3.6.4 Tree influence

Foundation designs shall take account of tree influence in cohesive soils.

Prior to the site being cleared, a tree survey should be carried out. This should include a site plan showing retained, recently removed and/or newly planted trees along with details of tree species and their height.

Tree species differ in the ability of their roots to grow and exploit the available water in a cohesive soil, particularly if it has high clay content. This is commonly referred to as their 'water demand'. If a tree cannot be identified, it must be assumed to have high water demand (deep rooting).

Although some trees are managed as pollards or are subject to periodic reduction to control their size, unless such treatment can be assured in the future, mature height should be used.

The mature heights of common tree species are provided in our online foundation depth calculator. Mature height should be used unless an Arboricultural report is obtained, indicating that a lesser height is appropriate for the conditions of the site.

Proximity

The closer the tree, the deeper the potential influence, and the guidance indicates the required foundation depth at any distance. The parts of the foundations closest to the tree require the greatest depth, but if preferred can be stepped down for more distant parts.

Measurement should be taken from the centre of the trunk to the nearest part of the foundations. If preferred, foundations depths can be stepped down at greater distances, by measurement to other locations around the building.

3.6.5 Foundation design

Foundations shall be appropriately designed and constructed to safely transmit loads without excessive movement. The following should be taken into account:

- Foundation depth calculator.
- Foundation depths.
- Trees removed prior and during construction.
- Heave precautions.
- Raft foundations in clay soils susceptible to heave/ shrinkage.
- Sloping sites.
- Protection of drains.
- Strip and mass fill foundations in non-shrinkable soils overlying shrinkable soils.
- Changes in level.

The for the purposes of our Warranty, the extent of risk depends on:

- The plasticity index of the soils.
- The potential for the tree species to cause clay soil desiccation.
- The height of the tree.
- The proximity of the tree to the foundations.
- The likely climatic conditions in the locality.
- The removal of trees growing in clay soils.

These risks should be fully considered by the designer within the design.

Foundation Depth Calculator

Foundation depth (see also 'Limitations of guidance' at the start of this section) can be determined using the foundation depth calculator found on our website. The depth of foundation is determined by inputting the:

- Plasticity index of soil.
- Tree type (this will determine the water demand of the tree).
- Mature height of the tree will automatically be determined.
- Distance of the relevant tree to the nearest part of foundations and distances elsewhere if stepping foundations.
- Allowance for climatic conditions.

Internal walls should also be taken to a suitable depth to avoid the effects of heave.

Where the foundation depth calculator identifies a minimum depth exceeding 1.5m, strip foundations must not be used. Mass fill or piled foundations must be adopted.

Foundation depth should be determined on the basis of the individual tree that requires the greatest depth.

Foundations depths

Depths in excess of 2.5m

Where the required foundation depths, are in excess of 2.5m, foundations must be designed by a suitable expert, i.e. an Engineer, taking account of the likely effect of soil movement on the foundations and substructure. Bored piles with ground beams or piled raft slabs are recommended, and may prove to be the most economical form of construction. Bored piles are an essential requirement for depths in excess of 3m. See the 'Foundations - Piles' section for further information.

Foundation depths less than 2.5m

Mass fill foundations are likely to be most economic at depths below 1.5m, but can be economic to depths up to 2.5m. However, bored piles are recommended.

For foundation depths in excess of 2m, bored piles with ground beams or piled raft slabs are recommended. All pile designs should be undertaken by a suitable expert, i.e. an Engineer. See the 'Foundations - Piles' section for further information.

Foundation depths to allow for proposed tree planting

Where there is a landscape plan specifying future tree planting, foundation depths should be calculated on the basis of the proposed species of tree and its proximity. If no species has been specified, they should be assumed to be high water demand.

Even if no tree planting has been specified, it is advisable to allow for reasonable future tree or shrub planting, or for the growth of self-seeded trees or shrubs, as shown in column 2 of Table 1.

If the building design or location is such that no tree planting is likely at any time in the future, minimum foundation depths, as shown in column 3 of the table below, should be used.

Table 1: Minimum foundation depths

Plasticity index	Minimum depth to allow for reasonable future tree/shrub planting	Minimum depth if no future tree/ shrub planting likely
40% and greater	1.50m	1.00m
20% to less than 40%	1.25m	0.9m
10% to less than 20%	1.00m	0.75m

Where the foundation depth calculator identifies a minimum depth exceeding 1.5m, raft foundations and strip foundations must not be used. Mass fill or piled foundations must be adopted.

As foundation depth depends on the proximity of the tree, the depth (see also 'Limitations of guidance' at the start of this section) can be reduced in steps with increasing distance. Steps should be in accordance with the 'Foundations - Mass Fill and Strip' section.

Varying foundation depths

As foundation depth depends on the proximity of the tree, the depth can be reduced in steps with increasing distance. Steps should be in accordance with the 'Foundations - Mass Fill and Strip' section.

Trees removed prior and during construction

If trees have been removed prior or during construction, then precautions must be taken to allow for the effects of rehydration and subsequent swelling of the soil. The design should be prepared on the assumption the tree is still present.

- Where the height of the removed trees is known, the foundation depth should be determined using the foundation depth calculator. Alternatively, if the height of a removed tree is more than 50% of the target mature height then the mature height should be used. Whereas if the height of the removed tree is less than 50% of the target mature height then use the actual height.
- If the identity is not known, it should be assumed the trees were deciduous with a high water demand, and if actual height is not known, it should be assumed to be 28m.
- Heave protection should be provided as per the guidance where trees remain.

Alternatively, the foundations and heave protection should be designed by an engineer taking into account the recommendations of this guidance, the site investigation report conclusions and recommendations incorporated from both a registered arboriculturalist and geo technical consultant reports. The design should be submitted before work commences on site.

Heave precautions

Where heave precaution is required, compressible material should be used. The compressible material must have an appropriate third party product conformity certificate for its use and should be positioned in accordance with Table 2.

Table 2: Position of heave precaution in various situations

Situation	Position of heave precaution
External mass fill and pier foundations [1]	Inside faces of external wall foundation that are greater than 1.5m in depth [2] All faces of pier foundations that are greater than 1.5m in depth [2]
Internal mass fill foundations [1]	None required
External wall ground beams for pier or piled foundations	Inside face and underside to all external ground beams
Internal ground beams for pier or piled foundations	Underside of all internal ground beams
Piled raft foundations	Underside of all piled raft foundations
Notes: [1] Or trench fill. [2] Where required based on the Tree (see guidance on Foundation depth calculator).	

The material must be capable of being compressed to allow for vertical and lateral swelling, in accordance with column 3 of Table 3.

Ground bearing slabs should not be used in ground conditions where heave can occur or where the foundation depth is greater than 1.5m (unless a ground bearing raft is adopted designed using our guidance). For mass fill foundations, a suspended floor construction should be used (e.g. cast in-situ concrete, precast concrete or timber). This must incorporate either a clear minimum void of a specified depth under the suspended floor or a proprietary compressible material/void former below the underside of the floor construction.

Note: the compressible material/void former must have an appropriate third party product conformity certificate for use in this situation.

The depth of the void should be in accordance with Table 3, or if a compressible material is used, it should be capable of compressing to provide a void of this thickness. The manufacturer's specifications must be checked to establish the actual thickness of compressible material required to both accommodate movement and be able to compress to the dimensions in Table 3.

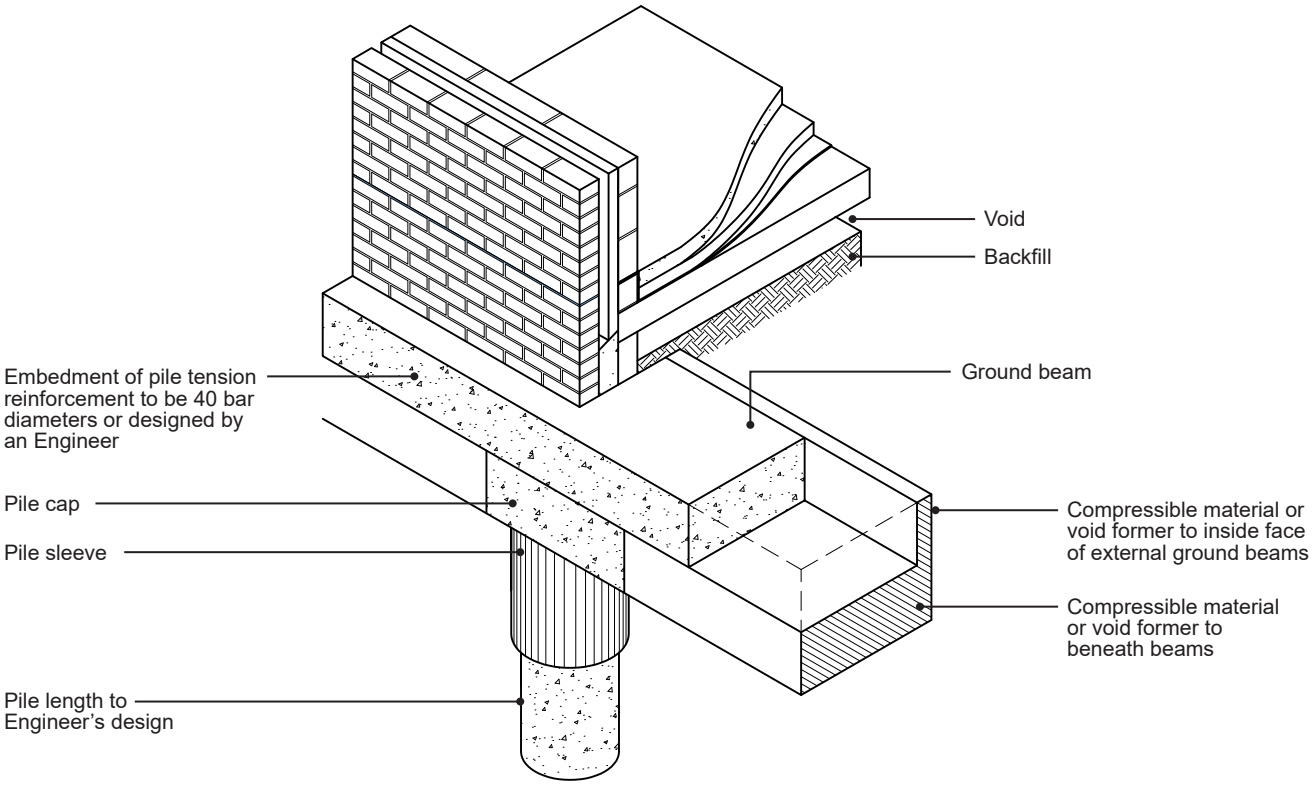
Table 3: Minimum void dimensions for foundations, ground beams, and suspended floor slabs

Volume change potential	Plasticity index	Void dimension against side of ground beam and foundation	Void dimension underground beams, suspended in-situ concrete ground floor & piled raft slabs	Void dimension under suspended precast concrete and timber floors [1]
High	40% and greater	35mm	150mm	300mm
Medium	20% to less than 40%	25mm	100mm	250mm
Low	10% to less than 20%	0mm	50mm	200mm
[1] Under suspended floors, the void dimension is measured from the underside of beam or joist to ground level and includes 150mm ventilation allowance.				

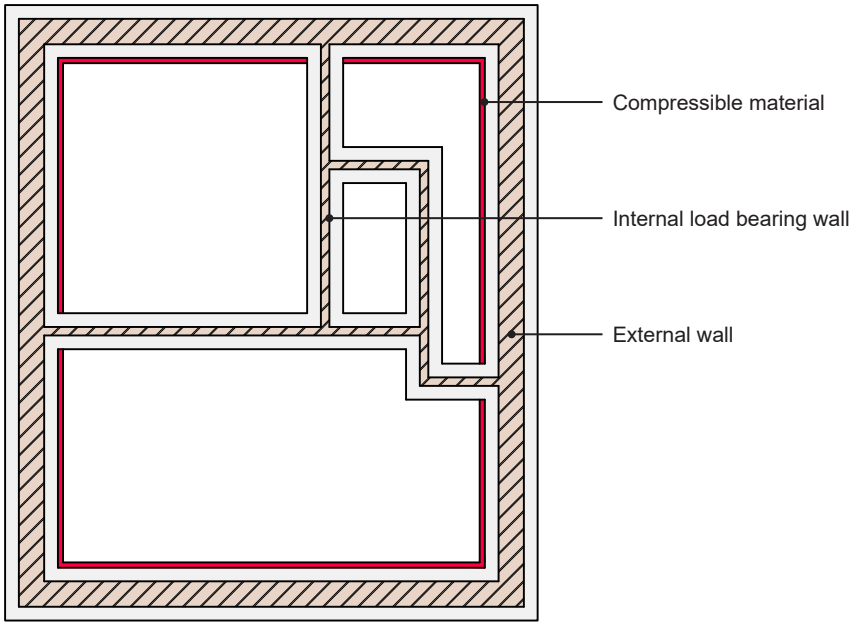
Please note: Void formers consist of materials that collapse to form a void into which the clay can swell. The compressible material/ Void former should have an appropriate third party product conformity certificate demonstrating their suitability as specified. The void dimension is the 'remaining void' after collapse. The thickness of the void former should be in accordance with the manufacturer's recommendations.

Typical foundation designs to allow for heave are shown in the following details.

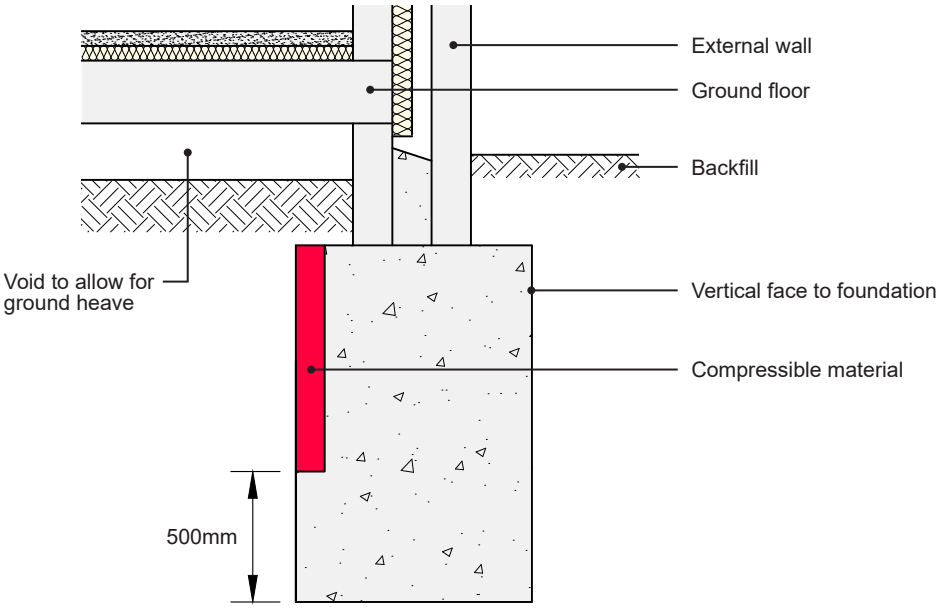
Heave protection - Section through pile and beam foundation



Plan of heave protection to a mass filled foundation



Heave protection - Section through a typical mass filled foundation



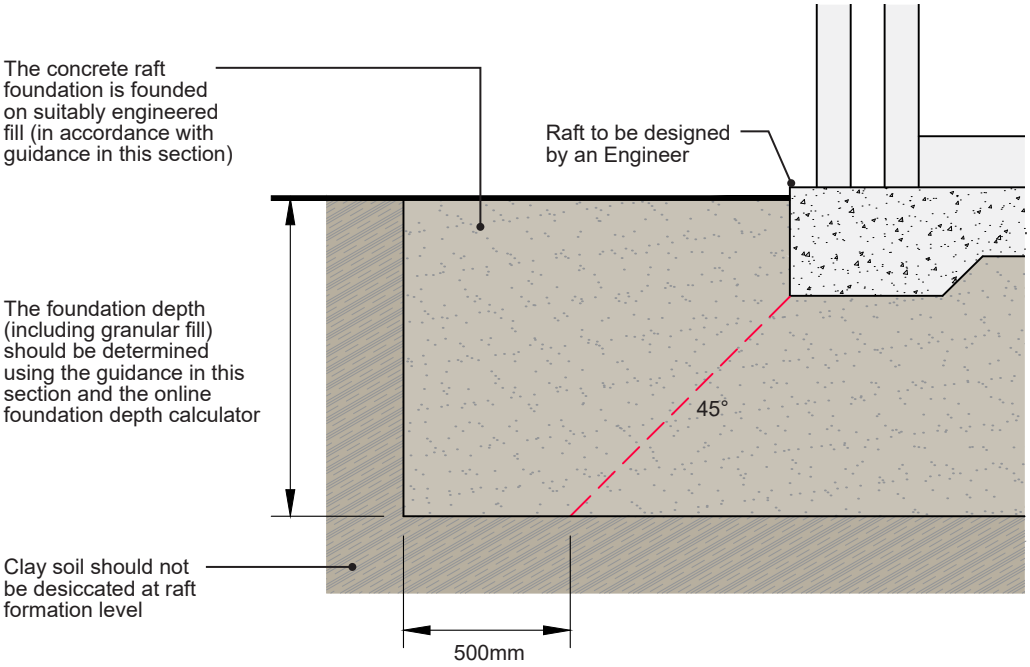
Raft foundations in clay soils susceptible to heave/shrinkage

Where a raft foundation is proposed in shrinkable / expandable soil within the influence of trees (existing, removed or proposed), it will be acceptable only if it is designed to meet the following conditions:

- It is designed by an Engineer and the stiffness of the raft is sufficient to avoid damage to the superstructure and services of the building for the design life of the building.
- Clay should not be desiccated at raft formation level unless it can be demonstrated the residual long term clay heave uplift will be no more than 25mm under the SLS load case: dead load plus 30% superimposed live load.
- Settlement, heave and tilt shall be compatible with the structure without causing structural damage. In general, settlement should not exceed 25mm and differential settlement gradients, across the raft, should not be steeper than 1/500. However, if the structure is engineered to be serviceable with total settlements and differential settlement gradients greater than these figures, then this solution will be considered on a case by case basis using suitable geo-structural analysis. The analysis shall be conducted for the SLS load case: dead load plus 30% superimposed live load.
- The foundation depth (including engineered fill) should be determined using the guidance in this section and the online foundation depth calculator, **and**

- The concrete raft foundation is founded on suitably engineered fill and in accordance with the following:
  - The depth of granular fill shall be based on a minimum of 50% of the depth as calculated using the Foundation Depth Calculator for strip/mass fill foundations and is not more than 1.25m deep (measured from the original ground level where ground levels have not been altered). Please refer to our 'Foundations – Trees and Clay' section where ground levels are altered.
  - The fill must bypass any made ground and be placed directly on natural ground.
  - The fill should be fully compacted in layers in accordance with the Engineer's specification ensuring a minimum dry density of 95% and max air voids of 5%. Where the depth of granular fill is greater than 1000mm a site specific earthworks specification and validation report, including testing will be required.
  - The ground level shall be taken as existing or proposed whichever is more onerous.
  - The fill should extend a minimum distance beyond the concrete footprint by a distance equal to a 45° line taken from the underside of concrete plus 500mm. If external buried services are installed on the perimeter of the raft foundation and are below the 45° notional bearing pressure dispersal line, then suitable measures must be taken to ensure the raft ground bearing pressures are transmitted, effectively, to the lower soils e.g. specify concrete bed and surround of services up to the notional 45° bearing pressure dispersal line.
- All materials on the perimeter and 1 metre inside of the raft must be non-frost susceptible for a depth of 450mm from finished external perimeter ground level.
- Services to the building should be designed to accommodate any settlement, heave or tilt.
- Under the raft footprint, services shall be have a concrete bed and surround and be hung from the soffit of the raft.

Where the foundation calculator depth is greater than 2.5m the design condition is outside the guidance of this Technical Manual and should not be used. An Engineer design or alternative foundation type will be required.



Sloping sites

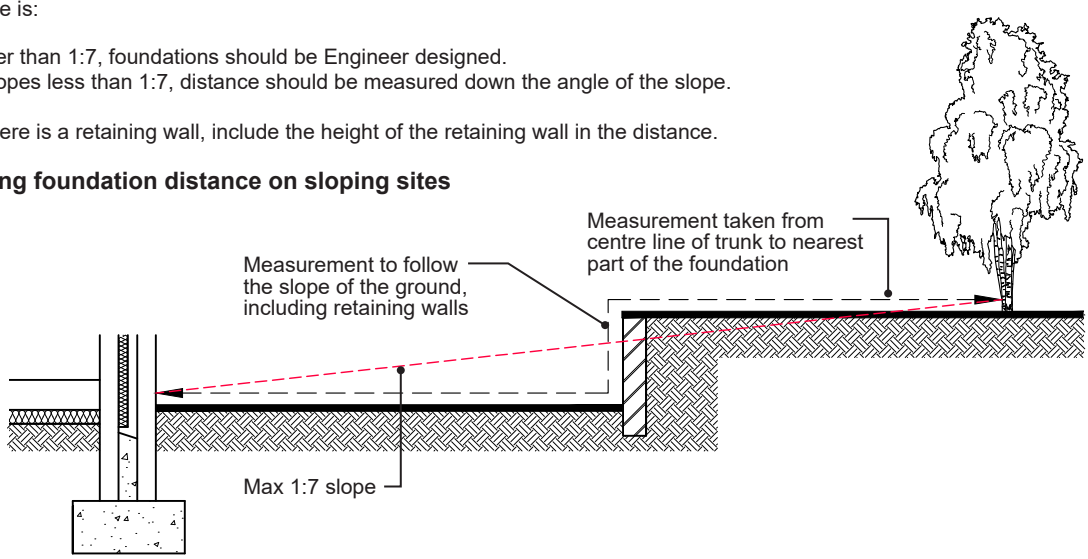
Foundations on sloping sites should be appropriately designed and constructed to safely transmit loads without excessive movement.

If the slope is:

- Greater than 1:7, foundations should be Engineer designed.
- For slopes less than 1:7, distance should be measured down the angle of the slope.

Note: If there is a retaining wall, include the height of the retaining wall in the distance.

Measuring foundation distance on sloping sites



Protection for drains

In addition to the requirements of the 'Drainage' section, drainage near trees should incorporate additional provisions. Where there is a volume change potential within the ground, the provisions include:

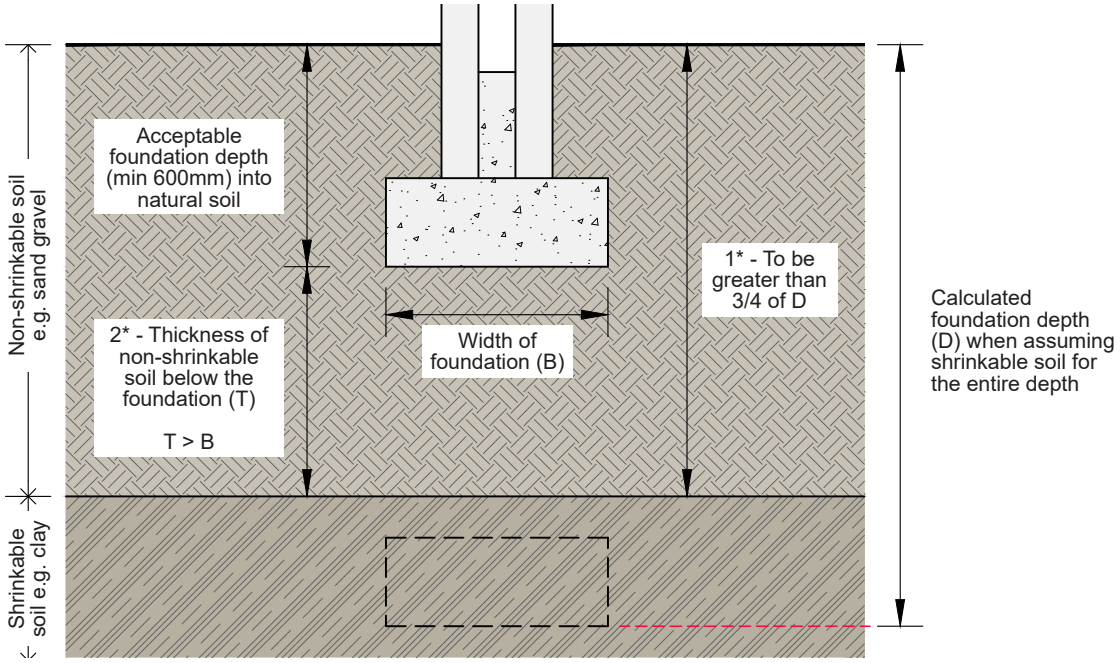
- Increased falls to cater for any ground movement.
- Deeper and wider backfill of granular material.
- A drainage system that is capable of movement should heave and shrinkage occur.
- Drainage pipes should not be encased in concrete.
- Additional clearance is required where drains pass through the structure of a building to allow for additional movement.

Strip and mass fill foundations in non-shrinkable soils overlying shrinkable soils

When a sufficient depth of non-shrinkable soil overlies shrinkable soil, the foundation depth can be assessed on the non-shrinkable material provided conditions 1 to 3 below are satisfied.

First, calculate the minimum foundation depth (D), assuming the soil type is shrinkable and under the influence of trees. This depth is taken from ground level.

Condition 1* - Ensure the thickness of the non-shrinkable soil, as measured from the ground level, is greater than 3/4 of dimension D (as shown below).
Condition 2* - Ensure the thickness of the non-shrinkable soil below the foundation (T) is greater than the width of the foundation (B) (as shown below).
Condition 3 - Ensure all other relevant requirements in the 'Foundations' section of the Technical Manual are met.



Changes in level

Where the ground level is raised or reduced, and trees are remaining, removed or proposed, the guidance in one of the below scenarios should be followed.

In all instances, ensure all other relevant requirements in the 'Foundations' section of the Technical Manual are met.

Scenario 1: Existing trees are remaining and the original ground level is raised

If ground levels are raised within the influencing distance of trees, the minimum foundation depth should be based on whichever provides the greater depth from either:

- The results given by the Foundation Depth Calculator when using the existing height of the tree or the mature height in instances where the existing height is currently at least 50% of the expected mature height, and the **original** ground level; **or**
- The results given by the Foundation Depth Calculator when using the mature height of the tree. This result should be measured from the **proposed** ground level.

Scenario 2: Existing trees are to be removed and the original ground level is raised

If ground levels are raised within the influencing distance of trees, the minimum foundation depth should be based on:

- The results given by the Foundation Depth Calculator when using the existing height of the tree or the mature height in instances where the existing height is currently at least 50% of the expected mature height, and the **original** ground level.

Scenario 3: New trees are proposed and the original ground level is raised

If ground levels are raised within the influencing distance of trees, the minimum foundation depth should be based on whichever provides the greater depth from either:

- The minimum foundation depth as given in column 3 of 'Table 1: Minimum foundation depths' in this section of the Technical Manual. This result should be measured from the **original** ground level; **or**
- The results given by the Foundation Depth Calculator when using the mature height of the tree. This result should be measured from the proposed ground level.

Scenario 4: Existing Trees are remaining and the original ground level is reduced

If ground levels are reduced within the influencing distance of trees, the minimum foundation depth should be based on:

- The results given by the Foundation Depth Calculator when using the mature height of the tree. This result should be measured from the **proposed** ground level.

Scenario 5: Existing trees are to be removed and the original ground level is reduced

If ground levels are reduced within the influencing distance of trees, the minimum foundation depth should be based on whichever provides the greater depth from either:

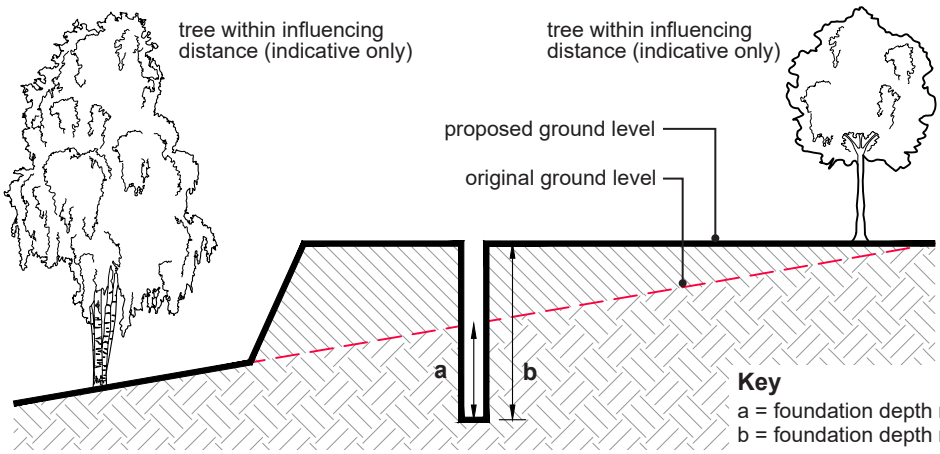
- The results given by the Foundation Depth Calculator when using the existing height of the tree or the mature height in instances where the existing height is currently at least 50% of the expected mature height, and the **original** ground level; **or**
- The minimum foundation depth as given in column 3 of 'Table 1: Minimum foundation depths' in this section of the Technical Manual. This result should be measured from the **proposed** ground level.

Scenario 6: New trees are proposed and the original ground level is reduced

If ground levels are reduced within the influencing distance of trees, the minimum foundation depth should be based on:

- The results given by the Foundation Depth Calculator when using the mature height of the tree. This result should be measured from the **proposed** ground level.

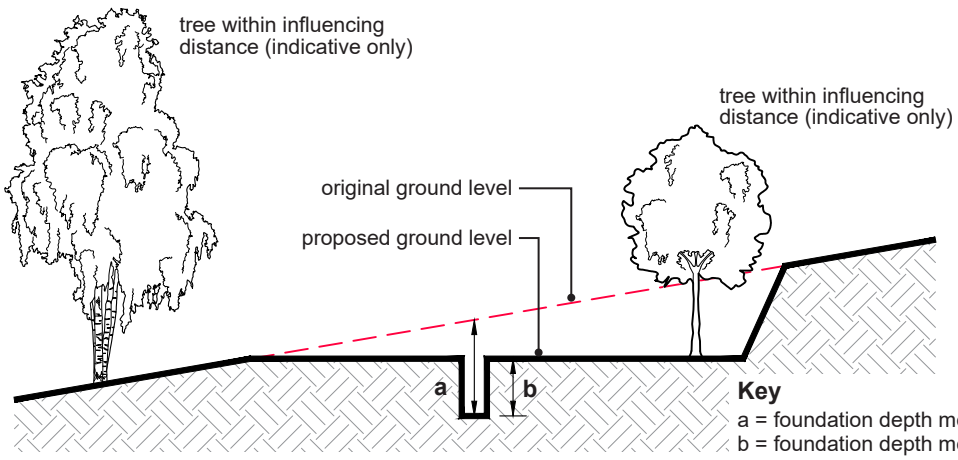
Where to measure when the ground level is raised



Key

a = foundation depth measured from the original ground level.
b = foundation depth measured from the proposed ground level.

Where to measure when the ground level is reduced



Key

a = foundation depth measured from the original ground level.
b = foundation depth measured from the proposed ground level.