STRUCTURAL GUIDANCE

BUILDING ON FILLED GROUND

LABC Warranty's Surveyors and Engineers are required to assess the structural design of foundations bearing on filled ground as part of the audit process on behalf of the Underwriter. The following guidance outlines recognised good practice in relation to building on fill which is acceptable to LABC Warranty. The structural design and construction should be in accordance with the LABC Warranty 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 report to be capable of carrying the load, using the appropriate soil properties obtained from geotechnical and load testing.

Groundworks shall be designed and validated by a suitably qualified Chartered Geotechnical 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 Project Structural 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.

Made ground / fill material is inherently variable in nature and unpredictable when considering its settlement properties. Foundations proposing to adopt made ground / fill as a formation for strip, trench or raft type foundations are unacceptable. Foundations must terminate in naturally occurring competent strata, as indicated within the project site investigation report.

REFERENCE DOCUMENTS

Building Regulations – Part A
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
BS 1377-9:1990 – 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
LABC Warranty Technical Manual –Chapter 5.2.
LABC 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)

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TECHNICAL DOCUMENTATION REQUIRED

The following documentation shall be submitted to LABC Warranty for assessment. In the absence of approval, works are proceeding at the Developer's own risk.

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 and 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 as indicated in LABC Warranty 'Piling Good Practice Guide' (if applicable)
c) Vibro foundation calculations as indicated in LABC Warranty ' Vibro Good Practice Guide' (if applicable)

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. We note 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 LABC Warranty for agreement prior to commencement. Following acceptance of the proposals, please contact us if anything is subsequently discovered on site, which affects the design and / or construction.

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BACKGROUND INFORMATION

The construction of building structures on fill or made ground is growing, as developable land areas are reducing and demands for new homes and dwellings increase. Inevitably, the construction and suitable performance of structures on sites displaying problematic geotechnical challenges and subsequent foundation solutions will continue to rise, and Engineers are faced with providing both economic and functional solutions.

Fill can be divided into 2 main types:

A. 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.

B. Non-Engineered Fill / Made Ground – Risks associated with sites covered with existing fill, then the risks are more difficult to assess and short of complete excavation of the fills, the risks cannot be fully quantified. Hence, alternative foundation solutions where loads can be transferred to competent strata are required.

A. ENGINEERED FILL

Generally cohesive/granular homogenous 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:

A1. Shallow Fill (i.e. less than 2.5m depth below ground level (bgl))
A2. Deep Fill (i.e. greater than 2.5m bgl)

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%

A1. SHALLOW FILL

Shallow fill generally relates to sites where poor ground is encountered close to the surface and excavation of the poor ground is an economic alternative by replacement with suitable materials. The points below highlight some of the criteria that should be considered:

- Depths up to 2.5m bgl
- Granular materials are normally adopted in this instance, compacted in discrete layers to replace made ground or very poor ground conditions close to the surface
- Strata underlying fill is capable of supporting the upfill material under the new loading regime – Site investigation (SI) to be undertaken to verify suitable ground conditions
- Engineered fill to be installed in accordance with Engineers Specification (Backfilling should be carried out to a specification based on the Department of Transport Specification for Highway Works, Part 2, Series 600 Earthworks (for structural fills)):
  - A compaction specification is required, supported by all testing and validation undertaken.
  - Details and locations of all tests are recorded, including interpretation by the Geotechnical Engineer
  - Engineered fill to extend beyond the foundation toe to ensure 45o spread down to naturally occurring strata below
- Good site supervision is essential along with accurate surface monitoring to ensure the long-term consolidation settlements predicted by modelling can be verified
- Confirmation that all unsuitable fill material/ made ground / organic material has been removed.

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- Testing regime to support long term settlement and differential settlement predictions:
    - Aim to achieve 95% dry density compaction of the fill material – on site testing to verify (e.g. nuclear density gauges)
    - Effective load testing (BRE, ICE, CIRIA etc. indicate plate load tests do not confirm the expected long-term settlement criteria)
- Ground water monitoring to be undertaken, if considered necessary, along with associated impact on underlying strata and engineered fill

Suggested Foundation Solutions for sites with shallow engineered fill:

- Raft foundations are most likely to be the adopted solution where engineered fill has been specified to replace existing poor ground conditions at shallow depths. Normal criteria should be followed based around the LABC Warranty guidance should this solution be considered.
- Piled foundations are potentially an alternative solution, although considering the shallow depth of poor ground and the potential economic savings associated with raft foundations, then these may or may not be viable. This option would negate the requirement for engineered fill as a solution. Normal criteria should be followed based around the LABC Warranty guidance should this solution be considered.
- Ground improvement techniques, such as vibro stone columns, may also be another alternative based on the ground being suitable and economic assessments. Normal criteria should be followed based around the LABC Warranty guidance should this solution be considered.

A2. DEEP FILL

Deep fill generally relates to the infill of former opencast mining sites, infilled railway cuttings and the like. The points below highlight some of the criteria that should be considered:

- Depths over 2.5m bgl.
- A desk study of former site uses required, including inspection of:
    - Old OS Maps.
    - Mine abandonment plans.
    - Final mining extraction plans to identify potential problematic areas.
    - Surface hollows arising out of solution features such as swallow holes in limestone strata, or crown holes due to shallow mine workings which have been filled. These underlying hazards could still result in potential foundation problems on other parts of the site.
- Extensive SI undertaken to:
    - Verify/validate the use of site won or off-site materials as fill. Extensive site testing, prior to upfilling process to enable modelling of proposed materials.
    - Identify refuse materials subject to crushing when loaded or collapse due to corrosion over time. Generally, such fills can be very localised and may not be encountered in a standard SI.
    - Identify large obstructions/voids tipped as a result of infill. Additional probe boreholes may be necessary to establish locations. Specific grouting techniques may be necessary as a result. This situation is particularly hazardous at the edges of quarries.
    - Identify the location of high wall areas via trial pits if the fill above is not too deep or alternatively adopt probing at 3m centres to establish the location and inclination of the quarry high wall locations.
    - Prove the depths of the underlying bedrock strata to firmly establish the interface between the fill materials and naturally occurring strata.

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- Re-use of site won materials (granular or cohesive) are chosen based on extensive testing, monitoring and modelling techniques to provide:
  - Extensive sampling of proposed fill materials in accordance with BS 1377. Tests should include moisture content, plastic limits, liquid limits, sulphate and pH analysis and determination of optimum dry density / moisture content ranges for all materials to establish compaction parameters.
  - Resident Engineer (RE) to monitor up-filling procedures and undertake daily testing to underpin Engineers Specification.
  - On site testing, throughout the upfilling / compaction process to enable comparisons to be made with the results obtained from the compaction field trials.
  - A settlement monitoring grid to be installed, with specific considerations for seasonal movements. Monitoring to be carried out for a period of at least 12 months with operations continuing a minimum of 6 months beyond the completion of the upfilling process. Survey data to be collated and a comparison made based on the predicted modelling settlements.
- Groundwater monitoring is required throughout and beyond the upfilling process to ensure:
  - Fills placed in water will generally be looser than fills placed in the dry, as the binders or clay matrix separate out.
  - The re-establishment of the original water table with old opencast sites is potentially problematic, as the rising of the water table softens the lower coal measures, shales and mudstones, potentially resulting in additional settlements occurring, sometimes long after the normal time period for which consolidation occurs. Where fills are compacted to 95% of their dry density, the effects of rising groundwater and water table re-establishment are generally insignificant.
- Engineered fill to be installed in accordance with Engineers Specification (Backfilling should be carried out to a specification based on the Department of Transport Specification for Highway Works, Part 2, Series 600 Earthworks (for structural fills)):
  - A compaction specification is required, supported by all testing and validation undertaken.
  - Details and locations of all tests including interpretation by the Geotechnical Engineer/RE.
  - Effective load testing (BRE, ICE, CIRIA etc. indicate plate load tests do not confirm the expected long-term settlement criteria).
- RE appointment essential, along with all necessary technical support staff, to ensure the works are carried out in accordance with the specification:
  - RE to confirm all works undertaken align with engineer's specification. Any variations to the specification are recorded.
  - RE to provide final report validating the upfilling procedure, including any specific parameters for re-development of the site.
- Partial depth ground improvement techniques are to be avoided.

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Suggested Foundation Solutions for sites with deep engineered fill:

- Raft foundations may be a potential foundation solution on deep engineered fill, subject to the:
  - SI confirming the existing strata will perform adequately under the loading regime.
  - SI confirms the long-term settlement criteria remain compliant.
  - Designated no-build zones should be identified around any high wall batters to prevent problems associated with differential settlements around high wall batter planes, where the fill depth increases in magnitude over a short horizontal distance.
  - Stiff raft foundations are suitable if field tests have shown that the fill materials are chemically stable and homogenous, and long-term consolidation settlements have ceased.
  - The width of the edge beams or central thickenings should be made sufficiently wide to sustain the allowable ground pressures.

- Piled foundations may be a potential foundation solution in deep engineered fill, subject to :
  - Piles not terminated in the fill material
  - Pile installation being unaffected by potential obstructions from boulders etc. Driven piles could potentially terminate at false bedrock depths.
  - Avoid driving piles on sloping rock strata. Driven piles are not recommended in localities where the pile toe cannot be socketed in or bedded down solid. Generally, such piles drift out of plumb during driving.
  - The piles must be designed to carry the normal gravity loads imposed by the building structure, but also include any additional loads due to negative skin friction (NSF) on the pile shaft as the fills consolidate.
  - Any increase in existing ground levels will also impact on the pile design and result in additional loads on the pile shaft.
  - A particular advantage of piling is that dwellings can be constructed over no-build zones, although specific pile selection will be key. Where an inclined rock stratum is present, it is essential the pile toe is adequately socketed into the rock. Hence, driven piles are not recommended in this instance, unless they are tube piles which can be socketed in by down the-hole drilling.
  - If bored piles are used, taken through the fills into good bearing strata, the depth of penetration can be determined by calculating skin friction and end bearing values using appropriate factors of safety. Any additional load effects, resulting from NSF effects will also need to be allowed.

- Ground improvement techniques, such as vibro stone columns, may be another alternative based on the ground being suitable and economic assessments. Normal criteria should be followed based around the LABC Warranty guidance should this solution be considered. Problems arise when:
  - Partial depth ground improvement techniques are proposed, as the untreated fill material is susceptible to potential excessive long-term and differential settlements.
  - A particular problem associated with vibro stone columns is the potential for the stone columns to act like vertical drains transmitting surface water or perched water down into the lower fills. This can result in inundation settlement of the fills and localised softening of cohesive strata.

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