PERMIT

Part 4 Foundations

Chapter 4.2

Building near trees



4.2 Building near trees

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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.

Damage should be avoided by erecting suitable fencing to create a tree protection zone for each remaining tree and ensuring this zone is left undisturbed during construction work.

Further guidance is given in BS 5837 and Appendix 4.2-E.

(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 and Appendix 4.2-E. 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.

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

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

[redacted] leafed

[redacted] lars and

[redacted] ers.

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

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

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.

[redacted]

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

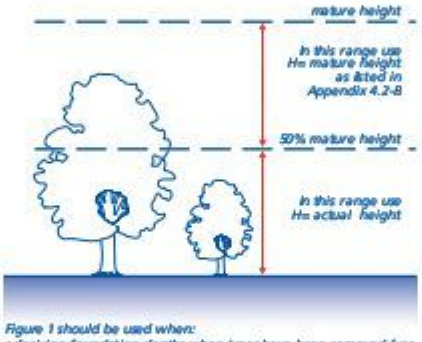


Figure 1 should be used when:
• deriving foundation depths when trees have been removed (use tree height at time of removal - see Design clause 4.2 - D5(a.i))
• checking the appropriate level from which depths should be measured when trees remain and ground levels are increased (use tree height at time 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 [redacted]ng garages, porches and [redacted]atories) should take account of [redacted]cts of soil desiccation caused by [redacted]s or existing trees and trees which [redacted]eduled to be planted.

[redacted]owing 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	
Mode	
Low	

Table 5 Minimum foundations depths outside zone of influence

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

(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

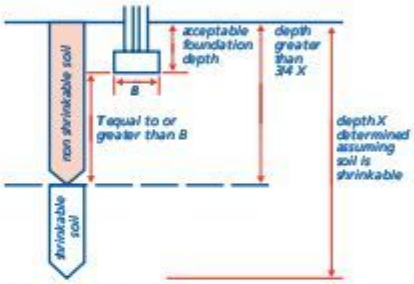
Non shrinkable soils such as sands and gravels may overlie shrinkable soil.

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:

- [redacted]itions exist across [redacted]uld be confirmed by [redacted]n
- [redacted]n 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.

[redacted]

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
[redacted]
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'.

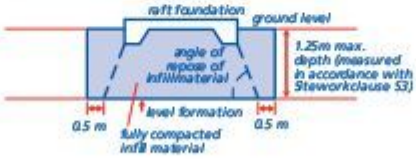
Reference should be made to Clause D8 to establish the precautions necessary to cater for potential heave.

(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
[redacted]
he infill extends beyond the edge of the oundation by a distance equal to the atural 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:

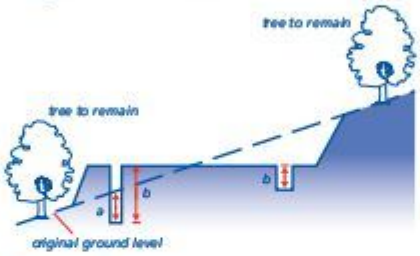
(a) measurement of foundation depths

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.

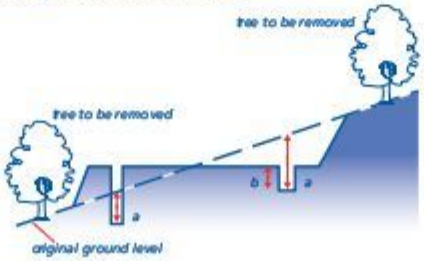
Where ground levels are reduced or increased (either in the recent past or during construction) foundation depths should be measured as shown in Figures 5 to 7.

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



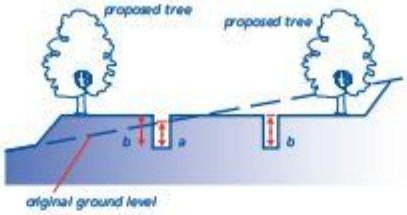
Use the lower of:
a: foundation depth based on appropriate tree height (see Figure 8)
b: foundation depth based on mature height of tree

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

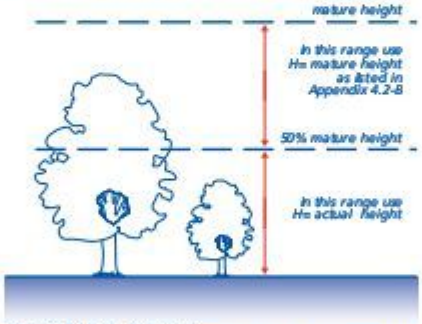


Figure 8 should be used when:
- *deriving foundation depths when trees have been removed (use tree height at time of removal - see Design clause 4.2 - D5(a))*
- *checking the appropriate level from which depths should be measured when trees remain and ground levels are increased (use tree height at time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

Table 8 Minimum foundation depths

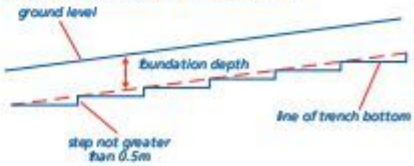
Volume change potential	Minimum depth [m]
High	1.0
Medium	0.9
Low	0.75

(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

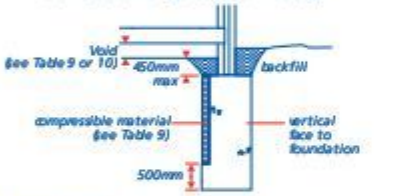
Heave precautions should be provided as shown in Figure 10.

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.

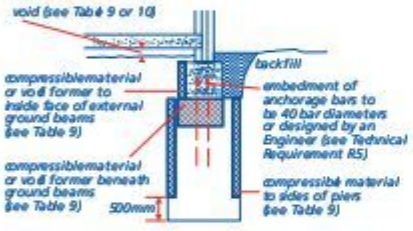
Compressible material should be provided against all faces of the pier foundation which are greater than 1.5m deep based on the appropriate tree height (see Figure 8).

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

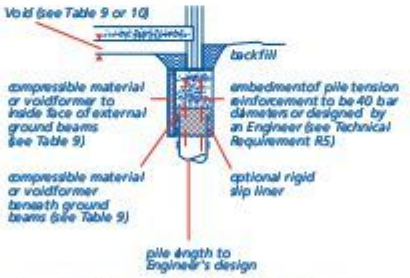
Heave precautions should be provided as shown in Figure 12.

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-F).

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))

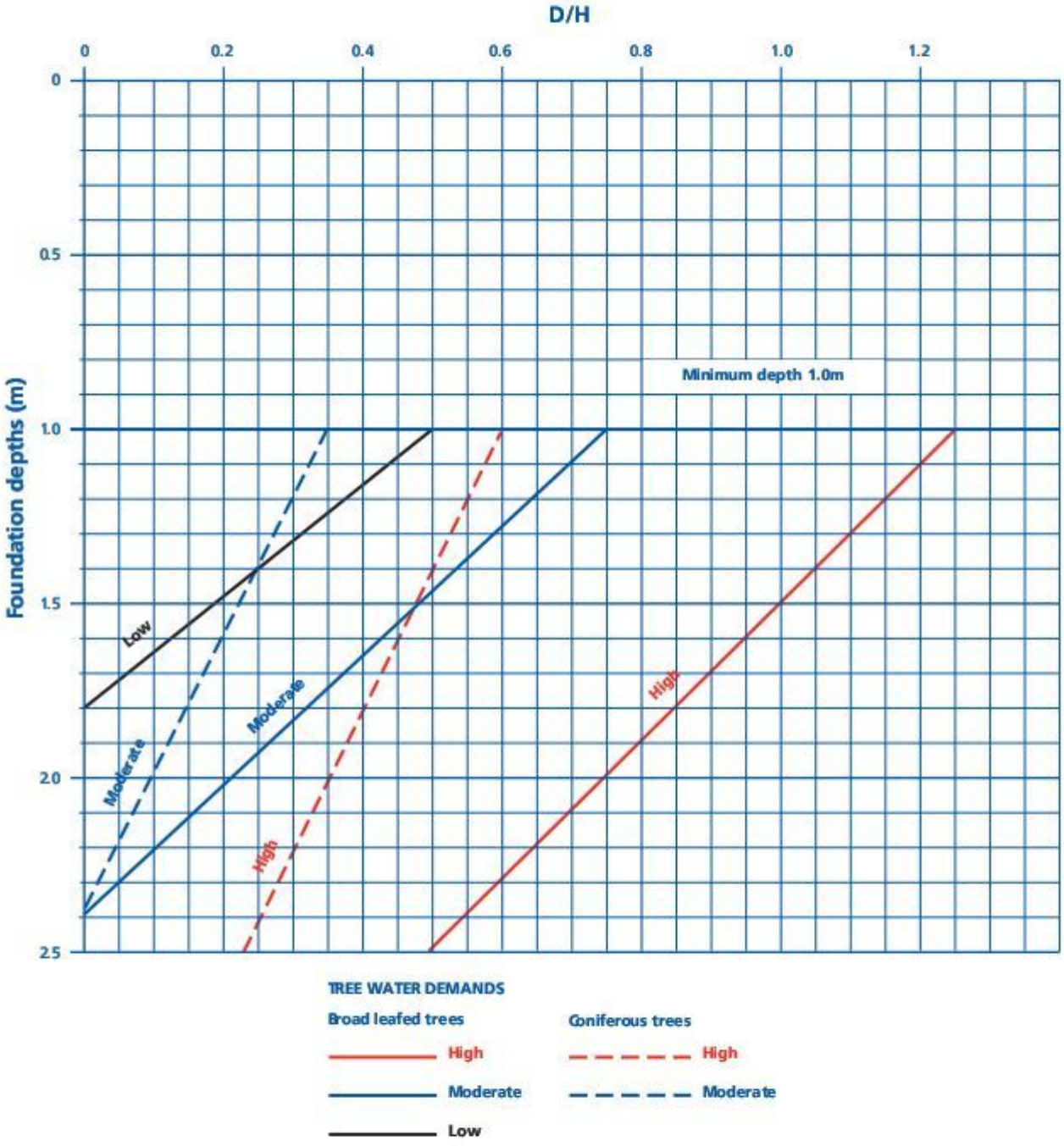


Chart 2 Soils with MEDIUM volume change potential: Modified Plasticity Index between 20% and less than 40%
(see Design clause D5(b))

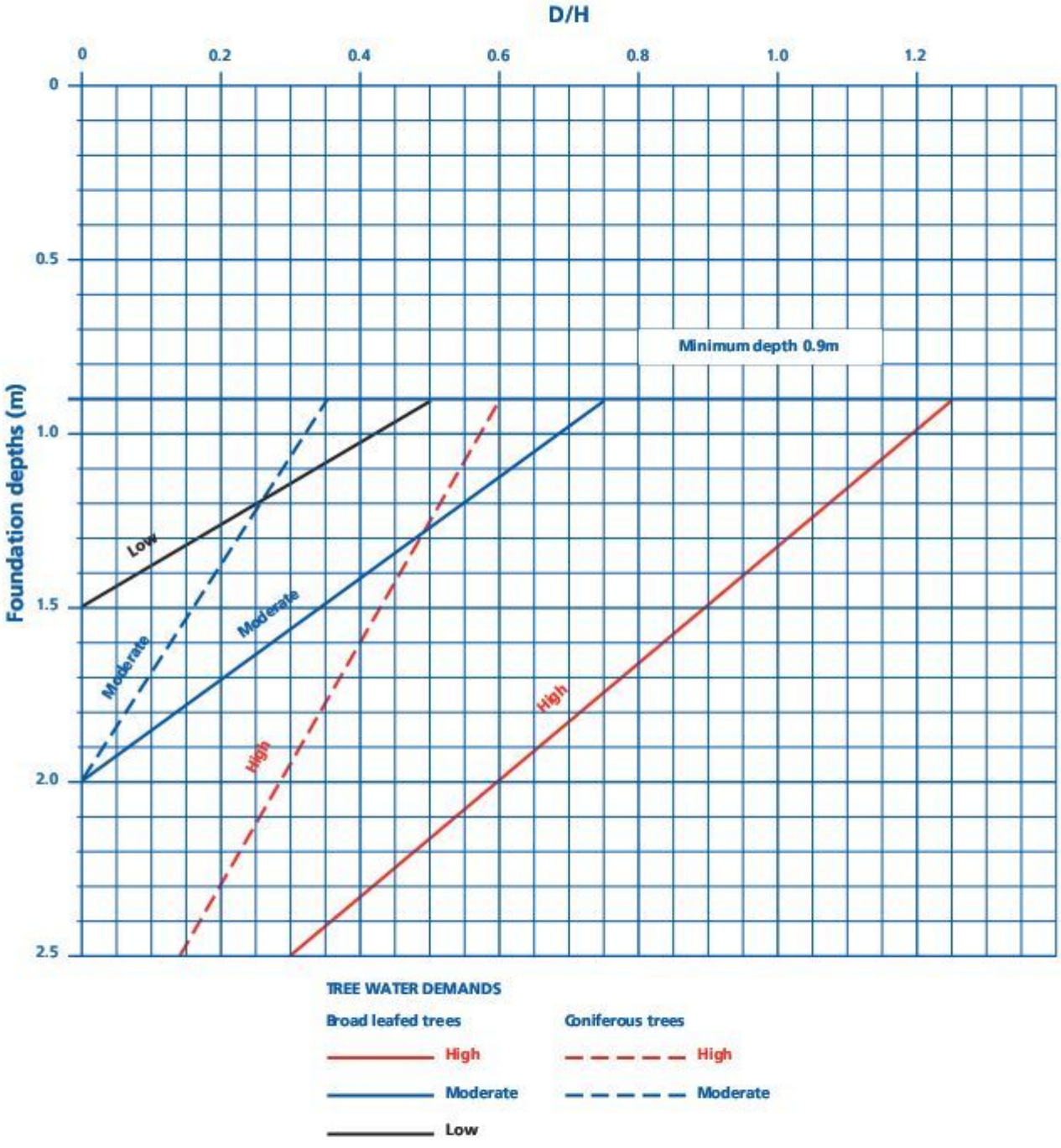
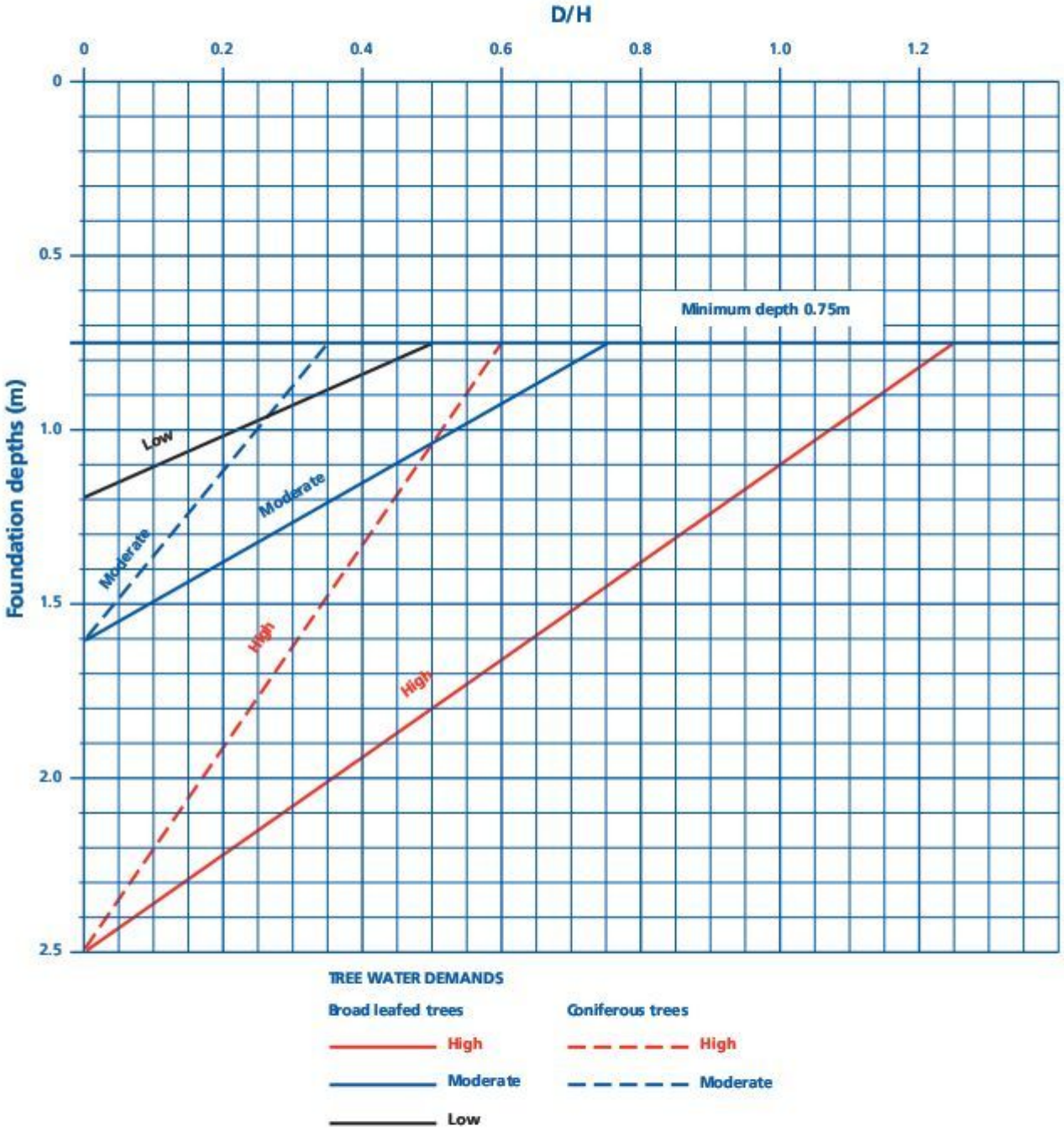


Chart 3 Soils with LOW volume change potential: Modified Plasticity Index 10 to less than 20%
(see Design clause D5(b))



Appendix 4.2-C

Foundation depth tables

Table 14 - HIGH shrinkage soil and HIGH water demand tree

Broad leafed trees

Foundation depth (m)												
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

Foundations greater than 2.5m deep to be Engineer designed

10m 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	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												
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32												
33												
34												
35												
36												
37												
38												

Foundations greater than 2.5m deep to be Engineer designed

10m minimum foundation depth

Table 15 - HIGH Shrinkage soil and MODERATE water demand tree

Broad leafed trees

Distance D (m)	Foundation depth (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		10m minimum foundation depth									1.00	1.10
22											1.00	1.05
23												1.00

Coniferous trees

Distance D (m)	Foundation depth (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		10m minimum foundation depth										
22												
23												

Table 16 - HIGH shrinkage soil and LOW water demand tree

Broad leafed trees

Distance D (m)	Foundation depth (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		10m minimum foundation depth								1.00	1.10	1.15
14											1.00	1.05
15												1.00

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						Foundations greater than 2.5m deep to be Engineer designed							
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		0.9m minimum foundation depth									0.90	1.00
37											0.90	0.95
38												0.90

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								Foundations greater than 2.5m deep to be Engineer designed				
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		0.9m minimum foundation depth										
37												
38												

Table 18 - MEDIUM shrinkage soil and MODERATE water demand tree

Broad leafed trees

Distance D (m)	Foundation depth (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		0.9m minimum foundation depth									0.90	1.00
22											0.90	0.95
23												0.90

Coniferous trees

Distance D (m)	Foundation depth (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		0.9m minimum foundation depth										
22												
23												

Table 19 - MEDIUM shrinkage soil and LOW water demand tree

Broad leafed trees

Distance D (m)	Foundation depth (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		0.9m minimum foundation depth								0.90	0.95	1.00
14											0.90	0.95
15												0.90

Table 20 - LOW shrinkage soil and HIGH water demand tree

Broad leafed trees

Distance D (m)	Foundation depth (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		075m minimum foundation depth									0.75	0.80
38												0.75

Coniferous trees

Distance D (m)	Foundation depth (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		075m minimum foundation depth										
38												

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		075m minimum foundation depth									0.75	0.85
22											0.75	0.80
23												0.75

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		075m minimum foundation depth										
22												
23												

Table 22 - LOW shrinkage soil and LOW water demand tree

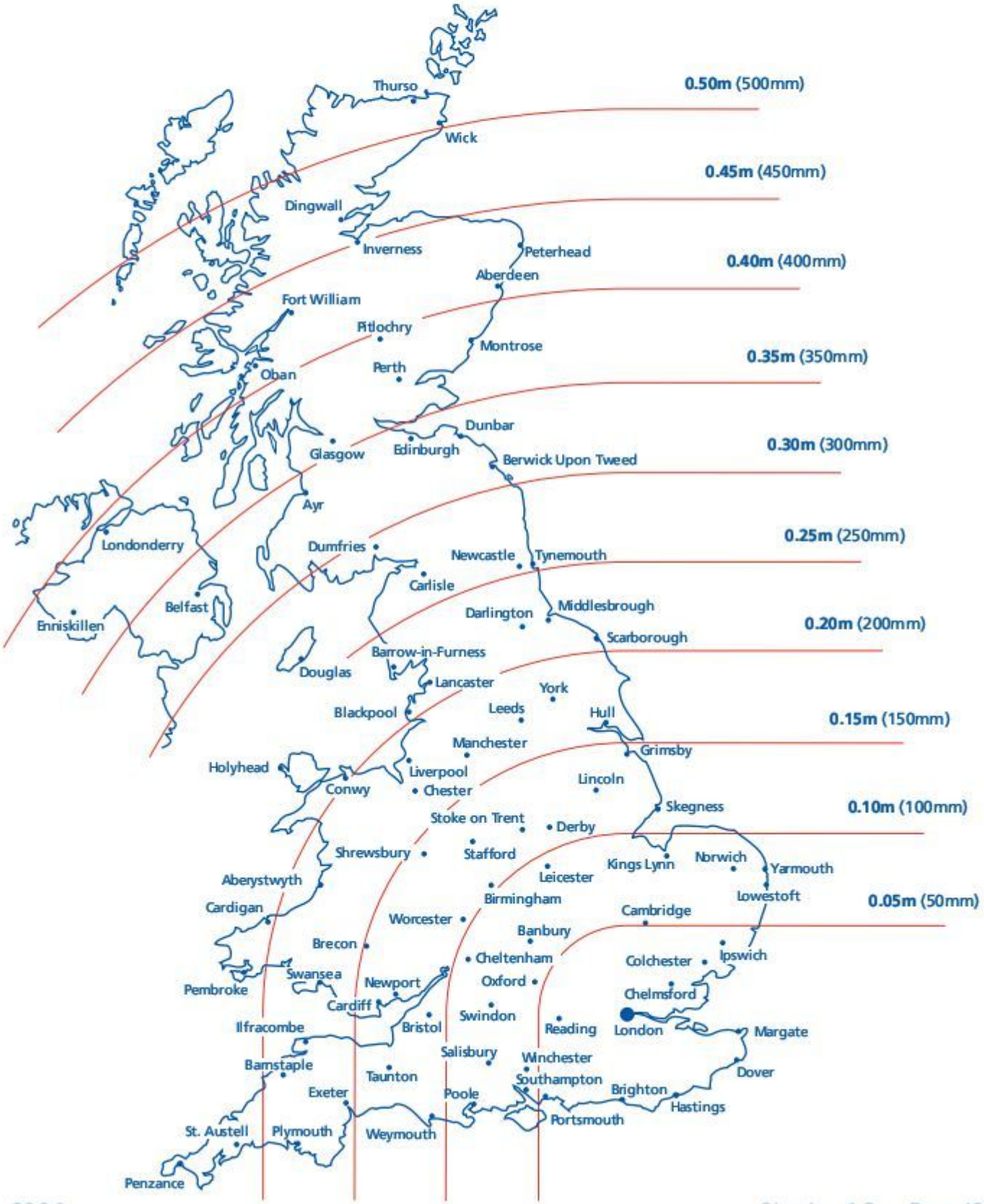
Broad leafed trees

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		075m minimum foundation depth								0.75	0.80	0.85
14											0.75	0.80
15												0.75

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

Damage to trees by construction work derived from BS 5837 : 1991

In order to avoid unacceptable damage as a result of construction activities, an area around each remaining tree should be protected from disturbance by fencing. This should not be removed or breached during construction operations without prior consultation with an arboricultural specialist. The fencing should protect as large an area around the tree as possible after consideration of all construction operations in its vicinity. The minimum distance left to be undisturbed around the tree is given in the table below.

Protection of trees: minimum distances for protective fencing around trees

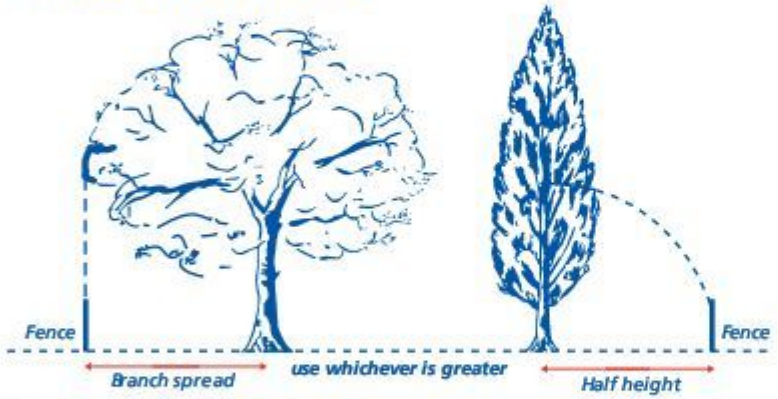
Tree age	Tree vigour	Trunk diameter (mm)	Minimum distance (m)
Young trees (age less than 1/3 expectancy)	Normal vigour	< 200 200 to 400 > 400	2.0 3.0 4.0
Young trees	Low vigour	< 200 200 to 400 > 400	3.0 4.5 6.0
Middle age trees (1/3 to 2/3 life expectancy)	Normal vigour	< 250 250 to 500 > 500	3.0 4.5 6.0
Middle age trees	Low vigour	< 250 250 to 500 > 500	5.0 7.5 10.0
Mature trees	Normal vigour	< 350 350 to 450 > 750	4.0 6.0 8.0
Mature trees and overmature trees	Low vigour	< 350 350 to 750 > 750	6.0 9.0 12.0

Note:

1 It should be emphasised that this table relates to distances from centre of tree to protective fencing. Other considerations, particularly the need to provide adequate space around the tree including allowances for future growth and working space will usually indicate that the structures should be further away.
2 With appropriate precautions, temporary site works can occur within the protected area, e.g. for access or scaffolding.
3 If it is deemed acceptable for construction works to occur closer than the minimum distance, the distance can be reduced by up to one third on one side only. If distances are reduced in this way, a corresponding increase in distances should be made in other directions.

As an alternative, the fencing may be erected below the outermost limit of the branch spread, or at a distance equal to half the height of the tree, as illustrated below. The distance by this method will usually be significantly greater than the distances in the table above.

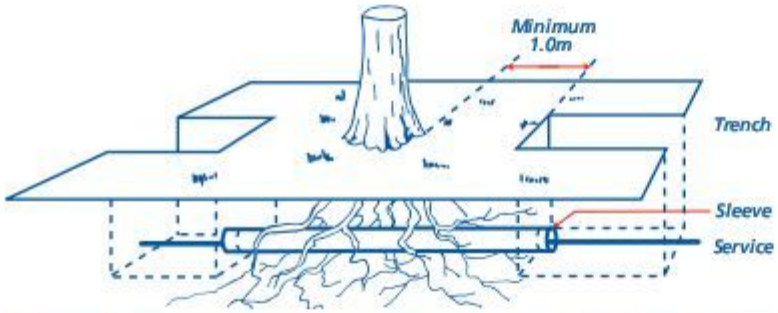
Alternative location for protective fencing



Trenching along radii to minimise damage

If it proves essential for a service trench to be taken closer to a tree than the minimum distance in the above table, root damage can be minimised by either:

- thrust boring a hole for the service, or
- radial trenching and tunnelling as illustrated below.



If building closer than the distances recommended in the table below, precautions should be taken to allow for future growth of the tree.

Minimum distance (m) between centre of tree and structure to allow for future tree growth

Type of structure	Mature height of tree		
	Up to 8m	8m to 15m	over 15m
Buildings and heavily loaded structures	-	0.5	1.2
Lightly loaded structures such as garages, porches, etc.	-	0.7	1.5
Drains and underground services			
< 1m deep	0.5	1.5	3.0
> 1m deep	-	1.0	2.0
*Masonry boundary walls	-	0.5	1.0
	-	(1.0)	(2.0)
*In-situ concrete paths and drives	-	0.5	1.5
	(0.5)	(1.0)	(2.5)
*Paths and drives with flexible surfaces or paving slabs	-	0.5	1.0
	(0.7)	(1.5)	(3.0)

*These distances assume that some movement and minor damage might occur. Guidance on distances which will generally avoid all damage is given in brackets.

Further information can be obtained by reference to BS 5837.

Appendix 4.2-F

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

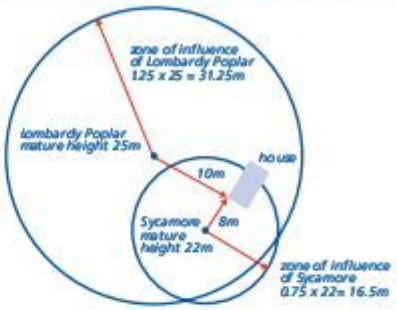
Institution of Structural Engineers
11 Upper Belgrave Street, London SW1X 8BH
Tel: 020 7235 4535; www.istructe.org.uk

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Building Research Establishment
Dr P G Biddle Arboricultural Consultant

Appendix 4.2-G

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 x 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:

Acceptable foundation types

New planting
(including shrubs)

Non shrinkable soil overlying shrinkable soil

Variations in foundation depths

Foundations on sloping ground

Precautions against heave
(including suspended floors)

Measurement of foundation depths

Foundation trench bottoms

Precautions for drainage</td>
<td>

D6(a)

D6(d),
D6(e)

D6(f)

D6(g),
S3(b)

D6(h)

D8,S4

S3(a)

S3(c)

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.

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