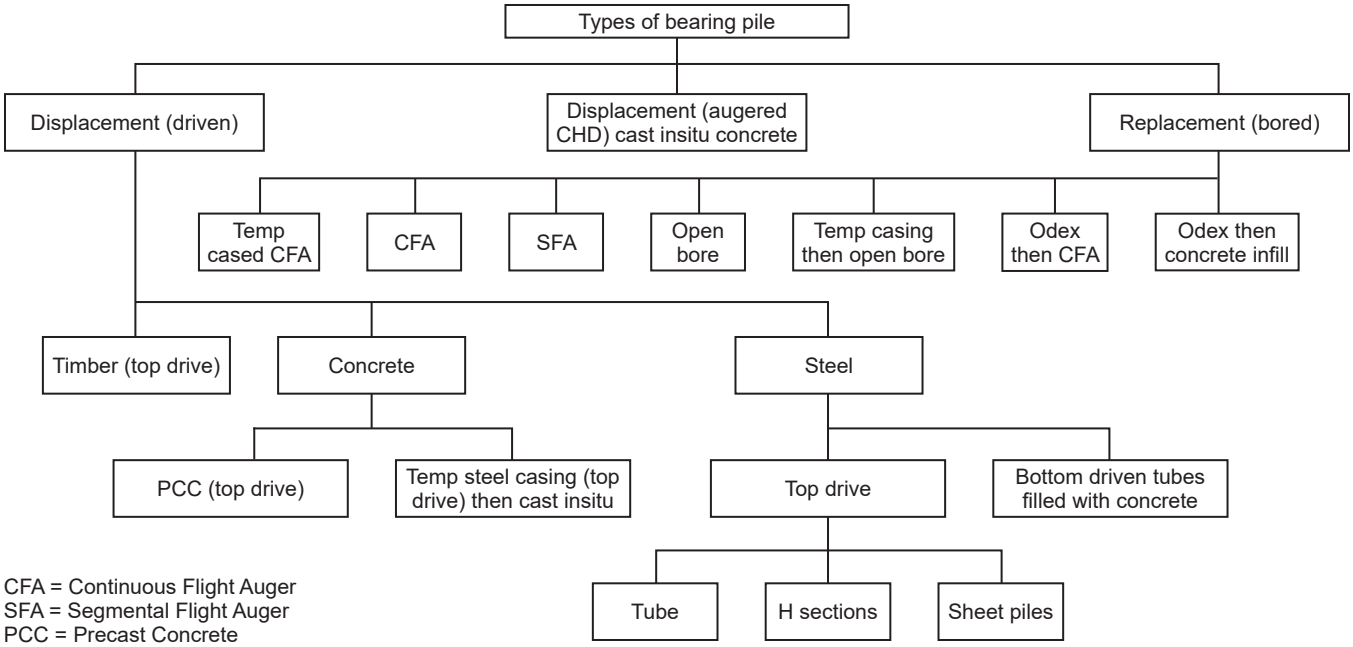
Introduction

This section provides guidance on meeting the performance requirements for piled foundations. Displacement and replacement pile types are covered within the guidance for this section:



CFA = Continuous Flight Auger
SFA = Segmental Flight Auger
PCC = Precast Concrete
CHD = Continuous Helical Displacement

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

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.

3.2.1 Compliance

Piled foundations shall meet the performance requirements of this section.

3.2.2 Information to be provided

The Designer shall provide sufficient design details to demonstrate it meets the requirements of this section.

A full set of design details, calculations, reports and other supporting information should 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 a suitable depth beneath the pile toe as outlined in the guidance within this section) 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

1. 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.
2. Concrete mix details and cube test results for the concrete used in the piles with tabulated results.
3. Integrity testing of all concrete piles with interpretive summary and conclusion.
4. 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).
5. Static load test results.
6. 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 and/or Warranty Structural Engineer, at their discretion, may also request supporting information that demonstrates suitability for use of any materials or systems contained within the above.

3.2.3 Ground conditions and site investigations

All sites shall have an appropriate level of site investigation which accurately assesses and investigates potential hazards which may effect the pile foundation design.

The pile foundation design shall take account of the site specific ground conditions.

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, ground contaminants, soil type and any existing workings or services that may clash with pile locations.

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.

Site investigations

Site investigations must be in accordance with the requirements of BS 5930 / BS EN1997-2.

The depth of the site investigation should 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). However this may be relaxed where (subject to prior discussion and agreement with the Warranty provider):

- Rock is encountered and the geology of the site is well known.
- The geology of the site is well known to a substantial depth in strong soils.

Generally, boreholes should be at centres of 10m to 30m for structures and at a minimum of 3 points on the site. However, closer borehole / probe / CPT spacings should be used where there are site specific hazards where there is the potential for large variations in soil properties across the site (e.g. a soil infilled valley, a quarry high wall, chalk dissolution features, subterranean salt, gypsum, shallow coal mining etc).

The investigation should include sufficient soil strength testing, throughout the anticipated pile length and beneath the pile, to enable geotechnical design of the piles, using proven design methods.

The Geotechnical Engineer must provide a risk assessment statement (in the site investigation) for the potential of ground water levels to rise in the next 60 years – taking into account the potential for increased rainfall, sea level rise, the reduction of flood plain storage in and around the site and possible failure of flood defences (assess the risk of potential climate change, increased development in flood plain areas and over-topping of flood defences by flood water).

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.

Checklist for site investigation information required:

The following information if applicable should be provided prior to any works commencing on site:

1. Phase 1 Desk Study report detailing the history of the site, potential hazards / risks below and above ground and likely soil types present on the site.
2. Topographical survey drawing of the site before the construction of the proposed development.
3. Cut and fill proposal drawings for the site.
4. External works finished ground levels around the proposed buildings.
5. Finished ground floor levels of the proposed buildings.
6. Tree report providing the locations, species and heights of all trees, hedgerows, bushes and shrubs in and around the site and which of these are to be removed.
7. Phase 2 Ground Investigation report(s) providing a summary of the development proposals and the following information by the use of appropriate investigation techniques and testing:
    a. Descriptions of soil types and stratification.
    b. Soil strength profiles with depth.

c. Level(s) of ground water.
d. Mining risk assessment specific to the site.
e. If subterranean mine workings are present, then the extent, depth and thickness of worked seams must be identified and fully specified by the use of reliable investigation techniques. A Coal Authority Mining Report, for the site, is required.
f. Identification of buried and overhead services on the site and wayleaves which must be complied with in the design.
g. An assessment of the risk of rock dissolution features on the site.
h. If there is a medium to high risk of rock dissolution features on the site, then appropriate investigations must be carried out to locate them - further detailed proposals will be required.
i. Plasticity indices and moisture contents of near surface soils to a depth of 4m.
j. Ground gas monitoring results on 6 separate site visits plus an interpretation of the results to provide the Characteristic Situation of the site - following the guidance of the current version of BS8485.
k. Classifications of the chemical aggressiveness of the soils and ground water in contact with new and existing concrete on site.
l. Identification of the contaminants in the soil and water and their concentrations.
m. Site remediation strategy statement to deal with soil and water contaminants.
n. An interpretive report giving recommendations for suitable foundation solutions.

Piles founded in or through difficult ground

Difficult ground is defined as ground with any of the following characteristics:

- The presence of rock.
- Chalk with dissolution features and/or bands of flint or large flint nodules.
- Hertfordshire pudding stone.
- Ground with cavities (potash, coal, brine and gypsum extraction).
- Backfilled quarries with no validated engineered fill.
- Backfilled quarries with buried highwalls.
- Subterranean mine workings which haven't been remediated by drill and grout remediation.
- Landfill sites where the landfill material identification is unknown or variable in composition.
- High water table.
- Ground water regime where the water table is effected by tidal influences.
- Collapsible soils.
- Severely contaminated ground and/or ground water.
- Fill with significant buried obstructions.
- Significant peat layers at depth below a pile toe.
- Geological fault lines identified on the site.

Replacement piles founded in rock

Where the pile design specifies a rock socket length at the toe of the pile, suitable piling installation equipment should be used and a suitable piling technique adopted to ensure the rock socket length is achieved (rock cutting lead auger). If the rock is too strong for cutting with an auger, then the Odex piling technique should be considered.

Replacement and displacement piles founded in chalk with dissolution features

The pile design and pile installation must follow the guidance contained in CIRIA PR86 and CIRIA C574.

If the Phase 1 Desk study report identifies a medium to high risk of chalk dissolutions being present on the site, then each pile position must be probed to determine the soil strength profile, ground water regime and depth to the chalk horizon. The dynamic probing technique is not acceptable in chalk (remoulding of the chalk occurs giving false relative strength data). Ideally, cone penetration testing with a gamma cone should be used for probing. Each pile is then designed based on the specific soil strength profile, water table level and chalk depth horizon.

In the case of replacement pile types, the piling rig drilling telemetry records for each pile must be provided. These records must identify drilled depth, continuous recording of bore diameter with depth, theoretical amount of concrete to fill the bore and the actual amount of concrete to fill the bore and the percentage overbreak. Where the percentage overbreak is greater than 30% on a pile, the Warranty provider and Pile Designer must be informed. The Pile Designer must check to determine whether the pile meets the load bearing requirements. This check must be submitted to the Warranty provider as soon as possible.

Replacement and displacement piles founded 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 foundation design to mitigate the effects of any unknown conditions. Since the presence of solution features cannot be readily identified during the installation of the piles, it is recommended that the probing of each pile position should be undertaken. 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. Generally, piles are not suitable unless founded below the grouted mine workings. If there is sufficient rock cover over the validated grouted mine workings, then piles founded above the grouted mine workings maybe acceptable if suitable calculations are produced (point load check at pile toe and equivalent raft bearing pressure analogy acting on a horizon 2/3rds of pile depth).

When piling adjacent to existing mine entries, assurance must be provided that adequate competent rock is present to found the piles and the stipulated rock socket lengths have been achieved. In addition, it must be proved that the piles will be unaffected by any partial or full collapse of a mine entry.

Piling in made ground

Piles terminating in, or relying on, made ground or un-engineered fill are not acceptable.

3.2.4 Pile design

The piling scheme shall be designed by a suitably qualified and experienced Engineer to safely transfer all loads without causing excessive settlement whilst taking account of parameters obtained from geotechnical testing and contained within the site investigation report.

The following piling information should be provided by the project structural engineer for all piles types:

- Assessment of loads on piles split dead, live and horizontal loads.
- Pile design calculations based on site investigation and structural engineers design loads.
- Pile layout drawings with unique pile reference numbers.
- Foundation general arrangement drawings.
- Pile schedule providing vertical and horizontal loads split dead, live and horizontal applied to each pile.
- Pile testing requirements.

Replacement piles

The following should be provided by the piling contractor for replacement piles:

- Pile design calculations using geotechnical soil strength parameters, groundwater regime, the Structural Engineer's loads and taking account of potential clay heave/shrinkage – where near surface soils are clays and any requirement for a rock socket at the toe of the pile.
- Fully detailed pile schedule.
- Concrete mix design certificates for piling concrete from all suppliers.
- A statement regarding any requirements for pile load testing.

Displacement piles

The following should be provided by the piling contractor for displacement piles:

- Complete description of the pile composition material's, section size and driving method (top drive or bottom driven).
- Driving hammer weight and drop height.
- Drop hammer efficiency. An in date hammer efficiency certificate must be provided for the actual hammer used on site.
- Pile set calculations using the Modified Hiley formula.
- Pile design calculations using the soil profile strength parameters, ground water regime, the Structural Engineer's loads and the potential for clay heave/shrinkage – where near surface soils are clays and any requirement for a rock socket at the toe of the pile.
- Pile load testing requirements (static load tests and dynamic load tests).

Influence of trees in clay

Where construction is to take place in cohesive soils and trees are/were/will be present:

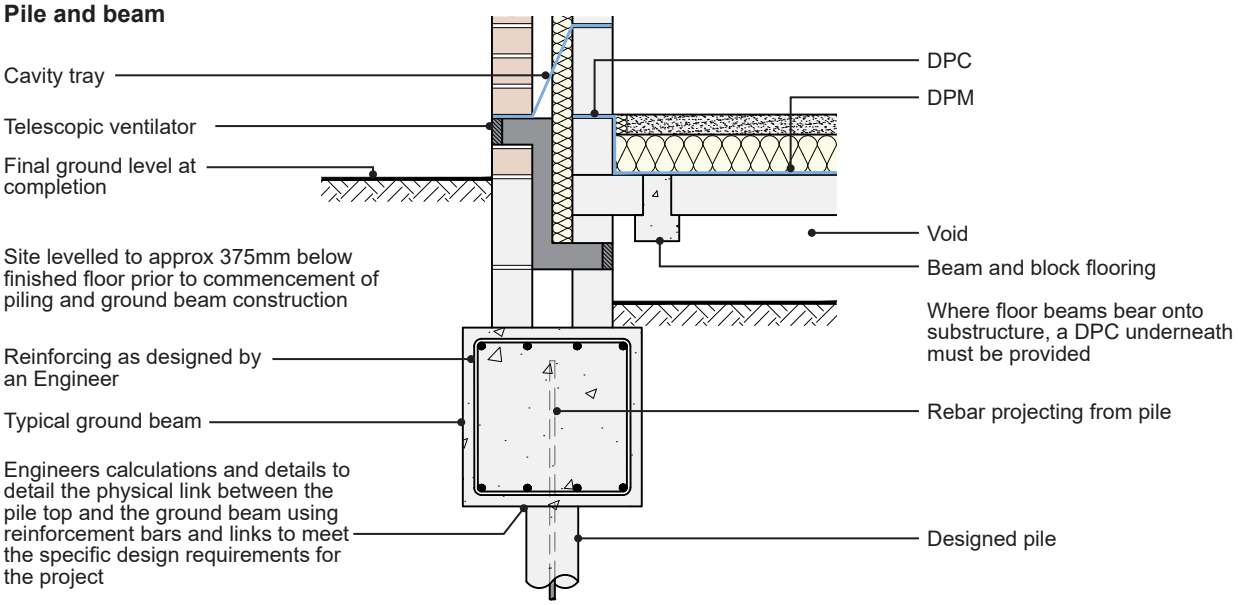
- Suitable heave precautions should be included in the design details for the protection of the piles, and ground beams or piled raft slabs.
- The piles must be deep enough to cater for heave.

For more information on trees, clay and heave precaution, please see the 'Foundations - Trees and Clay' section.

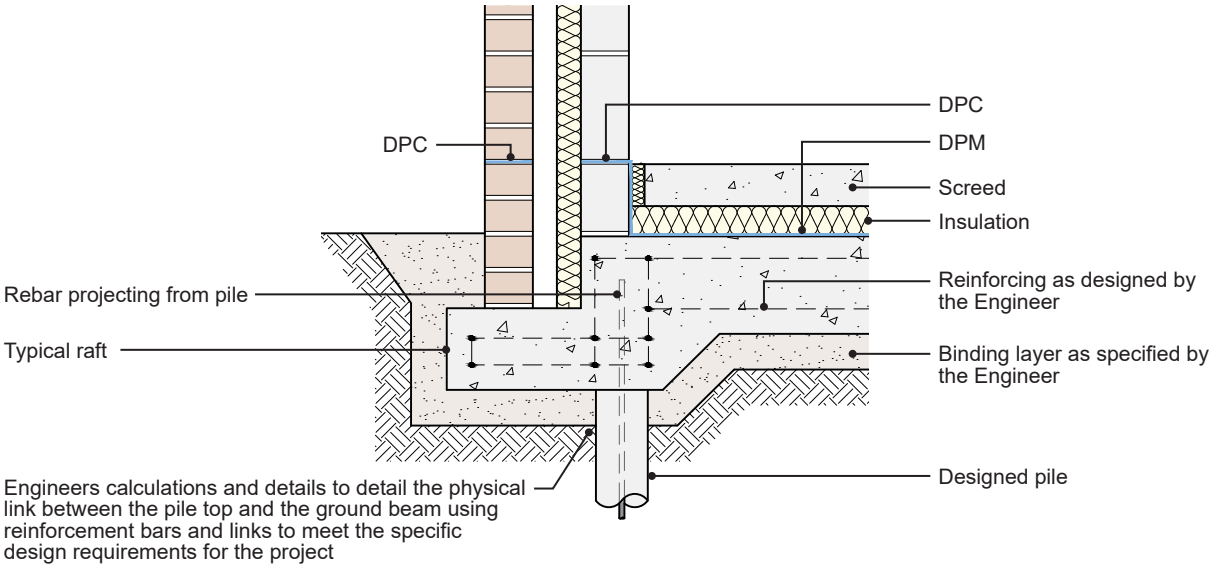
Ground beam and piled raft slabs

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 and beam



Piled raft



3.2.5 Pile testing

Pile testing shall be conducted according to current British Standards and Codes of Practice, taking into account the specific ground conditions present on site. The testing proposal shall be discussed with the Warranty Engineers at the earliest opportunity.

3.2.6 Pile installation records

Pile installation records shall be made available for all piles installed.

Replacement piles

The following must be provided for all piles:

- Pile installation records (site logs) must be provided for all piles. These records must include details of:
  - The piling company.
  - Piling rig used.
  - Rig crew details.
  - Pile type.
  - Pile diameter.
  - Unique pile references.
  - Piling platform levels.
  - Pile depth installed.
  - Details of the rebar installed in the pile.
  - The day of drilling.
  - The concrete mix used to fill the piles and which piles had concrete test cubes taken.
  - Any problems experienced with installation of the piles must be recorded.
- Pile integrity test reports including vibration traces for all piles and a summary of the results (pass or fail).
- 28 day concrete test cube results for piling concrete for each day of piling.
- Piling rig telemetry records must be provided – if they are available.

If there are pile installation difficulties, then the Project Structural Engineer and Warranty provider must be informed as soon as possible.

Displacement piles

Pile driving installation records (site logs) must be provided for all piles. These records must include details of:

- The piling company.
- Piling rig used.
- Rig crew details.
- Hammer weight.
- Driving efficiency of the actual hammer used on site (including in date efficiency certificate).
- Hammer drop height.
- Pile type (steel, concrete or timber).
- Pile section size.

- Unique pile reference numbers.
- Piling platform levels.
- Pile depth installed.
- The levels of segmental pile section joints (where applicable).
- Pile driving records for each pile (penetration for each ten blows to build up a driving / penetration profile for the pile) and the date of driving each pile. Re-strikes of particular piles must be recorded and issued to the Warranty provider.

If the driven piles gain the majority of their support from clay or chalk, then 10% of the piles shall be subjected to a re-strike, after a suitable length of time (allowance for increased pore water pressures to dissipate at pile toe or shaft annulus slurries to drain after the initial drive). The purpose of the re-strike records is to determine whether the pile has improved driving blow count / vertical displacement characteristics (stiffer) or worse blow count / settlement characteristics (less stiff than assumed). If the latter, then the Pile Designer, Structural Engineer and Warranty provider must be informed, as soon as possible, and a technical discussion held on, maybe, downrating the ultimate load capacity of particular piles, exhibiting this characteristic, and the possibility of installing additional piles.

Where particular driven piles display the characteristics of quake during and/or after driving (upward movement of the pile head). The reasons for this phenomenon must be established and the implications on foundation design identified and communicated, to the Structural Engineer and Warranty provider, as soon as possible. If it is decided a foundation re-design is required to counter the quake characteristics of the driven pile, then these re-designs must be submitted, as soon as possible, to the Warranty provider, for consideration. Further discussion within the Design Team will be required and agreement reached with the Warranty provider. Any works constructed on top of these piles, before agreement with Warranty provider, will be at the Client's risk. The Client, in this case, is the company applying for a Building Warranty.

Where driven pile depths vary considerably over short distances (using a driven pile set formula to determine pile depth), the reasons for this phenomenon must be established as soon as possible – for example, a possible scenario could be short piles into a backfilled quarry side wall (into rock) or internal subterranean highwall (into rock), end bearing piles onto subterranean cobbles and boulders and long piles into deep fill.

It is probable that additional ground investigation will be required to establish where these subterranean features are present – to allow a detailed appraisal of the problem.

The choice of driven piling method, piling rig and pile section material type is important for particular ground conditions. It is not acceptable to state on pile driving records that a pile has been driven to refusal – if the following applies:

1. 220mm diameter, steel cased, bottom driven piles are driven into stiff to very stiff clays. Alternatively, driving into rock strata where a rock socket cannot be achieved and required by the geotechnical design of the pile (a pile driving set formula calculation on it's own is not acceptable).
2. Top drive precast concrete piles driven into moderately weak rock or stronger. The Warranty provider will consider top drive thick walled steel tubes driven into this type of strata – if practical refusal is achieved (10 blows for 25mm vertical displacement) using a suitable heavy hammer and hammer drop height.
3. Where, as installed driven piles have not achieved the depths required by the geotechnical pile design (using appropriate soil / rock parameters), then static load tests on sacrificial piles are likely to be required where the soil/rock strata present are stiff clays or the unconfined compressive strengths and rock quality indices are unknown.

3.2.7 Alignment of piles

The Piling Contractor shall 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).

References

- 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