Pell Frischmann

# O2 Finchley Road

## Geotechnical Interpretative Report

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# Executive Summary


| | |
|---|---|
| **Site Name** | O2 Finchley Road |
| **Location** | Finchley road, London, NW3 6LU (National Grid Reference: 525650, 184730) |
| **Development Proposals** | Mixed use residential and commercial development set within landscaped areas of public open space. |
| **Site investigation scheme** | A scheme specific ground investigation was undertaken in September 2021 to establish the ground and groundwater conditions present on site. In situ geotechnical tests were undertaken and geotechnical and geoenvironmental samples collected for analysis. The interpretation of the geotechnical data is presented in this report together with geotechnical design parameters. The interpretation of geoenvironmental data is presented in a separate quantitative land contamination risk assessment report. |
| **Ground Conditions** | Made Ground was encountered to depths of between 0.45 and 2.94 mbgl across the site. The upper 0.45m generally consists of subgrade, gravel or clay with fragments of flint and brick with disturbed London Clay at lower depths (0.45 and 1.10m thick) which in turn overlies the London Clay Formation which was proven to a depth >60m bgl. |
| **Groundwater Conditions** | Perched water was found in the Made Ground overlying the London Clay at levels varying between 1.26m and 1.89m below ground level.<br>Groundwater seepage was observed in two locations within the London Clay at depths of 2.4m and 3.9 mbgl. |
| **Foundation Options** | Pile foundations bearing in the London Clay Formation are considered the most suitable foundation design for the proposed development. Where a proposed building and ground conditions are compatible a raft-enhanced pile group could also be considered. |

# 1 Introduction

This Geotechnical Interpretative Report (GIR) for the proposed redevelopment of the Finchley Road site (the site) has been prepared by Pell Frischmann (PF) under instruction from Landsec. The report is based on the results of the intrusive site-specific ground investigation undertaken by RSK in 2021.

This aims of this report are as follows;

- Interpret the results of the ground investigation undertaken and reported by RSK and develop a Ground Model for the site.
- Derive geotechnical parameters for design;
- Provide recommendations and preliminary designs for foundations and sub-structure elements.

## 1.1 Description of Site

The Finchley Road site is in the London Borough of Camden within the ward of West Hampstead. It is bounded by Blackburn Road, which envelops the site along its southern and northern edge, also extending to the west. Finchley Road (A41) bounds the site to the east, with Billy Fury Way to the west. The site location is shown in Figure 1. The Thameslink Bedford-Brighton railway line runs along the northern edge of the site, and the London Underground Jubilee and Metropolitan lines run above ground along the southern edge of the site, a rail bridge and a 5m retaining wall to the east, West End Road to the west and residential buildings.

The site currently comprises commercial and industrial land-uses including from east to west: the O2 Centre, a car park, a Homebase store, car dealerships and a builder's yard. The wider area predominantly comprises a mixture of residential and commercial land-uses, with occasional industrial land-uses.

Figure 1: Site Location

| Site location | |
|---|---|
|  |  |
| Ordnance Survey (OS) Open Mapping | Google Satellite Image |
| Site information | Details |
| Site area | 5.75 hectares (Ha) |
| National Grid Reference (centre of the site) (NGR) | 525650, 184730 |
| Nearest (central) postcode | NW3 6LU |

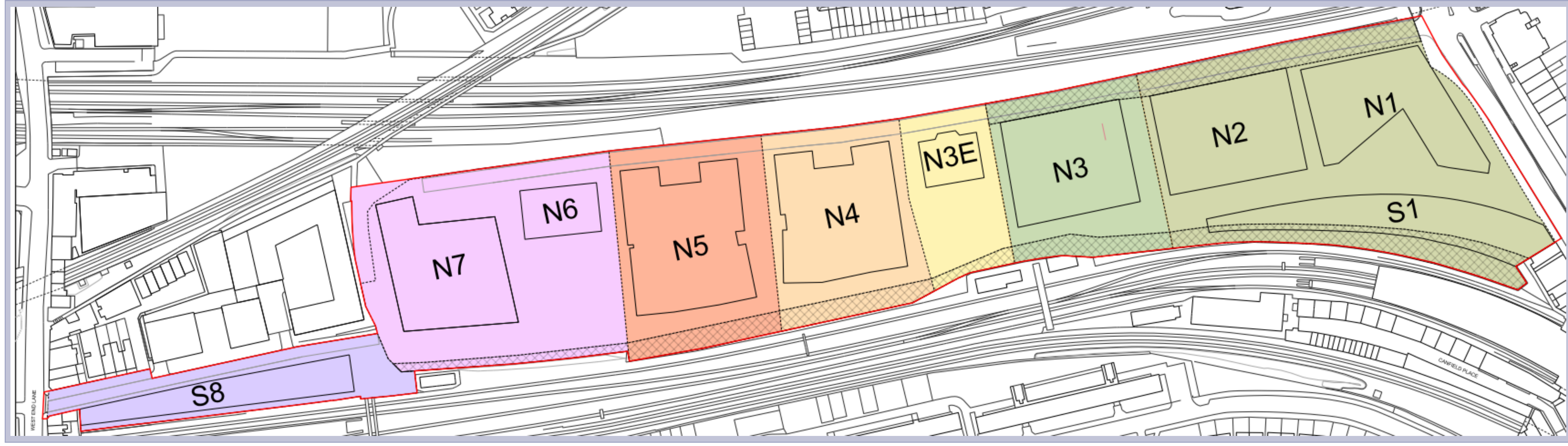
## 1.2 Proposed Development

The proposed development comprises a mixed use residential and commercial buildings set within areas of landscaped public open space. The evolving masterplan replaces the existing retail premises, showrooms and car parking with a vibrant mixed-use community. Part of the Development will be residential led with mixed tenures. A minimum of 35% affordable housing by floorspace (GIA) and habitable room will be included across the Development. The outline proposals will provide retail area, cinema, indoor sport and recreation space, day care centre/ nursery, commercial space, health centre, public open space, play space and private amenity. The masterplan consists of 1,856 homes within modern, low carbon and energy efficient apartment blocks, ranging from six to fifteen storeys. The masterplan seeks to create a locally integrated and highly sustainable new community in the London Borough of Camden, refer to Figure 5.

**Figure 2: Proposed Development**

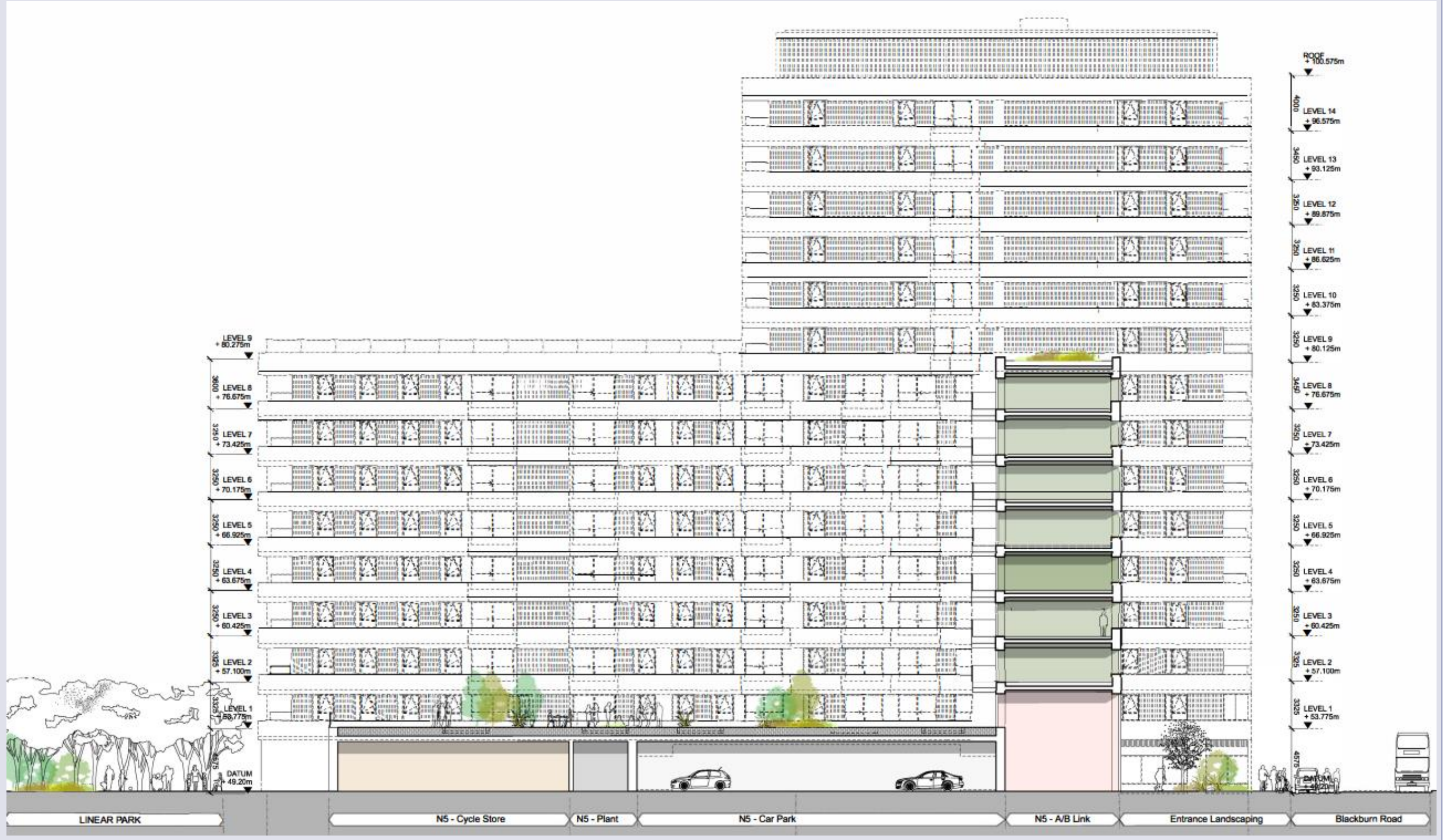
**Development overview**

**Lower ground floor**




**Illustrative phasing plan**


Cross section from east to west across N3, showing ground floor commercial / community space and bike & refuse stores, with residential units on floors 1-9.




Cross section from north to south across N5, showing groundfloor parking / bike storage, comercial / community space and refuse stores, with residential units on floors 0-14 and a raised podium garden on floor 1.


View of southern face of N4 development showing central raised podium gardens, with 8 & 9 story blocks in front and the outline of the 13 & 14 story blocks in the back.


Cross section from east to north to south across N5, showing groundfloor parking / bike storage, comercial / community space and refuse stores, with residential units on floors 0-14 and a raised podium garden on floor 1.

# 2 Ground Conditions

## 2.1 Published Information

The published geology of the area is shown on the geological map for North London (Sheet 256), scale 1:50,000), published by the British Geological Survey (BGS), see Figure 3. Derivatives of the BGS mapping are included in the Geology Report (Landmark) presented in the Pell Frischmann Land Contamination Desk Study (document 104878-PEF-ZZ-XX-RP-GG-600002), and further geological information has also been obtained from the BGS website. This mapping does not record any superficial deposits over the site and indicates the bedrock of the London Clay Formation present over the whole site area.

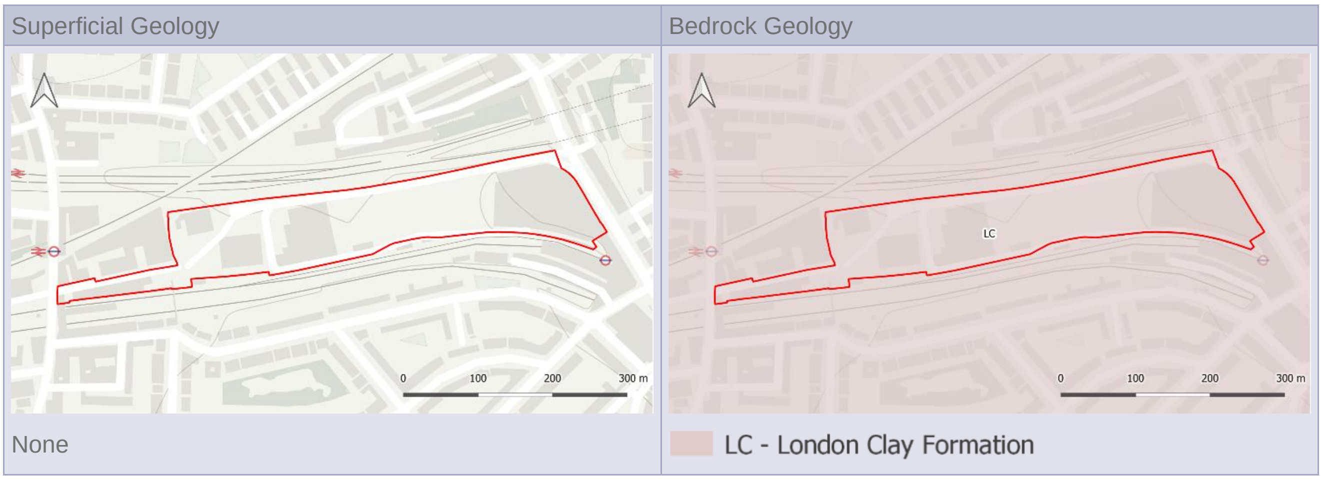



**Figure 3: Published Geology**

## 2.2 RSK Ground Investigation

RSK carried out a site-specific ground investigation (refer to RSK report 1921993 R01(02), December 2021) in accordance with Pell Frischmann's specification (document reference: 104878-PEF-XX-XX-SP-C-200004) between 14th September and 28th September 2021. The investigation included the following:

- 4 No. cable percussion boreholes; 5 No. were originally scheduled but 1 No. was unable to be advanced.
- 6 No. dynamic sampling boreholes to a maximum depth of 6.45m bgl.
- 2 No. mechanically excavated trial pits to complete BRE365 soakaway testing; 3 No. were originally scheduled but 1 No. was unable to be excavated.
- Geotechnical laboratory testing.
- Geo-environmental laboratory testing.

The assessment and interpretation of geoenvironmental testing is presented in the Pell Frischmann quantitative land contamination risk assessment report (document reference 104878-PEF-ZZ-XX-RP-GG-600003).

Details of the exploratory hole locations are summarised below and shown on the investigation location plan presented in Figure 4.

**Table 1: RSK 2021 Summary of Exploratory Hole Schedule.**

| Hole ID | Type | Final Depth (m) |
|---|---|---|
| BH02 | BH | 60 |
| BH03 | BH | 35 |
| BH04 | BH | 35 |
| BH05 | BH | 35 |

| | | |
|---|---|---|
| WS01a | WS | 4.45 |
| WS02 | WS | 6.45 |
| WS03 | WS | 4.45 |
| WS04 | WS | 3.45 |
| WS05 | WS | 3.45 |
| WS06 | WS | 3.5 |
| TP02 | TP | 3.75 |
| TP03 | TP | 3.9 |
| BH = cable percussion borehole, WS = window sample, TP = trial pit | | |


**Figure 4: RSK 2021 Geotechnical Investigation Locations**

# 3 Strata Encountered

Table 2 summarises the overall vertical distribution of the strata encountered by the exploratory holes. Further details of the encountered materials are provided in the report sections below.

**Table 2: Ground Conditions Summary**

| Location | Made Ground | Made Ground – Reworked London Clay | | London Clay Formation | |
|---|---|---|---|---|---|
| | Base (m bgl) | Base (m bgl) | *Thickness (m)* | Base (m bgl) | *Thickness (m)* |
| BH02 | 1.90 | 2.90 | *1.00* | >60.00 | *>57.10* |
| BH03 | 1.50 | 2.60 | *1.10* | >35.00 | *>32.40* |
| BH04 | 0.50 | 1.60 | *1.10* | >35.00 | *>33.40* |
| BH05 | 1.00 | - | - | >35.00 | *>34.00* |
| WS01A | 1.15 | 2.10 | *0.95* | >4.45 | *>2.35* |
| WS02 | 1.90 | 2.40 | *0.50* | >6.45 | *>4.05* |
| WS03 | 1.70 | - | - | >4.45 | *>2.75* |
| WS04 | 0.70 | - | - | >3.45 | *>2.75* |
| WS05 | 0.45 | 0.90 | *0.45* | >3.45 | *>2.55* |
| WS06 | 1.60 | 2.00 | *0.40* | >3.50 | *>1.50* |
| TP02 | 1.60 | - | - | >3.75 | *>2.15* |
| TP03 | 2.95 | - | - | >3.90 | *>0.95* |

## 3.1 Made Ground

Made Ground was encountered directly under a surface cover of hardstanding (macadam or concrete slab) within all exploratory locations. The composition was typically described as silty sandy GRAVEL or gravelly SAND. Made Ground was encountered to greater thicknesses within the central portion of the carpark, becoming clayey from a depth of approximately 1.0m bgl with this deeper material described as reworked London Clay, typically comprising silty gravely CLAY with frequent black relict rootlets, the gravel typically consisted of rounded flints, but occasionally included anthropogenic materials including brick and concrete fragments. Figure 5 shows the range of particle gradings recorded for the Made Ground encountered at the site.

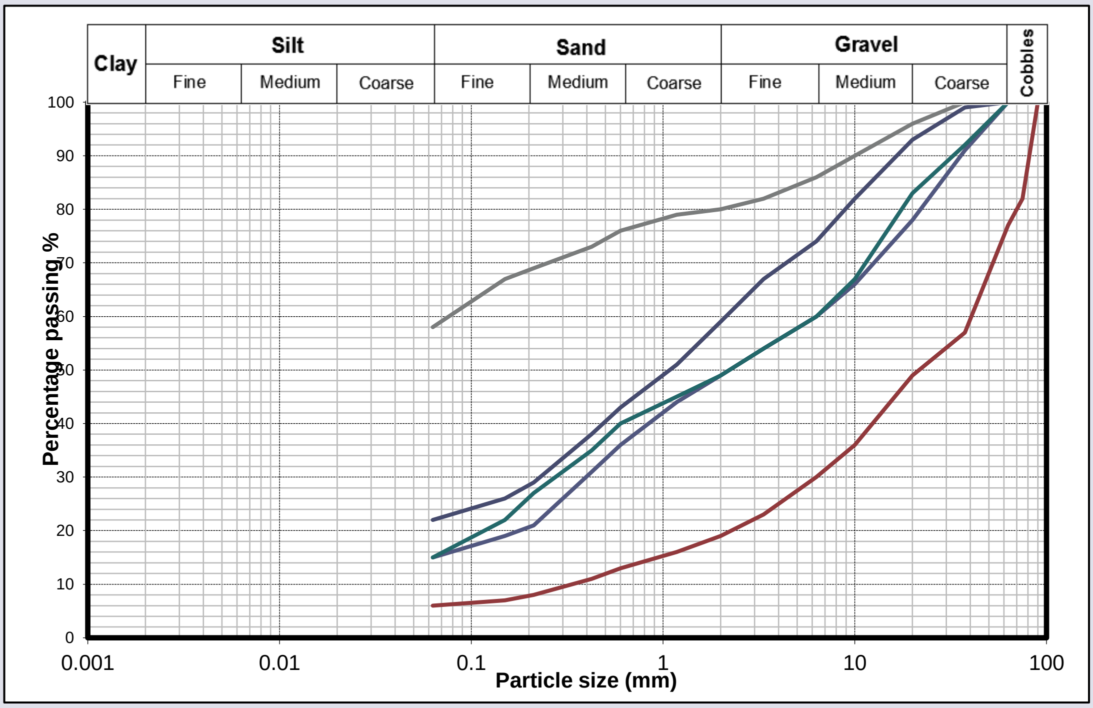



**Figure 5: Particle Size Distribution for Made Ground Samples**

Two California Bearing Ratio plate tests were carried out in TP02 and TP03 at approximately 0.5m bgl and respectively obtained the results of 13 and 9.4%. The test results are presented in appendix C.

## 3.2 London Clay Formation

London Clay Formation was encountered within all exploratory locations underlaying the Made Ground as reworked/weathered London Clay for the first 1-2m, and typically comprised firm to stiff brown clay becoming blue grey silty clay at depth with numerus selenite crystals or thin weak layers of Claystone noted at shallower depths. From a depth of 10mbgl the London Clay becomes a stiff to very stiff fissured dark grey CLAY with localised shell fragments.

### 3.2.1 Undrained Strength

77 No. SPT tests were carried out with "N" values ranging from 6 to 50+ with a mean of 46. These results can be correlated to an equivalent undrained shear strength using the relationship of Stroud and Butler (1975) based on a representative Plasticity Index (PI) for the London Clay. Atterberg Limits tests have been undertaken on 33 samples, the average PI of the clay is 45%. Based on the PI obtained, the following relationship between undrained strength and depth is as given below:

*Undrained shear strength, $s_u = 4.5 * SPT$ (kPa)*

However, the interpretation provided by F.White *et al* (1974) which is specifically tailored to the interpretation of London Clay parameters from SPT test results. This interpretation would provide the following undrained shear strength:

***Undrained shear strength, $s_u = 5.5 * SPT$ (kPa)***

31 undrained shear strength triaxial compression tests were undertaken on shallow samples of cohesive material.

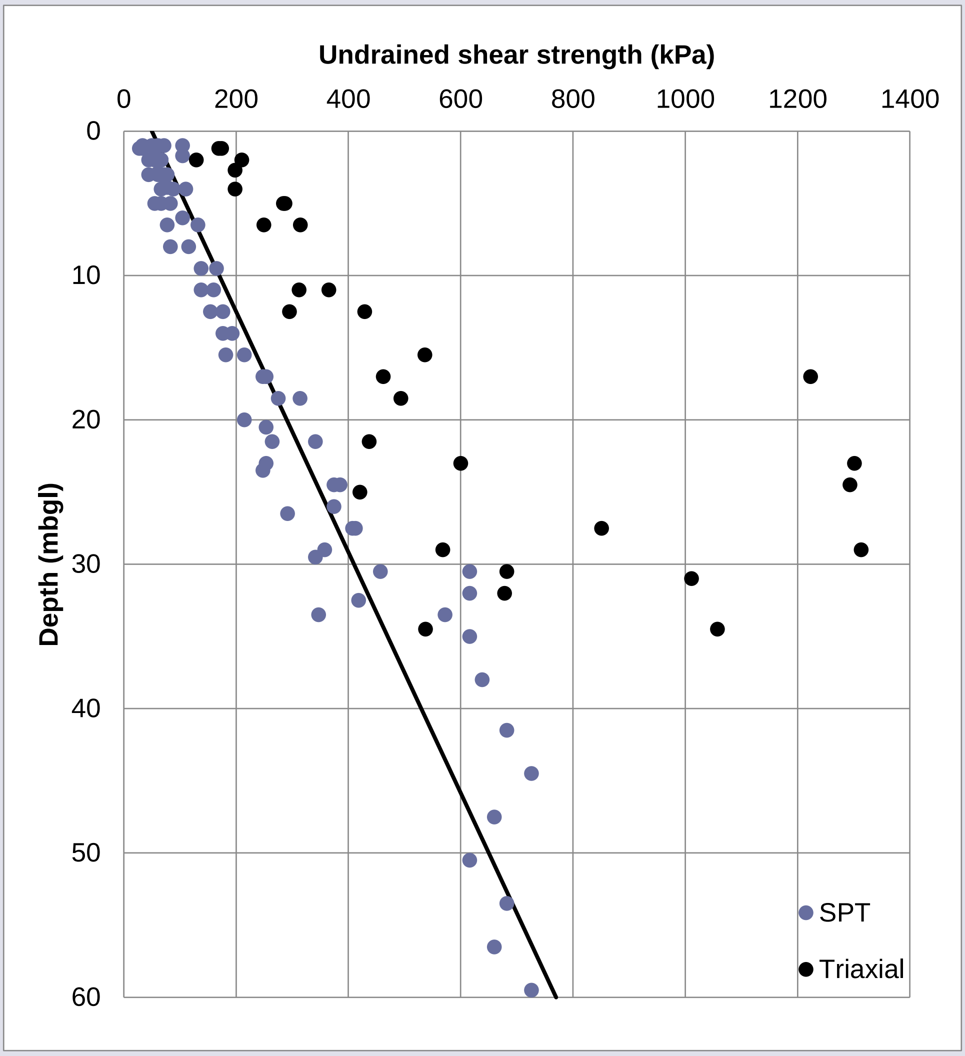



**Figure 6: London Clay Undrained Shear Strength Results**

When compared to the undrained shear strength predicted by the SPT results, the triaxial test results returned higher values which is conventionally attributed to the size effect of the triaxial specimens and the characteristic undrained strength has been based on the SPT data shown in Figure 6. The design value for the London clay is taken as follows:

***Undrained shear strength = 50 + 12 z kPa***

### 3.2.2 Drained Strength Parameters

Based on experience and reported values in the literature appropriate drained strength parameters for the London Clay are taken as follows.

Effective cohesion c' = 5 kPa

Drained friction angle $\varphi_d = 25^\circ$

### 3.2.3 Stiffness Parameters

One dimensional consolidation tests were undertaken on London Clay but due to the small number of tests, the parameters derived from the SPT testing will be considered to estimate the soil stiffness instead.

#### 3.2.3.1 Undrained Vertical Stiffness

The vertical stiffness of the London Clay can be derived from the undrained shear strength using the relationship described by Tomlinson (1963):

$$\frac{E_u}{s_u} = 500$$

Where:

- $E_u$ is the undrained modulus
- $s_u$ is undrained shear strength

Using this equation, the data obtained from the SPT tests interpreted in section 3.2.1 can be correlated to an equivalent stiffness.

$$\boldsymbol{E_u = 25 + 6\,z\,MPa}$$

#### 3.2.3.2 Drained Vertical Stiffness

The drained stiffness (E') is determined from the undrained values assuming a relationship

E' = 0.8 Eu

Hence:

**E' = 20 + 4.8 z**

#### 3.2.3.3 Undrained Lateral Stiffness

In a similar manner to the vertical stiffness, the lateral stiffness can be derived from the undrained shear strength with the following relationship:

$$\frac{E_u}{s_u} = 1000$$

Using this equation, the data obtained from the SPT tests interpreted in section 3.2.1 can be correlated to an equivalent stiffness.

$$\boldsymbol{E_u = 50 + 12\,z\,MPa}$$

#### 3.2.3.4 Drained Lateral Stiffness

The drained stiffness (E') is determined from the undrained values assuming a relationship

E' = 0.8 Eu

Hence:

**E' = 40 + 9.6 z**

## 3.3 Summary of Design Parameters

The characteristic Geotechnical Design Parameters for the strata relevant to the site are summarised in the following table.

| Deposit/Stratum | $\gamma_{SAT}$ | $\phi'_{peak}$ | $\phi'_{crit}$ | $c'_{peak}$ | $c'_{crit}$ | $S_u$ | Vertical | | Lateral | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | $E_u$ | E' | $E_u$ | E' |
| | (kN/m$^3$) | (°) | (°) | (kPa) | (kPa) | (kPa) | (MPa) | (MPa) | (MPa) | (MPa) |
| Made Ground (cohesionless) | 18 | - | 30 | 0 | 0 | - | - | - | - | - |
| Made Ground (cohesive) | 18 | - | 22 | 0 | 0 | 25 | - | - | - | - |
| London Clay | 20 | 23 | 22 | 5 | 0 | 50 + 12 z | 25 + 6 z | 20 + 4.8 z | 50 + 12 z | 40 + 9.6 z |

## 3.4 Groundwater Conditions

The RSK 2021 ground investigation includes two rounds of groundwater monitoring of installations in five of the investigation locations. The groundwater installation details and monitoring results are summarised in Table 3.

**Table 3: Groundwater Observations During RSK Monitoring**

| Hole ID | Response zone depth (m) & stratum | Ground elevation (m AOD) | Depth to water – visit 1 (mb TOC) | Depth to water – visit 2 (mb TOC) | Depth to water – visit 3 (mb TOC) | Depth to water – visit 4 (mb TOC) | Ground water elevation range (m AOD) |
|---|---|---|---|---|---|---|---|
| BH02 | 2.0m MG & RE LCF | 49.37 | 1.26 | 1.40 | 1.42 | 1.38 | 47.95 to 48.11 |
| BH03 | 1.50m MG | 49.41 | Dry | Dry | Dry | Dry | No GW |
| WS02 | 2.35m MG | 49.35 | Dry | Dry | Dry | Dry | No GW |
| WS03 | 2.70m MG & LCF | 49.04 | 1.35 | Dry | 1.57 | 1.81 | 47.23 to 47.69 |
| WS06 | 2.0m MG & RE LCF | 49.27 | 1.78 | 1.78 | 1.80 | 1.89 | 47.38 to 47.49 |
| MG = Made Ground, RE-LCF = Reworked London Clay Formation, LCF = London Clay Formation | | | | | | | |

These results show a groundwater level varying between 1.26m and 1.89m when present. This water is perched water which seeps through the made ground and rests at the top of the impermeable London Clay Formation.

## 3.5 Ground Aggressivity

### 3.5.1 Sulphate class

**Table 4: Sulphate Classification**

| Hole ID | BH02 | BH02 | BH03 | BH03 | BH03 | BH04 | BH04 | BH05 | BH05 | WS01A | WS03 | WS04 | WS05 | WS06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elevation | 1.10 | 10.00 | 0.00 | 2.50 | 10.50 | 0.00 | 10.50 | 0.00 | 2.70 | 0.75 | 0.60 | 0.35 | 1.00 | 0.40 |
| PH | 8.58 | 8.77 | 9.08 | 8.61 | 8.51 | 10.81 | 8.93 | 10.29 | 8.53 | 10.66 | 8.64 | 9.10 | 8.46 | 10.62 |
| Sulphate BRE (water sol 2:1) mg/l | 302 | 538 | 373 | 136 | 450 | 251 | 527 | 209 | 1070 | 343 | 221 | 182 | 257 | 379 |

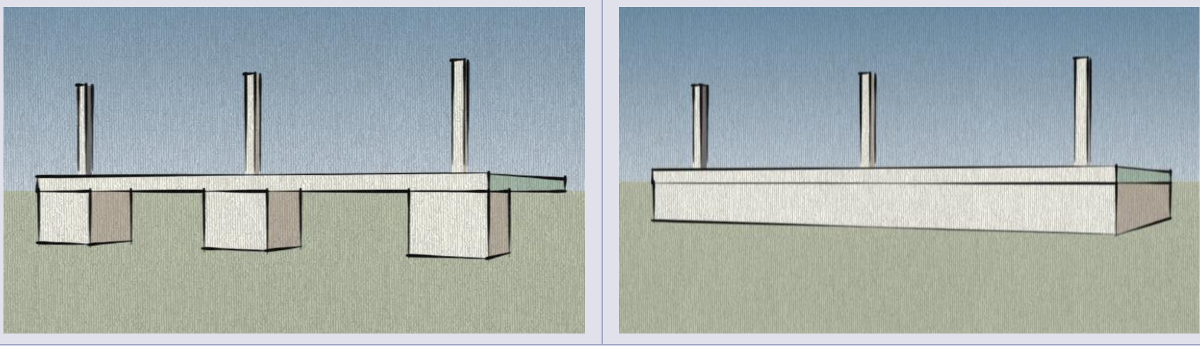
Based upon the BRE Special Digest 1 for concrete in aggressive ground, the sulphate class for the site is DS-2 (Sulphate content 500 – 1500 mg/l). Based on a PH greater than 3.5, the ACEC class for the site is AC-1s.

# 4 Foundation Options

Shallow and deep foundations have been considered for this development refer to Figure 7. Given the size of the structures proposed it is anticipated that pile foundations will be required, however shallow foundations may be suitable for smaller auxiliary structures as part of the proposed development.

The shallow foundations could comprise pad, strip or raft foundations, dependent on the column loadings and the differential settlement criteria. If the column loads are significant, and/or differential settlement criteria cannot be achieved with shallow foundations, then piled foundations would be utilsied.

**Figure 7: Pad / Strip Foundation (Left) and Raft Foundation (Right)**



The structures requiring piled foundations could either use a conventional pile group or a piled-raft depending on the structural configuration and loadings, and ground conditions for each specific case.

The pile load bearing capacity would be derived from both shaft friction and end bearing capacity derived from the London Clay Formation. Any contribution from Made Ground is ignored.

# 5 Geotechnical Risk Register

A geotechnical risk register (Table 6) has been produced for the scheme in order to identify potential hazards, the probability of the hazard occurring, impact and risk rating. In addition, an estimate of cost implications if the risk occurred prior to the implementation of risk control measures is provided (Table 5).

It is a simple qualitative risk assessment and should not be viewed as definitive. This Risk Assessment reflects the current level of understanding of the geotechnical and geo-environmental aspects of the scheme and will be subject to revision. The risk rating is defined by the following relationship:

**Table 5: Risk Assessment Criteria and Rating**

| Probability (P) | | Impact (I) | | Time | Cost |
|---|---|---|---|---|---|
| Very likely | 5 | Very likely | 5 | >10 weeks on completion | Very High |
| Probable | 4 | Probable | 4 | >1 week on completion | High |
| Possible | 3 | Possible | 3 | >4 weeks: <1 week on completion | Moderate |
| Unlikely | 2 | Unlikely | 2 | 1 to 4 weeks: none on completion | Low |
| Negligible | 1 | Negligible | 1 | <1 week to activity: none on completion | Minimal |

**Table 6: Geotechnical Risk Register**

| Hazard / Risk | Cause | Consequence(s) | Pre-Control | | | Mitigation | Post-Control | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | P | I | R | | P | I | R |
| Unforeseen ground conditions / General ground risk | -Unusual ground conditions. | -Increased geotechnical risk.<br>-Conservative design approach.<br>-Instability of excavations | 4 | 3 | 12 | -Appropriate ground investigation coverage with contamination risk assessment.<br>-Appropriate design parameters and design methods. | 2 | 3 | 6 |
| Unexploded Ordnance (UXO) | -Breaking ground in areas at risk of containing UXO | -Explosion resulting in anything from no injury or minor injury to multiple fatalities of construction workers and general public.<br>-Delay in construction.<br>-Significant cost of remediation.<br>-Damage to existing infrastructure. | 3 | 5 | 15 | Refer Detailed Unexploded Ordnance (UXO) Threat & Risk Assessment:<br>- UXO Safety & Awareness Briefings<br>-Operational UXO Emergency Response Plan<br>-Where trial pits, excavation and trenches are undertaken Non-intrusive UXO Survey and/or EOD Banksman Support into previously undisturbed ground.<br>-Where 'blind' intrusive works into previously undisturbed ground are proposed, an intrusive UXO survey (employing down-hole magnetometer or MagCone techniques) is recommended. | 1 | 5 | 5 |
| Pollution of Environment | -Unsuitable handling and storage of potentially contaminated sub-surface material(s) during construction<br>-Flooding of construction works with sediment loaded water. | -Potential cost of additional disposal<br>-Health risks<br>-Disturbing materials could mobilise contaminants in dust blow, leachate, etc.<br>-Migration to adjacent land<br>-Impact on adjacent ecology<br>-Legal liability for nuisance, etc. | 2 | 2 | 4 | -Removal of unsuitable material(s) and replacement with acceptable materials<br>-Suitable handling and storage methodologies including appropriate PPE<br>-Removal and disposal to off-site licensed landfill<br>-Ensure imported materials are suitable for use and have appropriate/adequate certification<br>-Use of appropriate construction method to minimise/reduce risk of developing pathway for contaminants | 1 | 2 | 4 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Damage to buried services | -Inaccurate / no service plans.<br>-Service location not undertaken prior to breaking ground during either construction or site investigation. | -Damage to utilities<br>-Health and safety risk to site personnel and general public<br>-Utilities temporarily unavailable<br>-Environmental impact<br>-Litigation | 3 | 5 | 15 | -Confirm accuracy of service plans on site by means of hand excavation and on-site detection to determine location and depth of services.<br>-Services plans to be sourced / produced prior to construction works commencing.<br>-Protect or divert services prior to construction works beginning on site.<br>-All work locations to be scanned for services prior to work commencing. | 2 | 5 | 10 |