Chapter

4.2

Building near trees

This chapter gives guidance on meeting the Technical Requirements 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 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.

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

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 deeper 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.**

4.2.1 Compliance

Also see: Chapter 2.1

When building near trees, hedgerows or shrubs, all foundations shall comply with the Technical Requirements.

Foundations near trees, hedgerows or shrubs that comply with the guidance in this chapter will generally be acceptable.

4.2.2 Provision of information

Designs and specifications shall be produced in a clearly understandable format, include all relevant information and be distributed to appropriate personnel.

The site plan should show the trees and hedgerows that affect the ground and works, as well as the type, depth and dimensions of the foundations that fall within their influence. Where trees or hedgerows are either not shown or are in different positions and shrinkable soil is identified, it may be necessary to adjust the foundation depths on site.

All necessary dimensions and levels should be indicated and relate to at least one benchmark and reference points on the site. Details should be provided with respect to:

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

4.2.3 Building near trees

Also see: Technical Requirements R5 and BS 5837

When building near trees, hedgerows or shrubs, the designs shall take account of:

a) physical growth of young trees
b) protection of remaining trees and hedgerows
c) removal of existing trees and hedgerows.

Before the site is cleared, a survey is required to record the location, heights and species of trees, hedgerows and shrubs on and adjacent to the site, which may affect the proposed development.

If the location of previously removed vegetation is not known, local enquiries and reference to aerial photographs should be carried out. Alternatively, the design should assume the worst conditions, or an engineer consulted to undertake a site-specific design based on all relevant information and in accordance with Technical Requirement R5.

Where root growth is noted within shrinkable soil and where records are not available, an engineer should be consulted to assess whether volume change is likely.

Physical growth of young trees

Damage to foundations resulting from the growth of trees and roots should be avoided by locating structures and services at a safe distance. Where this cannot be achieved, precautions which allow for future growth should be taken which include:

- reinforcing foundations to resist lateral forces
- bridging walls or structural slabs over the roots, allowing sufficient clearance or reinforcing to avoid cracking
- laying paving and other surfaces on a flexible base to allow for some movement.

Protection of remaining trees and hedgerows

Roots often extend to distances in excess of the height of the tree, the majority are within 600mm of the surface and project radially. All parts of the system are easily susceptible to damage which may not regenerate and which can affect the stability of the tree.

This 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
- the compaction of soil around trees by heavy plant
- the storage of heavy materials around trees
- covering the 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.

Removal of existing trees and hedgerows

Statutory Requirements, planning conditions, conservation area restrictions or tree preservation orders may result in protected trees and hedgerows being retained. The local planning authority should be consulted.

Dead trees and hedgerows should be removed. Unstable trees should be made steady or felled. If necessary, specialist advice should be obtained from a registered arboriculturalist.

4.2.4 The effects of trees on shrinkable soils

Foundations shall be designed to make allowance for the effect of trees, hedgerows and shrubs on shrinkable soils. Items to be taken into account include:

a) soil classification, shrinkage and heave
b) water demand, tree heights and zone of influence of trees
c) climate.

Soil classification, shrinkage and heave

Shrinkable soils, that are widely distributed throughout the UK, often change volume as moisture content fluctuates seasonally and as a result of factors, including the action of tree roots. The resulting shrinkage or swelling can cause subsidence or heave damage to foundations, the structures they support and services.

The following definitions are used to classify soil properties:

Shrinkable soils	Over 35% fine particles and a Modified Plasticity Index of 10% or greater
Fine particles	Nominal diameter less than 60μm, ie, clay and silt particles
Plasticity Index (Ip)	A measure of volume change potential 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 and the smaller particles analysed. This is a requirement of BS 1377 which specifies the test procedure
Modified Plasticity Index (I'p)	Defined as the Ip of the soil multiplied by the percentage of particles less than 425μm $I'p = \frac{Ip \times \%\ \text{less than } 425\mu m}{100\%}$

Table 1: Modified Plasticity Index related to 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.

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 results are representative. High volume change potential should be assumed if the volume change potential is unknown.

Water demand, tree heights and lateral zone of tree influence

Water demand varies according to tree species and size. Water demand categories of common tree species are given in the table below.

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 assumptions about water demand as listed in Table 2 may be made for broad-leafed trees:

Table 2: Water demand of broad-leaf trees by species

Tree species	Water demand
All elms, eucalyptus, hawthorn, oaks, poplars and willows	High water demand
All others	Moderate water demand

Table 3 shows the water demand categories and the average mature heights to which healthy trees of the species may be expected to grow in favourable ground and environmental conditions. This information:

- should be used for trees that are to remain or are scheduled to be planted
- may be used even when actual heights are greater.

Table 3: Water demand of tree species in relation to their height

High water demand species	Mature height (m)	Moderate water demand species	Mature height (m)	Low water demand species	Mature height (m)
Broad-leafed trees:					
English elm	24	Acacia (False)	18	Birch	14
Wheatley elm	22	Alder	18	Elder	10
Wych elm	18	Apple	10	Fig	8
Eucalyptus	18	Ash	23	Hazel	8
Hawthorn	10	Bay laurel	10	Holly	12
English oak	20	Beech	20	Honey locust	14
Holm oak	16	Blackthorn	8	Hornbeam	17
Red oak	24	Japanese cherry	9	Laburnum	12
Turkey oak	24	Laurel cherry	8	Magnolia	9
Hybrid black poplar	28	Orchard cherry	12	Mulberry	9
Lombardy poplar	25	Wild cherry	17	Tulip tree	20
White poplar	15	Horse chestnut	20		
Crack willow	24	Sweet chestnut	24		
Weeping willow	16	Lime	22		
White willow	24	Japanese maple	8		
		Norway maple	18		
		Mountain ash	11		
		Pear	12		
		Plane	26		
		Plum	10		
		Sycamore	22		
		Tree of heaven	20		
		Walnut	18		
		Whitebeam	12		
Coniferous trees:					
Lawson's cypress	18	Cedar	20		
Leyland cypress	20	Douglas fir	20		
Monterey cypress	20	Larch	20		
		Monkey puzzle	18		
		Pine	20		
		Spruce	18		
		Wellingtonia	30		
		Yew	12		

Tree identification can be assisted by reference to a tree recognition book. Information may be obtained from suitable alternative authoritative sources for trees not listed in this chapter.

When the species is known but the subspecies is not, the greatest height listed for the species should be assumed.

Where hedgerows contain trees, their effect should be assessed separately and the height of the species likely to have the greatest effect should be used.

Table 3a provides guidance to be used in assessing the effects of trees and their water demand when they are subjected to heavy crown reduction or removal. 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.

Table 3b, on the other hand gives the lateral extent of the zone of influence of trees. So any foundation located within these zones will be influenced by the tree and should be designed to meet the requirements of this chapter.

Table 3a: Guidance for factors affecting the mature height and water demand of trees

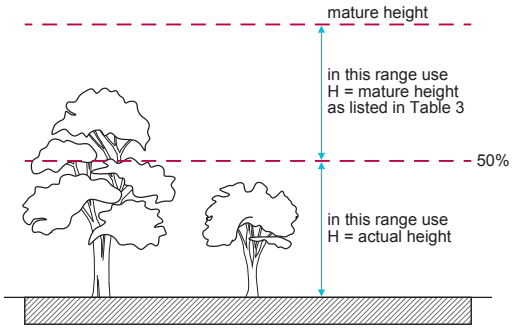
Influencing factor	Guidance
Heavy crown reduction or pollarding (previously or planned)	The mature height should be used, or a registered arboricuturalist should be consulted to undertake a site-specific assessment.
Removal of trees (previously or planned)	The water demand of a semi-mature tree may be equal to that of a mature tree, though for a sapling or young tree will be significantly less.
	
	Height H should be determined in accordance with this diagram when: • deriving foundation depths when trees have been removed, based on tree height at the time of removal • checking the appropriate level from which depths should be measured when trees remain and the ground level is increased, based on tree height at time of construction relative to original ground level – see Fig 1 of clause 4.2.9 b, or • determining if heave precautions are to be provided, based on tree height at time of construction – see clause 4.2.10 d

Table 3b: Zone of influence (lateral extent) of trees

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

Climate

High rainfall reduces moisture deficits caused by trees and hedgerows, while cool, damp weather reduces the rate of water loss from trees thus reducing the risk of soil movement.

The driest and hottest areas in the UK generally exist in southeast England; therefore, the greatest risk occurs in that area and diminishes with distance north and west. A 50mm decrease can be made to the foundation depth determined in accordance with this chapter for every 50 miles distance north and west of London. Where it is unclear which zone applies, the lower reduction value should be used.

4.2.5 Foundations in all soil types

Foundations in all soil types shall be appropriately designed and constructed to transmit loads to the ground safely and without excessive movement.

Different foundation types should not be used to support the same structure unless the foundation and superstructure design are undertaken by an engineer.

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

4.2.6 Excavation of foundations

Also see: Chapter 4.1, 4.3, 4.4, 4.5 and Technical Requirement R5

Excavation of foundations shall take account of the design and be suitable to receive concrete.

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

Foundation depths should be measured on the centre line of the excavation and from ground level determined from Clause 4.2.9.

Some root activity may be expected below the depths determined in accordance with this guidance. However, if significant quantities of roots are unexpectedly encountered in the base of the trench, an engineer should be consulted to determine if the excavation should be deepened.

4.2.7 Foundations in shrinkable soils

*Also see: NHBC Foundation Depth Calculator App: **www.nhbc.co.uk/apps***

Foundations shall be capable of accommodating the effects of trees, shrubs and hedgerows on shrinkable soils without excessive movement. Items to be taken into account include:

a) foundation type
b) distance between tree and foundation
c) method of assessment of foundation depths
d) foundation depths related to the zone of influence of new tree planting
e) foundation depths related to new shrub planting.

Landscape and foundation designs should be compatible, and planting schedules produced by a qualified landscape architect or other suitably qualified person and agreed with the local planning authority before work commences on site.

Foundation type

Foundations to all permanent structures, including garages, porches and conservatories, should take account of the effects of soil desiccation. Foundation types that are acceptable in shrinkable soils include strip, trench fill, pier and beam, pile and beam, and raft, providing they:

- are capable of supporting the applied loads without undue settlement
- include suitable heave precautions.

Variations to the foundation depths derived from this chapter may be permitted where:

- it is necessary to take account of local ground conditions
- other foundation depths are traditionally acceptable
- designed in accordance with Technical Requirement R5.

Root barriers are not an acceptable alternative to the guidance given.

Distance between tree and foundation

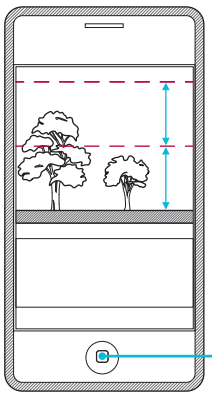
The distance (D) between the centre of the trunk and the nearest face of the foundation should be used to derive the foundation depths.

D = 2m where trees which have been, or are to be, removed from within 2m of the face of the proposed foundation are less than 50% of the mature height as given in Table 3. This is to avoid a 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.

Method of assessment of foundation depths

Foundation depths should be determined according to the guidance provided in this document. If in doubt, assume the worst conditions or consult an engineer. Foundations deeper than 2.5m should be designed by an engineer in accordance with Technical Requirement R5.

One of the following methods may be used to assess the foundation depth where foundations are in the zone of influence of existing or proposed trees.



Foundation Depth Calculator App.
www.nhbc.co.uk/apps

Method	Taking account of	Comments
Design in accordance with this chapter to a depth derived from the charts in Clause 4.2.12, tables in Clause 4.2.13 or the Foundation Depth Calculator App	• site investigation • soil volume change potential • water demand of the tree • appropriate tree height (H) • distance (D) of the tree(s) from the foundations • geographical location of the site north and west of London • appropriate heave precautions	The most onerous conditions should be assumed in the absence of derived information
Design by an engineer in accordance with Technical Requirement R5	• the recommendations of this chapter • site investigation • advice, when necessary, from a registered arboriculturalist or other competent person whose qualifications are acceptable to NHBC	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 prior to work commencing on site

Foundation depths related to the zone of influence of new tree planting

Foundation depths relating to the zone of influence of proposed tree planting should be in accordance with any of the following:

- foundation depth charts in Clause 4.2.12
- tables in Clause 4.2.13
- the Foundation Depth Calculator App.

Minimum foundation depths outside of the zone of influence of trees can be determined from Tables 4 and 5.

Table 4: Minimum foundation depths

Volume change potential	A) Minimum foundation depth (m) (allowing for restricted new planting)	B) Minimum foundation depth (m) (where planting is outside the zone of influence of trees)
High	1.50	1.0
Medium	1.25	0.9
Low	1.0	0.75

Table 5: Where foundation depths are in accordance with column A or column B in Table 4, tree planting should be restricted to:

Water demand	No tree planting zone for column A in Table 4	No tree planting zone / zone of influence for column B in Table 4
High	1.0 x mature height	1.25 x mature height
Moderate	0.5 x mature height	0.75 x mature height
Low	0.2 x mature height	0.50 x mature height

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 in accordance with Table 6.

Table 6: Shrub planting

Volume change potential	A) Minimum foundation depth (m)	B) Minimum foundation depth (m)
High	1.50	1.0
Medium	1.25	0.9
Low	1.0	0.75

The foundation design should consider shrub planting as follows:

Shrubs that have a maximum mature height of 1.8m	Use foundation depth from column **B**
Climbing shrubs which require wall support and have a maximum mature height of 5.0m	Use foundation depth from column **B**
Pyracantha and cotoneaster whose mature height exceeds 1.8m	Use foundation depth from column **B** and plant at least 1.0 x mature height from foundation, or use foundation depth from column **A** and plant at least 0.5 x mature height from foundation
All others	Use foundation depth from column **B** and plant at least 0.75 x mature height from foundation, or use foundation depth from column **A** with no restriction on minimum distance from foundation

4.2.8 Design and construction of foundations in shrinkable soils

Also see: BRE Digest 298, Chapters 4.3, 4.4 and Technical Requirement R5

Foundations in shrinkable soils shall be appropriately designed and constructed.

Reference should be made to Clause 4.2.10 to establish the precautions necessary to cater for potential heave.

The following will only be acceptable if they are designed by an engineer and account for all potential movement of the soil on the foundations and substructure:

- trench fill foundations deeper than 2.5m
- pier and beam foundations
- pile and beam foundations
- rafts.

Trench fill foundations

If trench fill foundations are deeper than 2.5m:

- the instability of the trench sides can lead to serious construction difficulties
- the design should take account of plot specific soil desiccation and the associated arboricultural advice
- additional heave precautions may be necessary to cater for lateral and shear forces acting on large vertical areas of foundation
- concrete overspill or overbreak in excavations should be avoided in order to reduce the possibility of additional vertical forces being transmitted to the foundation
- compressible material should be correctly placed to avoid excessive heave forces being applied to the foundations
- construction joints need to be detailed to account for increased lateral forces.

Pier and beam foundations

Pier depths not exceeding 2.5m depth may be derived from Clause 4.2.7. Pier depths greater than 2.5m require site specific assessment.

Pile and beam foundations

When selecting and designing pile and ground beam foundations, piles should be:

- designed with an adequate factor of safety to resist uplift forces on the shaft due to heave
- reinforced for the length of the member governed by the heave design.

Sufficient anchorage should be provided below the depth of desiccated soil. Slip liners may be used to reduce uplift but the amount of reduction is small, as friction between materials cannot be eliminated.

Bored, cast-in-place piles are well suited to counteracting heave. Most types have a straight-sided shaft, while some are produced with a contoured shaft to increase load capacity. The design should allow for the enhanced tensile forces in these piles.

Driven piles are less well suited to counteracting heave and are difficult to install in stiff desiccated clay without excessive noise and vibration. The joint design of these piles should be capable of transmitting tensile heave forces.

Ground beams should be designed to account for the upward forces acting on their underside and transmitted from the compressible material or void former prior to collapse, and in accordance with the manufacturer's recommendations.

Raft foundations

Raft foundations in shrinkable soils will only be acceptable where all of the following apply:

- design is by an engineer in accordance with Technical Requirement R5
- NHBC is satisfied that the raft is sufficiently stiff to resist differential movements
- NHBC is satisfied that the raft is founded on granular infill placed and fully compacted in layers and in accordance with the engineer's specification. Where required by NHBC, site inspections are to be undertaken by the engineer to verify suitable compaction of the fill
- the raft is generally rectangular in plan with a side ratio of not more than 2:1
- foundation depth is derived in accordance with Clause 4.2.7, and is less than 2.5m.

4.2.9 Foundation depths for specific conditions in shrinkable soils

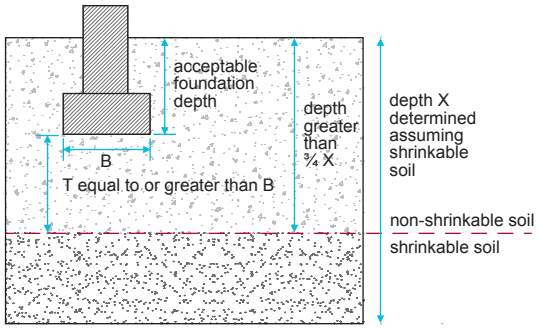
Foundations in shrinkable soils shall be designed to transmit loads to the ground safely and without excessive movement. Items to be taken into account include:

a) strip and trench fill foundations in non-shrinkable soils overlying shrinkable soil
b) measurement of foundation depths
c) granular infill beneath raft foundations in shrinkable soils
d) steps in foundations.

Strip and 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 overlying non-shrinkable soil if all the following are satisfied:

- conditions of Chapter 4.3 'Strip and trench fill foundations' are met
- consistent soil conditions exist across each plot and this is confirmed by the site investigation
- depth of the non-shrinkable soil is greater than ¾ foundation depth X, where X is the foundation depth determined using charts in Clause 4.2.12, tables in Clause 4.2.13 or the Foundation Depth Calculator App, assuming all the soil is shrinkable
- the thickness T of non-shrinkable soil below the foundation is equal to, or more than, the width of the foundation B
- proposals are submitted to, and approved by, NHBC prior to work commencing on site.



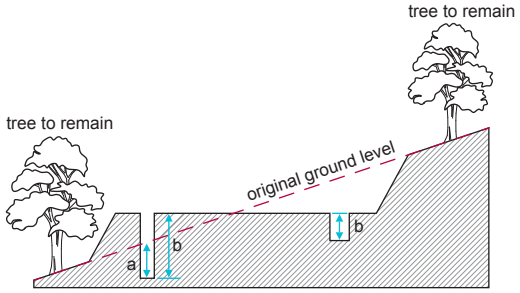
Where any of the above are not met foundation depths should be determined as for shrinkable soil.

Measurement of foundation depths

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

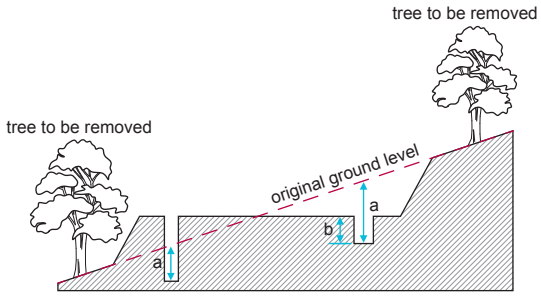
Measurement of foundation depths where ground levels are reduced or increased, either in the recent past or during construction, should be as shown in figures 1, 2 and 3.

Figure 1: Levels from which foundation depths are measured where trees or hedgerows are to remain



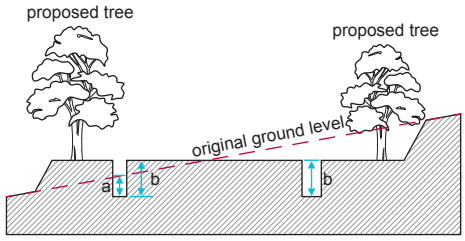
Use the lower of:
a) foundation depth based on appropriate tree height (see Table 3a)
b) foundation depth based on mature height of tree.

Figure 2: 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 Table 3a)
b) minimum foundation depth (see Table 4 column B).

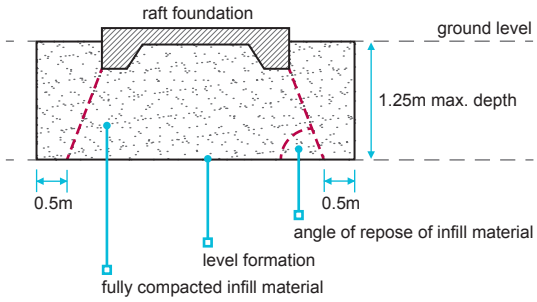
Figure 3: Levels from which foundation depths are measured where trees or hedgerows are proposed



Use the lower of:
a) minimum foundation depth (see Table 4 column B)
b) foundation depth based on mature height of tree.

Granular infill beneath raft foundations in shrinkable soils

Granular infill together with raft slab foundation can be used as an alternative to deep trench fill foundation. Where adopted, granular infill should be placed beneath raft foundations on shrinkable soils as shown below.



Infill should:

- be at least 50% of the foundation depth determined for a trench fill foundation and not more than 1.25m deep (measured from ground level determined in accordance with 4.2.9b)
- extend beyond the edge of the foundation by a distance equal to its natural angle of repose, plus 0.5m.
- be placed in accordance with specification within Chapter 4.6 'Engineered fill'.

Steps in foundations

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

Where foundations are to be stepped to take account of the influence of trees, hedgerows and shrubs, they should be stepped gradually, with no step exceeding 0.5m.

4.2.10 Heave precautions

Also see: BRE Digests 240 & 241; Chapter 2.1 and BS 5837

Foundations, substructures and services shall be suitably designed and detailed to prevent excessive movement due to heave. Heave precautions shall be incorporated into foundations and substructures in accordance with the design. Items to be taken into account include:

a) potential for ground movement
b) minimum void dimensions
c) proprietary heave materials
d) heave precautions for foundations
e) other foundation types
f) suspended ground floors
g) paths and driveways.

Where foundations and substructure may be subject to heave, they should be protected by voids, void formers or compressible materials.

Where proprietary materials are used, the design of foundations and substructure should take into account the upward force transmitted through the compressible material or void former prior to collapse (refer to manufacturer's data).

This section provides guidance on heave precautions for common building elements when located within the influence of trees which are to remain or be removed, including:

- trench fill foundations
- pier and beam foundations
- pile and beam foundations
- other foundation types
- paths and driveways
- new drainage.

Potential for ground movement

After the felling or removal of trees and hedgerows on shrinkable soils, heave can occur, as the absorbed moisture causes swelling. Heave can also occur beneath a building where:

- roots are severed
- water enters the ground from leaking drains and services
- there are changes in ground water conditions.

Minimum void dimensions

Voids should be provided to accommodate movement due to heave forces acting against foundations and suspended ground floors in accordance with Table 7.

Table 7: Void dimensions

Volume change potential	Void dimension against side of foundation and ground beam	Void dimension under ground beams, and suspended in-situ concrete ground floor	Void dimension under suspended precast concrete and timber floors(1)
High	35mm	150mm	300mm
Medium	25mm	100mm	250mm
Low	0mm	50mm	200mm

Notes
1 Under suspended floors, the void dimension is measured from the underside of beam or joist to ground level and includes 150mm ventilation allowance.

Void formers consist of materials that collapse to form a void into which the clay can swell. The void dimension is the 'remaining void' after collapse. The thickness of the void former should be in accordance with the manufacturer's recommendations.

Proprietary materials to accommodate heave

Compressible material compacts as clay expands; the void dimension is the amount the material should be able to compress to accommodate heave. The thickness of compressible material required should be established from the manufacturer's recommendations, but generally will be approximately twice the void dimension shown.

Each material should be assessed in accordance with Technical Requirement R3 and used in accordance with the independent assessment and the manufacturer's recommendations.

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

Heave precautions for foundations

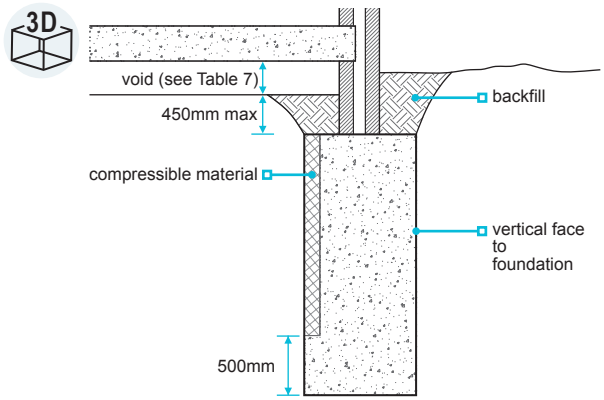
Table 8 shows where heave precautions are required for trench fill, pier and beam, and pile and beam foundation types which are in the zone of influence of trees (see Table 3b) which are to remain or be removed.

Table 8: Position of heave precautions

Situation (see figures 4, 5 & 6)	Trench fill	Pier and beam	Pile and beam
External trench fill and pier foundations. Unless NHBC is satisfied that the soil is not desiccated compressible material should be provided to the:	Inside faces of external wall foundations deeper than 1.5m, based on the appropriate tree height	All faces of pier foundations deeper than 1.5m, based on the appropriate tree height	N/A
External ground beams Unless NHBC is satisfied that the soil is not desiccated compressible material or void formers should be provided to the:	N/A	Inside faces	Inside faces
Internal trench fill foundations and ground beams Compressible material required:	No	No	No
External and internal ground beams Compressible material, void former or void should be provided to the underside of:	N/A	All	All
Heave precautions required for proposed trees where the soil is not desiccated:	No	No	No

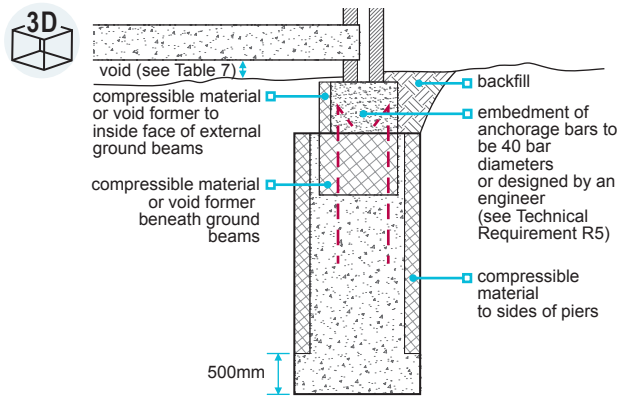
On pilecaps, heave precaution measures should be assessed on a project-by-project basis. Lightly loaded pilecaps consisting of between one and three piles are more susceptible to heave movement than heavily loaded pilecaps. Omission of heave precaution measures should be justified by the designers, particularly on lightly loaded pilecaps.

Figure 4: Heave precautions for trench fill foundations up to 2.5m deep



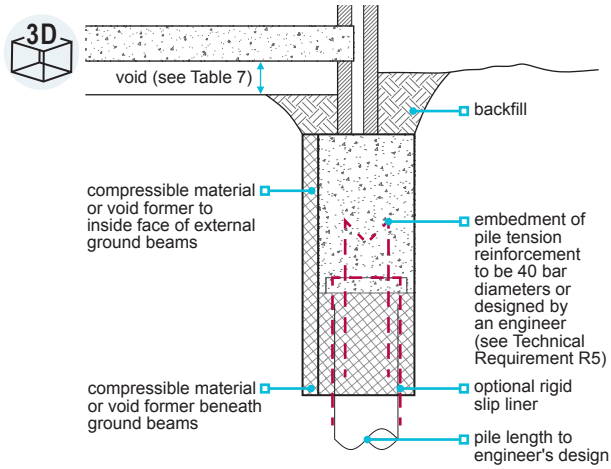
It is essential that:
- Compressible material is provided to the entire area shown, and the foundation excavation has a vertical face.
- Where the excavation is battered or if there is overbreak or concrete overspill, it may be necessary to consult an engineer.

Figure 5: 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.

Figure 6: 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.

Raft foundations constructed in accordance with Clause 4.2.8 and Clause 4.2.9 should provide adequate protection from heave.

Other foundation types

All foundations not covered in this chapter, but specifically designed to counteract heave, should be:

- designed by an engineer taking account of this guidance
- submitted to NHBC prior to commencing work on site.

Suspended ground floors

Suspended ground floors with voids in accordance with Table 7 should be used in situations where heave can occur within the area bounded by the foundations, including where:

- foundation depth, determined in accordance with this chapter, is more than 1.5m, unless NHBC is satisfied the soil is not desiccated, or
- ground floor construction is undertaken when the surface soils are seasonally desiccated (ie, during summer and autumn), unless NHBC is satisfied the soil is not desiccated.

Paths and driveways

Paths and driveways should be designed and detailed to cater for the likely ground movement.

4.2.11 New drainage

Also see: Chapter 5.3

Drainage shall be in accordance with the design and allow for ground movement.

To protect against the effects of heave, drainage should be designed:

- to take account of potential ground movement as shown in Table 9, including where pipes and services pass through substructure walls or foundations
- with gradients which may need to be greater than those in Chapter 5.3 'Drainage below ground' as these do not account for possible ground movement
- to use alternative means of catering for the movement when sufficient falls cannot be provided, for example by deepening the excavation and laying the pipework on a granular bedding of suitable thickness to reduce the extent of potential movement.

Table 9: Volume change potential

Volume change potential	Potential ground movement (mm)
High	150
Medium	100
Low	50

Note

Existing land drains should be maintained or diverted.

Where the void beneath a suspended floor is liable to flooding, adequate drainage should be provided to take away any flood water.

4.2.12 Method of assessment of foundation depths using charts

Foundation depths shall be determined to prevent excessive movement due to ground heave.

A detailed method of assessing foundation depths of up to 2.5m using Charts 1-3 are given in the worked Example of clause 4.2.14 of this chapter.

Table 10 can be used in determining the D/H ratio needed for use within the charts, where:

D is the distance measured from the centre of the trees or hedgerows to the face of the foundation and

H is the appropriate height of trees (mature or actual, depending on what is being assessed).

Table 10: Determination of D/H value

Determination of D/H value															
Distance D (m)	Tree 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	0.96	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 (ie, 1.0m, 0.9m and 0.75 m for high, medium and low volume change potential soils respectively).

Chart 1: Soils with HIGH volume change potential – Modified Plasticity Index 40% or greater

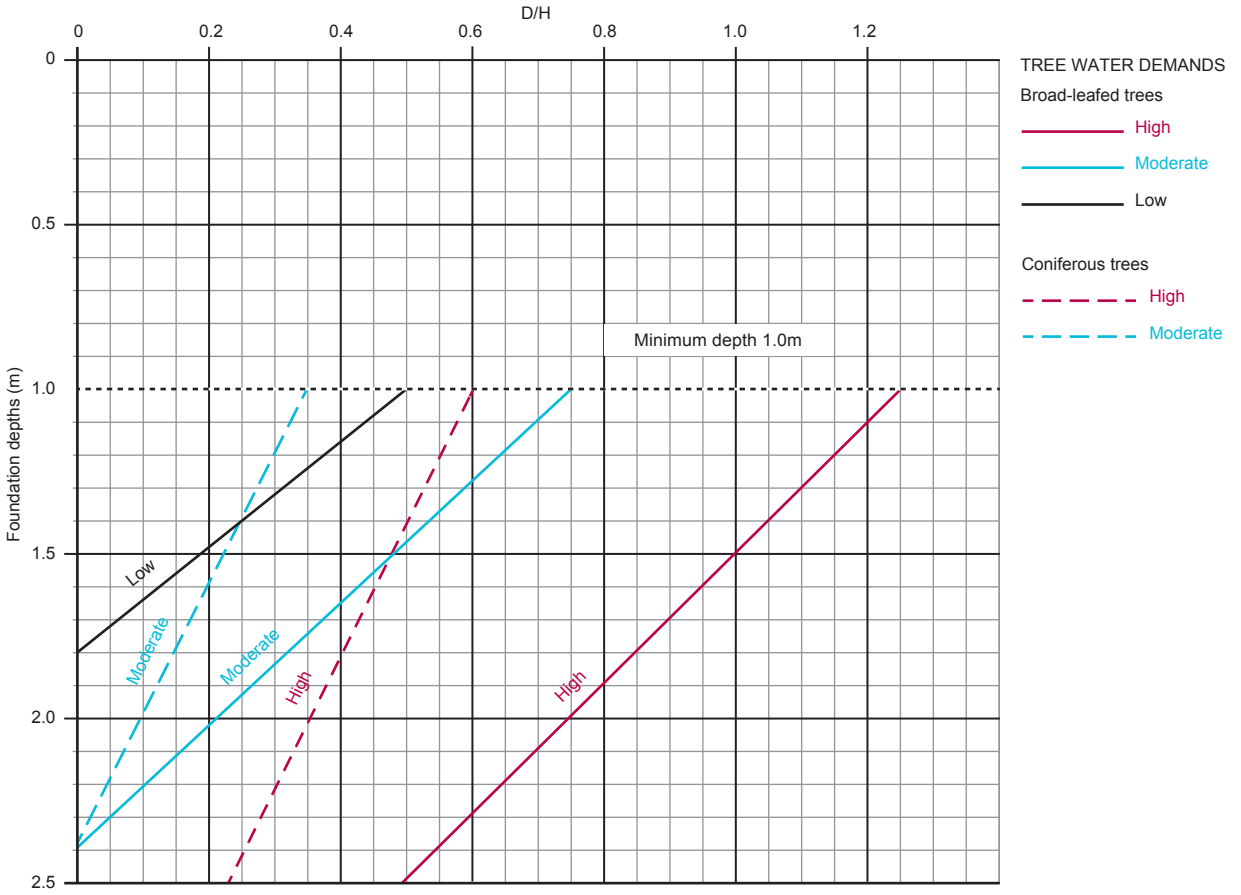


Chart 2: Soils with MEDIUM volume change potential – Modified Plasticity Index between 20% and less than 40%

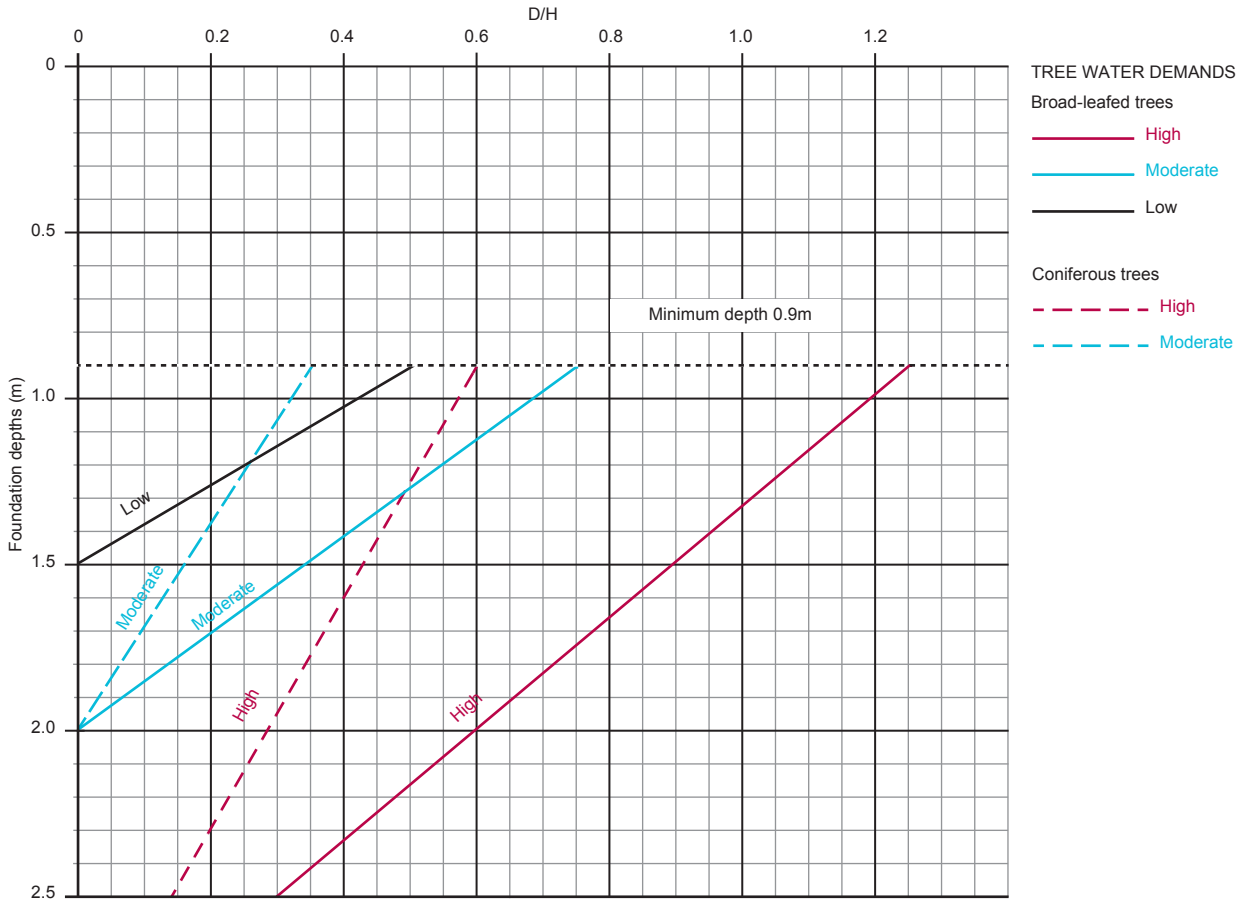
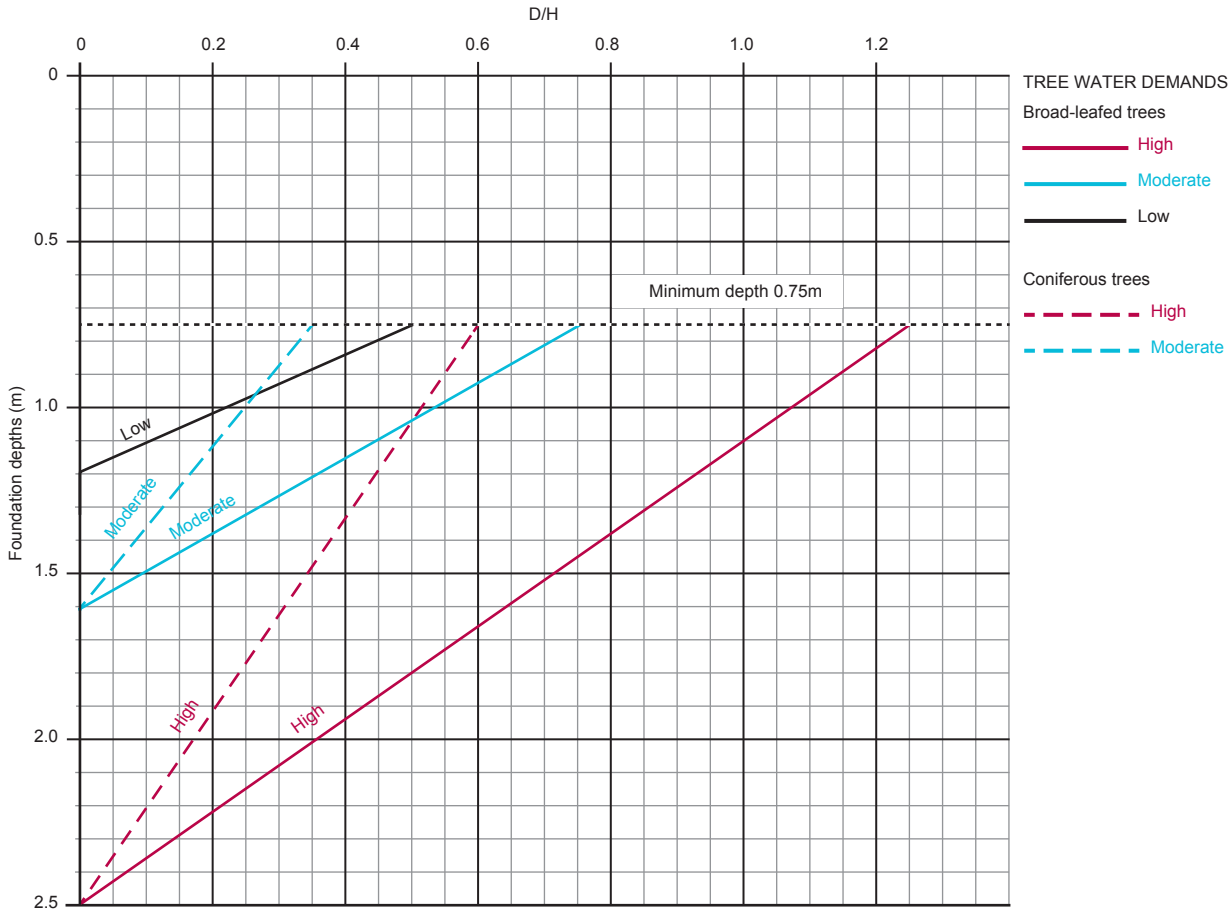


Chart 3: Soils with LOW volume change potential – Modified Plasticity Index 10 to less than 20%



4.2.13 Method of assessment of foundation depths using tables

Foundation depths shall be determined to prevent excessive movement due to ground heave.

A detailed method of assessing foundation depths of up to 2.5m using Tables 11-19 are given in the worked Example of clause 4.2.14 of this chapter.

Tables 11-13 are for use in High volume change potential soils, and Tables 14-16 and 17-19 are for use in Medium and Low volume change potential soils respectively.

Table 11: HIGH volume change potential 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				Foundations greater than 2.5m deep to be engineer designed								
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		1.0m minimum foundation depth									1.00	1.05
38												1.00

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					Foundations greater than 2.5m deep to be engineer designed						
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			1.0m minimum foundation depth									
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
32												
33												
34												
35												
36												
37												
38												

Table 12: HIGH volume change potential 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		1.0m minimum foundation depth									1.00	1.10
22											1.00	1.05
23												1.00

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		1.0m minimum foundation depth										
22												
23												

Table 13: HIGH volume change potential 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		1.0m minimum foundation depth								1.00	1.10	1.15
14											1.00	1.05
15												1.00

Table 14: MEDIUM volume change potential 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

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		Foundations greater than 2.5m deep to be engineer designed						
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 15: MEDIUM volume change potential 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		0.9m minimum foundation depth									0.90	1.00
22											0.90	0.95
23												0.90

Coniferous												
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		0.9m minimum foundation depth										
22												
23												

Table 16: MEDIUM volume change potential 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		0.9m minimum foundation depth								0.90	0.95	1.00
14											0.90	0.95
15												0.90

Table 17: LOW volume change potential 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		0.75m minimum foundation depth									0.75	0.80
38												0.75

Coniferous

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		0.75m minimum foundation depth										
38												

Table 18: LOW volume change potential 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		0.75m minimum foundation depth									0.75	0.85
22											0.75	0.80
23												0.75

Coniferous												
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		0.75m minimum foundation depth										
22												
23												

Table 19: LOW volume change potential 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		0.75m minimum foundation depth								0.75	0.80	0.85
14											0.75	0.80
15												0.75

4.2.14 Worked example

The following is an example of how to determine foundation depths using the information in this chapter. The process may be repeated to allow the foundation to be stepped as its distance from the tree increases.

Step 1

Determine the volume change potential of the soil. Ensure the site investigation includes representative sampling and testing.

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 $\frac{100}{100}$ = 36%

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 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.

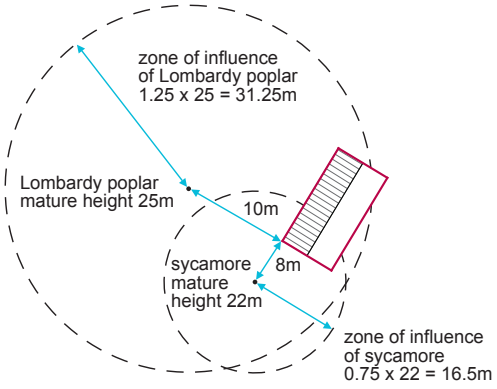
Step 2

Establish the species, mature height and water demand of all trees and hedgerows within the influencing radii.

Lombardy poplar	Sycamore
Mature height = 25m Water demand = high	Mature height = 22m Water demand = moderate

Step 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.



Step 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.

Lombardy poplar	Sycamore
Tree to remain. Therefore: H = mature height = 25m	Tree to be removed Mature height = 22m Actual height = 15m Actual height greater than 50% mature height. Therefore: H = mature height = 22m

Step 5

Measure the distance D from the centre of the trees or hedgerows to the face of the foundation.

Lombardy poplar	Sycamore
Distance D = 10m from foundation	Distance D = 8m from foundation

Step 6

Either:

- use the NHBC Foundation Depth Calculator App, or
- select steps 6C (a) and (b) if using charts in Clause 4.2.12 to derive depths, or
- select step 6T if using tables in Clause 4.2.13.

Step 6C (a)

Calculate D/H value

Distance D from face of foundation (step 5) divided by the appropriate tree height H (Step 4).
Alternatively D/H can be obtained from Clause 4.2.12.

Lombardy poplar	Sycamore
D = 10 = D/H = 0.4 H = 25	D = 8 = D/H = 0.36 H = 22

Step 6C (b)

Determine foundation depth using the charts in Clause 4.2.12 as follows:

Volume change potential	Chart number
High	1
Medium	2
Low	3

Lombardy poplar	Sycamore
In this example, the volume change potential is medium, then from Chart 2 for broad-leafed high water demand trees at D = 0.4 H Foundation depth = 2.33m	In this example, the volume change potential is medium, then from Chart 2 for broad-leafed moderate water demand trees at D = 0.36 H Foundation depth = 1.50m

The Lombardy poplar is the tree requiring the greater depth (2.33m).

Step 6T

Determine foundation depth using the tables in 4.2.13 as follows:

Volume change potential	Tree water demand	Table number
High	High Moderate Low	11 12 13
Medium	High Moderate Low	14 15 16
Low	High Moderate Low	17 18 19

Step 7

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.

Oxford is between 50 and 100 miles NW of London. From 4.2.5, a reduction of 0.05m is permitted.

Final foundation depth = 2.33 – 0.05 = 2.28m

4.2.15 Further information

- *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'*
- *BS 1377 'Methods of test for soils for civil engineering purposes'*
- *BS 5837 'Trees in relation to design, demolition and construction – Recommendations'*
- *BS 5930 'Code of practice for ground investigations'*
- *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*
- *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*
- *Institution of Civil Engineers 1-7 Great George Street, London SW1P 3AA; Tel: 020 7222 7722;* ***www.ice.org.uk***
- *Institution of Structural Engineers 47-58 Bastwick Street, London EC1V 3PS; Tel: 020 7235 4535.*

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.