Contractor should satisfy the Engineer that the load measuring equipment he proposes to use is capable of indicating the full value of the test load and the incremental values in which it is to be applied.

6 The Maintained Load Test may provide a workable means for accepting piles and for determining remedial measures, lb prevent delays, a shorter Maintained Load Test, as described in 'Piling - Model Procedures and Specifications' published by the Institution of Civil Engineers, may be used with the approval of the Engineer. This may be considered appropriate in situations where most of the settlement is expected to take place relatively quickly, e.g. in free draining granular soils.

7 When testing a main pile, a Maintained Load Test would normally be applied and the maximum test load should be 1.5 times the working load. The value of the test load and the number of increments, which should be not less than 4, together with the limits of permissible movement and recovery, should be shown on the Drawings. Where a large number of piles are used, it may be advantageous to test trial piles to failure to achieve optimum design.

8 The failure of a pile under a Maintained Load Test may be due to faulty workmanship or material, or to the failure of the ground supporting the pile. Where the pile itself has failed, e.g. sudden excessive deflection under load caused by collapse due to necking of a cast-in-place pile, remedial measures are required. Where the supporting ground has failed then, as the Engineer will have determined the diameter and length of the pile or accepted the Contractor's proposals, the cost of remedial measures will normally be borne by the Employer. The test failure criterion is normally accepted as a pile movement of 10% of its equivalent diameter.

9 Subject to the agreement of the Engineer, the Contractor may carry out integrity testing of piles where there is some doubt as to the soundness of a pile. Integrity testing should not generally be used to assess the load carrying capacity of a pile. Where integrity testing is to be specified for quality control of cast-in-place piles, an Additional or Substitute Clause will be required, cross-reference in Appendix 1/5.

10 Where the Engineer wishes to determine the ultimate capacity of a pile, the loading in the Maintained Load Test may be increased progressively by increments in order to reach the ultimate bearing capacity, or failure, of the pile. The point at which the soil fails to support the pile may not be clearly shown by the results obtained and for this reason a Constant Rate of Penetration or Constant Rate of Uplift Test is more suitable. Tests to failure should not be carried out on main piles. Maximum applied loads should be limited to avoid physical breakage of the pile.

11 For continuous structures, values for movement and recovery should be stated under working load as these are of prime importance in the design. Where they are required they should be stated on the Drawings.

12 For further information on the type of pile test and test procedure see British Standard 8004 : 'Code of Practice for Foundations', 'Piling - Model Procedures and Specifications' published by ICE, and DOE and CIRIA Report PG7 (1980) : Tile Load Testing Procedures'.

NG 1607 Diaphragm Wall Construction

1 The tremie pipe used for placing concrete in diaphragm walls should be clean, watertight, without projecting flanges and extend to the bottom of the trench excavation before concreting. All drilling fluid should be expelled from the pipe during the initial charging process. Sufficient embedment of the tremie pipe in the concrete should be maintained throughout the concreting to prevent re-entry of drilling fluid and at no time should the foot of the pipe be lifted clear of the placed concrete.

2 The Contractor's proposals for concrete cast under drilling fluid should be checked to ensure that they meet the following:

(i) Aggregates should preferably be naturally rounded, well graded gravels and sands when they are readily available in the locality. The maximum aggregate size should be 20 mm. The sand should conform with Grading M of IS 5. The use of other aggregates may be permitted subject to the suitability of the diameter of the tremie pipe used for placing the concrete.

(ii) A cement content of not less than 400 kg/m^{1} should be maintained.

(iii) The slump value of fresh concrete measured at the time of discharge should be between 150 mm and 200 mm and the water/cement ratio should not exceed 0.6.

(iv) The mix should be designed to give the required high workability and specified characteristic strength.

3 Where diaphragm walling is subsequently to receive a finish, this should be detailed on the Drawings and any treatment of the diaphragm walling concrete should be stated.

NG SAMPLE APPENDIX 16/1: REQUIREMENTS FOR PILING AND DIAPHRAGM WALLING

[Note to compiler: Include here:]

Piling

1 Requirements for piling if different from the requirements of sub-Clause 1601.2.

2 Requirements for time of stressing if different from the requirements of sub-Clause 1602.3.

3 Whether there is a requirement for demonstrating that final set is maintained *[1603.10].*

4 Requirements for inspection of pile borings and/or casings *[1603.13].*

5 Full details of piling required including proof loading tests, etc. and cross-references to appropriate Drawing Numbers *[1605.3, 1605.4].*

Diaphragm Walling

1 Full details of diaphragm walling required including cross-references to appropriate Drawing Numbers *[1607.1].*

2 Requirements for the Contractor to provide drawings showing full details of wall panel sizes, recesses and reinforcement *[1607.1J. [Requirements for working drawings, if required, should be scheduled in Appendix 1.4]*