# Geotechnical and Ground Movement Assessment

of

# 11 Fitzjohn's Avenue
# Camden
# NW3 5JY

for

## Fitzjohn's Avenue Hampstead Ltd

**LBH4424gma Ver 1.2**

**October 2016**

LBH WEMBLEY

Geotechnical & Environmental

Project No: LBH4424gma

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# Contents

# Foreword-Guidance Notes

GENERAL

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The report may present an opinion on the disposition, configuration and composition of soils, strata and any contamination within or near the site based upon information received from third parties. However, no liability can be accepted for any inaccuracies or omissions in that information.

DRAWINGS

Any plans or drawings provided in this report are not meant to be an accurate base plan, but are used to present the general relative locations of features on, and surrounding, the site.

# 1. Introduction

### 1.1 Report Structure

The report commences with the findings of a ground investigation, followed by a discussion of geotechnical design issues. There follows the results of ground movement analyses undertaken using the soil model derived from the results of the ground investigation and the construction proposals outlined in the Structural Engineers Report by Blue Engineering.

Finally, an assessment of the potential damage to the neighbouring structures is made.

# 2. Ground Conditions

### 2.1 Exploratory Work

In early September 2016 an intrusive site investigation was undertaken comprising two cable percussion boreholes constructed to a depth of 15m using a cable percussion rig. From these boreholes samples were taken for laboratory testing.

A series of structural trial pits were constructed in September 2016 to expose the party wall and existing building foundations and the details of these have been recorded by the structural engineers.

The borehole records, trial pit logs and test results are included in the Appendices to this report.

The intrusive investigation has confirmed that, beneath a limited thickness of made ground, the London Clay Formation is present.

### 2.2 Made Ground

Beneath the existing paving slabs, made ground was encountered to a maximum depth of around 1m depth in the boreholes and trial pits.

The made ground was found to consist of dirty brown clayey sandy soil with stones, brick and concrete fragments. A layer of domestic ashy material was found within BH2.

### 2.3 London Clay Formation

Directly beneath the made ground, soils representative of the London Clay Formation were encountered. These soils comprised firm to stiff, becoming stiff to very stiff, orange-brown and mottled grey silty clay. The upper zone of brown weathered clay was found to pass down into typical unweathered grey clay at approximately 6m depth.

The results of the plasticity index testing have confirmed the stratum to be of high shrinkability.

No claystones were encountered in the boreholes, but can be expected to be present within the strata.

### 2.4 Groundwater

No groundwater was encountered during the borehole investigation. Groundwater standpipes were installed in both boreholes to permit future monitoring for the presence of any groundwater.

It is noted that the site lies within an area that is at potential risk of surface water flooding and that some trapped perched water was apparently noted in the foundation trial pits.

# 3. Geotechnical Assessment

The proposed development includes the excavation of a basement to a depth of approximately 3.5m underneath the main house , and extending into the garden and into an area where an existing single storey link building is to be demolished.

It is envisaged to construct the new basement using conventional underpinning with the structural loads being supported by the new underpinning.

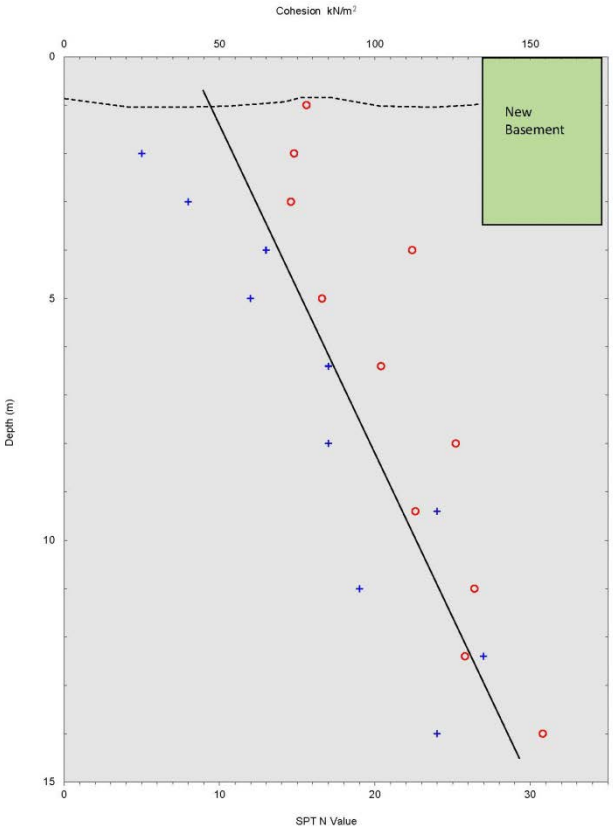
## 3.1 Selected Values for Geotechnical Design

*Made Ground*

A thickness of up to approximately 1m of made ground is expected. A nominal bulk unit weight of 17 kN/m$^3$ is ascribed to this material.

*London Clay*

The London Clay extends to some 80m depth. A bulk unit weight of this material has been taken to be 18 kN/m$^3$. The plot of undrained cohesion versus depth shown here suggests a design average undrained cohesion of 45 kN/m$^2$ at the surface of the Clay (approximately +63.5 mOD) increasing by approximately 7kN/m$^2$ per m depth. (NB. Red Circles denote Triaxial Compression Test results and blue crosses denote in-situ Standard Penetration Test results)




*Groundwater*

The London Clay is assumed to be saturated, with an assumed piezometric surface at 1m depth.

## 3.2 Basement Construction

It is anticipated that the basement construction will by-pass the near-surface soils and extend down into the London Clay Formation.

A key factor in the design of the new basement construction will be the need to preserve the stability of the adjacent buildings and highway at all times, both during excavation and construction and in the permanent situation.

Due to the access restrictions at the site, it is envisaged that the new basement will be supported in both the temporary and permanent situations by underpinning beneath the existing property, designed to apply a net allowable bearing pressure of 150kN/m$^2$.

### 3.3 Basement Waterproofing

Groundwater is not present within the soils at this site. However, there is the potential for surface water to collect around the basement structure in the long term. Hence, the basement should be fully waterproofed and it will be necessary for the basement to be designed to withstand hydrostatic pressures in accordance with the guidance provided in BS8102:2009, Code of Practice for the Protection of Below-Ground Structures against Water from the Ground. A ground water table at 1m depth should be assumed for the purposes of hydrostatic design.

### 3.4 Basement Floor Slab

Although the analysis set out later in this report predicts potential post-construction heave movements of up to 25mm, it is noted that the present engineering design is for ground bearing flooring. In this case care will need to be taken to ensure that the basement floor is indeed capable of successfully re-distributing the heave forces without cracking and of accommodating an overall potential post construction upwards movement of some 10mm.

In the area of proposed tension piles at the rear of the basement, it should be noted that if the floor is to be ground bearing here also these piles will be subject to full heave forces rather than hydrostatic uplift only.

### 3.5 Foundation Concrete

The results of chemical analyses carried out on selected samples of the soils encountered indicate soluble sulphate concentrations falling within Class DS-2 as defined by BRE Special Digest 1 (2005). The recommendations of that guidance for Class DS-2 sulphate conditions should therefore be followed, assuming an Aggressive Chemical Environment for Concrete (ACEC) site classification of AC-1s for static groundwater.

### 3.6 Hydrological and Hydrogeological Effects

#### 3.6.1 Impact on Groundwater Flow

Given the absence of groundwater, the proposed development is not expected to have any significant impounding effect upon groundwater.

#### 3.6.2 Impact of Infiltration

The site is currently partially hard surfaced, with some soft landscaping at the front, side and rear gardens. The proposed basement will lead to a slight reduction in soft landscaping, particularly at the side of the property. It is therefore envisaged that there will be some negative effect upon infiltration and a slight increase in the amount of rainfall or run-off to be collected and discharged.

#### 3.6.3 Impact on Surface Water Flooding and Surface Water Flow

Given the impermeability of the soils , the new development is not expected to have any substantial effect upon the risk of surface water flooding or surface water flow other than a slight loss of potential flood water storage in the present garden area that is to be developed.

# 4. Ground Movement Assessment

## 4.1 Ground Model

Excavation of the basement will result in unloading of the clay leading to theoretical heave movement of the underlying soil in both the short and long term. An analysis has been carried for a modelled situation, based on a soil model devised from both published information on the London Clay and the results of the ground investigation. The soil layers of this model are detailed in the table below.

| Analysis Layer: | Upper Boundary (m OD) | Thickness (m) | Average $C_u$ (kN/m$^2$) | Soil Stiffness (kN/m$^2$) | |
|---|---|---|---|---|---|
| | | | | $E_u$ | E' |
| London Clay | +61.0 | 2.00 | 65 | 29250 | 16250 |
| London Clay | +59.0 | 2.00 | 80 | 36000 | 20000 |
| London Clay | +57.0 | 3.00 | 90 | 40500 | 22500 |
| London Clay | +54.0 | 4.00 | 115 | 51750 | 28750 |
| London Clay | +50.0 | 5.00 | 140 | 63000 | 35000 |
| London Clay | +45.0 | 5.00 | 175 | 78750 | 43750 |
| London Clay | +40.0 | 5.00 | 210 | 94500 | 52500 |
| London Clay | +35.0 | 5.00 | 245 | 110250 | 61250 |
| Assumed Rigid | +30.0 | | | | |

The Undrained Modulus of Elasticity (Eu) has been based upon an empirical relationship of Eu = 450 x Cu, and the Drained Modulus of Elasticity (E') has been based upon an empirical relationship of 250 x Cu.

Poisson's Ratios of 0.5 and 0.1 have been used for short term (undrained) and long term (drained) conditions respectively.

## 4.2 Method of Analysis

The analysis, undertaken using the SAPPER programme, uses classic modified Boussinesq elasticity theory, assuming uniform (fully flexible) loading/unloading of rectangular areas applied to a semi-infinite elastic half-space, using the above parameters for stratified homogeneity and with the introduction of an assumed rigid boundary at +30mOD.

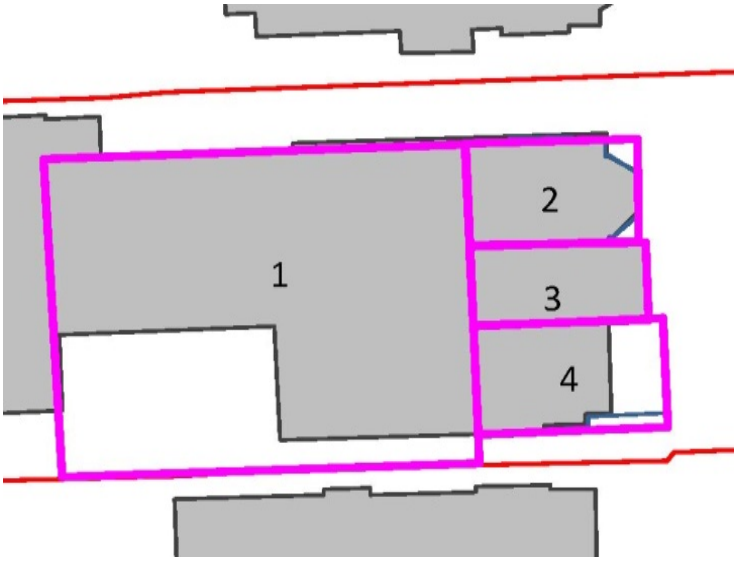
The analysis calculates the theoretical Boussinesq elastic stress decrease due to the applied net unloadings (over the given unloaded areas) at the mid-level of each of the 8 No. soil layers defined above.

Short-term and long-term heave movements are then calculated at each calculation point for each stratum, using the given values of Stiffness Moduli and Poisson's Ratio over the whole area of the site on a 1m by 1m grid.

### 4.1 Neighbouring Structures

The neighbouring structure to the south (No.9) already has recently had a basement constructed at a similar level to that which is proposed and hence while there may be some slight uplift experienced as a result of the new basement this property should not be unduly affected by the proposed excavation.

The neighbouring property to the north (No.13) is some distance away and, while it should not suffer any direct loss of support it may again be potentially affected by some mild long term uplift movements due to the soil unloading.




**Loaded Areas**

### 4.2 Loading / Unloading

Due to the irregular shape of the proposed excavation, a number of rectangular load areas have been modelled.

When considering the ground movements associated with the proposed development, the maximum excavation depth is envisaged to be 3.5m, and is envisaged to result in unloading of approximately -62kN/m2.

| Areas | X1 | Y1 | X2 | Y2 | Loading ($kN/m^2$) |
|---|---|---|---|---|---|
| **1** | 34 | 14 | 52 | 29 | -62 |
| **2** | 52 | 24 | 59 | 29 | -62 |
| **3** | 52 | 20.5 | 59 | 24.5 | -62 |
| **4** | 52 | 15 | 60.5 | 20.5 | -62 |

**Loaded Areas Co-ordinates and Loading Values**

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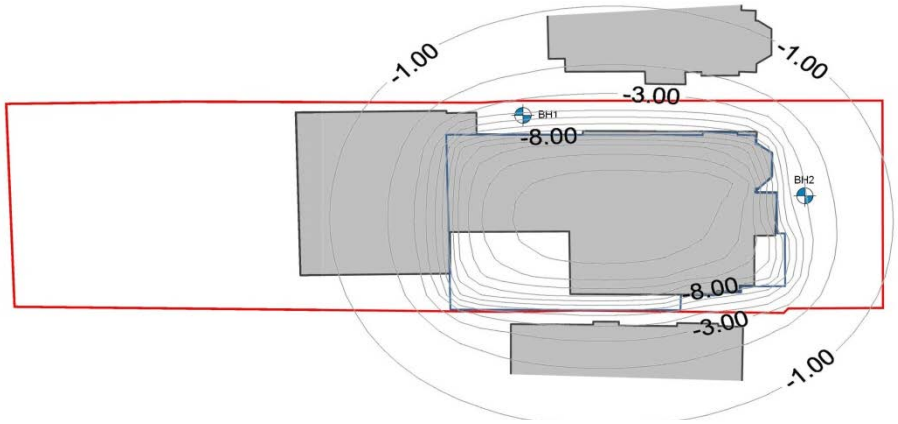
### 4.2.1 Short Term Heave Movements due to Excavation

The potential effect of the planned basement excavations has been considered applying a net unloading of approximately -62kN/m$^2$ soil unloading in the basement area.

The analysis suggests that, by the time basement excavation is complete, up to -12mm of heave is likely to have taken place within the centre of the basement area.




**Theoretical Short Term Heave Movements due to Excavation**

Outside the site, the analysis suggests that by the time basement construction is complete less than -5mm of heave beneath the neighbouring properties.

### 4.3 Long Term Movements

Within the area of the existing villa there will be no significant new loading to counteract the soil unloading due to excavation. Within parts of the rear basement extension there is an area that will be subjected to the loading of a new storey, but for the most part again there will be no meaningful new construction loading to resist the long term heave movements.

The analysis suggests that, following completion of the new construction, long term heave movement of up to 24 mm, could be expected to occur on a similar pattern to the above, with an average of about 10mm expected within the building area.

### 4.1 Impact on neighbouring structures

There will be some degree of short and long term global heave movements due to the weight of soil that is to be removed during the basement excavation. This movement could proceed for several decades and although it will be principally evident within the central area of the site it may be also expected to potentially affect the surrounding ground.

The neighbouring structure to the south (No.9) already has recently had a basement constructed at a similar level to that which is proposed and hence while there may be some slight uplift experienced as a result of the new basement this property should not be unduly affected by the proposed excavation.

The neighbouring property to the north (No.13) is some distance away and, while it should not suffer any direct loss of support it may again be potentially affected by some mild long term uplift movements due to the soil unloading.

The Camden Planning Guidance (CPG4) states that "*the design and construction methodology should aim to limit damage to the existing building on the site and to all adjoining buildings to Category 1 … and should never be more than Category 2"*.

The ground settlements behind a conventionally underpinned wall cannot be modelled. However, it can be stated that, provided horizontal movements can be adequately limited by good workmanship and temporary propping, the scale of damage due to soil (and wall) yielding will be minimised.

Broadly speaking, it is assessed that if overall lateral ground movements can be limited to less than 5mm, Burland scale Category 1 (Very Slight) damage to No. 13 can be expected for the situation at this site, whilst no movements are envisaged to affect No.9 due to the new basement being constructed at that property.

Additionally, it is concluded that there will be no significant risk to the integrity of the adjacent highways or to the services that have been identified as lying beneath these and the pavements.

# APPENDIX

**SITE PLAN SHOWING INVESTIGATION POSITIONS**

**BOREHOLE LOGS**

**TRIAXIAL TEST RESULTS**

**SPT/CU PLOTS**

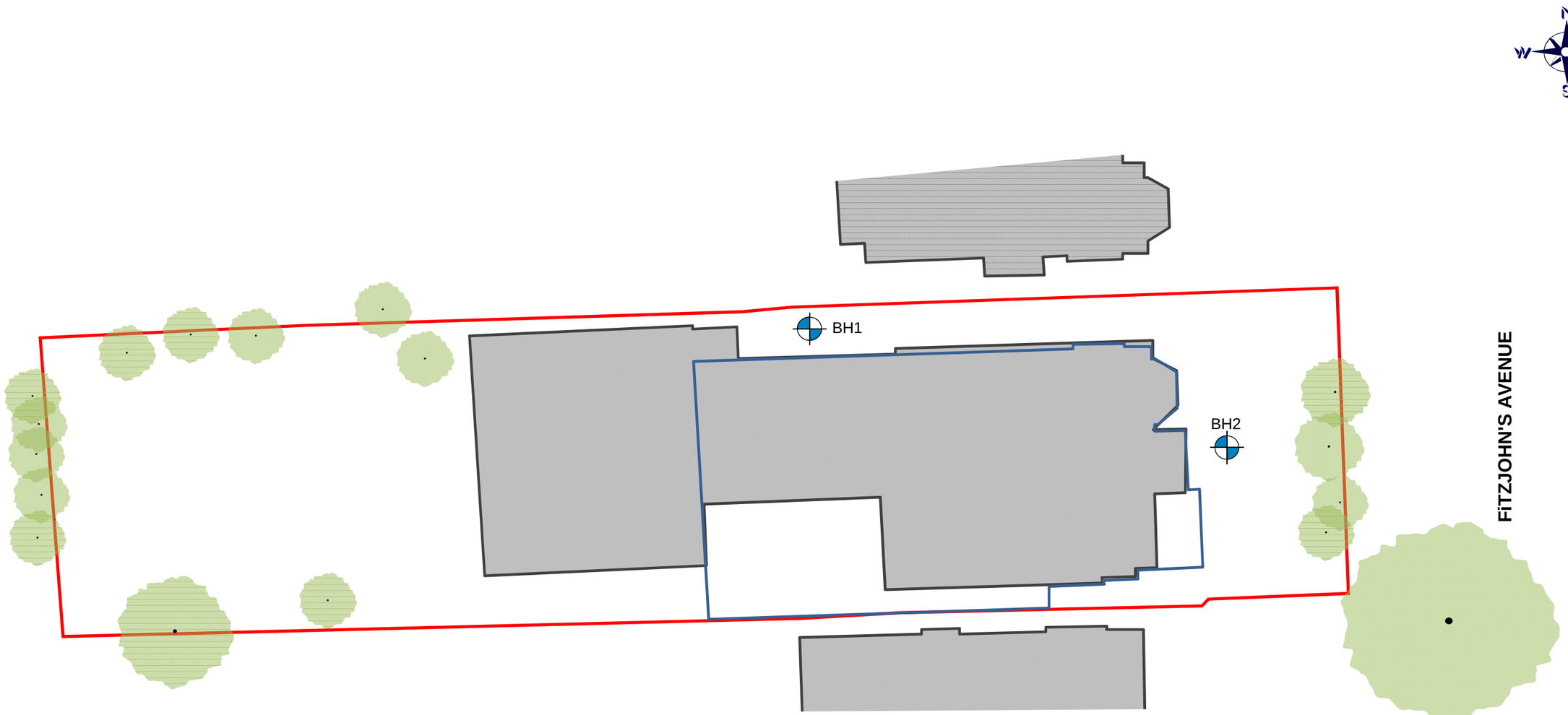
**SULPHATE ANALYSES**

**INDEX PROPERTIES**

PROJECT: 11 Fitzjohn's Avenue, Camden, NW3 5JY
CLIENT: Fitzjohns Avenue Hampstead Ltd

LBH4424

# SITE PLAN




Site Boundary

Existing Buildings

Proposed Basement

LBH Borehole (Sept 2016)

PROJECT: 11 Fitzjohn's Avenue, Camden, NW3 5JY LBH4424

CLIENT: Fitzjohns Avenue Hampstead Ltd

# BOREHOLE No 1

METHOD OF BORING: Cable percussion - 150 mm dia - cased to 1.50m

Period: 06/09/16

| GROUND WATER | | | | |
|---|---|---|---|---|
| Strike at | Inflow rate | Sealed at | Date | 06/09/2016 |
| | Non-encountered | | Time | |
| | | | BH Depth | 15.00 |
| | | | Casing Depth | 1.50 |
| | | | Water Level | DRY |

REMARKS: 1 Hours breaking out surfacing and digging inspection pit to check for presence of buried services.
50mm diameter standpipe installed to 8m depth with response zone between 1m and 8m depth, bentonite seal installed from ground level to 1m depth

Ground level = +64.5mOD

| Samples No | Samples Type | Depth m | SPT N | Legend | Depth m | Description |
|---|---|---|---|---|---|---|
| | | | | | 0.20 | MADE GROUND (paving slab over sand and concrete sub-base) |
| | | | | | 0.40 | MADE GROUND (brick fill) |
| 1 | D | 1.50 | | | | firm to stiff orange-brown silty CLAY with scattered black pebbles |
| 2 | U | 2.00-2.45 | | | 2.20 | |
| 3 | D | 2.50 | | | | stiff orange-brown / grey mottled silty CLAY with scattered traces of dead roots |
| | SPT | 3.30 | 8 | | | |
| 4 | D | 3.45 | | | | |
| 5 | U | 4.00-4.45 | | | 4.30 | |
| 6 | D | 4.50 | | | | Stiff becoming very stiff grey silty CLAY with abundant crystals |
| | SPT | 5.30 | 12 | | | |
| 7 | D | 5.45 | | | | |
| 8 | U | 6.50-6.95 | | | 6.80 | |
| 9 | D | 7.00 | | | | Very stiff grey silty CLAY |
| | SPT | 8.30 | 17 | | | |
| 10 | D | 8.45 | | | | |
| 11 | U | 9.50-9.95 | | | | |
| 12 | D | 10.00 | | | | |

U=Undisturbed
B= Bulk
D=Disturbed
W=Water

PROJECT: 11 Fitzjohn's Avenue, Camden, NW3 5JY LBH4424

CLIENT: Fitzjohns Avenue Hampstead Ltd

# BOREHOLE No 1

METHOD OF BORING: Cable percussion - 150 mm dia - cased to 1.50m

Period: 06/09/16

| GROUND WATER | | | | |
|---|---|---|---|---|
| Strike at | Inflow rate | Sealed at | Date | 06/09/2016 |
| Non-encountered | | | Time | |
| | | | BH Depth | 15.00 |
| | | | Casing Depth | 1.50 |
| | | | Water Level | DRY |

REMARKS: 1 Hours breaking out surfacing and digging inspection pit to check for presence of buried services.
50mm diameter standpipe installed to 8m depth with response zone between 1m and 8m depth, bentonite seal installed from ground level to 1m depth

| Samples No | Samples Type | Depth m | SPT N | Legend | Depth m | Description |
|---|---|---|---|---|---|---|
| | | | | | | Very stiff grey silty CLAY |
| | SPT | 11.30 | 19 | | | |
| 13 | D | 11.45 | | | | |
| 14 | U | 12.50-12.95 | | | | |
| 15 | D | 12.95 | | | | |
| | SPT | 14.30 | 24 | | | |
| 16 | D | 14.45 | | | | |
| | | | | | 15.00 | |

U=Undisturbed
B= Bulk
D=Disturbed
W=Water

PROJECT: 11 Fitzjohn's Avenue, Camden, NW3 5JY LBH4424

CLIENT: Fitzjohns Avenue Hampstead Ltd

# BOREHOLE No 2

METHOD OF BORING: Cable percussion - 150 mm dia - cased to 1.50m

Period: 07/09/16

| GROUND WATER | | | Date | 07/09/2016 |
|---|---|---|---|---|
| Strike at | Inflow rate | Sealed at | Time | |
| Non-encountered | | | BH Depth | 15.00 |
| | | | Casing Depth | 1.50 |
| | | | Water Level | DRY |

REMARKS: 1 Hours breaking out surfacing and digging inspection pit to check for presence of buried services.
50mm diameter standpipe installed to 8m depth with response zone between 1m and 8m depth, bentonite seal installed from ground level to 1m depth
2 Hours moving equipment and casing between positions due to limited access Ground level = +65.0mOD

| Samples No | Samples Type | Depth m | SPT N | Depth m | Description |
|---|---|---|---|---|---|
| | | | | 0.20 | MADE GROUND (paving slab over sand and concrete sub-base) |
| | | | | 0.35 | MADE GROUND (brick fill) |
| 1 | D | 0.90 | | 0.80 | MADE GROUND (firm dirty brown silty clay with roots and brick fragments) |
| 2 | U | 1.10-1.55 | | 1.10 | MADE GROUND (black ashy sand) |
| 3 | D | 1.55 | | 1.70 | Firm to stiff orange-brown silty CLAY with scattered black pebbles |
| | SPT | 2.30 | 10 | | Stiff orange-brown / grey mottled silty CLAY with scattered traces of dead roots |
| 4 | D | 2.45 | | | |
| 5 | U | 3.00-3.45 | | | |
| 6 | D | 3.45 | | | |
| | SPT | 4.30 | 13 | | |
| 7 | D | 4.45 | | | |
| 8 | U | 5.00-5.45 | | 5.30 | |
| 9 | D | 5.45 | | | Stiff becoming very stiff grey silty CLAY with abundant crystals |
| | SPT | 6.80 | 17 | | |
| 10 | D | 6.95 | | | |
| 11 | U | 8.00-8.45 | | 8.30 | |
| 12 | D | 8.45 | | | Very stiff grey silty CLAY |
| | SPT | 9.80 | 24 | | |
| 13 | D | 9.95 | | | |

U=Undisturbed
B= Bulk
D=Disturbed
W=Water

PROJECT: 11 Fitzjohn's Avenue, Camden, NW3 5JY LBH4424

CLIENT: Fitzjohns Avenue Hampstead Ltd

# BOREHOLE No 2

METHOD OF BORING: Cable percussion - 150 mm dia - cased to 1.50m

Period: 07/09/16

| GROUND WATER | | | | |
|---|---|---|---|---|
| Strike at | Inflow rate | Sealed at | Date | 07/09/2016 |
| Non-encountered | | | Time | |
| | | | BH Depth | 15.00 |
| | | | Casing Depth | 1.50 |
| | | | Water Level | DRY |

REMARKS: 1 Hours breaking out surfacing and digging inspection pit to check for presence of buried services.
50mm diameter standpipe installed to 8m depth with response zone between 1m and 8m depth, bentonite seal installed from ground level to 1m depth
2 Hours moving equipment and casing between positions due to limited access

| Samples No | Samples Type | Depth m | SPT N | Legend | Depth m | Description |
|---|---|---|---|---|---|---|
| | | | | | | Very stiff grey silty CLAY |
| 14 | U | 11.00-11.45 | | | | |
| 15 | D | 11.45 | | | | |
| | SPT | 12.80 | 27 | | | |
| 16 | D | 12.95 | | | | |
| 17 | U | 14.00-14.45 | | | | |
| 18 | D | 14.45 | | | | |
| | | | | | 15.00 | |

U=Undisturbed
B= Bulk
D=Disturbed
W=Water

PROJECT: 11 Fitzjohn's Avenue, Camden, NW3 5JY

CLIENT: Fitzjohns Avenue Hampstead Ltd

Project No LBH4424

# SPT RESULTS

| Borehole No | Depth at Start of Test (m) | Spoon or Sone | Blow for each successive 75mm penetration | | | | | | Water Level (m) | Is Hole Blowing? | N Value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BH1 | 3.00 | S | 1 | 1 | 2 | 2 | 2 | 2 | DRY | - | 8 |
| | 5.00 | S | 1 | 2 | 2 | 3 | 3 | 4 | DRY | - | 12 |
| | 8.00 | S | 2 | 3 | 4 | 4 | 4 | 5 | DRY | - | 17 |
| | 11.00 | S | 3 | 3 | 4 | 5 | 5 | 5 | DRY | - | 19 |
| | 14.00 | S | 3 | 4 | 5 | 6 | 6 | 7 | DRY | - | 24 |
| BH2 | 2.00 | S | 1 | 2 | 2 | 3 | 2 | 3 | DRY | - | 10 |
| | 4.00 | S | 2 | 2 | 3 | 3 | 3 | 4 | DRY | - | 13 |
| | 6.50 | S | 2 | 3 | 4 | 4 | 4 | 5 | DRY | - | 17 |
| | 9.50 | S | 3 | 4 | 6 | 5 | 6 | 7 | DRY | - | 24 |
| | 12.50 | S | 4 | 4 | 6 | 7 | 7 | 7 | DRY | - | 27 |

# Unconsolidated Undrained Triaxial Compression tests without measurement of pore pressure
## Summary of Results

**Tests carried out in accordance with BS1377:Part 7 : 1990 clause 8 or 9 as appropriate to test**

| Job No. | Project Name | Programme | |
|---|---|---|---|
| 21560 | 11 Fitzjohn's Avenue | Samples received | 08/09/2016 |
| | | Schedule received | 09/09/2016 |
| Project No. | Client | Project started | 09/09/2016 |
| LBH4424 | LBH Wembley | Testing Started | 21/09/2016 |

| Hole No. | Sample | | | | Soil Description | Test Type | Density | | w | Length | Diameter | σ3 | At failure | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ref | Top | Base | Type | | | bulk | dry | | | | | Axial strain | σ1 - σ3 | cu | Mode | |
| | | | | | | | Mg/m3 | | % | mm | mm | kPa | % | kPa | kPa | | |
| BH1 | - | 2.00 | - | U | Medium strength fissured brown mottled blue grey silty CLAY | UU | 1.98 | 1.54 | 29 | 198 | 102 | 40 | 10 | 147 | 74 | C | |
| BH1 | - | 4.00 | - | U | High strength fissured brown mottled blue grey silty CLAY with scattered traces of selenite | UU | 1.88 | 1.43 | 32 | 198 | 102 | 80 | 7.1 | 223 | 112 | B | |
| BH1 | - | 6.50 | - | U | High strength fissured brown mottled blue grey silty CLAY with scattered traces of selenite | UU | 2.00 | 1.56 | 28 | 198 | 102 | 130 | 4.0 | 204 | 102 | B | |
| BH1 | - | 9.50 | - | U | High strength fissured dark grey silty CLAY | UU | 2.05 | 1.63 | 26 | 198 | 102 | 190 | 4.0 | 226 | 113 | B | |
| BH1 | - | 12.50 | - | U | High strength fissured dark grey silty CLAY | UU | 2.01 | 1.57 | 28 | 198 | 102 | 250 | 6.6 | 258 | 129 | B | |
| BH2 | - | 1.10 | - | U | High strength slightly fissured brown, orange brown and reddish brown slightly sandy slightly gravelly silty CLAY (gravel is fmc and sub-angular to sub-rounded) | UU | 1.84 | 1.45 | 27 | 198 | 102 | 22 | 4.5 | 157 | 78 | B | |
| BH2 | - | 3.00 | - | U | Medium strength fissured brown mottled blue grey silty CLAY | UU | 1.98 | 1.53 | 29 | 198 | 102 | 60 | 12 | 147 | 73 | C | |
| BH2 | - | 5.00 | - | U | High strength fissured brown mottled blue grey silty CLAY with scattered traces of selenite | UU | 1.94 | 1.47 | 32 | 198 | 102 | 100 | 5.6 | 166 | 83 | B | |
| BH2 | - | 8.00 | - | U | High strength fissured dark grey silty CLAY with scattered traces of selenite | UU | 2.02 | 1.61 | 26 | 198 | 102 | 160 | 6.6 | 251 | 126 | B | |
| BH2 | - | 11.00 | - | U | High strength fissured dark grey silty CLAY | UU | 2.05 | 1.62 | 27 | 198 | 102 | 220 | 7.6 | 263 | 132 | B | |
| BH2 | - | 14.00 | - | U | Very high strength fissured dark grey silty CLAY | UU | 2.03 | 1.58 | 28 | 198 | 102 | 280 | 8.1 | 307 | 154 | B | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |

Legend
UU - single stage test (single and multiple specimens) σ3 Cell pressure Mode of failure ; B - Brittle
UUM - Multistage test on a single specimen σ1 - σ3 Maximum corrected deviator stress P - Plastic
suffix R - remoulded or recompacted cu Undrained shear strength, ½ (σ1 - σ3) C - Compound


**Test Report by K4 SOILS LABORATORY**
**Unit 8 Olds Close Olds Approach**
**Watford Herts WD18 9RU**
**Tel: 01923 711 288**
**Email: james@k4soils.com**


**Checked and Approved**
Initials: J.P
Date: 22/09/2016

2519 Approved Signatories: K.Phaure (Tech.Mgr) J.Phaure (Lab.Mgr) MSF-5-R7b

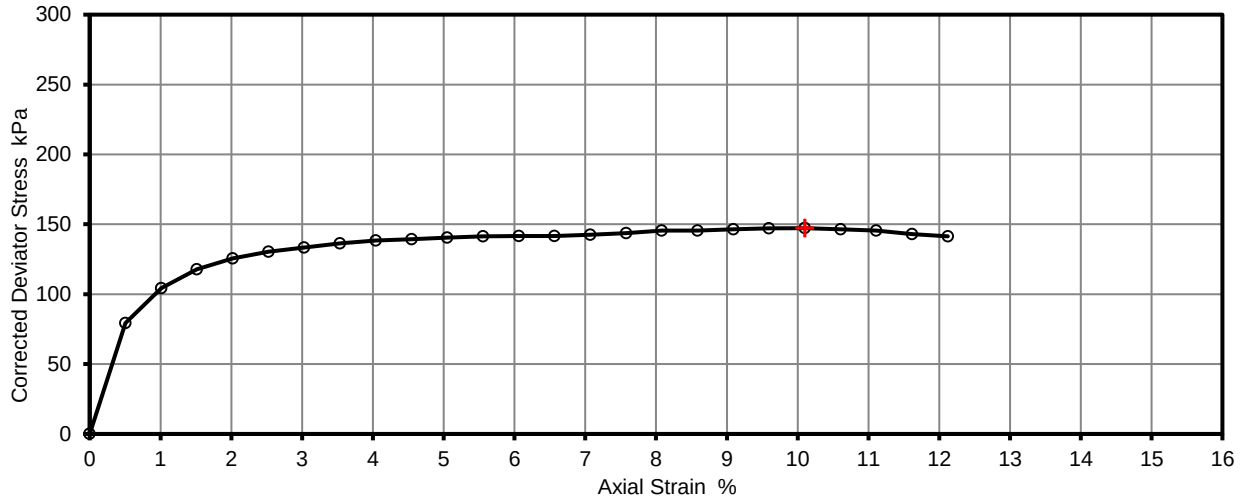
| | | | | | |
|---|---|---|---|---|---|
| | **Unconsolidated Undrained Triaxial Compression Test without measurement of pore pressure - single specimen** | | | Job Ref | 21560 |
| | | | | Borehole/Pit No. | BH1 |
| Site Name | 11 Fitzjohn's Avenue | | | Sample No. | - |
| Project No. | LBH4424 | Client | LBH Wembley | Depth | 2.00 m |
| Soil Description | Medium strength fissured brown mottled blue grey silty CLAY | | | Sample Type | U |
| | | | | Samples received | 08/09/2016 |
| | | | | Schedules received | 09/09/2016 |
| Test Method | BS1377 : Part 7 : 1990, clause 8, single specimen | | | Date of test | 21/09/2016 |

**Remarks**

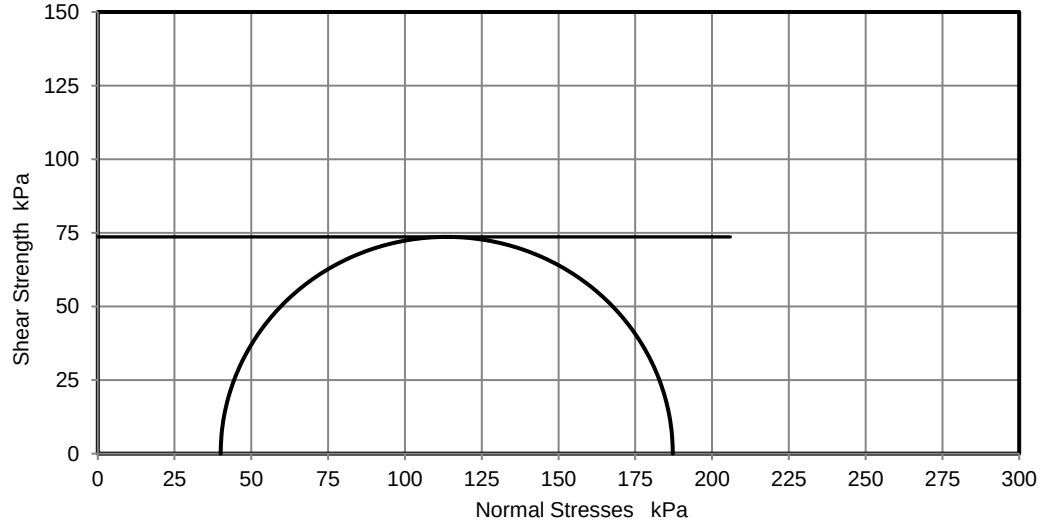
Position within sample

| | | |
|---|---|---|
| Test Number | 1 | |
| Length | 198.0 | mm |
| Diameter | 102.0 | mm |
| Bulk Density | 1.98 | Mg/m3 |
| Moisture Content | 29 | % |
| Dry Density | 1.54 | Mg/m3 |
| Rate of Strain | 2.0 | %/min |
| Cell Pressure | 40 | kPa |
| Axial Strain | 10.1 | % |
| Deviator Stress, ( σ1 - σ3 )f | 147 | kPa |
| Undrained Shear Strength, cu | 74 | kPa ½( σ1 - σ3 )f |
| Mode of Failure | Compound | |

**Deviator Stress v Axial Strain**




**Mohr Circles**




Deviator stress corrected for area change and membrane effects

Mohr circles and their interpretation is not covered by BS1377. This is provided for information only.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UKAS TESTING 2519

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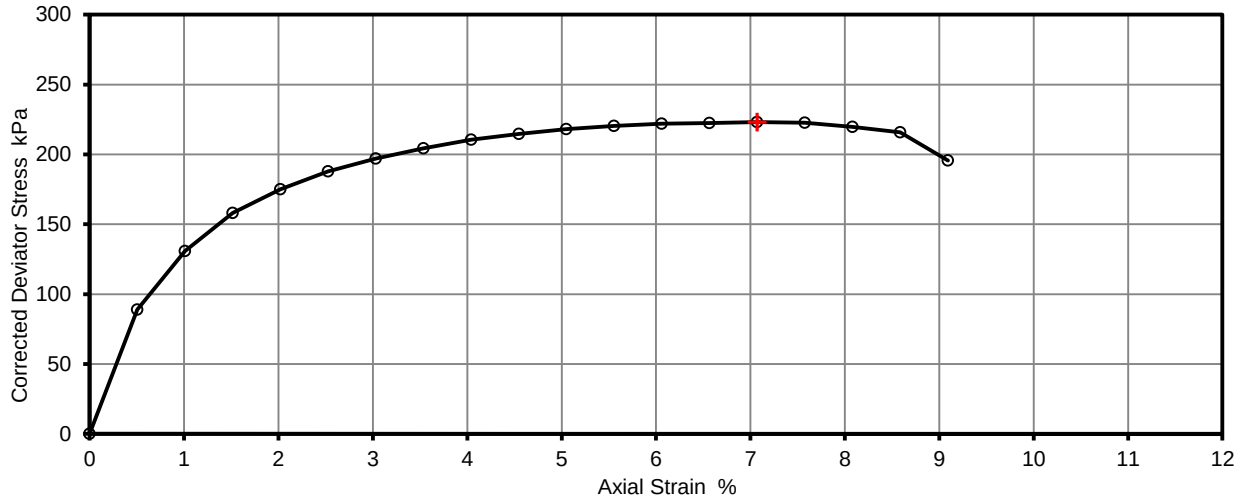
| | | | | | |
|---|---|---|---|---|---|
| | **Unconsolidated Undrained Triaxial Compression Test without measurement of pore pressure - single specimen** | | | Job Ref | 21560 |
| | | | | Borehole/Pit No. | BH1 |
| Site Name | 11 Fitzjohn's Avenue | | | Sample No. | - |
| Project No. | LBH4424 | Client | LBH Wembley | Depth | 4.00 m |
| Soil Description | High strength fissured brown mottled blue grey silty CLAY with scattered traces of selenite | | | Sample Type | U |
| | | | | Samples received | 08/09/2016 |
| | | | | Schedules received | 09/09/2016 |
| Test Method | BS1377 : Part 7 : 1990, clause 8, single specimen | | | Date of test | 21/09/2016 |

**Remarks**

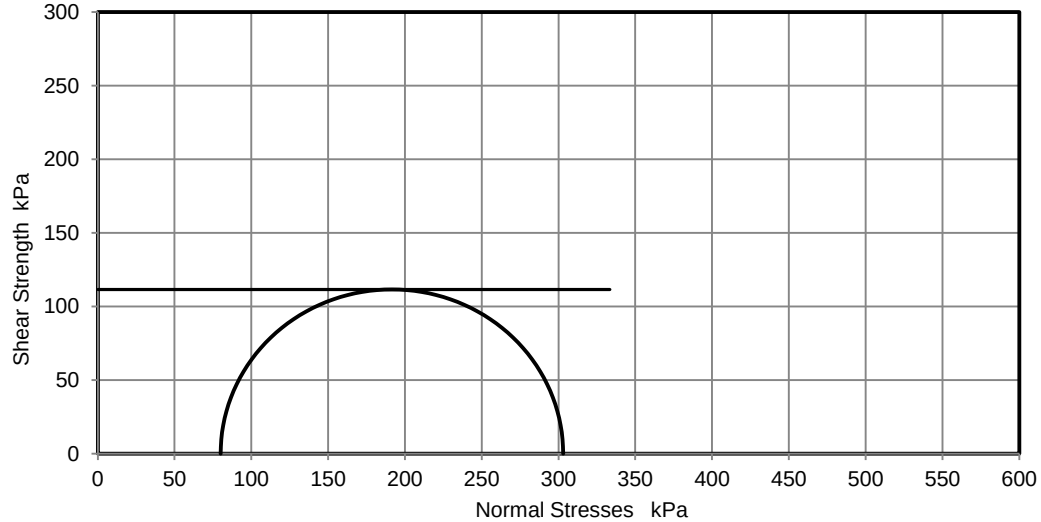
Position within sample

| | | |
|---|---|---|
| Test Number | 1 | |
| Length | 198.0 | mm |
| Diameter | 102.0 | mm |
| Bulk Density | 1.88 | Mg/m3 |
| Moisture Content | 32 | % |
| Dry Density | 1.43 | Mg/m3 |
| Rate of Strain | 2.0 | %/min |
| Cell Pressure | 80 | kPa |
| Axial Strain | 7.1 | % |
| Deviator Stress, ( σ1 - σ3 )f | 223 | kPa |
| Undrained Shear Strength, cu | 112 | kPa ½( σ1 - σ3 )f |
| Mode of Failure | Brittle | |

**Deviator Stress v Axial Strain**




**Mohr Circles**

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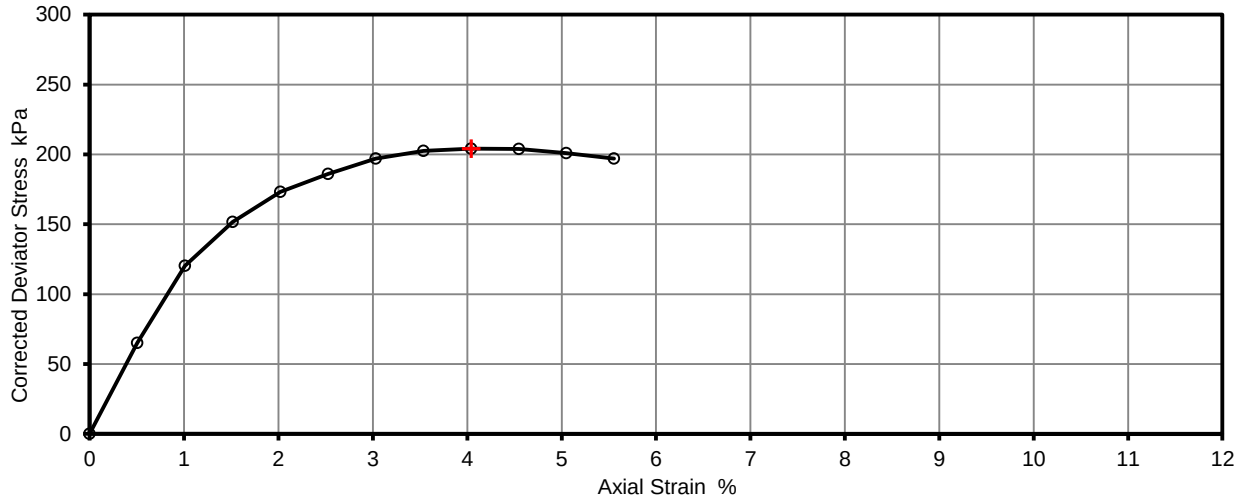
| | | | | | |
|---|---|---|---|---|---|
| | **Unconsolidated Undrained Triaxial Compression Test without measurement of pore pressure - single specimen** | | | Job Ref | 21560 |
| | | | | Borehole/Pit No. | BH1 |
| Site Name | 11 Fitzjohn's Avenue | | | Sample No. | - |
| Project No. | LBH4424 | Client | LBH Wembley | Depth | 6.50 m |
| Soil Description | High strength fissured brown mottled blue grey silty CLAY with scattered traces of selenite | | | Sample Type | U |
| | | | | Samples received | 08/09/2016 |
| | | | | Schedules received | 09/09/2016 |
| Test Method | BS1377 : Part 7 : 1990, clause 8, single specimen | | | Date of test | 20/09/2016 |

**Remarks**

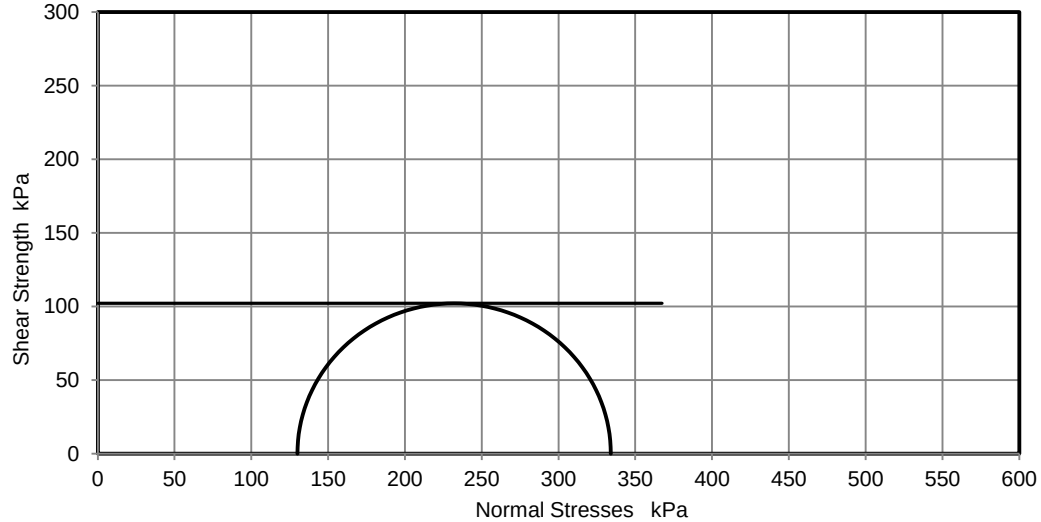
Position within sample

| | | |
|---|---|---|
| Test Number | 1 | |
| Length | 198.0 | mm |
| Diameter | 102.0 | mm |
| Bulk Density | 2.00 | Mg/m3 |
| Moisture Content | 28 | % |
| Dry Density | 1.56 | Mg/m3 |
| Rate of Strain | 2.0 | %/min |
| Cell Pressure | 130 | kPa |
| Axial Strain | 4.0 | % |
| Deviator Stress, ( σ1 - σ3 )f | 204 | kPa |
| Undrained Shear Strength, cu | 102 | kPa ½( σ1 - σ3 )f |
| Mode of Failure | Brittle | |

**Deviator Stress v Axial Strain**




**Mohr Circles**

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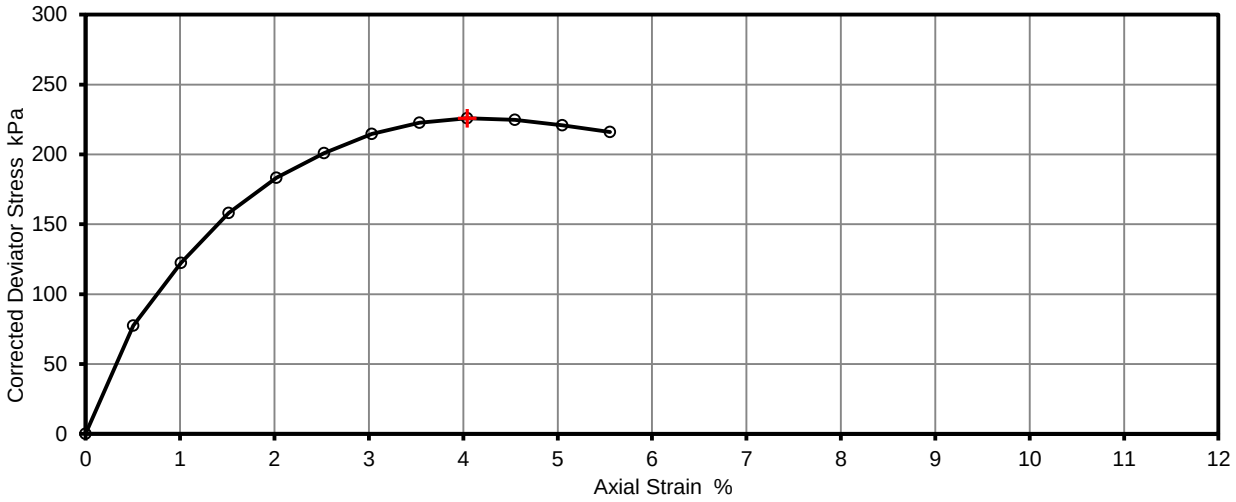
| | | | | | | |
|---|---|---|---|---|---|---|
| | **Unconsolidated Undrained Triaxial Compression Test without measurement of pore pressure - single specimen** | | | Job Ref | 21560 | |
| | | | | Borehole/Pit No. | BH1 | |
| Site Name | 11 Fitzjohn's Avenue | | | Sample No. | - | |
| Project No. | LBH4424 | Client | LBH Wembley | Depth | 9.50 | m |
| Soil Description | High strength fissured dark grey silty CLAY | | | Sample Type | U | |
| | | | | Samples received | 08/09/2016 | |
| | | | | Schedules received | 09/09/2016 | |
| Test Method | BS1377 : Part 7 : 1990, clause 8, single specimen | | | Date of test | 21/09/2016 | |

**Remarks**

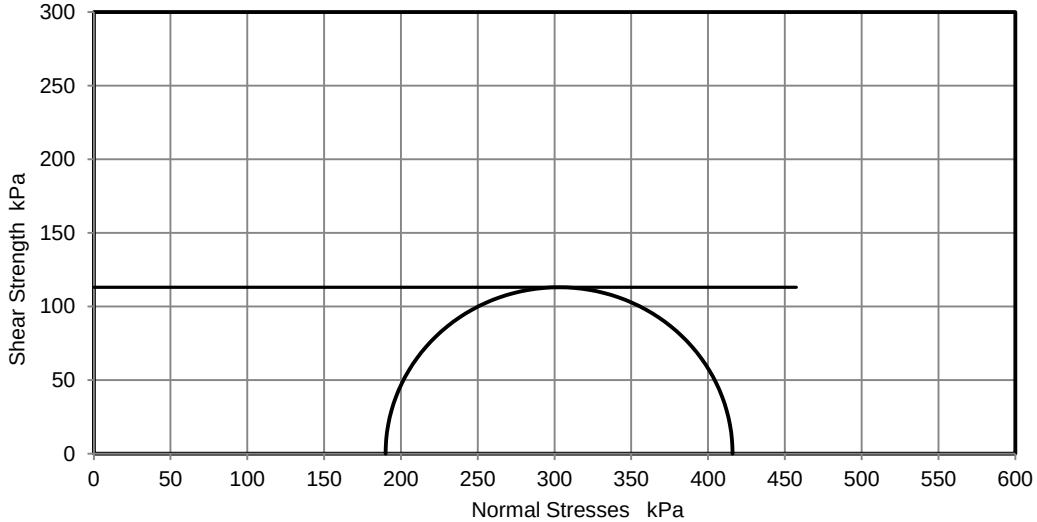
Position within sample

| | | |
|---|---|---|
| Test Number | 1 | |
| Length | 198.0 | mm |
| Diameter | 102.0 | mm |
| Bulk Density | 2.05 | Mg/m3 |
| Moisture Content | 26 | % |
| Dry Density | 1.63 | Mg/m3 |
| Rate of Strain | 2.0 | %/min |
| Cell Pressure | 190 | kPa |
| Axial Strain | 4.0 | % |
| Deviator Stress, ( σ1 - σ3 )f | 226 | kPa |
| Undrained Shear Strength, cu | 113 | kPa ½( σ1 - σ3 )f |
| Mode of Failure | Brittle | |

**Deviator Stress v Axial Strain**




**Mohr Circles**

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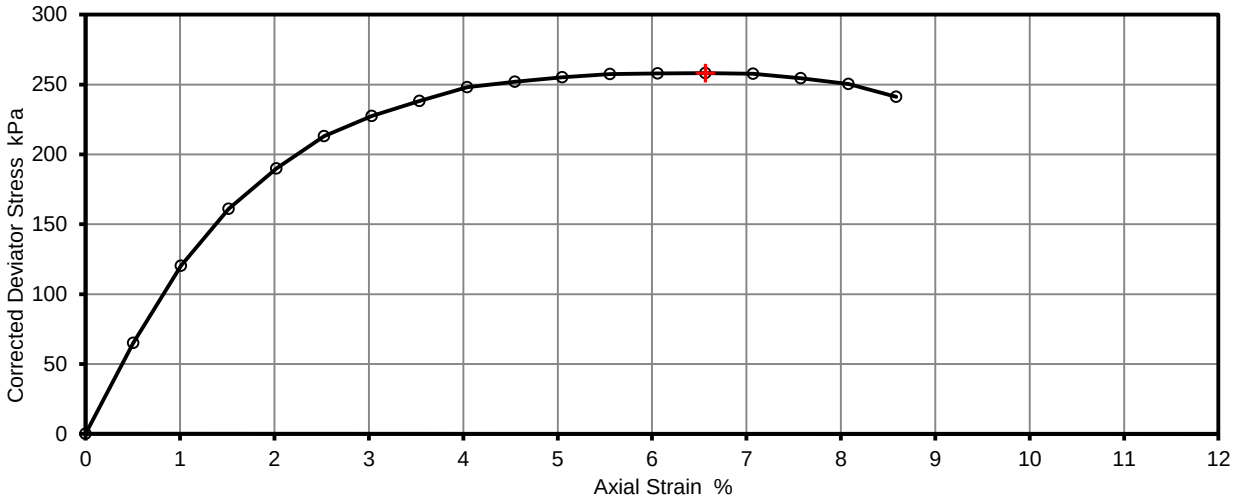
| | | | | | |
|---|---|---|---|---|---|
| | **Unconsolidated Undrained Triaxial Compression Test without measurement of pore pressure - single specimen** | | | Job Ref | 21560 |
| | | | | Borehole/Pit No. | BH1 |
| Site Name | 11 Fitzjohn's Avenue | | | Sample No. | - |
| Project No. | LBH4424 | Client | LBH Wembley | Depth | 12.50 m |
| Soil Description | High strength fissured dark grey silty CLAY | | | Sample Type | U |
| | | | | Samples received | 08/09/2016 |
| | | | | Schedules received | 09/09/2016 |
| Test Method | BS1377 : Part 7 : 1990, clause 8, single specimen | | | Date of test | 21/09/2016 |

**Remarks**

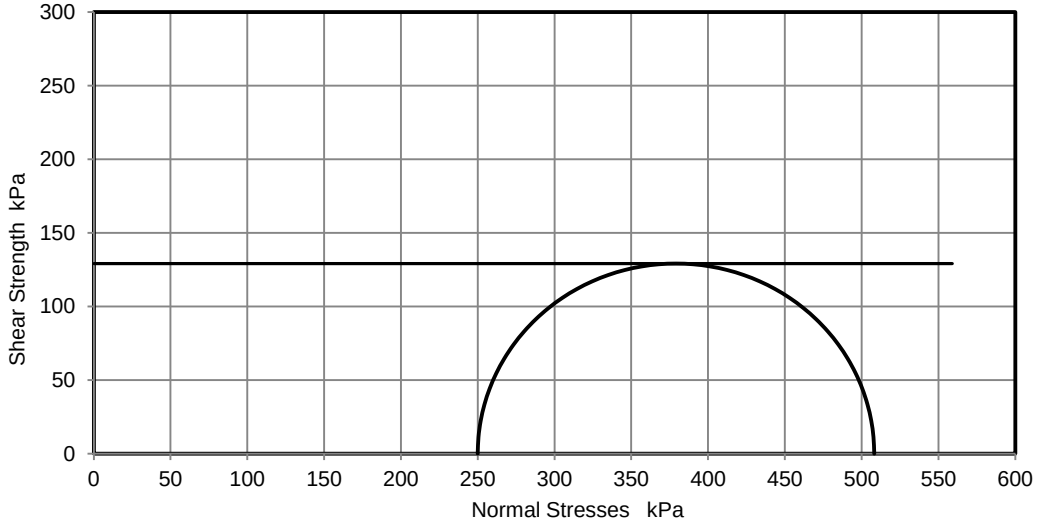
Position within sample

| | | |
|---|---|---|
| Test Number | 1 | |
| Length | 198.0 | mm |
| Diameter | 102.0 | mm |
| Bulk Density | 2.01 | Mg/m3 |
| Moisture Content | 28 | % |
| Dry Density | 1.57 | Mg/m3 |
| Rate of Strain | 2.0 | %/min |
| Cell Pressure | 250 | kPa |
| Axial Strain | 6.6 | % |
| Deviator Stress, ( σ1 - σ3 )f | 258 | kPa |
| Undrained Shear Strength, cu | 129 | kPa ½( σ1 - σ3 )f |
| Mode of Failure | Brittle | |

**Deviator Stress v Axial Strain**




**Mohr Circles**

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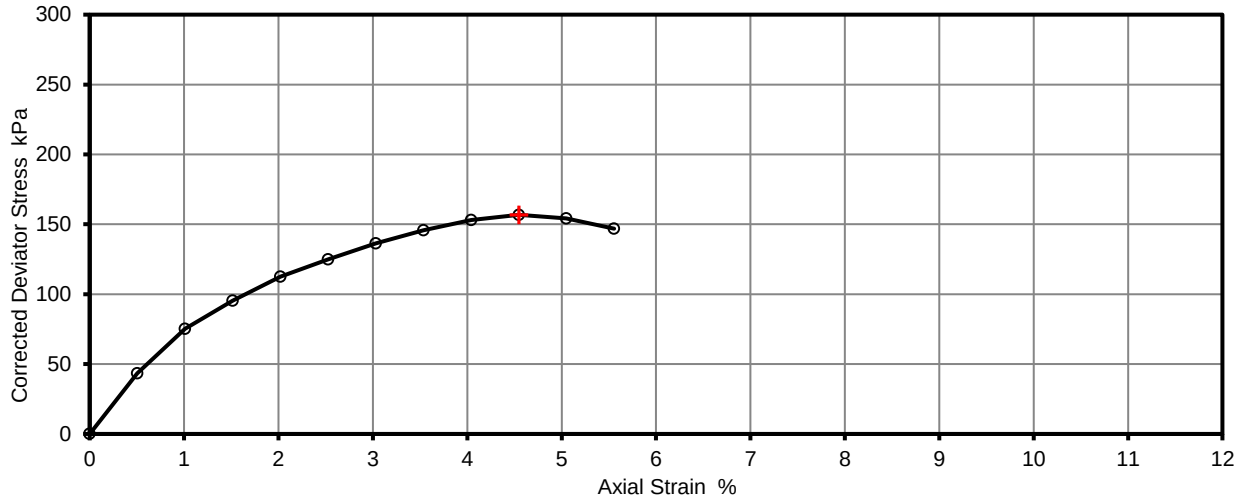
| | | | | | |
|---|---|---|---|---|---|
| | **Unconsolidated Undrained Triaxial Compression Test without measurement of pore pressure - single specimen** | | | Job Ref | 21560 |
| | | | | Borehole/Pit No. | BH2 |
| Site Name | 11 Fitzjohn's Avenue | | | Sample No. | - |
| Project No. | LBH4424 | Client | LBH Wembley | Depth | 1.10 m |
| Soil Description | High strength slightly fissured brown, orange brown and reddish brown slightly sandy slightly gravelly silty CLAY (gravel is fmc and sub-angular to sub-rounded) | | | Sample Type | U |
| | | | | Samples received | 08/09/2016 |
| | | | | Schedules received | 09/09/2016 |
| Test Method | BS1377 : Part 7 : 1990, clause 8, single specimen | | | Date of test | 21/09/2016 |

**Remarks**

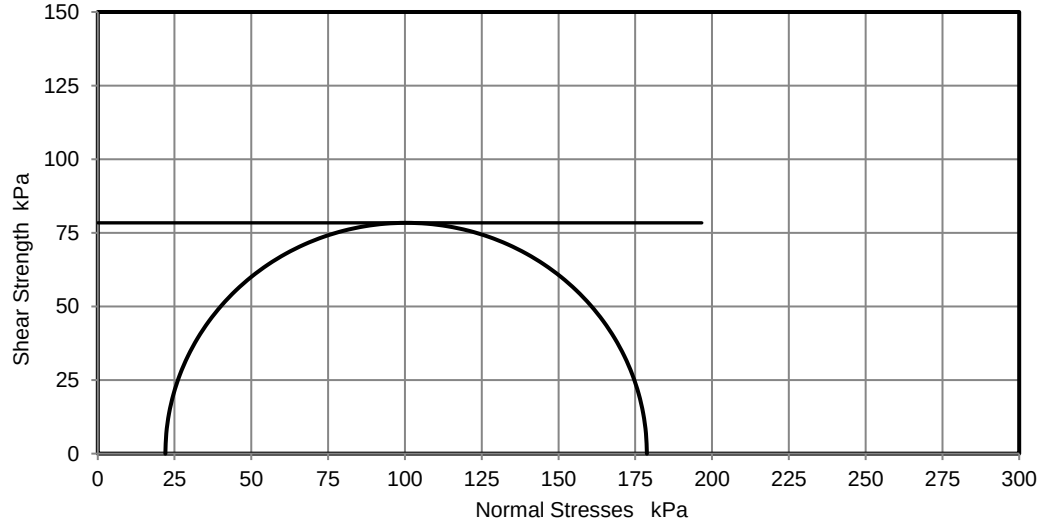
Position within sample

| | | |
|---|---|---|
| Test Number | 1 | |
| Length | 198.0 | mm |
| Diameter | 102.0 | mm |
| Bulk Density | 1.84 | Mg/m3 |
| Moisture Content | 27 | % |
| Dry Density | 1.45 | Mg/m3 |
| Rate of Strain | 2.0 | %/min |
| Cell Pressure | 22 | kPa |
| Axial Strain | 4.5 | % |
| Deviator Stress, ( σ1 - σ3 )f | 157 | kPa |
| Undrained Shear Strength, cu | 78 | kPa ½( σ1 - σ3 )f |
| Mode of Failure | Brittle | |

**Deviator Stress v Axial Strain**




**Mohr Circles**

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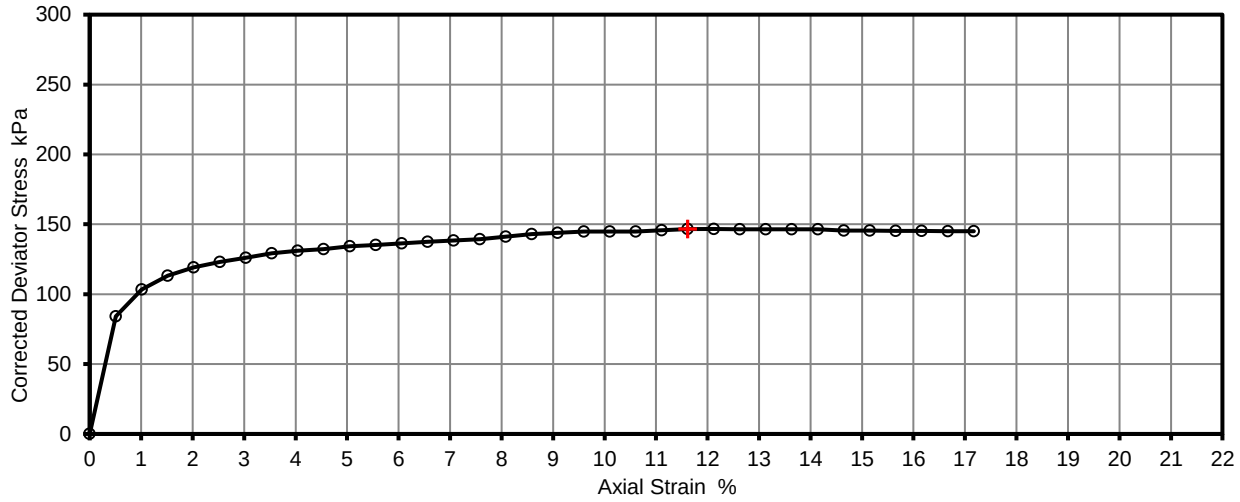
| | | | | | |
|---|---|---|---|---|---|
| | **Unconsolidated Undrained Triaxial Compression Test without measurement of pore pressure - single specimen** | | | Job Ref | 21560 |
| | | | | Borehole/Pit No. | BH2 |
| Site Name | 11 Fitzjohn's Avenue | | | Sample No. | - |
| Project No. | LBH4424 | Client | LBH Wembley | Depth | 3.00 m |
| Soil Description | Medium strength fissured brown mottled blue grey silty CLAY | | | Sample Type | U |
| | | | | Samples received | 08/09/2016 |
| | | | | Schedules received | 09/09/2016 |
| Test Method | BS1377 : Part 7 : 1990, clause 8, single specimen | | | Date of test | 21/09/2016 |

**Remarks**

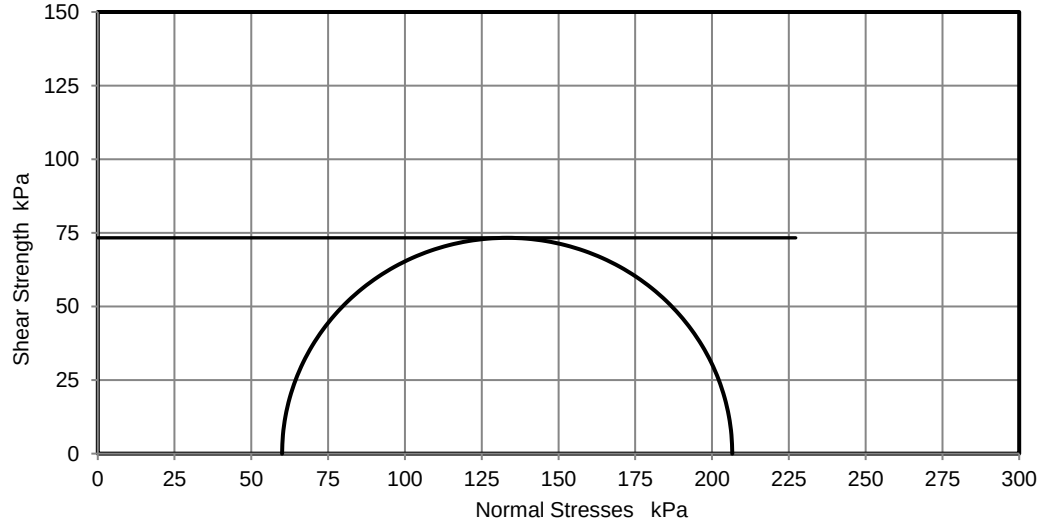
Position within sample

| | | |
|---|---|---|
| Test Number | 1 | |
| Length | 198.0 | mm |
| Diameter | 102.0 | mm |
| Bulk Density | 1.98 | Mg/m3 |
| Moisture Content | 29 | % |
| Dry Density | 1.53 | Mg/m3 |
| Rate of Strain | 2.0 | %/min |
| Cell Pressure | 60 | kPa |
| Axial Strain | 11.6 | % |
| Deviator Stress, ( σ1 - σ3 )f | 147 | kPa |
| Undrained Shear Strength, cu | 73 | kPa ½( σ1 - σ3 )f |
| Mode of Failure | Compound | |

**Deviator Stress v Axial Strain**




**Mohr Circles**

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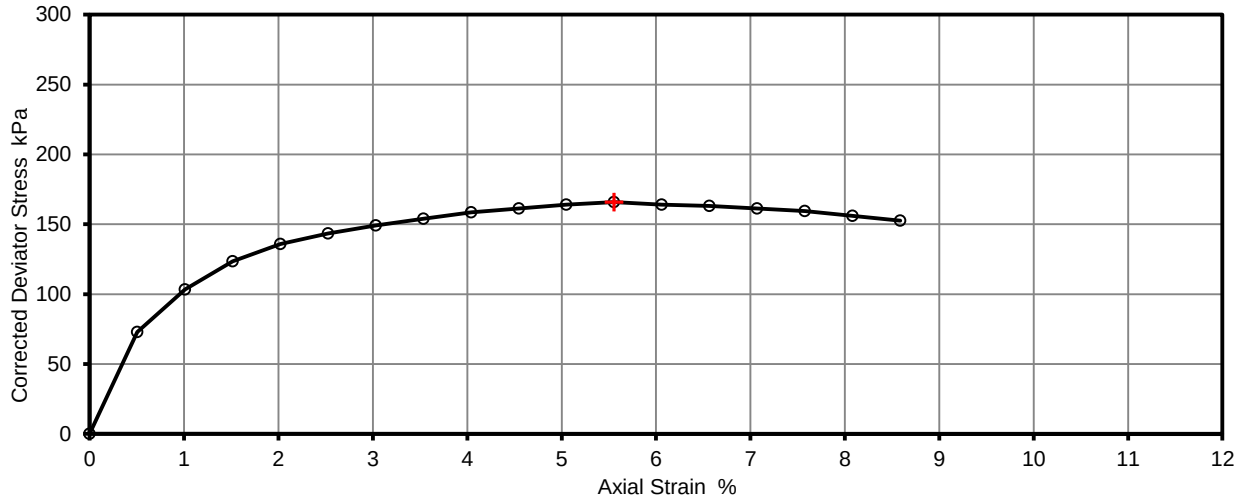
| | | | | | |
|---|---|---|---|---|---|
| | **Unconsolidated Undrained Triaxial Compression Test without measurement of pore pressure - single specimen** | | | Job Ref | 21560 |
| | | | | Borehole/Pit No. | BH2 |
| Site Name | 11 Fitzjohn's Avenue | | | Sample No. | - |
| Project No. | LBH4424 | Client | LBH Wembley | Depth | 5.00 m |
| Soil Description | High strength fissured brown mottled blue grey silty CLAY with scattered traces of selenite | | | Sample Type | U |
| | | | | Samples received | 08/09/2016 |
| | | | | Schedules received | 09/09/2016 |
| Test Method | BS1377 : Part 7 : 1990, clause 8, single specimen | | | Date of test | 21/09/2016 |

**Remarks**

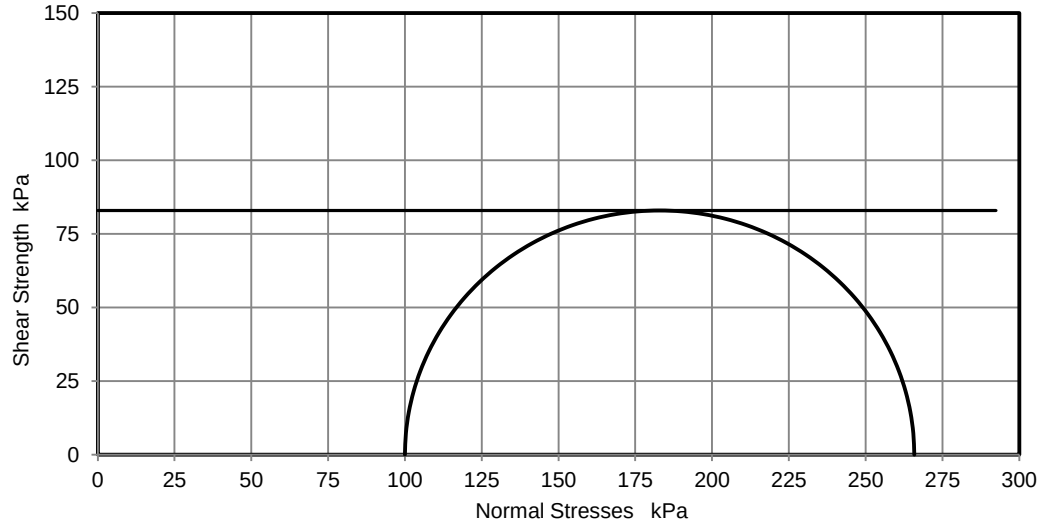
Position within sample

| | | |
|---|---|---|
| Test Number | 1 | |
| Length | 198.0 | mm |
| Diameter | 102.0 | mm |
| Bulk Density | 1.94 | Mg/m3 |
| Moisture Content | 32 | % |
| Dry Density | 1.47 | Mg/m3 |
| Rate of Strain | 2.0 | %/min |
| Cell Pressure | 100 | kPa |
| Axial Strain | 5.6 | % |
| Deviator Stress, ( σ1 - σ3 )f | 166 | kPa |
| Undrained Shear Strength, cu | 83 | kPa ½( σ1 - σ3 )f |
| Mode of Failure | Brittle | |

**Deviator Stress v Axial Strain**




**Mohr Circles**

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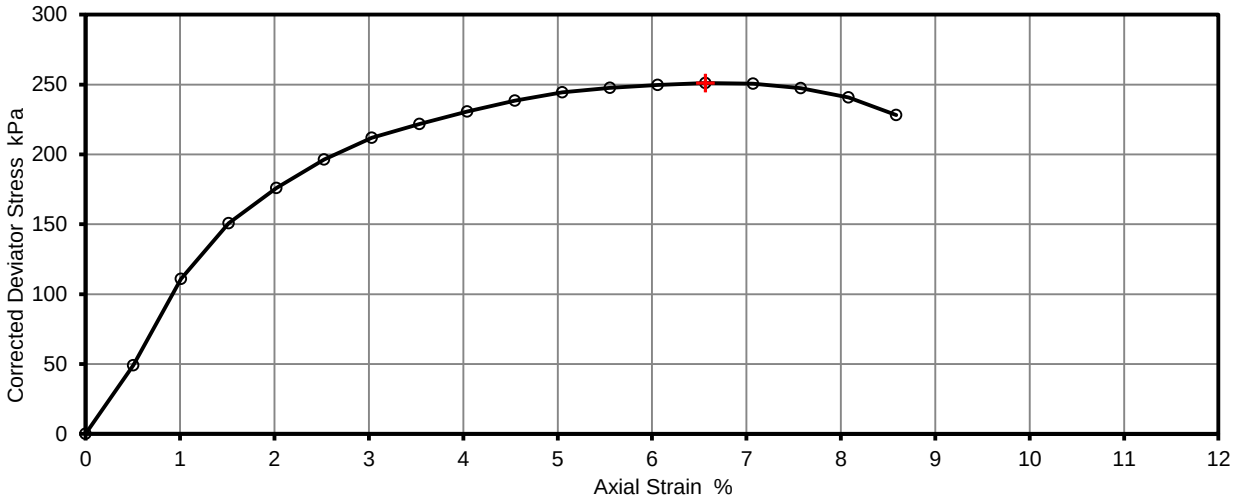
| | | | | | |
|---|---|---|---|---|---|
| | **Unconsolidated Undrained Triaxial Compression Test without measurement of pore pressure - single specimen** | | | Job Ref | 21560 |
| | | | | Borehole/Pit No. | BH2 |
| Site Name | 11 Fitzjohn's Avenue | | | Sample No. | - |
| Project No. | LBH4424 | Client | LBH Wembley | Depth | 8.00 m |
| Soil Description | High strength fissured dark grey silty CLAY with scattered traces of selenite | | | Sample Type | U |
| | | | | Samples received | 08/09/2016 |
| | | | | Schedules received | 09/09/2016 |
| Test Method | BS1377 : Part 7 : 1990, clause 8, single specimen | | | Date of test | 21/09/2016 |

**Remarks**

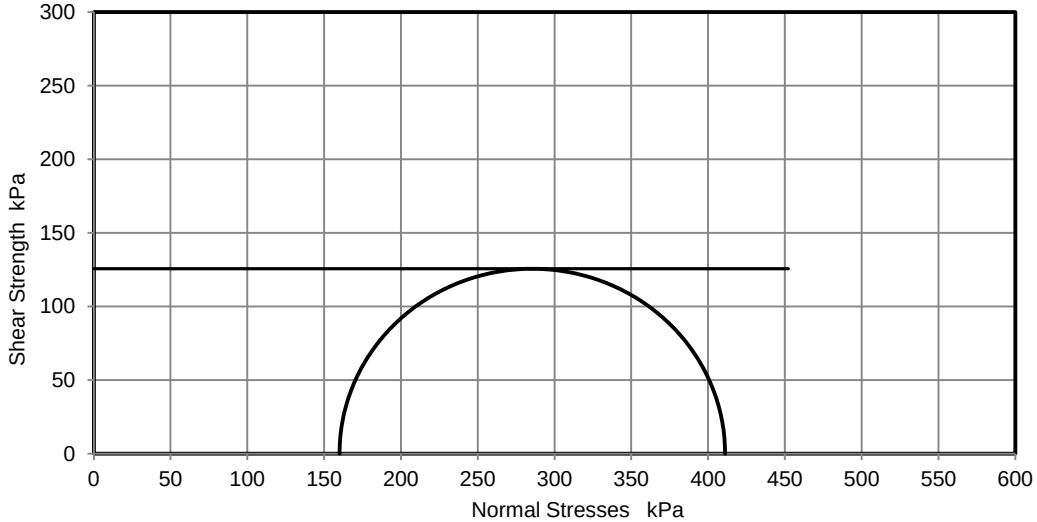
Position within sample

| | | |
|---|---|---|
| Test Number | 1 | |
| Length | 198.0 | mm |
| Diameter | 102.0 | mm |
| Bulk Density | 2.02 | Mg/m3 |
| Moisture Content | 26 | % |
| Dry Density | 1.61 | Mg/m3 |
| Rate of Strain | 2.0 | %/min |
| Cell Pressure | 160 | kPa |
| Axial Strain | 6.6 | % |
| Deviator Stress, ( σ1 - σ3 )f | 251 | kPa |
| Undrained Shear Strength, cu | 126 | kPa ½( σ1 - σ3 )f |
| Mode of Failure | Brittle | |

**Deviator Stress v Axial Strain**




**Mohr Circles**

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**Email: James@k4soils.com**


**Checked and Approved**
Initials: J.P
Date 22/09/2016

UKAS TESTING 2519

*Approved Signatories: K.Phaure (Tech.Mgr) J.Phaure (Lab.Mgr)*

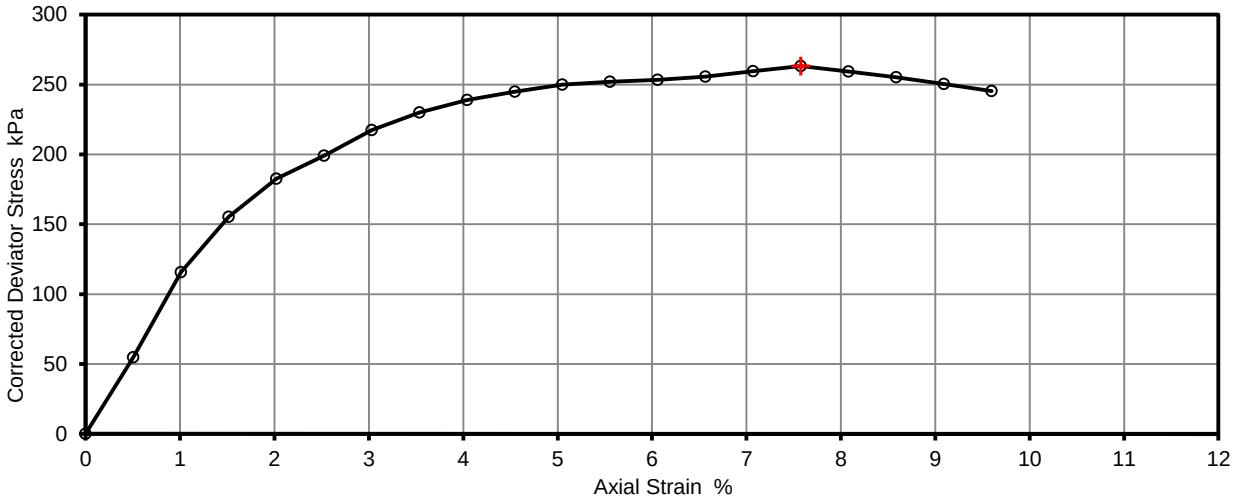
| | | | | | |
|---|---|---|---|---|---|
| | **Unconsolidated Undrained Triaxial Compression Test without measurement of pore pressure - single specimen** | | | Job Ref | 21560 |
| | | | | Borehole/Pit No. | BH2 |
| Site Name | 11 Fitzjohn's Avenue | | | Sample No. | - |
| Project No. | LBH4424 | Client | LBH Wembley | Depth | 11.00 m |
| Soil Description | High strength fissured dark grey silty CLAY | | | Sample Type | U |
| | | | | Samples received | 08/09/2016 |
| | | | | Schedules received | 09/09/2016 |
| Test Method | BS1377 : Part 7 : 1990, clause 8, single specimen | | | Date of test | 21/09/2016 |

**Remarks**

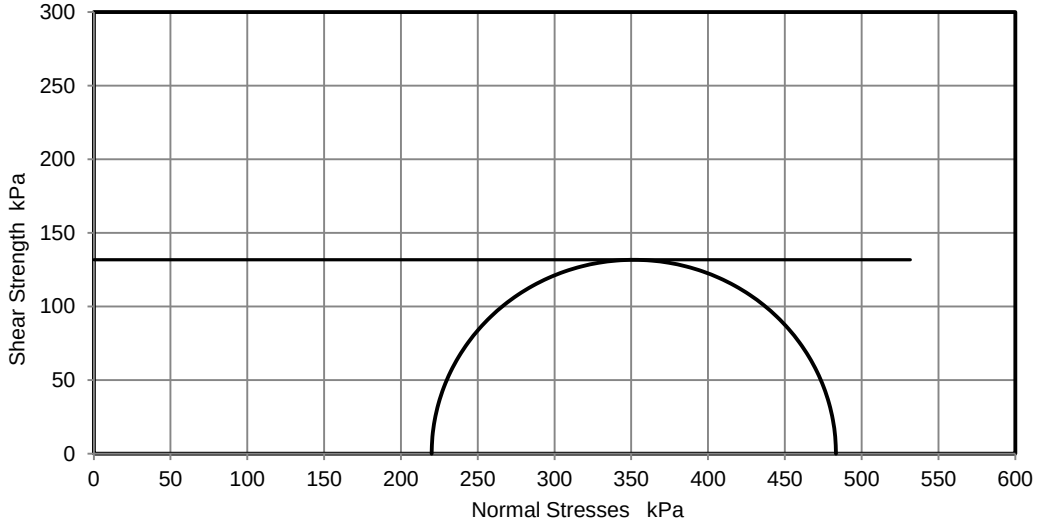
Position within sample

| | | |
|---|---|---|
| Test Number | 1 | |
| Length | 198.0 | mm |
| Diameter | 102.0 | mm |
| Bulk Density | 2.05 | Mg/m3 |
| Moisture Content | 27 | % |
| Dry Density | 1.62 | Mg/m3 |
| Rate of Strain | 2.0 | %/min |
| Cell Pressure | 220 | kPa |
| Axial Strain | 7.6 | % |
| Deviator Stress, ( σ1 - σ3 )f | 263 | kPa |
| Undrained Shear Strength, cu | 132 | kPa ½( σ1 - σ3 )f |
| Mode of Failure | Brittle | |

**Deviator Stress v Axial Strain**




**Mohr Circles**




Deviator stress corrected for area change and membrane effects

Mohr circles and their interpretation is not covered by BS1377. This is provided for information only.


**Test Report by K4 SOILS LABORATORY**
**Unit 8 Olds Close Olds Approach**
**Watford Herts WD18 9RU**
**Tel: 01923 711 288**
**Email: James@k4soils.com**


**Checked and Approved**
Initials: J.P
Date 22/09/2016

UKAS TESTING 2519

*Approved Signatories: K.Phaure (Tech.Mgr) J.Phaure (Lab.Mgr)*

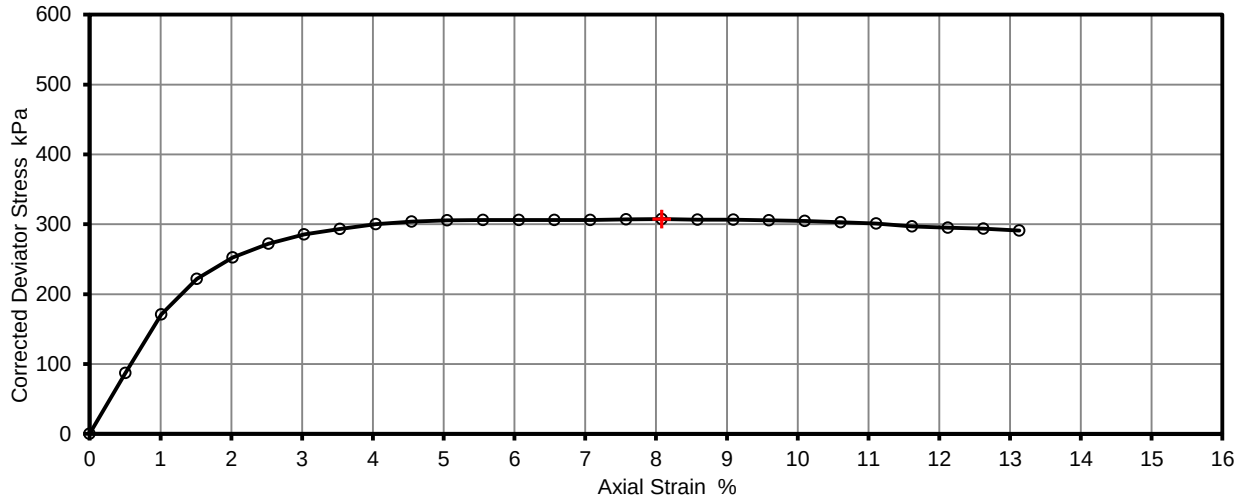
| | | | | | | |
|---|---|---|---|---|---|---|
| | **Unconsolidated Undrained Triaxial Compression Test without measurement of pore pressure - single specimen** | | | Job Ref | 21560 | |
| | | | | Borehole/Pit No. | BH2 | |
| Site Name | 11 Fitzjohn's Avenue | | | Sample No. | - | |
| Project No. | LBH4424 | Client | LBH Wembley | Depth | 14.00 | m |
| Soil Description | Very high strength fissured dark grey silty CLAY | | | Sample Type | U | |
| | | | | Samples received | 08/09/2016 | |
| | | | | Schedules received | 09/09/2016 | |
| Test Method | BS1377 : Part 7 : 1990, clause 8, single specimen | | | Date of test | 21/09/2016 | |

**Remarks**

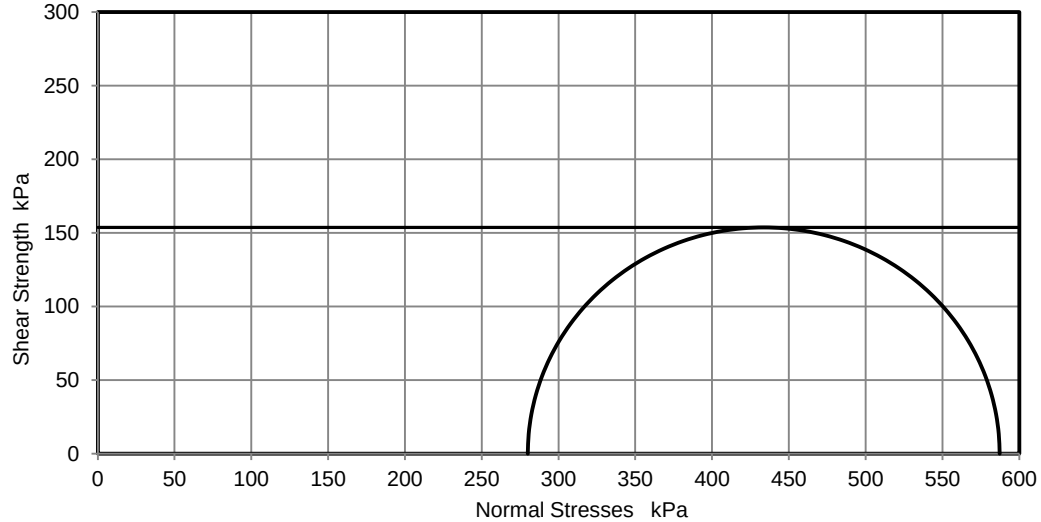
Position within sample

| | | |
|---|---|---|
| Test Number | 1 | |
| Length | 198.0 | mm |
| Diameter | 102.0 | mm |
| Bulk Density | 2.03 | Mg/m3 |
| Moisture Content | 28 | % |
| Dry Density | 1.58 | Mg/m3 |
| Rate of Strain | 2.0 | %/min |
| Cell Pressure | 280 | kPa |
| Axial Strain | 8.1 | % |
| Deviator Stress, ( σ1 - σ3 )f | 307 | kPa |
| Undrained Shear Strength, cu | 154 | kPa ½( σ1 - σ3 )f |
| Mode of Failure | Brittle | |

**Deviator Stress v Axial Strain**




**Mohr Circles**




Deviator stress corrected for area change and membrane effects

Mohr circles and their interpretation is not covered by BS1377. This is provided for information only.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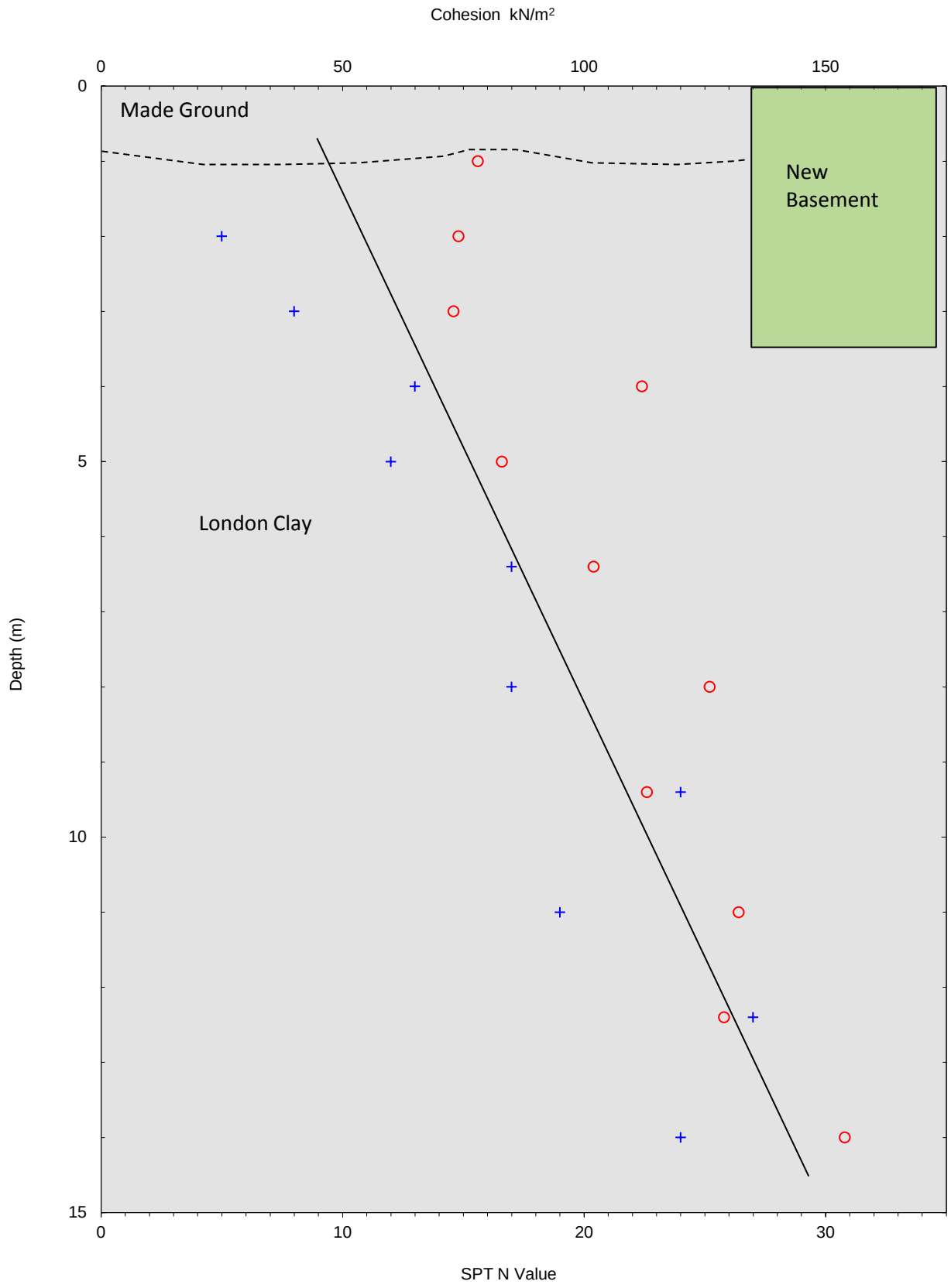
UKAS TESTING
2519

*Approved Signatories: K.Phaure (Tech.Mgr) J.Phaure (Lab.Mgr)*

| PROJECT: | 11 Fitzjohn's Avenue, Camden, NW3 5JY | **SPT & COHESION / DEPTH GRAPH** |
|---|---|---|
| CLIENT: | Fitzjohns Avenue Hampstead Ltd | |




Cohesion = 5 N

o = Cohesion

+ = SPT

| Project No. LBH4424 | **LBH WEMBLEY Geotechnical & Environmental** |
|---|---|

## Sulphate Content (Gravimetric Method) for 2:1 Soil: Water Extract and pH Value - Summary of Results

**Tested in accordance with BS1377 : Part 3 : 1990, clause 5.3 and clause 9**

| Job No. | Project Name | Programme | |
|---|---|---|---|
| 21560 | 11 Fitzjohn's Avenue | Samples received | 08/09/2016 |
| | | Schedule received | 09/09/2016 |
| Project No. | Client | Project started | 09/09/2016 |
| LBH4424 | LBH Wembley | Testing Started | 21/09/2016 |

| Hole No. | Sample | | | | Soil description | Dry Mass passing 2mm | SO3 Content | SO4 Content | pH | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| | Ref | Top | Base | Type | | % | g/l | g/l | | |
| BH1 | - | 2.00 | - | U | Medium strength fissured brown mottled blue grey silty CLAY | 100 | 0.44 | 0.53 | 8.02 | |
| BH1 | - | 6.50 | - | U | High strength fissured brown mottled blue grey silty CLAY with scattered traces of selenite | 100 | 0.59 | 0.70 | 8.08 | |
| BH2 | - | 3.00 | - | U | Medium strength fissured brown mottled blue grey silty CLAY | 100 | 0.19 | 0.23 | 7.96 | |
| BH2 | - | 8.00 | - | U | High strength fissured dark grey silty CLAY with scattered traces of selenite | 100 | 0.49 | 0.58 | 8.02 | |
| | | | | | | | | | | |
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**Email: James@k4soils.com**

**Checked and Approved**

**Initials J.P**

**Date: 22/09/2016**

# Summary of Natural Moisture Content, Liquid Limit and Plastic Limit Results

| Job No. | Project Name | Programme | |
|---|---|---|---|
| 21560 | 11 Fitzjohn's Avenue | Samples received | 08/09/2016 |
| | | Schedule received | 09/09/2016 |
| Project No. | Client | Project started | 09/09/2016 |
| LBH4424 | LBH Wembley | Testing Started | 21/09/2016 |

| Hole No. | Sample | | | | Soil Description | NMC | Passing 425µm | LL | PL | PI | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ref | Top | Base | Type | | % | % | % | % | % | |
| BH1 | - | 2.00 | - | U | Medium strength fissured brown mottled blue grey silty CLAY | 31 | 100 | 76 | 28 | 48 | |
| BH1 | - | 6.50 | - | U | High strength fissured brown mottled blue grey silty CLAY with scattered traces of selenite | 29 | 100 | 73 | 26 | 47 | |
| BH2 | - | 3.00 | - | U | Medium strength fissured brown mottled blue grey silty CLAY | 31 | 99 | 89 | 33 | 56 | |
| BH2 | - | 8.00 | - | U | High strength fissured dark grey silty CLAY with scattered traces of selenite | 26 | 100 | 68 | 23 | 45 | |
| | | | | | | | | | | | |
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| | | | | | | | | | | | |

**Test Methods: BS1377: Part 2: 1990:**
Natural Moisture Content : clause 3.2
Atterberg Limits: clause 4.3 and 5.0

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**Checked and Approved**

**Initials** **J.P**

**Date:** 22/09/2016