Chapter 4.5

Raft, pile, pier and beam foundations

4.5 Raft, pile, pier and beam foundations

CONTENTS

SCOPE

This Chapter gives guidance on meeting the Technical Requirements and recommendations for raft, pile, pier abd beam foundations.

DESIGN STANDARDS

4.5 - D1 Design shall meet the Technical Requirements

Design that follows the guidance below will be acceptable for raft, pile, pier and beam foundations.

STATUTORY REQUIREMENTS AND OTHER STANDARDS

4.5 - D2 Design shall comply with statutory requirements

Design should be in accordance with relevant Building Regulations and other statutory requirements.

4.5 - D3 Design shall follow relevant Standards and Codes of Practice

Relevant British Standards and Codes of Practice include:

BS 648	Schedule of weights of building materials
BS EN 1991	Actions on structures
BS EN 1992	Design of concrete structures
BS EN 1997-1	Geotechnical design:General rules
BS 10175	Investigation of potentially contaminated sites - Code of practice.

HAZARDOUS GROUND

4.5 - D4 The design of foundations shall take account of the characteristics of the site, its ground and any hazards

Where there is hazardous ground, the foundation design must be carried out by an Engineer in accordance with Technical Requirement R5.

Details of ground hazards to be taken into consideration are given in Chapters:
4.1 'Land quality - managing ground conditions'
4.2 'Building near trees'

NOTIFICATION

4.5 - D5 NHBC shall be notified before work starts on site

NHBC Rules state:
"If a Home is to be constructed on a Hazardous Site you must before making an Application for Inspection notify the NHBC in writing of the particular hazards which arise. You must do this at least 8 weeks before work begins on the site."

SUPERVISION BY AN ENGINEER

4.5 - D6 When foundations have been designed by an Engineer, the Builder shall require the Engineer to visit the site during construction

The visits by the Engineer are necessary so that the Engineer can be satisfied that the design of the foundation is suitable for the actual ground conditions encountered and that the construction is in accordance with the design.

REQUIREMENT FOR FOUNDATIONS

4.5 - D7 All masonry and all loadbearing elements shall be adequately supported by foundations

Elements requiring foundations include the following:
- external walls
- separating (party) walls
- chimney breasts
- piers
- internal loadbearing or masonry walls
- sleeper walls.

SITE CONDITIONS

4.5 - D8 Foundations shall be designed to suit site conditions

Items to be taken into account include:

(a) site and ground appraisals
All information relating to the site and its ground conditions which is necessary for full and proper foundation design should be obtained.

(b) dwelling design
Foundation design should take account of the shape, size and construction of the dwellings as well as the site layout.

Foundations for terraced dwellings may require special precautions to prevent damage from differential settlement.

(c) site layout
Building over changes in ground characteristics should be avoided.

(d) site levels
Stepped foundations and suspended floor slabs may be needed for sloping sites.

(e) sulfate and acids in ground or groundwater
Sulfates and other chemicals can cause expansion and disruption of concrete. Also, high acidity, for example in peat, or permeable soil with acidic groundwater, can cause damage to concrete. Where concrete is at risk from chemical attack from the ground or where the groundwater is highly mobile, the level of sulfate and other chemicals should be determined, in terms of the ACEC Class (Aggressive Chemical Environment for Concrete Class) in accordance with BRE Special Digest 1. Where sulfates or high acidity in ground or groundwater are present, reference should be made to Chapter 2.1 'Concrete and its reinforcement' (each section) for guidance concerning acceptable concrete mixes.

(f) trees
Where trees are nearby or are to be planted nearby (especially where the soil is shrinkable), foundations should be designed as shown in Chapter 4.2 'Building near trees'.

(g) frost susceptible soils
To avoid damage from frost action, the depth to the underside of the foundation in frost susceptible ground should be at least 450mm below finished ground level.

DIFFERENTIAL SETTLEMENT

4.5 - D9 Foundations shall be designed to take account of differential settlement

Foundations should be designed to avoid any local stress points or any differential settlement. Foundations for attached bays, porches, garages, conservatories and other structures should be a continuation of those for the main dwelling, unless the design indicates an alternative which takes account of differential movement, for example separate foundations. Foundations adjoining those of an existing building may require special precautions to limit differential movement.

SERVICES, INCLUDING DRAINAGE

4.5 - D10 Foundation design shall take account of access for services

Where services are to pass through, or under, foundations provision should be made for suitable ducts or lintels to enable them to be installed later, in such a way as not to impair structural stability. For further details, reference should be made to the Design and Sitework sections of Chapters:
5.1 'Substructure and ground bearing floors'
5.3 'Drainage below ground'
8.1 'Internal services'.

MOVEMENT JOINTS

4.5 - D11 Movement joints should be suitable for their intended purpose

Movement joints should be located so as to limit the risk of damage caused by movement. Suitable materials are given in the Materials section.

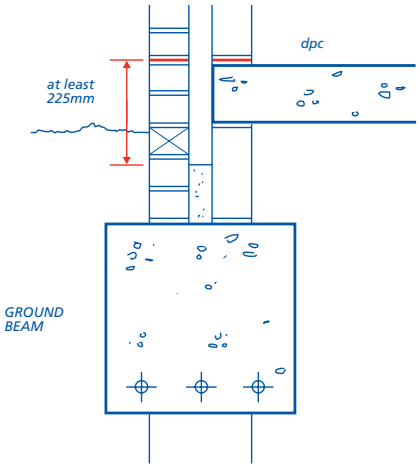
DAMP-PROOFING

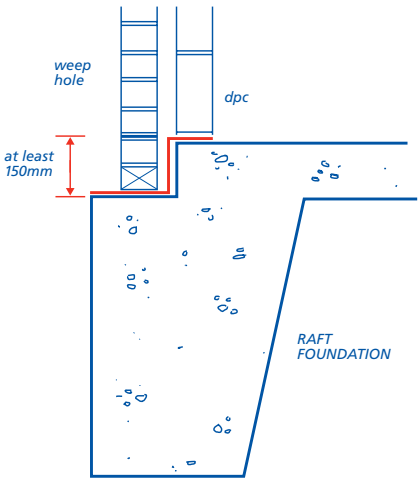
4.5 - D12 The foundation design shall prevent the passage of moisture to the inside of the dwelling

Items to be taken into account include:

(a) a drained cavity

Cavity walls should drain below dpc and prevent water flooding cavities above dpc levels or crossing from the outside to the inside. A clear cavity of 225mm minimum below dpc is required. Where foundations other than strip or trench fill are used, including those for timber framed dwellings, this may be reduced to 150mm minimum below dpc provided that weep holes and other measures, where necessary, are taken to ensure that the cavity can drain freely. Dpc cavity trays are not an acceptable weather-proofing to the edges of specialised foundations, such as rafts and ground beams.





(b) damp-proof membranes

For the provision of damp-proof membranes, reference should be made to Chapters 5.1 'Substructure and ground bearing floors' (each section) and 5.2 'Suspended ground floors' (each section).

SAFE TRANSMISSION OF LOADS

4.5 - D13 Foundations shall transmit the loads from the structure to the supporting strata safely and without excessive settlement

Items to be taken into account include:

(a) need for adequate stiffness to ensure differential movement does not adversely affect the supported structure
(b) the nature and bearing capacity of the fill material to be placed under the foundation
(c) specification of concrete
(d) cover to reinforcement

RAFT FOUNDATIONS

Rafts and semi-rafts should:

- meet Clauses D1 to D12, where applicable
- prevent the erosion of ground beneath the raft
- be designed to accommodate, where required, warm air ducts, service ducts or services without any adverse effect upon performance of the foundation.

Where appropriate, precautions should be taken to limit the risk of ducts becoming flooded.

Semi-raft foundations on made ground should follow the guidance given in Appendix 4.5-A.

For details of suitable fill for raft foundations, refer to Chapter 5.1 'Substructure and ground bearing floors' Appendix 5.1-A.

PILED FOUNDATIONS

Piled foundations should:

- meet Clauses D1 to D12, where applicable
- follow the guidance given in Sitework clause 4.5 - S11.

The design should specify precautions to be taken in cohesive soils where volume changes can occur.

The bearing capacity and integrity of piles should be confirmed by testing, when required.

PIER/PAD AND BEAM FOUNDATIONS

Pier/pad and beam foundations should:

- meet Clauses D1 to D12, where applicable.

VIBRATORY GROUND IMPROVEMENT TECHNIQUES

Vibratory ground improvement should:

- meet Clauses D1 to D12, where applicable
- comply with Chapter 4.6 'Vibratory ground improvement techniques'.

PROVISION OF INFORMATION

4.5 - D14 Drawings and specifications should be produced in a clearly understandable format

All relevant information needed for the completion of the sitework should be stated clearly and unambiguously and be readily available to all concerned.

All necessary dimensions and levels should be indicated and related to:

- at least one bench mark, and
- reference points on site.

4.5 - D15 Designs and specifications, together with relevant site information, shall be distributed to appropriate personnel

Details should be provided with respect to:

- dimensions, type and depth of foundations
- junctions
- steps
- movement and construction joints
- detailing of ducts
- location of services
- critical sequences of construction.

Designers need to be aware of the ground conditions and, in particular, any features requiring special attention, such as any existing sewers or other services, levels of water table and the presence of any deleterious substances, especially sulfates.

Where toxic materials (or materials likely to present a health hazard) are found, all available information should be supplied to NHBC, together with proposals for dealing with the hazard.

MATERIALS STANDARDS

4.5 - M1 All materials shall:
(a) meet the Technical Requirements
(b) take account of the design

Materials that comply with the design and the guidance below will be acceptable for raft, pile, pier and beam foundations.

Materials for raft, pile, pier and beam foundations should comply with all relevant standards, including those listed below. Where no standard exists, Technical Requirement R3 applies (see Chapter 1.1 'Introduction to the Standards and Technical Requirements').

References to British Standards and Codes of Practice include those made under the Construction Products Directive (89/106/EEC) and, in particular, appropriate European Technical Specifications approved by a European Committee for Standardisation (CEN).

CONCRETE

4.5 - M2 Concrete shall be of a mix design which will achieve the required strength and be sufficiently resistant to chemical and frost action

For guidance on the specification and use of concrete, particularly in relation to the choice of mix to achieve sufficient structural strength and resist deterioration due to ground aggressivity and frost action, reference should be made to Chapter 2.1 'Concrete and its reinforcement' (each section).

REINFORCEMENT

4.5 - M3 Reinforcement shall be sufficient to ensure proper transfer of loads

Reinforcement shall be in accordance with Chapter 2.1 'Concrete and its reinforcement' (each section).

OTHER MATERIALS

4.5 - M4 Compressible materials shall be capable of absorbing potential heave forces, where appropriate

Proprietary materials should be either assessed in accordance with Technical Requirement R3 or acceptable to NHBC through established custom and practice.

4.5 - M5 Sealing materials for movement joints shall be suitable for their intended purpose

Joints often fail because the likely variation in the size of the joint is not compatible with the movement capability of the sealing material.

Factors to be taken into account when choosing materials for movement joints should include:

- designed joint width
- actual joint width
- joint depth
- anticipated movement
- movement capability of seal
- surface preparation
- backing medium
- projected life span of joint.

Sealants should be such that there is good adhesion between the sealant and the material either side of the joint.

Back up material should be resilient and should not adhere to, or react with, the sealant.

The compressibility of the sealant back-up/joint filler is possibly the most critical factor in the design of an adequate joint for fired clay brickwork.

A pressure of about 0.1N/mm2 should be sufficient to compress the material to 50% of its original thickness. Flexible cellular polyethylene, cellular polyurethane or foam rubbers are the most satisfactory materials for backing to movement joints in fired clay brickwork.

Hemp, fibreboard, cork and similar materials are suitable for movement joints in concrete, but should not be used for expansion joints in fired clay brickwork.

SITEWORK STANDARDS

4.5 - S1 All sitework shall:
(a) meet the Technical Requirements
(b) take account of the design
(c) follow established good practice and workmanship

Sitework that follows the design and the guidance below will be acceptable for raft, pile, pier and beam foundations.

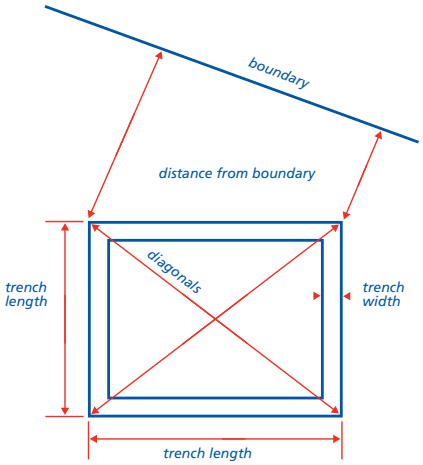
SETTING OUT FOUNDATIONS

4.5 - S2 The setting out of foundations shall take account of the design details

The accuracy of setting out should be checked by control measurements of trenches, including their location relative to site boundaries and adjacent buildings. Levels should be checked against bench marks, where appropriate.

In particular, for excavations check:

- trench lengths
- trench widths
- length of diagonals between external corners.

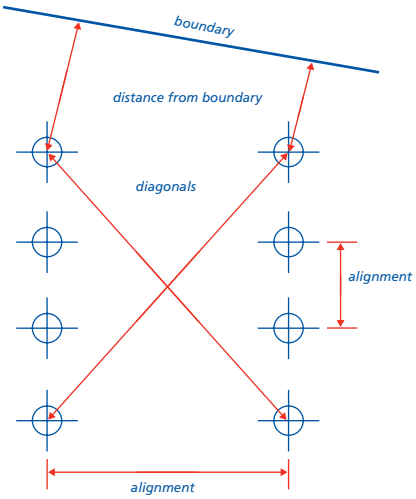


In addition, for piles, pier and beam foundations and ground improvement techniques, check:

- spacing
- alignment
- positions in relation to the proposed superstructure.

Walls should be located centrally on the foundation, unless specifically designed to do otherwise.

Any discrepancy in dimensions, and any ground condition that causes the design to be modified, should be reported formally to the Engineer. Resulting variations should be recorded and distributed to all concerned (including NHBC).



EXCAVATIONS

4.5 - S3 Excavations for foundations shall take account of design dimensions

Excess excavations should be avoided. Inaccuracy may prevent walls and piers being located centrally and therefore result in eccentric loading of foundations, possibly foundation failure.

To avoid damage, foundation excavation should be kept free from water (see Clause S5).

4.5 - S4 Excavations shall take account of localised effects

Where localised changes in strata give rise to differences in bearing capacity, reference should be made to the Engineer to ensure this has been allowed for in the design.

At soft spots, excavations should be deepened locally to a sound bottom or, alternatively, the concrete should be reinforced.

Hard spots should be removed.

Where roots are visible on the sides or bottoms of excavations (especially in clay soils), the Engineer should be consulted and the design depth modified.

Where there are, or have been, trees or hedges, foundation depth should be in accordance with the guidance given in Chapter 4.2 'Building near trees'.

4.5 - S5 Excavation bottoms, when prepared for concreting, shall be compact, reasonably dry and even

Trench bottoms affected by rainwater, ground water or drying should be re-bottomed to form a sound surface.

SERVICES AND DRAINAGE

4.5 - S6 Existing services shall be adequately protected

Any existing services, such as cables, water pipes or gas mains, may need to be supported and protected. Any existing drains should be diverted, or bridged, to prevent any foundation loads being transmitted to them.

Services should not be rigidly encased in concrete, masonry, etc.

Land drains should be diverted to a suitable outfall.

4.5 - S7 Provision shall be made for service entries or services

For relevant details, reference should be made to the Design and Sitework sections of Chapters:
5.1 'Substructure and ground bearing floors',
5.3 'Drainage below ground'
8.1 'Internal services'

Where services pass through foundations, they must not affect the ability of the foundation to carry loads.

Services should be either sleeved or passed through a suitably strengthened opening in the foundation.

In the case of drains, it is important to leave sufficient space for movement, to ensure that the drain is capable of maintaining line and gradient and any movement which may take place.

REINFORCEMENT

4.5 - S8 Reinforcement shall be cut, bent and placed as shown in the design

Reinforcement shall be clean and free from loose rust and should be placed correctly. Bars should be properly supported to ensure that the cover indicated in the design is maintained.

Bars should be secured at laps and crossings.

CONCRETING

4.5 - S9 Concrete shall be correctly mixed, placed and cured

Concreting should be carried out, as far as possible, in one operation, taking account of weather conditions and available daylight. Concrete should be placed as soon as possible after the excavation or, where necessary, after the reinforcement has been checked. Excavation and/or reinforcement may need to be approved by the Engineer or his representative, before concreting commences. In England and Wales, foundations should be approved by the person responsible for the Building Control inspections, before the concrete is placed.

Mixing, placing, testing and curing of concrete should be carried out as indicated in Chapter 2.1 'Concrete and its reinforcement' (each section) and when work is carried out in cold weather, Chapter 1.4 'Cold weather working'.

RAFT FOUNDATIONS

4.5 - S10 Raft and semi-raft foundations shall be constructed in accordance with the design

Raft and semi-raft foundations should be constructed in accordance with Clauses S1 to S9, as appropriate.

PILED FOUNDATIONS

4.5 - S11 Piled foundations shall be constructed in accordance with the design

Items to be taken into account include:

(a) alignment
Piles are to be vertical, unless designed otherwise.

Piles are to be installed by an appropriate specialist under the Engineer's supervision.

(b) load capacity verification
Care should be taken to ensure that the bond of beams to pads and piles is in accordance with the design and is adequate.

Test loading should be undertaken when required.

The Builder is to obtain written confirmation that the piles are suitable for their design load.

If piles are more than 75mm out of position, or out of alignment by more than 1 : 75, the Engineer should reconsider the adequacy of the foundation design.

Unless otherwise recommended by the Engineer, NHBC will expect piles which are misaligned by more than 150mm in any direction, or which are more than 5° from their specified rake, to be replaced, or additional piles to be provided in accordance with design modifications provided by the Engineer.

PIER AND BEAM FOUNDATIONS

4.5 - S12 Pier and beam foundations shall be constructed in accordance with the design

Pier/pad and beam (and reinforced concrete strip) foundations should be constructed to meet Clauses S1 to S9, as appropriate.

Appendix 4.5-A

Guidance for the design of semi-raft foundations on made ground

The following notes are to be used as a guide for Engineers designing raft foundations, but are by no means exhaustive. Special consideration will be required for certain sites.

1 Raft foundations are to be designed by a Chartered Civil or Structural Engineer taking account of ground conditions and the results of the site appraisal and ground assessment.
2 Sufficient internal beams are to be provided to adequately stiffen the slab.
3 The area between downstand beams should not be greater than 35m^2.
4 The ratio of adjacent sides on plan should not exceed 2 : 1.
5 The minimum depth of perimeter and party wall beams is to be 450mm. On larger dwellings some internal beams should be of the same depth as the perimeter beams.
6 Perimeter and internal beams should be sufficiently wide at their base to carry their total loading at the allowable bearing pressure for the site.
7 Beams are to be designed to span 3m simply supported and cantilever 1.5m.
8 Beams are to use properly formed reinforcement in accordance with BS EN 1992-1-1
9 Where mesh is used in beams, it should be delivered to the site pre-bent.
10 All beams should be cast on a minimum of 50mm concrete blinding.
11 Minimum cover to reinforcement should be 40mm.
12 Floor slabs should be a minimum 150mm thick, with nominal top face reinforcement as a minimum and anti-crack reinforcement in the bottom face, if appropriate.
13 Stools or similar should be used to support floor slab mesh during casting.
14 Corners and junctions to beams should be adequately tied using similar reinforcement to the beams.
15 A minimum cavity drain of 225mm below dpc is to be maintained.

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