Appendix 6: Ground Movement and Damage Impact Assessment

A-squared | Studio

27 John's Mews

Ground Movement Assessment Report

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EXECUTIVE SUMMARY

A-squared Studio Engineers Ltd (A-squared) has been appointed by Ross and Partners Ltd to produce a Ground Movement Assessment (GMA) for the proposed redevelopment scheme at 27 John's Mews in London. The proposed scheme involves the demolition and subsequent redevelopment of 27 John's Mews – the proposals include demolition of most of the building structure, construction of single-storey basement and erection of the new structure behind the retained façade.

The proposed basement is approximately 3m in depth. Traditional underpinning techniques are going to be used for the proposed basement deepening works while the existing front façade is going to be retained. During construction, the earth retention system will be supported by horizontal props and bracing – ensuring a robust means of preventing excessive ground movements.

The property is surrounded by several existing low-rise residential and office structures. Structures located to the North are Grade II listed two-storey masonry residential buildings with partial single-storey basement located next to 25 John's Mews. To the East, there is a single-storey office building connected with the taller structure located next to 30 John Street. The single-storey office does not have a basement but shares a masonry party wall with the 27 John's Mews property. On the South boundary, there is a five-storey tall more contemporary residential reinforced concrete building originating from the twentieth century (build around 60's-70's). There is a single-storey 3m deep basement that extends below the building to the South, its courtyard and the structure located next to 31-32 John Street.

Utilising the developed 3D analytical model, a building damage assessment was evaluated in accordance with the Burland criteria, taking account the various stages of the construction process, extending from demolition through to completion.

The study does not consider any interaction between the proposed development and other third-party assets, such as underground services.

The analysis has been undertaken with the aid of commercially available software packages Oasys Pdisp and Xdisp, allowing the short and long-term cumulative vertical and horizontal ground movements induced by demolition, basement excavation and subsequent permanent works construction to be assessed.

The damage assessment has been undertaken in accordance with industry best practice and the damage categorisation defined by Burland/Ciria C580/C760. The assessment indicated maximum potential damage categories of *Category 1 – Very Slight;* applicable to a select number of façades, as detailed in the results section of this report. All other neighbouring properties were assessed to be subject to *Category 0 – Negligible.*

1 INTRODUCTION

A-squared Studio Engineers Ltd (A-squared) has been appointed by Ross and Partners Ltd to undertake a ground movement assessment (GMA) for the 27 John's Mews development in London.

The A-squared scope comprises an assessment of the potential impact of the proposed redevelopment works on the various neighbouring properties.

1.1 STUDY AIMS & OBJECTIVES

A ground movement and impact assessment has been carried out in order to estimate the potential damage induced by the proposed redevelopment at 27 John's Mews on the neighbouring properties.

The scheme includes the partial demolition of the existing 27 John's Mews property and retention of its façade along with selected elements of superstructure. The proposed development will comprise the excavation of a single-storey basement via traditional underpinning techniques.

The assessment encompasses properties located within the *zone of influence* of the proposed scheme as well as the façade which is to be retained as part of the new development. The GMA assessment is based on *greenfield* ground movements neglecting the stiffness of any structures. The adopted assessment methodology provides a robust and conservative assessment representative of current industry best practice, as detailed in Section 3.

The modelling works carried out and described herein are provided to:

- Assess the impact on ground movements induced by the proposed works on adjacent properties and select retained façade of the development under consideration.
- Inform Party Wall awards.
- Facilitate and inform aspects of substructure construction and design.

This report provides a detailed description of the:

- Site and proposed development.
- Modelling parameters and input.
- Analyses and results.

The GMA should be read in conjunction with the broader Basement Impact Assessment (BIA) prepared by the project team.

1.2 REFERENCES

A summary of the primary references that have been utilised in the development of this GMA is summarised below.

Reference reports and drawings prepared for the proposed development:

- Current design information/data and drawings (available at the time of undertaking the GMA), prepared by the project design team.
- 27 John's Mews Site Investigation Report. Report reference: C14337 issue dated January 2018. Prepared by Ground Engineering Ltd.

Information available in the public domain:

- British Geological Survey online database (various sources).
- Google Earth Pro.

2 THE SITE & DEVELOPMENT

2.1 SITE LOCATION AND PROPOSED DEVELOPMENT

The proposed development is located at 27 John's Mews, London, at an approximate National Grid Reference of TQ 30813 82003. The site location is presented in Figure 2.1 and the building context in Figure 2.2.

The property is surrounded by several existing low-rise (up to 5 storeys) residential and office structures. 30 John Street low-rise building located behind the 27 John's Mews property is sharing the party wall with the property under consideration.

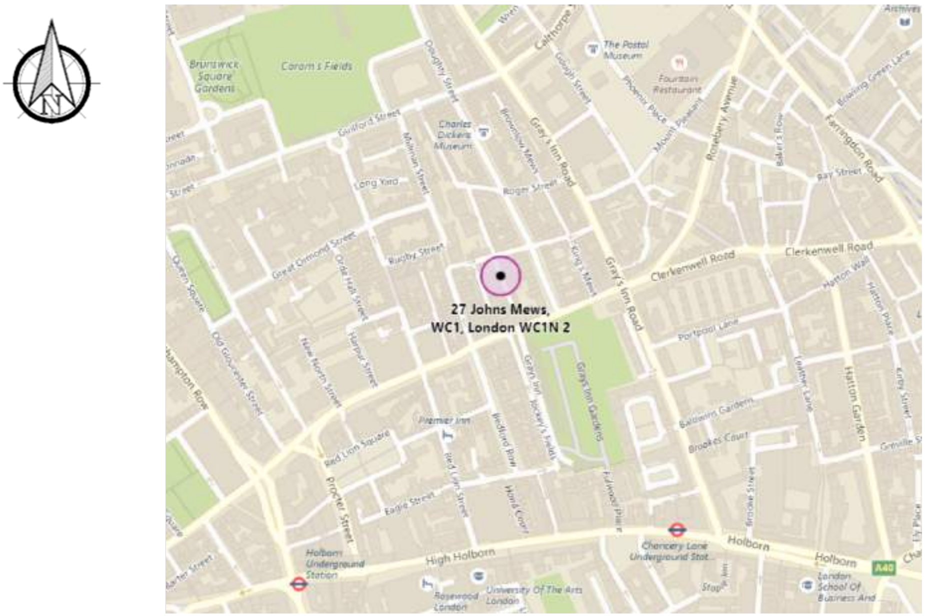

Figure 2.1 27 John's Mews development location **(image courtesy of Bing Maps).**

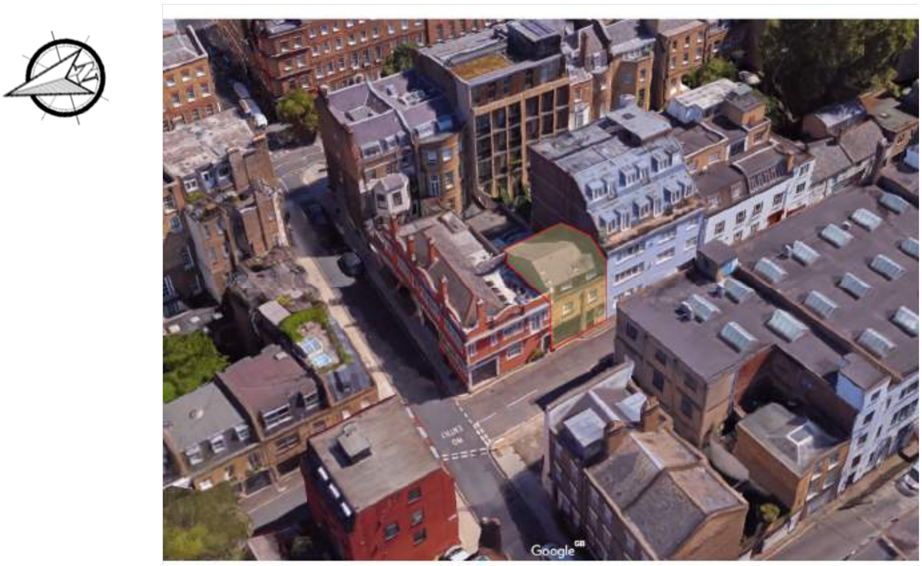

Figure 2.2 27 John's Mews development **(images courtesy of Google Maps).**

The redevelopment basement is approximately rectangular in footprint, consisting of an excavation area as depicted in Figure 2.3. In Figure 2.3, the narrower cross-section through the building, shows the proposed permanent works solution highlighted in yellow.

The proposed scheme involves the excavation and construction of a basement which is approximately 3.0m deep, via traditional underpinning techniques. To account for the proposed slab thickness and additional groundworks necessary for casting a slab, a 3.5m deep excavation has been modelled during the calculations presented in the further sections of this report. The proposed structural foundation solution is 350mm reinforced concrete slab connected with underpins.

The Structural Engineers provided bearing pressure diagram shown in Figure 2.5 which incorporates all loads imposed on the building within the structural model. The bearing pressure diagram was incorporated within the geotechnical calculations to accurately model the building behaviour during the short and long term.

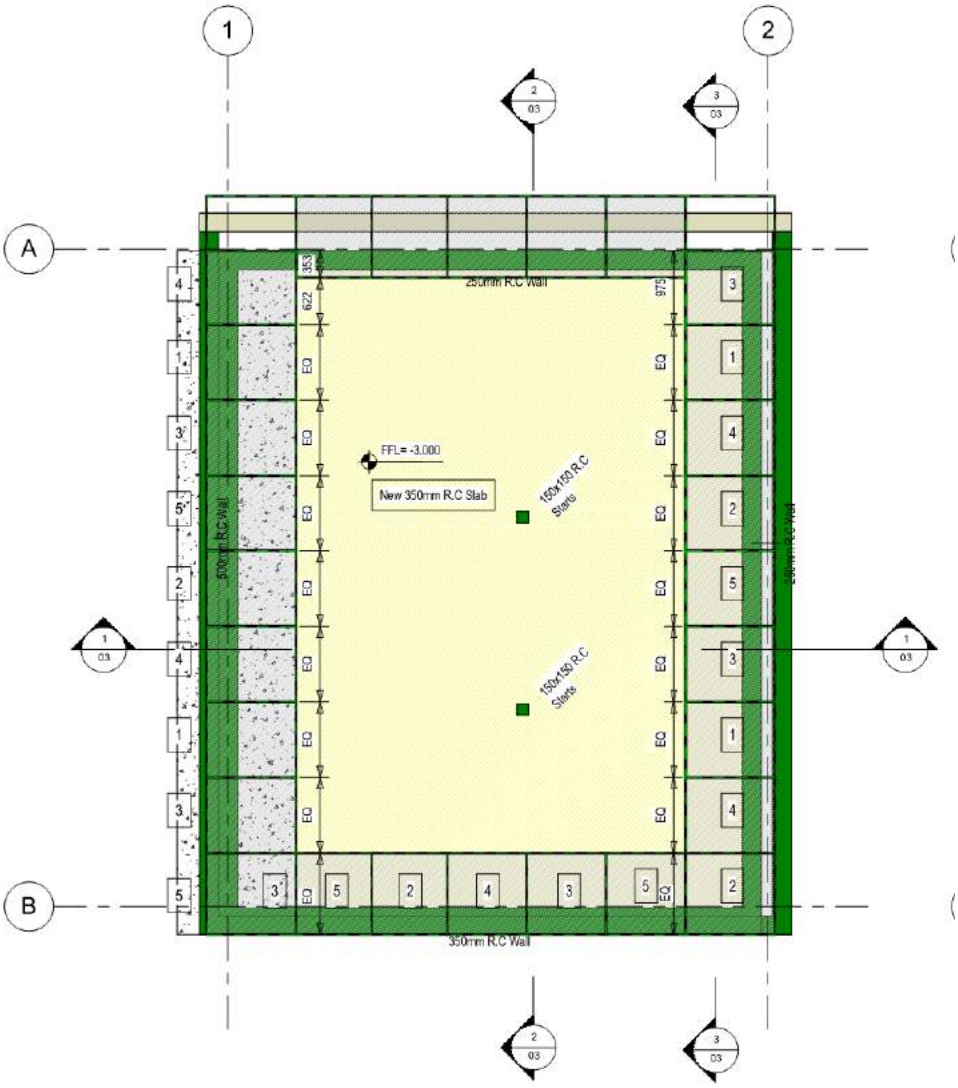

Figure 2.3 Proposed basement level layout showing the extent of underpinning.

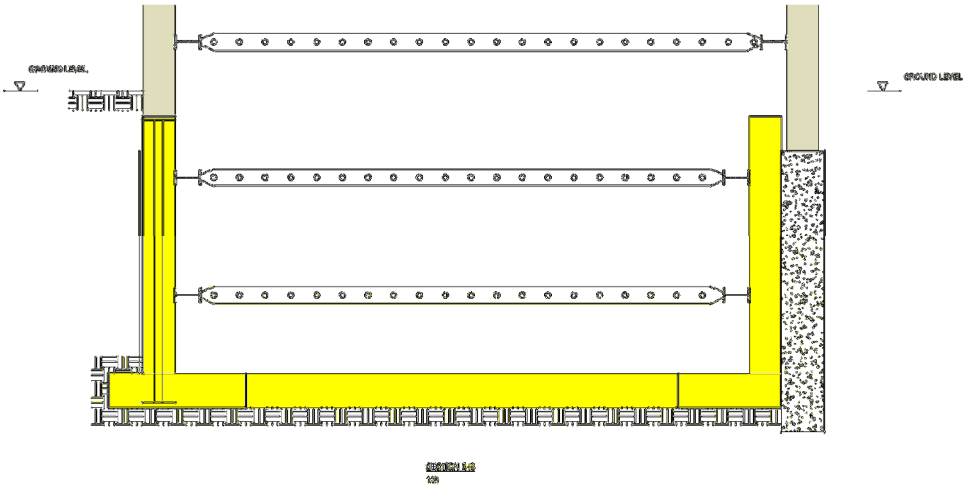

Figure 2.4 Proposed basement section B-B (see Figure 2.3) showing also the extent of temporary propping and underpinning works.

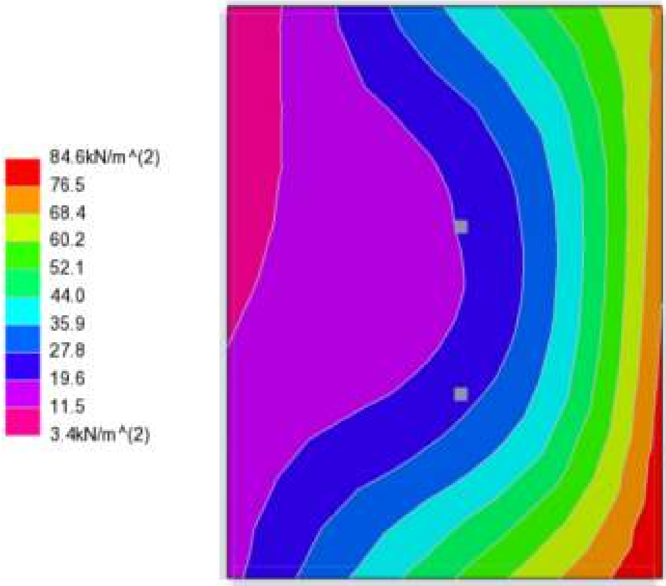

Figure 2.5 Bearing pressures adopted for calculations (provided by Ross and Partners Ltd).

3 GEOLOGY AND GROUND WATER

Intrusive ground investigation works were carried out by Ground Engineering Ltd and the Site Investigation Report was issued in January 2018 in order to inform the substructure design development and to support the GMA process presented herein.

The site stratigraphy obtained through the above-mentioned ground investigation is shown in Table 3.1. It is worth noting that available exploratory holes were drilled from within the existing building, therefore the retrieved data could be assumed to be uniform with respect to the strata elevations despite lack of detailed OS coordinates.

Table 3.1 Summary of adopted stratigraphy (based on Ground Engineering Ltd).

Formation	Adopted thickness [m]	Depth to the top [mbgl]
Made Ground	3.75	0.00
River Terrace Deposits (Lynch Hill Gravels)	1.45	3.75
London Clay	14.00	5.20
Lambeth Group	Not proven	19.20

The highest recorded ground water level was recorded at 3.46mbgl during the ground investigation works. It has therefore been concluded, on the basis of the current scheme intent, that the excavation works will take place in dry conditions with only finite perched ground water inflow. However, it is feasible that this perched ground water table may rise due to seasonal variations or during high rainfall events. This facet should be given due consideration in the ongoing scheme design and realisation.

Should the intent of the scheme be modified such that greater basement depth is required, the ground water conditions should be reviewed in more detail in order to gauge the viability of the underpinning excavation methodology below the water table.

In summary, based on the findings of the ground investigation it is assumed that the following ground water conditions are present:

- Perched groundwater table above the London Clay Formation, which is subject to seasonal level fluctuation within the upper granular deposits (Made Ground and River Terrace Deposits) – at the time of the ground investigation works (November / December 2017) the perched groundwater elevation was found to fluctuate from 3.46mbgl to 6.50mbgl.

- The substructure designer should consider the aforementioned groundwater conditions and potential variation accordingly when evaluating earth retention and foundation system typologies/solutions and temporary work design where local dewatering might be necessary.

4 IMPACT ASSESSMENT EVALUATION

4.1 ASSESSMENT DETAILS

The assessment has been undertaken using the commercially available software Oasys Pdisp and Xdisp, which consider the three-dimensional ground movement field induced by the proposed excavation works.

Ground movements will arise as a result of various mechanisms which are mobilised as part of the implementation of the proposed scheme. The demolition of existing building, basement excavation process, and underpinning will induce ground movements arising from the overburden removal and loss of lateral restraint. The permanent condition loading will partially reinstate a portion of the removed overburden, yielding settlements across the foundation system.

The induced ground movements will extend over a given *zone of influence* surrounding the building/basement footprint. The assessment presented herein adopts the normalised ground displacement curves reported in CIRIA C580 (and newly published CIRIA C760). In addition to the effects arising from basement excavation/construction, the ground movement effects associated with the installation of the underpinning have been considered.

A series of three-dimensional models of the proposed scheme have been developed in Oasys Xdisp/Pdisp and combined by means of superposition in order to enable ground movement assessments to be carried out representing the various displacement fields summarised above. The ground movement displacement fields were separated into two assessment typologies (Method 1 and Method 2), based on the approach followed and their configuration, as detailed below:

Method 1

In the first option (***Method 1***), the *worst-case* heave condition was assessed by assuming that no lateral or downward ground movement takes place during the underpinning operations (effectively assuming a *wished-into-place* underpin solution).

Heave movements arising from the proposed basement excavation were assessed using Oasys Pdisp.

The proposed excavation and associated heave was modelled by applying an upward (unloading) stress at the formation level, which is equivalent to the total stress relief (approximately 70 kPa) imposed by the planned depth of excavation beneath the existing ground floor level.

For the short-term analysis, representing the condition immediately following excavation, the soil mass was modelled using *undrained* elastic stiffness parameters.

The long-term behaviour of the soil was captured by using *drained* elastic stiffness parameters. The effect of increased building loads, associated with the proposed renovation works, were also incorporated in this phase. Figure 2.5 shows the intensity of the bearing pressure as applied in the Pdisp model.

Method 2

The second option (***Method 2***) assesses horizontal movements and ground settlements (as opposed to the governing vertical ground movement field evaluated in Method 1) imposed by the proposed excavation and underpinning works.

The assessment was carried out using Oasys Xdisp by adopting the following CIRIA C760 normalised ground movement curves as to assess ground movements due to installation and bulk excavation:

- Underpin installation: *Installation of planar diaphragm wall in stiff clay*.
- Mass excavation to formation: *Excavation in front of a high stiffness wall in stiff clay*.

The empirical data set for diaphragm wall installation is not strictly compatible with the construction technologies adopted in underpinning works. However, it is assessed that the ground movement mechanisms are reasonably well-matched and in lieu of better empirical relationships, the diaphragm wall curves are considered to provide a reasonable approximation.

Similarly, the excavation in stiff clay is not fully representative with the retained soil characteristics (i.e. sands and gravels overlying clay). However, it is noted that CIRIA C760 does not provide any empirical relationship for this type of soil induced movements and that the selected curve is representative.

This methodology is considered reasonable in this instance and once again, bounds the solution between maximum potential heave, settlements and lateral deformations anticipated for the type of construction presented herein, which are inherently subject to satisfactory control of workmanship.

The effect of the proposed building loads was also incorporated into the analysis by superimposing the long-term ground displacements due to the permanent foundation loads evaluated from Pdisp.

These analyses enabled the production of an *envelope* of damage classification results – with the worst-case results presented herein. A representative geometry has been adopted for defining the excavation/installation geometry implemented in the 3D modelling efforts. The geometry adopted was carefully assessed based on the effects of all basement sides with respect to the soil retention system typology and excavation depths. An indicative plot of the analytical model is presented below in Figure 4.1 and displays the excavation area and the numerous adjacent properties included in the damage assessment.

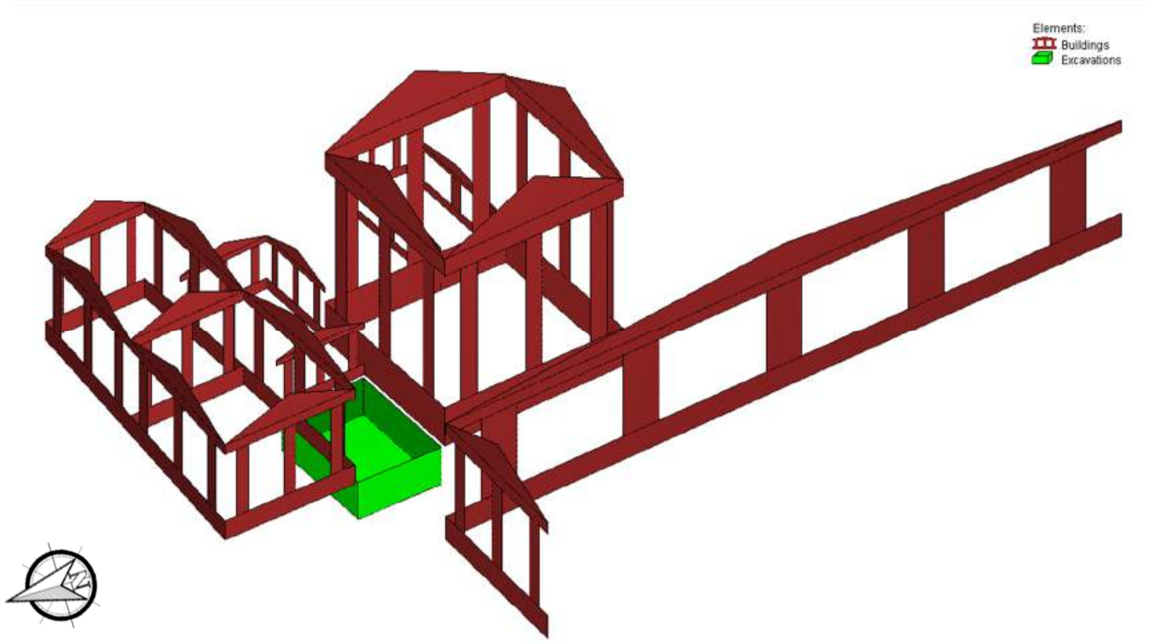

Figure 4.1 Indicative plot of three-dimensional analytical model using the Oasys Xdisp software suite (soil removed for clarity of presentation).

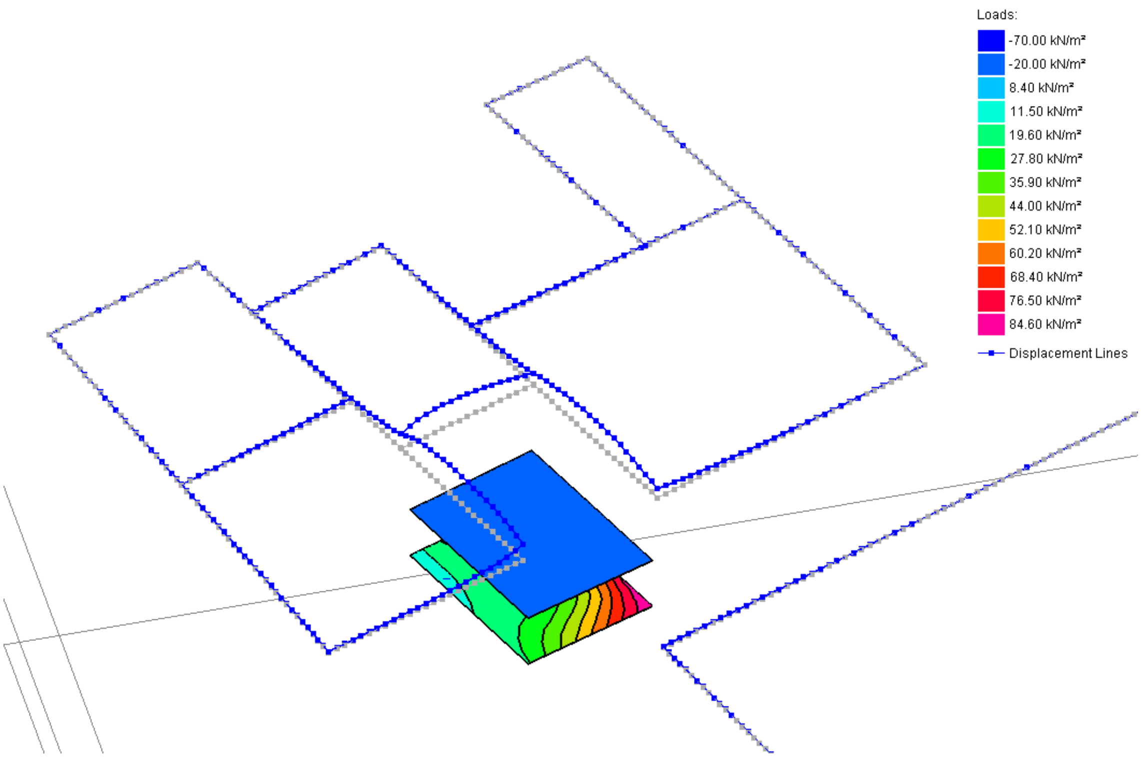

Figure 4.2 Three-dimensional Pdisp model with assigned loads and adjacent building outlines shown in both deformed (blue) and undeformed shapes (grey) for the demolition, excavation and long-term loading (example output).

4.2 GROUND MODEL

The adopted ground model has been evaluated based on the site-specific ground investigation information (as referenced previously in Section 1). The ground conditions were found to comprise the following (in order succession):

- Made Ground – dark brown and brown, clayey sand and gravel with occasional brick and concrete cobbles. The gravel fraction consisted of brick, concrete, ash, flint, mortar, slate and fragments of bones, glass and pottery.
- River Terrace Deposits (Lynch Hill Gravel) – very dense, light brown, slightly silty, very sandy gravel, with a gravel fraction of angular to rounded flint and occasional quartzite.
- London Clay Formation – stiff, fissured grey brown clay with occasional silt partings.

The above include the strata of engineering interest and significance, taking cognisance of the scale of the proposed development and zone of influence. It is noted that limited presence of Alluvium was encountered in TP1. It is recommended that the project earthworks specification considers this aspect and any potential mitigation requirements.

Table 4.1 Summary of ground model and geotechnical parameters adopted for analysis purposes

Stratum	**Top of stratum**	**Thickness**	**Undrained Young's Modulus, E_u** [1]	**Drained Young's Modulus, E'** [1]
[-]	[mbgl]	[m]	[MPa]	[MPa]
Made Ground	0.00	3.75	-	10.0
River Terrace Deposits	3.75	1.45	-	18.0
London Clay	5.20	14.00 [2]	20 + 2.6 z [3]	16 + 2.0 z [3]
Lambeth Group	19.20	Not proven		

Notes:
1. The stiffness data (E_u and E') has been evaluated empirically taking into consideration the nature of the geotechnical/soil-structure interaction mechanisms and level of anticipated strain within the soil mass.
2. *Rigid boundary* assumed at approximately 30mbgl for analytical purposes.
3. z refers to the depth in metres below the top of the London Clay Formation. Due to lack of the laboratory results for the Lambeth Group, the London Clay profile has been conservatively adopted also for the Lambeth Group.

4.3 IMPACT ASSESSMENT

4.3.1 GENERAL

The potential impact/damage induced on primary façade/wall elements of the buildings around the proposed scheme have been evaluated on the basis of the calculated ground movement field (including select retained façades forming part of the proposed development). The masonry walls of concern are shown in Figure 4.3, including the wall nomenclature/reference system adopted. The arrangement is based on the currently available survey information and presents an array of masonry façades running both perpendicular and parallel to the proposed basement (covering the key deformation mechanisms). In total, 20 façades were considered within the current study and these are grouped in the following manner:

- 1 & 2: Assembly Hall façades located close to the excavation
- 3 – 6: 25 John's Mews
- 7 – 9: 13 Northington Street
- 10 – 13: 30 John Street (low-rise part)
- 14 – 16: 31-32 John Street (low-rise part)
- 17 – 20: 29-31 John's Mews.

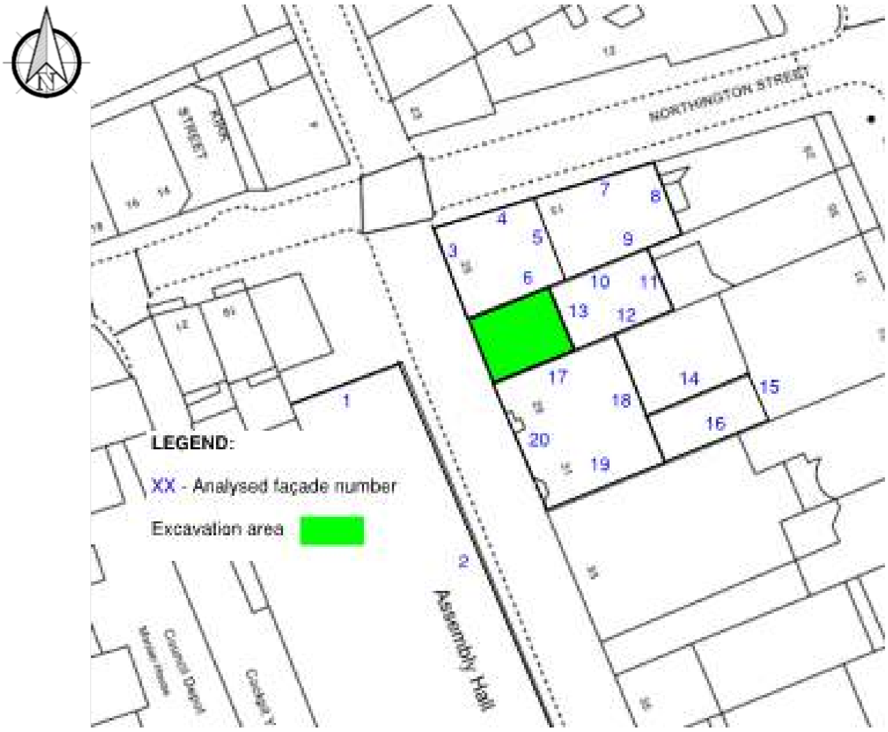

Figure 4.3 Simplified scheme and nomenclature for each building façade/masonry wall element. Green area depicts approximate location of the excavation.

Each wall has been assumed to behave as an equivalent beam subject to a bending and extension/compression deformation mechanism, based on the evaluated *greenfield* ground movement, as outlined previously.

Tensile strains induced within the building masonry walls have been evaluated based on the deflection ratios Δ/L estimated from the analyses. The assessment considers the well-established Burland (1997) damage classification method, as presented and summarised in Figure 4.4 and Figure 4.5. The adopted techniques and normalised empirical ground movement data sets are also detailed in CIRIA C580/C760.

This method involves a relatively simple but robust means of assessment, which is widely adopted and is considered to comprise an industry standard/best practice basis for impact assessments of this typology.

Potential damage categories are directly related to the tensile strains induced by the assessed basement excavation, arising from a combination of direct tension and bending induced tension mechanisms. The evaluated damage categories correspond to an *unlikely to be exceeded* scenario (on the basis of the data sets adopted and greenfield assumptions).

The long-term (i.e. to the point of full excess pore water pressure dissipation and permanent works structural loading) ground movement contour plots from the analysis are presented in Section 4.3.2. These plots display peak ground movements adjacent to the basement perimeter wall at the mid span location.

Ground movement performance criteria for the earth retention system have been evaluated as part of the GMA process presented herein. The values stated should be adhered to during the works to ensure that the findings of this GMA remain valid.

Category of damage	**Description of typical damage** (ease of repair is underlined)	**Approximate crack width (mm)**	**Limiting tensile strain ε_{lim} (per cent)**
0 Negligible	Hairline cracks of less than about 0.1 mm are classed as negligible.	< 0.1	0.0–0.05
1 Very slight	Fine cracks that can easily be treated during normal decoration. Perhaps isolated slight fracture in building. Cracks in external brickwork visible on inspection.	< 1	0.05–0.075
2 Slight	Cracks easily filled. Redecoration probably required. Several slight fractures showing inside of building. Cracks are visible externally and some repointing may be required externally to ensure weathertightness. Doors and windows may stick slightly.	< 5	0.075–0.15
3 Moderate	The cracks require some opening up and can be patched by a mason. Recurrent cracks can be masked by suitable linings. Repointing of external brickwork and possibly a small amount of brickwork to be replaced. Doors and windows sticking. Service pipes may fracture. Weathertightness often impaired.	5–15 or a number of cracks > 3	0.15–0.3
4 Severe	Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Windows and frames distorted, floor sloping noticeably. Walls leaning or bulging noticeably, some loss of bearing in beams. Service pipes disrupted.	15–25 but also depends on number of cracks	> 0.3
5 Very severe	This requires a major repair involving partial or complete rebuilding. Beams lose bearings, walls lean badly and require shoring. Windows broken with distortion. Danger of instability.	usually > 25 but depends on number of cracks.	

Figure 4.4 Building damage classification, after Burland et al. 1977, Boscardin and Cording 1989 and Burland 2001 - relationship between category of damage and limiting strain ε_{lim}.

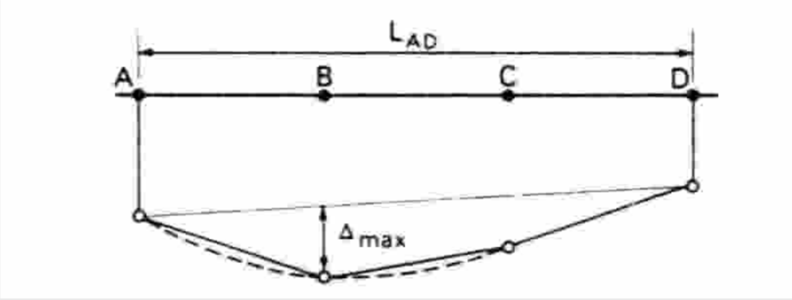

Figure 4.5 Definition of relative deflection Δ and deflection ratio Δ/L.

4.3.2 RESULTS

The results of the assessment are presented in Table 4.2. Note that the results presented in this table represent the worst-case results envelope arising from all analysis runs. Damage category results are presented in Figure 4.6 for the affected façades. Figure 4.7 and Figure 4.8 depict the vertical and horizontal displacements, respectively, induced by the underpinning installation and basement excavation calculated as per CIRIA C580 installation of planar diaphragm wall in stiff clay and CIRIA C580 *excavation in front of high stiffness wall in stiff clay*.

Vertical deflections of the foundation system of up to 10mm were evaluated in the area of high loading as presented in Figure 2.5. Up to 7 mm of lateral deflections were evaluated in the proximity of the excavated areas, resulting from installation and excavation works as well as effects produced by structural loading.

Table 4.2 Evaluated damage categories (refer to Figure 4.3 for building/wall nomenclature)

Façade reference	Analysis configuration			
	Method 1		Method 2	
	A1[1]	A2[2]	B1[3]	B2[4]
1	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
2	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
3	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 1 – Very Slight
4	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
5	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
6	Category 0 - Negligible	Category 0 - Negligible	Category 1 – Very Slight	Category 1 – Very Slight
7	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
8	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible

Façade reference	Analysis configuration			
	Method 1		Method 2	
	A1[1]	A2[2]	B1[3]	B2[4]
9	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
10	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
11	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
12	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
13	Category 1 – Very Slight	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
14	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
15	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
16	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
17	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 1 – Very Slight
18	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
19	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
20	Category 0 - Negligible	Category 0 - Negligible	Category 1 – Very Slight	Category 0 - Negligible

[1] Short-term effect of demolition and overburden removal.
[2] Long-term effect of demolition, overburden removal and permanent loading.
[3] CIRIA analysis of excavation and installation effects.
[4] CIRIA analysis of excavation and installation effects combined with long-term effects of permanent loading.

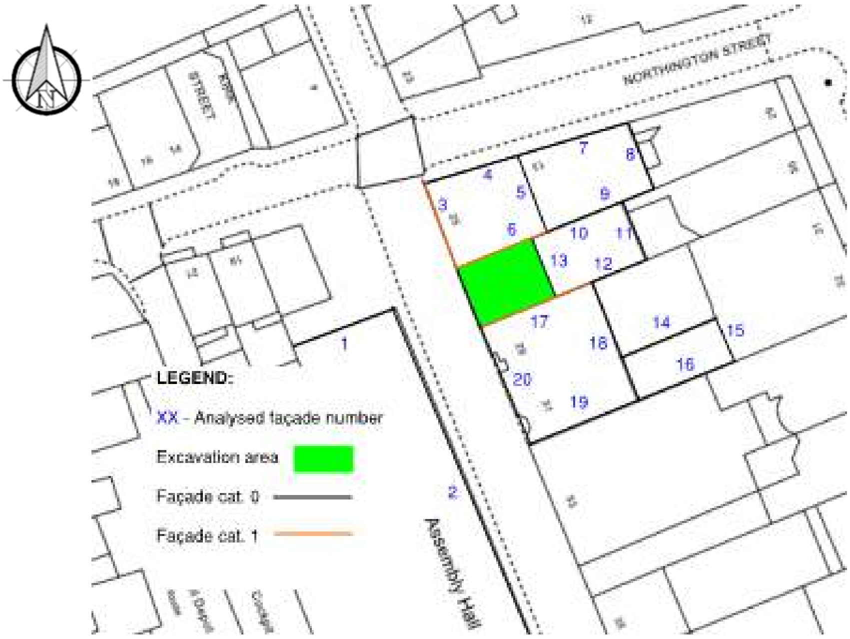

Figure 4.6 Damage category results, after analyses B1 and B2.

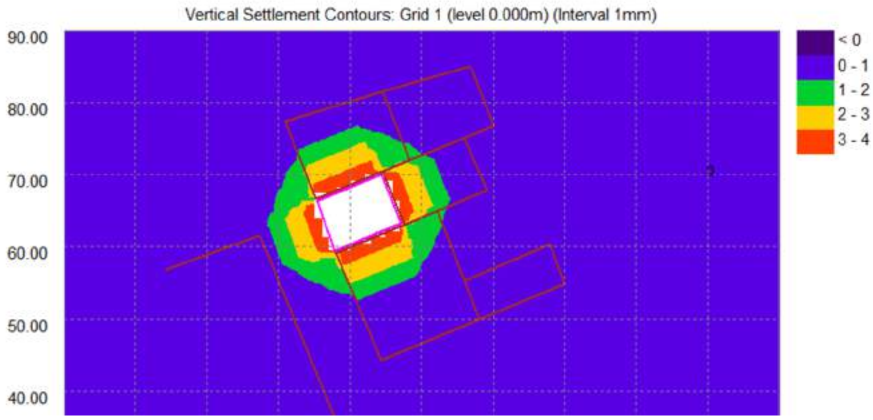

Figure 4.7 Resultant Xdisp vertical displacement contours for various excavation boundary conditions - configuration B1, underpinning installation and excavation (CIRIA C580/C760).

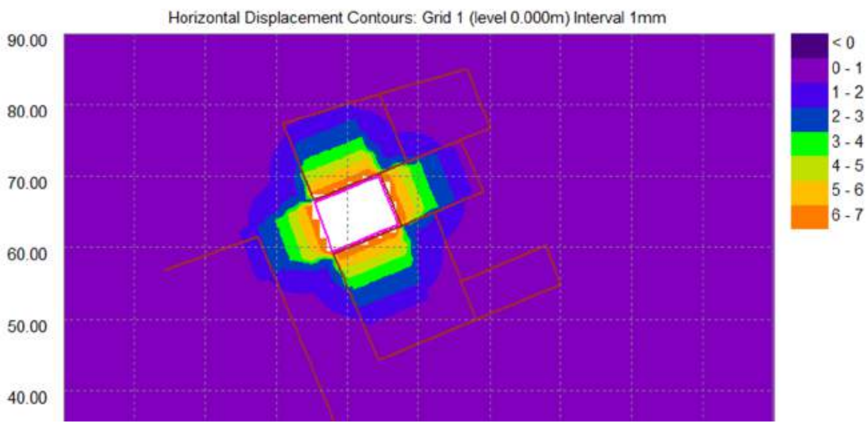

Figure 4.8 Resultant Xdisp horizontal displacement contours for various excavation boundary conditions - configuration B1, underpinning installation and excavation (CIRIA C580/C760).

5 CONCLUSIONS & CLOSING REMARKS

The interaction between the proposed 27 John's Mews development and the neighbouring properties within the zone of influence of the scheme has been reviewed as part of the GMA study presented herein. The impact of the basement excavation stage of construction has been reviewed on the basis of a propped underpinned solution (during the temporary works stage), utilising the CIRIA C580/C760 ground movement curves for retaining walls in stiff clay.

The proposed development construction operations comprise a series of stages, including demolition of the existing property, underpin installation, bulk excavation and construction of the proposed permanent works elements. The impact of the various stages of construction have been reviewed on the basis of two alternative methods (i.e. evaluating the effects of unloading/overburden removal using Pdisp and simulating the excavation induced ground movements using empirical CIRIA curves in Xdisp).

These two different scenarios have been considered in order to bind the potential ground movements arising from excavation operations (i.e. maximum potential heave and settlement respectively). This strategy ensures a robust evaluation of potential impact in light of the bespoke, intricate and workmanship dependent basement construction methodology. Both short-term (undrained) and long-term (drained) conditions have been assessed by adopting the relevant soil stiffness parameters for each case.

The results from the GMA analyses are presented in Table 4.2 (denoting the evaluated damage categorisation in accordance with the Burland criteria described herein). It is observed that the maximum potential damage classification for the neighbouring properties is *Category 1 – Very Slight.*

It is noted that the predicted ground movements, the associated wall tensile strains and level of damage categorisation are considered to be moderately conservative in view of the relatively cautious data selection and *greenfield* nature of the assessment undertaken.

It is recommended that this report is reviewed and understood in full by the project team and major stakeholders. Where significant changes are made to items such as construction sequencing, temporary propping arrangements and scheme design the engineer should thoroughly review the discrepancy and evaluate any potential impacts on ground movement and building damage. If necessary, the building damage categories should be re-evaluated.

It is critical that the permanent and temporary works designs are carried out in a coordinated manner between performance specified elements and substructure contractors, with the aim to ensure that such design elements are in alignment with the assumptions/findings of the GMA and overall design intent.

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