Pile Foundations

To facilitate the processing of pile foundation submissions and to ensure proper design and construction of pile foundation works, the following guidelines should be observed.

Recognized Types of Pile Foundation

2. A recognized type of pile foundation is regarded as the piling system recognized by the Building Authority prior to the approval of piling plans through the submission of relevant technical details for assessment, normally by the registered structural engineer (RSE) in conjunction with the registered specialist contractor experienced in such system. A list of recognized types of pile foundation is available from the Buildings Department (BD).

3. Where it is proposed to use a piling system, which is not a recognized type, the RSE is advised to prove its acceptability to the Building Authority (BA) before detailed piling plans are submitted for approval. To enable the BA to fully consider the system, all relevant technical details on materials, manufacturing process, structural design, method of installation, method of assessing foundation capacity and applicability relating to ground conditions and selected examples of the use of the system elsewhere, if applicable, should be submitted following which a demonstration of the system may be called for.

Piling Plans Submission

4. The following particulars are required, under Building (Administration) Regulations 8 and 10, to be included in the pile foundation submission for approval:

Particulars to be shown on the piling plan

(a) a block plan showing the location of the site;

(b) details showing the characteristic features of the site and environs, including locations of ground investigation boreholes, slopes, existing foundations, nullahs, retaining walls and the like;

(c) layout arrangement, identification, expected depths and cut-off levels of the piles;

(d) layout arrangement of the pile caps;

(e) size, shape and structural details of the pile element, including details of the shoe, head, splices and cap/pile connection;

(f) pile bearing capacity and method of verification on site;

/(g) .....

(g) specification of structural materials;

(h) magnitude of characteristic dead, imposed and wind loads and their critical combinations acting on each pile or each group of piles;

(i) installation specifications, such as founding criteria, method of installation, method of overcoming underground obstruction;

(j) method of controlling and monitoring the verticality, inclination and alignment of piles during installation;

(k) details of monitoring requirements for adjacent and nearby buildings, structures, land, street and services; and

(l) Where dynamic pile driving formula is used, the parameters for the assessment of the ultimate pile capacity, such as the effective energy per blow, efficiency of blow and penetration of pile for a hammer blow.

Particulars to be given in separate documents

(m) site investigation report including results of ground investigation, necessary field and laboratory tests and photographs of all the soil samples and rock cores taken;

(n) design calculations based on recognized foundation engineering principles; and

(o) appraisal report on the effects of the piling works on surrounding land and structures, including any proposal of precautionary and protective measures.

Design of Pile Foundations

5. In the design of pile foundations, the general guidelines as given in Practice Note for Authorized Persons and Registered Structural Engineers (PNAP) 141 should be followed. Further guidelines for specific aspects of group reduction factor, uplift and lateral resistances are given in Appendix A.

6. As the use of minipiles and socketted steel H-piles has become more and more common in recent years, and in view of the special founding criteria and unique method of installation of these two types of piles, particular guidelines on their design and construction are given in Appendices B and C respectively.

Pre-design Ground Investigations

7. Prior to the design of the pile foundation, sufficient ground investigations should be carried out so that adequate information on the geology of the site can be obtained and hence the general founding levels of the piles can be estimated. For further guidelines on ground investigation works, please refer to PNAP 132.

/Pre-drilling .....

Pre-drilling

8. For piles founded on rock, sufficient pre-drilling should be carried out prior to the installation works, such that the quality of the founding rock can be identified and the appropriate founding levels can be determined. The pre-drilling should be sunk to at least 5 m below the rock head of the specified grade.

9. Pre-drilling should be carried out for each of the large diameter bored piles, barrettes and the like, and the records of the pre-drilling should be submitted to BD at suitable intervals during the construction of the piles.

10. For minipiles, socketted steel H-piles and similar small diameter bored piles founding on rock, pre-drilling at location in close proximity of the piles should be made. The number of pre-drilled boreholes required should be such that the pile tip of every such pile should be within 5 metres from a pre-drilled hole. The pre-drilling should be sunk into the rock mass for at least 5 m below the rock head of the specified grade or the designed length of the rock socket of the nearest pile, whichever is the deeper.

Post Construction Proof Drilling

11. When large diameter bored piles, barrettes and the like are completed, core-drilling should be carried out at the concrete/rock interface for each of these piles. To facilitate successful core-drilling at the interface, a pipe of not less than 150 mm diameter may be left in at about 1 m above the interface. The core-drilling should be carried down to at least 1 m below the interface.

12. It is always expected that the concrete should be in good contact with rock at the interface and the rock is consistently of the required grade beneath the pile base. However, minor imperfection observed during the interface core-drilling, such as a thin layer of sediment, segregated concrete or weathered seam in the rock beneath the pile base, may be considered acceptable provided that the RSE can demonstrate his acceptance with justifications. As an alternative, the RSE may include in the foundation plans, proposals of remedial works for rectifying any such imperfections at the interface if found. The proposals should provide details of the method statement and the supervision required by the RSE.

13. For minipiles, socketted steel H-piles and the like, there would be practical problem for core-drilling at the concrete/rock interface. To verify the rockhead profile and hence assess the adequacy of the socketted length for these types of piles, some additional proof drill holes should be sunk into the rock mass and down to at least 5 m below the as-built top level of the rock socket of the nearest pile or to the as-built bottom level of the rock socket of the nearest pile, whichever is the deeper. The number of post-installation boreholes should be at least 2 for sites with 100 piles or less; or 1% of the number of piles for sites with more than 100 piles (any fraction of a borehole so calculated should be construed as one additional borehole). The RSE should determine the location of the boreholes. When submitting the certificate on completion of the piling works (Form BA 14), the RSE should submit an assessment report with a rockhead contour plan based on the ground investigation, the pre-drilling and the post-installation drilling, together with the piling record plan.

Registered Specialist Contractor in the Ground Investigation Field Work Category

14. With effect from 2 July 2001, all ground investigation works, pre-drilling, interface core-drilling, post-installation drilling and proof test core-drilling must be carried out by a Registered Specialist Contractor in the Ground Investigation Field Works category. For details of this category of the specialist contractor, please refer to PNAP 244. The contractor who is appointed to carry out proof test core-drilling required under Building (Construction) Regulation 30 should make declaration on its connection with the foundation contractor, including whether or not it is a holding/subsidiary/an associated company of the foundation contractor, or has financial relationship with it (e.g. cross-directorship), or has financial interest in the foundation works.

Quality Supervision for Piles Foundations

15. Adequate supervision should be provided for the pre-drilling, construction and proof test of pile foundations to ensure built quality. Requirements for quality supervision to be provided for pile foundation works are stipulated in PNAP 242.

Pile Foundations in the Scheduled Areas

16. Some special requirements for pile foundations in the Scheduled Areas are given in PNAP 161.

Form BA 14

17. Upon completion of the piling works, a specified Form BA14 certifying the completion should be submitted in the manner prescribed in Building (Administration) Regulation 25. For exceptionally large sites, foundation works may be suitably phased and separately considered for proof testing. BD should be consulted as early as possible on such special arrangement. To expedite the selection of piles for proof tests, piling record plans and reports may be separately submitted prior to the submission of the specified Form BA14.

Piling Record Plan and Reports

18. Upon completion of the piling work two sets of piling record plan and reports should be submitted as may be required under Building (Administration) Regulation 10 to certify the satisfactory completion of the piling works. These should include:

(a) a plan showing characteristic features of the site and the identification, location, depth and size of each pile as constructed;

(b) a report listing the date of construction, the quality and quantity of materials used and driving performance or excavation record of each pile;

/(c) .....

(c) reports on any tests as required for the particular piling system; and

(d) an assessment report with rock head contour plans, as appropriate.

Within 14 days of the receipt of these documents, BD would inform the AP/RSE of the representative piles identified for proof tests. To avoid unnecessary delay, the AP/RSE should ensure that full information on the completed piles is included in the piling record plan and reports.

Proof Tests

19. Proof tests on foundation units are required under Building (Construction) Regulation 30. Except in special circumstances where the standard of acceptance is to be determined according to the design and factor of safety, the BA will normally be satisfied if the procedures and criteria described in Appendix D are followed. Alternative procedures and acceptance criteria, supported by justification based on recognized foundation engineering principles and relevant to a particular site and building may also be adopted.

20. Alternative procedures and acceptance criteria, or methods other than test loading or core-drilling, which can demonstrate the performance of the foundation under loads or verify the integrity and the load-response interaction between the foundation unit and the bearing stratum may also be adopted. In this connection, the following should be submitted well in advance of the completion of the foundation works so that the BA may fully consider the suitability of the proposed method of testing:

(a) relevant recognized engineering principles and theories for the proposed method of testing;

(b) detailed procedures of testing;

(c) acceptance criteria;

(d) interpretation of the test results; and

(e) any verification tests performed to justify the parameters to be used in the proof test.

Further On Site Tests

21. Whenever doubt exists as to the design assumption or load carrying capacity of any pile foundation, further on site tests may be required under Building (Construction) Regulation 29.

Amendments to Approved Plans

22. For submission of amendment plans and their related consent applications, the fast track procedures for securing consent for amendments outlined in PNAP 215 shall apply.

23. Consent to the commencement of the pile cap and superstructure works will not be given until:

(a) satisfactory piling records have been submitted;

(b) specified Form BA14 has been submitted;

(c) the required proof tests have been satisfactorily carried out; and

(d) all relevant imposed conditions including materials testing requirement have been complied with.

Concurrent Processing of Applications

24. Procedures are in place in BD for concurrent processing of applications for approval and consent in respect of new foundation works. Except in cases where any imposed condition should require to be first met, e.g. shoring to adjoining buildings to be completed before piling works may commence, BD will consider giving approval of plans for foundation works and consent for such works at the same time. If an AP or RSE wishes to take advantage of these procedures, he should co-operate with the department by ensuring that an application for consent is not submitted before the 32nd day of the submission of plans for approval, to avoid unnecessary complications in administrative work.

25. To minimize the idling time on construction sites, applications may also be made for consent to commence excavation works for substructures prior to the final completion of foundation works, provided that the supervision plan for the excavation works is submitted and any earth-retaining elements (such as sheet piles) have been satisfactorily installed. These procedures mean that earth-retaining elements may be installed concurrently with the foundation works, thereby allowing excavation works for substructures to be carried out while foundation record plans are being examined and proof tests arranged. Consent for the construction of substructure elements (pile caps, for example) will be given only after satisfactory completion of the required proof tests.

(C M LEUNG)
Building Authority

Ref.: BD GP/BREG/C/11

First issued February 1980
Last revision June 2000
This revision January 2002 (AD/NB2) — Paragraph 12 added and Paragraphs 8, 10, 13 and Appendix D amended.

Index under: Pile Foundations
Pre-drilling
Core-drilling Test

Appendix A
(PNAP 66)

Guidelines for Specific Aspects of Pile Foundation Design

Group Reduction Factor

1. The group reduction factor should be determined with respect to the bearing capacity and settlement of the group by recognized foundation engineering principles. In the case of a group of 5 or more vertically loaded piles driven to a satisfactory set in cohesionless soil, a group reduction factor of 0.85 may be considered as generally acceptable. Alternative values of group reduction factor supported by a justification based on recognized principles and relevant to a particular site and building may also be adopted.

2. Generally, group reduction factors need not be applied where -

(a) the spacings are of more than 3 times the perimeter of the piles, measured from centre to centre; or

(b) the load capacity of the piles is derived from end-bearing on rock with unconfined compressive strength of not less than 10 MPa and with equally strong material beneath.

Uplift Resistance of Piles

3. The allowable uplift resistance of a pile group should be the lesser of the following:

(a) the sum of the allowable uplift resistance of the piles in the group; and

(b) the shear resistance mobilised on the surface perimeter of the group plus the effective weight of soil and piles enclosed in this perimeter.

4. The allowable uplift capacity of a pile may be taken as:

$$\frac{\text{Ultimate uplift shaft resistance}}{\text{Fs}} + \text{Effective self weight of pile}$$

where Fs is a factor of safety not less than 3. Other values of Fs may be used having regard to the nature of the ground, its variability over the site and the reliability of the method by which the ultimate shaft resistance is determined.

/5. .....

5. For piles under tension, proof test is normally required to justify the tension capacity unless the assumed tension capacity is less than half of the compressive capacity resulting only from shaft friction and bond between the pile and the surrounding soil. In any case, the adequacy of the soil mass together with the weight and possible shear resistance of the rock cone supporting the pile should be checked for uplifting effect. However, the shape or vertical angle of the rock cone may vary depending on the rock joint pattern as determined by suitable field tests.

Lateral Resistance of Piles

6. In the design of piles resisting lateral forces, consideration should be given to :

(a) the shear capacity of the soil;

(b) the structural capacity of the pile; and

(c) the deflection of the pile that the superstructure may tolerate.

7. When methods based on simplified assumptions and graphical solutions are used in the analysis, the parameters adopted should represent the characteristics of the pile and the soil.

Appendix B
(PNAP 66)

Guidelines on the Design and Construction of Minipiles

Minipiles

1. Minipiles are bored piles with a diameter normally not exceeding 400mm and taking up vertical loads by one or more steel bars encased in grout.

Design of Minipiles

2. In the design of minipiles, the following principles should be adopted :

(a) The structural capacity of a minipile should be derived solely from the steel bars. Because of the comparatively high stress in the steel bars and strain incompatibility, contribution from the grout and steel casing should be ignored. The allowable stresses of steel bars should be in accordance with the Code of Practice for the Structural Use of Concrete;

(b) For minipiles socketted into rock, the foundation capacity should be derived from the frictional resistance at the interface between grout and rock. The rock socket should be formed in grade III or better rocks, with core recovery greater than 85%. The design bond strength between rock and grout for compression should not exceed 0.7 MPa;

(c) For minipiles relying on soil friction, testing on trial pile is normally required to be carried out to verify the design assumptions;

(d) Minipiles should not be designed to resist lateral load by bending in view of their limited bending capacity. When lateral loads are to be resisted by the pile cap, the lateral displacement should be restricted to a magnitude which can be tolerated by the minipiles; and

(e) The allowable buckling capacity of the mini-piles should be checked. In assessing the buckling capacity of the piles, lateral restraints from the grout, steel casing if permanent and the surrounding soil may be allowed.

Construction of Minipiles

3. In the construction of minipiles, the following should be considered :

(a) Steel casing should be provided to support the pre-drilled hole within the soil strata and if necessary in the fractured rock, during construction;

(b) Permanent steel casing should be provided to enhance corrosion protection;

(c) A non-shrink cement grout with a minimum characteristic compressive strength of 30 MPa at 28 days should be used for encasing the steel bars;

(d) Verticality, inclination and alignment of the minipiles should be checked during installation, to verify any design assumption on eccentric moments induced in the piles.

(6/2000)

Appendix C
(PNAP 66)

Guidelines on the Design and Construction of Socketted Steel H-piles

Socketted Steel H-piles

1. Socketted steel H-piles are piles formed by inserting steel H-piles in pre-bored holes sunk into Grade III or better rock, and subsequently filling the holes with cement grout.

Design of Socketted Steel H-piles

2. In the design of socketted steel H-piles, the following principles should be adopted :

(a) The maximum allowable axial working stress should not exceed 50% of the yield stress of the steel H-pile. Contribution of the cement grout to the structural capacity should be neglected;

(b) The maximum combined stress due to the axial load and bending moment should not exceed 50% of the yield stress of the steel H-pile;

(c) The rock socket should be formed in grade III or better rocks, with a core recovery greater than 85%. The design bond strength between the rock and grout for compression should not exceed 0.7 MPa;

(d) The design bond strength between the grout and steel H-pile should not exceed 0.6 MPa. For grouting under water, a reduction factor of 0.8 should be applied to the bond strength;

(e) Where horizontal loads are to be taken by the piles, the rock socket should be checked for any additional stresses induced.

Construction of Socketted Steel H-piles

3. In the construction of socketted steel H-piles, the following should be considered :

(a) The prebored holes should be large enough to enable the installation of steel H-piles and to allow a minimum cover of 40 mm to the steel H-piles;

(b) A temporary casing should be provided in the pre-boring process down to rockhead level to prevent soil from falling into the pre-bored hole;

(c) Before the steel H-pile is inserted in the pre-bored hole, the hole should be cleaned to ensure that it is free from debris and soil; and

(d) The grout should be non-shrink and have a minimum characteristic strength of 30 MPa at 28 days.

(6/2000)

Appendix D
(PNAP 66)

Proof Tests

Proof Tests by Imposition of Test Loads

1. For proof tests carried out by means of the imposition of test loads :

(a) The pile should be tested to the load capacity at cut-off level with no allowance for group effect;

(b) For compression test, the test load should be 2 times the design compression capacity under working load;

(c) For tension test, the test load should be 2 times the design uplift capacity of pile under working load;

(d) The load should be applied in 2 equal increments up to 50% of the test load of the pile, then released and reapplied in 4 equal increments up to the full test load and maintained for at least 72 hours before removal;

(e) The load at each stage should be held for a period of 10 minutes or longer until the rate of settlement/pull-out is less than 0.05 mm in 10 minutes;

(f) The test load should be measured by a calibrated load measuring device and also by a calibrated pressure gauge in the hydraulic system; and

(g) The test shall be deemed to be unsatisfactory if any of the following conditions apply :

(i) the maximum settlement/pull out at the head of the pile during the test exceeds the value

$$\frac{PL}{AE} + \frac{d}{120} + 4\,\text{mm} \qquad \text{for compression test; or}$$

$$\frac{PL}{AE} + 4\,\text{mm}, \qquad \text{for tension test}$$

where P = the test load in kN as given in 1(b) and 1(c) above;
L = the length of the pile in mm;
A = the cross-section area of the pile in mm^2;
E = the Young's modulus for the material of the pile in kN/mm^2; and
d = the least lateral dimension of the pile in mm;

(ii) when the rate of recovery after the removal of the maximum test load is less than 0.1 mm/hour observed in a period of not less than 15 minutes, the residual settlement/heave at the head of the pile exceeds the value d/120 + 4 mm for compression test or 4 mm for tension test.

Proof Tests by Core-drilling

2. For proof tests carried out by core-drilling :

(a) the core-drilling should be taken through the full depth of the pile and carried down to a distance of at least half a diameter of the pile base, or 600 mm, whichever is larger, into the ground upon which the pile is founded;

(b) the completed core so taken should be properly marked and arranged in order for inspection;

(c) the concrete cores should not show evidence of honeycombing or segregation of individual constituent materials;

(d) any rock core obtained shall be visually examined to conform with the required rock material specified in the design;

(e) the cores shall also be examined to confirm the adequacy of the interface between the concrete and rock; and

(f) where large diameter bored piles, barrettes or the like are founded on soil, standard penetration tests shall be carried out at a maximum interval of 1.5 m from the pile founding level down to a distance of at least 3 times the diameter of the pile base, or 5 m, whichever is larger, to verify the required soil strength.