# GROUND INVESTIGATION & GROUND MOVEMENT ASSESSMENT REPORT

7 Denmark Street
London WC2

Client: Cord Contracting Co Limited

J18119

June 2018




GEA

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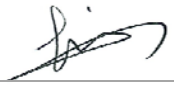
| **Report prepared by** |  |  | |
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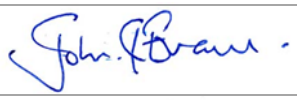
| |  | | |
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This report is intended as a Ground Investigation Report (GIR) as defined in BS EN1997-2, unless specifically noted otherwise. The report is not a Geotechnical Design Report (GDR) as defined in EN1997-2 and recommendations made within this report are for guidance only.

## CONTENTS

# EXECUTIVE SUMMARY

*This executive summary contains an overview of the key findings and conclusions. No reliance should be placed on any part of the executive summary until the whole of the report has been read. Other sections of the report may contain information that puts into context the findings that are summarised in the executive summary.*

## BRIEF

This report describes the findings of a ground investigation and ground movement assessment carried out by Geotechnical and Environmental Associates Limited (GEA) on the instructions of Cord Contracting Co Ltd with respect to the construction of a two-storey extension to the rear of the existing property, including an extension to the existing single level basement. The site has previously been the subject of a Basement Impact Assessment (BIA) by Engenuiti (ref 029-S-REP010 Rev01, dated December 2017), which was submitted in support of the planning application for the proposed development and has been audited on behalf of London Borough of Camden by Campbell Reith. The purpose of this investigation has been to review the screening and scoping elements of the previous BIA, provide supplementary desk study information, to determine the ground conditions and to provide an assessment of the potential impact of the proposed basement on the hydrogeological setting of the site and the surrounding built environment. Contamination testing did not form part of the project brief.

## GROUND CONDITIONS

Beneath a nominal to significant thickness of made ground, Lynch Hill Gravel was encountered over the London Clay Formation, which was proved to the maximum depth investigated, of 5.00 m (17.34 m OD). The made ground generally comprised light grey silty clayey sand with frequent fragments of brick, clinker, flint gravel and concrete, and extended to depths of between 0.40 m (21.94 m OD) and 2.50 m (22.54 m OD). The Lynch Hill Gravel consisted of light orange-brown, grey and light yellowish grey, locally clayey, silty gravelly sand which extended to the maximum depth investigated in Borehole No 1, of 5.00 m (20.04 m OD) and to 2.50 m (19.84 m OD) in Borehole No 2, which was advanced from existing basement level. The London Clay was found to comprise soft light brown silty clay to a depth of 3.00 m (19.34 m OD) over firm fissured grey silty clay to the maximum depth investigated of 5.00 m (17.34 m OD).

Groundwater was only encountered during drilling in Borehole No 1, from within the Lynch Hill Gravel at a depth of approximately 1.80 m below basement level (20.54 m OD), and was subsequently measured at a depth of 2.19 m (20.15 m OD) on a single occasion.

## SUMMARY OF BIA SCREENING STAGE

On the basis of the review of the previous BIA, the following screening subterranean groundwater and slope stability questions were carried forward to the scoping stage, which have each been assessed on the basis of the supplementary desk study information and ground investigation.

- The site is located within the Secondary 'A' Aquifer of the Lynch Hill Gravel Member.
- Denmark Street runs parallel to the northern boundary of the site.

## BIA CONCLUSIONS

The ground investigation has confirmed the findings of previous investigations carried out on adjacent sites, in that the Lynch Hill Gravel is present over the London Clay Formation. Groundwater has been measured at a depth of 2.19 m below existing basement level, approximately 4.70 m below ground level and therefore the proposed basement extension will not extend below the groundwater table and will not have an impact on the local hydrogeological setting.

## GROUND MOVEMENT ASSESSMENT

The analysis has predicted that the proposed basement construction should result in a building damage category for sensitive structures of no greater than Category 0 (negligible). Therefore, the movements associated with the proposed basement excavation are considered to be acceptable and within the limits required by the London Borough of Camden for basement developments. The proposed development is not considered to pose a risk to the stability of the neighbouring properties or the footway or carriageway of Denmark Street.

# Part 1: INVESTIGATION REPORT

This section of the report details the objectives of the investigation, the work that has been carried out to meet these objectives and the results of the investigation. Part 2 of this report comprises the ground movement assessment and Basement Impact Assessment conclusions.

## 1.0 INTRODUCTION

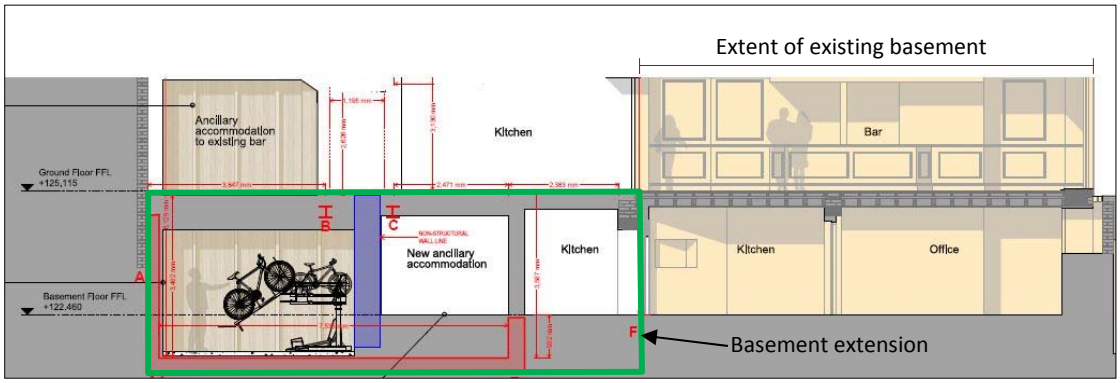
Geotechnical and Environmental Associates (GEA) has been commissioned by Cord Contracting Co Ltd to carry out a review of a previous Basement Impact Assessment (BIA) report carried out for No 7 Denmark Street, London WC2H 8LZ.

The BIA (ref: 029-S-REP010 Rev01, dated December 2017) was carried out by the structural engineers for the project, Engenuiti, and was submitted in support of the planning application for the proposed basement development. The report has subsequently been audited on behalf of London Borough of Camden by Campbell Reith as part of the application validation process, with the findings and conclusions documented in their Basement Impact Assessment Audit report (ref: 12727-48, dated April 2008). The audit concluded that a site-specific ground investigation should be carried out, in addition to a ground movement analysis (GMA).

On the basis of the above, the review of the previous BIA has been supplemented with additional desk study research of the site, a ground investigation and a ground movement analysis (GMA). The review of the BIA has principally been carried out to assess the previous answers to the subterranean (groundwater) and slope stability screening questions, in order to provide the relevant qualifications in accordance with the planning guidelines from the London Borough of Camden. Contamination testing did not form part of the project brief.

### 1.1 Proposed Development

It is understood that it is proposed to refurbish the existing building through the construction of a two-storey rear extension, which will include the extension of the existing single level basement beneath the entire footprint of the site. The basement extension will extend to approximately 3.50 m (18.74 m OD) below ground floor level, approximately 1.00 m below existing basement level, as shown by the cross section below.




This report is specific to the proposed development and the advice herein should be reviewed if the proposals are amended.

## 1.2 Purpose of Work

The principal technical objectives of the work carried out were as follows:

- to research the history of the site;
- to review previous ground investigations and the previous BIA;
- to determine the ground conditions and hydrogeological conditions; and
- to assess the possible impact of the proposed development on the surrounding structures and local hydrogeology.

## 1.3 Scope of Work

In order to meet the above objectives, a limited desk study was carried out in addition to a ground investigation. The following activities were carried out:

- a review of readily available geological maps;
- a review of historical Ordnance Survey (OS) maps sourced from the Envirocheck database; and
- two window sample boreholes advanced to 5.00 m,
- the installation of two groundwater monitoring standpipes to depths of 3.80 m and 4.35 m and two subsequent monitoring visits;
- a Ground Movement Analysis (GMA) and building damage assessment; and
- provision of a report presenting and interpreting the above data, together with our advice and recommendations with respect to the proposed development.

The exploratory methods adopted in this investigation have been selected on the basis of the constraints of the site including but not limited to access and space limitations, together with any budgetary or timing constraints. Where it has not been possible to reasonably use an EC7 compliant investigation technique a practical alternative has been adopted to obtain indicative soil parameters and any interpretation is based upon engineering experience, local precedent where applicable and relevant published information.

### 1.3.1 Basement Impact Assessment

The work carried out also includes a review of the previous Hydrogeological Assessment and Land Stability Assessment (also referred to as Slope Stability Assessment), all of which form part of the BIA procedure specified in the London Borough of Camden (LBC) Planning Guidance[1] and their Guidance for Subterranean Development[2] prepared by Arup ('the Arup Report'). The aim of the work is to provide information on groundwater and land stability and in particular to assess whether the development will affect neighbouring properties or groundwater movements and whether any identified impacts can be appropriately mitigated by the design of the development.

1 London Borough of Camden Planning Guidance (CPG) *Basements and lightwells* March 2018
2 Ove Arup & Partners (2010) *Camden geological, hydrogeological and hydrological study. Guidance for Subterranean Development.* For London Borough of Camden November 2010

### 1.3.2 Qualifications

The land stability element of the BIA has been carried out by Martin Cooper, a BEng in Civil Engineering, a chartered engineer (CEng), member of the Institution of Civil Engineers (MICE), and Fellow of the Geological Society (FGS) who has over 25 years' specialist experience in ground engineering. The subterranean (groundwater) flow assessment has been carried out by John Evans, MSc in Hydrogeology, Chartered Geologist (CGeol) and Fellow of the Geological Society of London (FGS).

The assessments have been made in conjunction with Steve Branch, a BSc in Engineering Geology and Geotechnics, MSc in Geotechnical Engineering, a Chartered Geologist (CGeol) and Fellow of the Geological Society (FGS) with over 30 years' experience in geotechnical engineering and engineering geology.

All assessors meet the qualification requirements of the Council guidance.

## 1.4 Limitations

The conclusions and recommendations made in this report are limited to those that can be made on the basis of the investigation. The results of the work should be viewed in the context of the range of data sources consulted, the number of locations where the ground was sampled and the number of soil, gas or groundwater samples tested; no liability can be accepted for information in other data sources or conditions not revealed by the sampling or testing. Any comments made on the basis of information obtained from the client or other third parties are given in good faith on the assumption that the information is accurate; no independent validation of such information has been made by GEA.

# 2.0 THE SITE

## 2.1 Site Description

The site is located in the London Borough of Camden, approximately 150 m southeast of Tottenham Court Road London Underground station and 420 m northwest of Covent Garden London Underground station. It may additionally be located by National Grid Reference 529893, 181237.

A walkover of the site was carried out by a geotechnical engineer from GEA at the time of the fieldwork. The site is roughly rectangular in shape, measuring approximately 23 m northwest-southeast, 7 m east-west, narrowing to a square shaped area measuring roughly 3 m by 3 m at the rear, and is within a mixed use commercial and residential setting. The site is occupied by a four-storey, Grade II listed building with a single level basement, which extends to a depth of 2.7 m (22.34 m OD) below ground level and is present below the front third of the site and out below the footway of Denmark Street as a vault.

The site fronts onto Denmark Street to the northeast and is bounded by a four-storey building to the east and a five-storey building to the west, which are occupied by music shops on the ground floors with residential apartments above. The site abuts 'No 122 Charing Cross' and 'Book Mews' to the rear, a concrete covered courtyard occupied by a single-storey outbuilding. No 6 Denmark Street and No 122 Charing Cross both include single level basement.

The site is essentially level and is accessed off Denmark Street. No areas of soft landscaping were noted on site.

## 2.2 Site History

The history of the site and surrounding area has been researched by reference to online data and historical Ordnance Survey (OS) maps sourced from archive Envirocheck database.

The earliest map studied, dated 1875, shows the site and the surrounding area to have been developed with rows of terraced houses fronting onto Denmark Street and Flitcroft Street. A brewery was present to 170 m northeast, St Giles Church and a disused graveyard approximately 60 m to the southeast and St Giles Hospital approximately 40 m to the southeast. By 1896, the site and surrounding buildings along Denmark Street are shown in the existing configuration. On the map dated 1953 the buildings east of No 7 are labelled as the site of St Giles Hospital. Online information indicates Nos 4, 5 and 6 were part of the hospital's grounds till the end of the 19th Century, primarily used by leper patients. The site and immediate surrounding area have remained essentially unchanged from the 1950s to the present day.

## 2.3 Other Information

A review of environmental information held by the Environmental Agency (EA) has indicated that there are no existing or historical landfill sites, waste management, transfer or disposal sites within 500 m of the site.

## 2.4 Geology

The British Geological Survey (BGS) map of the area (sheet 256) indicate that the site is underlain by Lynch Hill Gravel over the London Clay Formation. The Lynch Hill Gravel comprises of sand and gravel, locally with lenses of silt, clay or peat. The London Clay typically comprises bioturbated or poorly laminated, blue-grey or grey-brown, slightly calcareous, silty to very silty clay, clayey silt and sometimes silt with layers of sandy clay.

Both GEA and Concept Site Investigations have carried out a ground investigation within Book Mews directly to the southeast of the site. Copies of the borehole records from the Concept Site Investigation have been provided by Engenuiti. The investigations generally encountered the expected ground conditions in that a significant thickness of made ground was encountered to 2.70 m and 4.50 m, whereupon medium dense to very dense brown and light orange-brown and brown gravelly sand, sandy gravel and sand and gravel of the Lynch Hill Gravel extended to depths of between 4.80 m and 5.77 m. The underlying London Clay Formation generally comprised firm becoming stiff and very stiff fissured brown mottled grey silty clay with occasional partings of orange-brown fine sand and silt with rare carbonaceous material and was proven to the maximum depth of investigation, of 30.35 m.

## 2.5 Hydrology and Hydrogeology

The Lynch Hill Gravel is classified as a Secondary 'A' Aquifer by the EA, which refers to permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. The London Clay is classified as a Non-Aquifer and Unproductive Stratum, which refers to a soil or rock with low permeability that has a negligible effect on local water supply or river base flow.

The permeability of the Lynch Hill Gravel is expected to range between about $1 \times 10^{-6}$ m/s and $1 \times 10^{-4}$ m/s. Published data for the permeability of the London Clay indicates the horizontal permeability to generally range between $1 \times 10^{-10}$ m/s and $1 \times 10^{-8}$ m/s, with an even lower vertical permeability. The London Clay is not capable of supporting a continuous groundwater table, although isolated pockets of perched groundwater do occur within fissures and silt and sand partings.

Within the aforementioned previous ground investigations, groundwater was encountered within the Lynch Hill Gravel at depths of between 3.66 m and 4.40 m. Groundwater would be expected to be flowing in a generally southeasterly direction towards the River Thames, located approximately 920 m to the southeast of the site.

Flood data obtained from the EA shows that the site is not within the likely zone of flooding or extreme flooding from rivers or seas without defences, whilst surface water flooding maps published by the EA indicate that the site is located in an area at low to medium risk from surface water flooding, although the site itself is not shown to have suffered from surface water flooding in 1975 and 2002 on Figure 15 of the Arup Report.

The site is entirely covered in hardstanding, such that infiltration of rainwater in to the ground beneath the site is limited to cracks or damage in the hardstanding, the majority of surface runoff is therefore likely to drain into combined sewers.

Reference to Figure 11 of the Arup Report in the Camden Basement Planning Guidance indicates the site is not located 500 m of any historical river courses.

# 3.0 SCREENING

GEA has carried out a review of the answers given for the subterranean and stability screening questions within the Engenuiti BIA report. The flowchart questions and responses to these questions are tabulated below.

## 3.1 Subterranean (groundwater) Screening Assessment

| Question | Response for 7 Denmark Street |
|---|---|
| 1a. Is the site located directly above an aquifer? | Yes. The site is on the Lynch Hill Gravel Formation classified as a Secondary 'A' Aquifer. This has been confirmed through desk study research |
| 1b. Will the proposed basement extend beneath the water table surface? | Unlikely. Groundwater monitoring from the nearby previous boreholes indicate groundwater to be present within the Lynch Hill Gravel at depths of between 3.7 m and 4.4 m below ground level |
| 2. Is the site within 100 m of a watercourse, well (used/ disused) or potential spring line? | No. |
| 3. Is the site within the catchment of the pond chains on Hampstead Heath? | No. |
| 4. Will the proposed basement development result in a change in the proportion of hard surfaced / paved areas? | No. The site is entirely covered in hardstanding, a condition that will remain post-development. |
| 5. As part of the site drainage, will more surface water (e.g. rainfall and run-off) than at present be discharged to the ground (e.g. via soakaways and/or SUDS)? | No. The existing surface drainage regime will be maintained. |
| 6. Is the lowest point of the proposed excavation (allowing for any drainage and foundation space under the basement floor) close to or lower than, the mean water level in any local pond or spring line? | No. There are no surface water features within 500 m of the site. |

The answers given in the Engenuiti BIA are considered to be correct and acceptable and therefore the assessment has identified the following potential issues that need to be assessed:

Q1a The site is located directly above the Lynch Hill Gravel Member, which is a Secondary 'A' Aquifer.

Q1b Although unlikely, there is a requirement to determine whether or not the basement structure will extend below the water table.

## 3.2 Stability Screening Assessment

| Question | Response for 7 Denmark Street |
|---|---|
| 1. Does the existing site include slopes, natural or manmade, greater than 7°? | No. A site walkover and topographical maps confirm that there are no slopes on the site. |
| 2. Will the proposed re-profiling of landscaping at the site change slopes at the property boundary to more than 7°? | No. See structural drawings within the Engenuiti BIA. |
| 3. Does the development neighbour land, including railway cuttings and the like, with a slope greater than 7°? | A site walkover and topographical maps confirm that there are no slopes on neighbouring sites. |
| 4. Is the site within a wider hillside setting in which the general slope is greater than 7°? | No, as above. |
| 5. Is the London Clay the shallowest strata at the site? | No. The geological map and previous investigations confirm that the Lynch Hill Gravel is the shallowest stratum. |
| 6. Will any trees be felled as part of the proposed development and / or are any works proposed within any tree protection zones where trees are to be retained? | No. No tree will be felled as part of the proposed basement development. |
| 7. Is there a history of seasonal shrink-swell subsidence in the local area and / or evidence of such effects at the site? | No. There is no evidence of heave related movement in the existing buildings. |
| 8. Is the site within 100 m of a watercourse or potential spring line? | No, as confirmed through topographical and historical maps of the area. |
| 9. Is the site within an area of previously worked ground? | Possibly. The boreholes from the previous investigations indicate significant thicknesses of made ground, although a review of historical maps did not indicate any potential areas of worked ground. |
| 10. Is the site within an aquifer? If so, will the proposed basement extend beneath the water table such that dewatering may be required during constructions. | Yes. The site is underlain by an aquifer and the basement structure could possibly extend below the water table |
| 11. Is the site within 50 m of Hampstead Heath ponds? | No. |
| 12. Is the site within 5 m of a highway or pedestrian right of way? | Yes. The site fronts onto Denmark Street to the north. |
| 13. Will the proposed basement significantly increase the differential depth of foundations relative to neighbouring properties? | No. The basement will be constructed down to similar levels as the adjacent buildings which also have single storey basements. The proposed founding depth will be lower than the foundations to some buildings on Denmark Street |
| 14. Is the site over (or within the exclusion zone of) any tunnels, e.g. railway lines? | No. See information contained within the Engenuiti BIA |

The answers given in the Engenuiti BIA are considered to be correct and acceptable and therefore the assessment has identified the following potential issues that need to be assessed:

Q9 There is the possibility that there is a significant thickness of made ground present below the site.
Q10 The site is located within the Secondary 'A' Aquifer of the Lynch Hill Gravel Member.
Q12 Denmark Street runs parallel to the northern boundary of the site.

## 4.0 SCOPING AND SITE INVESTIGATION

The purpose of scoping is to assess in more detail the factors to be investigated in the impact assessment. Potential impacts are assessed for each of the identified potential impact factors.

### 4.1 Potential Impacts

The following potential impacts have been identified by the screening process

| Potential Impact | Consequence |
|---|---|
| The site is located directly above an aquifer | The site is underlain by the Lynch Hill Gravel Member, which is classified as a Secondary 'A' Aquifer. This has the potential of being able to support local water supplies as well as forming an important source of base flow for local rivers. There is the potential for the hydrogeological setting to be affected by a basement structure that extends below the groundwater table. |
| There is the potential for significant thicknesses of made ground to be present below the site. | Poorly compacted made ground can give rise to instabilities within excavations and it is not uncommon for existing buildings and structures in London to be founded on such soils. Stability of the excavation and surrounding properties can be an issue in such circumstances. |
| The site located within 5 m of Denmark Street public highway and pedestrian right of way. | The public walkway of Denmark Street borders the site to the north and the excavation of a basement can cause instability of such structures. However, the proposed basement expansion is actually over 5 m away from the footway. |

These potential impacts have been investigated through the site investigation, as detailed below.

### 4.2 Exploratory Work

Access to the rear of the property was limited by the presence of the existing house. Therefore, in order to meet the objectives described in Section 1.2, as far as possible within the access restrictions, two boreholes were drilled to a depth of 5.00 m using window sampling equipment to allow the logging of the underlying geology and the recovery of disturbed samples. Two standpipes were installed in each of the boreholes to depths of 3.80 (21.24 m OD) and 4.35 m (17.99 m OD), which have been monitored on two occasions, one week and three weeks after installation.

All of the above work was carried out under the supervision of a geotechnical engineer from GEA.

The borehole records are enclosed, together with a site plan indicating the exploratory positions. The Ordnance Datum (OD) level shown on the borehole have been interpolated from spot heights shown on site survey drawings (ref 07397 01 - 02, dated Jan 2008), which were provided by Engenuiti.

### 4.3 Sampling Strategy

Borehole No 1 was advanced from existing basement level to 5.00 m (17.34 m OD), whilst Borehole No 2 was advanced to 5.00 m (20.04 m OD) from ground floor level at the rear of the site, in the area of the proposed excavation. The borehole positions were positioned on site by GEA, whilst avoiding areas of known services.

## 5.0 GROUND CONDITIONS

Beneath a nominal to significant thickness of made ground, Lynch Hill Gravel was encountered over the London Clay Formation, which was proved to the maximum depth investigated, of 5.00 m (17.34 m OD).

### 5.1 Made Ground

Beneath the existing ground floor and basement floor slabs, the made ground generally comprised light grey silty clayey sand with frequent fragments of brick, clinker, flint gravel and concrete, and extended to depths of between 0.40 m (21.94 m OD) and 2.50 m (22.54 m OD).

Apart from the presence of extraneous material, no visual or olfactory evidence of contamination was noted in the made ground.

### 5.2 Lynch Hill Gravel

The Lynch Hill Gravel generally comprised light orange-brown, grey and light yellowish grey, locally clayey, silty gravelly sand which extended to the maximum depth investigated in Borehole No 1, of 5.00 m (20.04 m OD) and 2.50 m (19.84 m OD) in Borehole No 2, which was advanced from existing basement level. The density of the granular soils prevented further progress of Borehole No 2.

These soils were observed to be free of any evidence of soil contamination.

### 5.3 London Clay

The London Clay was encountered in Borehole No 2 only and soft light brown silty clay to a depth of 3.00 m (19.34 m OD) over firm fissured grey silty clay to the maximum depth investigated of 5.00 (17.34 m OD).

These soils were observed to be free of any evidence of soil contamination.

### 5.4 Groundwater

Groundwater was only encountered during drilling in Borehole No 1, from within the Lynch Hill Gravel at a depth of approximately 1.80 m below basement level (20.54 m OD), and was subsequently measured at a depth of 2.19 m (20.15 m OD) on a single occasion.

# Part 2: GROUND MOVEMENT ASSESSMENT & BIA CONCLUSIONS

This section of the report comprises an analysis of the ground movements arising from the proposed basement and foundation scheme and the information obtained from the investigation, presented in Part 1 of the report.

## 6.0 INTRODUCTION

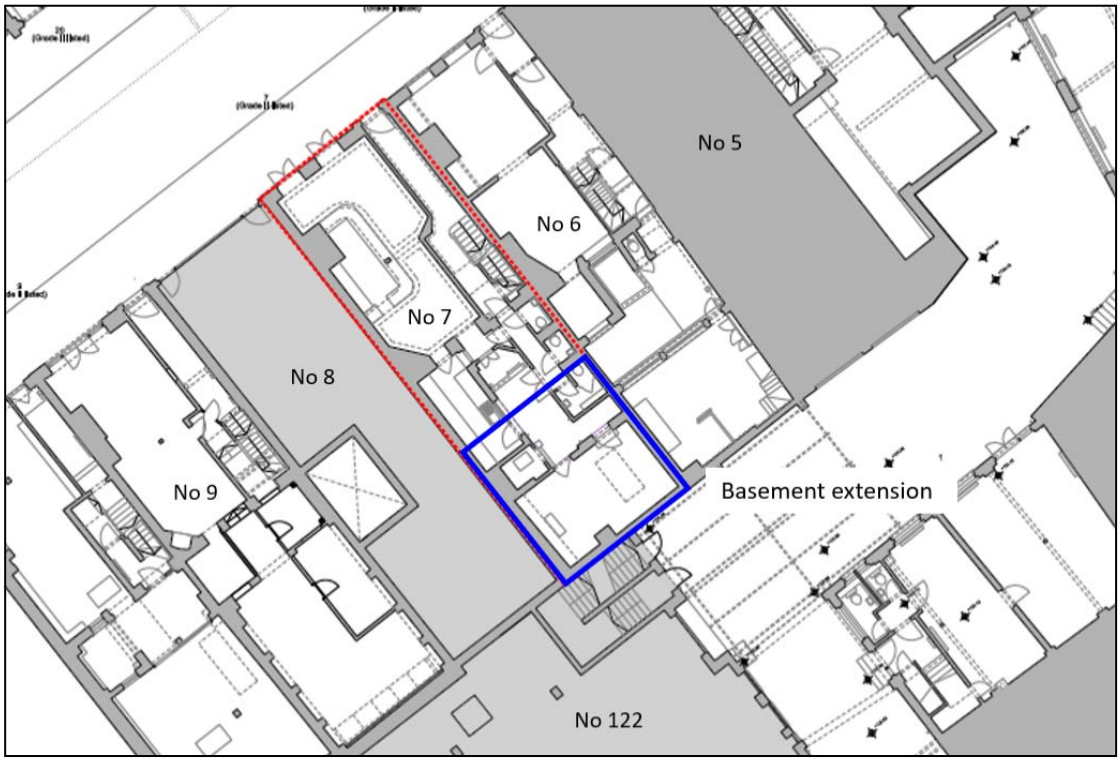
The sides of a basement excavation will move to some extent regardless of how they are supported. The movement will typically be both horizontal and vertical and will be influenced by the engineering properties of the ground, groundwater level and flow, the efficiency of the various support systems employed during underpinning and piling and the efficiency or stiffness of any support structures used.

An analysis has been carried out of the likely movements arising from the proposed basement excavation and the results of this analysis have been used to predict the effect of these movements on surrounding structures.

It is understood that it is proposed to excavate a single level basement extension below the rear of the site, which will extend to a depth of 3.50 m below ground floor level. It is currently proposed to form the basement retaining walls using conventional underpinning.

### 6.1 Basis of Ground Movement Assessment

#### 6.1.1 Nearby Sensitive Structures

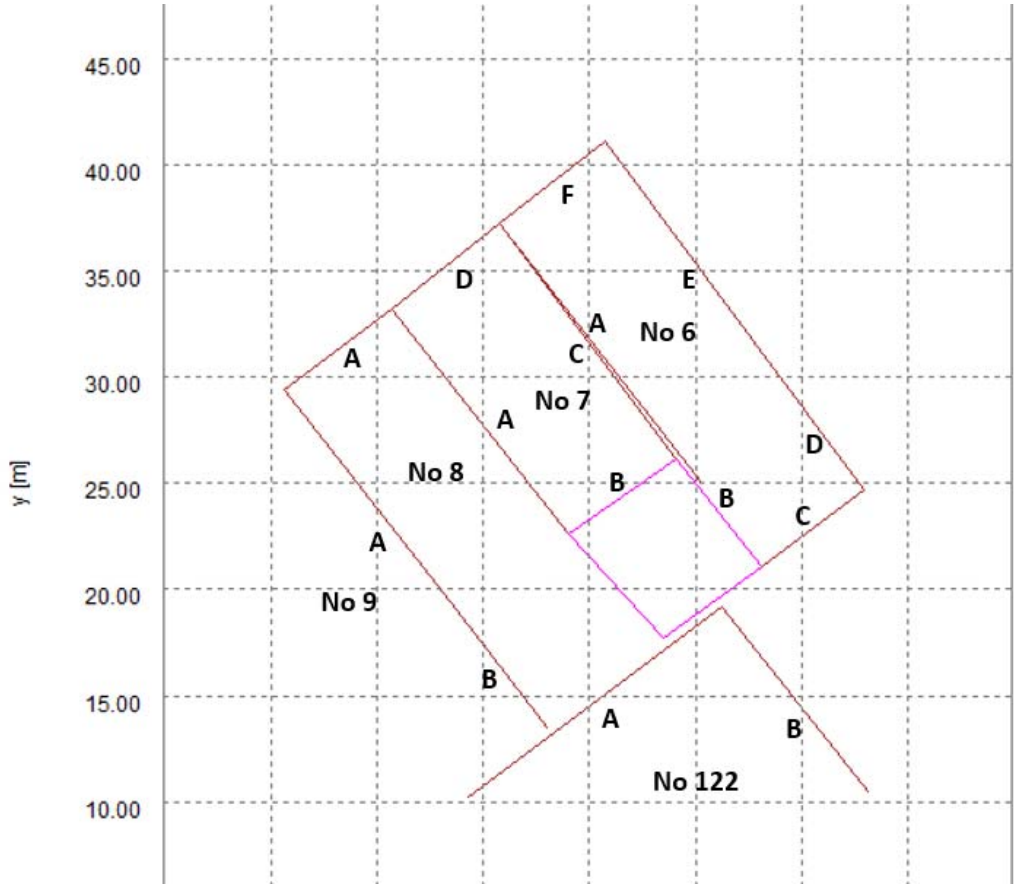


Sensitive structures relevant to this assessment are Nos 6 and 8 Denmark Street to the east and west respectively, 122 Charing Cross Road to the south and the retained Grade II listed structure of No 7 Denmark Street, which is adjacent to the northern extent of the proposed basement extension. A plan showing the locations of the site and neighbouring buildings is shown on the previous page.

Each of the surrounding structures include basement levels and the heights of the buildings have been provided on survey drawings provided by Engenuiti, who have also supplied existing foundation levels. The heights and foundation levels of each of the nearby sensitive structures are summarised in the table below, with the diagram below showing the sensitive structures in relation to the proposed basement excavation.

| Sensitive Structure | Structure Reference | Foundation level (m AOD) | Height of building above ground level (m) |
|---|---|---|---|
| No 6 Denmark St | A | -2.50 | 15 |
| | B to D | -0.70 | 9 |
| | E to F | -2.50 | 15 |
| No 7 Denmark St | A to D | -3.50 | 15 |
| No 8 & No 9 Denmark St | 9A, 9B & 8A | -3.50 | 18 |
| No 122 Charing Cross Rd | A to B | -3.50 | 18 |

The diagram below details the sensitive structures in relation to the proposed excavation.



The following drawings have been referred to, where relevant, to model the sensitive structures and proposed excavation.

| Drawing Reference | Drawing Title |
|---|---|
| 1401_7D(00)000, dated August 2014 | Existing Location Plan |
| 1401_7D(00)200, dated August 2014 | Proposed Basement and Ground Floor Plan |
| 1401_7D(00)231, dated August 2014 | Proposed Section |
| 07397-01B, dated January 2008 | Basement Plan |
| 07397-02F, dated January 2008 | Ground Floor and Site Plan |
| 07397-05A, dated January 2008 | Denmark Street Elevation 1 |

### 6.2 Construction Methodology

It is proposed to construct the 3.50 m deep basement excavation through localised underpinning of the existing foundations using a hit and miss approach, with panels of no more than 1.2 m in length. The underpinning will be carried out in a single stage from the base of the existing foundations, of 1.80 m below ground level, down to formation level. Temporary support and propping will be adopted to maintain stability. The underpins will be adequately laterally propped and sufficiently dowelled together, and the concrete will be cast and adequately cured prior to excavation of the basement and removal of the formwork and supports. It is assumed that the corners of the excavation will be locally stiffened by cross-bracing or similar and that the new retaining walls will not be cantilevered at any stage during the construction process.

## 7.0 GROUND MOVEMENTS

An assessment of ground movements within and surrounding the excavations has been undertaken using the X-Disp and P-Disp computer programs licensed from the OASYS suite of geotechnical modelling software from Arup. These programs are commonly used within the ground engineering industry and are considered to be appropriate tools for this analysis.

The X-Disp program has been used to predict ground movements likely to arise from the construction of the proposed through lateral movement (horizontal movement) of soil behind the proposed bored pile and insitu reinforced concrete retaining walls. The analysis of potential ground movements within the excavation and vertical movements outside of the retaining walls, as a result of unloading of the underlying soils, has been carried out using the Oasys P-Disp Version 19.3 – Build 12 software package and is based on the assumption that the soils behave elastically, which provides a reasonable approximation of soil behaviour at small strains. The ground movements predicted by P-Disp have then been imported into the X-Disp program, which has then been used to undertake the subsequent damage assessment associated with the construction of the proposed underpins.

For the purpose of these analyses, the corners have been defined by x and y coordinates, with the x-direction approximately parallel with the orientation east-west, whilst the y-direction is approximately parallel with the orientation of north-south. Vertical movement is in the z-direction. Wall lengths of less than 10 m have been modelled as 1 m long structural elements, while greater than 10 m wall lengths have been modelled as 2 m elements to reflect the greater stiffness of the longer walls.

The full outputs of all the analyses are included within the appendix.

## 7.1 Movements within the Excavation (Heave)

### Model Used

Unloading of the London Clay will take place as a result of the proposed excavation and the reduction in vertical stress in the short term will cause heave to take place. Undrained soil parameters have been used to estimate the potential short-term movements, which include the "immediate" or elastic movements as a result of the basement excavation. Drained parameters have been used to provide an estimate of the total movement, which includes long term swelling that will continue for a number of years.

The elastic analysis requires values of soil stiffness at various levels to calculate displacements. Values of stiffness for the soils at this site are readily available from published data and we have used a well-established method to provide our estimates. Published data[3] indicates stiffness values of 750 x Cu for the London Clay and a ratio of E' to Eu of 0.75, and it is considered that this provides a sensible approach. The strength profile of the underlying clay has been extrapolated from the results of the aforementioned nearby GEA ground investigations. The results show a typical profile for London Clay.

For granular soils of the Kempton Park Gravel, a relationship of 2000 x SPT 'N' has been used to obtain values of Youngs Modulus.

The proposed basement excavation will result in an unloading of around 60 kN/m$^2$. The existing loads, as provided by the structural engineers, have been taken into consideration in analysing the short-term heave, as the building will remain in place during excavation. These loads, in addition to the new proposed loads, have also been taken into account in analysing the total drained movements.

The soil parameters used in this assessment have been established from the investigation on site and previous cable percussion boreholes advanced during the Concept site investigation in the adjacent Book Mews; they are tabulated below.

| Stratum | Depth range (m) | Eu (MPa) | E' (MPa) |
|---|---|---|---|
| Made Ground | GL to 2.5 | 7.5 | 4.5 |
| Lynch Hill Gravel | 2.5 to 6.0 | 54 | 54 |
| London Clay | 6.0 to -30.0 | 41.5 to 112.5 | 24.5 to 67.5 |

A rigid boundary for the analysis has been set at 30 m below the site, at which depth the London Clay is expected to be essentially incompressible and not affected by the basement excavation.

### Results

The predicted movements are summarised in the table below; the results are presented below and in subsequent tables to the degree of accuracy required to allow predicted variations in ground movements around the structure(s) to be illustrated, but may not reflect the anticipated accuracy of the predictions.

[3] Burland JB, Standing, JR, and Jardine, FM (2001) *Building response to tunnelling, case studies from construction of the Jubilee Line Extension* CIRIA Special Publication 200

| Location | Heave Movement (mm)* | | |
|---|---|---|---|
| | Short-term Heave (Excavation Phase) | Long-term Heave (post construction) | Total Heave |
| Centre of main excavation | 6 | 1 | 7 |
| Edge of excavations | 3 | 1 | 4 |
| At 5 m from edge of excavations | 0 to 1 | 0 to 1 | 0 to 2 |

The P-Disp analysis indicates that, by the time the basement excavation and construction is complete, up to 6 mm of heave is likely to have taken place across the centre of the excavation, reducing to less than 5 mm at the edges. Following completion of the basement construction, taking into consideration the proposed loads, 7 mm of heave is likely to occur across the centre of the excavation, reducing to 4 mm at the edges.

If a compressible material is used beneath the slab, it will need to be designed to be able to resist the potential uplift forces generated by the ground movements. In this respect, potential heave pressures are typically taken to equate to around 40% of the total unloading pressure.

## 7.2 Ground Movements – Surrounding the Excavation

### Model Used

For the X-Disp analysis, the soil movement relationships used for the embedded retaining walls are the default values within CIRIA report C760[4], which were derived from a number of historic case studies. Published data for ground movements associated with underpinned retaining walls and the subsequent excavation of a new basement is limited compared to other types of retaining wall discussed above. It is possible to use the well-documented predictions and movement curves for embedded retaining walls contained within CIRIA C760, although this approach is considered to be conservative. Therefore, the analysis of potential ground movements associated with the underpinned basement, as a result of unloading of the underlying soils has been carried out using the Oasys P-Disp software package as discussed previously. The analysis of potential horizontal ground movements associated with the basement and lower ground floor excavations have been modelled using Oasys X-Disp using a ratio of horizontal movement of 0.015% of the basement excavation depth relative to the underside of the foundations of the adjacent structures. The movements predicted by the P-Disp assessment for vertical movement were imported into the X-Disp model and a combined model and building damage assessment completed.

### Results

The predicted movements are based on the worst case of the individually analysed segments of ‘hogging’ and ‘sagging’ and these are summarised in the tables below. It should be noted that the combined effect of segments acting together typically improves the resultant movements and therefore these values are deemed to be conservative. The structures location plan in the appendix details the position of each of the walls.

The results discussed below and have been presented to the degree of accuracy required to allow predicted variations in ground movements around the structures to be illustrated, but may not reflect the anticipated accuracy of the predictions.

[4] Gaba, A, Hardy, S, Powrie, W, Doughty, L and Selemetas, D (2017) *Embedded retaining walls – guidance for economic design* CIRIA Report C760

The analysis has indicated that the maximum horizontal settlements that will result from the construction of underpinning installation are less than 5 mm.

# 8.0 BUILDING DAMAGE ASSESSMENT

In addition to the above assessment of the likely movements that will result from the proposed development, the neighbouring buildings are considered to be sensitive structures, requiring Building Damage Assessments, on the basis of the classification given in Table 6.4 of C760[1]. The structures location plan in the appendix details the position of each of the walls.

## 8.1 Damage to Neighbouring Structures

The movements resulting from the wall installation phase and the combined retaining wall installation and basement excavation phases, have been estimated using the X-Disp modelling software to carry out an assessment of the likely damage to adjacent properties and the results are summarised for the combined wall installation and excavation in the table below.

| Sensitive Structure | Structure Reference | Category of Damage* |
|---|---|---|
| 6 Denmark Street | A to F | Category 0 – Negligible |
| Retained elevations of 7 Denmark Street | A, C and D | Category 0 – Negligible |
| 8 Denmark Street | A | Category 0 – Negligible |
| 9 Denmark Street | A and B | Category 0 – Negligible |
| 122 Charing Cross Road | A and B | Category 0 – Negligible |

**From Table 6.4 of C760[1]: Classification of visible damage to walls.*

The analysis has predicted that the proposed basement construction may result in a building damage category for sensitive structures of Category 0 (negligible). These movements reflect the relatively minor excavation required and are within the acceptable limits required by the London Borough of Camden.

## 8.2 Monitoring of Ground Movements

The predictions of ground movement based on the ground movement analysis should be checked by monitoring of adjacent properties and structures. The structures to be monitored during the construction stages should include all of the sensitive structures included within the assessment. Condition surveys of the existing structures should be carried out before and after the proposed works.

The precise monitoring strategy will be developed at a later stage and it will be subject to discussions and agreements with the owners of the adjacent properties and structures. Contingency measures will be implemented if movements of the adjacent structures exceed predefined trigger levels. Both contingency measures and trigger levels will need to be developed within a future monitoring specification for the works.

## 9.0 BIA CONCLUSIONS

The ground investigation has confirmed the findings of previous investigations carried out on adjacent sites, in that the Lynch Hill Gravel is present over the London Clay Formation. Groundwater has been measured at a depth of 2.19 m below existing basement level, approximately 4.70 m below ground level, and therefore the proposed basement extension will not extend below the groundwater table and will therefore not have an impact on the local hydrogeological setting.

The analysis has predicted that the proposed basement construction may result in a building damage category for sensitive structures of no greater than Category 0 (negligible). Therefore, the movements associated with the proposed basement excavation are considered to be acceptable and within the limits required by the London Borough of Camden for basement developments. The proposed development is not considered to pose a risk to the stability of the neighbouring properties or the footway or carriageway of Denmark Street.

## 10.0 OUTSTANDING RISKS AND ISSUES

This section of the report aims to highlight areas where further work is required as a result of limitations on the scope of the investigation and analysis, or where issues have been identified by the work that warrant further consideration. The scope of risks and issues discussed in this section is by no means exhaustive, but covers the main areas where additional work may be required.

The ground is a heterogeneous natural material and variations will inevitably arise between the locations at which it is investigated. This report provides an assessment of the ground conditions based on the discrete points at which the ground was sampled, but the ground conditions should be subject to review as the work proceeds to ensure that any variations from the Ground Model are properly assessed by a suitably qualified person.

A detailed monitoring regime is recommended at detailed design stage in order to ensure ground movements are restricted to acceptable limits.

# APPENDIX

Borehole Records

Site Plan

Archive Borehole Records

**P-DISP ANALYSIS:**

Short Term Movement Plot

Total Movement Plot

**X-DISP ANALYSIS**

**Wall Installation and Basement Excavation combined**
Contour Plots of Horizontal Movements (underpinning)

**BUILDING DAMAGE ASSESSMENT – RESULTS TABLE**

GEA

Geotechnical & Environmental Associates

Widbury Barn | Widbury Hill | Ware | SG12 7QE

| Site | Number |
|---|---|
| 7 Denmark Street, London, WC2H 8LZ | BH1 |

| Excavation Method | Dimensions | Ground Level (mOD) | Client | Job Number |
|---|---|---|---|---|
| Drive-in Windowless Sampler | | 22.34 | Cord Contracting Co Ltd | J18119 |
| | **Location** | **Dates** | **Engineer** | **Sheet** |
| | Basement lightwell | 25/05/2018 | Engenuiti | 1/1 |

| Depth (m) | Sample / Tests | Water Depth (m) | Field Records | Level (mOD) | Depth (m) (Thickness) | Description | Legend | Water |
|---|---|---|---|---|---|---|---|---|
| | | | | | (0.40) | MADE GROUND (fine grained concrete to 100 mm over light grey silty gravelly sand with lumps pf clay and frequent fragments of cocnrete, flint, brick and clinker). | | |
| | | | | 21.94 | 0.40 | | | |
| | | | | | (0.40) | Light orange-brown sandy slightly gravelly CLAY. Gravel is fine subrounded flint. Sand is fine to coarse. | | |
| | | | | 21.54 | 0.80 | | | |
| | | | | | (0.20) | Light orange-grey clayey SAND. Sand is fine to coarse | | |
| | | | | 21.34 | 1.00 | | | |
| 1.00 | D1 | | | | (0.60) | Dark orange-brown silty gravelly SAND. Gravel is fine subrounded flint. Sand is fine to coarse, (Damp). | | |
| | | | | 20.74 | 1.60 | | | |
| | | | Water strike(1) at 1.80m. | | | Light yellow-grey silty Sand. Sand is fine to coarse. | | ▽1 |
| 2.00 | D2 | | | | (0.90) | | | |
| 2.50 | D3 | | | 19.84 | 2.50 | Soft light brown silty CLAY | | |
| | | | | | (0.50) | | | |
| | | | | 19.34 | 3.00 | Firm fissured light grey silty CLAY. | | |
| 3.50 | D4 | | | | | | | |
| 4.00 | D5 | | | | (2.00) | | | |
| | | | | 17.34 | 5.00 | Complete at 5.00m | | |

**Remarks**

Borehole fell back from 3.80 m to 4.00 m.

| Scale (approx) | Logged By |
|---|---|
| 1:50 | LS |

**Figure No.** J18119.BH1

GEA
Geotechnical & Environmental Associates
Widbury Barn | Widbury Hill | Ware | SG12 7QE

| Site | Number |
|---|---|
| 7 Denmark Street, London, WC2H 8LZ | BH2 |

| Excavation Method | Dimensions | Ground Level (mOD) | Client | Job Number |
|---|---|---|---|---|
| Drive-in Windowless Sampler | | 25.04 | Cord Contracting Co Ltd | J18119 |
| | **Location** | **Dates** | **Engineer** | **Sheet** |
| | Ground floor | 25/05/2018 | Engenuiti | 1/1 |

| Depth (m) | Sample / Tests | Water Depth (m) | Field Records | Level (mOD) | Depth (m) (Thickness) | Description | Legend | Water |
|---|---|---|---|---|---|---|---|---|
| | | | | | (0.80) | MADE GROUND (dark grey black silty sand with fragments of brick and flint). | | |
| | | | | 24.24 | 0.80 | MADE GROUND (light grey clayey sand with frequent fragments of clinker, brick, flint and rare concrete). | | |
| | | | | | (1.70) | ... becoming sandy clay at 1.40 m. | | |
| | | | | 22.54 | 2.50 | Light yellow-grey very sandy slighty gravelly CLAY. Gravel is fine subrounded flint. Sand is fine to coarse. | | |
| | | | | 22.54 | 2.50 | Light orange silty gravelly SAND. Gravel is fine to medium subrounded flint. | | |
| 3.00 | D1 | | | | | ... becoming green grey at 3.00 . | | |
| 3.80 | D2 | | | | (2.50) | ... becoming sand only at 3.80 m. | | |
| | | | | 20.04 | 5.00 | Terminated at 5.00m | | |

**Remarks**
Borehole terminated due to dense sand.

| Scale (approx) | Logged By |
|---|---|
| 1:50 | LS |

**Figure No.**
J18119.BH2

GEA

www.gea-ltd.co.uk

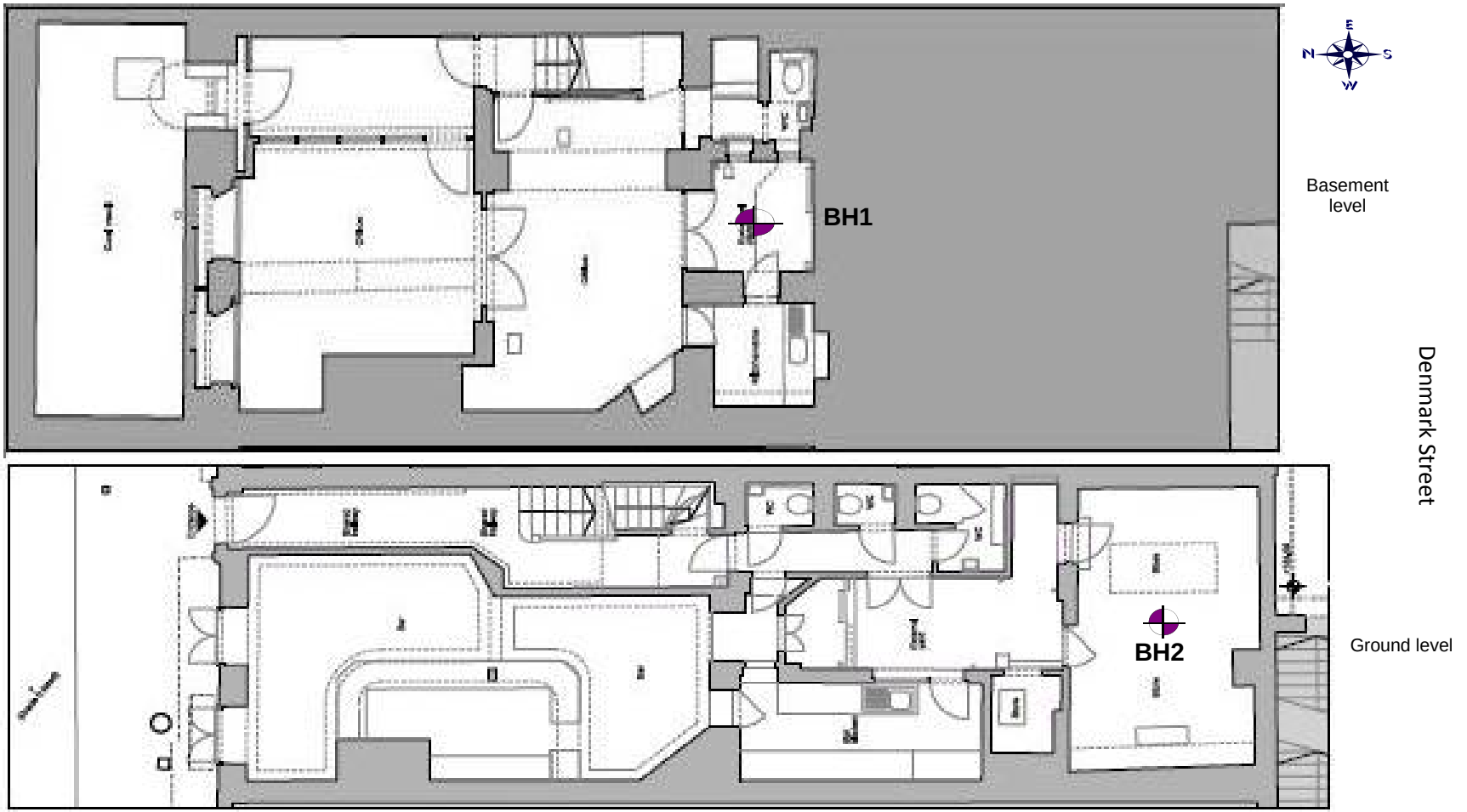
Herts | 01727 824666  Notts | 01509 674888

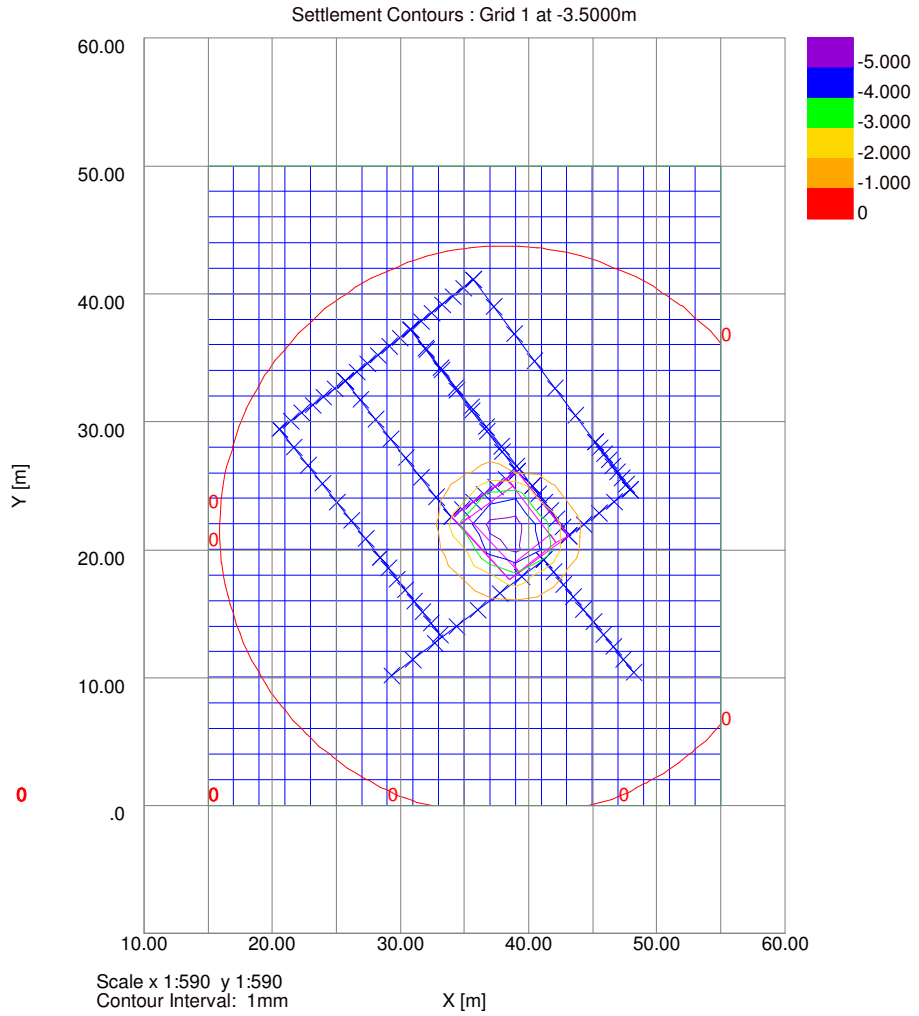
# Site Plan

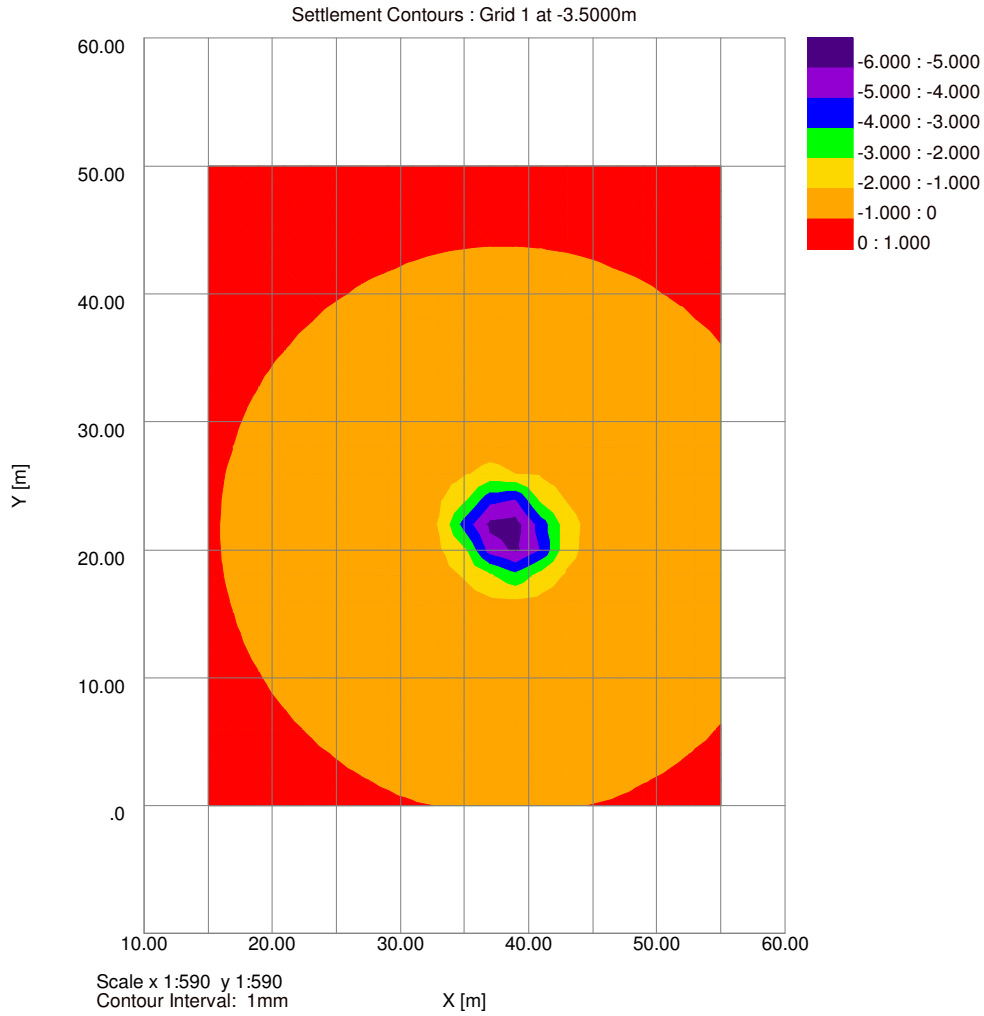
| | |
|---|---|
| **Site** | 7 Denmark Street, London, WC2H 8LZ |
| **Client** | Cord Contracting Co Ltd |
| **Engineer** | Engenuiti |

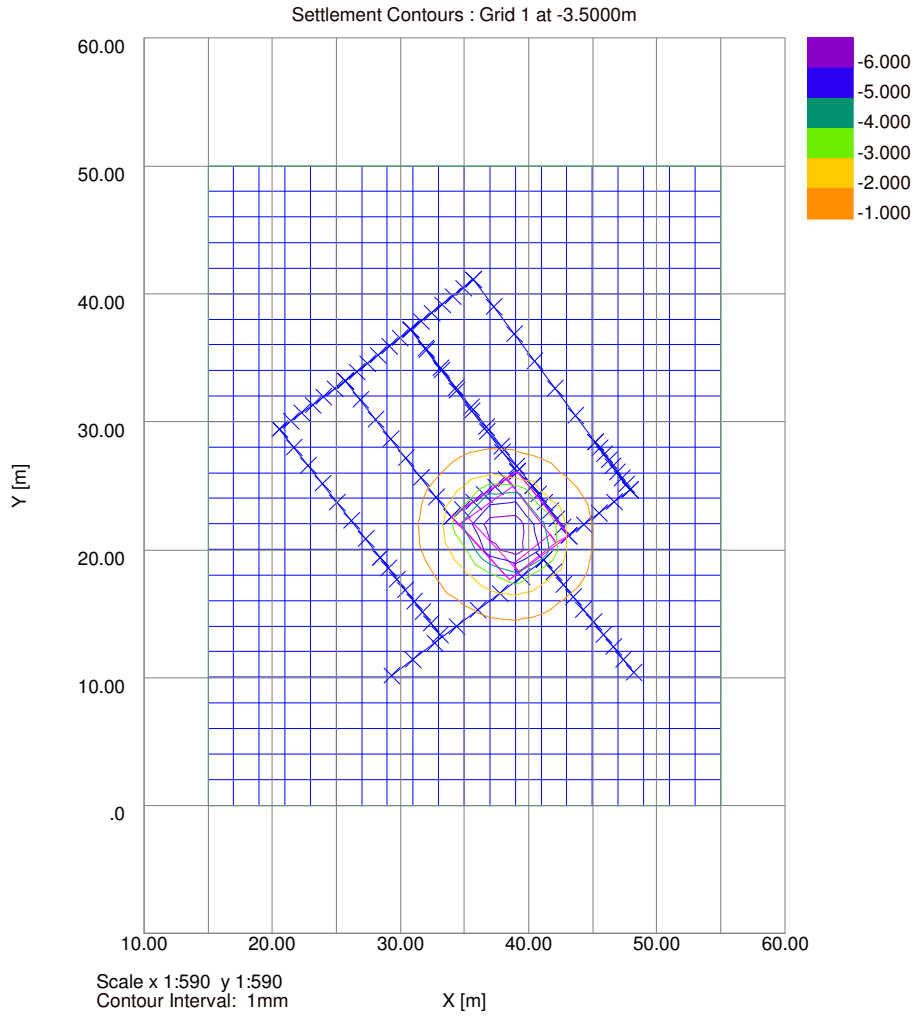
**Job Number** J18119

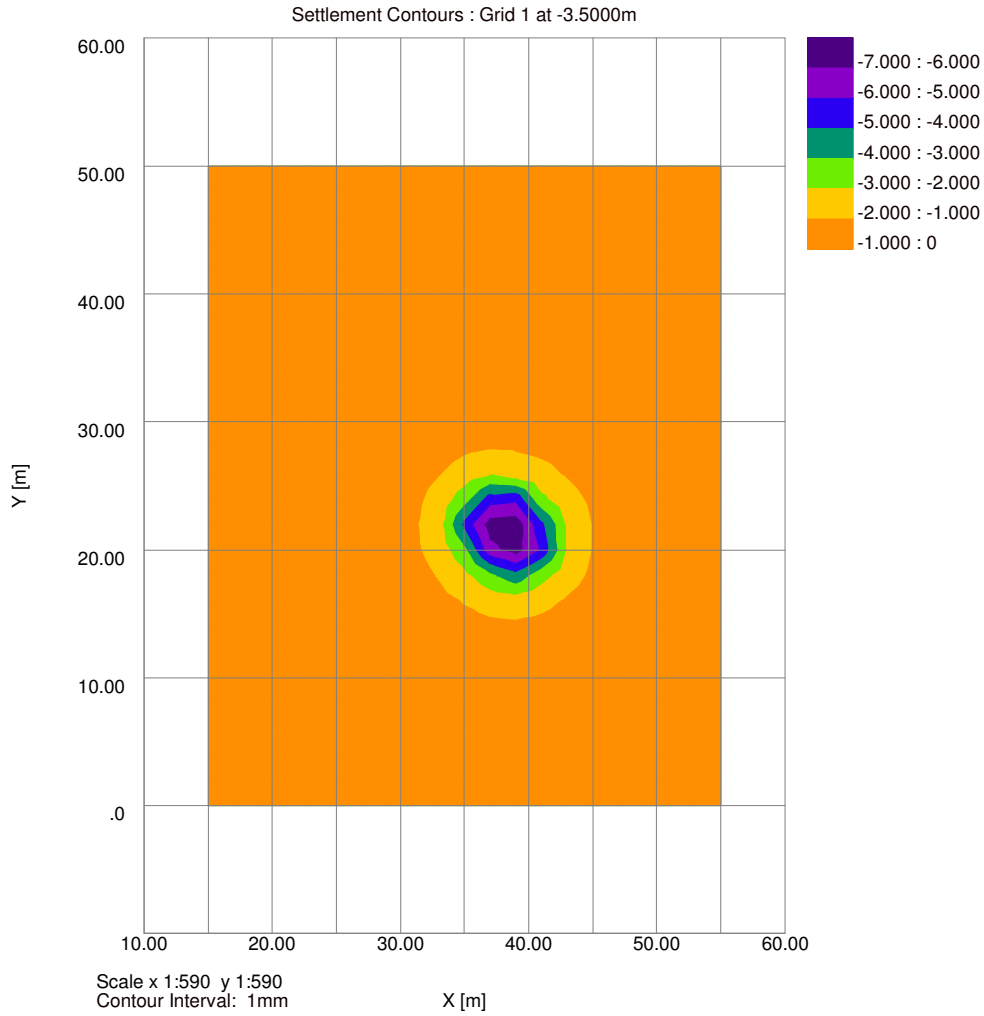
**Sheet** 1 / 1



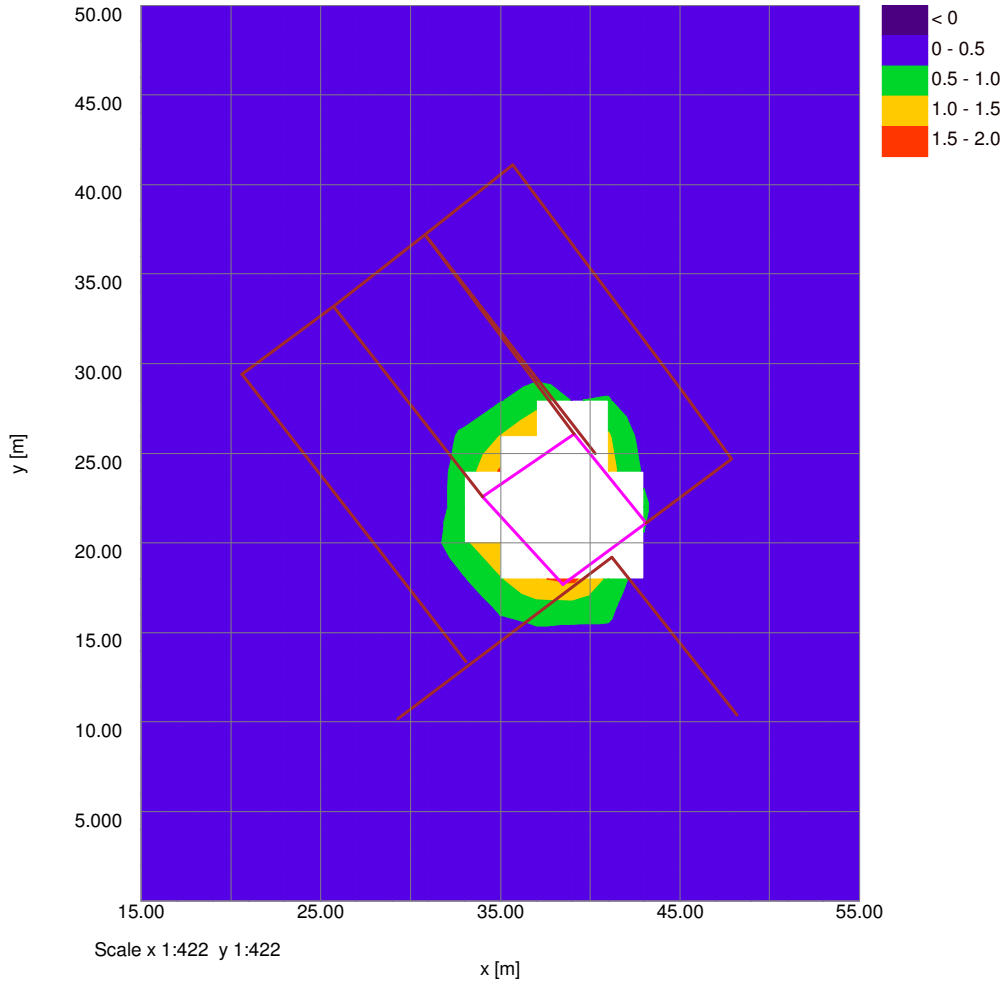

Settlement Contours : Grid 1 at -3.5000m
-5.000
-4.000
-3.000
-2.000
-1.000
0
60.00
50.00
40.00
30.00
20.00
10.00
.0
Y [m]
10.00
20.00
30.00
40.00
50.00
60.00
X [m]
Scale x 1:590 y 1:590
Contour Interval: 1mm


Settlement Contours : Grid 1 at -3.5000m
-6.000 : -5.000
-5.000 : -4.000
-4.000 : -3.000
-3.000 : -2.000
-2.000 : -1.000
-1.000 : 0
0 : 1.000
60.00
50.00
40.00
30.00
20.00
10.00
.0
Y [m]
10.00
20.00
30.00
40.00
50.00
60.00
X [m]
Scale x 1:590 y 1:590
Contour Interval: 1mm

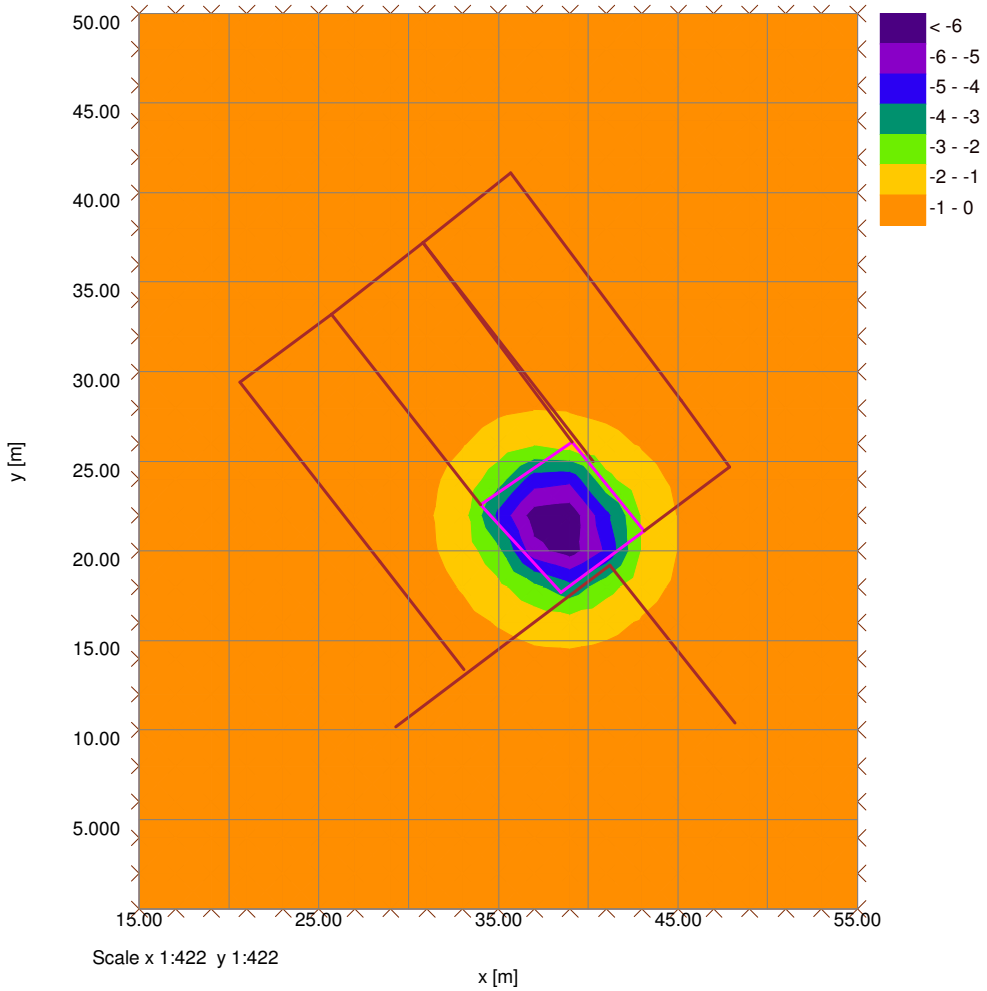

Settlement Contours : Grid 1 at -3.5000m
60.00
50.00
40.00
30.00
20.00
10.00
.0
Y [m]
10.00
20.00
30.00
40.00
50.00
60.00
X [m]
-6.000
-5.000
-4.000
-3.000
-2.000
-1.000
Scale x 1:590 y 1:590
Contour Interval: 1mm


Settlement Contours : Grid 1 at -3.5000m
60.00
50.00
40.00
30.00
20.00
10.00
.0
Y [m]
10.00
20.00
30.00
40.00
50.00
60.00
X [m]
-7.000 : -6.000
-6.000 : -5.000
-5.000 : -4.000
-4.000 : -3.000
-3.000 : -2.000
-2.000 : -1.000
-1.000 : 0
Scale x 1:590 y 1:590
Contour Interval: 1mm

Horizontal Displacement Contours: Grid 1 (level 0.000m) Interval 0.5mm



Vertical Settlement Contours: Grid 2 (level -3.500m) (Interval 1mm)



***Utility Strain Calculation Options***

Neglect beneficial contribution of axial strains : No

***Specific Building Damage Results - Horizontal Displacements***

Structure: No 6 Denmark Street | Sub-structure: No6 A

| Dist. | Coordinates | | | Displacements | | | |
|---|---|---|---|---|---|---|---|
| | x | y | z | x | y | Horizontal displacement along the Line | Horizontal displacement perpendicular to Line |
| [m] | [m] | [m] | [m] | [mm] | [mm] | [mm] | [mm] |
| 0.0 | 30.80000 | 37.20000 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 1.9328 | 31.98750 | 35.67500 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 3.8656 | 33.17500 | 34.15000 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 5.7985 | 34.36250 | 32.62500 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 7.7313 | 35.55000 | 31.10000 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 9.6641 | 36.73750 | 29.57500 | -2.50000 | 0.13457 | -0.19703 | 0.23814 | -0.014876 d |
| 11.597 | 37.92500 | 28.05000 | -2.50000 | 0.34961 | -0.54554 | 0.64523 | -0.059331 d |
| 13.530 | 39.11250 | 26.52500 | -2.50000 | 0.021970 | -0.65695 | 0.53183 | -0.38628 d |
| 15.463 | 40.30000 | 25.00000 | -2.50000 | -1.0749 | -0.85992 | 0.018074 | -1.3764 d |

d - Displacements include imported displacements.

Structure: No 6 Denmark Street | Sub-structure: No6 C

| Dist. | Coordinates | | | Displacements | | | |
|---|---|---|---|---|---|---|---|
| | x | y | z | x | y | Horizontal displacement along the Line | Horizontal displacement perpendicular to Line |
| [m] | [m] | [m] | [m] | [mm] | [mm] | [mm] | [mm] |
| 0.0 | 43.10000 | 21.10000 | -0.70000 | -0.15186 | -0.12149 | -0.19438 | -0.0060743 d |
| 1.5000 | 44.30000 | 22.00000 | -0.70000 | -0.047847 | -0.037126 | -0.060553 | -992.73E-6 d |
| 3.0000 | 45.50000 | 22.90000 | -0.70000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 4.5000 | 46.70000 | 23.80000 | -0.70000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 6.0000 | 47.90000 | 24.70000 | -0.70000 | 0.0 | 0.0 | 0.0 | 0.0 d |

d - Displacements include imported displacements.

Structure: No 6 Denmark Street | Sub-structure: No6 D

| Dist. | Coordinates | | | Displacements | | | |
|---|---|---|---|---|---|---|---|
| | x | y | z | x | y | Horizontal displacement along the Line | Horizontal displacement perpendicular to Line |
| [m] | [m] | [m] | [m] | [mm] | [mm] | [mm] | [mm] |
| 0.0 | 47.90000 | 24.70000 | -0.70000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 0.57255 | 47.56250 | 25.16250 | -0.70000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 1.1451 | 47.22500 | 25.62500 | -0.70000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 1.7176 | 46.88750 | 26.08750 | -0.70000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 2.2902 | 46.55000 | 26.55000 | -0.70000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 2.8627 | 46.21250 | 27.01250 | -0.70000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 3.4353 | 45.87500 | 27.47500 | -0.70000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 4.0078 | 45.53750 | 27.93750 | -0.70000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 4.5804 | 45.20000 | 28.40000 | -0.70000 | 0.0 | 0.0 | 0.0 | 0.0 d |

d - Displacements include imported displacements.

Structure: No 6 Denmark Street | Sub-structure: No6 E

| Dist. | Coordinates | | | Displacements | | | |
|---|---|---|---|---|---|---|---|
| | x | y | z | x | y | Horizontal displacement along the Line | Horizontal displacement perpendicular to Line |
| [m] | [m] | [m] | [m] | [mm] | [mm] | [mm] | [mm] |
| 0.0 | 45.20000 | 28.40000 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 2.6433 | 43.61667 | 30.51667 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 5.2867 | 42.03333 | 32.63333 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 7.9300 | 40.45000 | 34.75000 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 10.573 | 38.86667 | 36.86667 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 13.217 | 37.28333 | 38.98333 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 15.860 | 35.70000 | 41.10000 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |

d - Displacements include imported displacements.

Structure: No 6 Denmark Street | Sub-structure: No6 F

| Dist. | Coordinates | | | Displacements | | | |
|---|---|---|---|---|---|---|---|
| | x | y | z | x | y | Horizontal displacement along the Line | Horizontal displacement perpendicular to Line |
| [m] | [m] | [m] | [m] | [mm] | [mm] | [mm] | [mm] |
| 0.0 | 35.70000 | 41.10000 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.0438 | 34.88333 | 40.45000 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2.0875 | 34.06667 | 39.80000 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3.1313 | 33.25000 | 39.15000 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4.1751 | 32.43333 | 38.50000 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5.2188 | 31.61667 | 37.85000 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6.2626 | 30.80000 | 37.20000 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |

Structure: No 9 Denmark Street | Sub-structure: No9 A

| Dist. | Coordinates | | | Displacements | | | |
|---|---|---|---|---|---|---|---|
| | x | y | z | x | y | Horizontal displacement along the Line | Horizontal displacement perpendicular to Line |
| [m] | [m] | [m] | [m] | [mm] | [mm] | [mm] | [mm] |
| 0.0 | 20.60000 | 29.40000 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.8118 | 21.71429 | 27.97143 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3.6235 | 22.82857 | 26.54286 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5.4353 | 23.94286 | 25.11429 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7.2470 | 25.05714 | 23.68571 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9.0588 | 26.17143 | 22.25714 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10.871 | 27.28571 | 20.82857 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12.682 | 28.40000 | 19.40000 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |

Structure: No 9 Denmark Street | Sub-structure: No9 B

| Dist. | Coordinates | | | Displacements | | | |
|---|---|---|---|---|---|---|---|
| | x | y | z | x | y | Horizontal displacement along the Line | Horizontal displacement perpendicular to Line |
| [m] | [m] | [m] | [m] | [mm] | [mm] | [mm] | [mm] |
| 0.0 | 28.40000 | 19.40000 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |

| Dist. | Coordinates | | | Displacements | | | |
|---|---|---|---|---|---|---|---|
| | x | y | z | x | y | Horizontal displacement along the Line | Horizontal displacement perpendicular to Line |
| | | | | | | [mm] | [mm] |
| 1.0888 | 29.07143 | 18.54286 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2.1776 | 29.74286 | 17.68571 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3.2664 | 30.41429 | 16.82857 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4.3552 | 31.08571 | 15.97143 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5.4441 | 31.75714 | 15.11429 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6.5329 | 32.42857 | 14.25714 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7.6217 | 33.10000 | 13.40000 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |

Structure: No 8 Denmark Street | Sub-structure: No8 A

| Dist. | Coordinates | | | Displacements | | | |
|---|---|---|---|---|---|---|---|
| | x | y | z | x | y | Horizontal displacement along the Line | Horizontal displacement perpendicular to Line |
| [m] | [m] | [m] | [m] | [mm] | [mm] | [mm] | [mm] |
| 0.0 | 25.70000 | 33.20000 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.0600 | 24.85000 | 32.56667 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2.1200 | 24.00000 | 31.93333 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3.1800 | 23.15000 | 31.30000 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4.2400 | 22.30000 | 30.66667 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5.3000 | 21.45000 | 30.03333 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6.3600 | 20.60000 | 29.40000 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 |

Structure: 122 Charing Cross Rd | Sub-structure: 122A

| Dist. | Coordinates | | | Displacements | | | |
|---|---|---|---|---|---|---|---|
| | x | y | z | x | y | Horizontal displacement along the Line | Horizontal displacement perpendicular to Line |
| [m] | [m] | [m] | [m] | [mm] | [mm] | [mm] | [mm] |
| 0.0 | 29.30000 | 10.20000 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 2.1314 | 31.00000 | 11.48571 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 4.2629 | 32.70000 | 12.77143 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 6.3943 | 34.40000 | 14.05714 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 8.5258 | 36.10000 | 15.34286 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 10.657 | 37.80000 | 16.62857 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 12.789 | 39.50000 | 17.91429 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 14.920 | 41.20000 | 19.20000 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |

d - Displacements include imported displacements.

Structure: 122 Charing Cross Rd | Sub-structure: 122B

| Dist. | Coordinates | | | Displacements | | | |
|---|---|---|---|---|---|---|---|
| | x | y | z | x | y | Horizontal displacement along the Line | Horizontal displacement perpendicular to Line |
| [m] | [m] | [m] | [m] | [mm] | [mm] | [mm] | [mm] |
| 0.0 | 41.20000 | 19.20000 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 1.2494 | 41.97778 | 18.22222 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 2.4988 | 42.75556 | 17.24444 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 3.7482 | 43.53333 | 16.26667 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 4.9976 | 44.31111 | 15.28889 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 6.2470 | 45.08889 | 14.31111 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 7.4964 | 45.86667 | 13.33333 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 8.7458 | 46.64444 | 12.35556 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 9.9952 | 47.42222 | 11.37778 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 11.245 | 48.20000 | 10.40000 | -3.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |

d - Displacements include imported displacements.

Structure: No 7 Retained | Sub-structure: No7 A

| Dist. | Coordinates | | | Displacements | | | |
|---|---|---|---|---|---|---|---|
| | x | y | z | x | y | Horizontal displacement along the Line | Horizontal displacement perpendicular to Line |
| [m] | [m] | [m] | [m] | [mm] | [mm] | [mm] | [mm] |
| 0.0 | 25.70000 | 33.20000 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 1.9233 | 26.88571 | 31.68571 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 3.8465 | 28.07143 | 30.17143 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 5.7698 | 29.25714 | 28.65714 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 7.6931 | 30.44286 | 27.14286 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 9.6164 | 31.62857 | 25.62857 | -2.50000 | 0.15972 | -0.21906 | 0.27094 | -0.0093003 d |
| 11.540 | 32.81429 | 24.11429 | -2.50000 | 0.37859 | -0.51926 | 0.64224 | -0.022045 d |
| 13.463 | 34.00000 | 22.60000 | -2.50000 | 0.88803 | -0.36061 | 0.83140 | 0.47687 d |

d - Displacements include imported displacements.

Structure: No 7 Retained | Sub-structure: No7 C

| Dist. | Coordinates | | | Displacements | | | |
|---|---|---|---|---|---|---|---|
| | x | y | z | x | y | Horizontal displacement along the Line | Horizontal displacement perpendicular to Line |
| [m] | [m] | [m] | [m] | [mm] | [mm] | [mm] | [mm] |
| 0.0 | 39.10000 | 26.10000 | -2.50000 | -0.12896 | -0.86912 | -0.61882 | 0.62375 d |
| 1.9800 | 37.91429 | 27.68571 | -2.50000 | 0.61708 | -0.89917 | -1.0896 | 0.044268 d |
| 3.9600 | 36.72857 | 29.27143 | -2.50000 | 0.24393 | -0.35544 | -0.43073 | 0.017499 d |
| 5.9400 | 35.54286 | 30.85714 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 7.9200 | 34.35714 | 32.44286 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 9.9000 | 33.17143 | 34.02857 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 11.880 | 31.98571 | 35.61429 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 13.860 | 30.80000 | 37.20000 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |

d - Displacements include imported displacements.

Structure: No 7 Retained | Sub-structure: No7 D

| Dist. | Coordinates | | | Displacements | | | |
|---|---|---|---|---|---|---|---|
| | x | y | z | x | y | Horizontal displacement along the Line | Horizontal displacement perpendicular to Line |
| [m] | [m] | [m] | [m] | [mm] | [mm] | [mm] | [mm] |
| 0.0 | 30.80000 | 37.20000 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 1.0803 | 29.95000 | 36.53333 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 2.1605 | 29.10000 | 35.86667 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 3.2408 | 28.25000 | 35.20000 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 4.3210 | 27.40000 | 34.53333 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 5.4013 | 26.55000 | 33.86667 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |
| 6.4815 | 25.70000 | 33.20000 | -2.50000 | 0.0 | 0.0 | 0.0 | 0.0 d |

d - Displacements include imported displacements.

***Specific Building Damage Results - Vertical Displacements***

Structure: No 6 Denmark Street | Sub-structure: No6 A

| Dist. | Coordinates | | | Displacements |
|---|---|---|---|---|

| Dist. | x | y | z | z |
|---|---|---|---|---|
| [m] | [m] | [m] | [m] | [mm] |
| **Vertical Offset 1** | | | | |
| 0.0 | 30.80000 | 37.20000 | -2.50000 | -0.36396 d |
| 1.9328 | 31.98750 | 35.67500 | -2.50000 | -0.12971 d |
| 3.8656 | 33.17500 | 34.15000 | -2.50000 | -0.18673 d |
| 5.7985 | 34.36250 | 32.62500 | -2.50000 | -0.27255 d |
| 7.7313 | 35.55000 | 31.10000 | -2.50000 | -0.40522 d |
| 9.6641 | 36.73750 | 29.57500 | -2.50000 | -0.61601 d |
| 11.597 | 37.92500 | 28.05000 | -2.50000 | -0.95219 d |
| 13.530 | 39.11250 | 26.52500 | -2.50000 | -1.3819 d |
| 15.463 | 40.30000 | 25.00000 | -2.50000 | -1.8711 d |

d - Displacements include imported displacements.

Structure: No 6 Denmark Street | Sub-structure: No6 C

| Dist. | x | y | z | z |
|---|---|---|---|---|
| [m] | [m] | [m] | [m] | [mm] |
| **Vertical Offset 1** | | | | |
| 0.0 | 43.10000 | 21.10000 | -0.70000 | -3.9354 d |
| 1.5000 | 44.30000 | 22.00000 | -0.70000 | -1.2244 d |
| 3.0000 | 45.50000 | 22.90000 | -0.70000 | -0.80501 d |
| 4.5000 | 46.70000 | 23.80000 | -0.70000 | -0.55355 d |
| 6.0000 | 47.90000 | 24.70000 | -0.70000 | -0.78577 d |

d - Displacements include imported displacements.

Structure: No 6 Denmark Street | Sub-structure: No6 D

| Dist. | x | y | z | z |
|---|---|---|---|---|
| [m] | [m] | [m] | [m] | [mm] |
| **Vertical Offset 1** | | | | |
| 0.0 | 47.90000 | 24.70000 | -0.70000 | -0.78577 d |
| 0.57255 | 47.56250 | 25.16250 | -0.70000 | -0.40470 d |
| 1.1451 | 47.22500 | 25.62500 | -0.70000 | -0.41394 d |
| 1.7176 | 46.88750 | 26.08750 | -0.70000 | -0.42034 d |
| 2.2902 | 46.55000 | 26.55000 | -0.70000 | -0.42369 d |
| 2.8627 | 46.21250 | 27.01250 | -0.70000 | -0.42394 d |
| 3.4353 | 45.87500 | 27.47500 | -0.70000 | -0.42112 d |
| 4.0078 | 45.53750 | 27.93750 | -0.70000 | -0.41537 d |
| 4.5804 | 45.20000 | 28.40000 | -0.70000 | -0.40691 d |

d - Displacements include imported displacements.

Structure: No 6 Denmark Street | Sub-structure: No6 E

| Dist. | x | y | z | z |
|---|---|---|---|---|
| [m] | [m] | [m] | [m] | [mm] |
| **Vertical Offset 1** | | | | |
| 0.0 | 45.20000 | 28.40000 | -2.50000 | -0.40691 d |
| 2.6433 | 43.61667 | 30.51667 | -2.50000 | -0.34446 d |
| 5.2867 | 42.03333 | 32.63333 | -2.50000 | -0.26332 d |
| 7.9300 | 40.45000 | 34.75000 | -2.50000 | -0.18831 d |
| 10.573 | 38.86667 | 36.86667 | -2.50000 | -0.12949 d |
| 13.217 | 37.28333 | 38.98333 | -2.50000 | -0.087091 d |
| 15.860 | 35.70000 | 41.10000 | -2.50000 | -0.11552 d |

d - Displacements include imported displacements.

Structure: No 6 Denmark Street | Sub-structure: No6 F

| Dist. | x | y | z | z |
|---|---|---|---|---|
| [m] | [m] | [m] | [m] | [mm] |
| **Vertical Offset 1** | | | | |
| 0.0 | 35.70000 | 41.10000 | -3.50000 | 0.0 |
| 1.0438 | 34.88333 | 40.45000 | -3.50000 | 0.0 |
| 2.0875 | 34.06667 | 39.80000 | -3.50000 | 0.0 |
| 3.1313 | 33.25000 | 39.15000 | -3.50000 | 0.0 |
| 4.1751 | 32.43333 | 38.50000 | -3.50000 | 0.0 |
| 5.2188 | 31.61667 | 37.85000 | -3.50000 | 0.0 |
| 6.2626 | 30.80000 | 37.20000 | -3.50000 | 0.0 |

Structure: No 9 Denmark Street | Sub-structure: No9 A

| Dist. | x | y | z | z |
|---|---|---|---|---|
| [m] | [m] | [m] | [m] | [mm] |
| **Vertical Offset 1** | | | | |
| 0.0 | 20.60000 | 29.40000 | -3.50000 | 0.0 |
| 1.8118 | 21.71429 | 27.97143 | -3.50000 | 0.0 |
| 3.6235 | 22.82857 | 26.54286 | -3.50000 | 0.0 |
| 5.4353 | 23.94286 | 25.11429 | -3.50000 | 0.0 |
| 7.2470 | 25.05714 | 23.68571 | -3.50000 | 0.0 |
| 9.0588 | 26.17143 | 22.25714 | -3.50000 | 0.0 |
| 10.871 | 27.28571 | 20.82857 | -3.50000 | 0.0 |
| 12.682 | 28.40000 | 19.40000 | -3.50000 | 0.0 |

Structure: No 9 Denmark Street | Sub-structure: No9 B

| Dist. | x | y | z | z |
|---|---|---|---|---|
| [m] | [m] | [m] | [m] | [mm] |
| **Vertical Offset 1** | | | | |
| 0.0 | 28.40000 | 19.40000 | -3.50000 | 0.0 |
| 1.0888 | 29.07143 | 18.54286 | -3.50000 | 0.0 |
| 2.1776 | 29.74286 | 17.68571 | -3.50000 | 0.0 |
| 3.2664 | 30.41429 | 16.82857 | -3.50000 | 0.0 |
| 4.3552 | 31.08571 | 15.97143 | -3.50000 | 0.0 |
| 5.4441 | 31.75714 | 15.11429 | -3.50000 | 0.0 |
| 6.5329 | 32.42857 | 14.25714 | -3.50000 | 0.0 |
| 7.6217 | 33.10000 | 13.40000 | -3.50000 | 0.0 |

Structure: No 8 Denmark Street | Sub-structure: No8 A

| Dist. | x | y | z | z |
|---|---|---|---|---|
| [m] | [m] | [m] | [m] | [mm] |
| **Vertical Offset 1** | | | | |
| 0.0 | 25.70000 | 33.20000 | -3.50000 | 0.0 |
| 1.0600 | 24.85000 | 32.56667 | -3.50000 | 0.0 |
| 2.1200 | 24.00000 | 31.93333 | -3.50000 | 0.0 |
| 3.1800 | 23.15000 | 31.30000 | -3.50000 | 0.0 |
| 4.2400 | 22.30000 | 30.66667 | -3.50000 | 0.0 |

| Dist. | Coordinates x | y | z | Displacements z |
|---|---|---|---|---|
| [m] | [m] | [m] | [m] | [mm] |
| 5.3000 | 21.45000 | 30.03333 | -3.50000 | 0.0 |
| 6.3600 | 20.60000 | 29.40000 | -3.50000 | 0.0 |

Structure: 122 Charing Cross Rd | Sub-structure: 122A

| Dist. | Coordinates x | y | z | Displacements z |
|---|---|---|---|---|
| [m] | [m] | [m] | [m] | [mm] |
| **Vertical Offset 1** | | | | |
| 0.0 | 29.30000 | 10.20000 | -3.50000 | -0.16452 d |
| 2.1314 | 31.00000 | 11.48571 | -3.50000 | -0.24889 d |
| 4.2629 | 32.70000 | 12.77143 | -3.50000 | -0.38558 d |
| 6.3943 | 34.40000 | 14.05714 | -3.50000 | -0.61841 d |
| 8.5258 | 36.10000 | 15.34286 | -3.50000 | -1.0428 d |
| 10.657 | 37.80000 | 16.62857 | -3.50000 | -1.8750 d |
| 12.789 | 39.50000 | 17.91429 | -3.50000 | -3.1917 d |
| 14.920 | 41.20000 | 19.20000 | -3.50000 | -6.7078 d |

d - Displacements include imported displacements.

Structure: 122 Charing Cross Rd | Sub-structure: 122B

| Dist. | Coordinates x | y | z | Displacements z |
|---|---|---|---|---|
| [m] | [m] | [m] | [m] | [mm] |
| **Vertical Offset 1** | | | | |
| 0.0 | 41.20000 | 19.20000 | -3.50000 | -6.7078 d |
| 1.2494 | 41.97778 | 18.22222 | -3.50000 | -1.9764 d |
| 2.4988 | 42.75556 | 17.24444 | -3.50000 | -1.2729 d |
| 3.7482 | 43.53333 | 16.26667 | -3.50000 | -0.86891 d |
| 4.9976 | 44.31111 | 15.28889 | -3.50000 | -0.61876 d |
| 6.2470 | 45.08889 | 14.31111 | -3.50000 | -0.45422 d |
| 7.4964 | 45.86667 | 13.33333 | -3.50000 | -0.34088 d |
| 8.7458 | 46.64444 | 12.35556 | -3.50000 | -0.26004 d |
| 9.9952 | 47.42222 | 11.37778 | -3.50000 | -0.20083 d |
| 11.245 | 48.20000 | 10.40000 | -3.50000 | -0.15657 d |

d - Displacements include imported displacements.

Structure: No 7 Retained | Sub-structure: No7 A

| Dist. | Coordinates x | y | z | Displacements z |
|---|---|---|---|---|
| [m] | [m] | [m] | [m] | [mm] |
| **Vertical Offset 1** | | | | |
| 0.0 | 25.70000 | 33.20000 | -2.50000 | -0.19281 d |
| 1.9233 | 26.88571 | 31.68571 | -2.50000 | -0.13851 d |
| 3.8465 | 28.07143 | 30.17143 | -2.50000 | -0.20175 d |
| 5.7698 | 29.25714 | 28.65714 | -2.50000 | -0.29997 d |
| 7.6931 | 30.44286 | 27.14286 | -2.50000 | -0.45983 d |
| 9.6164 | 31.62857 | 25.62857 | -2.50000 | -0.73827 d |
| 11.540 | 32.81429 | 24.11429 | -2.50000 | -1.2715 d |
| 13.463 | 34.00000 | 22.60000 | -2.50000 | -4.9721 d |

d - Displacements include imported displacements.

Structure: No 7 Retained | Sub-structure: No7 C

| Dist. | Coordinates x | y | z | Displacements z |
|---|---|---|---|---|
| [m] | [m] | [m] | [m] | [mm] |
| **Vertical Offset 1** | | | | |
| 0.0 | 39.10000 | 26.10000 | -2.50000 | -2.8012 d |
| 1.9800 | 37.91429 | 27.68571 | -2.50000 | -1.0633 d |
| 3.9600 | 36.72857 | 29.27143 | -2.50000 | -0.66625 d |
| 5.9400 | 35.54286 | 30.85714 | -2.50000 | -0.42796 d |
| 7.9200 | 34.35714 | 32.44286 | -2.50000 | -0.28276 d |
| 9.9000 | 33.17143 | 34.02857 | -2.50000 | -0.19100 d |
| 11.880 | 31.98571 | 35.61429 | -2.50000 | -0.13110 d |
| 13.860 | 30.80000 | 37.20000 | -2.50000 | -0.36396 d |

d - Displacements include imported displacements.

Structure: No 7 Retained | Sub-structure: No7 D

| Dist. | Coordinates x | y | z | Displacements z |
|---|---|---|---|---|
| [m] | [m] | [m] | [m] | [mm] |
| **Vertical Offset 1** | | | | |
| 0.0 | 30.80000 | 37.20000 | -2.50000 | -0.36396 d |
| 1.0803 | 29.95000 | 36.53333 | -2.50000 | -0.094844 d |
| 2.1605 | 29.10000 | 35.86667 | -2.50000 | -0.097651 d |
| 3.2408 | 28.25000 | 35.20000 | -2.50000 | -0.099264 d |
| 4.3210 | 27.40000 | 34.53333 | -2.50000 | -0.099597 d |
| 5.4013 | 26.55000 | 33.86667 | -2.50000 | -0.098627 d |
| 6.4815 | 25.70000 | 33.20000 | -2.50000 | -0.19281 d |

d - Displacements include imported displacements.

***Specific Building Damage Results - All Segments***

Structure: No 6 Denmark Street | Sub-structure: No6 A

| Vertical Offset from Line for Vertical Movement Calculations | Segment | Start | Length | Curvature | Deflection Ratio | Average Horizontal Strain | Max Tensile Strain | Max Gradient of Horizontal Displacement Curve | Max Gradient of Vertical Displacement Curve | Min Radius of Curvature | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|---|
| [m] | | [m] | [m] | | [%] | [%] | [%] | | | [m] | |
| 0.0 | 1 | 0.0 | 15.460 | Sagging | 0.0046004 | 121.27E-6 | 0.0058543 | 265.88E-6 | 253.18E-6 | 10468. | 0 (Negligible) |

Tensile horizontal strains are +ve, compressive horizontal strains are -ve.

Structure: No 6 Denmark Street | Sub-structure: No6 C

| Vertical Offset from Line for Vertical Movement Calculations | Segment | Start | Length | Curvature | Deflection Ratio | Average Horizontal Strain | Max Tensile Strain | Max Gradient of Horizontal Displacement Curve | Max Gradient of Vertical Displacement Curve | Min Radius of Curvature | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|---|
| [m] | | [m] | [m] | | [%] | [%] | [%] | | | [m] | |
| 0.0 | 1 | 0.0 | 5.9900 | Sagging | 0.032031 | 0.0032451 | 0.032698 | -89.209E-6 | -0.0018072 | 797.30 | 0 (Negligible) |

Tensile horizontal strains are +ve, compressive horizontal strains are -ve.

Structure: No 6 Denmark Street | Sub-structure: No6 D

| Vertical Offset from Line for | Segment | Start | Length | Curvature | Deflection Ratio | Average Horizontal | Max Tensile | Max Gradient of | Max Gradient of Vertical | Min Radius of | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|---|

| Vertical Movement Calculations | | Segment | Start | Length | Curvature | Deflection Ratio | Average Horizontal Strain | Max Tensile Strain | Max Gradient of Horizontal Displacement Curve | Max Gradient of Vertical Displacement Curve | Min Radius of Curvature | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [m] | | | [m] | [m] | | [%] | [%] | [%] | | | [m] | |
| 0.0 | 1 | | 0.0 | 1.7001 | Sagging | 0.015018 | 0.0 | 0.014881 | 0.0 | -665.57E-6 | 670.91 | 0 (Negligible) |
| | 2 | | 1.7001 | 2.8799 | Hogging | 317.28E-6 | 0.0 | 315.18E-6 | 0.0 | -14.760E-6 | 106420. | 0 (Negligible) |

Tensile horizontal strains are +ve, compressive horizontal strains are -ve.

Structure: No 6 Denmark Street | Sub-structure: No6 E

| Vertical Offset from Line for Vertical Movement Calculations | Segment | Start | Length | Curvature | Deflection Ratio | Average Horizontal Strain | Max Tensile Strain | Max Gradient of Horizontal Displacement Curve | Max Gradient of Vertical Displacement Curve | Min Radius of Curvature | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|---|
| [m] | | [m] | [m] | | [%] | [%] | [%] | | | [m] | |
| 0.0 | 1 | 0.0 | 4.8542 | Hogging | 174.83E-6 | 0.0 | 173.63E-6 | 0.0 | -30.692E-6 | 280980. | 0 (Negligible) |
| | 2 | 4.8542 | 11.006 | Sagging | 609.50E-6 | 0.0 | 604.57E-6 | 0.0 | -30.692E-6 | 82751. | 0 (Negligible) |

Tensile horizontal strains are +ve, compressive horizontal strains are -ve.

Structure: No 6 Denmark Street | Sub-structure: No6 F

| Vertical Offset from Line for Vertical Movement Calculations | Segment | Start | Length | Curvature | Deflection Ratio | Average Horizontal Strain | Max Tensile Strain | Max Gradient of Horizontal Displacement Curve | Max Gradient of Vertical Displacement Curve | Min Radius of Curvature | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|---|
| [m] | | [m] | [m] | | [%] | [%] | [%] | | | [m] | |
| 0.0 | All settlements are less than the Settlement Trough Limit Sensitivity. | | | | | | | | | | |

Tensile horizontal strains are +ve, compressive horizontal strains are -ve.

Structure: No 9 Denmark Street | Sub-structure: No9 A

| Vertical Offset from Line for Vertical Movement Calculations | Segment | Start | Length | Curvature | Deflection Ratio | Average Horizontal Strain | Max Tensile Strain | Max Gradient of Horizontal Displacement Curve | Max Gradient of Vertical Displacement Curve | Min Radius of Curvature | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|---|
| [m] | | [m] | [m] | | [%] | [%] | [%] | | | [m] | |
| 0.0 | All settlements are less than the Settlement Trough Limit Sensitivity. | | | | | | | | | | |

Tensile horizontal strains are +ve, compressive horizontal strains are -ve.

Structure: No 9 Denmark Street | Sub-structure: No9 B

| Vertical Offset from Line for Vertical Movement Calculations | Segment | Start | Length | Curvature | Deflection Ratio | Average Horizontal Strain | Max Tensile Strain | Max Gradient of Horizontal Displacement Curve | Max Gradient of Vertical Displacement Curve | Min Radius of Curvature | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|---|
| [m] | | [m] | [m] | | [%] | [%] | [%] | | | [m] | |
| 0.0 | All settlements are less than the Settlement Trough Limit Sensitivity. | | | | | | | | | | |

Tensile horizontal strains are +ve, compressive horizontal strains are -ve.

Structure: No 8 Denmark Street | Sub-structure: No8 A

| Vertical Offset from Line for Vertical Movement Calculations | Segment | Start | Length | Curvature | Deflection Ratio | Average Horizontal Strain | Max Tensile Strain | Max Gradient of Horizontal Displacement Curve | Max Gradient of Vertical Displacement Curve | Min Radius of Curvature | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|---|
| [m] | | [m] | [m] | | [%] | [%] | [%] | | | [m] | |
| 0.0 | All settlements are less than the Settlement Trough Limit Sensitivity. | | | | | | | | | | |

Tensile horizontal strains are +ve, compressive horizontal strains are -ve.

Structure: 122 Charing Cross Rd | Sub-structure: 122A

| Vertical Offset from Line for Vertical Movement Calculations | Segment | Start | Length | Curvature | Deflection Ratio | Average Horizontal Strain | Max Tensile Strain | Max Gradient of Horizontal Displacement Curve | Max Gradient of Vertical Displacement Curve | Min Radius of Curvature | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|---|
| [m] | | [m] | [m] | | [%] | [%] | [%] | | | [m] | |
| 0.0 | 1 | 0.0 | 14.920 | Sagging | 0.019826 | 0.0 | 0.021495 | 0.0 | 0.0016496 | 1728.6 | 0 (Negligible) |

Tensile horizontal strains are +ve, compressive horizontal strains are -ve.

Structure: 122 Charing Cross Rd | Sub-structure: 122B

| Vertical Offset from Line for Vertical Movement Calculations | Segment | Start | Length | Curvature | Deflection Ratio | Average Horizontal Strain | Max Tensile Strain | Max Gradient of Horizontal Displacement Curve | Max Gradient of Vertical Displacement Curve | Min Radius of Curvature | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|---|
| [m] | | [m] | [m] | | [%] | [%] | [%] | | | [m] | |
| 0.0 | 1 | 0.0 | 11.240 | Sagging | 0.035601 | 0.0 | 0.032365 | 0.0 | -0.0037870 | 314.72 | 0 (Negligible) |

Tensile horizontal strains are +ve, compressive horizontal strains are -ve.

Structure: No 7 Retained | Sub-structure: No7 A

| Vertical Offset from Line for Vertical Movement Calculations | Segment | Start | Length | Curvature | Deflection Ratio | Average Horizontal Strain | Max Tensile Strain | Max Gradient of Horizontal Displacement Curve | Max Gradient of Vertical Displacement Curve | Min Radius of Curvature | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|---|
| [m] | | [m] | [m] | | [%] | [%] | [%] | | | [m] | |
| 0.0 | 1 | 0.0 | 13.460 | Sagging | 0.022322 | 0.0061747 | 0.031717 | -193.02E-6 | 0.0019239 | 949.18 | 0 (Negligible) |

Tensile horizontal strains are +ve, compressive horizontal strains are -ve.

Structure: No 7 Retained | Sub-structure: No7 C

| Vertical Offset from Line for Vertical Movement Calculations | Segment | Start | Length | Curvature | Deflection Ratio | Average Horizontal Strain | Max Tensile Strain | Max Gradient of Horizontal Displacement Curve | Max Gradient of Vertical Displacement Curve | Min Radius of Curvature | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|---|
| [m] | | [m] | [m] | | [%] | [%] | [%] | | | [m] | |
| 0.0 | 1 | 0.0 | 13.860 | Sagging | 0.010372 | 0.0044648 | 0.016561 | -332.67E-6 | -877.92E-6 | 2395.0 | 0 (Negligible) |

Tensile horizontal strains are +ve, compressive horizontal strains are -ve.

Structure: No 7 Retained | Sub-structure: No7 D

| Vertical Offset from Line for Vertical Movement Calculations | Segment | Start | Length | Curvature | Deflection Ratio | Average Horizontal Strain | Max Tensile Strain | Max Gradient of Horizontal Displacement Curve | Max Gradient of Vertical Displacement Curve | Min Radius of Curvature | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|---|
| [m] | | [m] | [m] | | [%] | [%] | [%] | | | [m] | |
| 0.0 | 1 | 0.0 | 3.2208 | Sagging | 0.0055644 | 0.0 | 0.0054994 | 0.0 | -249.13E-6 | 3430.1 | 0 (Negligible) |
| | 2 | 3.2208 | 0.076665 | Hogging | 22.806E-6 | 0.0 | 22.781E-6 | 0.0 | 1.4939E-6 | 925330. | 0 (Negligible) |
| | 3 | 3.2974 | 3.1826 | Sagging | 0.0019470 | 0.0 | 0.0019248 | 0.0 | 87.190E-6 | 9778.6 | 0 (Negligible) |

Tensile horizontal strains are +ve, compressive horizontal strains are -ve.

***Specific Building Damage Results - Critical Values for All Segments within Each Sub-Structure***

Structure: No 6 Denmark Street | Sub-structure: No6 A

| Vertical Offset from Line for Vertical Movement Calculations | Deflection Ratio | Average Horizontal Strain | Max Slope | Max Settlement | Max Tensile Strain | Max Gradient of Horizontal Displacement Curve | Max Gradient of Vertical Displacement Curve | Min Radius of Curvature (Hogging) | Min Radius of Curvature (Sagging) | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|
| [m] | [%] | [%] | | [mm] | [%] | | | [m] | [m] | |
| 0.0 | 0.0046004 | 121.27E-6 | 253.18E-6 | 1.8705 | 0.0058543 | 265.88E-6 | 253.18E-6 | - | 10468. | 0 (Negligible) |

Structure: No 6 Denmark Street | Sub-structure: No6 C

| Vertical Offset from Line for Vertical Movement Calculations | Deflection Ratio | Average Horizontal Strain | Max Slope | Max Settlement | Max Tensile Strain | Max Gradient of Horizontal Displacement Curve | Max Gradient of Vertical Displacement Curve | Min Radius of Curvature (Hogging) | Min Radius of Curvature (Sagging) | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|
| [m] | [%] | [%] | | [mm] | [%] | | | [m] | [m] | |
| 0.0 | 0.032031 | 0.0032451 | -0.0018072 | 3.9354 | 0.032698 | -89.209E-6 | -0.0018072 | - | 797.30 | 0 (Negligible) |

Structure: No 6 Denmark Street | Sub-structure: No6 D

| Vertical Offset from Line for Vertical Movement Calculations | Deflection Ratio | Average Horizontal Strain | Max Slope | Max Settlement | Max Tensile Strain | Max Gradient of Horizontal Displacement Curve | Max Gradient of Vertical Displacement Curve | Min Radius of Curvature (Hogging) | Min Radius of Curvature (Sagging) | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|
| [m] | [%] | [%] | | [mm] | [%] | | | [m] | [m] | |
| 0.0 | 0.015018 | 0.0 | -665.57E-6 | 0.78577 | 0.014881 | 0.0 | -665.57E-6 | 106420. | 670.91 | 0 (Negligible) |

Structure: No 6 Denmark Street | Sub-structure: No6 E

| Vertical Offset from Line for Vertical Movement Calculations | Deflection Ratio | Average Horizontal Strain | Max Slope | Max Settlement | Max Tensile Strain | Max Gradient of Horizontal Displacement Curve | Max Gradient of Vertical Displacement Curve | Min Radius of Curvature (Hogging) | Min Radius of Curvature (Sagging) | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|
| [m] | [%] | [%] | | [mm] | [%] | | | [m] | [m] | |
| 0.0 | 609.50E-6 | 0.0 | -30.692E-6 | 0.40691 | 604.57E-6 | 0.0 | -30.692E-6 | 280980. | 82751. | 0 (Negligible) |

Structure: No 6 Denmark Street | Sub-structure: No6 F

| Vertical Offset from Line for Vertical Movement Calculations | Deflection Ratio | Average Horizontal Strain | Max Slope | Max Settlement | Max Tensile Strain | Max Gradient of Horizontal Displacement Curve | Max Gradient of Vertical Displacement Curve | Min Radius of Curvature (Hogging) | Min Radius of Curvature (Sagging) | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|
| [m] | [%] | [%] | | [mm] | [%] | | | [m] | [m] | |

Structure: No 9 Denmark Street | Sub-structure: No9 A

| Vertical Offset from Line for Vertical Movement Calculations | Deflection Ratio | Average Horizontal Strain | Max Slope | Max Settlement | Max Tensile Strain | Max Gradient of Horizontal Displacement Curve | Max Gradient of Vertical Displacement Curve | Min Radius of Curvature (Hogging) | Min Radius of Curvature (Sagging) | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|
| [m] | [%] | [%] | | [mm] | [%] | | | [m] | [m] | |

Structure: No 9 Denmark Street | Sub-structure: No9 B

| Vertical Offset from Line for Vertical Movement Calculations | Deflection Ratio | Average Horizontal Strain | Max Slope | Max Settlement | Max Tensile Strain | Max Gradient of Horizontal Displacement Curve | Max Gradient of Vertical Displacement Curve | Min Radius of Curvature (Hogging) | Min Radius of Curvature (Sagging) | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|
| [m] | [%] | [%] | | [mm] | [%] | | | [m] | [m] | |

Structure: No 8 Denmark Street | Sub-structure: No8 A

| Vertical Offset from Line for Vertical Movement Calculations | Deflection Ratio | Average Horizontal Strain | Max Slope | Max Settlement | Max Tensile Strain | Max Gradient of Horizontal Displacement Curve | Max Gradient of Vertical Displacement Curve | Min Radius of Curvature (Hogging) | Min Radius of Curvature (Sagging) | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|
| [m] | [%] | [%] | | [mm] | [%] | | | [m] | [m] | |

Structure: 122 Charing Cross Rd | Sub-structure: 122A

| Vertical Offset from Line for Vertical Movement Calculations | Deflection Ratio | Average Horizontal Strain | Max Slope | Max Settlement | Max Tensile Strain | Max Gradient of Horizontal Displacement Curve | Max Gradient of Vertical Displacement Curve | Min Radius of Curvature (Hogging) | Min Radius of Curvature (Sagging) | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|
| [m] | [%] | [%] | | [mm] | [%] | | | [m] | [m] | |
| 0.0 | 0.019826 | 0.0 | 0.0016496 | 6.7076 | 0.021495 | 0.0 | 0.0016496 | - | 1728.6 | 0 (Negligible) |

Structure: 122 Charing Cross Rd | Sub-structure: 122B

| Vertical Offset from Line for Vertical Movement Calculations | Deflection Ratio | Average Horizontal Strain | Max Slope | Max Settlement | Max Tensile Strain | Max Gradient of Horizontal Displacement Curve | Max Gradient of Vertical Displacement Curve | Min Radius of Curvature (Hogging) | Min Radius of Curvature (Sagging) | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|
| [m] | [%] | [%] | | [mm] | [%] | | | [m] | [m] | |
| 0.0 | 0.035601 | 0.0 | -0.0037870 | 6.7078 | 0.032365 | 0.0 | -0.0037870 | - | 314.72 | 0 (Negligible) |

Structure: No 7 Retained | Sub-structure: No7 A

| Vertical Offset from Line for Vertical Movement Calculations | Deflection Ratio | Average Horizontal Strain | Max Slope | Max Settlement | Max Tensile Strain | Max Gradient of Horizontal Displacement Curve | Max Gradient of Vertical Displacement Curve | Min Radius of Curvature (Hogging) | Min Radius of Curvature (Sagging) | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|
| [m] | [%] | [%] | | [mm] | [%] | | | [m] | [m] | |
| 0.0 | 0.022322 | 0.0061747 | 0.0019239 | 4.9665 | 0.031717 | -193.02E-6 | 0.0019239 | - | 949.18 | 0 (Negligible) |

Structure: No 7 Retained | Sub-structure: No7 C

| Vertical Offset from Line for Vertical Movement Calculations | Deflection Ratio | Average Horizontal Strain | Max Slope | Max Settlement | Max Tensile Strain | Max Gradient of Horizontal Displacement Curve | Max Gradient of Vertical Displacement Curve | Min Radius of Curvature (Hogging) | Min Radius of Curvature (Sagging) | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|
| [m] | [%] | [%] | | [mm] | [%] | | | [m] | [m] | |
| 0.0 | 0.010372 | 0.0044648 | -877.92E-6 | 2.8012 | 0.016561 | -332.67E-6 | -877.92E-6 | - | 2395.0 | 0 (Negligible) |

Structure: No 7 Retained | Sub-structure: No7 D

| Vertical Offset from Line for Vertical Movement Calculations | Deflection Ratio | Average Horizontal Strain | Max Slope | Max Settlement | Max Tensile Strain | Max Gradient of Horizontal Displacement Curve | Max Gradient of Vertical Displacement Curve | Min Radius of Curvature (Hogging) | Min Radius of Curvature (Sagging) | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|
| [m] | [%] | [%] | | [mm] | [%] | | | [m] | [m] | |
| 0.0 | 0.0055644 | 0.0 | -249.13E-6 | 0.36396 | 0.0054994 | 0.0 | -249.13E-6 | 925330. | 3430.1 | 0 (Negligible) |

***Specific Building Damage Results - Critical Segments within Each Structure***

| Structure Name | Parameter | Critical Sub-Structure | Critical Segment | Start | End | Curvature | Max Slope | Max Settlement | Max Tensile Strain | Min Radius of Curvature (Hogging) | Min Radius of Curvature (Sagging) | Damage Category |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | [m] | [m] | | | [mm] | [%] | [m] | [m] | |
| No 6 Denmark Street | Max Slope | No6 C | 1 | 0.0 | 5.9900 | Sagging | **0.0018072** | 3.9354 | 0.032698 | - | 797.30 | 0 (Negligible) |
| | Max Settlement | No6 C | 1 | 0.0 | 5.9900 | Sagging | 0.0018072 | **3.9354** | 0.032698 | - | 797.30 | 0 (Negligible) |
| | Max Tensile Strain | No6 C | 1 | 0.0 | 5.9900 | Sagging | 0.0018072 | 3.9354 | **0.032698** | - | 797.30 | 0 (Negligible) |
| | Min Radius of Curvature (Hogging) | No6 D | 2 | 1.7001 | 4.5800 | Hogging | 14.760E-6 | 0.42394 | 315.18E-6 | **106420.** | - | 0 (Negligible) |
| | Min Radius of Curvature (Sagging) | No6 D | 1 | 0.0 | 1.7001 | Sagging | 665.57E-6 | 0.78577 | 0.014881 | - | **670.91** | 0 (Negligible) |
| No 9 Denmark Street | All settlements are less than the Settlement Trough Limit Sensitivity. | | | | | | | | | | | |
| | All settlements are less than the Settlement Trough Limit Sensitivity. | | | | | | | | | | | |
| | All settlements are less than the Settlement Trough Limit Sensitivity. | | | | | | | | | | | |
| | All settlements are less than the Settlement Trough Limit Sensitivity. | | | | | | | | | | | |
| | All settlements are less than the Settlement Trough Limit Sensitivity. | | | | | | | | | | | |
| No 8 Denmark Street | All settlements are less than the Settlement Trough Limit Sensitivity. | | | | | | | | | | | |
| | All settlements are less than the Settlement Trough Limit Sensitivity. | | | | | | | | | | | |
| | All settlements are less than the Settlement Trough Limit Sensitivity. | | | | | | | | | | | |
| | All settlements are less than the Settlement Trough Limit Sensitivity. | | | | | | | | | | | |
| 122 Charing Cross Rd | Max Slope | 122B | 1 | 0.0 | 11.240 | Sagging | **0.0037870** | 6.7078 | 0.032365 | - | 314.72 | 0 (Negligible) |
| | Max Settlement | 122B | 1 | 0.0 | 11.240 | Sagging | 0.0037870 | **6.7078** | 0.032365 | - | 314.72 | 0 (Negligible) |
| | Max Tensile Strain | 122B | 1 | 0.0 | 11.240 | Sagging | 0.0037870 | 6.7078 | **0.032365** | - | 314.72 | 0 (Negligible) |
| | Min Radius of Curvature (Hogging) | | - | - | - | - | - | - | - | - | - | - |
| | Min Radius of Curvature (Sagging) | 122B | 1 | 0.0 | 11.240 | Sagging | 0.0037870 | 6.7078 | 0.032365 | - | **314.72** | 0 (Negligible) |
| No 7 Retained | Max Slope | No7 A | 1 | 0.0 | 13.460 | Sagging | **0.0019239** | 4.9665 | 0.031717 | - | 949.18 | 0 (Negligible) |
| | Max Settlement | No7 A | 1 | 0.0 | 13.460 | Sagging | 0.0019239 | **4.9665** | 0.031717 | - | 949.18 | 0 (Negligible) |
| | Max Tensile Strain | No7 A | 1 | 0.0 | 13.460 | Sagging | 0.0019239 | 4.9665 | **0.031717** | - | 949.18 | 0 (Negligible) |
| | Min Radius of Curvature (Hogging) | No7 D | 2 | 3.2208 | 3.2974 | Hogging | 1.4939E-6 | 0.099282 | 22.781E-6 | **925330.** | - | 0 (Negligible) |
| | Min Radius of Curvature (Sagging) | No7 A | 1 | 0.0 | 13.460 | Sagging | 0.0019239 | 4.9665 | 0.031717 | - | **949.18** | 0 (Negligible) |