GOOD PRACTICE GUIDE

PILING

LABC Warranty's Surveyors and Engineers are required to assess the structural design and installation of piled foundations as part of the audit process on behalf of the Underwriter. The following guidance outlines recognised good practice in relation to piling which is acceptable to LABC Warranty. Pile design and installation should be in accordance with the LABC Warranty Technical Manual and recognised publications from British Standards, Eurocodes, CIRIA, BRE, ICE, FPS and LDSA.

TECHNICAL DOCUMENTATION REQUIRED

The following documentation shall be submitted to LABC Warranty for assessment. Items 1-5 should be submitted prior to commencement of piling on site. In the absence of approval, works are proceeding at the Developer's own risk. Items 6-10 shall be submitted as soon as they become available, prior to construction continuing over the piles.

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. Project Structural Engineer's Specification for Piling Works to include the allowable pile settlements and testing requirements
4. Calculations demonstrating how the load on each pile was derived
5. Pile design calculation (for vertical, horizontal, tensile and heave forces) to geotechnical parameters in Site Investigation Report and a copy of the pile set design (for driven piles, if applicable). 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

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 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
8. Integrity testing of all concrete piles with interpretive summary and conclusion
9. Dynamic load testing results (where applicable) with analysis of long-term settlement, interpretive summary and conclusion
10. Static load test results with interpretive summary and conclusion

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 LABC Warranty for agreement prior to commencement.

REFERENCE DOCUMENTS

BS EN 1997-1:2004 + A1:2013 - Eurocode 7: Geotechnical Design (EC7)
BS 8004:2015 - Code of Practice for Foundations

BS EN 1997-2:2007 – Ground Investigation and testing
BS 5930: 2015 - Code of Practice for Ground Investigations
ICE Specification for Piling and Embedded Retaining Walls (3rd Edition 2016)
London District Surveyors Association (LDSA) - Guidance Notes for the Design of Straight Shafted Bored Piles in London Clay (2017)

PILING

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 properties obtained from geotechnical testing and contained in the appropriate site investigation report. The piles shall be designed in accordance with BS8004:2015 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 Project Structural 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 underperformance, the capacity of the questionable piles shall be demonstrated by means of static load testing and it shall be confirmed by the Project Structural Engineer that the piles are fit for purpose.

GEOTECHNICAL SITE INVESTIGATION

A detailed, site specific, interpretive, Phase 2 Geotechnical Site Investigation should take place and be in accordance with BS5930/BSEN1997-2 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, additional investigation and testing will be required e.g. by carrying out additional boreholes to the above depth, as considered necessary to establish the required geotechnical parameters.

PILE DESIGN

A pile layout drawing and piling schedule should be prepared by the Project Structural 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 BS8004:2015 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 Project Structural Engineer.

In all cases, a geotechnical and structural design should be carried out to current standards in order 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 expected vertical, horizontal, tensile, heave and negative skin friction forces.

The skin friction adhesion factor (α) should be in accordance with BS8004:2015 (clause 6.4.1.2.3).

BS8004:2015 (Clause 6.1.1) & BSEN1997-1 (Clause 7.4.1) permits pile design to be carried out by:

- Static pile formulae based on ground parameters from the site investigation and appropriate safety factors
- The results of dynamic load tests (provided they have been verified by static tests in comparable situations)
- 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 the 1st option applies. 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) 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 Project Structural 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 tests don't necessarily need to have been carried out on the particular site), as required by BS8004:2015.

PILING

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 us prior to commencement of piling.

PILE DESIGN FACTOR OF SAFETY

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

EC7 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

Refer to BSEN1997-1 for full tables.

Alternative Factors of Safety depending upon load testing undertaken (using traditional approach):

Preliminary Pile Tests (PPT)	Working Pile Tests (WPT)	Typical Factor of Safety
No	No load testing on WP	3.0
No	Load testing on 1% min of WP	2.5
Yes (rate to be agreed)	Load testing on 1% min of WP	2.0

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.

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.

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 dissolution 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. 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

PILING IN MADE GROUND

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

PILE INSTALLATION & TESTING

Piles should be installed and tested to ensure that they meet the design requirements. The Project Structural 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) submitted to us 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), 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 Project Structural 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 Project Structural Engineer should advise on the remedial measures proposed and seek agreement with us. It is recommended that such agreement is obtained prior to continuance of work. 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 BS8004:2015 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.

BS8004:2015 (Clause 6.1.1) & BSEN1997-1 (Clause 7.4.1) permits pile design to be carried out by:

- Static pile formulae based on ground parameters from the site investigation and appropriate safety factors
- The results of dynamic tests (provided they have been verified by static load tests in comparable situations)
- 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 the 1st option applies. 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 Project Structural Engineer).

PILING

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 BS8004:2015.

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 LABC Warranty for agreement prior to commencement.