PREMIER GUARANTEE®

ON YOUR SITE, BY YOUR SIDE

# TECHNICAL MANUAL

## VERSION 16

## 3: FOUNDATIONS

# 3. Foundations

**Contents**

## Limitations of Functional Requirements

1. These Functional Requirements do not and will not apply to create any Policy liability for any remedial works carried out by the Contractor or otherwise, nor to any materials used in those remedial works.
2. The guidance provided in this Section, is guidance that provides a suggested solution to meeting the Functional Requirements. If an alternative solution is selected, then this must still meet the Functional Requirements.

## Workmanship

1. Ground improvement schemes should be appropriately tested to confirm that the completed works meet design specifications. The testing regime must be agreed with the Warranty Surveyor prior to commencement of work (applicable to: 'Engineered Fill' and 'Vibratory Ground Improvement' only).
2. The Developer shall ensure that adequate quality control procedures are in place. The quality control and testing must identify that site work meets the design intention. All procedures should be auditable and available for inspection (applicable to: 'Engineered Fill' and 'Vibratory Ground Improvement' only).
3. Foundations should be of a suitable depth in order to achieve a satisfactory level of performance.
4. Excavations for foundations shall be accurate in line, width and depth, and suitable for the type of foundation which form the basis of the design.
5. All work is to be carried out by a technically competent person in a workmanlike manner.
6. Concreting shall not take place during cold weather periods where the working temperature is below 2°C or where ground conditions are frozen.
7. Pile foundation schemes must be tested to confirm that the installation meets the design requirements.

## Materials

1. All materials should be stored, installed and protected correctly in a manner that will not cause damage or deterioration of the product.
2. All materials, products and building systems shall be appropriately tested and approved for their intended purpose.
3. All load bearing structural elements providing support to the Home will have a service life of not less than 60 years, unless specifically agreed otherwise with us. All other parts of the Home will have a lesser durability and need planned maintenance, repair or replacement during that reduced period.
4. All materials should be suitable for the relative exposure of the building in accordance with the relevant British Standards.

## Design

1. A site investigation report should be completed at an appropriate level for the risk in accordance with the relevant British Standard.
2. A detailed design by an appropriately qualified person should be supplied and provide the following information (applicable to: 'Engineered Fill' and 'Vibratory Ground Improvement' only):
    a. Depth of original soil types below the structure.
    b. Details of any filled ground and its suitability to accept ground improvements techniques.
    c. Gas generation or spontaneous combustion from ground conditions.

    The investigation must be endorsed by the Specialist Foundations Contractor.
3. The foundation type and depth must be suitable to resist movement due to the influence of nearby trees.
4. Piled foundation designs must be supported by structural calculations provided by an Engineer. Calculations for full piling systems must be provided by, or endorsed by, the piling specialist.
5. Raft foundation designs must be supported by structural calculations provided by an Engineer.
6. Evidence must be provided to demonstrate the foundation design meets the requirements of Building Regulations.
7. The design and specification shall provide a clear indication of the design intent and demonstrate a satisfactory level of performance.
8. The following additional elements shall be supported by structural calculations designed by an Engineer:
    a. Structural elements outside the parameters of Building Regulations.
    b. Specialist structural works.
    c. Reinforced concrete elements.
    d. Precast structural elements.
    e. Any engineered beams/posts manufactured off-site.

# 3.
# Foundations

## 3.1
## Mass Fill and Strip

## Provision of information

A full set of design drawings and specifications shall be made available to the Warranty Provider and all other interested parties prior to the associated works starting on site. This may include:

1. Site investigation report appropriate for the site specific conditions (please note, a minimum phase one desktop study is required in all circumstances).
2. Where the ground is contaminated a full design package including details of all materials to be used along with a remediation report will be required.
3. Full set of detailed drawings including:
   a) Foundation layouts.
   b) Section drawings showing depth and width of foundations.
   c) Layout drawings showing position of trees in proximity to any foundations.
   d) Location of any services in close proximity to the foundations.
   e) Details of movement joints, junctions or steps in the foundations.
   f) Details of heave precaution requirements.
4. Full set of structural calculations and drawings.

The Warranty Surveyor, at their discretion, may also request supporting information that demonstrates suitability for use of any materials or systems contained within the above.

## Limitations of guidance

The following situations are not covered by this guidance:

- Mass filled foundations and strip foundations for buildings other than dwellings.
- Buildings greater than three storeys.
- Foundations on filled ground.
- Mass fill foundations and strip foundations where foundation depths exceed 2.5m.

## Design

Mass filled and strip foundations shall be designed to ensure that the building is appropriately supported at all times without excessive settlement. This foundation type should only bear onto original ground, where it does not, the foundation should be designed by a Structural Engineer and appropriately reinforced. It is therefore important that site conditions are appropriately assessed prior to the building design. Please see the ‘Ground Conditions’ section.

For ‘low rise structures’, the foundations should be designed to ensure a maximum settlement of 25mm is not exceeded.

In relation to differential settlements, a design limit for maximum tilt of 1/500 is appropriate for the load case, 100% Dead load plus 30% superimposed live load. Where it is clear 100% superimposed live loads will occur for long periods of time, differential settlement checks shall be carried out for 100% Dead and 100% superimposed live load. More stringent values may be required due to the particular circumstances (e.g. medium and high rise structures).

## Influence of trees in clay

Foundation design should take into account influence from nearby trees. Where construction is to take place in cohesive soils and trees are/were/will be present:

For mass fill foundations:

- If the foundation depth is greater than 1.5m, then heave protection will be required.
- Where foundation depths exceed 2m, short bored piles with ground beams or piled rafts slabs are recommended. All pile designs should be undertaken by an Engineer.
- Foundation depths required to exceed 2.5m are beyond the scope of the online foundation depth calculator and must be a piled engineered solution.

For strip foundations:

- Where construction is to take place in cohesive soils and trees are/were/will be present, and the foundation depth is required (using the online foundation depth calculator) to exceed 1.5m, heave protection will be necessary and strip foundations will not be suitable. Mass fill or short bored piles should be adopted (see the ‘Foundations - Mass Fill’ and ‘Foundations - Piles’ guidance).

Further guidance can be found in the ‘Foundations - Trees and Clay’ section.

## Minimum foundation dimensions

- Mass fill and strip foundations should be of a 600mm minimum width for external walls and must take loadings and ground conditions into account. For widths that are less than 600mm for the external wall, an engineer design must be provided.
- For single leaf internal walls up to 150mm thick, foundations may be reduced in width to 450mm ensuring that a 150mm projection either side of the internal wall is provided.
- The minimum thickness of strip foundations should be 150mm.
- Foundations should be situated centrally below the wall.

## Foundation depths

The depth of all foundations should be determined by specific site conditions. All foundations must bear onto virgin stable subsoil and, except where strip foundations are founded on rock. The foundations should have a minimum depth of 450mm, measured from finished ground level to their underside, to avoid the action of frost. This depth however, will commonly need to be increased in areas subject to long periods of frost or in order that loads are transferred to suitable ground.

Where trees are situated close to a proposed building founded on a clay soil, the foundation depth/design will be affected; further guidance is available in the ‘Foundations - Trees and Clay’ section. In clay soils with a plasticity index greater than or equal to 10%, foundations should be taken to a depth where anticipated ground movement will not impair the stability of any part of the building, taking into account the influence of vegetation and trees on or adjacent to the site. The depth to the underside of foundations on clay soils should not be less than 750mm, as measured from finished ground level, and depths may need to be increased in order that loads are transferred to suitable ground.

For minimum depths of foundations in cohesive soils where trees are/were/will be present, please use the online foundation depth calculator. Further guidance can be found in the ‘Foundations - Trees and Clay’ section.

## Minimum foundation depths

| Modified plasticity index (x) | Volume change potential | Minimum foundation depth (m) |
|---|---|---|
| 40% and greater | High | 1.00 |
| 20% to less than 40% | Medium | 0.9* |
| 10% to less than 20% | Low | 0.75* |
| Note: *If the modified plasticity index is not confirmed, the minimum foundation depths should be 1m. | | |

The Plasticity Index may be used without modification; for soils comprising of pure clays, with 100% of particles less than 425μm, the Plasticity and Modified Plasticity Indexes will be the same. The adoption of the Modified Plasticity Index in mixed soils, such as glacial till, however, may result in a more economical design.

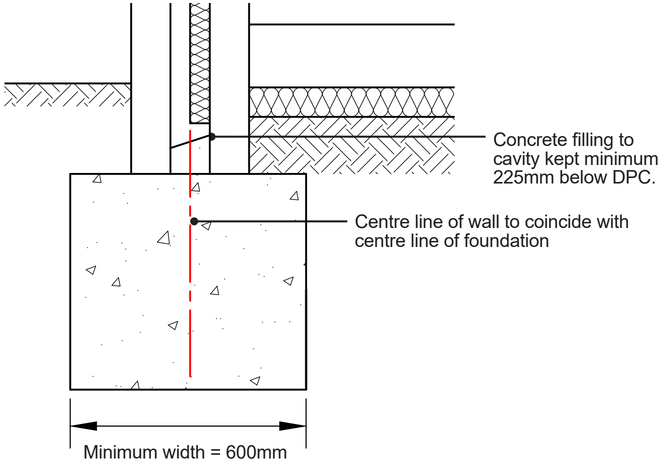
## Flexible and rigid retaining walls

**Flexible retaining walls**
For the purposes of Warranty, flexible retaining walls may be defined as walls that support soil laterally whilst allowing deformations of the unsupported edge of the flexible retaining wall. Examples of flexible retaining walls include gabion, crib, block, timber or modular retaining wall systems.

Flexible retaining walls should not be used to support the structure of the property, garages, roads, drives, car parking areas or drainage systems.

**Rigid retaining walls**
Where rigid retaining walls are specified which support the foundations of a building, an Engineers design must be provided to confirm capable of maintaining stability for a period of at least 60 years and all works to the rigid retaining wall should be completed prior to works for the foundations of the property starting.

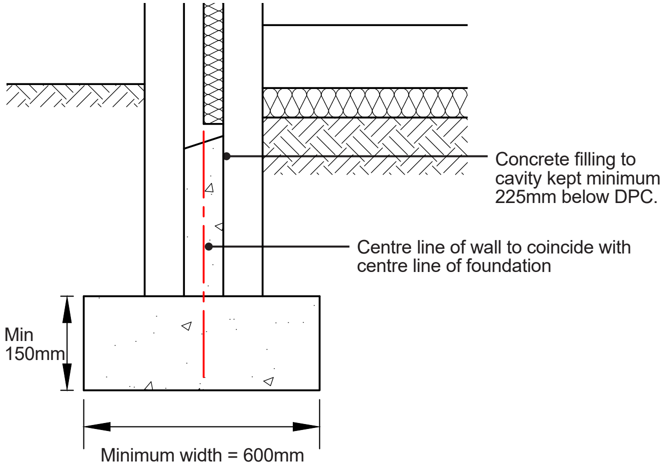
## Typical mass filled foundation




Depth of foundation (below ground level) to be taken to:

- Suitable virgin sub-soil.
- A depth that gives sufficient bearing and protection from frost.
- When building on cohesive soils, is at a depth that is not under potential influence of nearby trees.
- Below the invert level of any adjacent drain/sewer.

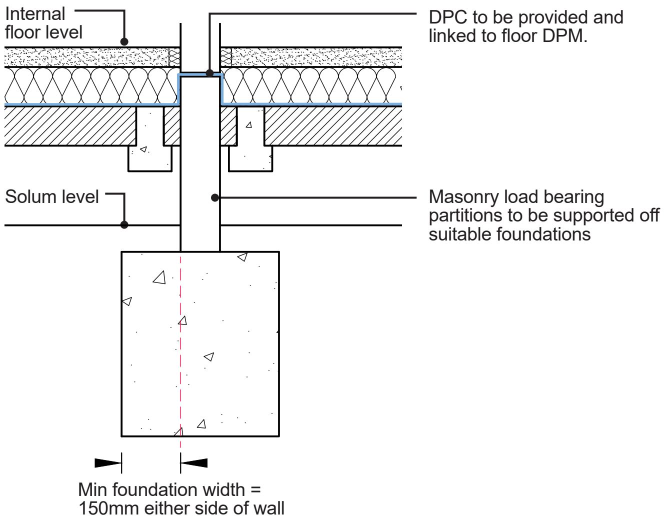
## Typical strip foundation




Depth of foundation (below ground level) to be taken to:

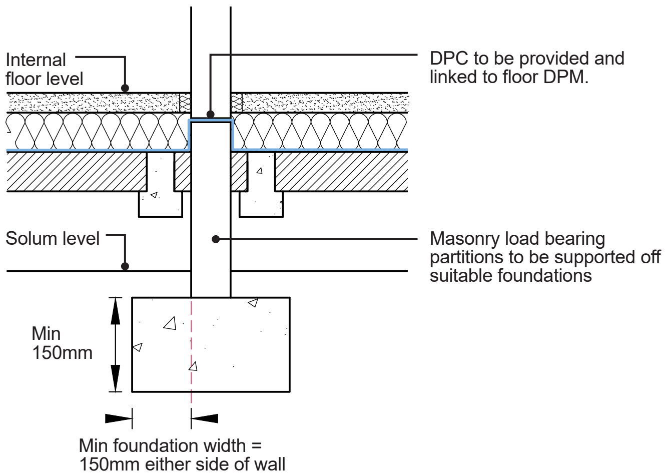
- Suitable virgin sub-soil.
- A depth that gives sufficient bearing and protection from frost.
- When building on cohesive soils, is at a depth that is not under potential influence of nearby trees.
- Below the invert level of any adjacent drain/sewer

## Internal wall foundation (mass fill)




- Foundation to be centrally located under the wall.
- The foundation width should be in accordance with the relevant Building Regulations.

## Internal wall foundation (strip)

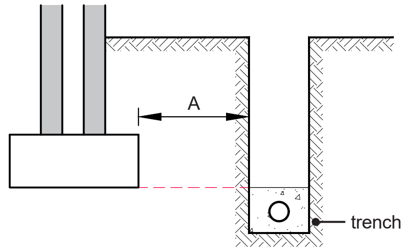



- Foundation to be centrally located under the wall.
- Width of strip foundation to ensure a 150mm minimum projection either side of the wall is provided.
- The thickness of the strip foundation should be at least 150mm.

## Protecting pipes adjacent to foundations

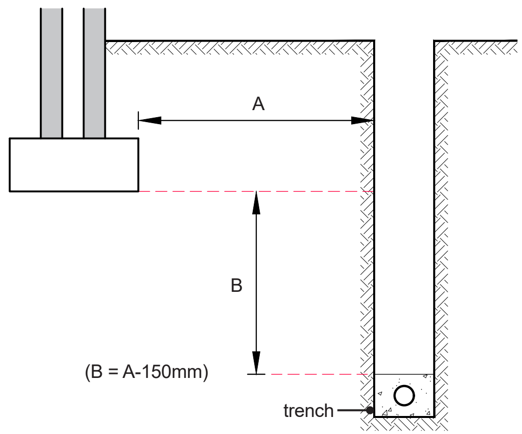
Where it is not physically practical to locate drains so they are not impacted by foundation loads, the pipes should be protected. Examples of how the pipes may be protected are given below:

**Scenario 1 - where A is less than 1m**




Where the trench is within 1m of the foundation, the trench is to be filled with concrete up to the lowest level of the foundation.

**Scenario 2 - where A is 1m or greater**




Where the trench is 1m or further from the foundation, the trench is to be filled with concrete up to measurement B as shown above.

Mass fill and strip foundations must be:

- Constructed to a depth which will not be affected by nearby drainage or other services.
- Any drain or service pipe must not pass through the base of the foundation. Where such services are at the same level, the base of the foundation must be stepped below and the drain/services sleeved through the substructure wall above.
- Existing ground water drains should be diverted to a suitable outfall.

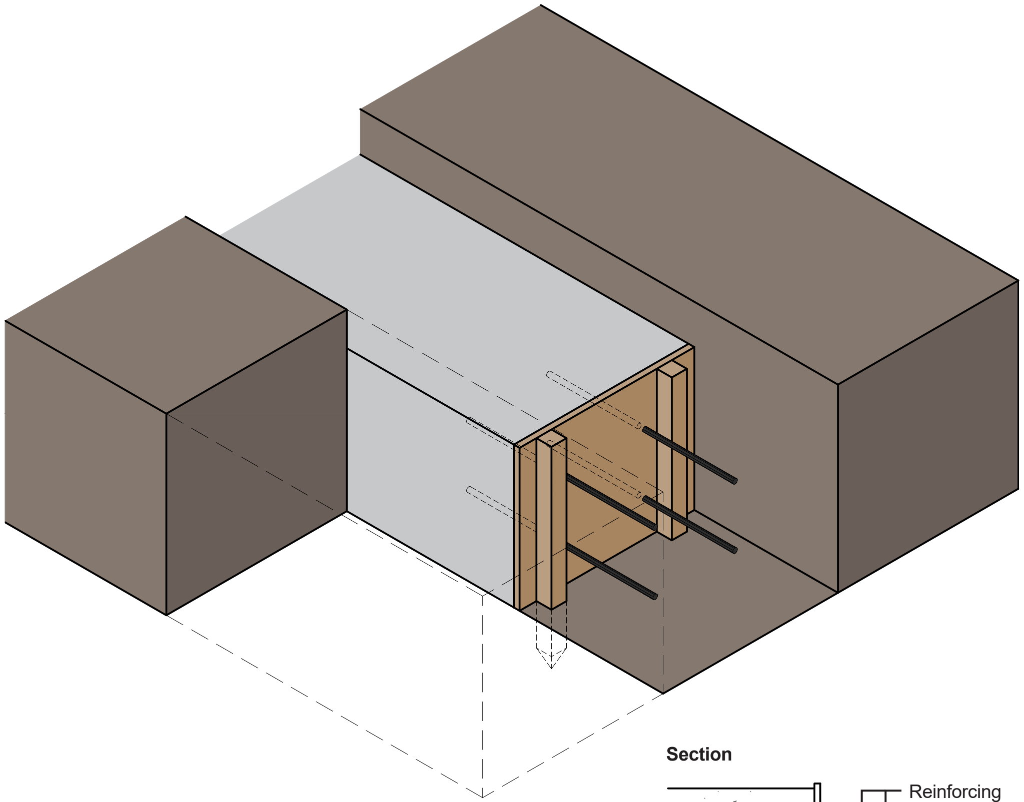
## Reinforcing

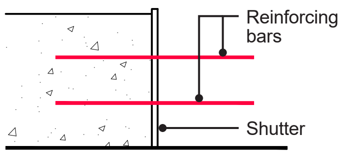
Mass fill and strip foundations should be reinforced where necessary to suit localised ground conditions. Reinforcement, if needed, should be clean and free from loose rust and should also be placed correctly. Bars, of an appropriate size, should be supported to guarantee that they are 75mm above the base of the foundation, or as indicated in the design. They should be secured at laps and crossings. If in doubt about any soft spots, the Engineer's advice should be taken prior to placing the concrete.

## Foundation joints

If construction joints are necessary, they should not be positioned within 2m of a corner or junction in the foundation. All shuttering should be removed before work progresses beyond the construction joint.

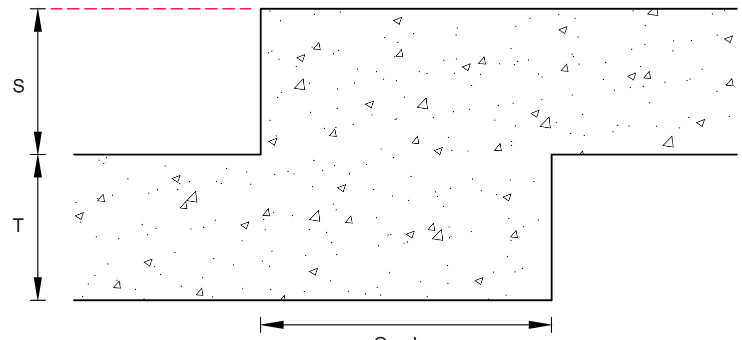
## Using reinforcement bars across a joint






## Steps in foundations

Steps in foundations must not be of a greater dimension than the thickness of the foundation. Where foundations are stepped (on elevation), they should overlap by twice the height of the step, or 1m whichever is the largest.




**Mass foundations:**
The overlap should not be less than:
- 2 x S, or
- 1m

whichever is the largest.

**Strip foundations:**
The overlap should not be less than:
- 2 x S, or
- T (max 500mm), or
- 300mm,

whichever is the largest

## Excavation

- Excavations should be to a depth that gives sufficient bearing and protection from frost damage.
- To avoid damage caused by frost, the depth of the foundation(s) in frost-susceptible ground should be at a minimum of 450mm below ground level. If the finished ground level will be above the existing ground level then, the foundation depth should be calculated from the existing, not finished, ground level.
- Where the depth of mass fill or strip foundations is in excess of 2.5m, they must be designed by a Chartered Structural Engineer in accordance with current British Standards and Codes of Practice. For trench fill, it is imperative to check that the finished foundation level is correct and horizontal. It will be difficult to adjust for discrepancies in the small number of brick courses between foundation and DPC level.
- Prior to concreting, excavations should be 'bottomed out' to remove any debris that may have fallen into the trench; the excavations should be free from water, and if it has been left open for a long period of time, further excavation may be required to a non-weathered strata.

Note: It is important that Health and Safety obligations are met and that excavations are appropriately supported to prevent collapse.

## Setting out foundations

The accuracy of setting out foundations should be checked by set controlled trench measurements, including their location relative to site borders and neighbouring buildings. Levels should be checked against benchmarks, where appropriate. In particular, for excavations check:

- Trench widths
- Trench lengths
- Length of diagonals between external corners

Walls should be located centrally upon the foundation, unless specifically designed otherwise. Any discrepancy in dimensions should be reported promptly to the designer. Resulting variations should be distributed to all concerned with site works, including the Warranty Surveyor.

Standards referred to:

- BS 8004 Code of Practice for foundations and Eurocode
- BS 5950-1 Structural use of steelwork in buildings and Eurocode
- BS 6399 Loadings for buildings and Eurocode
- BS 8103 Structural design of low rise buildings and Eurocode
- BS 8110 Structural use of concrete and Eurocode

# 3.
# Foundations

## 3.2
## Piles

## Provision of information

A full set of design drawings and specifications shall be made available to the Warranty Provider and all other interested parties prior to the associated works starting on site. This may include:

**To be submitted prior to commencement on site**
1. Desk study, investigative and interpretive Site Investigation Report(s) (to at least 5m below the pile toe) with associated geotechnical testing sufficient for pile design including DS / ACEC requirements for buried concrete, heave and shrinkage.
2. Foundation drawings, pile layouts and pile schedule (with pile reference numbers and loadings).
3. Engineer's specification for piling works to include the allowable pile settlements and testing requirements.
4. Calculations for the substructure and for the derivation of the load on each pile.
5. Pile design calculation (for vertical, horizontal, tensile and heave forces) to geotechnical parameters in site investigation report. This should include the pile designer's written confirmation that the site investigation is adequate to ensure that the pile design complies with British Standards. This should also include confirmation, justification, type and number of any preliminary and/or working pile load tests required to satisfy the design.

**To be submitted prior to construction continuing over the piles**
6. Pile installation logs (with pile numbers cross-referenced to the pile layout drawing), including details of re-strikes, rock sockets, rig telemetry records, and concrete volume.
7. Concrete mix details and cube test results for the concrete used in the piles with tabulated results.
8. Integrity testing of all concrete piles with interpretive summary and conclusion.
9. Dynamic load testing results with analysis of long-term settlement, interpretive summary, and conclusion. The correlating static load test for each differing length, load and diameter must be included (and the relevant boreholes if the static testing was undertaken at a different site).
10. Static load test results.
11. Pile Designers interpretive summary and conclusion on completion of the works.

Please note: In the absence of approval, works are proceeding at the Developer's own risk.

The Warranty Surveyor, at their discretion, may also request supporting information that demonstrates suitability for use of any materials or systems contained within the above.

## Piled foundations

Piles are used to transfer loads from buildings to the supporting ground and are utilised in a wide range of applications where conventional strip footings are inappropriate. They are particularly employed where soft or loose soils overlay strong soils or rocks at depths that can be reached conveniently by driving or boring. They are often the most economical type of foundation when very heavy loads must be supported or uplift forces need to be resisted. Large piles are extremely useful for limiting the settlements of large structures on deep stiff clays; smaller versions can provide appropriate foundations for houses and other small buildings on stiff clays liable to shrinkage and swelling.

## Limitations of guidance

The following situations are beyond the scope of this guidance.
- Innovative foundation systems that do not have third-party approval or accreditation.
- Piling systems where the structural design is not endorsed by the Specialist Piling Contractor.

## Influence of trees in clay

Foundation design should take into account influence from nearby trees. Where construction is to take place in cohesive soils and trees are/were/will be present:
- Suitable heave precautions should be included in the design details for the protection of the piles, and
- Ground beams or piled raft slabs.
- The piles must be deep enough to cater for heave.

For more information on this, please see the 'Foundations - Trees and Clay' section.

## Pile classification

Piles of many different types and methods of installation have been developed to suit the wide variety of soils. Piles generally fall into two main types:
- Bored and dug, including short bored and secant (replacement piles).
- Driven and jacked piles, steel, concrete and timber (displacement piles).

## How piling systems work

There are two groupings of piles, based on the way that they transfer loads to the ground:
- End bearing piles derive the greater part of their support from bearing forces at the base. They act largely as columns transferring loads through soft deposits, usually to dense granular soil or rock at the foot of the pile.
- Friction piles on the other hand, develop most of their support from friction between the shaft and the soil, usually firm clay.

## Choosing the right piled solution

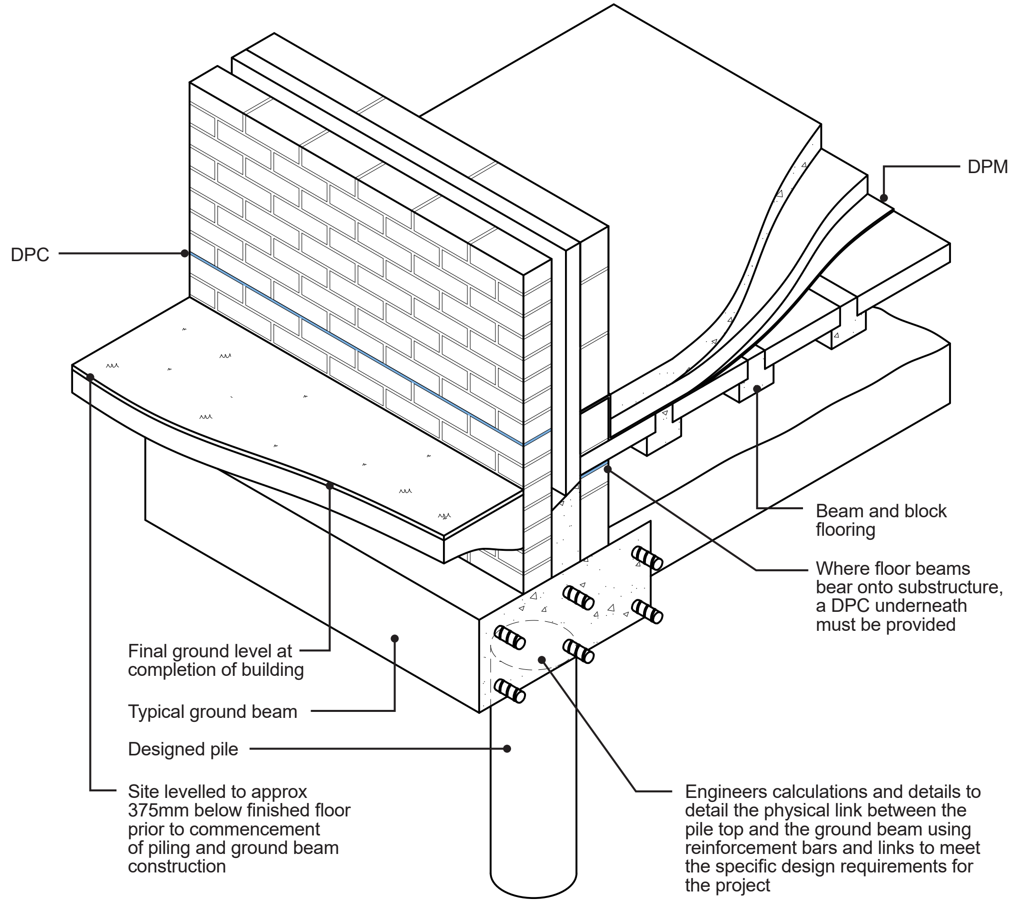
The choice of piling system to support the structure will depend entirely upon the ground conditions. It is important to have the appropriate site investigation works carried out to determine depths of filled ground, the bearing capacity of soils, soil type and any existing workings or services that may clash with pile locations.

Note: For further guidance on ground condition assessments, please refer to the 'Ground Conditions' section.

Analysis of the site investigation report should be completed by a Specialist Piling Contractor and Structural Engineer, as they are best placed to design the most economical piling system.

Piles are particularly appropriate for heave sites (trees removed), for which they are strongly recommended.

Pile layouts can be readily designed to accommodate an individual plot. A good design will seek to achieve cost savings in foundation excavation and materials.



## Alignment of piles

The Piling Contractor should take care to ensure that the piles are installed vertically and pile tops are correctly aligned to support the foundation system.

An acceptable level of tolerance is for a pile to be offset in plan from the theoretical position by no more than 75mm, with vertical alignment no worse than 1m in every 75m (1:75).

## Ground beams/piled raft slabs

Piles should be capped with an appropriate ground beam system or slab. There should be adequate connections between the beam or slab to the pile to ensure that the loads are transmitted effectively. The beam/slab should be adequately anchored to the pile to resist uplift on sites that are susceptible to heave. All external, internal, partition and party walls can be accommodated using this system. The foundation design should be supported by structural calculations provided by an Engineer or Specialist sub-contractor.

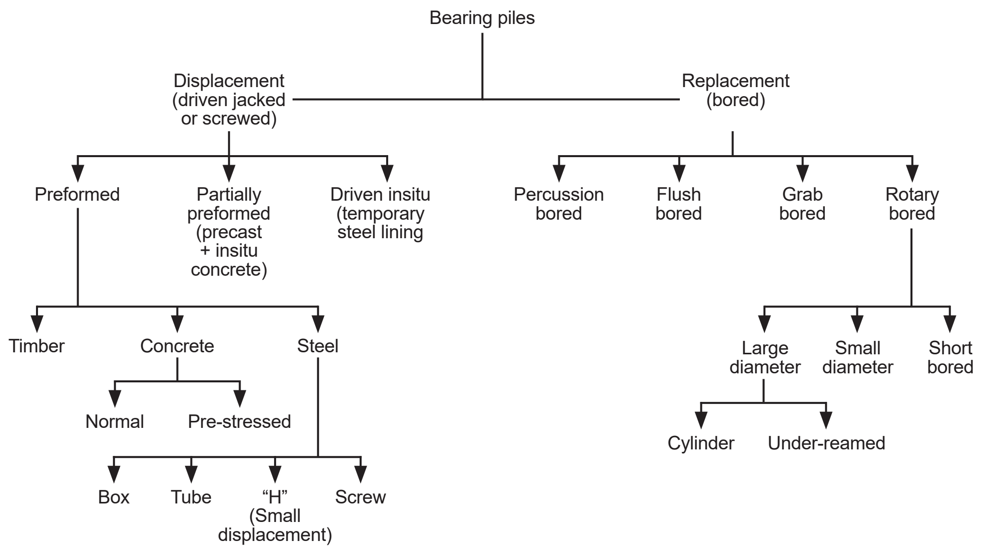
## Pile construction records

Pile construction records should be made available for all piles installed. The records should include the following information:

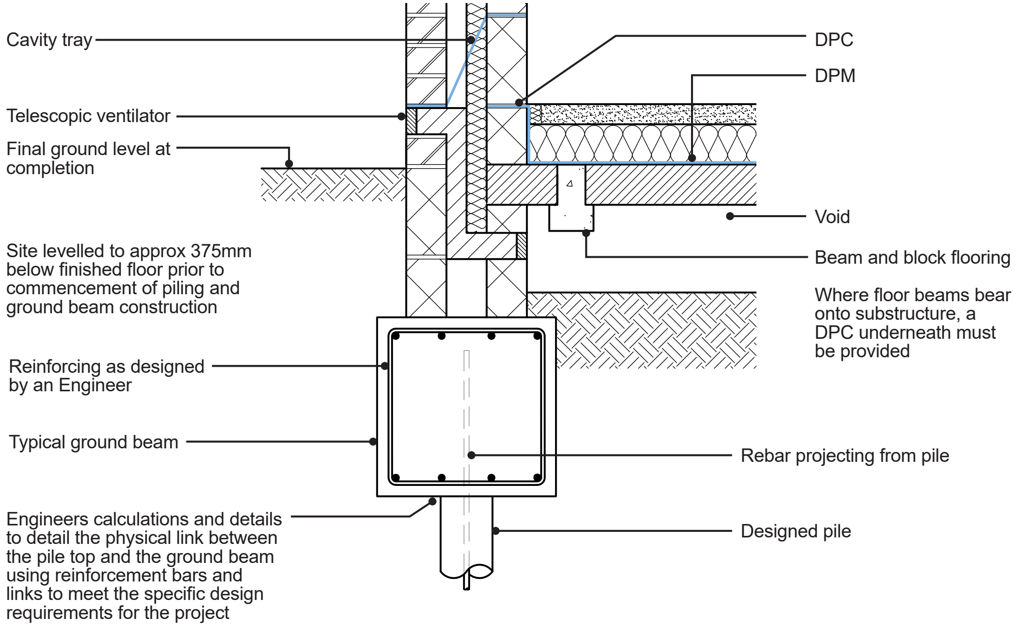
- Pile type (driven steel tube, driven precast concrete, Continuous Flight Auger (CFA), open hole auger bored, etc.).
- Pile dimensions (diameter or width/breadth).
- Pile depth.
- Driving records from driven piles, including hammer type, weight, drop height, sets, hammer efficiency.
- Up to date pile driving hammer energy efficiency test certificate.
- Pile verticality confirmation, which should be no more than 1:75 from vertical.
- 28 day concrete test cube results for cast insitu piles.
- Concrete mix design certificates for piling concrete from all suppliers – where piles are cast insitu.

For CFA and concrete screw piles, the Warranty Surveyor should be given the computer output for concrete volume and rig performance.

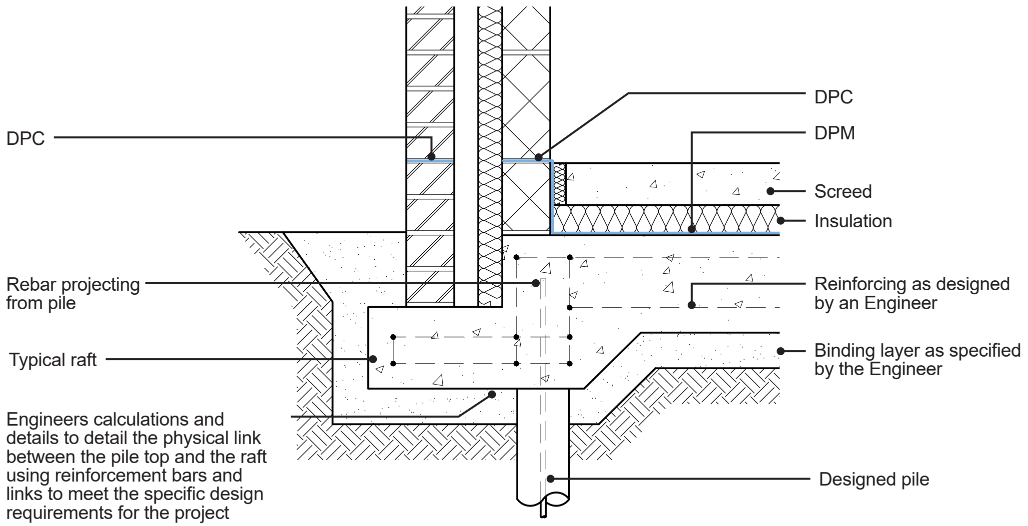
## The range of piling types (BRE publication)




## Pile and beam




## Piled raft



## Key requirements

The piling scheme shall be designed to clearly demonstrate that the piles are capable of supporting and transferring the foundation design loads safely to known soil strata that are, in turn, capable of supporting the pile loads using the appropriate soil parameters obtained from geotechnical testing and contained in the appropriate site investigation report. The piles shall be designed in accordance with BS 8004:2015 and shall ensure that long term settlement does not exceed 10mm or 1:500 (differential, between adjacent piles) at working load and 15mm at 1.5 times working load, unless more stringent criteria are required by the Engineer.

Pile installation record sheets shall show clearly that all piles installed have achieved sufficient depth with respect to the pile design calculations. Where there is any doubt concerning the depth of the piles, as a result of any encountered voids or boulders, or there is any other reason to suspect under-performance, the capacity of the questionable piles shall be demonstrated by means of static load testing and it shall be confirmed by the Engineer that the piles are fit for purpose.

## Reference documents

- BS EN 1997-1 Eurocode 7: Geotechnical design (EC7)
- BS 8004 - Code of practice for foundations
- BS EN 1997-2 - Ground investigation and testing
- BS 5930 - Code of practice for ground investigations
- ICE Specification for piling and embedded retaining walls (3rd edition)
- London district surveyors association (LDSA) - Guidance notes for the design of straight shafted bored piles in London clay
- PERKO, H.A. Helical piles – a practical guide to design and installation. Hobokon, New Jersey: John Wiley, 2009, ISBN 978 0 470 40479 9
- BS EN 1993-5: Eurocode 3: Design of Steel Structures – Part 5: Piling

## Geotechnical site investigation

A detailed, site specific, interpretive, Phase 2 Geotechnical Site Investigation should take place and be in accordance with BS 5930 / BS EN1997-2 and extend to depths beneath the pile toe of at least 3 x pile diameter or 5m or the smallest plan dimension encompassing the pile group (whichever is the greatest). Refer to ‘Published Minimum Requirements for Site Investigation’ by the Federation of Piling Specialists (July 2013). Generally, boreholes should be at centres of 10m to 30m for structures and at a minimum of 3 points, but closer borehole spacing’s should be used where there are site-specific hazards (e.g. soluble soils, mining features etc.) or where there are large variations in soil properties.

The investigation should include sufficient geotechnical testing throughout the length and beneath the pile to enable an accurate geotechnical design of the pile in accordance with proven design methods.

If the Site Investigation is found to contain insufficient information to verify the proposed design of the piles, the pile designer should request additional investigation and testing e.g. additional boreholes to the above depth, as considered necessary to establish the required geotechnical parameters.

## Pile design

A pile layout drawing and pile load schedule should be prepared by the Engineer, indicating the pile reference numbers, all loadings to which each pile will be subjected and details of connections between piles and the substructure. Calculations should clearly demonstrate how the load on each pile was derived.

The piles shall be designed in accordance with BS8004/BSEN1997-1 and shall ensure that long term settlement does not exceed 10mm or 1:500 (differential, between adjacent piles) at working load and 15mm at 1.5 times working load, unless more stringent criteria are required by the Engineer.

In all cases, a geotechnical and structural design should be carried out to current standards in order to produce a Geotechnical Design Report to confirm the required pile length, reinforcement etc. and to reflect the ground conditions as confirmed by the site specific Site Investigation Report. The pile design should prove that the pile can support all compressive, horizontal, tensile, heave and negative skin friction forces.

The skin friction adhesion factor (α) should be in accordance with BS 8004 (clause 6.4.1.2.3). An adhesion factor greater than 0.5 will not be acceptable unless supported by maintained static load tests on 1% of working piles.

BS 8004 (clause 6.1.1) and BS EN1997-1 (clause 7.4.1) permits pile design to be carried out one of the following options:

1. Geotechnical/Static pile design based on soil parameters from the site investigation and appropriate safety factors.
2. The results of dynamic load tests (provided they have been verified by static load tests in comparable situations).
3. Pile driving formula (provided they have been verified by static tests in comparable situations).

If the results of appropriate static load testing are not available for the site, then only option 1 can be used as the basis of design. In this case, all driven piles should be installed to the lengths indicated in the static pile design calculation and representative dynamic tests with settlement analysis (e.g. CAPWAP) carried out (typically 3% to 5% per static pile design), but this may need to be increased if there are any concerns regarding the pile installation or if required by the Engineer.

However, if the piles cannot be driven to the lengths indicated in the static pile design (as is often the case), then reliance switches to dynamic tests and/or dynamic formulae, both of which need to be verified by previous evidence of acceptable performance in static load tests on the same type of pile, of similar length and cross section and in similar ground conditions (the static load tests don’t necessarily need to have been carried out on the particular site), as required by BS 8004:2015.

A pile schedule should be produced indicating the pile numbers (referenced to the drawings), pile loads, pile type and diameter, pile length, required rock socket length, and details of required reinforcement. Piles for new developments should be not less than 150mm diameter or equivalent.

## Alternative pile types and design methods

If alternative pile types or non-standard design methods are being considered, please contact the Warranty Surveyor prior to commencement of piling.

## Additional design requirements for helical (screw) piles

Helical (or Screw) piles are manufactured steel foundations that are rotated into the ground to support structures. The basic components of a helical pile include the lead, extensions, helical bearing plates, and pile cap.

The following design requirements should also be considered for helical (screw) piles:
- Helical piles should be designed and installed in accordance with BS 8004:2015+A1:2020 Annex A and ICE Specification for Piling and Embedded Retaining Walls (SPERW).
- The helical pile designer/supplier should demonstrate clearly in calculations which design method has adopted i.e. plugged shaft or individual plate method. Adopted soil parameters shall be derived from an adequate site investigation.
- Tension piles shall also include a soil wedge check.
- Shaft resistance shall be ignored when deriving the pile design resistance.
- Building near trees. Shaft adhesion in the zone of tree influence shall be calculated. Sufficient tension capacity should be provided to resist heave forces. No helix shall be installed in the heave zone.
- A structural design of all component’s including helix, helix welds, connections to the ground beams/foundation system etc. shall be provided.
- The helix should be spaced at a minimum of 1.5 times the shaft diameter.
- Helix diameters shall be no greater than those above.
- Corrosion protection. A 60 year design life based on section loss shall be demonstrated. Cathodic protection, galvanise or other coating will not be acceptable.
- The GA/Fabrication drawings and schedules for the piles/pile components shall be provided and identify the steel grade (Minimum J0), helix numbers and setting out as a minimum.

## Pile design factor of safety for all Piles construction

The factor of safety is dependent on the extent of site investigation, design method/code/standard, confidence in the design, the proposed pile load testing regime, and should be in accordance with design method being used.

**Additional pile design factor of safety (geotechnical) for helical (screw) piles**
Design Factors of safety shall be based on Eurocode design (BS EN 1997-1:2004+A1:2013). Resistance factors shall be based on R4 values for a driven pile as per Table A.NA.6.

Lateral load capacity and displacement shall be based on industry-accepted methods in line with cl.6.4.5 of BS 8004:2015 including elasticity theory, p-y curves, subgrade reaction models, or any other approved numerical models.

## Flexible and rigid retaining walls

**Flexible retaining walls**
For the purposes of Warranty, flexible retaining walls may be defined as walls that support soil laterally whilst allowing deformations of the unsupported edge of the flexible retaining wall. Examples of flexible retaining walls include gabion, crib, block, timber or modular retaining wall systems.

Flexible retaining walls should not be used to support the structure of the property, garages, roads, drives, car parking areas or drainage systems.

**Rigid retaining walls**
Where rigid retaining walls are specified which support the foundations of a building, an Engineers design must be provided to confirm capable of maintaining stability for a period of at least 60 years and all works to the rigid retaining wall should be completed prior to works for the foundations of the property starting.

## BS EN 1997-1 Partial factors depending upon load testing undertaken (for bored or continuous flight auger piles)

| Direction of load | Load tests | Partial factor for shaft resistance | Partial factor for base resistance | Model factor |
|---|---|---|---|---|
| Compression | None | 1.6 | 2.0 | 1.4 |
| | WPT only | 1.4 | 1.7 | 1.4 |
| | PPT and WPT | 1.4 | 1.7 | 1.2 |
| Tension | None | 2.0 | - | 1.4 |

## BSEN1997-1 Partial Factors depending upon load testing undertaken (for driven piles)

| Direction of load | Load tests | Partial factor for shaft resistance | Partial factor for base resistance | Model factor |
|---|---|---|---|---|
| Compression | None | 1.5 | 1.7 | 1.4 |
| | WPT only | 1.3 | 1.5 | 1.4 |
| | PPT and WPT | 1.3 | 1.5 | 1.2 |
| Tension | None | 2.0 | - | 1.4 |

WPT: Working Pile Test.
PPT: Preliminary Pile Test.
Refer to BSEN1997-1 for full tables and commentary.

Note: It is not acceptable to adopt a higher factor of safety in place of an adequately detailed Site Investigation.

The guidelines contained in LDSA guidance should be used for the design of straight shafted bored piles in London clay.

## Piling in rock/boulders

If rock sockets are required by the pile design, then the achievement of such sockets during pile installation should be demonstrated. Where there are boulders, it needs to be demonstrated that piles are not founded on, or partly on, boulders. It is advisable to ensure that piles are taken down through strata containing cobbles/boulders. Pre-drilling may be required.

“Rig refusal” will not be accepted in the event that design rock socket lengths are not achieved, In the event of this, static load testing and additional site investigation and geotechnical testing will be required.

## Piling in chalk

Reference should be made to CIRIA PR86 and CIRIA C574 for pile design and installation. Where the risk of solution features as obtained from a Groundsure or Envirocheck hazard map is moderate or high (i.e. not low), probing should be carried out at each pile location in accordance with CIRIA PR86. Piles should be designed to take into account the risk of a solution feature around, adjacent or beneath the pile (refer to clause 7.10.2 of CIRIA C574). Should concrete flows significantly exceed the volume of the pile during installation (suggestive of a solution feature/void), measures should be taken immediately to mitigate the risk e.g. additional probing, deeper piles, relocation of piles, load testing etc.

On sites previously classified as low risk, should a potential solution feature be encountered during excavation/inspection/construction of the foundations, the foundation design should be amended accordingly to ensure that the soils within the feature are not required to provide long term support to the foundations. This will likely involve, as considered appropriate, those steps undertaken on sites with a moderate and high risk of the presence of solution features.`

## Piling in ground subject to cavitation

Where the ground is subject to potential cavitation as a result of gypsum dissolution, brine dissolution etc., the pile design and installation should take into account any existing and future cavitation. As such, some form of redundancy may need to be considered within the design to counteract any unknown conditions. As the presence of solution features cannot be readily identified during the installation of the piles, it is recommended that probing be undertaken at each pile location. Geophysical investigation or similar is recommended in order to locate existing cavities.

## Piling over mine workings

With regard to piling over or near to historical mine workings reference should be made to CIRIA SP32 and CIRIA C758D. Piles are not generally suitable unless founded below the grouted horizons. When piling adjacent to existing mine entries, assurance needs to be provided that adequate competent rock is available, that stipulated rock sockets are achieved and that piles will not be affected by any potential future collapse or partial collapse of the mine entry.

## Piling in made ground

Piles terminating in, or relying on, made ground/fill are not acceptable.

## Pile installation and testing

Piles should be installed and tested to ensure that they meet the design requirements. The Engineer shall review all pile installation records and testing results and advise on remedial works to address any unusual results or failures.

## Pile installation records (logs)

Copies of the site-recorded pile installation records (logs) shall be provided for each pile indicating the pile number (correctly referenced to the drawing), pile load, pile length, reinforcement details and any sleeving requirements.

For driven piles, the first pile driven should record the number of blows for the first 100mm of each metre of depth, and the set (including dates) achieved during installation and on re-strike should be indicated.

Should driven piles vary considerably in length across short distances, then the pile installation should be immediately re-assessed and details (including subsequent results of further investigation and a plot of pile lengths on the pile layout drawing and sections) submitted to the Warranty Surveyor for review. Installing piles to “rig-refusal” or reference to the limitations of the piling rig shall not be accepted as the sole proof of adequacy of the pile length. If the pile static design lengths are not being achieved on site, then static pile load tests may be required in order to ensure compliance with the British Standards and/or carrying out additional site investigation to prove the adequacy of the pile.

Re-strikes shall be carried out on driven piles (typically at a rate of 10%) following a suitable time allowance. If sets have relaxed on re-strike, the adequacy of the piles shall be re-evaluated (e.g. by additional testing).

Rig telemetry should be recorded, stored and provided as a matter of course for projects with continuous flight auger (CFA), sectional flight auger (SFA) or continuous helical displacement (CHD) piles.

## Concrete mix and cube test results

Concrete mix details and cube test results for the concrete used in the piles shall be provided with tabulated results, similar to that in Concrete Advice Note No.30 (The Concrete Society) Tables 1 and 3. Delivery records, cross referenced to the pile layout/numbers, should also be kept for possible future reference. The Engineer shall review all concrete cube testing results and, in the case of any unusual results or failures, advise on any remedial works proposals necessary.

## Pile integrity testing

The integrity of the full depth and cross-section of all CFA, SFA, CHD, bored piles (including retaining walls) should be established by integrity testing using recognised methods. Should integrity testing indicate anomalies, then the Engineer should advise on the remedial measures proposed and seek agreement with us. It is recommended that such agreement is obtained prior to work continuing.

Note: Integrity testing should not be considered as replacement for sufficient site investigation or other types of testing, particularly static load testing. 100% of such piles shall be integrity tested.

## Dynamic load testing

Dynamic load testing shall be carried out in accordance with BS 8004 and shall include analysis of long term settlements. There should be adequate site investigation to 5m below the pile toe as required by the British Standards.

BS 8004 (clause 6.1.1) & BS EN1997-1 (clause 7.4.1) permits pile design to be carried out by one of the following options:

1. Geotechnical/Static pile design based on soil parameters from the site investigation and appropriate safety factors.
2. The results of dynamic load tests (provided they have been verified by static load tests in comparable situations).
3. Pile driving formula (provided they have been verified by static load tests in comparable situations).

If the results of appropriate static load testing are not available for the site, then only option 1 above can be used as the basis of design. In this case, all driven piles should be installed to the lengths indicated in the static pile design and representative dynamic tests with settlement analysis (e.g. CAPWAP) are carried out (typically 3% to 5% per static pile design but this may need to be increased if there are any concerns regarding the pile installation or if required by the Engineer).

However, if the piles cannot be driven to the lengths indicated in the static design (as is often the case), then reliance switches to dynamic tests and/or dynamic formulae, both of which need to be verified by previous evidence of acceptable performance in static load tests on the same type of pile, of similar length and cross section and in similar ground conditions (the static tests don’t necessarily need to have been carried out on the particular site), as required by BS 8004.

## Static load testing

Preliminary Pile Tests (PPT): Maintained load (ML) testing up to the unfactored ultimate resistance (commonly defined as settlement equivalent to 10% of the pile diameter) in accordance with BS 8004, SPERW, or other accepted standards; normally carried out before work starts on site or at the very beginning of a project.

Working Pile Tests (WPT): Maintained load (ML) testing up to at least 1.5 times working load in accordance with BS 8004, SPERW, or other accepted standards. Working Pile Tests shall be carried out at a rate of 1 per 100 piles or part thereof (not less than 1%).

Note: Where there are large variations in substrata revealed either by the Site Investigation or during the construction of piles, load tests should be carried out in each zone and the level of testing reassessed accordingly for each design situation. Similarly, load testing should reflect the various pile lengths and loadings.

If there are queries with regard to anything not covered within this document and/or it is intended that the Site Investigation, pile design, installation or testing is to deviate from the above guidance, then please contact the Warranty Surveyor for agreement prior to commencement.

## Helical (screw) pile installation and testing

**Installation**
The following should be considered during the installation of helical (screw) piles:

- Installation must be undertaken by an installer approved by the specialist manufacturer/system promoter.
- Site welding is not permitted.
- Whilst installation may be informed by the Capacity-to-Torque Ratio the installed lengths shall achieve the geotechnical design length. Failure to do so may lead to the pile being rejected.

**Testing**
During installation and following completion of the works, the pile designer will also be required to undertake the following:

- Oversee any pile load tests including the static load test undertaken in accordance with the ICE ‘Specification for Piling and Embedded Retaining Walls’, as specified by the Engineer.
- Validate installation of the piles through submission of a report confirming review of the pile installation logs to confirm that the piles have been installed into suitable stratum, to the required torque and have the required design capacity, satisfactory undertaking of the pile load test/s, installation is to tolerances set out within the system installation guidance, and confirmation that all components utilised were supplied by the specialist manufacturer.
- Static load test piles shall be in accordance with the design factors of safety adopted.

# 3.
# Foundations

## 3.3
## Raft

## Provision of information

A full set of design drawings, calculations and specifications shall be made available to the Warranty Provider and all other interested parties prior to the associated works starting on site. This may include:

1. Phase 1 Desk Study Report and Phase 2 Geotechnical Site Investigation Reports including site-specific recommendations for raft foundations (and allowable bearing pressures) to ensure long term settlement does not exceed 25mm or 1/500 (differential).
2. Structural drawings:
   a) GA and RC drawings, including a drawing register sheet.
   b) Details of internal and external thickening to cater for loadings and the effects of frost.
   c) Details of any insulation beneath the raft.
3. Structural calculations:
   a) Demonstrating that the ground bearing pressure does not exceed the allowable value specified in the Site investigation report. Localised areas of higher bearing pressures (e.g. beneath load-bearing walls, thickening or point loads) should be considered.
   b) Demonstrating that the raft (i.e. the thickening, slab and beams) can span a 3.0 metre ‘soft spot’ and cantilever 1.5 metres.
   c) Demonstrating the adequacy of any insulation beneath the raft (in relation to loadings, creep and groundwater). The insulation must have appropriate 3rd party approval certification and compressive creep must be limited to a maximum 2% reduction for a 50/60 year period.
4. Plans and details of the proposed raft showing reinforcing positions and a bar schedule, to be used by the reinforcing steel supplier and installer.
5. Confirmation that all made ground and organic matter beneath the foundation has been or shall be removed/replaced with appropriate material, or treated.
6. Details of engineered granular fill below the raft (including its depth and lateral extent, ensuring a 45º spread from the edge), along with its compaction specification, testing and Geotechnical Engineer’s validation. Where Manual for Highway Works (MHW) specification for engineered granular fill is indicated, details shall conform with MHW Volume 1 Series 600 Earthworks Cl:610 ‘Fill to Structures’.
7. Calculations demonstrating how the depth of granular fill has been determined to cater for the effects of heave and shrinkage (if shrinkable soils are present).
8. Details of any ground treatment (e.g. vibro treatment, cement-lime stabilisation etc.).

Please note: if there are queries with regard to anything not covered or it is intended to deviate from the above guidance, then please contact the Warranty Surveyor for agreement prior to commencement. Following acceptance of the proposals, please refer back to the Warranty Surveyor if anything is subsequently discovered on site, which affects the design and/or construction of the raft.

The Warranty Surveyor, at their discretion, may also request supporting information that demonstrates suitability for use of any materials or systems contained within the above.

## Limitations of guidance

Rafts are not considered an accepted method of foundations where the ground conditions are susceptible to heave or shrinkage (e.g. where trees are present or have been removed) unless appropriate measures have been taken to mitigate the effects of heave or shrinkage. For further clarification, please refer to the ‘Foundations - Trees and Clay’ section.

## Introduction

A raft foundation consists of a reinforced concrete slab, whose thickness and stiffness are designed to spread the applied wall and column loads over a large area and reduce differential settlement gradients.

For domestic applications, rafts are often built with thickened perimeters to provide protection against frost heave, in which case they are effectively trench fill foundations with integral ground bearing floor slabs. Down stand edge beams also serve to stiffen the foundation’s structure.

Rafts are used where it is necessary to limit the load applied to the underlying soil or to reduce the effects of differential foundation movements due to variable soil conditions or variations in loading.

## Materials

Materials and workmanship should meet the requirements set out in the ‘Appendix C - Materials, Products, and Building Systems’ section.

## Ground conditions

Raft foundations are usually designed for sites with variable ground conditions with low ground bearing capacities. It is therefore important to complete a suitable Site Investigation to meet the requirements of the ‘Ground Conditions’ section and ascertain the bearing capacity and suitability of the ground.

## Structural design

Structural calculations should be provided by an Engineer, confirming that the raft design is suitable for bearing onto the ground and that the ground bearing capacity safely supports the structure and it will limit long term total and differential settlements to acceptable levels.

## Key requirements

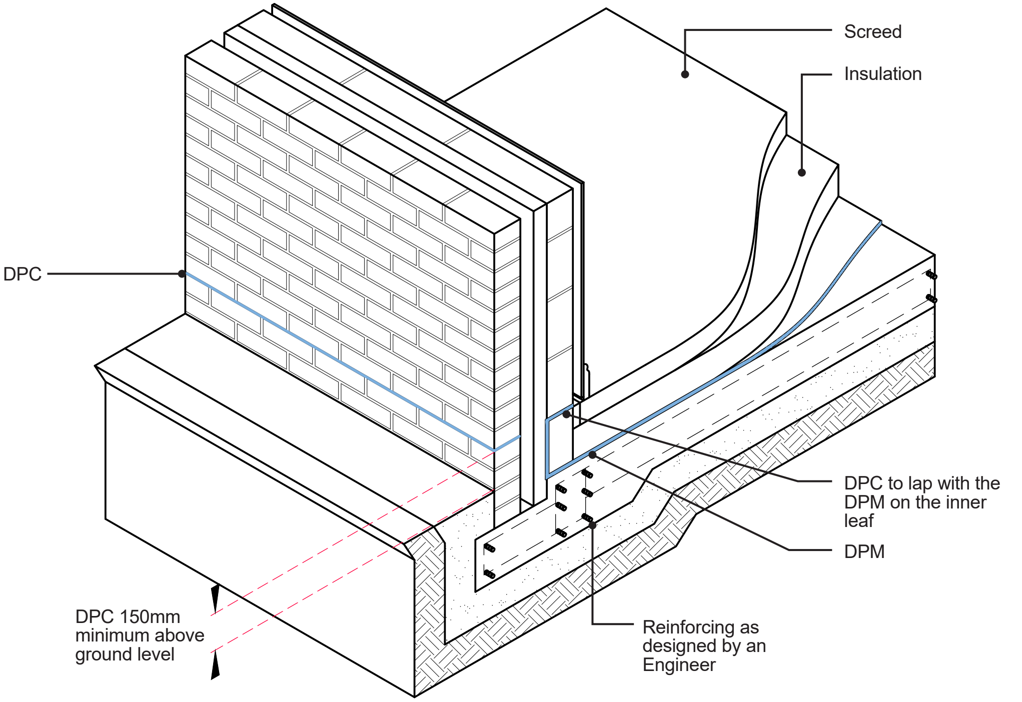
The raft foundations shall be designed to clearly demonstrate that the rafts, insulation and any treated ground are capable of supporting and transferring the foundation design loads safely to known soil strata that are, in turn, capable of supporting the loads, using the appropriate soil properties obtained from geotechnical testing and contained in the appropriate Site Investigation report. The rafts shall be designed in accordance with BS 8004:2015 and shall ensure that long term settlement does not exceed 25mm or 1:500 (differential), unless more stringent criteria are required by the Engineer.

## Thermal insulation products below the structural raft

Where thermal insulation products are used below the structural raft they should:

- Meet the requirements of BS EN 1606 Thermal insulation products for building applications.
- Meet BS EN 13163 (for EPS insulation).
- Meet BS EN 13164 (for XPS insulation).
- The Engineer should ensure that the design limits ‘compressive creep’ to a maximum 2% reduction for a 50/60 year period.
- The insulation product must have third party product approval certification for use below a structural raft foundation (including below external walls).

## Typical raft foundation



## Damp proof membranes (DPM), damp proof courses (DPC), and floor finishes

The raft foundation and the junction with the wall should be appropriately constructed to resist ground moisture penetration.

A DPM can be placed beneath the raft, wrapped around the external toe and lapped into the internal DPC. However, this detail can be difficult to implement on-site, and puncturing of the membrane can commonly occur when placing reinforcing. The preferred method is to place the DPM on top of the raft slab beneath the floor insulation or screed.

## Stepped membranes

DPM should be continuous where floors are stepped, a waterproof specialist must select an approved waterproof membrane to meet the requirements of BS 8120 to provide a continuous barrier that is compatible with the floor DPM/DPC.

## Damp proofing

**Damp proof courses (DPC)**
DPC's should be of a flexible material that is suitable for its intended use and the DPC should have appropriate third-party certification. Blue brick or slates will not be accepted as a DPC.

DPC's should be laid on a mortar bed and correctly lapped at junctions and corners. The depth of lap should be the same as the width of the DPC.

DPC's should not bridge any cavities unless it is acting as a cavity tray. Where a cavity tray is required (e.g. over a telescopic floor vent) please refer to the 'External Walls' section for cavity tray, weep holes and stop end requirements.

**Damp proof membranes (DPM)**
A DPM should be provided beneath all ground-supported slabs or cast in-situ reinforced slabs. DPM's should be linked to the DPC and be a minimum 1200g polythene. Other DPM's may be considered if they have appropriate third-party certification and are installed in accordance with the manufacturer's instructions.

**Cavity trays**
For guidance on cavity trays, please refer to the 'External Walls' section.

## Concreting of floors

Prior to concreting, any water or debris that may have collected on top of the DPM should be removed. Expansion joints should be provided and constructed in accordance with the Engineers design.

## Bricks and blocks below ground

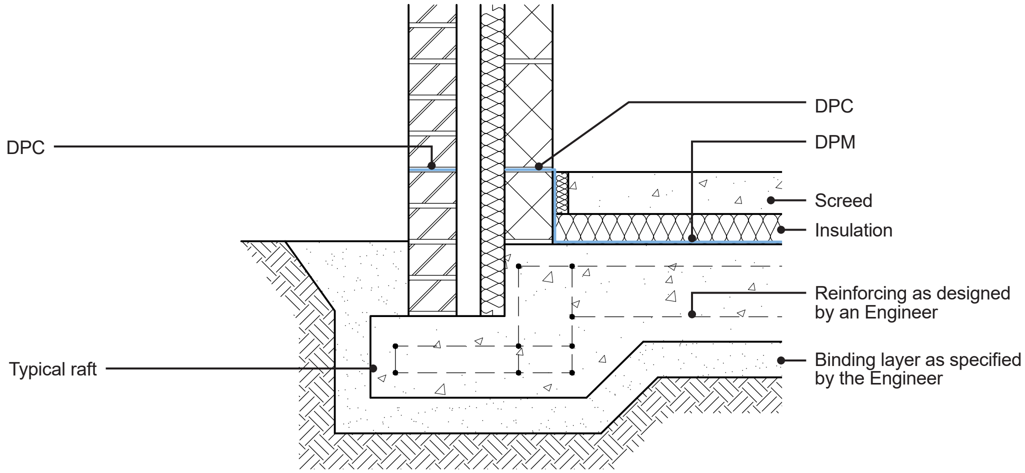
The selected bricks should be appropriately durable against saturation. See 'Appendix C - Materials, Products, and Building Systems' for further guidance.

If there are sulphates in the ground and/or there is ground water present, confirmation by the manufacturer that the brick or block is suitable for use below ground should be provided.

## Reference documents

- BS EN 1997-1 - Eurocode 7: Geotechnical design (EC7)
- BS 8004 - Code of practice for foundations and Eurocode
- BS EN 1997-2 - Ground investigation and testing
- BS 5930 - Code of practice for ground investigations
- Manual for Highway Works Volume 1 Series 600 Earthworks

## Typical raft foundation design




## Ducts and sleeving

Any service penetrations that pass through the raft should be appropriately sleeved to protect the service duct. Service duct positions should be planned and indicated on drawings to prevent reinforcing bars from being cut, unless the structural design has catered for this.

## Flexible and rigid retaining walls

**Flexible retaining walls**
For the purposes of Warranty, flexible retaining walls may be defined as walls that support soil laterally whilst allowing deformations of the unsupported edge of the flexible retaining wall. Examples of flexible retaining walls include gabion, crib, block, timber or modular retaining wall systems.

Flexible retaining walls should not be used to support the structure of the property, garages, roads, drives, car parking areas or drainage systems.

**Rigid retaining walls**
Where rigid retaining walls are specified which support the foundations of a building, an Engineers design must be provided to confirm capable of maintaining stability for a period of at least 60 years and all works to the rigid retaining wall should be completed prior to works for the foundations of the property starting.

# 3.
# Foundations

## 3.4
## Engineered Fill

## Provision of information

A full set of design drawings, calculations and specifications shall be made available to the Warranty Provider and all other interested parties prior to the associated works starting on site. This may include:

1. Site Investigation Reports including site-specific recommendations for foundations to ensure long term settlement does not exceed 25mm (10mm for piles) or 1/500 (differential).
2. Structural drawings:
   a) Site layout plan including proposed finished floor levels for all plots.
   b) Topographical survey confirming existing ground levels. Subsequent site level surveys indicating areas where earthworks are required to achieve final construction levels. If piling or ground improvement techniques are to be adopted, piling platform and/or vibro platform levels are required.
   c) GA and RC drawings, including a drawing register sheet.
   d) Piling & Vibro layout drawings (if applicable), including a drawing register sheet.
   e) The design of the dwellings should allow a degree of articulation with movement joints sufficient to accommodate the maximum allowable differential settlement above, also at thresholds and service entries.
3. Structural calculations:
   a) Demonstrating that the ground bearing pressure does not exceed the allowable value specified in the Site Investigation Report.
   b) Piled foundation calculations (please refer to the ‘Piling Good Practice Guide’ available on our website).
   c) Vibro foundation calculations (please refer to the ‘Piling Good Practice Guide’ available on our website).
4. Earthworks Specification including:
   a) Confirmation that works are supervised by a suitably experienced independent Chartered Geotechnical Engineer.
   b) Proposals for load testing to determine the expected long-term settlement and differential settlement of the fill. Please note: We consider that plate load tests do not confirm the expected long-term performance of the ground.
   c) Allowable bearing pressures, expected settlement and differential settlement.
   d) Consideration of the effects of slag, burnt shale and expansive soils.
   e) Consideration of self-weight settlement of the fill.
   f) Collapse compression analysis in accordance with BRE IP5/97.
   g) Details of any ground treatment (e.g. vibro treatment, cement-lime stabilisation etc.).
5. Geotechnical validation report including:
   a) Confirmation that all made ground and organic matter was removed.
   b) Details of formation levels prior to filling works.
   c) Depths of all cut and fill carried out across the site with levels linked to the original site investigation.
   d) Details demonstrating compliance with Clause 610 of the Specification for Highway Works (for structural fills).
   e) Details and locations of all tests and interpretation by the Geotechnical Engineer.
   f) Confirmation of the bearing capacity achieved by the earthworks and confirmation that long-term settlement will not exceed 25 mm or 1:500 differential settlement.

If there are queries with regard to anything not covered within this document and/or it is intended to deviate from the above guidance, then please contact the Warranty Engineers for agreement prior to commencement. Following acceptance of the proposals, if anything is subsequently discovered on site, which affects the design and/or construction, please contact the Warranty Surveyor immediately.

The Warranty Surveyor, at their discretion, may also request supporting information that demonstrates suitability for use of any materials or systems contained within the above.

## Limitations of guidance

The following situations are beyond the scope of this guidance:

- Where the original ground or sub-strata is unstable or will continue to settle.
- Sites with soft clays with a low bearing capacity (Undrained cohesion = 30kN/$m^2$ or less).
- Filled ground where high levels of voids are anticipated.
- Clay fill, where the water will influence the foundation or where collapse may occur.

Each development site has its own specific characteristics, and where conditions do not clearly fall within the guidance given, clarification should be sought from the Warranty Surveyor or a suitably qualified and experienced expert.

Fill or made ground can be divided into 2 main types:
1. Engineered Fill: When placed as part of the construction process and carried out to an engineered specification to high standards with good quality control and adequate engineering supervision, then risks can be assessed and may be quite small.
2. Non-Engineered Fill/Made Ground: Risks associated with sites covered with existing fill are more difficult to assess and short of complete excavation, the risks cannot be fully quantified. Therefore, alternative foundation solutions where loads can be transferred to competent strata are required.

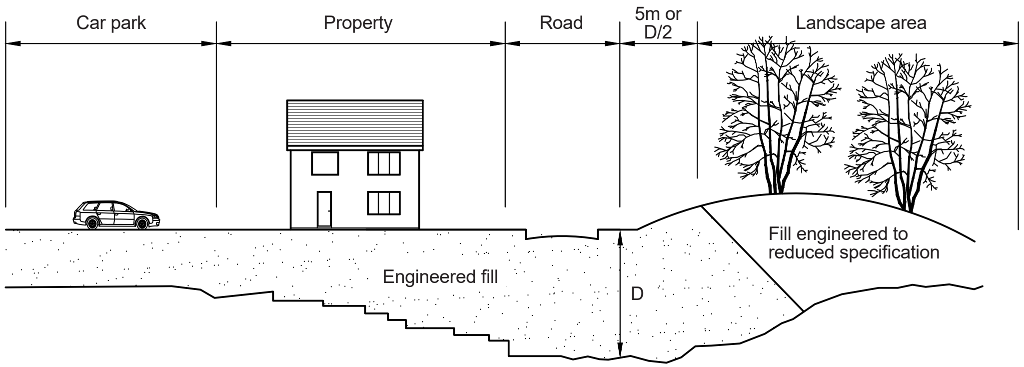
## Engineered fill

Generally cohesive/granular homogeneous material specifically selected to replace either made ground or infill voids left by other processes is adopted. Fill has been divided into 2 further categories. These are:

- Shallow fill (i.e. less than 2.5m depth below ground level).
- Deep fill (i.e. greater than 2.5m).

For further guidance on foundation types suitable for building on ‘Shallow’ and ‘Deep’ fill, please refer to our Warranty good practice guide ‘Building on Fill’ which can be found on the website.

## Typical engineered fill construction - Figure 1




## Design of engineered fill

Careful selection of the material and controlled placement should ensure that the engineered fill forms an adequate foundation material; however, in some circumstances, significant ground movements can occur.

A specification for engineered fill shall be prepared, covering materials, compaction, workmanship and validation testing. This specification shall be prepared by an Engineer.

Engineered fill should be designed and placed in accordance with recognised good practice, as noted in the references at the end of this section.

Engineered fills used to produce suitably shaped landforms for structures should be constructed to high standards to minimise the risk of ground movements causing damage to property built on shallow foundations.

In designing and specifying a fill to form a foundation for buildings, the following technical requirements should be established:

- A well-constructed excavation, safely executed, with all soft and hard spots removed and made reasonably dry and well drained.
- Sound fill without undesirable material and capable of compaction as specified, provided with starter and capping layers as necessary.
- Placement and compaction to ensure that the performance of the fill will meet required criteria as a foundation fill.
- Appropriate monitoring; the Designer must ensure that all work can be carried out safely as required by the Health and Safety Executive Construction Design and Management Regulations.

## Fill selection

Fill should be clearly categorised into material that may and may not be used: unsuitable fill, general fill, restricted fill and special fill. Fill materials must not present an environmental or health hazard.

Unsuitable fill should not be used at any location on the site.

General fill is all material except that which is unsuitable, restricted or special, and is normally the majority of the material used. It may include natural soils as well as some waste products.

Restricted fill is material that would be general fill except that it contains minerals hostile to the built environment. It can include natural materials such as pyritic shales, sulphate-bearing clays and waste materials, including burnt colliery discard and steel slag. Its use is precluded where ground water could rise to the underside of the deepest foundation, or where it is rejected for pollution reasons. For some developments, such as housing with gardens, restricted fills would include fills that are harmful to people.

Special fill is high-quality material, such as well-graded natural sands and gravels, crushed rock or clean demolition rubble. Its use will often have to be reserved for specifically defined purposes, such as a capping layer or backfill to retaining walls. Where possible though, granular soils should be used as general fill since these materials drain readily and consolidate quickly. The smaller the predominant particle size, the longer the potential time required for consolidation under the self-weight of the fill.

Materials considered to be unsuitable for use as fill are:

- Swamp or marsh land materials.
- All organic or part organic materials.
- Materials subject to spontaneous combustion.
- Colliery shales, ironstone shales and similar materials which have the potential for expansion due to oxidation of pyrites.
- Frozen materials or materials which are frost susceptible.
- Any materials which have a higher moisture content than the maximum permitted for such materials as defined in the specification.
- Clays with high plasticity index exceeding 55%.

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

- Acid wastes.
- Reactive materials.
- Materials that include sulphates (e.g. gypsum).
- Organic materials.
- Toxic materials.
- Materials that cause noxious fumes, rot, undue settlement or damage to surrounding materials.

The sample tests should be carried out by a suitably qualified person and it may be necessary to take a number of samples to identify the material characteristics of the fill accurately.

## End product criteria

The greatest threats to successful in-service performance are:

- Collapse settlement due to inundation of dry or inadequately compacted fills.
- Excessive consolidation settlement of wet compressible fill.
- Heave or settlement of clay fill due to climatic changes or vegetation.

These ground movements depend on moisture movement, so by reducing the voids in a fill, the opportunities for excessive in-service movements should be restricted. A maximum allowable air-voids content of 5% is a suitable criterion for most clay fills. However, specifying a 5% air-voids content is insufficient, as this value may easily be achieved by adding water to the fill without increasing compactive effort.

A suitable alternative control method is to specify a minimum acceptable density as a proportion of the maximum dry density measured in a standard laboratory compaction test. Limits on moisture content are also required.

If the fill is too wet, there could be excessive consolidation settlement and if the fill is too dry, it might be vulnerable to collapse compression.

## Placing engineered fill

A successful engineered fill requires not only an appropriate specification but also adequate control during placement. All the work must be carried out with due regard to safety, as required by the Construction Design and Management Regulations.

## Site preparation and disposition of fill

The site should be cleared of all topsoil and other unsuitable material.

Soft spots and hard spots, such as derelict foundations, should be removed together with ponds and surface water from depressions. Removing water by pumping may be necessary when filling some excavations below the ground water level.

When a variety of material types are used as fill, they should be deposited in horizontal layers across the site. If there is only a limited amount of good granular material, it will be best to use it in layers interspersed between layers of poorer cohesive fill.

The fill thickness should be reasonably constant beneath a structure to minimise differential settlement.

Feather-edges, resulting in foundations set partly on fill and partly on natural ground, should be avoided, and the site worked in such a way that structures are located either directly on natural ground or directly over fill of a consistent thickness.

If fill is to be placed over sloping natural ground, some stepping of the ground formation level will be necessary. Construction over the face of a quarry or an opencast mining high wall should be avoided.

Special measures may have to be taken by providing flexible connections for services at the location of high walls and by thickening construction for service and estate roads.

If the natural ground on which the fill rests is soft and compressible (for example, layers of peat or soft clay), the surface of the fill may settle appreciably and unevenly as a result of the weight of the fill consolidating the soft layers below. This settlement will, of course, be additional to that resulting from the compression of the fill itself.

Sensitive structures may warrant a surface (or capping) layer formed from special fill compacted to more onerous standards than the underlying fill. This should help minimise the differential settlement suffered by the structure.

Where landscaped or other non-load bearing areas form part of a development, they need less compaction than the load-bearing areas. There should be a transition zone around the load-bearing area, as shown in Figure 1.

## Flexible and rigid retaining walls

Flexible retaining walls
For the purposes of Warranty, flexible retaining walls may be defined as walls that support soil laterally whilst allowing deformations of the unsupported edge of the flexible retaining wall. Examples of flexible retaining walls include gabion, crib, block, timber or modular retaining wall systems.

Flexible retaining walls should not be used to support the structure of the property, garages, roads, drives, car parking areas or drainage systems.

**Rigid retaining walls**
Where rigid retaining walls are specified which support the foundations of a building, an Engineers design must be provided to confirm capable of maintaining stability for a period of at least 60 years and all works to the rigid retaining wall should be completed prior to works for the foundations of the property starting.

## Fill placement

Fill should be placed in horizontal layers, with each layer separately compacted.

For a given item of plant, compaction performance will be determined by fill layer thickness, fill moisture content and the number of passes of the compaction equipment. There are however, other factors such as the need to avoid excessive handling.

Whenever possible, site trials should be undertaken to determine the correct criteria. Some general information about placing fills is given in BS 6031.

Each layer should be of a thickness that allows the compactive energy to spread throughout the layer, producing the specified fill density and low air-voids content. Loose layers with a thickness greater than 250mm are unlikely to be satisfactory for earth fills compacted to support low rise structures. It may be necessary to use layers of 200mm or less.

Moisture content at the time of placing a fill is fundamental to subsequent performance, particularly where the fill contains a large proportion of fine grained cohesive material. If the fill is too dry, there is the possibility of heave or collapse settlement; if it is too wet, there is the possibility of insufficient strength and high compressibility. It will be difficult to achieve air-voids content of 5% or less when the moisture content is low. In the same way that the addition of too much water can detract from the performance of engineered fill, soil can be over compacted.

Granular soils and cohesive soils drier than optimum, when rolled excessively, become over-stressed and what should have been a firm compacted surface becomes a loose tilth. This should be avoided whenever possible. Where a fill containing a large proportion of fine grained cohesive material (for example, clay) is used, filling during wet weather should be avoided.

## Quality control and testing of fill during placement

Quality control procedures should be implemented to ensure compliance with the specification. The nature of the control procedure will depend on the type of specification adopted.

The end product specification requires an appropriate type and quantity of testing of the fill during placement to ensure that the desired end product is being achieved. Depending upon the type of contract, quality control may be the responsibility of the Engineer or of the contractor working under the supervision of the Engineer.

Control parameters should be the same as those determined during the site investigation stage. Both design and control parameters must be reproducible, a term that denotes the range within which measurements made on the same fill by different operators using different equipment should agree.

The following are the most significant control parameters:

- Moisture content, in respect of an optimum moisture content established at the Site Investigation stage.
- Dry density, in respect of the already established maximum dry density.
- Air-voids content, which depends on moisture content and dry density.
- Un-drained shear strength, which is an alternative to monitoring moisture content and dry density for clay fills.

The laboratory compaction tests and the associated field control tests are suitable for a wide range of fill types and form the most generally applicable approach. For cohesive soils, un-drained shear strength forms an alternative basis for specification and control testing. However, different methods of measuring the un-drained shear strength, such as the unconfined compression test and the vane test, can give significantly different values. The measured value of cohesion can be sensitive to a detailed test procedure, such as the rate of shearing.

It is important for the method of testing to be strictly specified. Where a cohesive fill contains gravel, it may not be possible to obtain sufficiently undisturbed samples for strength tests. On larger sites, employing in-situ methods, such as the cone penetrometer (BS 1377: Part 9), could be considered.

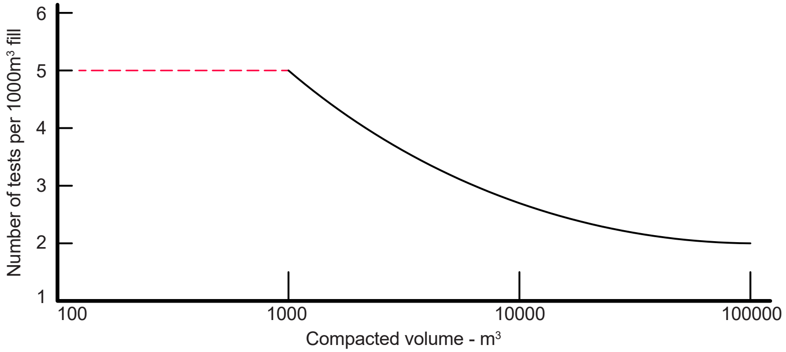
Small sites are generally more difficult to work than large sites, as finished work may be damaged more easily in confined working areas and deficiencies in site preparation usually reflect more readily in poorer quality compaction than on larger sites. Consequently, it is necessary to test more frequently on a small site than on a large one.

A suggested minimum test frequency is presented in Figure 2. However, each site should be judged on its own merits, with careful note taken of any problems revealed during site investigation. In very variable or difficult conditions, more frequent testing may be required. Tests in visually doubtful areas, and re-tests of failed areas, should be carried out in addition to those recommended in Figure 2.

Modern compaction control requires laboratory and field testing during the Site Investigation, and during, and possibly following, the earthworks. The results of this work must be recorded, collated and presented to demonstrate the quality of the operation. The required documentation includes:

- Summary of the specification requirements and the end product in terms of the selected geotechnical parameters for the various fills (based on-site investigation information).
- List of the required suitability tests; one form to be completed for each borrow pit under investigation.
- Suitability test results for each borrow pit.
- List of the required control tests.
- Results of the control tests on each fill type, layer or area, as appropriate.
- A list of post-compaction monitoring requirements.
- The results of post-compaction monitoring; all completed forms should be signed and dated by the person responsible and a list prepared of any required action or remedial work to be carried out.

## Number of tests - figure 2




## Monitoring of fill performance - post compaction

Monitoring provides a check on the performance of the fill after compaction and is particularly important where vulnerable structures are to be built or foundation loading is unusually large. It is also required where the fill is relatively deep or substantial ground water rise within the fill is expected.

Monitoring techniques include:

- Surface levelling stations to measure the settlement of the fill surface.
- Magnet extensometers to measure the settlement of incremental depths of fill.
- Standpipe piezometers to measure the rise in the ground water table in the fill after placement.
- Load tests for direct estimation of settlement of surface layers produced by loadings.

Surface levelling stations are easy to install and very effective. By optical levelling of the stations, measurement can be made of the total vertical movement of the fill upon which they rest, together with any movement of the underlying natural ground. Although this is unlikely to be large if all soft material has been removed prior to compaction. Levelling stations should be sufficiently robust to resist damage due to construction traffic. A round headed bolt cast into a 1m concrete cube set 300mm into the fill has been found to be effective.

Magnet extensometers are unlikely to be necessary in shallow-depth fill. Standpipes or piezometers will be of advantage if there is reason to suspect that ground water will rise into the fill at any time in the future, with consequent settlement.

## Relevant British Standards and guidance documents

Relevant British Standards Codes of Practice and authoritative documents include:

- BS 6031 Code of Practice for earthworks
- BS 1377: Part 9 Methods of tests for soils for civil engineering purposes. In-situ tests
- BS 10175 Investigation of potentially contaminated sites - Code of practice
- BS EN 1991 Actions on structures
- BS EN 14731 Execution of special geotechnical works. Ground treatment by deep vibration
- BS EN 1997-1 General rules
- BS EN 1997-2 Ground investigation and testing
- BS EN ISO 14688 Geotechnical investigation and testing - Identification and classification of soil
- BS EN ISO 14689 Geotechnical investigation and testing - Identification and classification of rock
- BS EN ISO 22476 Geotechnical investigation and testing - Field testing
- BR 391 Specifying vibro stone columns
- Institute of Civil Engineers (ICE) specification for ground treatment: Notes for guidance, 1987
- CIRIA C572: Treated ground: Engineering properties and performance, 2002
- CIRIA C573: A guide to ground treatment, 2002
- BRE 424: Building on fill: Geotechnical aspects
- BRE Information Paper 5/97: Collapse compression on inundation

## Introduction

The following guidance outlines recognised good practice in relation to building on fill. The structural design and construction should be in accordance with the Functional Requirements of this Technical Manual and recognised publications from British Standards, Eurocodes, CIRIA, BRE and ICE.

## Key requirements

The foundation scheme shall be designed to clearly demonstrate that the foundations are capable of supporting and transferring the design loads safely to known soil strata that can be demonstrated from the appropriate project site investigation reports to be capable of carrying the load, using the appropriate soil properties obtained from geotechnical and load testing.

Groundwork shall be designed and validated by an Engineer to ensure that settlement will not exceed 25 mm (10mm for piles) or differential settlement tilt greater than 1:500 for low-rise buildings unless more stringent criteria are required by the Engineer.

Partial depth foundation solutions where either piles or ground improvement techniques (i.e. vibro stone columns, vibro concrete columns etc.) terminate in the fill material, and do not penetrate to naturally occurring competent strata below, are not acceptable.

Untreated made ground/fill material is inherently variable in nature and unpredictable when considering its settlement properties. Foundations proposing to bear upon untreated made ground/fill as a formation for strip, trench or raft type foundations are unacceptable.

## Testing

Testing is carried out to confirm that the ground improvement works meet the design criteria. The tests are usually completed to determine the ground bearing capacity.

The Engineer shall require the specialist contractor to verify that the ground treatment has been completed to a satisfactory standard. This will usually include carrying out suitable testing to establish the degree of ground improvement, its load-bearing characteristics and settlement potential.

These tests may include:

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

The plate tests should be carried out with a 600mm diameter plate and minimum test load of 11 tonnes.

**Mini zone tests**
A mini zone test (dummy footing) can be used as a limited substitute for zone tests. The test should be applied to at least two stone columns and the area of foundation they support. To be useful, mini zone tests should be continued for long enough to establish the presence of creep behaviour.

Mini zone tests (dummy footing) should be carried out at a rate of one test per 1000m2-3000m² of treated ground, along with penetration tests at a rate of one test for 20-50 stone columns, or one test for not more than 500m² of treated ground, with a minimum of one test per structural unit. Alternatively, in the absence of penetration tests, one test per ten houses (with a minimum of two tests per site) would suffice.

**Zone tests**
An isolated pad or strip footing is used to test up to eight stone columns and the intervening ground. Loadings, which should simulate the building loads, are held for 24 hours at predetermined stages to examine creep behaviour.

**In-situ tests**
Where vibration will improve the ground itself, e.g. granular materials, then in-situ testing is appropriate. The improvement can be assessed when the test results are compared with the in-situ test results recorded during the pre-treatment investigation.

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

On completion of the treatment, the Engineer is to confirm that the treated ground has achieved the anticipated condition assumed in the design, and provide evidence in writing to the Warranty Surveyor.

## Reference documents

- Current regional Building Regulations
- BS EN 1997-1 - Eurocode 7: Geotechnical Design (EC7)
- BS 8004 - Code of Practice for Foundations
- BS EN 1997-2 - Ground Investigation and testing
- BS 5930 - Code of Practice for Ground Investigations
- BS 1377-9 - Methods of test for soils for civil engineering purposes. In-situ tests
- BRE IP 5/97 - Building on Fill: collapse compression on inundation
- BRE Building on Fill 3rd edition: geotechnical aspects
- Department of Transport Specification for Highway Works, Part 2, Series 600 Earthworks
- Warranty Good practice guides, to ensure long term and differential settlement criteria remain compliant:
  - Raft Foundations (Long term settlement 25mm and 1/500 differential)
  - Piling (Long term settlement 10mm and 1/500 differential)
  - Vibro ground improvement (Long term settlement 25mm and 1/500 differential)

# 3.
# Foundations

## 3.5
## Vibratory Ground Improvement

## Provision of information

A full set of design drawings, specifications, calculations and site investigation reports shall be made available to the Warranty Provider and all other interested parties. Items 1-3d should be submitted prior to commencement of vibro treatment on site. In the absence of approval, works are proceeding at the Developer's own risk. Items 3e-3g shall be submitted as soon as they become available, prior to construction continuing over the vibro stone columns.

1. Phase 1 Desk Study Report (including Groundsure) and Phase 2 Geotechnical site investigation reports with appropriate geotechnical testing.
2. Structural Engineers foundation drawings and design calculations. Strip footings should be designed for the specified bearing pressures and be designed to span between vibro stone columns.
3. Vibro stone columns:
    a) Written confirmation from the vibro designer that the ground conditions are suitable for vibro treatment and that the site investigation report is adequate for the purposes of the design and installation of stone columns. Deepening of foundations in respect of trees/clay soils to be taken into account.
    b) Vibro stone column layout drawings.
    c) Vibro design calculations confirming full-depth of made ground and soft/loose natural strata.
    d) Confirmation of proposed testing regime (i.e. plate and dummy footing tests etc., see notes below). A minimum of 1% of stone columns should be subject to dummy footing test.
    e) Vibro installation logs (with vibro column numbers referenced to the vibro layout drawing). Logs should include date, column number, depth, diameter, weight of stone, confirmation of the platform level in relation to the finished floor levels and site investigations and details demonstrating that all low-strength/loose natural strata (SPT<10) and all made ground/fill have been suitably treated.
    f) Copies of all testing carried out (with the locations referenced to the drawings) and interpretation of test results.
    g) Written confirmation from the vibro designer that the as-built installation has achieved the required bearing capacity and settlement characteristics.

The Warranty Surveyor, at their discretion, may also request supporting information that demonstrates suitability for use of any materials or systems contained within the above.

## Introduction

Vibratory ground improvement techniques are generally used to increase load-bearing capacity and reduce settlements to acceptable limits within undisturbed natural soils and filled ground.

Soft soils can be reinforced to achieve improved specification requirements, whilst slopes can be treated to prevent slip failure, both natural soils and made ground can be improved.

The ground must be suitable for vibratory ground improvement and designed in-accordance with recognised methods (e.g. Priebe). The treatment must extend through the full extent of the filled or poor ground and reach natural competent ground.

Foundations supported by vibratory ground improvement techniques require a coordinated design by an Engineer and specialists who are experienced with this type of construction.

## Limitations of guidance

The following situations are beyond the scope of this guidance:

- Where the original ground or sub-strata is unstable or will continue to settle.
- Sites with soft clays with a low bearing capacity (Undrained cohesion = 30kN/$m^2$ or less).
- Filled ground where high levels of voids are anticipated.
- Clay fill, where the water will influence the foundation or where collapse may occur.

Each development site has its own specific characteristics, and where conditions do not clearly fall within the guidance given, clarification should be sought from the Warranty Surveyor or a suitably qualified and experienced expert.

## Desk study and site investigation

All projects will require a site specific phase 1 desk study report (including Groundsure or similar) and a phase 2 geotechnical site investigation reports with appropriate geotechnical testing.

A site specific geotechnical site investigation should take place and be in accordance with BS 5930/EC7 and extend into adequate strata beneath the filled or poor-strength strata above. The investigation should include enough geotechnical testing to enable accurate geotechnical design of the vibro stone columns in accordance with proven design methods.

The scheme shall be designed to clearly demonstrate that the foundations and treatment of the ground with vibro stone columns are capable of supporting and transferring the foundation design loads safely to known natural soil strata'

The foundations and vibro stone columns shall be designed in accordance with BS 8004:2020 and shall ensure that long term settlement does not exceed 25mm or 1:500 (differential) at working load, unless more stringent criteria are required by the Engineer.

The developer shall obtain written confirmation from the Engineer and specialist contractor that the site is suitable for the proposed ground improvement system, and that all detrimental factors associated with the site and the proposed development have been taken into account.

The results of the investigation should be presented to the Warranty Engineer prior to the commencement of work on site.

## Desk study and site investigation results

**Properties of the natural materials under the site**
The site investigation should determine the depths and properties of the natural materials under the site, including the presence of geological hazards, cavities, mine-workings and associated features, rocks or soils that may dissolve or erode when water passes over them.

Through the process of a site investigation, it should first be established by the Engineer or suitably qualified specialist that the ground is capable of being improved by a vibratory ground improvement technique.

**Extent of any areas of made ground on the site**
The extent of any areas of made ground on the site should be established, including its history, composition and behaviour.

A site specific geotechnical site investigation should take place and be in accordance with BS 5930/EC7 and extend into adequate strata beneath the filled or poor-strength strata above.

**Materials susceptible to heave or shrinkage**
The extent of any shrinkable materials or materials susceptible to heave (clays, slag, burnt shale etc.) should be established. The necessary Atterberg tests and swelling tests should be conducted as appropriate.

**Constituent materials**
The proportions, compaction and distribution of the constituent materials throughout its depth should be established.

The investigation should include enough geotechnical testing to enable accurate geotechnical design of the vibro stone columns in accordance with proven design methods.

**Fill materials**
The grading and particle size distribution of fill materials should be established. See Conditions acceptable for treatment.

**Existing or redundant services**
The presence and extent of any existing or redundant services and drains should be investigated, and the associated backfill to the excavations. In addition, the effect that any proposed sustainable drainage system (SUDS) or soakaways might have on the ground conditions should be identified.

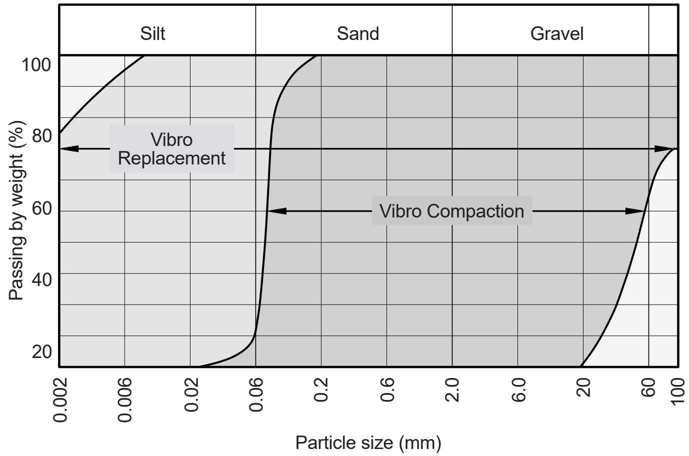
**Ground water**
The investigations should identify the presence, level and nature of any ground water, and if it is likely to rise and cause heave or collapse by saturation.

**Contaminated substances**
Contaminated substances including any potential for gas generation from fill materials such be identified. Any potential for combustion from contaminated substances should also be identified.

The Engineer should supervise the site investigation, taking account of the findings of the desk study, and first establish whether there are any contaminated substances or gases present.

**Existing obstructions**
It should also be established at an early stage whether the site has previously contained any buildings or structures, and whether they have been completely removed, including basement walls, floor slabs, etc.

## Conditions acceptable for treatment

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## Unsuitable ground conditions

For Warranty purposes, the following ground conditions are not considered suitable for vibratory ground improvement.

- Highly shrinkable clays with a plasticity index greater than 40%.
- Soft clays with undrained shear strength less than CU = 30kPa.
- Ground with a peat layer greater than 200mm should be viewed as unsuitable. Multiple peat layers with a combined depth greater than stone column diameter are unsuitable. In addition, variations in peat thickness may cause differential settlements.
- Voided fill ground created by landfill or with concrete rubble or brick fill of unsuitable grading.
- Non-engineered fill material may result in the following:
    - Original ground or sub-strata is unstable or will continue to settle.
    - The location and mobility of ground water within or entering the fill – as this has the potential to trigger inundation settlement (if the fill has not been previously saturated).
    - Inundation settlement (also known as collapse compression) – associated with the permeation of water into poorly compacted fills and partially saturated fills with a high air voids ratio. Refer to BRE IP 5/97.
- Degradable material - organic material where the percentage per volume may cause excessive settlement to foundations.
- Ground gases including carbon dioxide and methane - Stone column installation will involve stone compaction, however, remaining voids can act as vertical vents to dangerous gases.

## Ground conditions and other factors that may increase the complexity of vibratory ground improvement

- Shrinkable material with volume change potential (VCP). If the presence of shrinkable soils is suspected, and no testing data is available to verify the VCP then high volume change potential should be assumed.
- VCP Soils with a modified plasticity index greater than 10%. The installation of Stone Columns in cohesive material should consider any adverse effects on existing structures and site drainage.
- For all soil types, stone columns can transmit water down to lower fills causing softening and inundation of the fill materials.
- Deepening of foundations and heave precautions need to be assessed in accordance with the guidance within our 'Foundations' section of this Technical Manual regardless of the vibro treatment.
- Partial depth treatment of filled ground:
    - Sites designated for partial treatment will be considered on a case-by-case basis.
    - Engineer to consider the combined performance of both treated and untreated zones considering overall settlements.
    - Partial-depth treatment of loose/low-strength natural soils (SPT <10, cu < 40kPa) and partial-depth treatment of made ground/fill is not acceptable.
- Obstructions - buried structures including drainage.
- Variations in the density of material to be treated.
- Variations in ground water - long or short term alterations to ground water levels that may cause settlement or heave of existing buildings.

## Limitations of treated ground

Buildings and long blocks with sensitive finishes should be avoided in areas with considerable variations in ground conditions.

In the case of stone columns, the un-cemented stone particles develop end bearing and skin frictional stresses. This process requires the soil surrounding the stone column to provide adequate lateral stresses to counter excessive bulging.

Soil types, such as peat and other weak materials, which include variations in thickness, may cause differential settlements.

Where the above limitations are found on site, the Engineer should:

- Determine foundation loads.
- Confirm the safe bearing pressure and settlement characteristics required.
- Compare design requirements with Interpretative Soil Investigation.
- Discuss viability of proposals and assess viable alternatives with specialist contractor.
- Submit proposals to the Warranty Provider at the earliest possible opportunity.

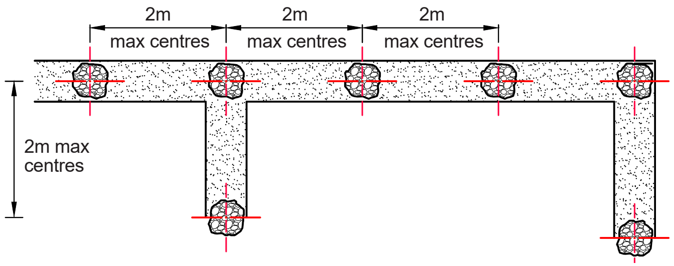
## Installation

A suitably qualified competent person should ensure:

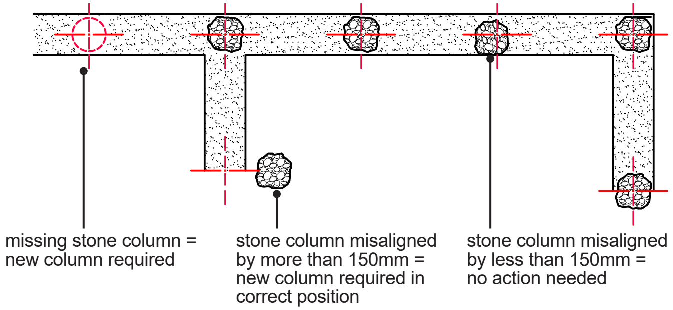
- There is appropriate site supervision and testing to achieve the required foundation design using vibro stone columns.
- Stone columns are located at the intersection of adjacent reinforced spread foundations.
- The minimum depth of stone columns is achieved.
- Any missing stone columns are replaced.

All installation criteria, including location and depth, are checked by suitably qualified competent person prior to the specialist plant leaving the site.

Stone columns can be centrally positioned under the foundation. For wider foundations, stone columns can be installed in a predetermined staggered arrangement under the spread foundation.

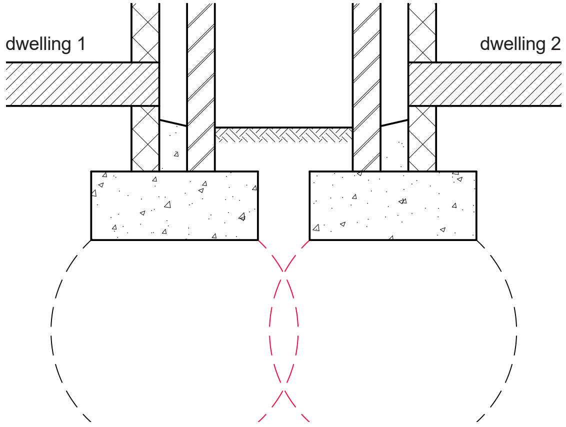



Stone columns which are misaligned by more than 150mm (centre to centre) in any direction should be replaced.




**Adjacent foundations and services**

- Design of vibratory ground improvement should consider adjacent foundations. Volume of soil treated should allow for the interaction of pressure bulbs and the resulting combined stresses.
- Service or drainage trenches - minimum clearance between foundations and excavations should be greater than depth of trench excavation minus the depth to the bottom of the concrete spread footing.

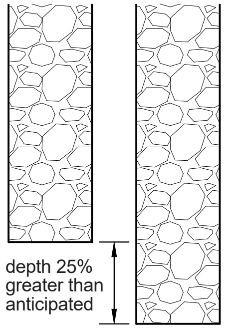


interaction of adjacent foundations

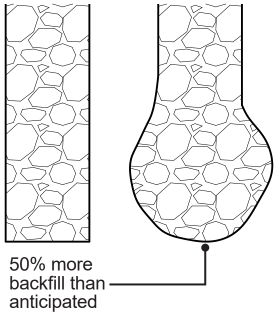
## Actions on unforeseen events

The following events should be reported to the design team/specialist contractor and Warranty provider as soon as possible.

**Where there is a reduction in treated depth in excess of 25%.**




**Where there is a significant increase in the quantity of backfill in comparison with similar treated depths.**




Design team/specialist contractor should submit recommendations to the builder and Warranty provider.

On completion of the treatment, the Engineer is to confirm that the treated ground has achieved the anticipated condition assumed in the design, and provide evidence in writing to the Warranty Engineer.

## Foundations

Foundations on sites with vibratory ground improvements should either be of a reinforced strip or raft type. Both foundations will require a full design by an Engineer.

Foundation drawings and calculations should be prepared by the Engineer indicating the required bearing capacity and settlement characteristics for the purposes of design of vibro stone columns.

Foundations should be sized for the specified safe bearing pressures and be designed to span between the centres of the vibro stone columns.

The designer/engineer should ensure the following:

- RC foundations must be a minimum RC25/30 or FND concrete.
- Foundations shall be designed to span between vibro stone columns and must incorporate top and bottom reinforcement.
- Bottom profile of concrete foundations is located a minimum 600mm bgl and founded on firm material of adequate bearing capacity.
- For 'low rise structures' foundations should be designed for maximum settlements of 25mm.
- In relation to differential settlement, a design limit for maximum tilt of 1/500 is appropriate. More stringent values may be required due to the particular circumstances (e.g. medium and high rise structures).

Irrespective of the provision of vibro stone columns, foundation depths and heave precautions must be in-accordance with the guidance provided in this Technical Manual, in respect of trees/clays, whilst ensuring that the vibro treatment is not detrimentally affected by deepening of the foundations. Further guidance can be found in the 'Foundations - Trees and Clay' section.

## Fill materials

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

- Acid wastes.
- Reactive materials.
- Materials that include sulphates (e.g. gypsum).
- Organic materials.
- Toxic materials.
- Materials that cause noxious fumes, rot, undue settlement or damage to surrounding materials.

The sample tests should be carried out by a suitably qualified person, and it may be necessary to take a number of samples to identify the material characteristics of the fill accurately.

## Sources of fill material

Where the material is of a stable and uniform type from one source, the testing regime may be reduced. However if the material is variable, or from a number of sources, then regular inspections and/or testing may be required.

Recycled aggregate or other building materials, such as crushed brick, should only be used following an inspection by the Warranty Surveyor.

Colliery shale and any other residue from mineral extraction or industrial process bi-products should only be used with specialist approval.

## Testing and validation of vibratory ground improvement techniques

Testing should be carried out across the full site and cover all of the various ground conditions to confirm that the ground improvement works meet the design criteria. The tests are usually completed to determine the ground bearing capacity.

The Engineer shall require the specialist contractor to verify that the ground treatment has been completed to a satisfactory standard. This will usually include carrying out suitable testing to establish the degree of ground improvement, its load-bearing characteristics and settlement potential. The testing also needs to be compatible with the following:

- Ground composition.
- Quality of the site investigation.
- Foundation design and depth of treatment.

## Testing foundation performance

Plates tests and any combination of the following - zone tests, dummy footing tests and/or pre- and post-treatment investigation - should be used on sites where any of the following apply:

- The treated ground consists of variable types of fill.
- The treated ground includes either peat, silt or clay.
- The ground water level is less than 1.5 x the foundation width below the bearing level.
- Partial depth treatment of fill.
- Variable depth of ground beneath each building.
- The ground to be treated exceeds 6m in depth.

The combination of testing requirements maybe reduced (with prior agreement with the Warranty provider) where the following criteria apply:

- The ground to be improved is well graded and granular.
- There is a low static ground water level that is greater than 1.5 x the foundation width below bearing level.
- The treatment has been taken to a depth below the foundation that is greater than 1.5 x the foundation width and this depth is confirmed with site logs.
- The ground is fill, and is treated to its full depth.
- Uniform ground beneath each building.
- Installation Site logging including print outs from in-cab monitoring is available.
- The site investigation is undertaken to a depth of at least 1.5 x the depth of the treatment.

| Test | Description | Notes |
|---|---|---|
| Plate Tests | 600mm diameter plates loaded to 3 x WL or 11 tonnes, whichever is greater. Minimum rate of 1 test per rig per day. | Plate tests alone may not provide a direct indication of the anticipated settlement of the completed structure. Usually they cannot be considered as the sole means of load testing. |
| Dummy Footing Test | 1500 x 600mm plates loaded to at least 1.5 times Working Load (kPa) for a minimum period of 13 hours. Minimum rate of one per week. | The test should be applied to at least two stone columns and the area of foundation they support. |
| Penetration Test | Rate of one per (20 to 50) stone columns or one test for not more than 500sqm with a minimum of 1 test for each structural unit. | Penetration tests will not be required if dummy footing tests are carried-out at the recommended rate. |
| Trial Pits | Trial pits can be excavated around stone columns to prove they are fully formed to the required depth and diameter. | This is a destructive test and therefore allowance should be made accordingly. |

## Flexible and rigid retaining walls

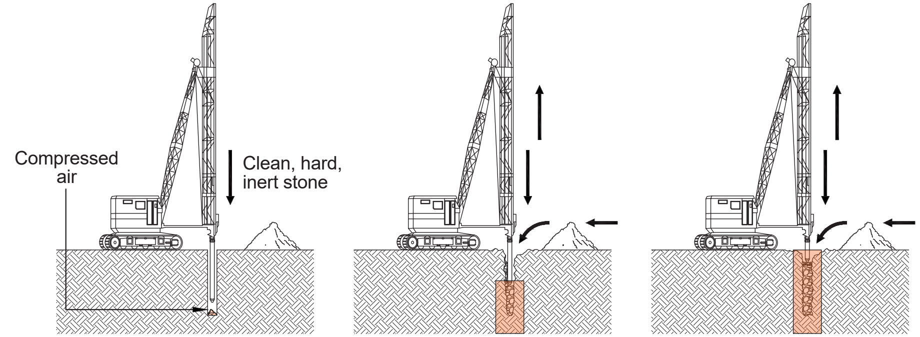
**Flexible retaining walls**
For the purposes of Warranty, flexible retaining walls may be defined as walls that support soil laterally whilst allowing deformations of the unsupported edge of the flexible retaining wall. Examples of flexible retaining walls include gabion, crib, block, timber or modular retaining wall systems.

Flexible retaining walls should not be used to support the structure of the property, garages, roads, drives, car parking areas or drainage systems.

**Rigid retaining walls**
Where rigid retaining walls are specified which support the foundations of a building, an Engineers design must be provided to confirm capable of maintaining stability for a period of at least 60 years and all works to the rigid retaining wall should be completed prior to works for the foundations of the property starting.

There are two vibratory techniques commonly used in the UK. These are known as the ‘dry bottom feed’ and ‘dry top feed’ methods; a third technique, less frequently used in the UK, is known as the ‘wet bottom feed’ method.

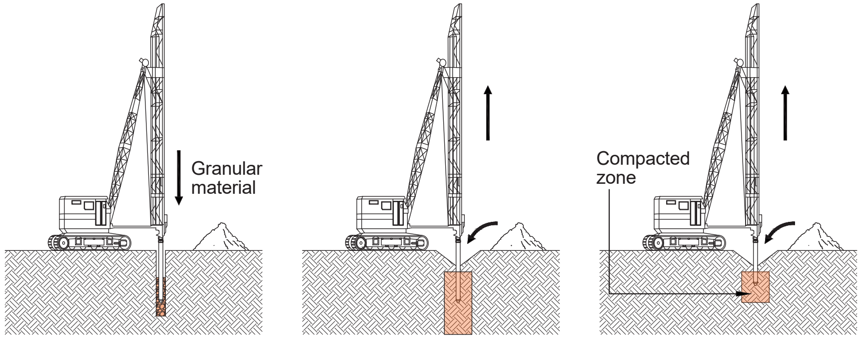
## Vibratory techniques: dry bottom feed method




Void is formed as vibrator displaces the ground | Stone backfill is placed into void during withdrawal of vibrator | Continuous stone column formed

The dry bottom feed method is used in weaker soil conditions or where there is a high water table and the borehole is liable to collapse between vibroflot insertions. The vibroflot penetrates using its mass, air flush and vibration, but at design depth, the stone is introduced via a hopper into a pipe fixed to the side of the vibroflot. The stone usually 40mm in size, exits the pipe at the tip of the vibroflot and reaches the bottom of the borehole. The stone is then compacted into the surrounding soil by repeated withdrawal and insertion of the vibroflot.

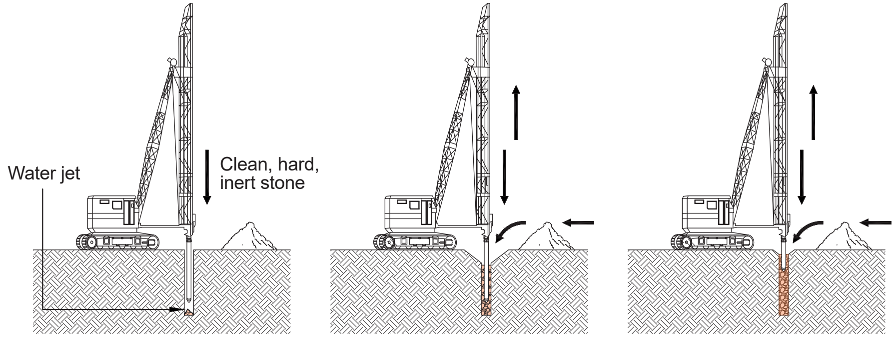
## Vibratory techniques: dry top feed method




Vibrator displaces the ground | Granular material is placed into the bore | Existing ground is compacted

In the dry top feed method, the vibroflot penetrates the weak soil or fill again using its mass, air flush and vibration to form a borehole. Once refusal or design depth is reached, the vibroflot is removed and stone fill is introduced into the bore, with the ‘charge’ typically 500mm-800mm deep. The vibroflot is re-inserted and ‘packs’ the stone into the surrounding strata. Successive charges of stone are added and compacted, bringing the column up to working level. Typically, the stone grading is 40mm-75mm.

## Vibratory techniques: wet bottom feed method




Void is formed as vibrator displaces the ground | Stone backfill is placed into void during withdrawal of vibrator | Continuous stone column formed

Where the ground contains fines and silts, water jetting from the tip of the vibroflot is used to remove loose materials and form a cavity for charges of stone to be added to replace and densify the soft ground. The carbon footprint of this activity is generally less than with comparable piling solutions.

## References

British Standards, codes of practice and good guidance relevant to vibratory ground improvement include the following:


- BS EN 1997-1:2004 + A1:2013 - Eurocode 7 Geotechnical Design (EC7).
- BS 8004:2015 + A1:2020 Code of Practice for Foundations.
- BS EN 1997-2:2007 Ground Investigation and testing.
- BS 5930: 2015 + A1:2020 Code of Practice for Ground Investigations.
- BS 6031 Code of Practice for earthworks.
- BS 1377 Part 9 Methods of tests for soils for civil engineering purposes. In-situ tests.
- BS 10175 Investigation of potentially contaminated sites - Code of Practice.
- BS EN 1991 Actions on structures.
- BS EN 14731 Execution of special geotechnical works. Ground treatment by deep vibration.
- BS EN 1997-1 General rules.
- BS EN 1997-2 Ground investigation and testing.
- BS EN ISO 14688 Geotechnical investigation and testing - Identification and classification of soil.
- BS EN ISO 14689 Geotechnical investigation and testing - Identification and classification of rock.
- BS EN ISO 22476 Geotechnical investigation and testing - Field testing.
- BR 391 Specifying vibro stone columns (BRE).
- BRE Information Paper 5/97 Collapse compression on inundation.
- BRE 424 Building on fill: Geotechnical aspects.
- CIRIA C572 Treated ground: Engineering properties and performance, 2002.
- CIRIA C573 A guide to ground treatment, 2002.
- ICE Specification for ground treatment: Notes for guidance, 1987.
- ICE Manual of geotechnical engineering: Volume II.

# 3.
# Foundations

## 3.6
## Trees and Clay

## Provision of information

A full set of design drawings and specifications shall be made available to the Warranty Provider and all other interested parties prior to the associated works starting on site. This may include:

1. Where trees are present, have been recently removed and/or are to be newly planted a site plan will need to be provided to show the tree and hedgerows that have influence on any foundations.
2. Details of tree species and their height.
3. Site investigation report appropriate for the site specific conditions. The volume change potential of the soil must be noted in the site investigation report.
4. Detailed foundation design with reference to trees which are present, recently removed and newly planted and the site specific site investigation report.

The Warranty Surveyor, at their discretion, may also request supporting information that demonstrates suitability for use of any materials or systems contained within the above.

## Introduction

The following guidance is provided for foundation design when building near trees, hedgerows or shrubs.

## Limitations of guidance

The following situations are beyond the scope of this guidance, and will require a site-specific assessment by a suitably qualified and experienced expert:

- Foundations with depths greater than 2.5m within the influence of trees in cohesive soils (note: Mass Fill or Piled Foundations should be adopted).
- Ground with a slope greater than 1:7.
- Man-made slopes, such as embankments and cuttings.
- Underpinning.
- Engineered foundation designs.

Each development site has its own specific characteristics, and where conditions do not clearly fall within the guidance given, clarification should be sought from the Warranty Surveyor or a suitably qualified expert.

## The nature of the problem

The roots of all vegetation take water from the soil to make good the water lost from the leaves. If the soil contains clay, it will shrink as it dries (desiccates), or swell if it rehydrates. If the shrinking or swelling extends below the foundations, they will subside or heave in response. If the movements are in excess of those that can be tolerated by the building, then damage is likely to occur.

Although all vegetation can cause soil drying, the roots of trees extend deeper and further and are thus particularly prone to causing damage. Large shrubs can also root to considerable depths, but their influence is more localised. Herbaceous plants and grass can also cause soil drying down to 1.5m, and may require clay heave precaution measures to be installed to foundations.

Damage is best avoided by increasing foundation depth to below the level where significant changes in moisture content are likely to occur. Root barriers are not acceptable as an alternative solution.

This guidance defines the depths that are required and the most suitable types of foundations. The extent of soil drying can be variable and unpredictable. The guidance within this section seeks to minimise the risk by striking a balance between the extent of risk and the costs of increasing foundation depth.

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 factors are considered in greater detail in the following sections.

## The soil

Soils may be broadly classified into two types:

- Cohesive soils comprise mainly of clay soil particles. Clay soils display plastic soil behaviour (they swell and shrink, dependent upon climatic conditions, tree root influence and other extraneous conditions – local excavations, burst water mains etc.) and will remain intact if placed into water. As they dry, they will become stiffer, and will eventually crumble if dried beyond a certain point. Potentially, these soils can damage foundations, if not engineered to take account of clay heave and shrinkage.
- Non-cohesive soils, comprising of gravels, sands and silts with perhaps a minor proportion of clay sized soil particles and will break up if placed in water. They are not subject to significant swelling or shrinkage.

The clay component of cohesive soils can vary widely; very few soils are pure clay, but they contain varying quantities of gravel, sand or silt. Clay soils are defined by their particle size (less than two microns), and it is only these clay particles that will shrink or swell. The particles are made-up of a complex molecular lattice structure that is capable of absorbing water.

If, the clay molecular lattice is not saturated it will swell when additional water is introduced. If, the clay molecular lattice is drying out, then it will shrink.

The potential of soil to swell or shrink can be determined by simple tests to determine moisture content , plastic limit (the moisture content below which it changes from being plastic and mouldable, and starts to crumble) and liquid limit (the moisture content above which it changes from being plastic, and starts to flow like a liquid). The plastic and liquid limits can be determined by Atterberg laboratory tests in accordance with BS 1377. The difference between the plastic and liquid limits is the plasticity index; the higher the plasticity index, the greater the potential volume changes.

Unless there is clear evidence that a cohesive soil is not present, Site Investigations will be required to determine the soil type to at least the depth of potential influence of adjacent trees. Usually, trial holes are an acceptable method for determining the soil strata, but specialist Site Investigation reports are preferred if available.

Soil samples should be taken from at least two depths, at 1.5m and 2.5m (or the base of the trial hole, whichever is the shallower), and sent to a soil laboratory for determination of plastic and liquid limit (and thus plasticity index). In addition, the moisture content of the samples is usually determined. The highest value of plasticity index should be used for determining foundation depth. Also see ‘Limitations of guidance’ at the start of this section.

**Made-up ground**
This refers to land or ground created by filling in a low area with non-original soils or other fill material. Often, such created land is not suitable for building without the use of specialist foundations. If there is high clay content within the made-up ground, then specialist foundations may require additional heave protection. It is also important to establish the depth of the made-up ground, because if it is a relatively shallow depth, the original soil below may be cohesive and within the zone of influence of the tree.

## Potential of trees to cause soil drying

**Tree species**
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’. Species such as Oak, Poplar and Eucalyptus are deemed as high water demand as they are particularly efficient at exploiting clay soils, rooting to considerable depth. A few species only rarely cause damage and are deemed of low water demand, whilst the majority fall into the moderate category.

Hardwood species tend to have a broad spreading root system, extending considerable distances laterally as well as to depth. By contrast, the influence of most conifers is more localised, but just as deep. A few species (of both hardwoods and conifers) have intermediate characteristics. The guidance takes account of the different patterns of rooting, but it must be emphasised that the distribution of roots can be variable, meaning the guidance should not be taken as indicating a ‘zone of influence’ of a tree.

Many Local Authorities will require a Tree Survey and Arboricultural Method Statement as part of the planning application. This will usually serve to identify all relevant trees both on and off-site. If a tree cannot be identified, it must be assumed to have high water demand (deep rooting).

**Height of tree**
The amount of water taken by the roots relates to the leaf area and the vigour of the tree. With open grown trees, height is usually considered the best indicator of leaf area. The greatest water uptake occurs as the tree reaches maturity, and so ‘mature height’ is the determining factor. Individual trees within a group or row will have a smaller leaf area, but as they compete with each other, the mature height of the individual trees remains the relevant factor.

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.

## 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.

## Foundation design

**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 1, should be used.

## Table 1: Minimum foundation depths

| Plasticity index | Minimum depth to allow for reasonable future tree/shrub planting (m) | Minimum depth if no future tree/shrub planting likely (m) |
|---|---|---|
| 40% and greater | 1.50 | 1.00 |
| 20% to less than 40% | 1.25 | 0.90 |
| 10% to less than 20% | 1.00 | 0.75 |

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.

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.

## 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 appropriate third party accreditation 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)<br><br>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.

Strip foundations will not be suitable where heave precautions are required.

Note: the compressible material/void former must have a third party approval 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.

## Varying foundation depths

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.

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

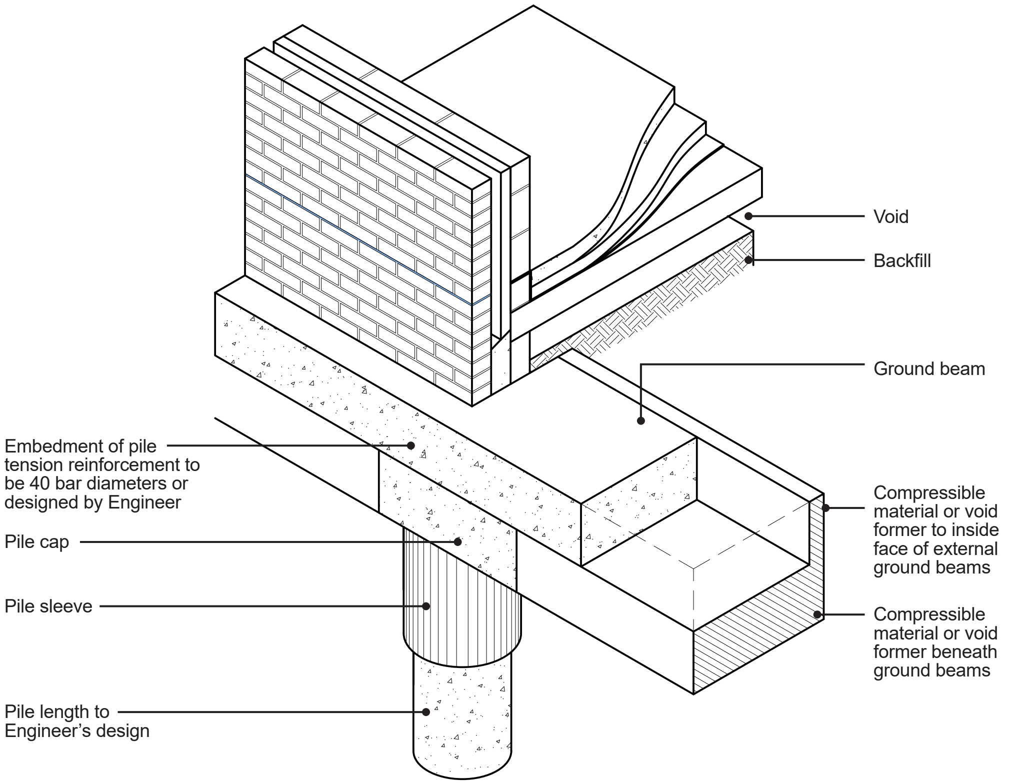
| Volume change potential | Plasticity index | Void dimension against side of ground beam and foundation | Void dimension underground beams, suspended in-situ concrete ground floor & piled raft slabs | Void dimension under suspended precast concrete and timber floors(1) |
|---|---|---|---|---|
| High | 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.

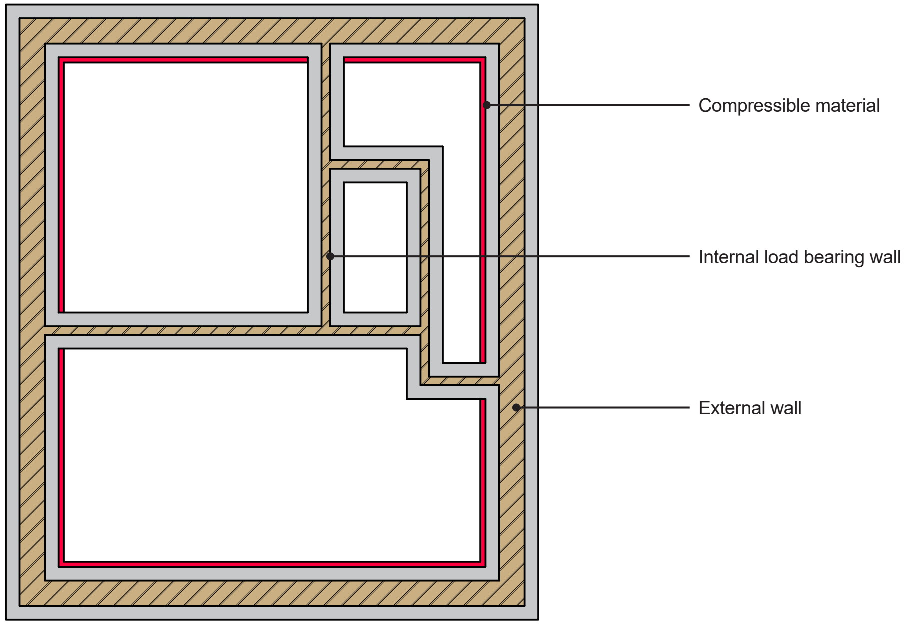
Please note: Void formers consist of materials that collapse to form a void into which the clay can swell. The compressible material/ Void former should have appropriate third party certification demonstrating their suitability as specified. The void dimension is the 'remaining void' after collapse. 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.

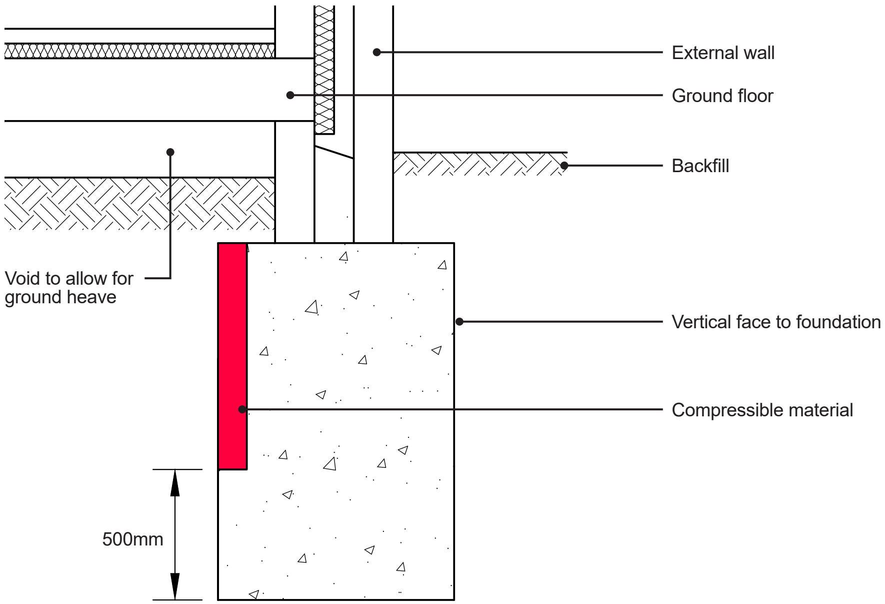
### Heave protection - Section through pile and beam foundation




### Plan of heave protection to a mass filled foundation




### Heave protection - Section through a typical mass filled foundation

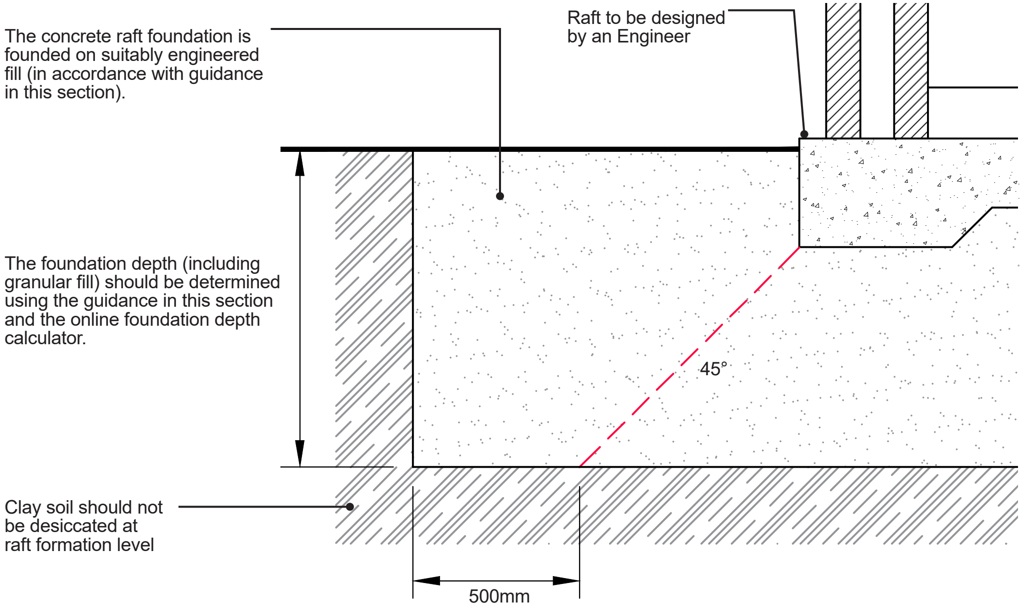


## Raft foundations in clay soils susceptible to heave/shrinkage

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 – Changes in level’ 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.

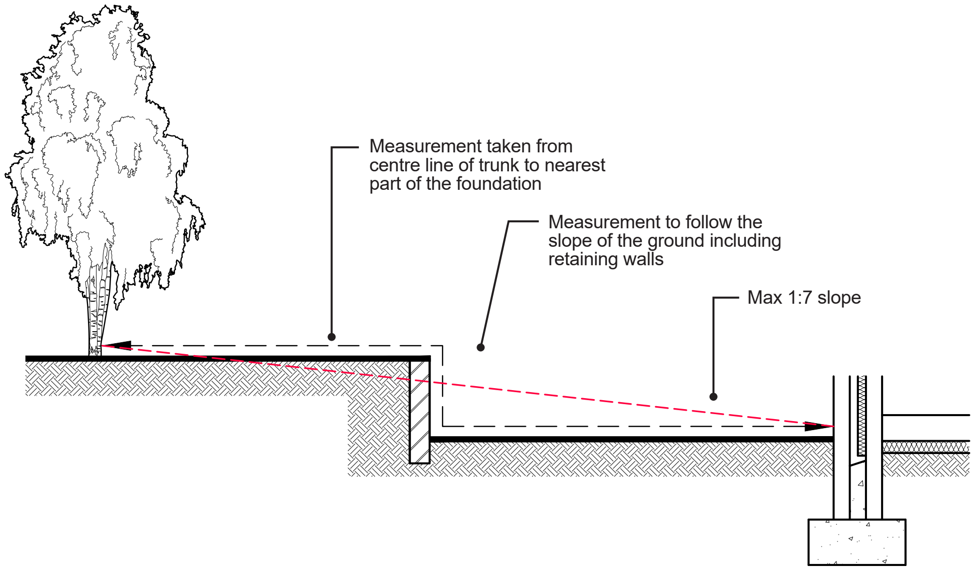


## Sloping sites

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

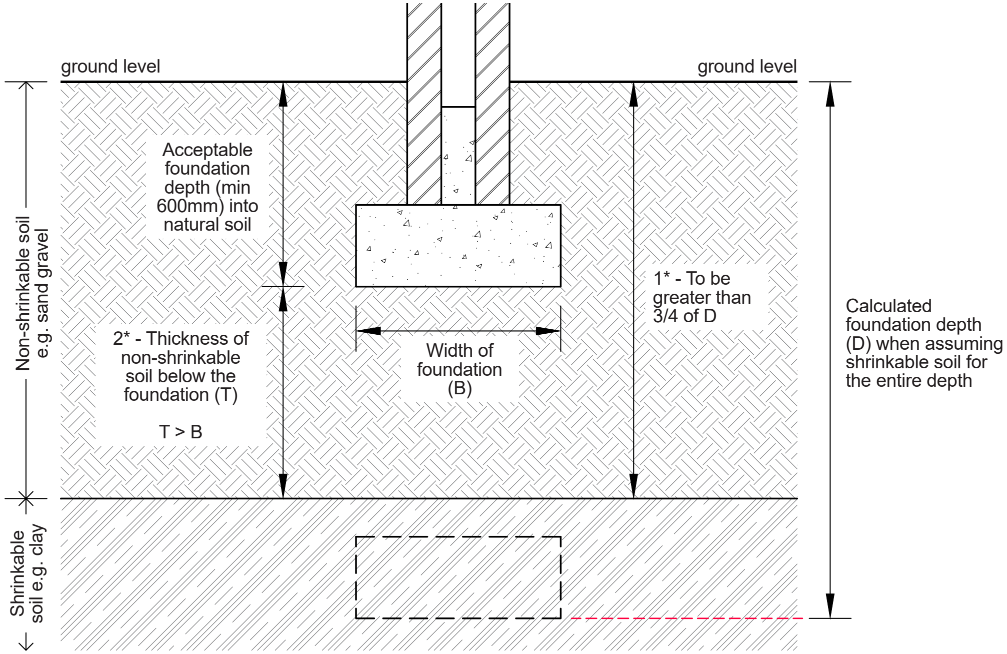
When a sufficient depth of non-shrinkable soil overlies shrinkable soil, the foundation depth can be assessed on the non-shrinkable material provided conditions 1 to 3 below are satisfied.

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 deeper foundation from either:

- The result of 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. This result should be measured from the **original** ground level; **or**,
- The result of 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 result of 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. This result should be measured from 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 deeper foundation from either:

- The minimum foundation depth as given in column 3 of ‘Table 1: Minimum foundation depths’ in the ‘Foundations – Trees and Clay - Foundation depth and heave precaution requirements’ section of the Technical Manual. This result should be measured from the **original** ground level; **or**,
- The result of 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 result of 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 deeper foundation from either:

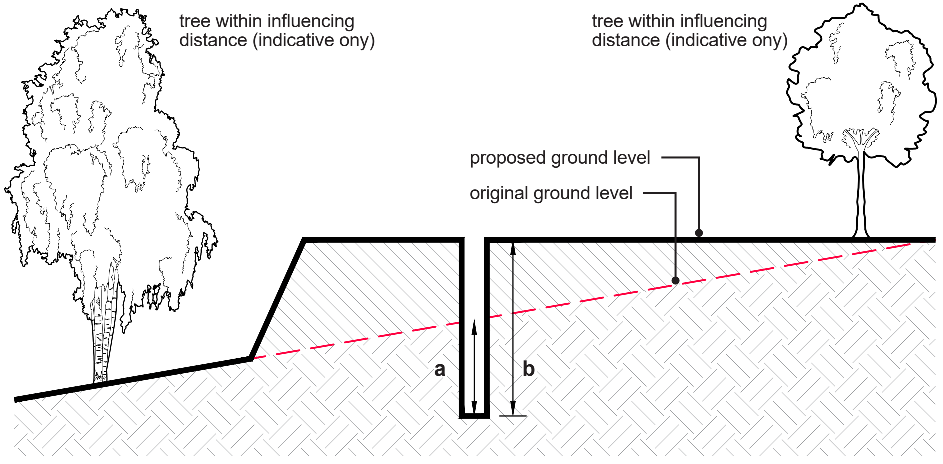
- The result of the Foundation Depth Calculator when using the existing height of the tree or the mature height in instances where the existing height is currently at least 50% of the expected mature height. This result should be measured from the **original** ground level; **or**,
- The minimum foundation depth as given in column 3 of ‘Table 1: Minimum foundation depths’ in the ‘Foundations – Trees and Clay - Foundation depth and heave precaution requirements’ 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:

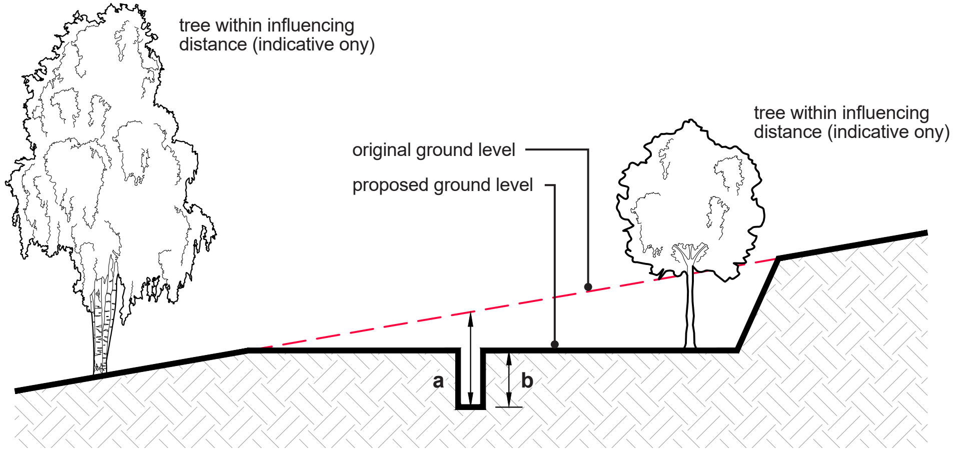
- The result of the Foundation Depth Calculator when using the mature height of the tree. This result should be measured from the **proposed** ground level.

## Where to measure when the original 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 original ground level is reduced




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

PREMIER GUARANTEE

ON YOUR SITE, BY YOUR SIDE

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