Local Authority Building Control

Technical Information Note 3
Driven and In-situ Piled Foundations

Cambridge City Council - East Cambridgeshire District Council - Fenland District Council,
Huntingdonshire District Council - Peterborough City Council - South Cambridgeshire District Council

INTRODUCTION

This guide is intended to give guidance in respect of issues such as the extent of site investigation and borehole information; piles driven to a pre-designed set; piles installed to a pre-designed length; factor of safety for pile design; load testing; detailed pile calculation; the party wall act and noise caused by piling.

1.0 Extent of Site Investigation and Borehole Information

1.1 The person carrying out this initial investigation should ideally have had previous experience of foundation proposals for the local and general area in order that as much information as possible can be obtained during one site visit only, without the need to return to site for further investigation. The findings, however, may suggest that an additional more detailed specialist geotechnical investigation may be prudent/required, in order to provide sufficient soils information for the specialist piling contractor to prepare his designs. Reference should also be made to the pile foundations preliminary investigation requirements contained within BS8004.

1.2 The designers of insitu piles will require engineering properties for the prevailing soil strata, obtained from insitu and laboratory testing, to a depth generally beyond the anticipated length of piles.

1.3 Other considerations such as the potential for buried obstructions, underground water courses, proximity of existing structures, for example, may also dictate the type and suitability of the chosen foundation system.

1.4 There may be a potential for nearby structures to be adversely affected by the piling works, particularly for driven piles, and this may dictate the type of pile chosen.

1.5 Further site investigation guidance is given within the District Surveyors Association [DSA] Policy Note No.1 “Guidance on Pile Design” (attached as appendix 1).

2.0 Load Testing and Factor of Safety

2.1 In general, an appropriate factor of safety for a single pile is suggested within BS8004 as being between two and three when considering the ability of the soil to accept the load. The actual value adopted will be chosen by the pile designer from a number of criteria of theoretical, practical and commercial considerations.

2.2 *Insitu Piles*

2.2.1 When the total number of piles is few, it may be more cost effective to adopt a higher factor of safety instead of providing load testing of working piles.

2.2.2 For a large number of piles, preliminary tests carried out on one or more piles installed prior to final pile design and the commencement of the main piling contract, together with load testing of working piles and in conjunction with a lower factor of safety, may be more cost effective.

2.3 *Driven Piles*

2.3.1 Since these piles are driven to a pre-designed set, load testing of working piles is not normally considered necessary.

2.4 The intensity of site investigation carried out will also influence the choice for factor of safety. For larger projects, more finances directed towards pre-contract site investigation should allow the pile designer to adopt a lower safety factor and therefore produce a more cost effective pile design.

2.5 Further load testing and factor of safety guidance is given in appendix 1.

3.0 Driven Piles Installed To A Set

3.1 When considering driven piles, it is essential that sufficient knowledge of the prevailing soil conditions is obtained whether by direct site investigation for the site in question or by experience from local sites.

3.2 The designers of driven piles will need to have confidence that, once the length of pile has obtained the required pre-design set, significantly weaker soil strata does not exist immediately beyond the installed pile length.

3.3 They will also have to satisfy themselves prior to commencement of the piling works that a suitable pile diameter has been chosen consistent with the anticipated pile length.

3.4 Local knowledge of previous projects in the area using driven piled foundations may be sufficient to offer the required confidence (but be aware of the requirements contained within BS8004 with regards to pile foundations preliminary investigations).

4.0 Insitu Piles

4.1 Insitu piles are installed to a pre-calculated design length using the soils information available. Variations in the soil strata between borehole locations can, and do, occur and are sometimes significant, thus giving rise to the necessity of an on-site testing regime for the installed working piles. This regime would normally be expected to consider two main areas as follows:

4.1.1 *The structural integrity of the piles:*
This can be compromised by prevailing characteristics of the soil such as flowing subterranean water courses, local collapse of the excavated bore, for example.

4.1.2 *Confirmation that the soil characteristics used within the theoretical design of the pile was realistic:*
This can be done either by

- evaluating the actual pile/soil interaction for a random number of the installed working piles.
- applying the required working load to the pile, increased by a suitable factor of safety, and recording the performance of the pile in terms of its downwards movement during loading and its recovery after removal of the load.

4.1.3 The structural integrity of the installed piles should be tested and, since the cost of integrity testing is often based upon one (or more) visits to site with the testing equipment, it is usually cost-effective to have tested as many of the piles as possible during each visit. For modest sized projects, this can often achieve testing of all piles within a single visit. Integrity testing of all working piles is recommended. The principle used for integrity testing is based on measuring the frequency and amplitude response of a pile, known as ‘Impulse’. This response (known as ‘Mechanical

Admittance' or 'Mobility') contains all the information necessary to check pile integrity. The equipment used is lightweight and portable and analysis of results can be carried out instantly on site to confirm the pile length and depth of any defects if they exist.

4.2 The evaluation of actual pile/soil interaction for an installed working pile, in terms of the load capability of the pile, can be easily done by testing such as C.A.P.W.A.P [CAse Pile Wave Analysis Programme]. This is a fairly accurate method for capacity prediction, which is performed by attaching sensors to the pile and imparting a stress wave to the pile head by a suitable falling weight (this can be done using a drop hammer applied by the piling contractor's plant). The sensors monitor the response in terms of the force and velocity of the stress wave from which a predicted capacity can be made.

Traditional load testing of a working pile is carried out by applying the required working load to the pile, increased by a suitable factor of safety, either by Kentledge or by hydraulic jack.

- *For the use of Kentledge (usually concrete or cast iron blocks)*, a platform is constructed over the installed working pile, supported from the ground. A jack is positioned on the prepared head of the working pile to jack against the Kentledge. Whilst load is gradually applied in increments, the downward movement and recovery of the working pile is measured.

- *For the use of a hydraulic jack to jack the pile into the ground*, uplift/tension piles are required either side of the pile, from which a beam is fixed to span over the installed working pile. The jack is positioned between the underside of the beam and the prepared head of the working pile. Whilst load is gradually applied in increments, the downward movement and recovery of the working pile, together with the upward movement of the uplift/tension piles are measured. These are correlated against one another in order to assess the movement of the working pile for the applied load.
  See also Appendix 1

5.0 Building Regulation Submission Requirements

5.1 In order that the submission may be examined against the requirements contained within Part A of the Building Regulations, sufficient load assessment calculations will be required either in consideration of the load attracted to each individual pile or demonstrating that the intended design working loads for the piles is not less than the most onerous load attracted to them.

5.2 For insitu piles, the design package will have to include sufficient site investigation to demonstrate that the engineering properties of each soil strata penetrated by the pile is consistent with the engineering properties used within the design. All methods that the pile uses to transfer the load from the pile into the soil (for example skin friction, end bearing) should be sufficiently analysed within the submitted calculations including the appropriate factor of safety for each category of applied pile load.

5.3 For driven piles, the design package will have to include details of the soil profile for the site and calculations for the required set for each category of applied pile load, including the appropriate factor of safety.

5.4 Piling installation and test records will be required in order to confirm compliance and performance with the pile design requirements for both insitu and driven piles.

5.5 Piling installation records should include:

5.5.1 *For driven piles:*
Record of the installed depth and set achieved for each individual pile.

5.5.2 *For insitu piles:*
Record of the installed depth for each individual pile.

5.6 Load test records should include:

5.6.1 *For driven piles:*
Testing of driven piles is not normally considered necessary. If any load or integrity testing has been carried out however, the records for any such testing should be submitted, identifying which piles the testing is relative to.

5.6.2 *For insitu piles:*
The records for all testing carried out (for example, integrity, C.A.P.W.A.P, Kentledge or jack load test) should be submitted, identifying which piles the testing is relative to.

6.0 Other considerations

6.1 <u>The Party Wall Act</u>

Many developments that are carried out can affect buildings or land belonging to a neighbour or adjoining land owner. This is particularly the case if you intend to carry out piling near to a neighbouring building.

For example, if you intend to:

- excavate or construct foundations for a new building or structure, within 3 meters of a neighbouring owner's building or structure where that work will go deeper than the neighbour's foundations, or

- excavate or construct foundations for a new building or structure within 6 meters of a neighbouring owner's building or structure where that work will cut a line drawn downwards at 45^{o} from the bottom of the neighbour's foundations

you will need to notify the adjoining owner, who can agree or disagree with what you propose. Where there is a disagreement, the Act provides for the resolution of disputes.

Building Control does not control or enforce the Party Wall Act. These are matters of private law. Building Control's only involvement could arise when a dispute occurs, as the local authority may appoint a third surveyor, to help resolve the dispute.

6.2 Management of Noise from Piling

We recognise that there is a need, by contractors, to ensure that residents and businesses are protected from environmental disturbance during construction of both major and smaller developments. Should piling be required on a site then the noise sensitivity of the area should be considered by the contractor when determining the method of piling to be used. It is recommended that the contractor liaise with our Environmental Protection department.

The use of conventional impact hammers should, wherever possible, be avoided.

Piling works may cause concern to local residents and noise complaints to the Council. Informing local residents of the dates and times the piling works are to start and finish is considered good practice towards the reduction of complaints about the site. Fliers placed into local resident's home giving the Site Manager's contact details are also recommended.

Where practicable, jacked piles shall be used in preference to piles driven using other methods. Any pile driving should be carried out by plant equipped with a recognised noise reduction systems.

7.0 **Additional Information**

Whilst every care has been taken in compiling this guidance note the Building Regulations are changed from time to time so it is important that you check that the information here is still current. The details highlighted in this guidance note are for general scenarios and each case should be taken on its own merits.

LABC Policy Note No 1

Guidance on Pile Design

DRIVEN AND INSITU PILES, NOT LESS THAN I5Omm DIAMETER **FOR** LOW RISE BUILDINGS UP **TO** FOUR STOREYS

INTRODUCTION

During the routine checking by Approving Authorities of pile design submissions, judgment is required on whether the site investigation, the pile testing and factor of safety employed will ensure performance of the pile.
The following notes are a broad framework to aid that decision making process.

SITE INVESTIGATION

The level of site investigation provided or proposed should be categorised as follows:

- Full: a properly planned and executed investigation, which has established all the required relevant information for the design and execution of the piled foundations. BS 5930*:* 1999 and the guidance of the Site Investigation Steering Group indicate how this can be achieved.

- Limited: an investigation usually including one or more boreholes and tests on samples, which together with desk study information provides substantial if not complete data for the design and execution of foundations. With a limited investigation the shortfall in information needs to be taken into account either in the design or by pile testing during construction.

- Minimum: a desk study and walkover survey including trial pits, from which information for the design and execution of the foundations is estimated.

PILE TESTING

Two kinds of tests are commonly specified:

- Preliminary pile tests: maintained load testing up to at least 2 times working load of Constant Rate of Penetration testing in accordance with BS 8004: 1986 or other accepted standards; normally carried out before work starts on site or at the very beginning of a project.

- Working pile tests: maintained load testing up to at least 1 *.5* times working load in accordance with BS 8004: 1986 or other accepted standards.

The level of pile testing provided or proposed should be categorised as:

- Full: one or two preliminary pile tests and where necessary working pile tests, so that the total number of piles tested is not less than 1 in 100 for the first 300 piles and for subsequent piles at a rate of not less than 1 in 300.

- Limited: working pile tests, so that the number of piles tested is not less than 1 in 100 for the first 300 piles and subsequently at a rate of not less than 1 in 300.

- None: no testing of the pile type on the building location or in similar soil conditions in the immediate vicinity of the site.

N0TE: Where there are large variations in substrata revealed either by the site investigation or during the construction of the piles, tests should be carried out in each zone and the level of testing reassessed accordingly for each design situation.

FACTOR OF SAFETY

Using the level of site investigation and the level of pile testing, table 1 gives an indication of the MINIMUM recommended factors of safety that should be used in the design of piles. Values should be adjusted to allow for extraordinary factors on a particular development.

Table 1: Minimum factors of safety for piles

Level of Testing	**Level of site investigation**		
	Full	Limited	Minimum
Full	2.0	2.25	2.5
Limited (Note 2)	2.25	2.5	3.0
None (Note 2)	2.5	3.0	3.0 (Note 3)

NOTE 1: Interpolation is permitted to allow other combinations of pile tests of site investigation.

NOTE 2: At the discretion of the design engineer and checking authority a lower factor of safety may be used where extensive existing soils data and experience of pile performance are available, but it should not be less than 2.0.

NOTE 3: Piling is only acceptable if suitable ground conditions can be verified through local knowledge or other methods.

ENHANCED SKIN FRICTION FACTORS IN LONDON CLAY

Where shear strength parameters are established from tests on 100mm rather than 38mm diameter samples, the results are often lower because fissures and other strength reducing features are more likely to be included within the larger size of samples. Consequently, the shaft adhesion can be calculated using a higher value of adhesion factor than *0.45,* as established by Skempton on the basis of 38mm samples. This has been verified by analysing pile tests (e.g. See D.C. Patel, Arup Geotechnics. Piling Europe 1992.) However, an overall limit on the average shaft adhesion should still apply. Skempton recommended 96 *kNIm2.*

Therefore, at the discretion of the design engineer and checking authority, an increased value for the adhesion factor alpha of up to 0.6 may be used in the pile design if the following conditions are complied with.

a) a full site investigation is undertaken;

b) shear strength values are based on tests on 100mm diameter samples.

INTEGRITY TESTING

Large strain (dynamic) testing is being increasingly proposed and used, normally for precast concrete piles. The pile to be tested is subjected to a heavy blow and the passage of the resulting compression wave through the pile and back to sensors is analysed using a computer. The information received can be used to verify soil parameters used in design and to estimate pile *capacity.*

Small strain (integrity) testing is frequently specified particularly for flight auger (CFA) produced piles. The pile is subjected to a light blow, usually from a hand held hammer and the resulting response is analysed to indicate the integrity and length of the pile. Where the length to diameter exceeds approximately 30: 1 or the pile has joints or variations in size, the method is likely to be ineffective. Much depends on the sensitivity of the equipment and skill of the operator. The method should not be used on its own to either prove or disprove the adequacy of piles; instead it can be helpful in identifying potentially defective piles by comparing responses. Because the cost of testing is usually small compared with the cost of coming to site, it is recommended that all piles are tested or alternatively as many as possible be tested at the first visit, and if the results are satisfactory then testing be continued on not less than *25 %* of the remaining piles. However, all piles should be tested in circumstances where suspected problems remain to be identified.

NEGATIVE SKIN FRICTION

Where piles pass through ground that may consolidate or change in volume (e.g. due to a change in water table or loading due to raising of levels) the effects of negative skin friction should be taken into account. The capacity of the pile to resist the additional compressive and tensile stresses should be checked at critical cross sections.

PILE DESIGN

To resist vertical loads

The working pile load should be assessed from equations [1] to [3].

$$Q_a = (Q_s + Q_b)/F_s \qquad [1]$$

$$Q_s = a \times C_{us} \times A_{se} \qquad [2]$$

$$Q_b = N_c \times C_{ue} \times A_b \qquad [3]$$

where:

- Q_a is the working pile load
- Q_s is the ultimate resistance from skin friction on the shaft
- Q_b is the ultimate resistance from end bearing on the base
- F_s is the factor of safety
- a is adhesion factor - usually taken to be *0.45*
- C_{us} is average undrained shear strength of the clay over the length of the pile being

taken into account in the design

A_{se}	is surface area of pile shaft being taken into account in the design
N_c	is bearing capacity coefficient normally taken as 9
C_{ue}	undrained shear strength at the base of the pile
A_b	is plan area at the base of the pile

Design for heave

Ground, that is affected by changes in moisture content and suffers shrinkage on drying out, can on taking up moisture again increase in volume and thereby via (negative) skin friction produce an upward vertical heave force on the pile. This upward force needs to be resisted by anchoring the pile into the stable ground below and by providing reinforcement within the pile to resist the resulting tension. The length of shaft subjected to heave is variable and depends on the site conditions.

Where piles need to resist heave the following procedure or similar should be followed in the design:

1 . Calculate the ultimate resistance from skin friction on the shaft, Q_s from equation [2], ignoring the shaft adhesion within the ground subject to moisture changes and possible future desiccation (i.e. normally ignore the top 3.5m below ground level where existing trees are remaining).

2. Check vertical load capacity using equations [1] and [3] and the value from equation [2], assuming the resistance from skin friction acts vertically upwards and ignoring any heave effects.

3. The design upward vertical heave force should be calculated from equation [4].

$$H = a_h \times C_{us} \times A_{sh} \times F_i \qquad [4]$$

where:

H	is the upward vertical heave force on the pile shaft
a_h	is the adhesion factor for heave taken to be not less than 0.6
A_{sh}	is surface area of pile shaft from ground level to the base of the heave zone normally taken as 3.5m.
C_{us}	is the average undrained shear strength of clay within the heave zone, normally taken as the average adhesion between 1.0m and 3.5m below ground level (i.e. ignoring the top 1.0m to allow for cutting back of piles).
F_i	is a factor of safety to allow for the inadequacy of S.I. data and variations in adhesion - normally taken as not less than 1 .5 or $2a/a_h$ whichever is the greater.

4. Check that design heave force is less than ultimate resistance from skin friction, see equation [5]:

$$H \leq Q_s \qquad [5]$$

NOTE: The ultimate resistance from skin friction is now acting downwards against the heave force. No assistance is assumed from the dead load of the superstructure because soil moisture movements can occur before the superstructure is built and even then the minimum dead load on individual piles can be negligible.

5 . Determine the area of reinforcement from equation [6]:

$$A_s = H/O.78fy$$

where:

A_s is the area of tension reinforcement required
f_y is the characteristic stress in tension of the reinforcement

MINIMUM SIZE AND REINFORCEMENT OF PILES

Piles for new development should be not less than 150mm diameter or equivalent.

Where feasible, it is recommended that all piles have a minimum of one T12 bar or equivalent for their entire length.

Piles intended to resist tensile forces, heave or negative skin friction should be designed and reinforced. Reinforcement should extend for the full anchorage length that is required safely to resist uplift.