NHBC Standards

2007

Effective from 1 September 2007

NHBC

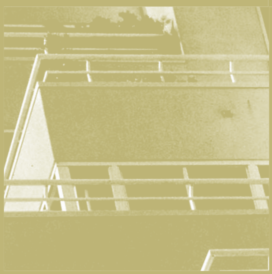
Part 4

Foundations

Part 4 **Foundations**

Chapter 4.1

Land quality - managing ground conditions



4.1 Land quality - managing ground conditions

4.1

CONTENTS

Hazardous sites

Builders are reminded that where a site* is hazardous, NHBC Rules state that, they must notify NHBC in writing at least 8 weeks before work begins.

Failure to provide NHBC with information about hazardous sites may result in a delay in processing the registration, hold up construction work on site and the issue of the 10 year cover.

* Site is defined in NHBC Rules as an area of land which is covered by a single detailed planning consent.

SCOPE

This Chapter gives guidance on meeting the Technical Requirements and recommendations for assessing the site with regard to managing the ground conditions.

Objectives

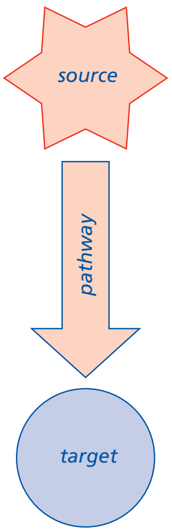
This chapter provides a framework for managing **geotechnical** and **contamination** issues with the objective of ensuring that:

- all sites are properly assessed and investigated
- foundations and substructure designs are suitable for the ground conditions
- sites are properly remediated where necessary or appropriate design precautions are taken, and
- appropriate documentation and validation can be provided to NHBC.

Assessment of geotechnical and contamination issues
Assessment should be carried out by direct investigation and examination of the ground, supplemented where necessary by results of laboratory testing on samples obtained.

Examples of potential hazards and associated risks relating to geotechnical and contamination issues are listed in Appendix 4.1-B.

Additionally, contaminated land should be assessed using the following framework:



a substance or group of substances with the potential to cause significant harm

a route by which a source could reach a target

that which could be significantly harmed by the source

Procedural summary

The processes to assess and manage the ground conditions are:

- illustrated in the **Procedural flowchart**, and
- described in detail in the pages that follow.

Useful references are contained in Appendix 4.1-A.

Initial assessment (Clauses D1 to D3)
NHBC requires **all** sites to be assessed by a **Desk study** and a **Walkover survey**.

The **Results** should be used to determine whether or not hazards are known or suspected.

Basic investigation (Clause D4)
Where hazards are not suspected a **basic investigation** will be required to support the results of the initial assessment.

Detailed investigation (Clause D5)
Where hazards are known or suspected a **detailed investigation** will be required.

Further investigation
Where the results of the basic investigation or detailed investigation are inconclusive, further site investigation will be required.

Where hazards are found (Clause D6)
Where hazards are identified, design precautions or remediation will be required to minimise their effects.

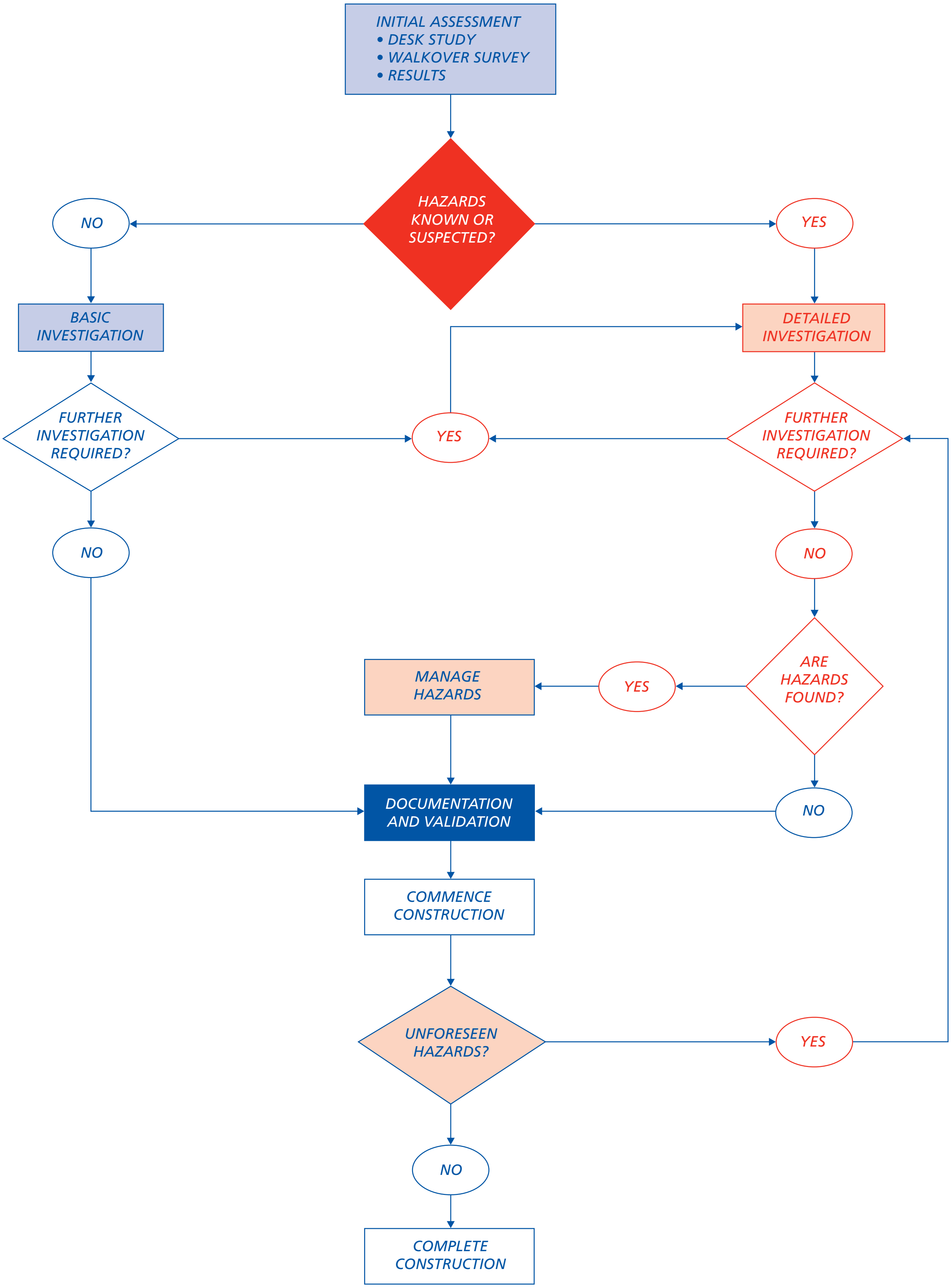
Documentation and validation (Clause D7)
NHBC will require documentation to show that:

- the site has been properly assessed and investigated
- where necessary, suitable precautions are incorporated into the design
- all necessary remediation has been carried out.

Unforeseen hazards (Clause D8)
If any unforeseen hazards are found during the course of construction, further investigation may be required.

4.1

Procedural flowchart



DESIGN STANDARDS

INITIAL ASSESSMENT

DESK STUDY

4.1 - D1 A desk study of the site and the surrounding area shall be undertaken by a suitable person

A desk study is the collection and examination of existing information obtained from a wide variety of sources.

It should indicate any potential hazards at an early stage and provide a basis for the investigation.

A suitable person, as described in Appendix 4.1-D, should carry out the desk study.

Items to be taken into account include:
(a) soils, geology, surface water and ground water
Investigate the soils, geology, surface water and ground water of the site and the surrounding area.

(b) use of the site and surrounding area
Research the current use and history of the site and surrounding area to assess the potential problems including those which may have been left by:
- industrial, commercial and agricultural uses including storage
- mining
- quarrying
- landfilling and tipping.

Some sites may have been associated with more than one process.

(c) sources of information
Refer to key sources of information including:
- the Environment Agency or its equivalent, for example coastal erosion, landfill sites, details of water abstraction
- the Local Authority, for example planning and environmental health
- county records offices, libraries, museums, and local history sources
- the utility companies
- the Coal Authority
  - mining reports - past, present and proposed mining
- the British Geological Survey
  - maps and information
- soil survey maps
- the Ordnance Survey
  - current and previous editions of plans and aerial photographs.

The above list is not exhaustive and local sources may be relevant.

(d) existing site information
Review all available information from:
- the vendor of the site
- previous in-house information
- ongoing monitoring.

INITIAL ASSESSMENT

WALKOVER STUDY

4.1 - D2 A walkover survey of the site and the surrounding area shall be undertaken by a suitable person

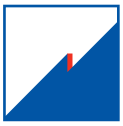
A walkover survey is a direct inspection of the site and the surrounding area carried out in conjunction with the desk study.

Look for indications of any potential hazards to provide a basis for the investigation.

A photographic record of the site can help in the reporting of the walkover survey.

A suitable person, as described in Appendix 4.1-D, should carry out the walkover survey.

Items to be taken into account include:
(a) topography



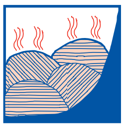
What is the significance of any abrupt changes in slope?

Are there any valley bottoms or depressions which may be soft or filled?

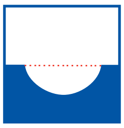
Is there evidence of overburden on slopes?

Is there excavation at the base of a slope?

Are there any signs of landslip, e.g. tilting trees, posts or walls?



Is there evidence of imported soil, tipped material or rubbish? Is it hot? Does it have an odour?



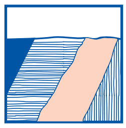
Are there signs of local subsidence?

(b) soils and rocks

What is the basic type of ground?

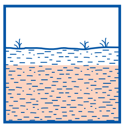
Is there any evidence of peat, silt or other highly compressible material at or below the surface?

Is there cracking or stickiness of the surface which may indicate a shrinkable sub-soil?

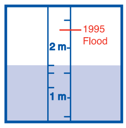


Are there sudden changes in conditions e.g. clay to chalk or soil to rock?

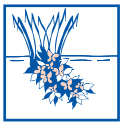
(c) surface water and ground water



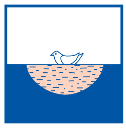
Is a high water table indicated, e.g. by waterlogged ground?



Are there any signs of flooding?



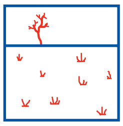
Are there any reeds or water-loving plants?



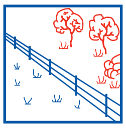
Are there any springs, ponds, wells, ditches or streams?

Is there any discoloured water? What is its source?

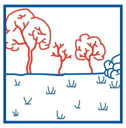
(d) vegetation (which may indicate the nature of the soils)



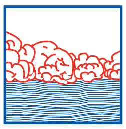
Is the vegetation sparse, dead or dying?



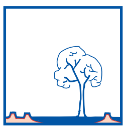
What is the type and condition of vegetation on land adjoining the site?



What are the species, height and condition of the trees?

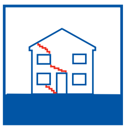


What are the species, height, spread and condition of hedges and scrub on clay?



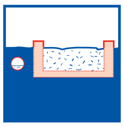
Is there evidence of former trees, hedges or scrub on clay?

(e) structural information



Is there evidence of damage to structures, e.g. cracking in buildings, on or around the site?

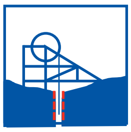
Is there other evidence of movement?



Is there evidence of any structures or services below ground?

(f) local information

Is there local knowledge of the site e.g. mining, refuse tipping, flooding?



Are there local industrial history records indicating past and present uses of the site?

Do local place names and street names give clues e.g. Brickfield Cottage, Water Lane?

INITIAL ASSESSMENT

RESULTS

4.1 - D3 The results of the desk study and walkover survey shall be recorded and evaluated by a suitable person

A suitable person, as described in Appendix 4.1-D, should record the results of the initial assessment and evaluate whether hazards are suspected.

The record should include the following as appropriate:

- site plans with dates, showing:
  - previous uses of the site
  - current uses of the site
  - the proposed site layout
- details of the geology of the site from:
  - geological maps
  - previous site investigations
  - laboratory test results
- photographs of the site to show particular points of interest or concern, (e.g. areas of ground instability), with dates
- copies and interpretation of aerial photographs, with dates
- a list of sources of information consulted (e.g. Environment Agency, Coal Authority, etc.) and copies of the information obtained.

Sites where hazards are not suspected

BASIC INVESTIGATION

4.1 - D4 A basic investigation of the site shall be carried out and recorded by a suitable person to the satisfaction of NHBC

Where the results of the initial assessment indicate that hazards are not suspected on the site, this should be substantiated by carrying out a **basic investigation**.

This approach is to provide assurance for all sites, regardless of how free of hazards they may appear.

Only suitable persons with the skills and knowledge described in Appendix 4.1-D should carry out the basic investigation.

The following provides a specification for the basic investigation for all sites.

Trial pits should be located so as to be representative of the site. (For more detailed information refer to BS 5930.)

The number and depth of trial pits needed depends upon:

- the proposed development
- how inconsistent the soil and geology is across the site
- the nature of the site.

The depth of the trial pits should not usually be less than 3m.

Items to be taken into account include:

(a) geotechnical investigation
(see Appendix 4.1-C)

A basic geotechnical investigation should be carried out. This will include trial pits and, where they do not provide sufficient information, boreholes will be necessary.

Physical tests, such as plasticity index tests, should be carried out as appropriate to support the results of the initial assessment.

Trial pits should be located outside the likely foundation area. The distance from the edge of the foundation should not be less than the trial pit depth.

(b) contamination investigation
(see Appendix 4.1-C)

A basic contamination investigation should be carried out as part of the basic geotechnical investigation. This should consist of sampling and testing of soil taken from trial pits during the geotechnical investigation, as found to be necessary from the outcome of the initial assessment.

During the excavation of the trial pits the use of sight and smell may help to identify certain contaminants.

Where there is any doubt about the condition of the ground a detailed investigation should be carried out (see 4.1 - D5).

FURTHER INVESTIGATION
If the basic investigation reveals the presence of geotechnical and/or contamination hazards further assessment is required and a **detailed investigation** should be carried out (see Clause D5).

Now refer to Clause D7, Documentation and Validation.

Sites where hazards are suspected

DETAILED INVESTIGATION

4.1 - D5 Where hazards are suspected a detailed investigation of the site shall be carried out, under the supervision of a consultant or specialist acceptable to NHBC, to determine and report on the nature and extent of all hazardous ground conditions

A **detailed investigation** should be carried out where:

- hazards are suspected from the outset
- the initial assessment identified hazards, or
- the basic investigation identified hazards.

The basic (geotechnical and contamination) investigation should form the minimum requirement for any site investigation.

In addition to the basic investigation, the detailed investigation should:

- adopt a structured and staged approach
- gather information based on clearly defined stages of investigation
- consider the immediate site and the adjacent area
- take into account the possibility of future development in the vicinity of the site
- consider the nature of the development
- consider the complexity of the ground conditions
- consider the presence of soil gas; if there is any possibility of gas being present, then a full gas investigation should be carried out, which should include flow measurements
- provide a clear understanding of the problems, and an understanding of the liabilities, which have to be managed in order to develop the site
- consider:
  - the surface water and groundwater conditions
  - the soils and geology, and
  - the previous site history.

A consultant or specialist acceptable to NHBC should be appointed to:

- design and supervise the detailed investigation
- present all the factual data obtained from the detailed investigation.

Guidance for the appointment of a consultant or specialist is given in Appendix 4.1-D.

MANAGING THE HAZARDS

4.1 - D6 Any hazardous ground conditions shall be satisfactorily managed under the supervision of a consultant or specialist acceptable to NHBC

As appropriate, the consultant or specialist acceptable to NHBC should:

- identify any results which show that design precautions and/or remediation may be necessary
- carry out a risk assessment to determine appropriate design precautions and/or remedial treatment
- specify the options for remediating any contamination that may be present and provide a remediation statement
- make recommendations as to appropriate design precautions including any ground improvement techniques as necessary
- make recommendations on appropriate precautions for all underground services serving the site
- ensure the works are appropriately supervised
- produce a remediation report.

Items to be taken into account include:

DESIGN CONSIDERATIONS

(a) design precautions

Solutions for dealing with geotechnical hazards include the following:

- specialist foundations:
  - piling and ground beams
  - rafts
- ground improvement techniques:
  - vibro
  - dynamic compaction
  - surcharging.

(b) remediation techniques

Solutions for dealing with contamination hazards include the following:

- risk avoidance - treatment to reduce the risk to the target by changing pathway or isolating the target by:
  - changing layout
  - building protective measures into construction
- engineering based - treatment to remove or isolate the contaminants or modify the pathway by:
  - excavation
  - providing ground barriers
  - covering and capping
- process based - treatment to remove, modify, stabilise or destroy the contaminants by:
  - physical means
  - biological means
  - chemical means
  - thermal means.

(c) site location

The identification of any constraints associated with the site and surrounding area which could restrict design precautions or remediation techniques should be identified and specified.

(d) timescale

Time constraints may influence the solution chosen since some techniques are very time consuming. This should not alter the requirement for effective remediation.

(e) consultation

In order to avoid abortive works it is important that the requirements of all statutory authorities are met by the proposed solution for the site.

REMEDIATION

(f) method statement

The method statement should detail the proposed remediation strategy for the site.

The statement should include the following details:

- original risk assessment, identification of the remediation objectives and outline information of the method chosen
- remediation objectives for ground, groundwater and soil gas
- working method for implementation of the remediation
- waste classification and methods for controlling and disposing of waste
- proposed supervision and monitoring of remediation
- all validation sampling and testing to be implemented.

(g) reports

The report should include the following information:

- photographic records, especially for work which will be buried (e.g. membranes)
- site diaries or drawings, environmental supervisor's site diary, and independent witness statements where appropriate
- accurate surveys of the levels and position of all remediated areas
- a description of any remedial materials used
- details of soil movements and waste transfer notes
- results of post-remediation sampling; laboratory certificates should be provided in appendices
- validation test results
- monitoring results
- details of all consultations and meetings with statutory authorities.

Now refer to Clause D7, Documentation and Validation.

All sites

DOCUMENTATION AND VALIDATION

4.1 - D7 Documentation and validation shall be provided to the satisfaction of NHBC that the site is suitable for the proposed development

Items to be taken into account include:

(a) geotechnical assessment

WHERE GEOTECHNICAL HAZARDS ARE PRESENT

NHBC should be provided with design proposals to overcome the hazards.

(b) contamination assessment

WHERE CONTAMINATION HAZARDS ARE NOT PRESENT

Evidence to substantiate that the site is not suspected to be hazardous may be asked for.

WHERE CONTAMINATION HAZARDS ARE PRESENT

NHBC should be provided with design proposals to overcome the hazards.

Radon gas

Where the site is within an area susceptible to radon it will be necessary to follow appropriate guidance in Building Regulations and associated documents.

The following table indicates the documentation required by NHBC.

Documentation required by NHBC				
	No geotechnical or contamination hazards present	Geotechnical hazards present (but no contamination hazards)	Contamination hazards present (but no geotechnical hazards)	Geotechnical and contamination hazards present
Initial assessment and basic investigation	✓	✓	✓	✓
Detailed investigation results		✓	✓	✓
Proposals to manage geotechnical hazards		✓		✓
Proposals to manage contamination			✓	✓

UNFORESEEN HAZARDS

4.1 - D8 Where any additional or unforeseen ground conditions are found during construction, the builder shall ensure that they are investigated and managed to the satisfaction of NHBC

As construction proceeds, additional or unforeseen hazards may be found. For example, it is possible to have undetected hazards which are missed by the site investigation.

Where additional or unforeseen hazards are found additional specialist advice is required so that the hazard is properly investigated, managed and validated.

APPENDIX 4.1-A

References

BRE:
- Report BR211 - 'Radon: Guidance on protective measures for new dwellings'
- Report BR212 - 'Construction of new buildings on gas-contaminated land'
- Report BR376 - 'Radon: guidance on protective measures for new dwellings in Scotland'
- Report BR413 - 'Radon: guidance on protective measures for new dwellings in Northern Ireland'
- Report BR414 - 'Protective measures for housing on gas-contaminated land'
- Digest 383 - 'Site investigation for low-rise buildings: Soil description'
- Special Digest 1 - 'Concrete in aggressive ground'

BSI:
- BS 5930 - Code of practice for site investigations
- BS 10175 - Investigation of potentially contaminated sites - Code of practice

CIRIA:
- Special publications 101 - 112 - Remedial treatment for contaminated land

DEFRA (Department for Environment, Food & Rural Affairs), its predecessor departments and the EA (Environment Agency):
- CLR Reports and CLEA (Contaminated Land Exposure Assessment) guidance, Software, Soil Guideline Values and Toxicological Reports
- Industry Profiles - information on the processes, materials and wastes associated with individual industries
- Waste Management Paper No 27 - The Control of Landfill Gas
- EA/NHBC R&D Publication 66 - Guidance for the safe Development of Housing on Land Affected by Contamination.

APPENDIX 4.1-B

Examples of potential hazards and associated risks

Potential hazard	Associated risk
High water table or low lying land	Flooding. Effects from sulfates or toxic or noxious materials which could be concentrated or transported by ground water.
Mining, past, present and proposed	Ground movement which will depend on the type of workings and materials extracted. Existence of methane and carbon dioxide.
Solution features in chalk and limestone including swallow holes	Underground cavities.
Trees	Shrinkage and heave of clay soils. See Technical Requirement R5. Physical damage caused by roots.
Peat	Acid attack. Changes in volume due to variations in moisture content. Production of methane and carbon dioxide.
Low bearing capacity ground	Settlement of foundations and sub-structures.
Infill and made ground including tipping	Release of gases which may be explosive or asphyxiating. Low bearing capacity causing settlement.
Former buildings or structures	Underground obstructions producing variations in bearing capacity and settlement characteristics.
Adjacent buildings	Effect on stability of both the new and existing buildings.
Existing drains, including land drains	Contamination, flooding, waterlogging and interruption of land drainage systems.
Sulfates in ground or ground water	Expansive reaction. Chemical attack on concrete, mortar and bricks or blocks made with cement.
Unstable ground subject to landslip	Ground movement.
Seas, lakes and rivers adjacent to land	Erosion.
Contamination	Substances which may be: • carcinogenic • toxic • asphyxiating • corrosive • phytotoxic • combustive • explosive • radioactive.

APPENDIX 4.1-C

Site investigation techniques

(In accordance with the recommendations of BS 5930 Site Investigations)

Site investigation normally comprises a combination of the following:

Direct investigation

These techniques involve actual examination of the ground using the following methods of investigation:

a) trial pits
Trial pits allow the detailed inspection, logging, sampling and in-situ testing of large volumes of natural soil or fill and the assessment of ground water conditions.

b) trenches
Trenches are extended trial pits or linked trial pits which are excavated where greater exposure of the ground conditions is required.

Trial pits and trenches should be positioned where they will not affect future foundations.

c) boreholes

- Shell and auger
  The conventional equipment used in the UK to drill boreholes in soils and weak rocks is the light cable percussion rig, often referred to as the shell and auger rig.
- Continuous flight auger
  Exploratory boreholes may also be drilled in soils by mechanical continuous flight augers of various sizes.
- Rotary drilling
  Rotary drilling is used to investigate rock and sometimes stiff soils such as Boulder Clay. The two basic rotary methods are open-hole drilling and rotary coring.

d) probes
Probing techniques can be used for the analysis of the relative density of soils and also for environmental sampling and monitoring (such as chemical and physical testing of gases, liquids and solids).

Indirect investigation

Geophysical techniques (for example, electromagnetic, resistivity, seismic, gravity and ground radar) provide indirect interpretations of ground conditions. These measure from the surface, variations in properties of the ground both horizontally and vertically and hence attempt to define subsurface conditions.

Geophysical methods rely for their effectiveness on marked contrasts in the physical properties being measured. The required contrasts are provided by boundaries between distinctive strata with different properties (for example, between sand and gravel and rockhead). Definable contrasts may also be provided by faulting, underground cables and pipelines or by cavities.

Sampling

The number and type of samples taken and tests which are carried out for any particular investigation are designed to be appropriate to the range of ground materials encountered and to the development which is planned. This is based on the results of the desk study, the walkover survey and the site investigation.

Samples should always be taken, stored and transported carefully to avoid cross contamination.

Samples can be taken of:

a) soils and rocks
Samples from trial pits and boreholes are taken to enable soil and rock descriptions to be made and to provide material for physical and chemical testing.

Samples of soils may be either 'disturbed' (that is, not retaining the original structure and consistency) or 'undisturbed'. Having undergone minimal disturbance, it follows that 'undisturbed' samples provide a more reliable indication of physical soil properties than 'disturbed' samples.

b) groundwater
Samples of groundwater are taken from trial pits, trenches and boreholes for chemical testing.

c) gas
Gas sampling may be carried out in boreholes, from standpipes which have been installed in trial pits or boreholes or from spike-holes which have been driven into the ground.

Testing

a) in-situ testing
A wide variety of in-situ tests can be used to support the results of direct testing. These range from basic tests undertaken by geologists or engineers using simple hand-held devices to elaborate methods that require specialist personnel and equipment.

b) laboratory testing
It is important that testing is undertaken using quality assured procedures by laboratories which are UKAS accredited for these tests.

Physical tests on soil and rock materials are carried out to provide the following information on ground:

- strength
- relative density
- deformation
- settlement
- consolidation characteristics
- permeability.

Chemical tests on soils, rocks, groundwater and gases can be carried out to provide an indication of potential contamination on the site.

APPENDIX 4.1-D

"Suitable persons" and "consultants or specialists"

SUITABLE PERSONS

The following skills and knowledge are required by the person responsible for the Initial Assessment (Clause D3), Basic Investigation (Clause D4) and Documentation and Validation (Clause D7):

- be able to carry out a desk study and walkover survey
- understand the hazards that can affect the development and know from where they originate
- know how to collect information relating to such hazards on and adjacent to the site
- be able to recognise the signs of potential hazards
- be able to determine when specialist advice and detailed testing is required, and
- be able to report the findings in a clear and concise manner.

CONSULTANTS OR SPECIALISTS

The following criteria should be used as guidance for the appointment of a consultant or specialist responsible for the Detailed Investigation (Clause D5), management of hazards (Clause D6) and Documentation and Validation (Clause D7):

Experience	has experience with similar types of site and development
Appropriate discipline(s)	a thorough understanding of all the relevant skills required on the project and has access to the skills of other disciplines including chemists, geologists, hydrogeologists and environmental chemists
Project management	ability to manage a project team consisting of the appropriate disciplines
Communication	able to communicate effectively within their organisation, with the client, statutory authorities and the general public
Reporting	can prepare comprehensive and well presented reports
Legislation	understands the legislation and liabilities associated with the area of the United Kingdom in which the development is being carried out
Quality assurance	has an appropriate quality management system and uses appropriately accredited laboratories
Risk management	can carry out risk assessments as part of the risk management process
Site investigation	can design site investigation programmes which include soil sampling, testing and laboratory analysis
Health and safety	is fully aware of all occupational hygiene issues and health and safety legislation
Engineering design	understands effective risk reduction techniques e.g. engineered foundations and sub-structure details or suitable remediation
Professional indemnity insurance	has, and maintains, appropriate Professional Indemnity Insurance for the work being carried out.

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Part 4 Foundations

Chapter 4.2

Building near trees

4.2 Building near trees

CONTENTS

SCOPE

This Chapter gives guidance on meeting the Technical Requirements and recommendations when building near trees, hedgerows and shrubs, particularly in shrinkable soils.

INTRODUCTION

The combination of shrinkable soils and trees, hedgerows or shrubs represents a hazard to structures that requires special consideration. Trees, hedgerows and shrubs take moisture from the ground and, in cohesive soils such as clay, this can cause significant volume changes resulting in ground movement. This has the potential to affect foundations and damage the supported structure. In order to minimise this risk, foundations should be designed to accommodate the movement or be taken to a depth where the likelihood of damaging movement is low.

This Chapter gives guidance for common foundation types to deal with the hazard and includes suitable foundation depths which have been established from field data, research, NHBC data and practical experience. The depths are not those at which root activity, desiccation and ground movement are non existent but they are intended to provide an acceptable level of risk. However, if significant quantities of roots are unexpectedly encountered in the base of the trench, the excavation may need to be deepened.

The interaction between trees, soil and buildings is dependent on many factors and is inherently complex. The relationship becomes less predictable as factors combine to produce extreme conditions. These are signified by the need for deeper foundations. Depths greater than 2.5m indicate that conditions exist where prescriptive guidance is less reliable.

The following situations are beyond the scope of the guidance in this Chapter and will require a site specific assessment by an Engineer (see Technical Requirement R5):

- foundations with depths greater than 2.5m within the influence of trees
- ground with a slope of greater than 1 in 7 (approximately 8°) and man made slopes such as embankments and cuttings
- underpinning.

Consideration has been given to the potential effects of climate change in the guidance provided.

The services of a specialist arboriculturalist may be helpful for the identification of the type and condition of trees that may affect building work. This includes trees both on and adjacent to the site.

DESIGN STANDARDS

4.2 - D1 Design shall meet the Technical Requirements

Design that follows the guidance below will be acceptable for building near trees, hedgerows and shrubs.

STATUTORY REQUIREMENTS

4.2 - D2 Design shall comply with all relevant statutory requirements

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

TREES AND HEDGEROWS ADJACENT TO STRUCTURES

4.2 - D3 The design shall take account of trees and hedgerows and their growth

Items to be taken into account include:

(a) removal of existing trees and hedgerows

Dead trees and dead hedgerows should be removed. Unstable trees should be made stable but where this is not possible they should be felled. If in doubt, advice should be obtained from a Registered Arboriculturalist.

Acts of Parliament, planning conditions, conservation area restrictions or tree preservation orders may mean that trees and hedgerows are protected and must be retained. The local planning authority should be consulted.

(b) protection of remaining trees and hedgerows

Most of a tree's root system is within 600mm of the surface and extends radially for distances often in excess of the tree's height. All parts of the root system are vulnerable to damage and once damaged, roots may not regenerate. Extensive root damage may impair the stability of the tree.

Root damage and tree instability can be caused by:

- stripping topsoil too close to trees
- excavating trenches for foundations and services too close to trees
- raising soil levels adjacent to trees, particularly where non-granular materials are used
- compaction of soil around trees by heavy plant
- storage of heavy materials around trees
- covering rooting area with impervious surfaces.

Trees should be protected from damage by:

- a fence or barrier. The fence or barrier should extend around a single trunk equivalent to a circle of radius 12 times the trunk diameter measured 1.5m above ground level. The shape of this area may change depending on specific factors such as local drainage, soil type, age and species of the tree. An arboriculturist may be required to assess these factors
- ensuring services are not routed close to trees or, where this is impractical, are installed in such a way as to minimise root damage.

Further guidance is given in BS 5837.

(c) allowance for physical growth of young trees

Direct damage due to the growth of the main trunk and roots of young trees should be avoided by locating structures and services at a safe distance from the trees. Further guidance is given in BS 5837. Where this cannot be achieved precautions should be taken to allow for future growth. For example:

- foundations should be reinforced to resist lateral forces
- walls or structural slabs should bridge over the roots allowing sufficient clearance for future growth or be reinforced to avoid cracking
- pavings and other surfaces should be laid on a flexible base to allow for some movement.

FOUNDATIONS (all soil types)

4.2 - D4 Foundations for all soil types shall be designed to transmit loads to the ground safely and without excessive movement

Foundations for all soil types should be designed and constructed in accordance with Chapter 4.1 'Land quality - managing ground conditions' and other relevant Chapters of the Standards (depending on site specific conditions).

Different foundation types should not be used to support the same structure unless the foundations and superstructure design are undertaken by an Engineer (see Technical Requirement R5).

The remainder of this Chapter gives additional guidance that applies when building near trees, hedgerows and shrubs on shrinkable soils as defined in Clause D5(b).

FOUNDATIONS (shrinkable soils)

4.2 - D5 The design shall make allowance for the effect of trees and hedgerows on shrinkable soils

Items to be taken into account include:

(a) shrinkage and heave

Shrinkable soils are subject to changes in volume as their moisture content is altered. Soil moisture contents vary seasonally and are influenced by a number of factors including the action of tree roots. The resulting shrinkage or swelling of the soil can cause subsidence or heave damage to foundations, the structures they support and services. Heave precautions are described in Clause D8.

Shrinkable soils are widely distributed throughout the UK. Local geological survey maps may give relevant information.

(b) soil classification

For the purposes of this Chapter, shrinkable soils are those containing more than 35% fine particles and having a modified Plasticity Index of 10% or greater.

Fine particles are defined as those having a nominal diameter less than 60μm, ie. clay and silt particles.

The Plasticity Index (Ip) of a soil is a measure of its volume change potential and is determined by Atterberg Limits tests. These tests are carried out on the fine particles and any medium and fine sand particles. Soil particles with a nominal diameter greater than 425μm are removed by sieving beforehand. The percentage of particles smaller than 425μm is routinely reported for Atterberg Limits tests. This is a requirement of BS 1377, which specifies the test procedure.

The Modified Plasticity Index (I'p) is defined as the Plasticity Index (Ip) of the soil multiplied by the percentage of particles less than 425μm.

i.e. $I'p = Ip \times \frac{\%\text{ less than } 425\mu m}{100\%}$

Modified Plasticity Index is related to volume change potential as shown in Table 1.

Table 1 Volume change potential

Modified Plasticity Index	Volume change potential
40% and greater	High
20% to less than 40%	Medium
10% to less than 20%	Low

Alternatively the Plasticity Index may be used without modification. For pure clays and other soils with 100% of particles less than 425μm the result will be the same. However, for mixed soils such as glacial tills, use of the modified Plasticity Index may result in a more economic design.

For further information about the modified Plasticity Index refer to BRE Digest 240.

The volume change potential should be established from site investigation and reliable local knowledge of the geology.

Sufficient samples should be taken to provide confidence that the test results are representative of the soil volume change potential for the site. If in doubt use the higher value of volume change potential.

If the volume change potential is unknown, high volume change potential should be assumed.

(c) water demand of trees

Water demand varies according to tree species and size.

Appendix 4.2-A gives the water demand categories of common tree species.

Where the species of a tree has not been identified, high water demand should be assumed.

Where the species of a tree has been identified but is not listed, the following assumptions may be made for broad leafed trees:

- high water demand - all Elms, Eucalyptus, Hawthorn, Oaks, Poplars and Willows
- moderate water demand - all others.

Where trees are not listed in Appendix 4.2-A, information may be obtained from suitable alternative authoritative sources (see Appendix 4.2-E).

Tree identification can be assisted by reference to a tree recognition book (see Appendix 4.2-E).

For the purposes of this Chapter, the zone (i.e. lateral extent) of influence of trees is shown in Table 2.

Table 2 Zone of tree influence

Water demand	Zone of influence
High	1.25 x mature height
Moderate	0.75 x mature height
Low	0.5 x mature height

(d) tree heights

Mature heights of common tree species are listed in Appendix 4.2-A. For the purposes of this Chapter, these are the average mature heights to which healthy trees of the species may be expected to grow in favourable ground and environmental conditions. These may be used even when the actual heights are greater.

The mature heights given in Appendix 4.2-A should be used for trees that are to remain or are scheduled to be planted and where ground levels are unaltered. Where ground levels are increased see also Figure 1 and Sitework clause S3(c).

Where there are different species within hedgerows, the mature height of the species likely to have the greatest effect should be used.

For trees which have been or are to be removed, allowance should be made for the fact that the water demand of a tree varies with its size and rate of growth (see Figure 1). The water demand of a semi-mature tree may be as great as that for a mature tree of the same species whereas the water demand for a sapling or young tree will be significantly less.

Figure 1 Tree height H to be used for particular design cases

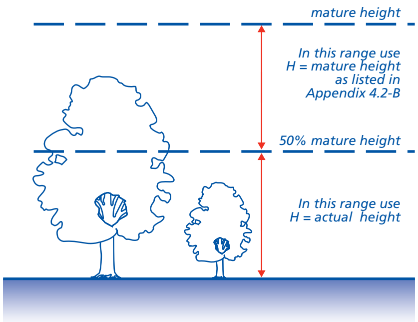


Figure 1 should be used when:
- *deriving foundation depths when trees have been removed (use tree height at time of removal - see Design clause 4.2 - D5(a))*
- *checking the appropriate level from which depths should be measured when trees remain and ground levels are increased (use tree height at time of construction relative to original ground level - see Figure 5)*
- *determining whether heave precautions should be provided (use tree height at time of construction - see Design clause 4.2 - D8(b) and (c)).*

Where trees have undergone or are to undergo heavy crown reduction or pollarding, the mature height should be used or a Registered Arboriculturalist should be consulted to undertake a site specific assessment.

(e) climate

High rainfall reduces moisture deficits caused by trees and hedgerows, and cool damp weather reduces the rate of water loss from the tree, thus reducing the risk of soil movement. As the driest and hottest conditions in the UK usually prevail in southeast England, the greater risk occurs in that area and diminishes with distance north and west.

For the purposes of this Chapter, the UK has been divided into zones at 50 mile intervals from London. After the foundation depth has been derived from Appendix 4.2-B or 4.2-C a reduction of 0.05m (50mm) may be made for every 50 miles distance north and west of London (see Appendix 4.2-D).

4.2 - D6 Foundations shall be capable of accommodating the effects of trees and hedgerows on shrinkable soils without excessive movement

Items to be taken into account include:

(a) foundations

Foundations to all permanent structures (including garages, porches and conservatories) should take account of the effects of soil desiccation caused by previous or existing trees and trees which are scheduled to be planted.

The following foundations will be acceptable in shrinkable soils, provided that they are capable of supporting the applied loads without undue settlement, heave precautions are taken as in Clause D8 and their design takes account of Clause D7:

- strip
- trench fill
- pier and beam
- pile and beam
- raft.

Variations to the foundation depths derived from this Chapter may be permitted where other foundation depths are traditionally acceptable or where necessary to take account of local ground conditions, provided that they can be supported by a design in accordance with Technical Requirement R5.

Root barriers are not a reliable means of reducing the effects of trees on foundations in shrinkable soils and are not an acceptable alternative to the guidance given in this Chapter.

Freestanding masonry walls should be constructed on foundations in accordance with this Chapter or be designed to accommodate likely ground movement, for example, by careful use of movement joints and reinforcement.

(b) method of assessment of foundation depths

One of the following methods may be used:

- design in accordance with this Chapter to a depth derived from Appendix 4.2-B or 4.2-C taking account of:
  - the site investigation
  - the soil volume change potential
  - the water demand of the tree
  - the appropriate tree height
  - the distance of the tree(s) from the foundations
  - the geographical location of the site north and west of London
  - appropriate heave precautions.

Note: the most onerous conditions should be assumed in the absence of any of the above information.

- design by an Engineer in accordance with Technical Requirement R5, taking account of:
  - the recommendations of this Chapter
  - results of the site investigation
  - advice, when necessary, from a Registered Arboriculturalist or other competent person whose qualifications are acceptable to NHBC.

Note: when this method is used and it results in foundation depths or other details less onerous than those derived from this Chapter, the design should be submitted to NHBC for approval prior to work commencing on site.

(c) distance between tree and foundation

The distance D between the centre of the trunk and the nearest face of the foundation should be used to derive the foundation depths from Appendix 4.2-B or 4.2-C.

For trees which have been or are to be removed from within 2m of the face of the proposed foundation and where the height on removal is less than 50% of the mature height given in Appendix 4.2-A, it may be assumed that D = 2m.

Note: This is to avoid the anomalous situation where, for example, a "sapling" removed from the foundation line would otherwise require an unnecessarily deep foundation since the D/H value would always be zero regardless of the height H of the tree.

(d) foundation depths related to proposed tree planting

Foundation depths relating to proposed tree planting should be based on one of the following:

- foundation depths derived in accordance with Appendix 4.2-B or 4.2-C, or
- foundation depths shown in Table 3 with limits agreed in the planting schedules to exclude trees within the distances from foundations shown in Table 4, or
- foundation depths shown in Table 5 with limits agreed in the planting schedules to exclude trees within the zone of influence shown in Table 2.

Table 3 Minimum foundations depths allowing for restricted new planting

Volume change potential	Minimum depth [m]
High	1.5
Medium	1.25
Low	1.0

Table 4 No tree planting zone for minimum depth foundations

Water demand	No tree planting zone
High	1.0 x mature height
Moderate	0.5 x mature height
Low	0.2 x mature height

Table 5 Minimum foundations depths outside zone of influence

Volume change potential	Minimum depth [m]
High	1.0
Medium	0.9
Low	0.75

Planting schedules should be agreed with the local planning authority before work commences on site.

The landscape and foundation designs should be compatible.

(e) foundation depths related to new shrub planting

Shrubs have considerable potential to cause changes in soil moisture content.

The foundation design should consider shrub planting as follows:

- Shrubs whose mature height does not exceed 1.8m and climbing varieties (i.e. those requiring a wall for support) whose mature height does not exceed 5m:
  - use foundation depth from Table 5
- Pyracantha and Cotoneaster whose mature height exceeds 1.8m:
  - use foundation depth from Table 5 and plant at least 1.0 x mature height from foundation, or
  - use foundation depth from Table 3 and plant at least 0.5 x mature height from foundation
- All others:
  - use foundation depth from Table 5 and plant at least 0.75 x mature height from foundation, or
  - use foundation depth from Table 3 - no restriction on minimum distance from foundation.

Planting schedules should be produced by a qualified landscape architect or other suitably qualified person and agreed with the local planning authority before work commences on site.

The landscape and foundation designs should be compatible.

Table 6 - removed April 2005

(f) strip or trench fill foundations in non shrinkable soils overlying shrinkable soil

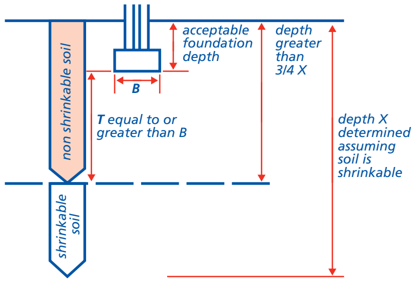
Non shrinkable soils such as sands and gravels may overlie shrinkable soil.

Foundations may be constructed on the overlying non shrinkable soil in accordance with Chapter 4.4 'Strip and trench fill foundations' provided all of the following conditions are satisfied, as illustrated in Figure 2:

- consistent soil conditions exist across each plot. This should be confirmed by the site investigation
- the depth of the non shrinkable soil is greater than 3/4 depth X, where X is the foundation depth determined using Appendix 4.2-B or 4.2-C, assuming that all the soil is shrinkable
- the thickness T of non shrinkable soil below the foundation is equal to or greater than the width of the foundation B
- the proposals are submitted to and approved by NHBC prior to work commencing on site.

Where any of the above conditions is not met, foundation depths should be determined as for shrinkable soil.

Figure 2 Foundations in non shrinkable soils overlying shrinkable soil



(g) stepped foundations

Where foundations are to be stepped to take account of the influence of trees, hedgerows and shrubs they should be stepped gradually in accordance with Chapter 4.4 'Strip and trench fill foundations' with no step exceeding 0.5m (see Sitework clause S3(b)).

(h) foundations on or near sloping ground

Where the foundations are on or adjacent to sloping ground greater than 1 in 7 (approximately 8°) and man-made slopes such as embankments and cuttings they should be designed by an Engineer (see Technical Requirement R5).

Items to be taken into account include:

- slope stability
- potentially enhanced desiccation due to increased run-off and the de-watering effects of the slope and vegetation.

4.2 - D7 Foundations in shrinkable soils shall be designed to transmit loads to the ground safely and without excessive movement

Items to be taken into account include:

(a) strip foundations

Strip foundations up to 1.5m deep should be constructed in accordance with the recommendations of this Chapter and Chapter 4.4 'Strip and trench fill foundations'. Depths should be determined in accordance with Clause D6.

(b) trench fill foundations

Trench fill foundations up to 2.5m deep should be constructed in accordance with the recommendations of this Chapter and Chapter 4.4 'Strip and trench fill foundations'. Depths should be determined in accordance with Clause D6.

Reference should be made to Clause D8 to establish the precautions necessary to cater for potential heave.

Trench fill foundations deeper than 2.5m will only be acceptable if they are designed by an Engineer (see Technical Requirement R5) taking account of all potential movement of the soil on the foundations and substructure.

The following will need to be taken into account if foundations are to be deeper than 2.5m:

- foundation depths should be designed taking account of soil desiccation and arboricultural advice
- additional heave precautions may be necessary to cater for lateral and shear forces acting on large vertical areas of foundation
- instability of the trench sides can lead to serious construction difficulties
- the foundation is dependent upon a high level of workmanship and detailing:
  - concrete overspill or overbreak in the excavations can result in additional vertical forces being transmitted to the foundation
  - construction joints will need to be detailed to take account of the increased lateral forces
  - compressible material should be correctly placed to avoid excessive heave forces being applied to the foundation.

(c) pier and beam foundations
Pier and beam foundations should be designed by an Engineer (see Technical Requirement R5) and constructed in accordance with the recommendations of this Chapter and Chapter 4.5 'Raft, pile, pier and beam foundations'.

Note: pier depths up to 2.5m may be derived from Clause D6. Pier depths greater than 2.5m require site specific assessment.

Reference should be made to Clause D8 to establish the precautions necessary to cater for potential heave.

(d) pile and beam foundations
Pile and beam foundations should be designed by an Engineer (see Technical Requirement R5) and constructed in accordance with the recommendations of this Chapter and Chapter 4.5 'Raft, pile, pier and beam foundations'.

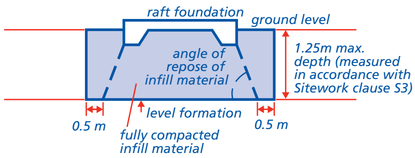
Reference should be made to Clause D8 to establish the precautions necessary to cater for potential heave.

(e) raft foundations
Raft foundations should be designed by an Engineer (see Technical Requirement R5) and constructed in accordance with the recommendations of this Chapter, Chapter 4.5 'Raft, pile, pier and beam foundations' and the following conditions.

Raft foundations will only be acceptable where all of the following apply, as illustrated in Figure 3:

- the foundation depth derived in accordance with Clause D6 is 2.5m or less
- the raft is founded on granular infill placed and fully compacted in layers in accordance with the Engineer's specification and to NHBC's satisfaction. The infill should not be less than 50% of the foundation depth derived in accordance with Clause D6 and should not exceed 1.25m. Site inspections by the Engineer may be required by NHBC to verify the compaction of the fill
- the infill extends beyond the edge of the foundation by a distance equal to the natural angle of repose of the infill plus 0.5m
- the raft is generally rectangular in plan with a side ratio of not more than 2:1
- NHBC is satisfied that the raft is sufficiently stiff to resist differential movements.

Figure 3 Requirements for raft foundations on shrinkable soils



DESIGNING TO ACCOMMODATE HEAVE

4.2 - D8 Foundations, substructure and services shall incorporate adequate precautions to prevent excessive movement due to heave

Heave can take place in a shrinkable soil when it takes up moisture and swells after the felling or removal of trees and hedgerows. It can also occur beneath a building if roots are severed or if water enters the ground from leaking drains, water services or changes in ground water conditions.

Items to be taken into account include:
(a) vegetation survey
Before the site is cleared, the location, heights and species of trees, hedgerows and shrubs on and adjacent to the site and which may affect proposed foundations should be surveyed and recorded.

If the location of previously removed vegetation is not known, local enquiries and reference to aerial photographs may be necessary. Otherwise the design should assume the worst conditions or an Engineer (see Technical Requirement R5) should be consulted to undertake a site specific design based on all relevant information.

Where root growth is noted within shrinkable soil and where records are not available, an Engineer (see Technical Requirement R5) should be consulted to assess whether heave is likely.

(b) heave precautions for trench fill foundations
Trench fill foundations should be designed in accordance with Clause D7. Any foundations deeper than 2.5m should be designed by an Engineer (see Technical Requirement R5).

Heave precautions should be used:

- where the foundation is within the zone of influence of trees (see Table 2), and
- where the foundation depth determined in accordance with Clause D6 is greater than 1.5m based on the appropriate tree height (see Figure 1).

Heave precautions for trench fill foundations up to 2.5m should be in accordance with Sitework clause S4(a).

(c) heave precautions for pier and beam foundations
Pier and beam foundations should be designed in accordance with Clause D7.

Heave precautions for piers should be used:

- where the foundation is within the zone of influence of trees (see Table 2), and
- where the foundation depth derived in accordance with Clause D6 is greater than 1.5m based on the appropriate tree height (see Figure 1).

Heave precautions for pier and beam foundations should be in accordance with Sitework clause S4(b).

(d) heave precautions for pile and beam foundations
Pile and beam foundations should be designed in accordance with Clause D7.

Heave precautions should be used for piles and ground beams in accordance with Sitework clause S4(c). In addition the following should be taken into account in the selection and design of piles:

- piles should be designed with an adequate factor of safety to resist uplift forces on the shaft due to heave by providing sufficient anchorage below the depth of desiccated soil. Slip liners may be used to reduce the uplift but the amount of reduction is small, as friction between materials cannot be eliminated
- piles should be reinforced for the length of the pile governed by the heave design
- bored, cast-in-place piles are well suited to this application. Most types have a straight-sided shaft but some construction techniques produce a contoured shaft, similar to a screw profile, to increase load capacity. The design should allow for the enhanced tensile forces in such piles
- driven piles are less well suited to this application and are difficult to install in stiff desiccated clay without excessive noise and vibration. Most types are jointed and, if these are to be used, the joint design should be capable of transmitting tensile heave forces
- piles and ground beams should be designed taking into account the upward force on the underside of the ground beams transmitted through the compressible material or void former prior to collapse (refer to manufacturer's data).

(e) suspended ground floors
Suspended ground floors should be used in all situations where heave can occur within the area bounded by the foundations. This includes:

- where the foundation depth derived in accordance with Clause D6 is greater than 1.5m based on the appropriate tree height (see Figure 1), unless NHBC is satisfied the soil is not desicated
- where ground floor construction is undertaken when surface soils are seasonally desiccated (i.e. during summer and autumn) unless NHBC is satisfied the soil is not desiccated.

The following types of suspended floor will be acceptable where there is potential for heave.

PRECAST CONCRETE
A minimum void depth should be provided between underside of beam and ground level as shown in Table 10 (see Sitework clause S4(d)).

TIMBER
A minimum void depth should be provided between underside of joist and ground level as shown in Table 10 (see Sitework clause S4(d)). All sleeper walls should have foundations with depths derived in accordance with Clause D6.

IN-SITU CONCRETE
A minimum void depth should be provided between the ground and the underside of slab as shown in Table 9 (see Sitework clause S4(d)). Where proprietary materials are used, they should be in accordance with Materials clause M2 and the design should take into account the upward force transmitted through the compressible material or void former prior to collapse (refer to manufacturer's data).

(f) heave precautions for raft foundations
Raft foundations constructed in accordance with Clause D7 should provide adequate protection from heave.

(g) other foundations
All foundations not covered in the above clauses, but specifically designed for heave, should be designed by an Engineer (see Technical Requirement R5) taking account of the recommendations of this Chapter and submitted to NHBC for approval prior to work commencing on site.

(h) heave precautions for new drains
Drainage should be constructed in accordance with Chapter 5.3 'Drainage below ground' with the following additional precautions to guard against the effects of heave:

- design gradients may need to be greater than the minimum gradients in Chapter 5.3 as these do not allow for possible ground movement. Where sufficient falls to cater for the likely movement cannot be provided, alternative means of catering for the movement should be used, for example taking the excavation deeper and laying the pipework on granular bedding of suitable thickness to reduce the extent of potential movement
- a drainage system capable of accommodating the likely movement should be used
- pipes and services passing through substructure walls or trench fill foundations should be designed and detailed so as to cope with the potential ground movements shown in Table 7.

Table 7 Potential ground movement

Volume change potential	Potential ground movement [mm]
High	150
Medium	100
Low	50

Existing land drains should be maintained or diverted. Where the void beneath suspended floors is liable to flooding, drainage should be provided.

(i) paths and driveways
Drives and pathways should be designed and detailed to cater for the likely ground movement.

Further guidance is given in BS 5837.

PROVISION OF INFORMATION

4.2 - D9 Designs and specifications shall be produced in a clearly understandable format and all relevant information shall be distributed to appropriate personnel

It is important that all relevant information needed for the completion of the sitework is readily available to all appropriate personnel.

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

- at least one benchmark, and
- reference points on site.

Details should be provided with respect to:

- site investigation
- site survey including location and height of trees and hedgerows affecting the site
- site layout
- dimensions, type and depth of foundations
- soil volume change potential
- tree species (including existing, removed and proposed) using English names
- planting schedules
- original and final ground levels
- technical method statements including critical sequences of construction
- location of services
- design of drainage system
- locations and detailing of:
  - steps in foundations
  - movement and construction joints
  - ducts and services passing through the foundations.

MATERIALS STANDARDS

4.2 - 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 building near trees.

Materials used when building near trees 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).

PROPRIETARY HEAVE MATERIALS

4.2 - M2 Proprietary heave materials shall be assessed in accordance with Technical Requirement R3

Where foundations and substructure could be subjected to heave, they should be protected by voids, void formers or compressible materials in accordance with the design.

Void formers consist of material that collapses to form a void into which the clay can swell reducing the build up of load on the foundation.

Compressible material, such as low density polystyrene, compacts as the clay expands reducing the build up of load on the foundation.

Each material should be used in accordance with the requirements of the relevant independent assessment and the manufacturer's recommendations.

SITEWORK STANDARDS

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

Sitework that complies with the design and guidance below will be acceptable for building near trees.

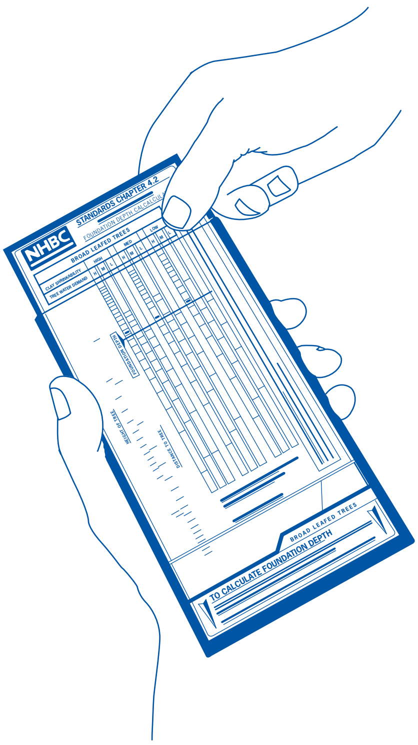
FOUNDATION DEPTHS

4.2 - S2 Foundation depths shall be in accordance with the design

A site plan should show the trees and hedgerows that affect the site together with the type, depth and dimensions of the foundations that are within the influence of those trees and hedgerows. Where trees or hedgerows are either not shown or are in different positions and there is shrinkable soil, it may be necessary to adjust the foundation depths on site. Foundation depths should be determined in accordance with Design clause D6 or the foundation depth calculator. If in doubt about any of the information either assume the worst conditions or consult a suitably qualified Engineer.

An Engineer should be consulted where foundation depths exceed 2.5m (see Technical Requirements R5).

Figure 4 NHBC foundation depth calculator



EXCAVATION FOR FOUNDATIONS

4.2 - S3 Excavation for foundations shall take account of the design and be suitable to receive concrete

Items to be taken into account include:

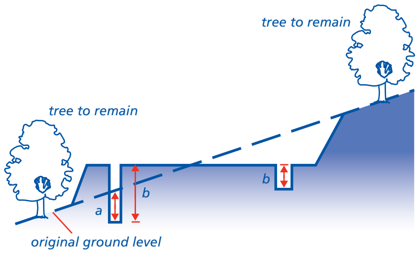
(a) measurement of foundation depths

Foundation depths should be measured on the centre line of the excavation.

Where ground levels are to remain unaltered foundation depths should be measured from original ground level.

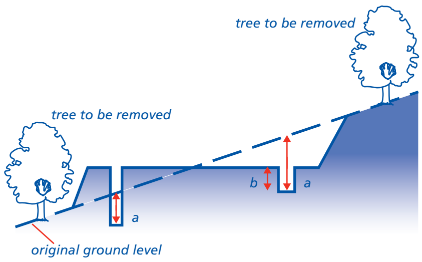
Where ground levels are reduced or increased (either in the recent past or during construction) foundation depths should be measured as shown in Figures 5 to 7.

Figure 5 Levels from which foundation depths are measured where trees or hedgerows are to remain



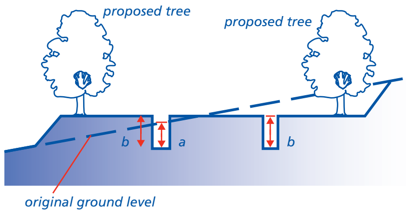
Use the lower of:
a: foundation depth based on appropriate tree height (see Figure 8)
b: foundation depth based on mature height of tree

Figure 6 Levels from which foundation depths are measured where trees or hedgerows are removed



Use the lower of:
a: foundation depth based on appropriate tree height (see Figure 8)
b: minimum foundation depth (see Table 8)

Figure 7 Levels from which foundation depths are measured where trees or hedgerows are proposed



Use the lower of:
a: minimum foundation depth (see Table 8)
b: foundation depth based on mature height of tree

Figure 8 Tree height H to be used for particular design cases

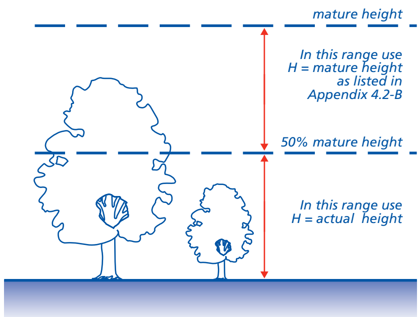


Figure 8 should be used when:
• deriving foundation depths when trees have been removed (use tree height at time of removal - see Design clause 4.2 - D5(a))
• checking the appropriate level from which depths should be measured when trees remain and ground levels are increased (use tree height at time of construction relative to original ground level - see Figure 5)
• determining whether heave precautions should be provided (use tree height at time of construction - see Sitework clause 4.2 - S4(a) and (b)).

Table 8 Minimum foundation depths

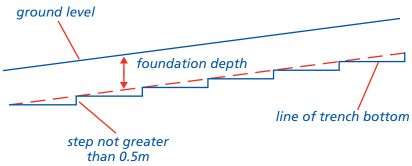
Volume change potential	Minimum depth [m]
High	1.0
Medium	0.9
Low	0.75

(b) stepped foundations

For stepped foundations, the relevant recommendations of Chapter 4.4 'Strip and trench fill foundations' should be followed with the additional precaution that the maximum step height should not exceed 0.5m as shown in Figure 9.

On sloping ground, foundation trenches can be gradually stepped so that the required foundation depth is reasonably uniform below ground level.

Figure 9 Stepped foundations



(c) trench bottoms

Where trench bottoms become excessively dried or softened due to rain or ground water, the excavation should be re-bottomed prior to concreting.

Some root activity may be expected below the depths determined in accordance with Design clause D6. However, if significant quantities of roots are unexpectedly encountered in the base of the trench, the excavation should be deepened or consult an Engineer.

HEAVE PRECAUTIONS

4.2 - S4 Heave precautions shall be incorporated into foundations and substructure in accordance with the design

The following details show the minimum requirements for common foundation types. They apply to all foundations within the zone of influence of trees which are to remain or be removed.

Correct placement of heave materials is essential to ensure the foundations and substructure are adequately protected from heave forces.

(a) heave precautions for trench fill foundations

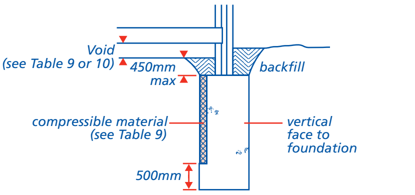
Heave precautions should be provided as shown in Figure 10.

Compressible material should be provided against the inside faces of all external wall foundations greater than 1.5m deep based on the appropriate tree height (see Figure 8).

No compressible material is required against the faces of internal foundations.

Heave precautions are not required for proposed trees as the soil has not been desiccated and therefore heave cannot take place.

Figure 10 Heave precautions for trench fill foundations up to 2.5m deep



It is essential that:

- *compressible material is provided to the entire area shown, and*
- *the foundation excavation has a vertical face. Where the excavation is battered or if there is over break or concrete overspill it may be necessary to consult an Engineer.*

Trench fill foundations deeper than 2.5m will only be acceptable where they are designed by an Engineer (see Technical Requirement R5).

(b) heave precautions for pier and beam foundations

Heave precautions should be provided as shown in Figure 11.

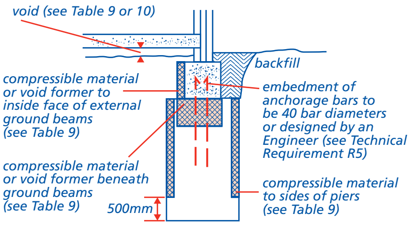
Compressible material should be provided against all faces of the pier foundation which are greater than 1.5m deep based on the appropriate tree height (see Figure 8).

A void, void former or compressible material should be provided below all ground beams.

Compressible material or a void former should also be provided against the inside faces of external ground beams unless NHBC is satisfied that the soil, at this level, is not desiccated.

Heave precautions are not required for proposed trees as the soil has not been desiccated and heave cannot take place.

Figure 11 Heave precautions for pier and beam foundations



It is essential that heave material is provided to the entire areas shown. Particular care should be taken to ensure that the full width of the ground beam is protected.

(c) heave precautions for pile and beam foundations

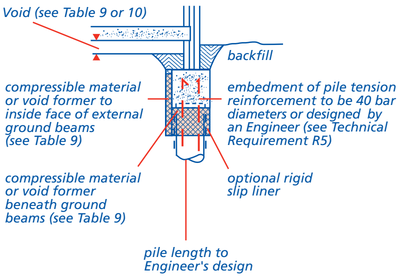
Heave precautions should be provided as shown in Figure 12.

A void, void former or compressible material should be provided below all ground beams.

Compressible material or a void former should also be provided against the inside faces of external ground beams unless NHBC is satisfied that the soil, at this level, is not desiccated.

Heave precautions are not required for proposed trees as the soil has not been desiccated and heave cannot take place.

Figure 12 Heave precautions for pile and beam foundations



It is essential that heave material is provided to the entire areas shown. Particular care should be taken to ensure that the full width of the ground beam and the areas around the piles are protected.

(d) minimum void dimensions

Voids should be provided to accommodate movement in accordance with Tables 9 and 10.

Table 9 Minimum void dimension for foundations, ground beams and suspended in-situ concrete ground floors

	Against side of foundation and ground beam	Under ground beam and suspended in-situ concrete ground floor
Volume change potential	Void dimension [mm][1]	Void dimension [mm][1]
High	35	150
Medium	25	100
Low	0	50

Note:

1 *For compressible material the void dimension is the amount the material should be able to compress to accommodate heave. The actual thickness of compressible material required should be established from the manufacturer's recommendations and is generally in the order of twice the void dimension shown. For void formers the void dimension is the remaining void after collapse. The actual thickness of void former required should be established from the manufacturer's recommendations.*

Table 10 Minimum void dimensions under precast concrete and timber ground floors

	Precast concrete	Suspended timber
Soil heave potential	Void dimension [mm][1]	Void dimension [mm][2]
High	225	300
Medium	175	250
Low	125	200

Note:

1 *Measurement from underside of beam to ground level (includes 75mm ventilation allowance).*

2 *Measurement from underside of joist to ground level (includes 150mm ventilation allowance).*

DRAINAGE

4.2 - S5 Drainage shall be in accordance with the design and allow for ground movement

Drainage construction should be in accordance with the design and the relevant recommendations of Chapter 5.3 'Drainage below ground' should be followed.

Additional items to take into account include:

- falls should be sufficient to cater for possible ground movement or alternative means should be used to reduce the extent of potential movement, for example by taking the excavation deeper and laying the pipework on granular bedding of suitable thickness
- a drainage system capable of accommodating the likely movement should be used
- pipes passing through substructure walls or trench fill foundations should have sufficient clearance to take account of the potential ground movement indicated in Table 11.

Table 11 Minimum allowance for potential ground movement

Volume change potential	Potential ground movement [m]
High	150
Medium	100
Low	50

Existing land drains should be maintained or diverted. Where the void beneath suspended floors is liable to flooding, drainage should be provided.

Appendix 4.2-A

Water demand and mature height of trees

Table 12

Broad leafed trees		
Water demand	**Species**	**Mature height [m]**
High	Elm	
	English	24
	Wheatley	22
	Wych	18
	Eucalyptus	18
	Hawthorn	10
	Oak	
	English	20
	Holm	16
	Red	24
	Turkey	24
	Poplar	
	Hybrid black	28
	Lombardy	25
	White	15
	Willow	
	Crack	24
	Weeping	16
	White	24
Moderate	Acacia false	18
	Alder	18
	Apple	10
	Ash	23
	Bay Laurel	10
	Beech	20
	Blackthorn	8
	Cherry	
	Japanese	9
	Laurel	8
	Orchard	12
	Wild	17
	Chestnut	
	Horse	20
	Sweet	24
	Lime	22
	Maple	
	Japanese	8
	Norway	18
	Mountain Ash	11
	Pear	12
	Plane	26
	Plum	10
	Sycamore	22
	Tree of Heaven	20
	Walnut	18
	Whitebeam	12
Low	Birch	14
	Elder	10
	Fig	8
	Hazel	8
	Holly	12
	Honey Locust	14
	Hornbeam	17
	Laburnum	12
	Magnolia	9
	Mulberry	9
	Tulip tree	20

Coniferous trees		
Water demand	**Species**	**Mature height [m]**
High	Cypress	
	Lawson's	18
	Leyland	20
	Monterey	20
Moderate	Cedar	20
	Douglas fir	20
	Larch	20
	Monkey Puzzle	18
	Pine	20
	Spruce	18
	Wellingtonia	30
	Yew	12

Note:
1 Where hedgerows contain trees, their effect should be assessed separately. In hedgerows, the height of the species likely to have the greatest effect should be used.
2 Within the classes of water demand, species are listed alphabetically; the order does not signify any gradation in water demand.
3 When the species is known but the sub-species is not, the greatest height listed for the species should be assumed.
| 4 Further information regarding trees may be obtained from the Arboricultural Association or the Arboricultural Advisory and Information service (see Appendix 4.2-E).

Appendix 4.2-B

Foundation Depth Charts

Table 13 Determination of D/H Value

Distance D (m)	Tree height H (m)														
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
1	0.50	0.25	0.17	0.13	0.10	0.08	0.07	0.06	0.06	0.05	0.05	0.04	0.04	0.04	0.03
2	1.00	0.50	0.33	0.25	0.20	0.17	0.14	0.13	0.11	0.10	0.09	0.08	0.08	0.07	0.07
3		0.75	0.50	0.38	0.30	0.25	0.21	0.19	0.17	0.15	0.14	0.13	0.12	0.11	0.10
4		1.00	0.67	0.50	0.40	0.33	0.29	0.25	0.22	0.20	0.18	0.17	0.15	0.14	0.13
5			0.83	0.63	0.50	0.42	0.36	0.31	0.28	0.25	0.23	0.21	0.19	0.18	0.17
6			1.00	0.75	0.60	0.50	0.43	0.38	0.33	0.30	0.27	0.25	0.23	0.21	0.20
7			1.17	0.88	0.70	0.58	0.50	0.44	0.39	0.35	0.32	0.29	0.27	0.25	0.23
8				1.00	0.80	0.67	0.57	0.50	0.44	0.40	0.36	0.33	0.31	0.29	0.27
9				1.13	0.90	0.75	0.64	0.56	0.50	0.45	0.41	0.38	0.35	0.32	0.30
10					1.00	0.83	0.71	0.63	0.56	0.50	0.45	0.42	0.38	0.36	0.33
11					1.10	0.92	0.79	0.69	0.61	0.55	0.50	0.46	0.42	0.39	0.37
12					1.20	1.00	0.86	0.75	0.67	0.60	0.55	0.50	0.46	0.43	0.40
13						1.08	0.93	0.81	0.72	0.65	0.59	0.54	0.50	0.46	0.43
14						1.17	1.00	0.88	0.78	0.70	0.64	0.58	0.54	0.50	0.47
15							1.07	0.94	0.83	0.75	0.68	0.63	0.58	0.54	0.50
16							1.14	1.00	0.89	0.80	0.73	0.67	0.62	0.57	0.53
17							1.21	1.06	0.94	0.85	0.77	0.71	0.65	0.61	0.57
18								1.13	1.00	0.90	0.82	0.75	0.69	0.64	0.60
19								1.19	1.06	0.95	0.86	0.79	0.73	0.68	0.63
20									1.11	1.00	0.91	0.83	0.77	0.71	0.67
21									1.17	1.05	0.95	0.88	0.81	0.75	0.70
22										1.10	1.00	0.92	0.85	0.79	0.73
23										1.15	1.05	1.96	0.88	0.82	0.77
24										1.20	1.09	1.00	0.92	0.86	0.80
25											1.14	1.04	0.96	0.89	0.83
26											1.18	1.08	1.00	0.93	0.87
27												1.13	1.04	0.96	0.90
28												1.17	1.08	1.00	0.93
29												1.21	1.12	1.04	0.97
30													1.15	1.07	1.00
31													1.19	1.11	1.03
32														1.14	1.07
33														1.18	1.10
34														1.21	1.13
35															1.17
36															1.20

Where no value is given in the table, minimum foundation depths apply (i.e. 1.0m, 0.9m and 0.75m for high, medium and low volume change potential soils respectively).

Chart 1 Soils with HIGH volume change potential: Modified Plasticity Index 40% or greater
(see Design clause D5(b))

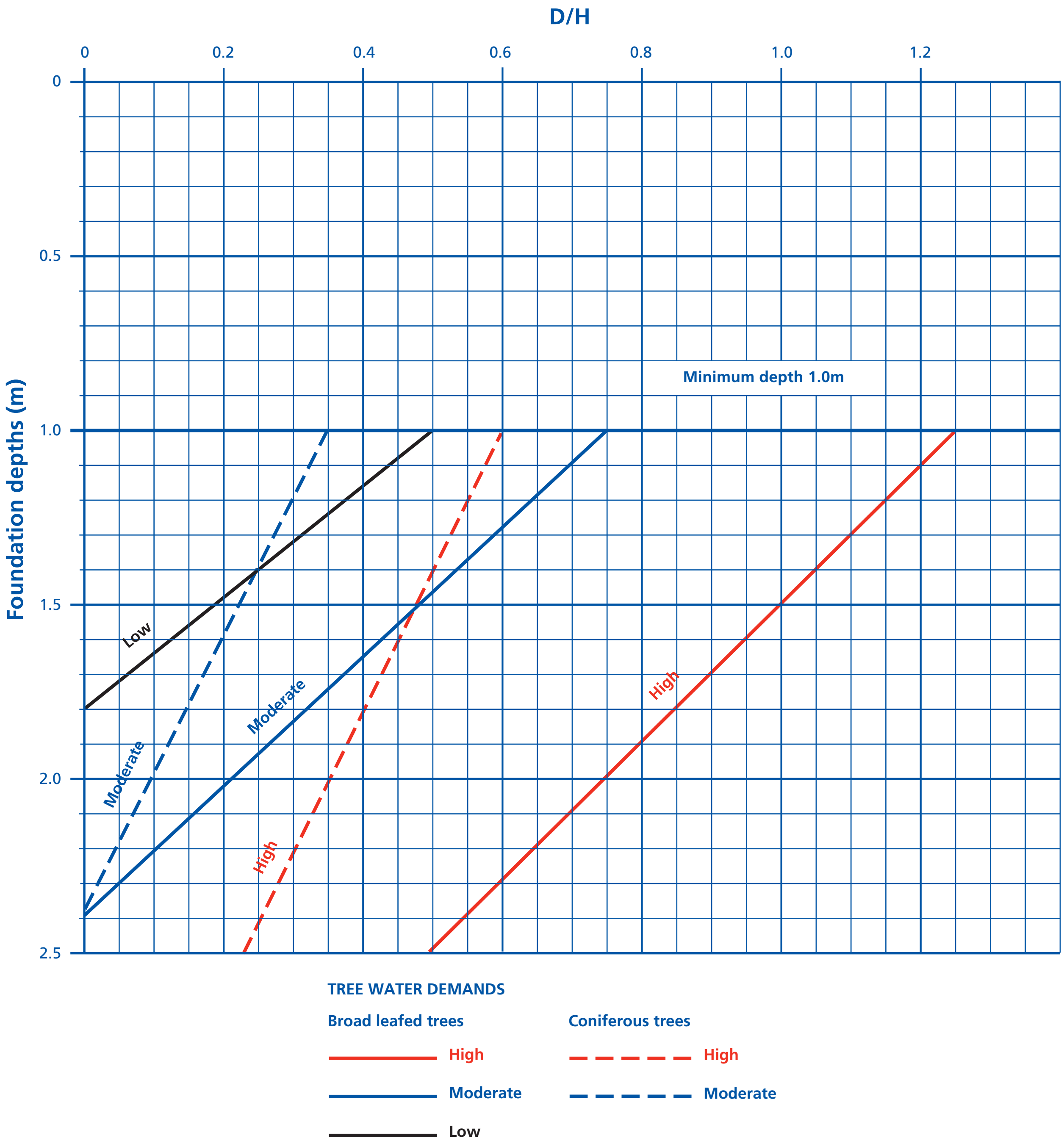


Chart 2 Soils with MEDIUM volume change potential: Modified Plasticity Index between 20% and less than 40%
(see Design clause D5(b))

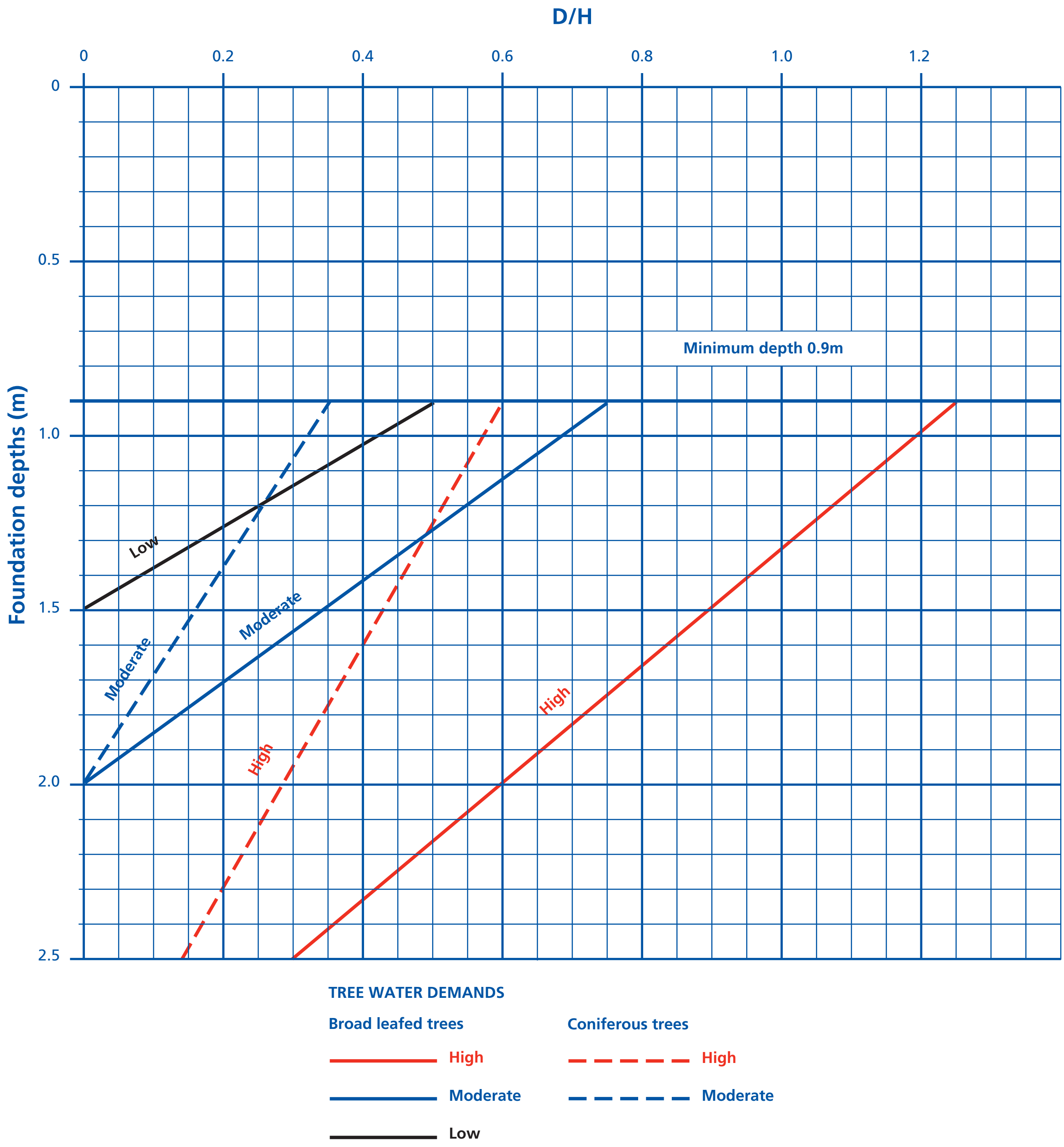
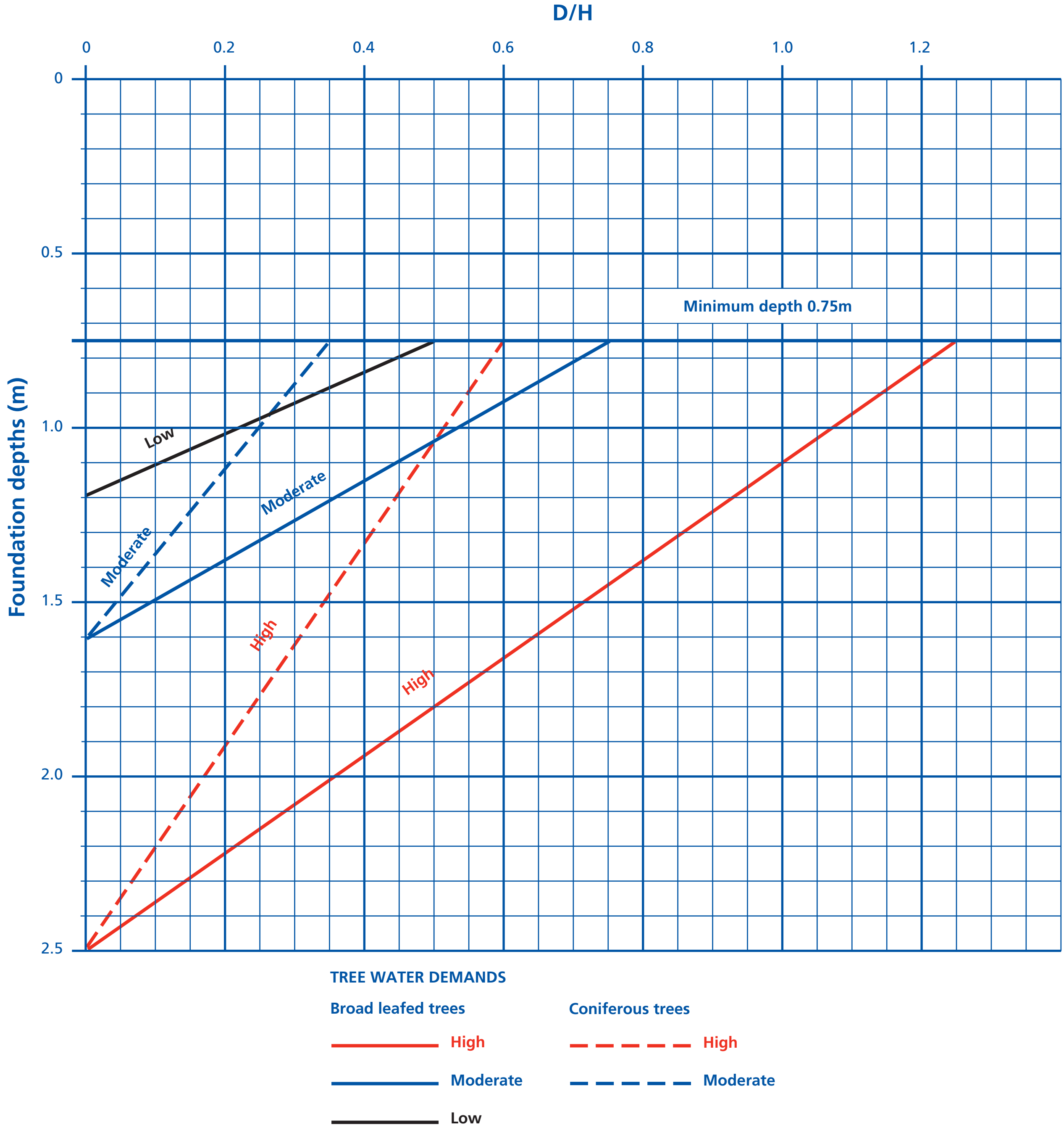


Chart 3 Soils with LOW volume change potential: Modified Plasticity Index 10 to less than 20%
(see Design clause D5(b))



Appendix 4.2-C

Foundation depth tables

Table 14 - HIGH shrinkage soil and HIGH water demand tree

Broad leafed trees

Foundation depth (m)

Foundations greater than 2.5m deep to be Engineer designed

1.0m minimum foundation depth

Distance D (m)	Tree height H (m) 8	10	12	14	16	18	20	22	24	26	28	30
1												
2												
3												
4	2.50											
5	2.25	2.50										
6	2.00	2.30	2.50									
7	1.75	2.10	2.35	2.50								
8	1.50	1.90	2.20	2.40	2.50							
9	1.25	1.70	2.00	2.25	2.40	2.50						
10	1.00	1.50	1.85	2.10	2.25	2.40	2.50					
11	1.00	1.30	1.70	1.95	2.15	2.30	2.40	2.50				
12	1.00	1.10	1.50	1.80	2.00	2.20	2.30	2.45	2.50			
13		1.00	1.35	1.65	1.90	2.10	2.20	2.35	2.45	2.50		
14		1.00	1.20	1.50	1.75	1.95	2.10	2.25	2.35	2.45	2.50	
15			1.00	1.40	1.65	1.85	2.00	2.15	2.25	2.35	2.45	2.50
16			1.00	1.25	1.50	1.75	1.90	2.05	2.20	2.30	2.40	2.45
17			1.00	1.10	1.40	1.65	1.80	1.95	2.10	2.20	2.30	2.40
18				1.00	1.25	1.50	1.70	1.90	2.00	2.15	2.25	2.30
19				1.00	1.15	1.40	1.60	1.80	1.95	2.05	2.15	2.25
20					1.00	1.30	1.50	1.70	1.85	2.00	2.10	2.20
21					1.00	1.20	1.40	1.60	1.75	1.90	2.00	2.10
22					1.00	1.10	1.30	1.50	1.70	1.85	1.95	2.05
23						1.00	1.20	1.45	1.60	1.75	1.90	2.00
24						1.00	1.10	1.35	1.50	1.65	1.80	1.90
25							1.00	1.25	1.45	1.60	1.75	1.85
26							1.00	1.15	1.35	1.50	1.65	1.80
27							1.00	1.05	1.25	1.45	1.60	1.70
28								1.00	1.20	1.35	1.50	1.65
29								1.00	1.10	1.30	1.45	1.60
30									1.00	1.20	1.40	1.50
31									1.00	1.15	1.30	1.45
32									1.00	1.05	1.25	1.40
33										1.00	1.15	1.30
34										1.00	1.10	1.25
35											1.00	1.20
36											1.00	1.10
37											1.00	1.05
38												1.00

Coniferous trees

Foundation depth (m)

Foundations greater than 2.5m deep to be Engineer designed

1.0m minimum foundation depth

Distance D (m)	Tree height H (m) 8	10	12	14	16	18	20	22	24	26	28	30
1												
2	2.50											
3	1.95	2.25	2.50									
4	1.45	1.85	2.15	2.35	2.50							
5	1.00	1.45	1.80	2.05	2.20	2.35	2.50					
6		1.00	1.45	1.75	1.95	2.15	2.25	2.40	2.50			
7		1.00	1.10	1.45	1.70	1.90	2.05	2.20	2.30	2.40	2.50	
8			1.00	1.15	1.45	1.65	1.85	2.00	2.15	2.25	2.35	2.40
9				1.00	1.20	1.45	1.65	1.80	1.95	2.10	2.20	2.25
10					1.00	1.20	1.45	1.65	1.80	1.90	2.05	2.15
11						1.00	1.25	1.45	1.60	1.75	1.90	2.00
12							1.00	1.25	1.45	1.60	1.75	1.85
13							1.00	1.05	1.25	1.45	1.60	1.70
14								1.00	1.10	1.30	1.45	1.60
15									1.00	1.10	1.30	1.45
16										1.00	1.15	1.30
17											1.00	1.15
18												1.00
19												
20												
21												
22												
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27												
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32												
33												
34												
35												
36												
37												
38												

Table 15 - HIGH Shrinkage soil and MODERATE water demand tree

Broad leafed trees

Foundation depth (m)

Distance D (m)	Tree height H (m) 8	10	12	14	16	18	20	22	24	26	28	30
1	2.20	2.25	2.25	2.30	2.30	2.30	2.35	2.35	2.35	2.35	2.35	2.35
2	1.95	2.05	2.10	2.15	2.20	2.20	2.25	2.25	2.25	2.30	2.30	2.30
3	1.70	1.85	1.95	2.00	2.05	2.10	2.15	2.15	2.20	2.20	2.20	2.25
4	1.50	1.65	1.80	1.90	1.95	2.00	2.05	2.10	2.10	2.15	2.15	2.15
5	1.25	1.50	1.65	1.75	1.85	1.90	1.95	2.00	2.05	2.05	2.10	2.10
6	1.00	1.30	1.50	1.60	1.70	1.80	1.85	1.90	1.95	2.00	2.00	2.05
7	1.00	1.10	1.35	1.50	1.60	1.70	1.75	1.85	1.90	1.90	1.95	2.00
8		1.00	1.20	1.35	1.50	1.60	1.65	1.75	1.80	1.85	1.90	1.90
9			1.00	1.20	1.35	1.50	1.60	1.65	1.70	1.75	1.80	1.85
10			1.00	1.10	1.25	1.40	1.50	1.55	1.65	1.70	1.75	1.80
11				1.00	1.15	1.30	1.40	1.50	1.55	1.65	1.70	1.75
12					1.00	1.20	1.30	1.40	1.50	1.55	1.60	1.65
13					1.00	1.05	1.20	1.30	1.40	1.50	1.55	1.60
14						1.00	1.10	1.25	1.35	1.40	1.50	1.55
15							1.00	1.15	1.25	1.35	1.40	1.50
16							1.00	1.05	1.20	1.25	1.35	1.40
17								1.00	1.10	1.20	1.30	1.35
18									1.00	1.15	1.20	1.30
19									1.00	1.05	1.15	1.25
20										1.00	1.10	1.20
21											1.00	1.10
22											1.00	1.05
23												1.00

1.0m minimum foundation depth

Coniferous trees

Foundation depth (m)

Distance D (m)	Tree height H (m) 8	10	12	14	16	18	20	22	24	26	28	30
1	1.90	2.00	2.10	2.15	2.15	2.20	2.20	2.25	2.25	2.25	2.30	2.30
2	1.40	1.60	1.75	1.85	1.90	2.00	2.00	2.05	2.10	2.10	2.15	2.15
3	1.00	1.20	1.40	1.55	1.65	1.75	1.80	1.85	1.90	1.95	2.00	2.00
4		1.00	1.10	1.30	1.40	1.55	1.60	1.70	1.75	1.80	1.85	1.90
5			1.00	1.00	1.15	1.30	1.40	1.50	1.60	1.65	1.70	1.75
6					1.00	1.10	1.20	1.35	1.40	1.50	1.55	1.60
7						1.00	1.00	1.15	1.25	1.35	1.40	1.50
8								1.00	1.10	1.20	1.30	1.35
9									1.00	1.05	1.15	1.20
10										1.00	1.00	1.10
11												1.00
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												

1.0m minimum foundation depth

Table 16 - HIGH shrinkage soil and LOW water demand tree

Broad leafed trees

Foundation depth (m)

Distance D (m)	Tree height H (m) 8	10	12	14	16	18	20	22	24	26	28	30
1	1.60	1.65	1.70	1.70	1.70	1.75	1.75	1.75	1.75	1.75	1.75	1.75
2	1.40	1.50	1.55	1.60	1.60	1.65	1.65	1.65	1.65	1.70	1.70	1.70
3	1.20	1.35	1.40	1.50	1.50	1.55	1.60	1.60	1.60	1.65	1.65	1.65
4	1.00	1.20	1.30	1.35	1.40	1.45	1.50	1.55	1.55	1.55	1.60	1.60
5		1.00	1.15	1.25	1.30	1.40	1.40	1.45	1.50	1.50	1.55	1.55
6			1.00	1.15	1.20	1.30	1.35	1.40	1.40	1.45	1.50	1.50
7				1.00	1.10	1.20	1.25	1.30	1.35	1.40	1.40	1.45
8					1.00	1.10	1.20	1.25	1.30	1.35	1.35	1.40
9						1.00	1.10	1.15	1.20	1.25	1.30	1.35
10							1.00	1.10	1.15	1.20	1.25	1.30
11								1.00	1.10	1.15	1.20	1.25
12									1.00	1.10	1.15	1.20
13										1.00	1.10	1.15
14											1.00	1.05
15												1.00

1.0m minimum foundation depth

Table 17 - MEDIUM shrinkage soil and HIGH water demand tree

Broad leafed trees

Foundation depth (m)												
Distance D (m)	Tree Height H (m)											
	8	10	12	14	16	18	20	22	24	26	28	30
1												
2												
3	2.40	2.50										
4	2.20	2.35	2.45									
5	1.95	2.20	2.30	2.40	2.50							
6	1.75	2.00	2.20	2.30	2.40	2.45	2.50					
7	1.55	1.85	2.05	2.20	2.30	2.35	2.45	2.50				
8	1.35	1.70	1.90	2.05	2.20	2.25	2.35	2.40	2.45	2.50		
9	1.15	1.50	1.75	1.95	2.10	2.20	2.25	2.35	2.40	2.45	2.50	2.50
10	0.90	1.35	1.60	1.80	1.95	2.10	2.20	2.25	2.30	2.35	2.40	2.45
11	0.90	1.15	1.50	1.70	1.85	2.00	2.10	2.20	2.25	2.30	2.35	2.40
12	0.90	1.00	1.35	1.60	1.75	1.90	2.00	2.10	2.20	2.25	2.30	2.35
13		0.90	1.20	1.45	1.65	1.80	1.95	2.05	2.10	2.20	2.25	2.30
14		0.90	1.05	1.35	1.55	1.70	1.85	1.95	2.05	2.10	2.20	2.25
15			0.90	1.20	1.45	1.60	1.75	1.85	1.95	2.05	2.10	2.20
16			0.90	1.10	1.35	1.55	1.70	1.80	1.90	2.00	2.05	2.10
17			0.90	1.00	1.25	1.45	1.60	1.70	1.85	1.90	2.00	2.05
18				0.90	1.15	1.35	1.50	1.65	1.75	1.85	1.95	2.00
19				0.90	1.05	1.25	1.40	1.55	1.70	1.80	1.90	1.95
20					0.90	1.15	1.35	1.50	1.60	1.75	1.80	1.90
21					0.90	1.05	1.25	1.40	1.55	1.65	1.75	1.85
22					0.90	0.95	1.15	1.35	1.50	1.60	1.70	1.80
23						0.90	1.10	1.25	1.40	1.55	1.65	1.75
24						0.90	1.00	1.20	1.35	1.45	1.60	1.70
25							0.90	1.10	1.25	1.40	1.50	1.60
26							0.90	1.05	1.20	1.35	1.45	1.55
27							0.90	0.95	1.15	1.30	1.40	1.50
28								0.90	1.05	1.20	1.35	1.45
29								0.90	1.00	1.15	1.30	1.40
30									0.90	1.10	1.20	1.35
31									0.90	1.00	1.15	1.30
32									0.90	0.95	1.10	1.25
33										0.90	1.05	1.15
34										0.90	1.00	1.10
35											0.90	1.05
36											0.90	1.00
37											0.90	0.95
38												0.90

Foundations greater than 2.5m deep to be Engineer designed

0.9m minimum foundation depth

Table 17

Coniferous trees

Foundation depth (m)												
Distance D (m)	Tree Height H (m)											
	8	10	12	14	16	18	20	22	24	26	28	30
1												
2	2.15	2.30	2.45	2.50								
3	1.70	1.95	2.15	2.25	2.35	2.45	2.50					
4	1.25	1.60	1.85	2.00	2.15	2.25	2.30	2.40	2.45	2.50	2.50	
5	0.90	1.25	1.55	1.75	1.95	2.05	2.15	2.20	2.30	2.35	2.40	2.45
6		0.90	1.25	1.50	1.70	1.85	1.95	2.05	2.15	2.20	2.25	2.30
7			1.00	1.25	1.50	1.65	1.80	1.90	2.00	2.10	2.15	2.20
8			0.90	1.00	1.25	1.45	1.60	1.75	1.85	1.95	2.00	2.10
9				0.90	1.05	1.25	1.45	1.60	1.70	1.80	1.90	1.95
10					0.90	1.10	1.25	1.45	1.55	1.65	1.75	1.85
11						0.90	1.10	1.25	1.40	1.55	1.65	1.75
12							0.90	1.10	1.25	1.40	1.50	1.60
13							0.90	0.95	1.10	1.25	1.40	1.50
14								0.90	1.00	1.15	1.25	1.40
15									0.90	1.00	1.15	1.25
16										0.90	1.00	1.15
17											0.90	1.05
18												0.90
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
32												
33												
34												
35												
36												
37												
38												

Foundations greater than 2.5m deep to be Engineer designed

0.9m minimum foundation depth

Table 18 - MEDIUM shrinkage soil and MODERATE water demand tree

Broad leafed trees

Foundation depth (m)												
Distance D (m)	Tree height H (m)											
	8	10	12	14	16	18	20	22	24	26	28	30
1	1.85	1.85	1.90	1.90	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95
2	1.65	1.75	1.80	1.80	1.85	1.85	1.85	1.90	1.90	1.90	1.90	1.90
3	1.45	1.60	1.65	1.70	1.75	1.80	1.80	1.80	1.85	1.85	1.85	1.85
4	1.30	1.45	1.55	1.60	1.65	1.70	1.75	1.75	1.80	1.80	1.80	1.80
5	1.10	1.30	1.40	1.50	1.55	1.60	1.65	1.70	1.70	1.75	1.75	1.80
6	0.90	1.15	1.30	1.40	1.45	1.55	1.60	1.60	1.65	1.70	1.70	1.75
7	0.90	1.00	1.15	1.30	1.40	1.45	1.50	1.55	1.60	1.65	1.65	1.70
8		0.90	1.05	1.20	1.30	1.35	1.45	1.50	1.55	1.55	1.60	1.65
9			0.90	1.10	1.20	1.30	1.35	1.40	1.45	1.50	1.55	1.60
10			0.90	0.95	1.10	1.20	1.30	1.35	1.40	1.45	1.50	1.55
11				0.90	1.00	1.10	1.20	1.30	1.35	1.40	1.45	1.50
12					0.90	1.05	1.15	1.20	1.30	1.35	1.40	1.45
13					0.90	0.95	1.05	1.15	1.25	1.30	1.35	1.40
14						0.90	1.00	1.10	1.15	1.25	1.30	1.35
15							0.90	1.00	1.10	1.15	1.25	1.30
16							0.90	0.95	1.05	1.10	1.20	1.25
17								0.90	1.00	1.10	1.15	1.20
18									0.90	1.00	1.10	1.15
19									0.90	0.95	1.00	1.10
20										0.90	0.95	1.05
21											0.90	1.00
22											0.90	0.95
23												0.90

0.9m minimum foundation depth

Coniferous trees

Foundation depth (m)												
Distance D (m)	Tree height H (m)											
	8	10	12	14	16	18	20	22	24	26	28	30
1	1.65	1.70	1.75	1.80	1.80	1.85	1.85	1.90	1.90	1.90	1.90	1.90
2	1.25	1.40	1.50	1.55	1.65	1.65	1.70	1.75	1.75	1.80	1.80	1.80
3	0.90	1.10	1.25	1.35	1.45	1.50	1.55	1.60	1.65	1.65	1.70	1.70
4		0.90	0.95	1.10	1.25	1.30	1.40	1.45	1.50	1.55	1.55	1.60
5			0.90	0.90	1.05	1.15	1.25	1.30	1.35	1.40	1.45	1.50
6					0.90	0.95	1.10	1.15	1.25	1.30	1.35	1.40
7						0.90	0.90	1.00	1.10	1.15	1.25	1.30
8								0.90	0.95	1.05	1.10	1.20
9									0.90	0.95	1.00	1.10
10										0.90	0.90	0.95
11												0.90
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												

0.9m minimum foundation depth

Table 19 - MEDIUM shrinkage soil and LOW water demand tree

Broad leafed trees

Foundation depth (m)												
Distance D (m)	Tree height H (m)											
	8	10	12	14	16	18	20	22	24	26	28	30
1	1.35	1.40	1.40	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.50	1.50
2	1.20	1.30	1.30	1.35	1.35	1.40	1.40	1.40	1.40	1.45	1.45	1.45
3	1.05	1.15	1.20	1.25	1.30	1.30	1.35	1.35	1.35	1.40	1.40	1.40
4	0.90	1.05	1.10	1.20	1.20	1.25	1.30	1.30	1.30	1.35	1.35	1.35
5		0.90	1.00	1.10	1.15	1.20	1.20	1.25	1.25	1.30	1.30	1.30
6			0.90	1.00	1.05	1.10	1.15	1.20	1.20	1.25	1.25	1.30
7				0.90	1.00	1.05	1.10	1.15	1.15	1.20	1.20	1.25
8					0.90	1.00	1.05	1.10	1.10	1.15	1.20	1.20
9						0.90	1.00	1.05	1.05	1.10	1.15	1.15
10							0.90	0.95	1.00	1.05	1.10	1.10
11								0.90	0.95	1.00	1.05	1.10
12									0.90	0.95	1.00	1.05
13										0.90	0.95	1.00
14											0.90	0.95
15												0.90

0.9m minimum foundation depth

Table 20 - LOW shrinkage soil and HIGH water demand tree

Broad leafed trees

Foundation depth (m)												
Distance D (m)	**Tree height H (m)**											
	8	10	12	14	16	18	20	22	24	26	28	30
1	2.35	2.40	2.40	2.40	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45
2	2.15	2.25	2.30	2.30	2.35	2.35	2.40	2.40	2.40	2.40	2.40	2.45
3	2.00	2.10	2.15	2.20	2.25	2.30	2.30	2.35	2.35	2.35	2.35	2.40
4	1.80	1.95	2.05	2.10	2.15	2.20	2.25	2.25	2.30	2.30	2.30	2.35
5	1.65	1.80	1.95	2.00	2.10	2.15	2.15	2.20	2.25	2.25	2.25	2.30
6	1.45	1.70	1.80	1.90	2.00	2.05	2.10	2.15	2.15	2.20	2.20	2.25
7	1.30	1.55	1.70	1.80	1.90	2.00	2.05	2.05	2.10	2.15	2.15	2.20
8	1.10	1.40	1.60	1.70	1.80	1.90	1.95	2.00	2.05	2.10	2.10	2.15
9	0.95	1.25	1.45	1.60	1.75	1.80	1.90	1.95	2.00	2.05	2.05	2.10
10	0.75	1.10	1.35	1.50	1.65	1.75	1.80	1.90	1.95	2.00	2.00	2.05
11	0.75	1.00	1.20	1.40	1.55	1.65	1.75	1.80	1.90	1.95	1.95	2.00
12	0.75	0.85	1.10	1.30	1.45	1.60	1.70	1.75	1.80	1.85	1.90	1.95
13		0.75	1.00	1.20	1.40	1.50	1.60	1.70	1.75	1.80	1.85	1.90
14		0.75	0.90	1.10	1.30	1.45	1.55	1.65	1.70	1.75	1.80	1.85
15			0.75	1.00	1.20	1.35	1.45	1.55	1.65	1.70	1.75	1.80
16			0.75	0.90	1.10	1.30	1.40	1.50	1.60	1.65	1.70	1.75
17			0.75	0.80	1.05	1.20	1.35	1.45	1.55	1.60	1.65	1.75
18				0.75	0.95	1.10	1.25	1.35	1.45	1.55	1.60	1.70
19				0.75	0.85	1.05	1.20	1.30	1.40	1.50	1.55	1.65
20					0.75	0.95	1.10	1.25	1.35	1.45	1.50	1.60
21					0.75	0.90	1.05	1.20	1.30	1.40	1.45	1.55
22					0.75	0.80	1.00	1.10	1.25	1.35	1.40	1.50
23						0.75	0.90	1.05	1.20	1.30	1.35	1.45
24						0.75	0.85	1.00	1.10	1.25	1.30	1.40
25							0.75	0.95	1.05	1.15	1.25	1.35
26							0.75	0.85	1.00	1.10	1.20	1.30
27							0.75	0.80	0.95	1.05	1.15	1.25
28								0.75	0.90	1.00	1.10	1.20
29								0.75	0.85	0.95	1.05	1.15
30									0.75	0.90	1.00	1.10
31									0.75	0.85	0.95	1.05
32									0.75	0.80	0.90	1.05
33										0.75	0.85	1.00
34										0.75	0.80	0.95
35											0.75	0.90
36											0.75	0.85
37											0.75	0.80
38												0.75

0.75m minimum foundation depth

Coniferous trees

Foundation depth (m)												
Distance D (m)	**Tree height H (m)**											
	8	10	12	14	16	18	20	22	24	26	28	30
1	2.15	2.25	2.30	2.30	2.35	2.35	2.35	2.40	2.40	2.40	2.40	2.40
2	1.80	1.95	2.05	2.10	2.15	2.20	2.25	2.25	2.30	2.30	2.30	2.35
3	1.45	1.65	1.80	1.90	1.95	2.05	2.10	2.10	2.15	2.20	2.20	2.25
4	1.05	1.35	1.55	1.70	1.80	1.85	1.95	2.00	2.05	2.05	2.10	2.15
5	0.75	1.05	1.30	1.50	1.60	1.70	1.80	1.85	1.90	1.95	2.00	2.05
6		0.75	1.05	1.25	1.45	1.55	1.65	1.70	1.80	1.85	1.90	1.95
7		0.75	0.80	1.05	1.25	1.40	1.50	1.60	1.65	1.75	1.80	1.85
8			0.75	0.85	1.05	1.20	1.35	1.45	1.55	1.60	1.70	1.75
9				0.75	0.90	1.05	1.20	1.35	1.45	1.50	1.60	1.65
10					0.75	0.90	1.05	1.20	1.30	1.40	1.50	1.55
11						0.75	0.90	1.05	1.20	1.30	1.35	1.45
12							0.75	0.95	1.05	1.15	1.25	1.35
13							0.75	0.80	0.95	1.05	1.15	1.25
14								0.75	0.80	0.95	1.05	1.15
15									0.75	0.85	0.95	1.05
16										0.75	0.85	0.95
17											0.75	0.85
18												0.75
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
32												
33												
34												
35												
36												
37												
38												

0.75m minimum foundation depth

Table 21 - LOW shrinkage soil and MODERATE water demand tree

Broad leafed trees

Foundation depth (m)												
Distance D (m)	Tree height H (m)											
	8	10	12	14	16	18	20	22	24	26	28	30
1	1.50	1.50	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.60	1.60	1.60
2	1.35	1.40	1.45	1.45	1.50	1.50	1.50	1.50	1.55	1.55	1.55	1.55
3	1.20	1.30	1.35	1.40	1.40	1.45	1.45	1.45	1.50	1.50	1.50	1.50
4	1.05	1.15	1.25	1.30	1.35	1.35	1.40	1.40	1.45	1.45	1.45	1.45
5	0.90	1.05	1.15	1.20	1.25	1.30	1.35	1.35	1.40	1.40	1.40	1.45
6	0.75	0.95	1.05	1.15	1.20	1.25	1.30	1.30	1.35	1.35	1.40	1.40
7	0.75	0.85	0.95	1.05	1.10	1.20	1.20	1.25	1.30	1.30	1.35	1.35
8		0.75	0.85	0.95	1.05	1.10	1.15	1.20	1.25	1.25	1.30	1.30
9			0.75	0.90	1.00	1.05	1.10	1.15	1.20	1.25	1.25	1.30
10			0.75	0.80	0.90	1.00	1.05	1.10	1.15	1.20	1.20	1.25
11				0.75	0.85	0.95	1.00	1.05	1.10	1.15	1.15	1.20
12					0.75	0.85	0.95	1.00	1.05	1.10	1.15	1.15
13					0.75	0.80	0.90	0.95	1.00	1.05	1.10	1.15
14						0.75	0.85	0.90	0.95	1.00	1.05	1.10
15							0.75	0.85	0.90	0.95	1.00	1.05
16							0.75	0.80	0.85	0.90	0.95	1.00
17								0.75	0.80	0.90	0.95	1.00
18									0.75	0.85	0.90	0.95
19									0.75	0.80	0.85	0.90
20										0.75	0.80	0.85
21											0.75	0.85
22											0.75	0.80
23												0.75

0.75m minimum foundation depth

Coniferous trees

Foundation depth (m)												
Distance D (m)	Tree height H (m)											
	8	10	12	14	16	18	20	22	24	26	28	30
1	1.30	1.40	1.40	1.45	1.45	1.50	1.50	1.50	1.50	1.55	1.55	1.55
2	1.00	1.15	1.20	1.25	1.30	1.35	1.40	1.40	1.40	1.45	1.45	1.45
3	0.75	0.90	1.00	1.10	1.15	1.20	1.25	1.30	1.30	1.35	1.35	1.40
4		0.75	0.80	0.95	1.00	1.10	1.15	1.20	1.20	1.25	1.25	1.30
5			0.75	0.75	0.85	0.95	1.00	1.05	1.10	1.15	1.20	1.20
6					0.75	0.80	0.90	0.95	1.00	1.05	1.10	1.15
7						0.75	0.75	0.85	0.90	0.95	1.00	1.05
8								0.75	0.80	0.85	0.95	0.95
9									0.75	0.80	0.85	0.90
10										0.75	0.75	0.80
11												0.75
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												

0.75m minimum foundation depth

Table 22 - LOW shrinkage soil and LOW water demand tree

Broad leafed trees

Foundation depth (m)												
Distance D (m)	Tree height H (m)											
	8	10	12	14	16	18	20	22	24	26	28	30
1	1.10	1.15	1.15	1.15	1.15	1.15	1.20	1.20	1.20	1.20	1.20	1.20
2	1.00	1.05	1.05	1.10	1.10	1.10	1.15	1.15	1.15	1.15	1.15	1.15
3	0.90	0.95	1.00	1.05	1.05	1.05	1.10	1.10	1.10	1.10	1.10	1.15
4	0.75	0.85	0.90	0.95	1.00	1.00	1.05	1.05	1.05	1.10	1.10	1.10
5		0.75	0.85	0.90	0.95	0.95	1.00	1.00	1.05	1.05	1.05	1.05
6			0.75	0.85	0.90	0.90	0.95	0.95	1.00	1.00	1.05	1.05
7				0.75	0.85	0.85	0.90	0.95	0.95	1.00	1.00	1.00
8					0.75	0.80	0.85	0.90	0.90	0.95	0.95	1.00
9						0.75	0.80	0.85	0.90	0.90	0.95	0.95
10							0.75	0.80	0.85	0.85	0.90	0.90
11								0.75	0.80	0.85	0.85	0.90
12									0.75	0.80	0.85	0.85
13										0.75	0.80	0.85
14											0.75	0.80
15												0.75

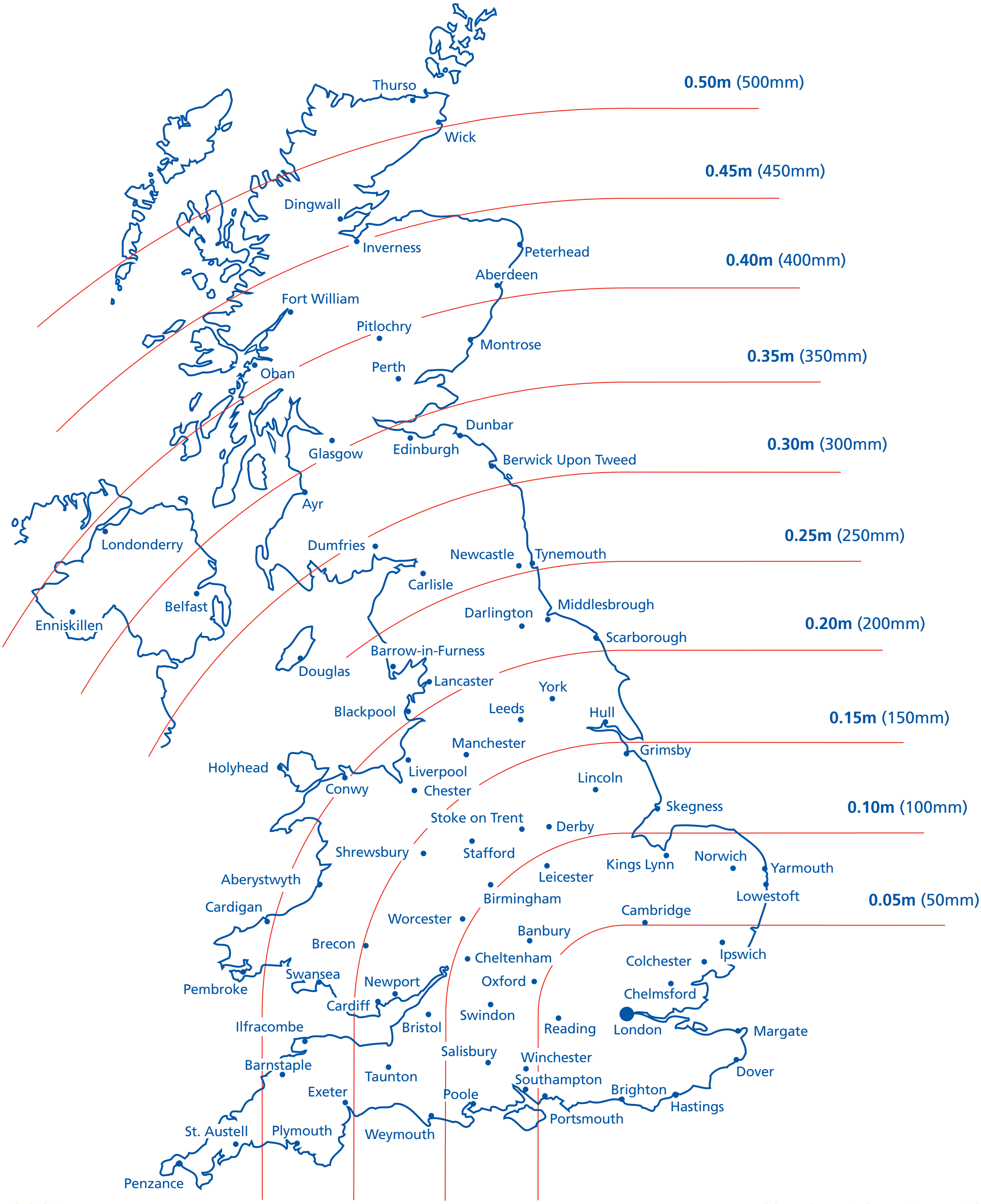
0.75m minimum foundation depth

Appendix 4.2-D

Climate zones

Figure 13 Reductions in foundation depth due to climate variations

The foundation depth may be reduced by the amounts shown on the map for each climatic zone (see Design clause D5(e)). Where it is unclear which zone applies, the lower reduction value should be used.



Appendix 4.2-E

Information sources and acknowledgements

INFORMATION SOURCES

Further recommendations and information can be obtained from:

Publications

BS 1377 'Methods of test for soils for civil engineering purposes'

BS 5837 'Guide for trees in relation to construction'

BS 5930 'Code of practice for site investigations'

BRE Digests 240, 241 and 242 'Low rise buildings on shrinkable clay soils', parts 1, 2 and 3

BRE Digest 298 'The influence of trees on house foundations in clay soils'

BRE Digest 412 'Desiccation in clay soils'

Tree Recognition - A Pocket Manual
by Ian Richardson and Rowena Gale, Richardson's Botanical Identifications, 49/51 Whiteknights Road, Reading, Berks RG6 7BB

Field Guide to the Trees of Britain and Northern Europe
by Alan Mitchell, Harper Collins, Glasgow

Geological survey maps
obtainable from British Geological Survey, Nicker Hill, Keyworth, Nottingham NG12 5GG
Tel: 0115 936 3100; www.bgs.ac.uk

Tree root damage to buildings

Vol.1 Causes, Diagnosis and Remedy
Vol. 2 Patterns of Soil Drying in Proximity to Trees on Clay Soils
by P G Biddle, Willowmead Publishing, Wantage OX12 9JA

Organisations

Arboricultural Association
Ampfield House, Ampfield, nr. Romsey, Hants SO51 9PA
Tel: 01794 368717; www.trees.org.uk

Arboricultural Advisory and Information Service
Forest Research Station, Alice Holt Lodge, Wrecclesham, Farnham, Surrey GU10 4LH
Tel: 01420 22022; www.treehelp.info
(Tree Helpline telephone no. 0906 516 1147)

Institution of Civil Engineers
1-7 Great George Street, London SW1P 3AA
Tel: 020 7222 7722; www.ice.org.uk

Institution of Structural Engineers
11 Upper Belgrave Street, London SW1X 8BH
Tel: 020 7235 4535; www.istructe.org.uk

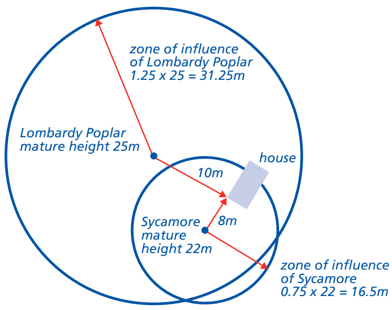
ACKNOWLEDGEMENTS

NHBC gratefully acknowledges the help given by authoritative organisations and individuals in the preparation of this Chapter, particularly:
Building Research Establishment
Dr P G Biddle Arboricultural Consultant

Appendix 4.2-F

Worked example

How to determine foundation depths from the Charts in Appendix 4.2-B or the Tables in Appendix 4.2-C.

Step		Ref	Example
1	**Determine the volume change potential of the soil**. Ensure the site investigation includes representative sampling and testing.	D5(b)	Site at Oxford, building near a Lombardy Poplar (to be retained) and a Sycamore (to be removed) From laboratory tests, **Plasticity Index, Ip = 36%.** Test results also report that 100% of particles are smaller than 425μm. Therefore, **modified Plasticity Index, $I'p = 36 \times \frac{100}{100} = 36\%$** From Table 1, **Volume change potential = Medium** (in the absence of tests assume high volume change potential) *This example is typical of Oxford Clay. More than 35% of the particles are smaller than 60μm and therefore the soil is shrinkable. 100% of the particles are smaller than 425μm and therefore the I'p is the same as the Ip.* *A typical Boulder Clay also has more than 35% of particles smaller than 60μm and is therefore also shrinkable. However, it may have only 80% of its particles smaller than 425μm in which case the I'p is 80% of the Ip.* *A typical clayey sand may have less than 30% of its particles smaller than 60μm in which case the soil would be non shrinkable.*
2	**Establish the species, mature height and water demand** of all trees and hedgerows within their influencing radii.	D5(c) and D5(d)	**Lombardy Poplar:** From Appendix 4.2-A **Mature height = 25m** **Water demand = High** **Sycamore:** From Appendix 4.2-A **Mature height = 22m** **Water demand = Moderate**
3	**Plot the trees and hedgerows relative to the foundations and draw their zones of influence** to determine which trees will affect the foundation design. Use a scaled plan.	D5(c)	
4	**Establish the appropriate tree height H to use.** Always use the mature height for remaining and proposed trees and hedgerows. The appropriate height to use for removed trees and hedgerows depends on the actual height when they are removed.	D5(d)	**Lombardy Poplar:** Tree to remain. Therefore, **H = Mature height = 25m** **Sycamore:** Tree to be removed **Mature height = 22m** **Actual height = 15m** Actual height greater than 50% mature height. Therefore, **H = Mature height = 22m**
5	**Measure the distance D** from the centre of the trees or hedgerows to the face of the foundation.	D6(c)	**Lombardy Poplar:** **Distance D = 10m from foundation** **Sycamore:** **Distance D = 8m from foundation**
6	Select Steps **6C(a) and (b)** if using **Charts in Appendix 4.2-B** to derive depths or select **Step 6T** if using **Tables** in **Appendix 4.2-C** to derive depths. Alternatively the NHBC foundation depth calculator may be used (see Sitework clause S2).		

<table>
<tr><td>6C (a)</td><td>Calculate D/H
i.e. distance D from face of foundation (Step 5) divided by the appropriate tree height H (Step 4). Alternatively D/H can be obtained from Table 13 in Appendix 4.2-B.</td><td></td><td><table><tr><td>Lombardy Poplar</td><td>Sycamore</td></tr><tr><td>$\frac{D}{H} = \frac{10}{25} = 0.4$</td><td>$\frac{D}{H} = \frac{8}{22} = 0.36$</td></tr></table></td></tr>
<tr><td>6C(b)</td><td>Determine foundation depth using the Charts in Appendix 4.2-B as follows:<table><tr><td>Volume change potential</td><td>Chart number</td></tr><tr><td>High</td><td>1</td></tr><tr><td>Medium</td><td>2</td></tr><tr><td>Low</td><td>3</td></tr></table></td><td></td><td><table><tr><td>Lombardy Poplar</td><td>Sycamore</td></tr><tr><td>In this example the volume change potential is Medium, then from Chart 2 for broadleafed high water demand trees at $\frac{D}{H} = 0.4$,

Foundation depth = 2.33m</td><td>In this example the volume change potential is Medium, then from Chart 2 for broadleafed moderate water demand trees at $\frac{D}{H} = 0.36$,

Foundation depth = 1.50m</td></tr><tr><td colspan="2">The Lombardy Poplar is the tree requiring the greater depth (2.33m)</td></tr></table></td></tr>
<tr><td>6T</td><td>Determine foundation depth using the Tables in Appendix 4.2-C as follows:<table><tr><td>Volume change potential</td><td>Tree water demand</td><td>Table number</td></tr><tr><td>High</td><td>High
Moderate
Low</td><td>14
15
16</td></tr><tr><td>Medium</td><td>High
Moderate
Low</td><td>17
18
19</td></tr><tr><td>Low</td><td>High
Moderate
Low</td><td>20
21
22</td></tr></table></td><td></td><td><table><tr><td>Lombardy Poplar</td><td>Sycamore</td></tr><tr><td>In this example the volume change potential is Medium and the water demand is High, then from Table 17, for broad leafed high water demand trees at D = 10m and H = 25m, Foundation depth = 2.33m (by interpolation)</td><td>In this example the volume change potential is Medium and the water demand is Moderate, then from Table 18, for broad leafed moderate water demand trees at D = 8m and H = 22m, Foundation depth = 1.50m</td></tr><tr><td colspan="2">The Lombardy Poplar is the tree requiring the greater depth (2.33m)</td></tr></table></td></tr>
<tr><td>7</td><td>Adjust the depth according to the climatic zone. A reduction may be made for distance north and west of London but the final depth should not be less than the minimum given in each Chart and Table.</td><td>D5(e)</td><td>Oxford is between 50 and 100 miles NW of London. From Appendix 4.2-D, a reduction of 0.05m is permitted.
Final foundation depth = 2.33 - 0.05 = 2.28m</td></tr>
<tr><td>8</td><td>Check that the recommendations of this Chapter have been met for:</td><td></td><td></td></tr>
<tr><td></td><td>Acceptable foundation types</td><td>D6(a)</td><td></td></tr>
<tr><td></td><td>New planting
(including shrubs)</td><td>D6(d),
D6(e)</td><td></td></tr>
<tr><td></td><td>Non shrinkable soil overlying shrinkable soil</td><td>D6(f)</td><td></td></tr>
<tr><td></td><td>Variations in foundation depths</td><td>D6(g),
S3(b)</td><td></td></tr>
<tr><td></td><td>Foundations on sloping ground</td><td>D6(h)</td><td></td></tr>
<tr><td></td><td>Precautions against heave
(including suspended floors)</td><td>D8,S4</td><td></td></tr>
<tr><td></td><td>Measurement of foundation depths</td><td>S3(a)</td><td></td></tr>
<tr><td></td><td>Foundation trench bottoms</td><td>S3(c)</td><td></td></tr>
<tr><td></td><td>Precautions for drainage</td><td>S5</td><td></td></tr>
</table>

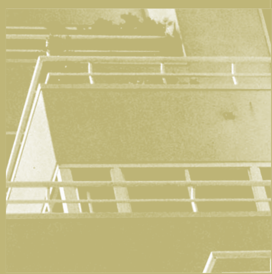
Note:
The above process may be repeated to allow the foundation to be stepped as its distance from the tree increases.

INDEX

Part 4 Foundations

Chapter 4.4

Strip and trench fill foundations



4.4 Strip and trench fill foundations

4.4

CONTENTS

SCOPE

This Chapter gives guidance on meeting the Technical Requirements and recommendations for strip and trench fill foundations.

DESIGN STANDARDS

4.4 - D1 Design shall meet the Technical Requirements

Design that follows the guidance below will be acceptable for both strip foundations and trench fill foundations.

STATUTORY REQUIREMENTS

4.4 - D2 Design shall comply with all relevant statutory requirements

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

REQUIREMENT FOR FOUNDATIONS

4.4 - D3 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 walls.

SLEEPER WALLS

In Scotland, a sleeper wall is also defined as a loadbearing element and must be provided with a suitable foundation.

In England, Wales, Northern Ireland and the Isle of Man, sleeper walls should not be built off oversite concrete:

- on shrinkable clay soils where heave could take place
- where infill below the oversite concrete is greater than 600mm
- which is less than 100mm thick.

In these situations, suitable foundations will be required.

SAFE TRANSMISSION OF LOADS

4.4 - D4 Foundations shall be designed to transmit loads to the ground safely and without excessive settlement

Items to be taken into account include:

(a) dead and imposed loads
Dead and imposed loads should be calculated in accordance with BS 6399 and BS 648.

Appendix 4.4-A shows suitable foundation dimensions and gives minimum widths of strip foundations for different sub-soil and wall loadings. Strip foundations should be 150mm to 500mm thick. Trench fill foundations should be greater than 500mm thick.

(b) stability of the dwelling and any associated constructions
Where appropriate, reference should be made to BS 8103.

Unless there are reasons for doing otherwise, foundations should be symmetrical beneath loadbearing elements.

Strip and trench fill foundations should be continuous throughout the building, including integral garages, porches, conservatories, bay windows, etc. The foundations should be of sufficient width throughout to avoid overstressing the ground, especially where the foundation is required to support piers or columns.

Reference should be made to Chapter 4.2 'Building near trees' where:

- soil is shrinkable
- trees have been, or are being, removed since heave is possible in these situations special precautions are necessary.

The width of the foundation will depend on the loadbearing capacity of the sub-soil and the loads from the building. However, the foundation width should not be less than the wall thickness, plus at least 50mm each side, to ensure that the foundation is not oversailed by any part of the wall.

(c) stability of any adjoining dwelling or construction
Foundations adjoining those of an existing building may require special design. If taken to a greater depth, such foundations will usually need to be Engineer designed and carefully supervised to check the standard of workmanship. Where necessary, allowance should be made in the design for differential movement.

DESIGN BY AN ENGINEER

4.4 - D5 Foundations on hazardous ground shall be designed by an Engineer

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

Foundations should be designed by an Engineer in accordance with Technical Requirement R5 where:

- buildings exceed 3 storeys in height
- retaining walls are required for habitable rooms below ground.

4.4 - D6 Where foundations are on hazardous ground, notice shall be given to NHBC before work starts on site

Where hazardous ground has been identified, NHBC must be notified before work starts. Hazardous ground is defined in Chapter 4.1 'Land quality - managing ground conditions'.

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."

SITE CONDITIONS

4.4 - D7 Foundation design shall take account of site conditions

Items to be taken into account include:

(a) the results of site appraisal
All relevant information about the nature and loadbearing capacity of the ground should be available before the foundations are designed.

Information about ground conditions and the past history of the site may be available from a number of sources. These include NHBC, Local Authorities and the area offices of the Gas, Water and Electricity Companies. Aerial photographs, Ordnance Survey maps and geological maps and surveys may often be studied at local Public Libraries and Record Offices.

Site assessment surveys may require supplementary site investigations involving trial pits and borings. Details are given in Chapter 4.1 'Land quality - managing ground conditions'.

(b) dwelling design and layout
Foundation design is governed by the shape and size of the dwellings as well as the site conditions. Foundations for terraced dwellings may require special precautions to prevent damage from differential settlement.

(c) site levels
Stepped foundations or suspended floors may be needed for sloping sites. Reference should be made to Clause D9 for stepped foundations and to Chapter 5.2 'Suspended ground floors' (Design).

FOUNDATION DEPTH

4.4 - D8 Foundation depth shall be adequate for the site conditions

Items to be taken into account include:

(a) soils with volume change potential
In shrinkable soils that are classified as containing more than 35% fine particles (clay and silt), and have a modified Plasticity Index of 10% or greater, the minimum foundation depth should be as in the following table:

Modified Plasticity Index	Volume change potential	Minimum depth (m)
40% and greater	High	1.0
20% to less than 40%	Medium	0.9
10% to less than 20%	Low	0.75

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

This depth should also be used when construction is undertaken during cold weather. Alternatively, precautions should be taken to prevent freezing of the ground.

(c) suitable bearing strata
The depth of foundations should be such as to give a clean, firm and adequate bearing for the design loads.

Trench fill foundations greater than 2.5m in depth must be designed by an Engineer in accordance with Technical Requirement R5.

STEPPED FOUNDATIONS

4.4 - D9 Foundations shall be taken to a suitable bearing level when building on sloping ground

Sloping ground may require stepped foundations.

Where foundations are stepped, the height of the step should not exceed the thickness of the foundation, unless it forms part of a foundation designed by an Engineer in accordance with Technical Requirement R5.

For details of stepped foundations, reference should be made to Sitework Clause 4.4 - S13(b).

SERVICES AND DRAINAGE

4.4 - D10 Foundation design shall make allowance for drainage and other services

Items to be taken into account include:

(a) ground water drainage
Provision should be made for adjusting any existing ground water drains affected by excavation work.

(b) existing services
Precautions should be taken to accommodate the effects of settlement, where drains run under or near a building.

(c) 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.

Reference should be made to Chapters 8.1 'Internal services' (Design and Sitework) and 5.3 'Drainage below ground' (Design and Sitework) for further details.

MOVEMENT JOINTS

4.4 - D11 Movement joints shall be suitable for their intended purpose

Where movement joints are specified in foundations, they should be continuous with those in the superstructure.

PROVISION OF INFORMATION

4.4 - D12 Drawings and specifications shall be produced in a clearly understandable format

It is important that all relevant information needed for the completion of the sitework is stated clearly and unambiguously and is readily available to all concerned.

All necessary dimensions and levels should be indicated and related to:
- at least one benchmark, and
- reference points on site.

All necessary details of junctions, steps, movement joints and, where necessary, any critical sequences of construction should be provided.

4.4 - D13 Designs and specifications, together with relevant site information, shall be distributed to appropriate personnel

Both designers and site operatives 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.

Information on ground conditions, the results of site investigation and the foundation design can be requested by NHBC, even for those sites which are not classified as hazardous.

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

4.4 - 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 both strip foundations and trench fill foundations.

Materials for strip and trench fill 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

4.4 - M2 Concrete shall be of a mix design which is suitable for the intended use

Items to be taken into account include:

(a) strength to safely transmit loads

(b) durability against chemical or frost action

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

REINFORCEMENT

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

Where reinforcement may be necessary, for example at construction joints or over small localised soft spots or changes in bearing strata, it should be in accordance with Chapter 2.1 'Concrete and its reinforcement' (each section).

OTHER MATERIALS

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

Proprietary materials should have been assessed in accordance with Technical Requirement R3.

SITEWORK STANDARDS

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

Sitework that complies with the design and the guidance below will be acceptable for both strip foundations and trench fill foundations.

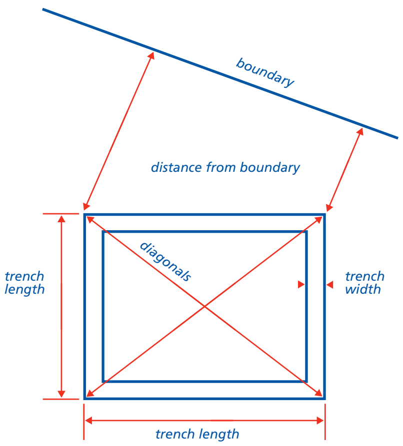
SETTING OUT FOUNDATIONS

4.4 - 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.



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

Any discrepancy in dimensions should be reported promptly to the designer. Resulting variations should be distributed to all concerned with sitework, including NHBC, where appropriate.

EXCAVATIONS

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

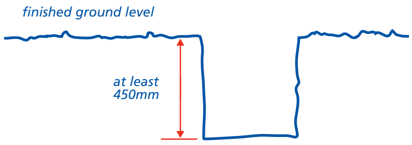
Excess excavation should be avoided. Inaccuracy may prevent walls and piers being located centrally and therefore result in eccentric loading of foundations and possible foundation failure.

Accurate trench digging is particularly important where the width of the foundation is only slightly wider than the wall to be supported.

Any ground condition that might cause the foundation design to be modified should be reported promptly to the designer.

4.4 - S4 Excavation shall be to a depth that gives adequate bearing and protection from frost damage

To avoid damage from frost action, the depth of foundation in frost susceptible ground should be at least 450mm below ground level. If finished ground level is to be above existing ground level then, in cold conditions when freezing is expected, the foundation depth should be taken from the existing, not finished, ground level.



4.4 - S5 Excavation in shrinkable soil shall take account of the foundation design

The design should specify the minimum foundation depth. In shrinkable soils, the minimum foundation depth should be as in the following table:

Volume change potential	Minimum depth (m)
High	1.0
Medium	0.9
Low	0.75

These minimum depths may only be used where any existing or proposed trees or shrubs are outside the zone of tree influence (See Chapter 4.2 'Building near trees' (Design)).

4.4 - S6 Excavations shall take account of localised effects

Where localised changes in strata give rise to differences in bearing capacity, special precautions will be necessary and reference should be made to the designer.

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

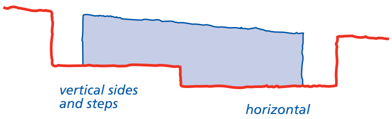
Hard spots should be removed.

Where roots are visible on the sides or bottoms of trenches (especially in clay soils), excavations may need to be taken deeper, or special precautions determined by an Engineer in accordance with Technical Requirement R5.

On sites where there are or have been trees, foundations constructed in accordance with the guidance given in Chapter 4.2 'Building near trees' will be acceptable to NHBC.

4.4 - S7 The shape of the trench shall not impair the performance of the foundation

Unless otherwise designed by an Engineer in accordance with Technical Requirement R5, trench bottoms should be horizontal with all loose material removed. Trench sides and steps should be, as near as possible, vertical.



4.4 - S8 Trench bottoms, when prepared for concreting, shall be compact, reasonably dry and even

If any part of a trench bottom is affected by rainwater, ground water or drying, it should be re-bottomed.

Trenches should be kept free of water.

SERVICES AND DRAINAGE

4.4 - S9 Existing services shall be adequately protected

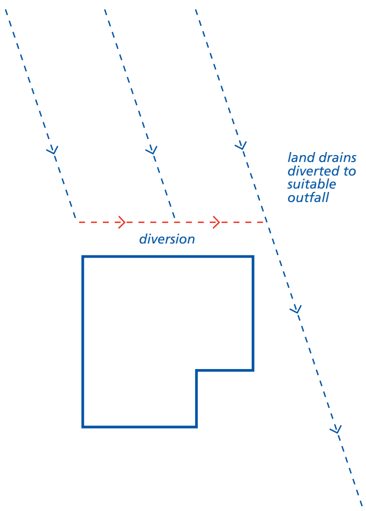
Any existing services, such as cables, water pipes or gas mains, may need to be supported and protected.

Drains which are redundant should be cut open and filled or removed.

Any existing drains should be diverted or adequately protected.

Services should not be rigidly encased in the foundations.

Ground water drains should be diverted.



4.4 - S10 Provision shall be made for service entries or services to safely pass through, or above, foundations

For details of underground drains and services, reference should be made to Chapters 8.1 'Internal services' (Design and Sitework) and 5.3 'Drainage below ground' (Design and Sitework). Reference should also be made to Chapter 5.1 'Substructure and ground bearing floors' (Design and Sitework).

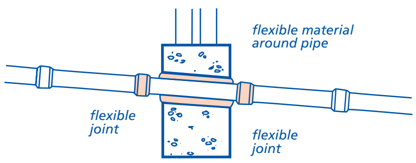
STRIP FOUNDATIONS

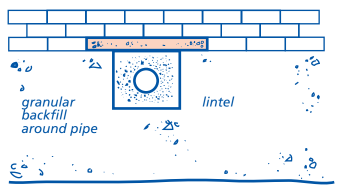
Services should not pass through strip foundations but through the masonry above. Adequate lintels should be provided in the masonry. Reference should be made to Chapter 5.1 ‘Substructure and ground bearing floors’ (Design and Sitework).

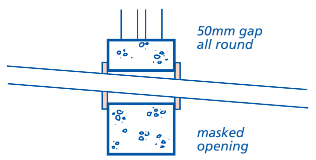
TRENCH FILL FOUNDATIONS

Where services pass through trench fill foundations, they should not affect the ability of the foundations to carry loads. Services should be either sleeved or passed through a suitably strengthened opening in the foundation. This is to ensure that differential movement will not damage services.

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.







GENERAL CONSTRUCTION

4.4 - S11 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 has been checked.

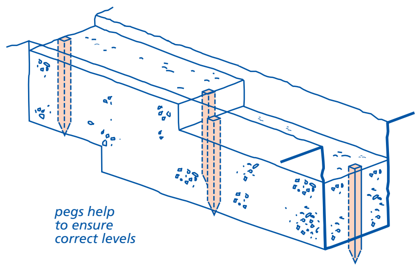
Mixing, placing, testing and curing of concrete should be carried out as indicated in Chapter 2.1 ‘Concrete and its reinforcement’ (each section), and for work carried out in cold weather, Chapter 1.4 ‘Cold weather working’.

The foundation thickness should be:

- 150mm to 500mm - for strip foundation
- not less than 500mm - for trench fill foundations.

Where trench fill foundations are in excess of 2.5m depth, they must be designed by an Engineer in accordance with Technical Requirement R5.

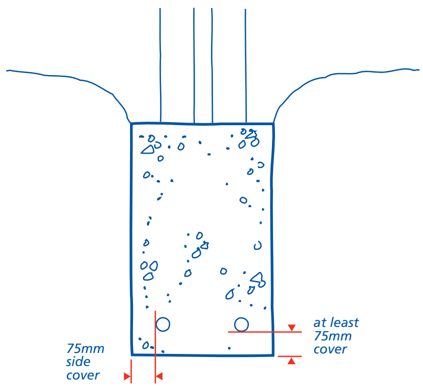
For trench fill, it is particularly important to check that the finished foundation level is correct and horizontal. It will be difficult to adjust for discrepancies in the small number of brick courses (possibly only 6) between foundation and dpc level.



4.4 - S12 Strip and trench fill foundations shall be reinforced, where necessary, to suit localised ground conditions

Reinforcement, if needed, should be clean and free from loose rust and should be placed correctly. Bars, of an appropriate size, should be properly supported to ensure that they are 75mm above the base of the foundation or as indicated in the design. They should be secured at laps and crossings.

If in doubt about any soft spots, the designer’s advice should be taken before placing the concrete.



STRIP AND TRENCH FILL FOUNDATIONS

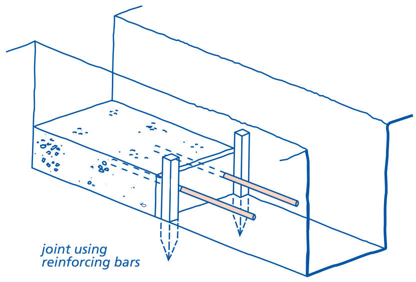
4.4 - S13 Strip and trench fill foundations shall be constructed to take account of the foundation design

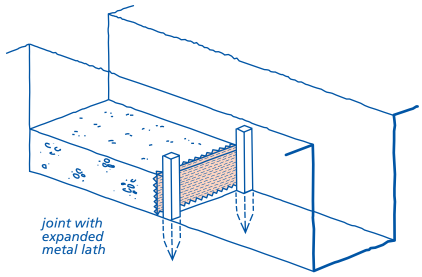
Items to be taken into account include:

(a) construction joints

STRIP FOUNDATIONS

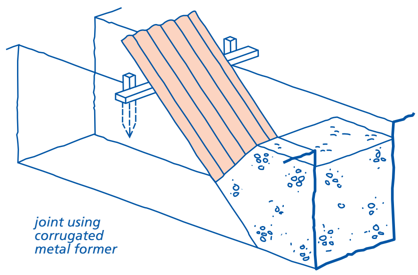
If construction joints are unavoidable, they should not be positioned near a return in the foundation. All shuttering should be removed before work continues beyond the construction joint. For strip foundations, construction joints may be formed by one of the methods shown below.

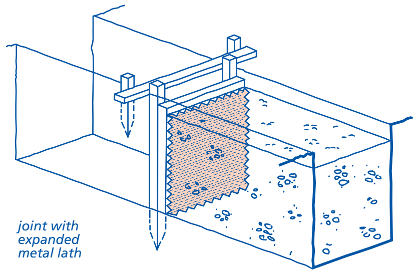




TRENCH FILL FOUNDATIONS

It is important that concrete mix, workability and placement are maintained throughout a trench fill foundation. However, where a joint is unavoidable, it should not be positioned near a return in the foundation. Before work continues beyond the construction joint, all shuttering should be removed. Construction joints may be formed by one of the methods shown below.





(b) stepping of foundations

Sloping ground may require stepped foundations.

Where foundations are stepped, the height of the step should not exceed the thickness of the foundation, unless it forms part of a foundation designed by an Engineer in accordance with Technical Requirement R5.

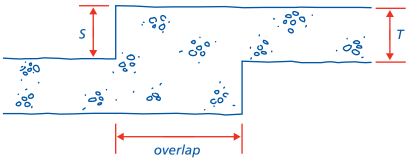
Foundation bottoms should be horizontal and steps, as near as possible, vertical.

STRIP FOUNDATIONS

The overlap should be *not less* than:

- 2 x S, or
- T (maximum 500mm), or
- 300mm,

whichever is the largest.

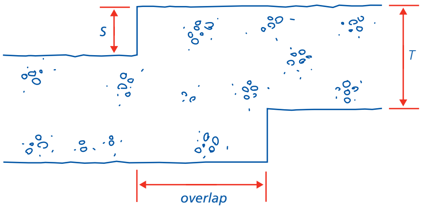


TRENCH FILL FOUNDATIONS

The overlap should be *not less* than:

- 2 x S, or
- one metre,

whichever is the larger.



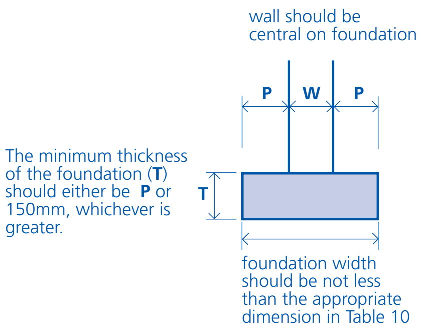
Appendix 4.4-A

Approved Document A1/2, Section 2E, specifies the size of strip foundations using Diagram 24 and Table 10.

Also see Technical booklet D of Building Regulations (N Ireland) 1990.

Strip foundations should be:
- Located centrally under the wall
- of thickness P or 150mm (whichever is greater)
- of the width shown in Table 10.

Diagram 24 Foundation dimensions



Trench fill foundations may be used as an alternative to strip foundations

Table 10 Minimum width of strip footings

Type of ground (including engineered fill)	Condition of ground	Field test applicable	Total load of load-bearing walling not more than (kN/linear metre)					
			20	30	40	50	60	70
			Minimum width of strip foundation (mm)					
I Rock	Not inferior to sandstone, limestone or firm chalk	Requires at least a pneumatic or other mechanically operated pick for excavation	in each case equal to the width of the wall					
II Gravel or Sand	Medium Dense	Requires pick for excavation. Wooden peg 50mm square in cross section hard to drive beyond 150mm	250	300	400	500	600	650
III Clay Sandy clay	Stiff Stiff	Can be indented slightly by thumb	250	300	400	500	600	650
IV Clay Sandy clay	Firm Firm	Thumb makes impression easily	300	350	450	600	750	850
V Sand Silty sand Clayey sand	Loose Loose Loose	Can be excavated with a spade. Wooden peg 50mm square in cross section can be easily driven	400	600	Note Foundations on soil types V and VI do not fall within the provisions of this section if the total load exceeds 30 kN/m			
VI Silt Clay Sandy clay Clay or silt	Soft Soft Soft Soft	Finger pushed in up to 10mm	450	650				
VII Silt Clay Sandy clay Clay or silt	Very soft Very soft Very soft Very soft	Finger easily pushed in up to 25mm	Refer to specialist advice					

This table is applicable only within the strict terms of the criteria described within it.

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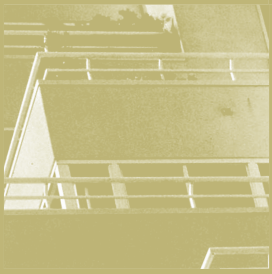
Part 4 Foundations

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 and beam foundations.

4.5

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 6399	Loading for buildings
BS 8004	Code of Practice for foundations
BS 8110	Structural use of concrete
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

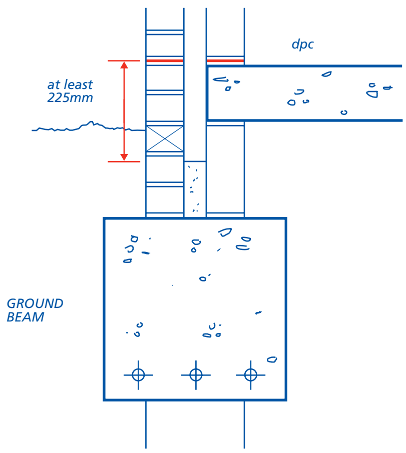
4.5 - D11 Movement joints should be suitable for their intended purpose

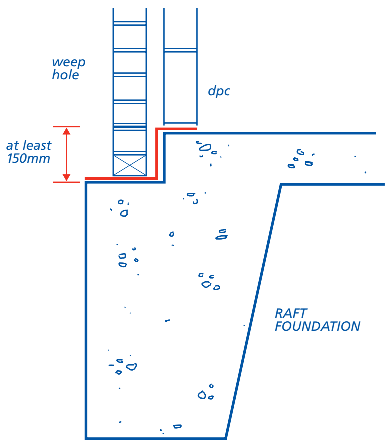
Movement joints should be located so as to limit the risk of damage caused by movement. Suitable materials are given in the Materials section.

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/mm^2 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.

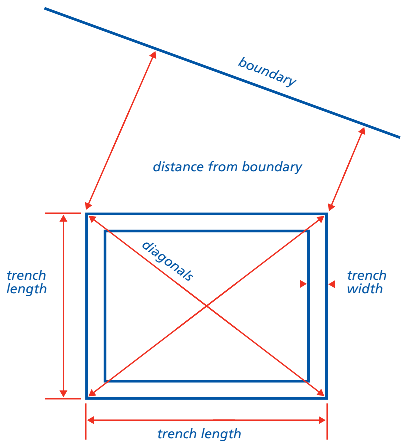
SETTING OUT FOUNDATIONS

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.

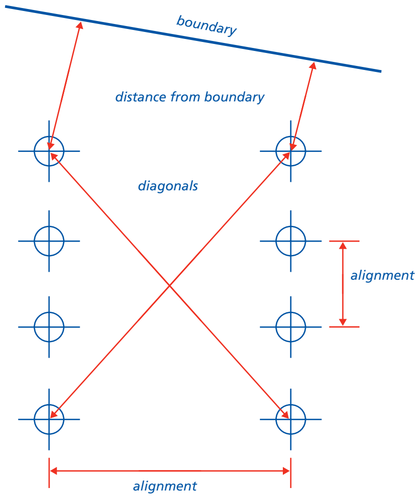


In addition, for piles, pier and beam foundations and ground improvement techniques, check:

- 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 8110.
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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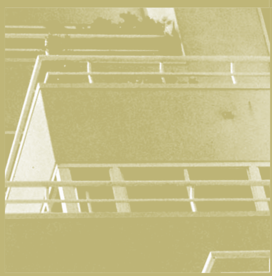
Part 4 Foundations

Chapter 4.6

Vibratory ground improvement techniques



4.6 Vibratory ground improvement techniques

4.6

CONTENTS

SCOPE

This Chapter gives guidance on meeting the Technical Requirements and recommendations for vibratory ground improvement techniques.

DESIGN STANDARDS

4.6 - D1 Design shall meet the Technical Requirements

Design that follows the guidance below will be acceptable for foundations on ground improved by vibratory techniques.

STATUTORY REQUIREMENTS AND OTHER STANDARDS

4.6 - D2 Design shall comply with statutory requirements

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

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

Relevant British Standards and Codes of Practice include:

BS 5930	Code of practice for site investigations
BS 8004	Code of practice for foundations
BS 8110	Structural use of concrete
BS 10175	Investigation of potentially contaminated sites - Code of practice.

HAZARDOUS GROUND

4.6 - D4 The design of foundations shall be undertaken by an Engineer and take account of the characteristics of the site, its ground and any hazards

The foundation design should be carried out by an Engineer in accordance with Technical Requirement R5 - see Chapter 1.1.

In this Chapter, the term "Engineer" means an engineer who is independent of the specialist contractor responsible for the vibratory ground improvement techniques.

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

4.6 - 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 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."

SITE INVESTIGATION

4.6 - D6 The Engineer shall commission a site investigation and advise the interested parties

The site investigation should take account of:

BS 5930	Code of practice for site investigations
BS 10175	Investigation of potentially contaminated sites - Code of practice.

Chapter 4.1 'Land quality - managing ground conditions'

The site investigation should at least determine:

- the depths and properties of the natural materials under the site, including the presence of caves, workings, or natural phenomena such as rocks or soils which dissolve or erode when exposed to the passage of water. The Engineer should establish the scope of, and supervise, the site investigation, taking account of the findings of the desk study. Data for comparison with post treatment properties should be established
- the extent and nature of any areas of filled ground on the site, including:
  - the proportions and distribution of constituent materials
  - the state of compaction of the fill material throughout its depth
  - the grading and particle size distribution of fill materials
  - the potential for gas generation from fill materials
  - the potential for spontaneous combustion of fill and/or natural deposits
- the presence and extent of any existing or redundant services and drains, and what information is available regarding the extent and nature of the backfill to the excavations
- the presence, level and nature of any ground water, and if it is likely to rise and cause heave or collapse by saturation
- whether the site has been previously occupied by any structure, and whether these structures have left any potential underground obstructions or hardspots, eg basement walls, floor slabs etc
- whether there are any contaminated substances or gases present or suspected.

The Specialist Contractor should be involved in the investigation.

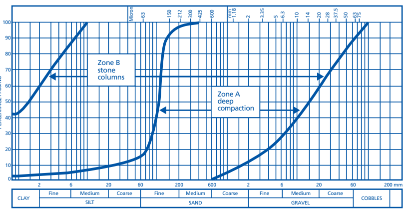
The results of the investigation should be sent to NHBC.

SUITABILITY OF GROUND CONDITIONS

4.6 - D7 The ground shall be suitable for vibratory ground improvement

The Engineer should assess the ground and be satisfied that it is suitable for treatment. Vibratory ground improvement techniques suitable for various ground conditions are detailed in Appendix 4.6-A.

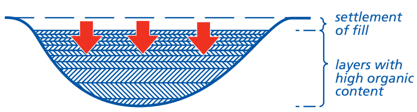
Items to be taken into account include:
(a) ground conditions acceptable for treatment
Conditions acceptable for treatment are only those within zones A and B of the chart.



Note: an enlarged chart appears in Appendix 4.6-A.

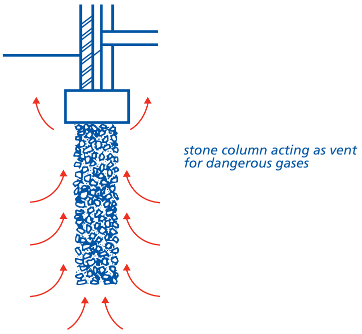
(b) ground conditions not acceptable for treatment
The following ground conditions are NOT acceptable for treatment:

- soft clays with an undrained shear strength less than 30kN/m². The wet process may be applicable to clays with a lower undrained shear strength but such sites should be examined individually. Under no circumstances can the treatment of clays with an undrained shear strength of 15kN/m² or less be accepted
- ground with peat layers close to foundation level or the base of the stone column, or where intermediate layers of peat are thicker than 200mm either as a single layer or the sum of the thicknesses of individual layers throughout the length of the stone column
- voided filled ground, eg old water tanks, pottery, glass bottles, concrete rubble or brick fill of unsuitable grading
- chalk fill or clay fills subject to:
  - collapse settlement
  - collapse caused by saturation
  - rising or fluctuating water levels
- filled ground still settling or expected to settle:
  - under its own weight
  - where there is a high organic content
  - where decay is continuing



4.6

- fill, containing degradable material where organic material forms more than 15% of fill by volume
- highly contaminated ground, eg toxic waste, or where inflammable, explosive or toxic gas generation will take place (stone columns may act as vertical vents)

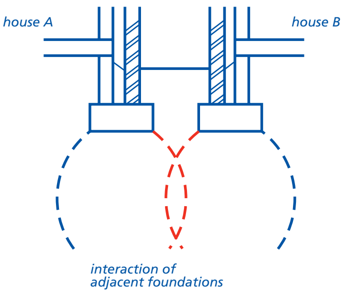


- clays with a plasticity index greater than 40%
- highly sensitive soils liable to collapse or remoulding

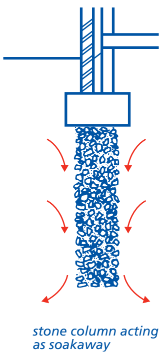
(c) detrimental factors

Factors to be considered include the following:

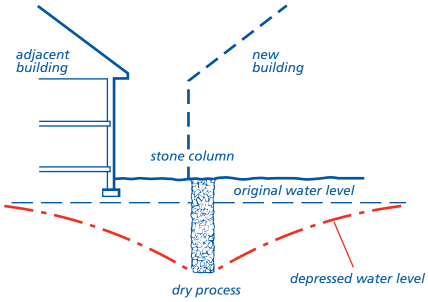
- where partial depth treatment of filled ground is proposed, the Engineer should be satisfied as to the anticipated performance of both the treated and untreated zones. The Specialist Contractor should take responsibility for the treated zone and the decision as to the depth of treatment
- the minimum depth of soil treated should allow for the interaction of adjacent foundations



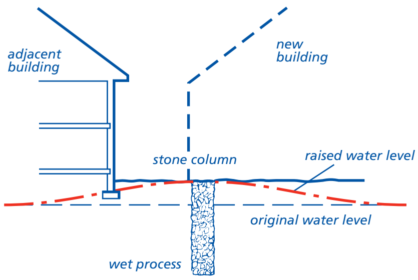
- stone columns may form vertical drains allowing the passage of water to a moisture susceptible strata, or provide seepage paths for gases



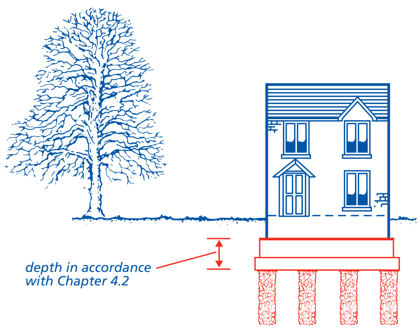
- obstructions and variations in the density of fill and natural ground (hard spots)
- alterations to the oversite level before or after treatment or disturbance of ground by excavations after treatment
- the location of changes in the profile of the natural underlying ground eg edges of pits or quarries, slopes, or manmade obstructions such as soakaways or drainage runs
- long term lowering of water table causing settlement of existing adjacent buildings



- short term rise in local water table due to large volumes of water used in wet process during construction causing settlement or heave of existing adjacent buildings



- surface water sewers should be used for rainwater disposal where possible, but where soakaways are necessary, these should be positioned so that their construction and operation is not detrimental to the treated ground
- soils with a modified Plasticity Index of 10% or greater should have foundations designed to accommodate volume changes, and the depth of concrete foundation should be in accordance with Chapter 4.2 'Building near trees'.



CONFIRMATION OF SUITABILITY OF PROPOSED TREATMENT

4.6 - D8 The builder shall obtain written confirmation from the Engineer and Specialist Contractor that the site is suitable for the proposed ground improvement system

Confirmation that the site is suitable for the proposed system should be made available to NHBC.

The Engineer and Specialist Contractor should agree the following in writing before work commences on site:

- a detailed schedule of work
- a programme of work
- what tests are to be carried out on completion of the work
- responsibility for procedures and tests.

For details of tests see Sitework clause S3.

The following should also be taken into account:

- the layout and depth of the stone columns and the accuracy to be achieved (see Sitework clause S2)
- what factors of safety have been incorporated into the design to allow for unforeseen contingencies
- the criteria for non acceptance of the vibrating poker work
- what calculations and case histories are required to justify the ground improvement proposals together with the layout of the stone columns and details of the equipment and process to be used on site.

These written agreements should be made available to NHBC before work commences on site.

COMPATIBILITY OF LAYOUT AND DESIGN FOR THE TREATED GROUND

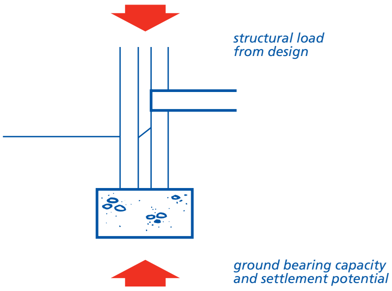
4.6 - D9 Design shall ensure that site layout and dwelling design are compatible with the treated ground

Items to be taken into account include:

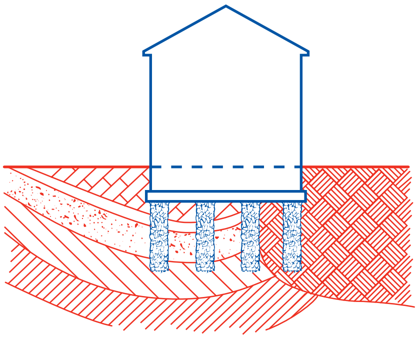
(a) limitations of the treated ground

The Engineer should:

- undertake discussion with the Specialist Contractor to confirm the feasibility of proposals
- determine the loads to be imposed by the buildings and assess against the results of the site investigation



- consider limitations of the configuration of the dwellings:
  - T-block vulnerable at junction
  - vulnerability of long blocks
- avoid siting buildings in locations where major changes in ground conditions can be expected



- advise and discuss design criteria with NHBC at the design stage.

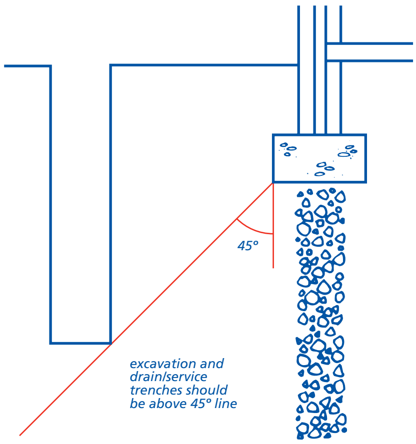
(b) limitations of ground support

The Engineer should:

- establish the likely limits of ground movement
- allow for ground movement in the design, including where appropriate:
  - position and spacing of movement joints
  - flexibility of masonry mortars
  - masonry reinforcement.

(c) drainage and service trenches

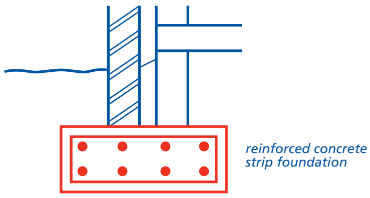
The Engineer should consider the influence of drainage and other service trenches on the stability of the complete design (see Sitework clause S4).



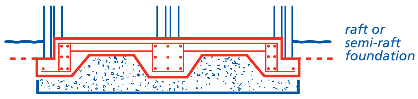
(d) suitable foundation types

The following criteria should be incorporated in the foundation design to ensure the compatibility and overall stability of the foundations and superstructure:

- only two types of foundations are suitable, both of which should comply with the minimum criteria for areas of reinforcement as defined in BS 8110. They are:
  - reinforced concrete strip foundation



  - reinforced concrete raft or semi-raft foundation positioned on a uniformly compacted bed of hardcore



- the depth of foundations to be a minimum of 600mm below the surface of the treated ground, and founded on firm material of adequate bearing capacity
- where the treated ground is of a granular nature, a reinforced concrete strip foundation will normally be acceptable provided that the full depth of all fill material is treated
- if the treated ground is of a cohesive nature, a suitably designed raft, semi-raft or reinforced concrete strip foundation will normally be acceptable. The reinforced concrete foundation should be designed to span between the centres of adjacent stone columns
- if partial depth treatment of filled ground is proposed then a suitably designed reinforced concrete raft or semi-raft foundation should be used
- if during excavations for foundations in treated ground it is found that excessive depths of concrete are required, then precautions should be taken to ensure overall stability of the foundations, and the Engineer should be satisfied that construction of the foundation will not be detrimental to the treated ground.

(e) use of suspended ground floors

Suspended ground floors should be provided for all dwellings where vibratory ground improvement has been carried out.

(f) notice to NHBC

Notice of the proposed development should be forwarded to NHBC.

Inform NHBC of the appointment of the Specialist Contractor and of the anticipated commencement date for treatment.

MATERIALS STANDARDS

4.6 - 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 use in conjunction with vibratory ground improvement techniques.

Materials for use in conjunction with vibratory ground improvement techniques shall 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).

STONE FILL

4.6 - M2 Stone fill for forming columns shall be compatible with the ground conditions, and be suitable for the vibratory ground improvement process

Stone fill should be clean, hard, inert material complying with the guidance given in Appendix 4.6-B.

In acidic ground conditions, limestone fill may not be acceptable.

Natural gravel or crushed rock aggregate of nominal single-size within the range 20-75mm will normally be acceptable.

GRANULAR MATERIAL

4.6 - M3 Granular material for raising site levels before treatment or adding during deep compaction shall:
(a) be free from hazardous materials unless appropriate precautions are taken, and
(b) be suitable for compaction

The appropriate precautions to be taken where hazardous materials are present in fill are detailed in Appendix 4.6-B.

The test requirements for fill given in Appendix 4.6-B should be followed where appropriate.

Well graded, inert fill which passes a 100mm x 100mm screen in all directions and contains less than 10% fine material of silt or clay size will normally be acceptable for raising site levels.

The grading of material for adding during deep compaction should be within Zone A of the chart shown in Design clause D7 and Appendix 4.6-A.

SITEWORK STANDARDS

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

Sitework that complies with the design and guidance below will be acceptable for vibratory ground improvement.

SITE SUPERVISION

4.6 - S2 The Builder shall ensure that the Engineer visits the site and provides competent supervision throughout the ground treatment process

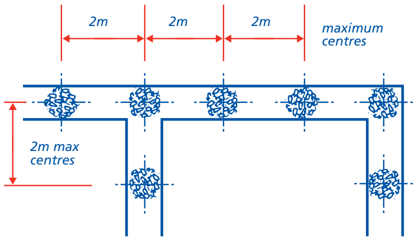
The Engineer should provide competent full time site supervision throughout the period of the ground treatment process.

Some aspects of sitework may be the responsibility of the Engineer or his representative, or of the Specialist Contractor, rather than of the Builder.

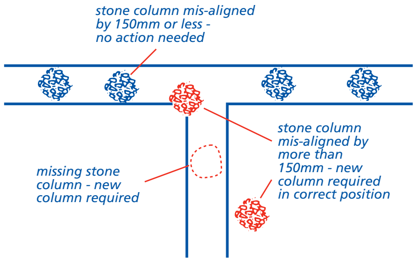
Items to be taken into account include:

(a) location, depth and alignment of columns
Supervision should be provided to ensure that:

- the minimum required depth of the stone columns is achieved, and they are correctly located. The Builder should provide sufficient profiles to enable locations to be checked
- the stone columns are located either centrally under the foundations they are to support or in the predetermined staggered arrangement, at a maximum of 2 metres centre to centre and at the intersection of adjacent reinforced concrete strips



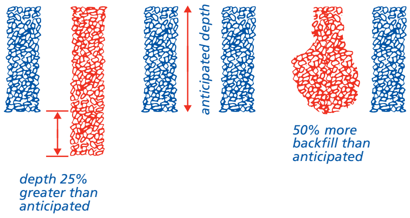
- missing stone columns are replaced
- stone columns which are misaligned by more than 150mm in any direction are replaced



- a check on the location of all stone columns is made by the Engineer's representative prior to the specialist plant leaving the site.

(b) unforeseen circumstances
Allowance should be made for:

- unforeseen changes in the site conditions, or trends which may affect site conditions. Changes should be recorded and reported to the Engineer immediately they become apparent
- changes in the anticipated depth of the compaction point in excess of 25% should be recorded and reported to the Engineer and Specialist Contractor as soon as possible but no later than the end of the day on which they occur
- variations of over 50% in the quantity of backfill used in compaction points of the same length. Variations should be recorded and reported to the Engineer and Specialist Contractor at the end of the day on which they occur
- unforeseen obstructions requiring either local removal and backfilling prior to treatment, or realignment of, and additional columns, coupled with local amendment of foundation design
- the effects of any of the above on the final efficiency of the treatment. These are to be fully considered by the Engineer and the Specialist Contractor. The Builder and NHBC are to be advised immediately about proposed remedial measures.



VERIFICATION OF COMPLETED TREATMENT

4.6 - S3 The Engineer shall require the Specialist Contractor to verify that the ground treatment is satisfactory

Items to be taken into account include:

(a) suitable testing
Tests should be carried out to establish the degree of ground improvement, its load-bearing characteristics and settlement potential.

The types of test that can be used are described in the following clauses. The Specialist Contractor should predict the results from his experience of work on the type of ground, prior to the test taking place. Prediction of the results and the degree of tolerance within those results is to be agreed with the Engineer prior to testing, and compared with the test results.

If for example a threefold improvement were predicted and only a twofold improvement achieved, this could mean that the ground was different to that indicated by the investigation, or that the treatment carried out differed from the specified treatment. In such a case, further investigation would be necessary.

Tests on ground containing clay soils may need to be delayed for a few days after the completion of treatment to allow excess pore pressures to dissipate.

The Engineer may choose any combination of the following tests:

- 600mm diameter plate tests or dummy footing tests using long stiffened steel plates
- mini zone test
- in-situ test
- trial pits
- zone test.

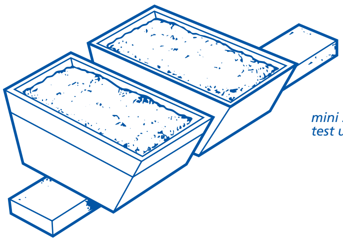
600MM DIAMETER PLATE TESTS OR DUMMY FOOTING TESTS USING LONG STIFFENED STEEL PLATES

This test will not determine the design but will allow for an assessment to be made of the workmanship on the stone columns. Plate tests should be carried out on stone columns or treated ground at a frequency of at least one test per day per rig.

MINI ZONE TEST

A mini zone test can be used as a limited substitute for zone tests. The test should be applied to at least two stone columns and the area of foundation which they support. The load may be applied through a rigid beam or stiffened plate using skips or other known loads arranged to give a uniform distribution of the load.

To be useful, mini zone tests should be continued for sufficient time for creep behaviour to be quantified and allowances for this time should be made in the overall project programme.



mini zone test using skips

IN-SITU TEST

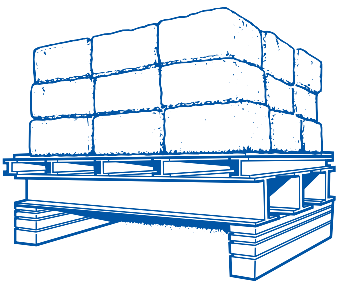
Where vibration will improve the ground itself, eg granular materials, then in-situ testing is appropriate. The improvement in density of deep fill (greater than 5m) should be checked in this manner. The improvement can be assessed when the test results are compared with the in-situ test results recorded during the pre-treatment investigation.

TRIAL PITS

Trial pits can be excavated around trial stone columns to prove that they are fully formed and to the required depth and diameter. This is a destructive test and allowance should be made accordingly.

ZONE TEST

An isolated pad or strip footing is used, and up to 8 stone columns and the intervening ground can be tested. Loadings, which must simulate the dwelling loads, are held for 24 hours at pre-determined stages to examine creep behaviour.



zone test

(b) written confirmation of completed treatment

On completion of the treatment the Engineer should:

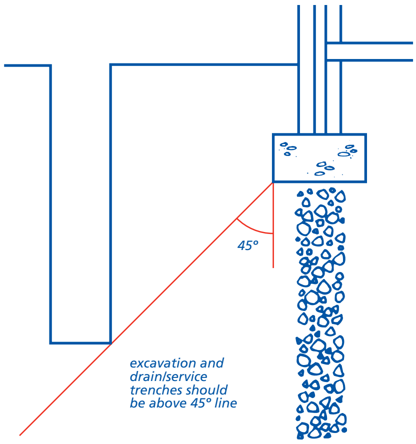
- from the results of the tests carried out satisfy himself that the treated ground has achieved the anticipated condition assumed in his design
- once satisfied with the effectiveness of the treatment in relation to the design, advise the Builder and NHBC accordingly in writing
- advise the Builder of any special precautions which should be taken for the positioning of services both beneath the dwelling and adjacent to it.

(c) record of the work

A comprehensive record of all works including information concerning the treatment, depth of fill, volume of stone used, on-site changes and all other relevant information, should be made available to NHBC.

4.6 - S4 The Builder shall ensure that treated ground is not disturbed by subsequent excavations

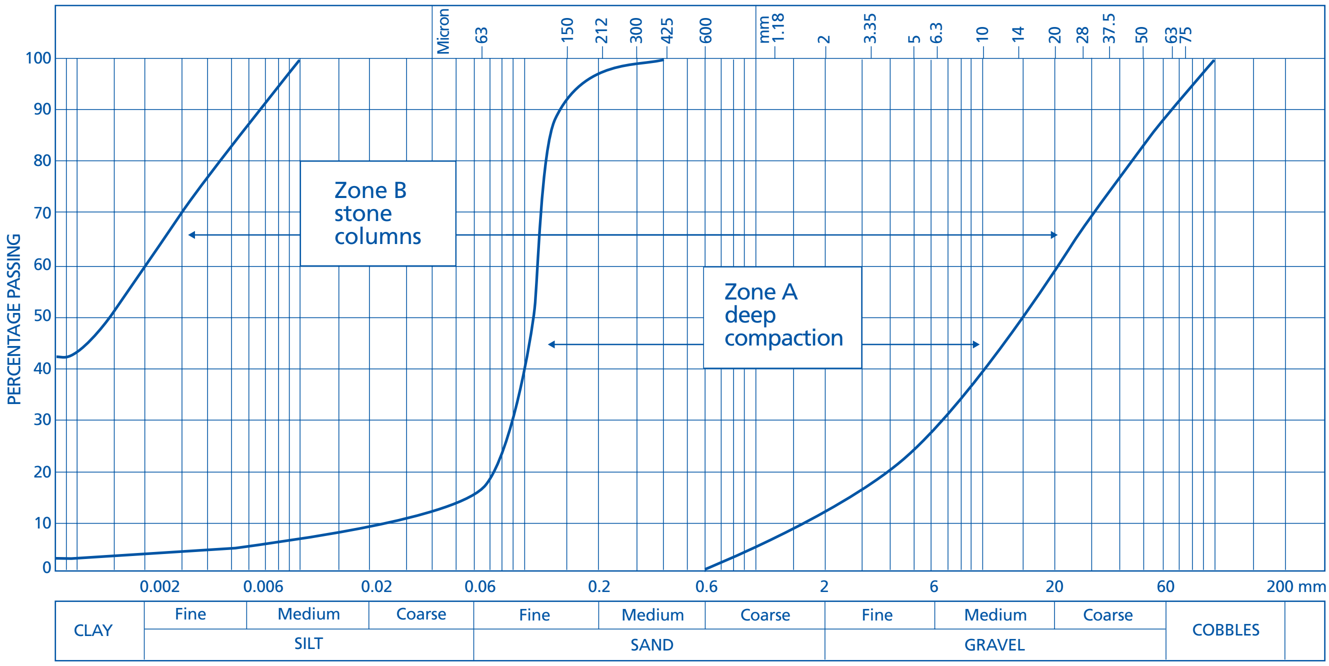
Ensure that the minimum clearance between excavations and foundations is not less than the depth of excavation minus the depth of the structural foundation.



Appendix 4.6-A

SOIL CLASSIFICATION CHART

Conditions acceptable for treatment are only those within zones A and B of the chart.



Vibratory techniques

The vibratory process is applied usually to weak natural soils and filled ground. The purpose is to improve the load bearing capacity, reduce settlement and provide an adequate bearing stratum for the foundation supporting the dwelling.

A decision to buy a hazardous site is an acceptance by the builder/developer of the risks involved. It is important that the ground hazards are assessed before buying the site, and that allowance is made in foundation design for any consequences of this assessment.

Hazardous sites are defined in NHBC Rules.

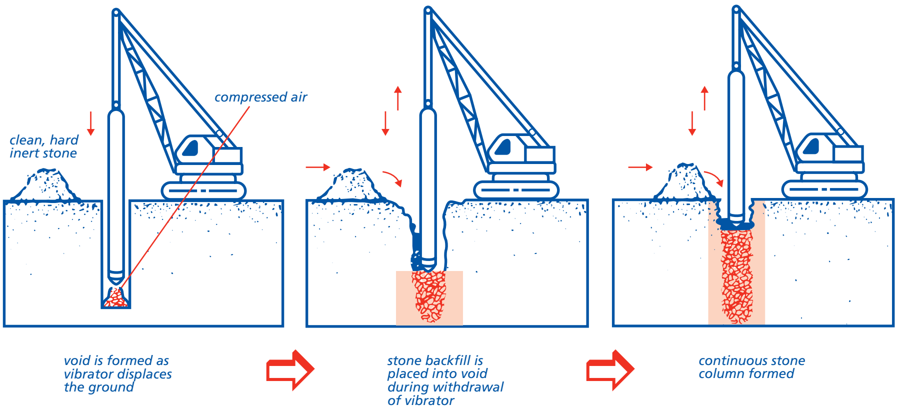
ACCEPTABLE METHODS

Several vibratory techniques are acceptable. Some use a vibrating poker suspended from a crane. The poker penetrates the ground under its own weight aided by horizontal vibration and thus forms a void. Other techniques use an impact hammer system to form and compact stone columns. The two common techniques are:

Stone columns - Dry process

(applicable to soft clays and silts and to inorganic filled ground)

The poker is withdrawn to leave a void which is partially filled with stone. The poker is then reintroduced and used to compact the stone and the surrounding strata. This process is repeated until the whole void is filled with compacted stone and the surrounding existing granular strata increased in density. Penetration of the poker is assisted by compressed air delivered to the nose of the vibrator which also releases suction on withdrawal.

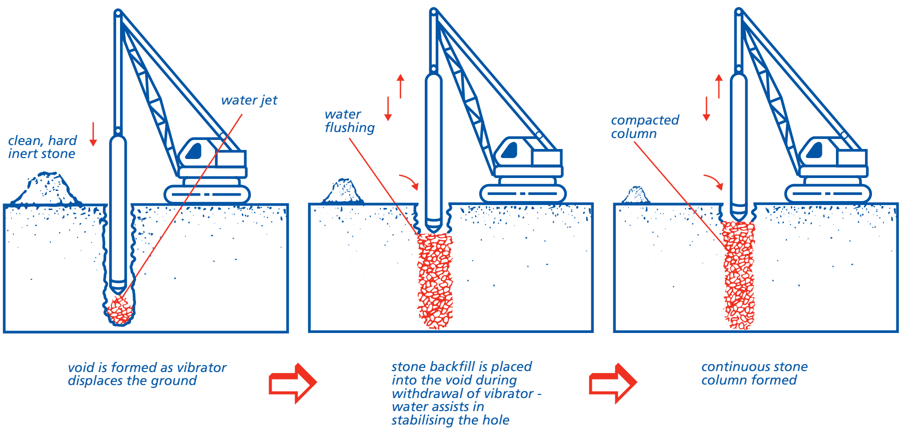


Stone columns - Wet process

(applicable to soft clays and silts and to inorganic filled ground, and where the water table is high)

The process is similar to the dry process except that water is used to maintain ground stability and to keep the stone 'clean' while it is being placed and compacted.

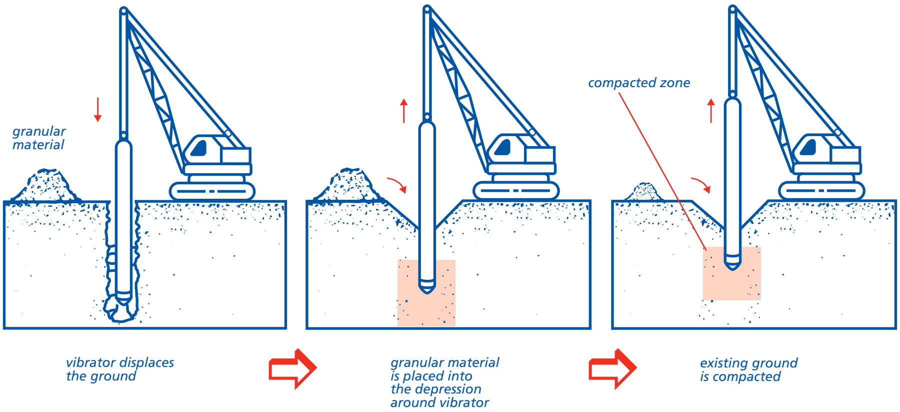
Note: Special bottom feed pokers or choke tubes which introduce stone into the void via the end of the poker or tube are available. These use compressed air as a flushing medium but can be used in weak ground or ground with a high water table.



A third technique is:

Deep Compaction
(applicable to saturated fine sands, which are rarely found in the UK)

After penetration the poker is withdrawn in stages and compacts the existing strata. Granular material is introduced in a similar manner to the wet and dry process. Water flushing, where excess water drains into sands, can assist this process.



Alternative systems, methods or variations to those given in this Chapter must be shown to be suitable for their purpose and for the conditions for which they are intended, prior to acceptance by NHBC.

On completion of the vibratory ground improvement, the combined ground/column system offers support to the foundations for the proposed structures. The application of vibratory techniques improves the strength of the combined ground/column system and the stiffness by between two and three times in clay soils. Settlements of the treated area may therefore be reduced to between half and a third of the magnitude of that which would otherwise occur.

Note: The stone columns produced by vibratory techniques are not piles and should never be considered so. Stone columns derive their capacity by interacting with the surrounding ground. Piles are more than 10 times stiffer than stone columns.

The compaction is localised and could be variable. Reinforced foundations are needed.

It should not be assumed that all of the surrounding ground has been improved.

Appendix 4.6-B

MATERIALS FOR USE AS FILL

Hazardous materials
The following materials require testing to ensure their suitability for use as fill to support structural foundations and slabs or as backfill to associated trenches:

- acid wastes
- reactive materials
- materials that include sulfates (eg gypsum)
- organic materials
- toxic materials
- materials that cause noxious fumes, rot, undue settlement or damage to surrounding materials.

Test requirements
Tests should be carried out by a suitably qualified person with a detailed knowledge of:

- the material to be tested, and
- the proposed conditions of use.

The samples tested must be representative of the true nature of the material. It may be necessary to take a number of samples to find out the material characteristics of the fill.

Sulfate content should be expressed as a percentage SO_4 by weight on the basis of acid soluble testing, taking full account of the recommendations of BRE Digest 363 and BS 5328 Part 1.

Sources of fill material
Where the material is of a stable and uniform type from one source, it may only be necessary to check its suitability once. If material is variable, or from a number of sources, it should all be suitable. Regular inspections and/or testing may be required.

Where industrial waste is permitted as fill material, it is essential that sufficient testing is carried out to ensure suitability.

Where material is obtained from stockpiles, check the material is uniform. Different forms of stockpiling can affect particle size/grading. The outside of a stockpile may be weathered and may not be the same as unweathered material.

Fill requiring NHBC approval
The following types of fill should not be used unless written permission has been obtained from NHBC:

- colliery shale and any other residue from mineral extraction
- slags
- furnace ashes and other products of combustion
- material obtained from demolition
- on wet sites, or sites with a high water table, crushed or broken bricks which have no limit on their soluble salt content (as defined in BS EN 771).

Expansive materials
Fill containing expansive materials is not acceptable for use as support to structural foundations and slabs or as backfill to associated trenches.

4.6

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