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Technical Appendix 11.6 - Summary of Ground Conditions
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West Midlands Interchange

Four Ashes Ltd

Technical Note

Project: West Midlands Interchange

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Subject: Summary of Ground Conditions

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Contents

1. Introduction

This technical note summaries the findings of geotechnical investigations carried out for Kilbride Holdings Limited at the site of the proposed Four Ashes strategic freight terminal located in the West Midlands.

The objectives of the technical note are:

- to summarise the sub-surface conditions over the site;
- to provide comments on the suitability of on-site soils for use in earthworks;
- to provide comments on suitable earthworks construction practice; and
- to provide comments on suitable foundations for proposed structures.

2. Site Location

The site is situated in south Staffordshire approximately ten kilometres (10km) to the north of Wolverhampton city centre and near to the village of Four Ashes.

The site is bounded on all sides by public roads and covers an area of approximately 300 Hectares. The completed development will include warehousing, office buildings, rail links, parking areas, access roads, bridges and under-passes.

The West Coast Mainline and Staffordshire and Worcestershire Canal pass through the site from approximately north to south. Calf Heath Reservoir is located to the north-east of the site and adjacent to junction 12 of the M6 motorway.

The small hamlet of Gailey and the Gailey Marina is present adjacent to the northern boundary of the site and an industrial development is present to the south-west.

3. Topographical Setting

The area of the site generally consists of gently undulating land.

Part of the site is occupied by the Calf Heath Quarry. In this area the site is characterised by the impact of quarrying operations on the landscape. A void exists where sand and gravel has been extracted and spoil heaps and lagoons are present.

The Four Ashes Quarry historical landfill site is located at the south west corner of the site.

The remainder of the site consists of farm land, dense woodland and coppice.

A tributary to the River Penk is present to the west of the site.

Ground elevation ranges across the site from about 108mAOD to 99mAOD from east to west.

4. Geology

The BGS 1:50,000 geological map indicates the site to be underlain by superficial Glaciofluvial Deposits of sands and gravels and Glacial Till consisting of gravelly red brown clay.

An area of Alluvium, consisting of residual deposits of peaty gravelly silty clay is indicated at the location of the tributary to the River Penk.

Beneath the superficial deposits and Alluvium, the Bromsgrove Sandstone and Wildmoor Sandstone Formations are present: which form part of the Sherwood Sandstone Group. Sandstone outcrops are indicated on the geological map at the northern extremity of the site in the vicinity of the Calf Heath Reservoir.

Coal measures are indicated at a depth of about 600m below the site area.

With the exception of the area of the Four Ashes and Calf Heath Quarries, there are no known excavations or other filling activities within the site boundaries.

The geology indicated by geological map was generally confirmed by the findings of the site investigations carried out.

5. Groundwater

Groundwater was generally encountered at approximately 2.5 to 4m below existing site ground level across the site. However groundwater was encountered at shallower or deeper levels in some localised areas and in one instance artesian water was encountered to a height of 0.8m above existing ground level.

6. Site Assessments and Investigations

An Environmental Site Assessment Report was prepared for this development by Environ Consultants Ltd. and submitted in June 2015. Other investigations have also been carried out in the general area of the site in the past, and the historical BGS borehole logs have been reviewed.

A ground investigation was also carried out for this development by RSA Geotechnics Ltd. and a factual and interpretive report submitted in April 2016.

Investigation work for this ground investigation included:

- A desk study of available information;
- 13 rotary cored boreholes to 20m depth;
- 24 rotary cored boreholes to 10m depth;
- 24 windowless sampling boreholes to 4m depth;
- 24 machine excavated trial pits to a maximum of 4m depth;
- 7 machine excavated soakage tests;
- 24 cone penetration tests; and
- the installation of groundwater monitoring standpipes.

Laboratory testing was conducted on samples of soil, rock and groundwater recovered from the investigation, consisting of the following determinations:

- natural moisture content

- Atterberg limit;
- particle size distribution;
- shear strength (triaxial test);
- drained shear strength (shear box);
- one-dimensional consolidation characteristics;
- California bearing ratio value;
- moisture condition value (MCV);
- point load strength;
- sulphate classification (BRE SD1);
- percentage organic matter; and
- moisture density relationship.

7. Summary of Ground Conditions

The findings of the ground investigations are in general agreement with the BGS geological map for the site area, the strata encountered during the ground investigation by RSA is summarised below:

Topsoil:

With the exception of the area of the Calf Heath Quarry, topsoil is noted as present over the majority of the site area. Topsoil was generally between 0.3 and 0.5m thick.

Made Ground:

Made ground was encountered in two main areas of the site, namely: Four Ashes Quarry (Historical Landfill Site) and Calf Heath Quarry.

The extent of the made ground at the site of the Four Ashes Quarry was not established due to the limited exploration carried out and further characterisation of the nature and extent of the landfilling activities will be required.

With respect to Calf Heath Quarry; the site is currently in various stages backfilling and mining activity. Various stockpiles of granular material, topsoil and spoil are present. The engineering characteristics of the spoil are unknown. However the spoil is likely to consist of low strength silt and clay size fines resulting from screening operations.

Alluvium:

A small area of Alluvium was encountered to the north-west of the site, between Gravelly Way and Gailey. The material generally consisted of sandy gravely silt and peat to a depth of about 2m below ground level.

Glacial Till:

Glacial Till was encountered in approximately two thirds of the exploratory holes across the site. Typically the till comprised of firm varying to stiff, red brown sandy silty clay of low to intermediate plasticity.

Glaciofluvial Deposits:

Glaciofluvial deposits were encountered in the majority of the exploratory holes and typically comprised medium to very dense, silty fine to coarse sand and gravel. Glaciofluvial deposits generally occurred below the Glacial Till: but occasionally within it.

Rock:

Mudstone and Siltstone of the Bromsgrove Sandstone Formation was encountered at shallow depth to the north-west of the site.

Elsewhere, also at shallow depth, Sandstone of the Wildmoor Sandstone Formation was encountered in most of the exploratory holes.

The depth to rock encountered varied from just below the topsoil layer to a depth of about 7.2m below ground level. However, the elevation of the top of rock was relatively consistent across the site at between 99.0 and 100.0mAOD.

8. Engineering Characteristics

Alluvium:

Alluvium encountered during explorations contained peat and other organic material. Soft clay and silt was also present. Such soils are low strength and highly compressible and are unsuitable for the support of structures or for use as general fill. However, these soils can be used for landscaping purposes.

Glacial Till:

Glacial Till encountered during the explorations generally consisted of a gravely sandy silty clay. Laboratory test results indicated that soil has a low to medium plasticity and volume change potential. Glacial Till will be suitable for use as general fill or as fill for the support of foundations.

Glaciofluvial Deposits:

Glaciofluvial Deposits encountered during the explorations generally consisted of medium to very dense silty fine to coarse sand and gravel. Glaciofluvial Deposits will be suitable for use as general fill or as fill for the support of foundations.

9. Comments

Proposed Development:

It is proposed to construct 14 large industrial warehouse units on the site with associated access and car parking pavements. According to preliminary design drawings, the development will include both cut and fill earthworks to form level floor and formation for pavements and access roads. Earthwork retaining structures and drainage basins are also required. It is proposed that the development will be achieved with an overall cut and fill balance of zero.

Existing Structures:

There are several residential masonry structures located across the site which will require demolition.

Salvageable waste material resulting from demolition can be crushed and re-used as hardcore.

Two steel pipe bridges adjacent to the Four Ashes industrial estate are to be dismantled and the recovered steel recycled.

Existing roadways across the site are to be cut out and the material can be recycled or if suitable re-used on-site as hardcore.

Cuts:

It is expected that excavation will expose firm varying to stiff sandy silty clay (Glacial Till) and medium dense varying to very dense fine to coarse sand & gravel (Glaciofluvial Deposits). Mudstone, siltstone and sandstone may also be encountered at relatively shallow depth.

Excavation may best be carried out using excavators and articulated trucks. The use of pan type scrapers may be considered, however their operation may be limited by the presence of “sticky” clay soils and large cobbles and boulders within the Glacial Till and Glaciofluvial Deposits. Excavation of rock may require the use of a ripping tool attached to the excavator.

Coal seams are present beneath the site at depth and as such will not be encountered within excavations. Moreover, the Coal Authority report for the site area states that past, present or future working of coal seams beneath the site will not likely influence the present ground surface.

Alluvium containing peat and soft cohesive material was encountered to the south-west of the site over a limited area and to a relatively shallow depth. The lateral extent of this material was not determined. However, where present in the zone of influence of any foundations, floor slabs or earthworks the material should be removed and replaced with compacted site won fill.

Filling

In general the Glacial Till, Glaciofluvial Deposits and ripped mudstone, siltstone and sandstone material won from cuts would be suitable for use as compacted fill material.

The following procedure should be followed for the preparation of formation and placement of compacted fill:

- Remove the topsoil and any other deleterious material or spoil;
- Scarify the exposed soil and condition it to optimum moisture content.
- Proof roll the exposed surface and treat any detected weak areas by removing the material and replacing it with compacted select fill or lean mix concrete;
- Place and compact selected granular (Glaciofluvial - sand and gravel) or cohesive (Glacial Till – sandy silty clay) fill material in horizontal layers not exceeding 250mm loose thickness;
- Compact cohesive material to at least 95% Modified Proctor dry density;
- Compact granular material to at least 95% Modified Proctor dry density or a minimum relative density of 80%.
- Beneath covered areas such as ground slabs, cohesive fill should be placed at a moisture content 0 to 3% above optimum in order to minimise the potential for heave of the surface due to wetting of the formation;
- Areas beneath ground slabs should have a final layer of at least 100mm thickness of select granular fill compacted to at least 95% Modified Proctor dry density or a minimum relative density of 80%;
- In-place field density tests and laboratory moisture-density tests are required to evaluate and certify compaction. The frequency of such testing will be detailed in the earthworks specification for the development;
- Care should be given so as not to over compact cohesive soil. Over compacted soil (greater than 100% maximum dry density) although denser than that required by the specification may have a lower strength. Consequently over compacted soil should be removed and re-compacted to the minimum dry density required and no greater than 100% maximum dry density.

Fills greater than 1m in height should be retained by an engineer designed retaining structure or battered to a maximum slope of 2.5:1 (H:V) and protected from erosion.

Minor fills, less than 1m, can be battered as outlined above or retained by a simple revetment type structure.

Groundwater:

Groundwater was generally encountered at between 2.5 and 4m below ground level across the site. However in localised areas groundwater was encountered close to ground surface and in one instance artesian water was present.

It is not envisaged that excavations for cutting or foundations will extend to any significant depth and formation levels for the development are generally above the levels of any groundwater encountered. Therefore major dewatering should not be required. However, localised dewatering may be required within excavations for foundations should perched water be penetrated. Such dewatering could be managed by pumping from sumps located within the excavations.

It should be noted that any excavation in granular soils below any groundwater penetrated will be unstable and subject to undermining and collapse. Should this be the case, appropriate measures with respect to the support of any affected structures and the general health and safety of site personnel need to be considered.

Trafficability:

The Glaciofluvial sands and gravels, when compacted and suitably maintained, would provide a trafficable surface for construction vehicles. However, dust control by periodic wetting and/or the application of calcium chloride will likely be required.

Glacial Till (clay) would not provide a suitable trafficable surface for construction vehicles as it will soften rapidly when wet and be subject significant rutting. Areas of exposed Glacial Till where haul roads are to be located will require a capping layer of hardcore or site won sand and gravel.

Earthworks and Retaining Structures:

A number of earth embankments are to be constructed to act as acoustic barriers throughout the site. Glacial Till and Glaciofluvial Deposits are suitable for the construction of these embankments. Typical stable side slopes for embankments constructed of these materials would be of the order 2.5:1 (H:V).

For embankments requiring steeper side slopes, retaining structures will be required. These structures could be supported on shallow spread footings and designed based on the basis of the presumptive bearing pressures stated in the section on foundations below. The type of retaining wall required will primarily depend on the height of soil to be retained. Typically gabion walls, crib walls, reinforced earth walls, sheet pile, masonry and gravity retaining walls would be considered.

Foundations:

With the exception of the areas bounded by the Four Ashes and Calf Heath Quarries it is considered that support for structural column loads could be provided by high level concrete pad foundations or strip footings.

The founding stratum would depend on the final ground profile beneath each foundation following cut and fill operations. The following situations could arise:

- Fill areas – column pads should be founded at least 0.9m below finished floor level in compacted Glacial Till (clay) or 0.45m in Glaciofluvial Deposits (sands and gravels). For preliminary design purposes foundations could be proportioned based on a presumptive bearing pressure of 200kN/m^2 for foundations bearing entirely on compacted Glacial Till (clay) or 500kN/m^2 for foundations bearing entirely on compacted Glaciofluvial Deposits (sands and gravels).

- Cut areas in soil - column pads should be founded at least 0.9m below finished floor level in compacted Glacial Till (clay) or 0.45m in Glaciofluvial Deposits (sands and gravels). For preliminary design purposes foundations could be proportioned based on a presumptive bearing pressure of 200kN/m^2 for foundations bearing entirely on medium to stiff Glacial Till (clay) or 500kN/m^2 for foundations bearing entirely on medium to compact Glaciofluvial Deposits (sands and gravels).

- Cut areas in rock – column pads should be socketed at least 0.5m into the rock. For preliminary design purposes foundations could be proportioned based on a presumptive bearing pressure of 1000kN/m^2.

The specified minimum footing depths take into account the depth of frost penetration and the possibility for heave within clay soils of high plasticity. It is noted however that based on the limited laboratory testing carried out; high plasticity clay soil was not detected within the samples tested. It is therefore possible that foundations depths within clay soil could be reduced following the favourable results of more extensive laboratory testing.

For foundations proportioned on the basis of presumptive bearing pressures, total settlements should be limited to less than 25mm and differential settlements limited to between 5 to 25mm between columns. 5mm being the differential settlement for adjacent foundations within similar material and 25mm for adjacent foundations in very stiff rock and a more compressible soil.

It is likely that the majority of settlement of foundations in granular material or on rock will occur during construction and on first application of building loads. Settlement of foundations in clay material will start during the construction period and continue for a period of time following completion of construction and application of the building loads.

Floor slabs should be cast independent of column pads or pier and beam footings on a compacted and prepared formation. For preliminary design purposes a modulus of subgrade reaction of 25,000kN/m^3 is suggested for slabs bearing on clay and 50,000kN/m^3 for slabs bearing on granular soil. Frequent control joints should be incorporated into slabs to allow for differential movements, particularly between cut and fill areas and areas where rock is at shallow depth.

Special considerations will be required for the design of foundations within the areas bounded by the Four Ashes and Calf Heath Quarries. Dependent upon the method employed to

restore Calf Heath Quarry and the findings of further investigations in the area of Four Ashes, column pad footings may provide a suitable foundation solution. However should it be determined that the ground is unsuitable, the following options for foundations may be considered:

- Excavate and re-compact unsuitable soil;
- Construct pad footings at greater depth, beyond any zone of unsuitable soil and re-compact formation beneath floor slabs if required; or
- Utilise in-situ ground improvement techniques.

At this stage of design it is not possible to suggest the most suitable foundation solution for these areas. However, when further information becomes available the above options can be considered further.

Pavements:

It is anticipated that vehicular traffic will comprise a range of commercial vehicles including multi-axle semi-trailers.

Both the Glacial Till and Glaciofluvial sands and gravels would provide a suitable formation to pavements. However, pavement constructed on sand and gravel formation would provide for a more economical design due to its greater design CBR value.
It is also noted that construction of pavement on a cohesive Glacial Till formation may prove problematic during periods of wet weather as the material will soften as its moisture content increases and will become extremely difficult to work with.

Drainage:

In general, suitable surface and subsurface drainage should be provided to ensure that:

- Water does not pond on the surface of pavements or earthwork formations;
- Foundation strata and fill embankments do not become saturated; and
- Pavement base material does not become saturated.

These measures should include table drains at the top and bottom of all battered slope sections.

All collected runoff and seepage waters should be directed from site in a controlled manner to an approved stormwater management system.