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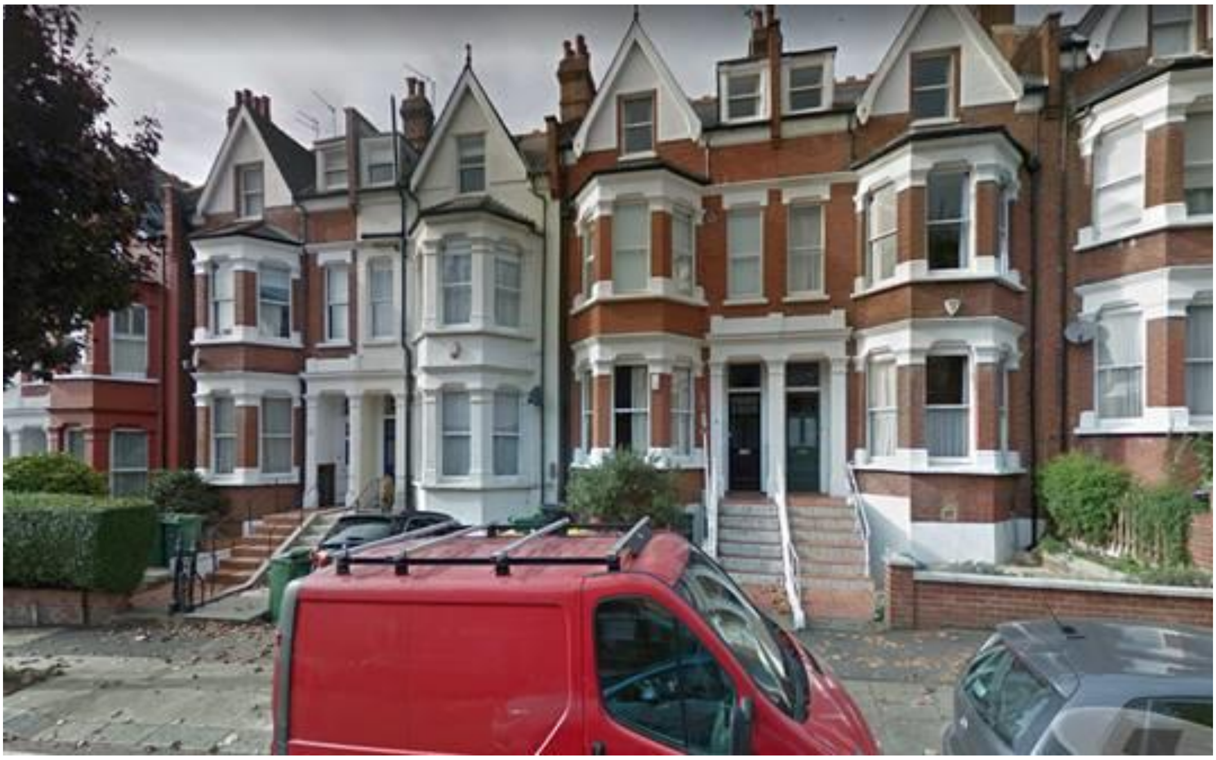
GROUND MOVEMENT ASSESSMENT

23 LYNCROFT GARDENS
WEST HAMPSTEAD
LONDON
NW6 1LB



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Report Title: Ground Movement Assessment for 23 Lyncroft Gardens, London, NW6 1LB

Report Status: Final v1.1

Job No: P189J1585

Date: 15 May 2019

Quality Control: Previous Release

Version	Date	Issued By
Final v1.0	02 May 2019	RS

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1 INTRODUCTION

1.1 Terms of Reference

1.1.1 Mr and Mrs Raja ("The Client") have commissioned Jomas Associates Ltd, to assess the impact of the proposed development at 23 Lyncroft Gardens, on the neighbouring buildings.

1.1.2 To this end a ground movement assessment (GMA) has been undertaken in accordance with Jomas Associates Limited's email proposal dated 15 April 2019.

1.2 Proposed Development

1.2.1 The proposed development comprises the underpinning of the party walls of 21 and 25 Lyncroft Gardens located in the south and north of the site respectively, as well as the underpinning of the western (front) façade of 23 Lyncroft Gardens. The deepening of the existing basement as well as the extension of the basement – in order to cover the entire property's footprint – form part of the proposed works.

1.3 Objectives

1.3.1 The objectives of the ground movement assessment are as follows:

- To determine the maximum horizontal and vertical ground movements induced by the proposed underpinning and excavation works.
- To determine the potential structural damage induced by the proposed works to the neighbouring buildings.

1.4 Supplied Documentation

1.4.1 Table 1.1 details the documents used to support this analysis:

Table 1.1: Supplied Reports

Title	Author	Reference	Date
Geotechnical Assessment Report for 23 Lyncroft Gardens, London, NW6 1LB	Jomas Associates Ltd	P1899J1585	16/01/19
Basement Impact Assessment (BIA)	CRE8 structures LLP	2018/023/RP/01	18/02/19
23 Lyncroft Gardens, London, NW6 1LB, Basement Impact Assessment Audit	Campbell Reith Hill LLP	12985-17-080419	22/02/19

1.5 Limitations

1.5.1 Jomas Associates Ltd has prepared this report for the sole use of Mr and Mrs Raja in accordance with the generally accepted consulting practices and for the intended purposes as stated in the agreement under which this work was completed. This report may not be relied upon by any other party without the explicit written agreement of Jomas Associates Limited. No other third party warranty, expressed or implied, is made as to the professional advice included in this report. This report must be used in its entirety.

1.5.2 Jomas Associates Limited does not assume any liability for the misinterpretation of information or for items not visible, accessible or present on the subject property at the time of this study.

1.5.3 Whilst effort has been made to ensure the accuracy of the data supplied, and analysis derived from it, there may be conditions at the site that have not been disclosed by the investigation and could not therefore be taken into account. As with any site, there may be differences in soil conditions between exploratory hole positions. Furthermore, it should be noted that groundwater conditions may vary due to seasonal and other effects and may at times be significantly different from those measured by the investigation. No liability can be accepted for any such variations in these conditions.

1.5.4 Any reports provided to Jomas Associates Limited have been reviewed in good faith. Jomas Associates Limited cannot be held liable for any errors or omissions in these reports, or for any incorrect interpretation contained within them.

1.5.5 This report has been carried out in accordance with the relevant standards and guidance in place at the time of the works. Future changes to these may require a re-assessment of the impact on the neighbouring properties.

2 SITE SETTING

2.1 Site Information

2.1.1 The site location plan is shown in Figure 2.1.

Table 2.1: Site Information

Name of Site	23 Lyncroft Gardens
Address of Site	23 Lyncroft Gardens, West Hampstead, London, NW6 1LB
Approx. National Grid Ref.	TQ 25405 85415
Site Area (Approx.)	200 m^2
Site Occupation	Short driveway, existing 3 storey residential building with a single level of basement occupying part of the building's footprint, garden area at the rear of property.
Local Authority	London Borough of Croydon

Figure 2.1: Site location plan. 23 Lyncroft Gardens approximate site footprint highlighted with magenta.

3 GROUND MOVEMENT ASSESSMENT

3.1 Overview

3.1.1 Ground movements will arise from a number of different sources as the works progress. These ground movements will extend over a given zone of influence surrounding the building footprint.

3.1.2 Ground movements associated with the proposed, providing a simplified account of the following.

- Installation works:
  - Ground movements associated with the proposed underpinning.
- Existing basement deepening/basement extension:
  - Ground movements associated with overburden removal (heave).
  - Ground movement associated with soil-structure interaction between the retaining walls, temporary propping system and retained ground mass.
- Long-term ground movements:
  - Ground movements associated with reloading the soil at a deeper level (proposed formation level) and soil consolidation/creep.

3.2 Means and Methods

3.2.1 The GMA has been carried out using proprietary spreadsheets and the commercially available software Oasys Pdisp and Xdisp which consider the three-dimensional ground movement field induced by the proposed excavation works.

3.2.2 In this analysis the soil is assumed to behave as an isotropic, linear elastic medium. Structural forces applied to the foundation are represented by applying pressures within the elastic half-space representing the foundation soils.

3.2.3 Greenfield assumptions have been adopted for this analysis, where the effects have surrounding anthropogenic structures has not been considered, i.e. the inherent stiffness of the structures under consideration have not been considered.

3.2.4 Installation effects (underpins construction) have been modelled with the application of CIRIA C760 *installation of planar diaphragm wall installation in stiff clay*. It is assumed that some effects of workmanship are intrinsically captured within the movement records. It is assumed that the ground works will be carried out by a competent and experienced groundworks contractor.

3.2.5 Excavation effects have been considered in two separate ways:

- Heave movements resulting from an overburden removal mechanism (due to bulk excavation works).

- Horizontal and vertical ground movements with respect to the CIRIA C760 *excavation in front of a stiff wall in stiff clay* empirical data set.

3.2.6 A proposed building loading of 10kPa per storey has been assumed for this analysis, resulting in 40kPa long-term building load. The proposed foundation system has been assumed to be a raft at the proposed formation level.

3.2.7 Uniformly distributed loading zones have been modelled for the buildings at a depth equal to the proposed formation level, in order to account for the unloading/reloading mechanisms.

3.2.8 A series of three-dimensional models of the proposed scheme have been developed in both software packages outlined previously and have been combined by means of superposition to represent the various ground displacement fields summarised above. An indicative plot of the analytical model is presented below in Figure 3.1.

3.2.9 The potential impact/damage induced on primary façade/wall elements of the buildings within the zone of influence of the proposed scheme has been evaluated on the basis of the calculated ground movement field.

3.2.10 The buildings included in the impact assessment were identified from a screening zone of influence. The zone of influence extends approximately between 3 to 4 times the depth of excavation. At this distance, the normalised ground movement curves in CIRIA indicate low ground movement. Neighbouring properties further afield are assessed to be at low risk of adverse impact from the proposed work due to their distance from the development site.

3.2.11 The structural walls of concern are shown in Figure 3.1 including the wall nomenclature/reference system adopted.

3.2.12 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.

3.2.13 Tensile strains induced within the building masonry walls have been evaluated based on a combination of direct tension and the deflection ratios Δ/L estimated from the analyses (Figure 3.2). The assessment considers the well-established Burland (1997) damage classification method, as presented and summarised in Figure 3.3. This method involves a 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 type.

3.2.14 Potential damage categories are directly related to the tensile strains induced by the assessed interim (short-term) and long-term phases of construction, arising from a combination of direct tension and bending induced tension mechanisms.

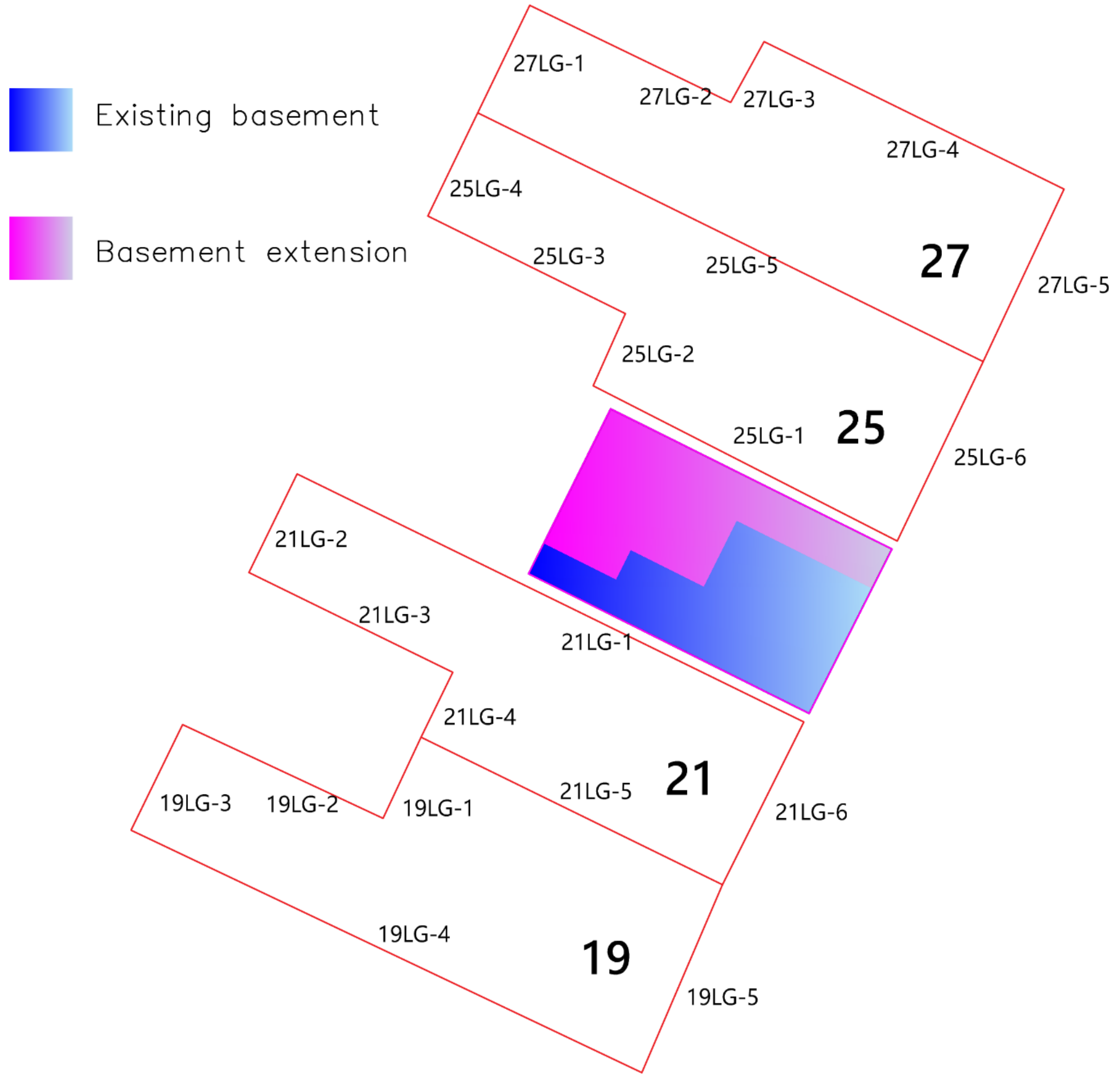

Figure 3.1: Idealised proposed scheme, neighbouring buildings within zone of influence (indicated with red lines) and adopted façade nomenclature. Numbers indicate the properties' addresses.

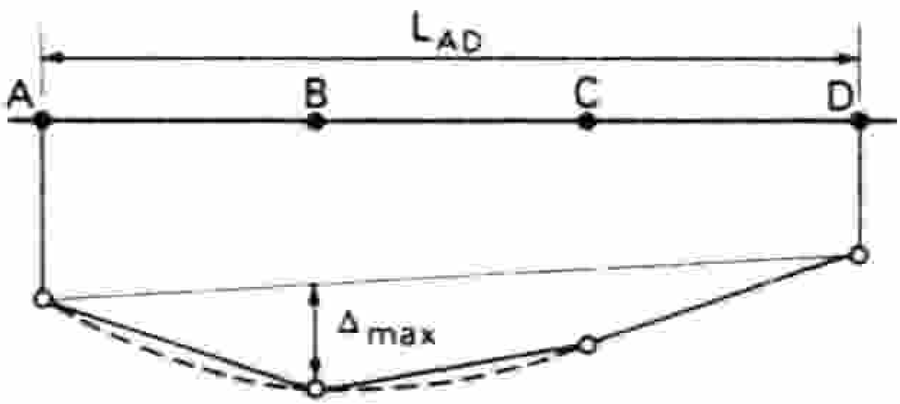

Figure 3.2: Definition of relative deflection Δ and deflection ratio Δ/L.

Building damage classification, after Burland et al 1977 and Boscardin and Cording 1989				
Category of damage		Description of typical damage (ease of repair is underlined)	Approximate crack width (mm)	Limiting tensile strain %
0	Negligible	Hairline cracks of less than about 0.1mm are classes 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. Weather-tightness 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, floors 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 3.3: Damage categorisation – relationship between category of damage and limiting strain ε_{lim}.

3.3 Ground Model

3.3.1 The following section summarises the ground model adopted for this analysis.

3.3.2 The stratigraphy discussed herein is based on the site-specific ground investigation carried out by Jomas Associates Ltd in January 2019. Hand penetrometer tests have been conducted during this investigation and indicated undrained shear strength values significantly higher than common findings.

3.3.3 Although the study presented herein takes cognisance of the site-specific ground investigation, strength and stiffness properties of the London Clay stratum have been informed by a nearby (6 Kidderpore Avenue, 300m to the north) site investigation due to the lack of SPT data.

3.3.4 Short-term (undrained) elastic stiffness parameters have been adopted for calculating the effects of overburden removal. Long-term (drained) elastic stiffness parameters have been adopted to account for the effects of soil reloading after the completion of the proposed works.

3.3.5 The undrained shear strength profile of London Clay is shown in Figure 3.2.

3.3.6 Table 3.1 presents the ground model adopted for this analysis.

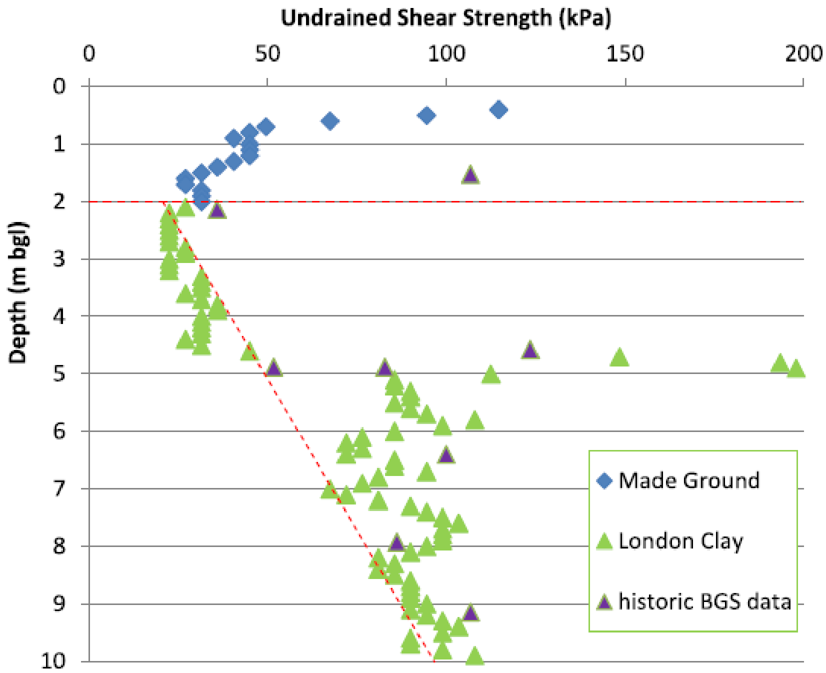

Figure 3.2: Adopted London Clay undrained shear strength profile from SPT and triaxial testing with interpreted trend (red dashed line) obtained from the 6 Kidderpore Ave. site investigation.

3.3.7 The correlations $E_u = 500c_u$ and $E' = 0.8E_u$ have been used to determine the drained Young's Modulus of the London Clay.

3.3.8 Based on the site-specific ground investigation data the Made Ground layer has been recorded to vary between 0.2m and 0.65m. The existing basement is indicated to be approximately 1.4mBGL. Therefore, the Made Ground stratum has been ignored for the study presented herein.

3.3.9 A rigid boundary of all models has been assumed at a depth of 15mBGL.

Table 3.1: Ground model and geotechnical parameters adopted for the GMA

Stratum	C_u (kPa)	Undrained Young's Modulus E_u (MPa)	Drained Young's Modulus E' (MPa)
London Clay	25.0 + 9.3z [1]	12.5 + 4.7z [1]	10.0 + 3.7z [1]

1. z is the depth from the top of the London Clay, in metres.

3.4 Impact Assessment Outcome

3.4.1 The assessment results indicate minimal impact on adjacent properties as a result of the proposed works. A maximum vertical and horizontal displacement of 6mm and 4mm, respectively has been calculated for the worst-case scenario representing the long-term effects of the proposed scheme (CIRIA C760 wall installation of planar diaphragm wall in stiff clay, CIRIA C760 excavation in front of a stiff wall in stiff clay, long-term reloading).

3.4.2 The maximum movement induced by the proposed development on the neighbouring properties has been observed on façade 25LG-1 which is subject to maximum vertical and horizontal displacements of 5mm and 2mm, respectively.

3.4.3 All façades included in the assessment have been evaluated to fall within damage *Category 0 – Negligible* based on the Burland damage criteria.

3.4.4 A perspective view of the Xdisp 3d model is depicted in Figure 3.3.

3.4.5 Contour plots of vertical and horizontal ground movements are presented below in Figures 3.4 and 3.5.

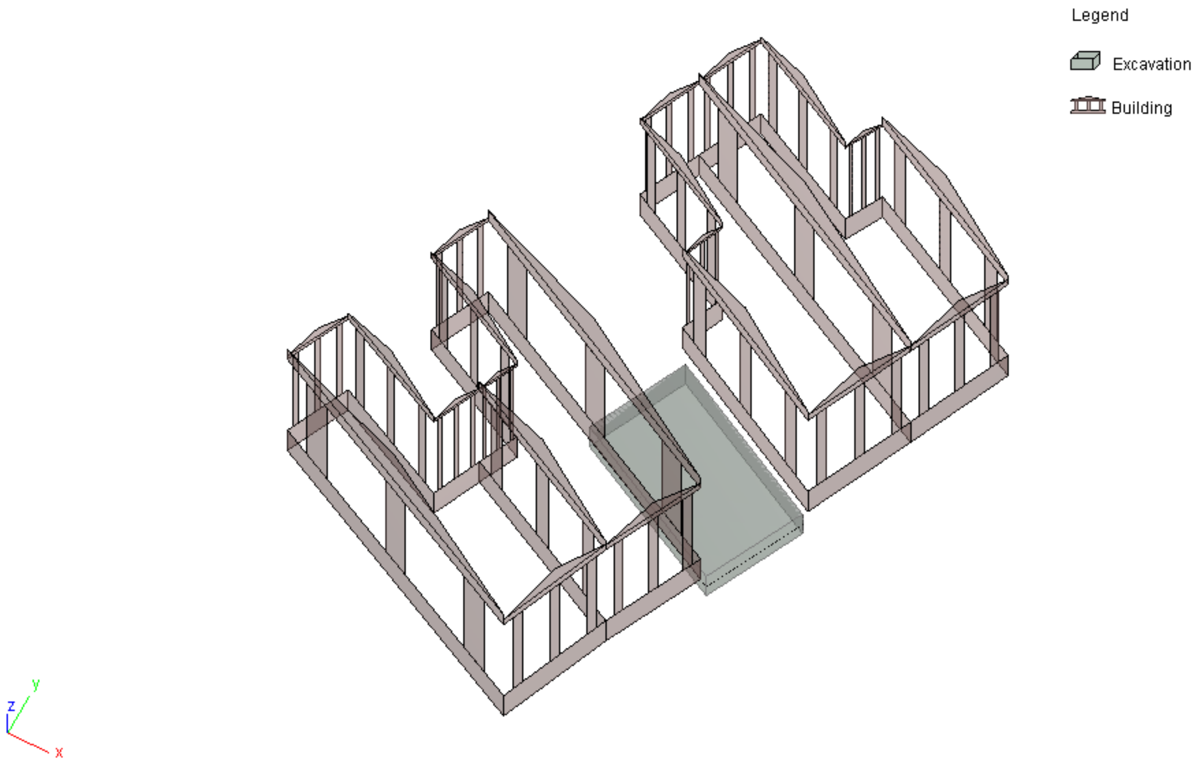

Figure 3.3: Perspective view of Xdisp 3d model indicating the excavation zones and neighbouring properties.

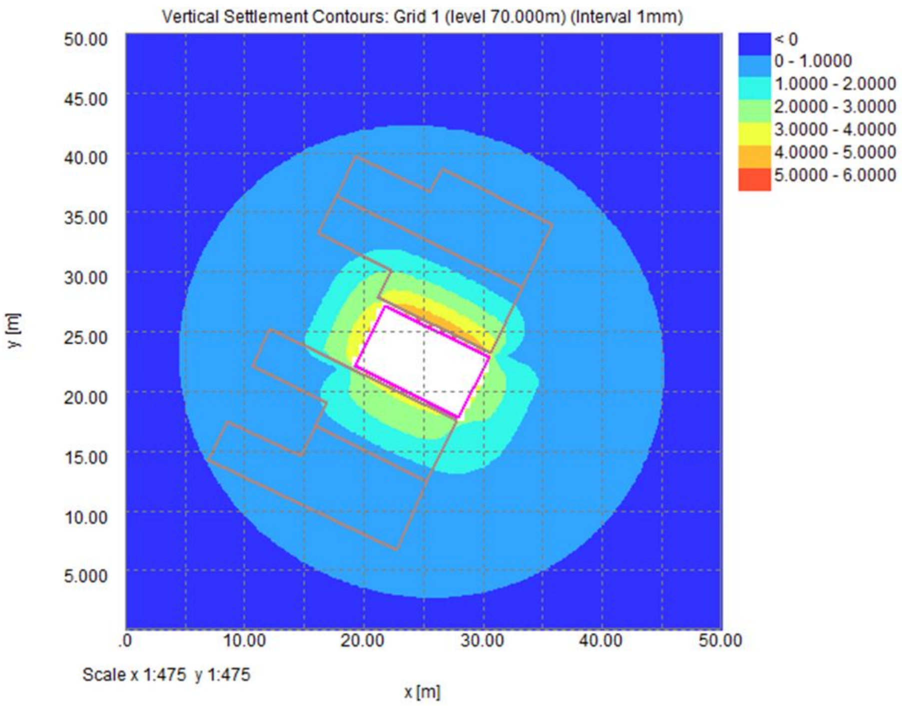

Figure 3.4: Vertical ground movement contour plot induced by the underpins installation, basement excavation and reloading of soil at a greater depth.

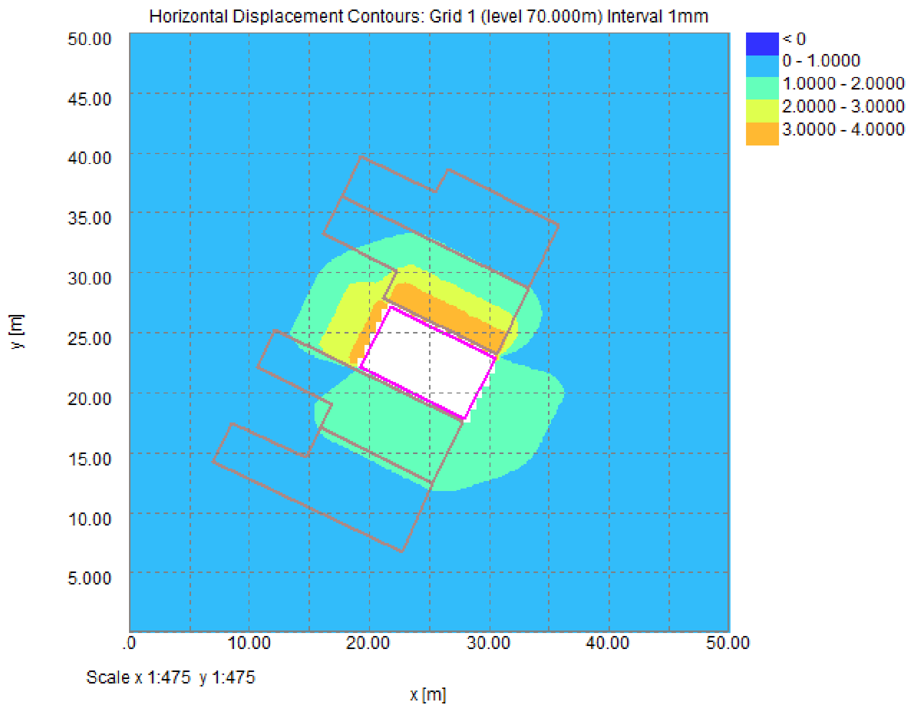

Figure 3.5: Resultant horizontal ground movement contour plot induced by the underpins installation, basement excavation and reloading of soil at a greater depth.

4 EXCAVATION MONITORING

4.1 Proposed monitoring objectives

4.1.1 A number of proposed monitoring objectives have been identified as follows:

- Construction process control: Provision of data that informs decisions made as an integral part of the basement excavation and propping activities.
- Design verification: Provision of data to validate assumptions and predictions made during the design process, and to verify that the pile wall is performing in line with the assumptions used in the Ground Movement Assessment.
- Risk management: Provision of data that may be used to trigger pre-planned contingency actions to control the risks associated with the impact of the basement works.
- Liability: Provision of evidence to any third parties.
- Asset protection: Provision of data that may be used in connection with contingency plans to protect adjacent properties.
- Legislative compliance: Provision of evidence in support of a safe system of work for the site personnel and any affected third parties. Also aids the various designers in meeting their CDM regulation obligations.

4.2 Trigger limits

4.2.1 The GMA presented herein has formed the basis of the deflection trigger limits presented in this section. Thus, the deflection values in the assessment are considered to be the upper limit in order to avoid damage to adjacent properties in excess of that considered allowable.

4.2.2 The following colour code system for the trigger values is proposed:

1. GREEN All behaviour is as predicted, continue excavation/earthworks operations, construction and monitoring accordingly.

2. AMBER Minor displacement occurring outside that predicted, but movement remaining within acceptable limits to prevent damage to neighbouring properties. Review/check monitoring data, increase monitoring frequency and review movement trends to establish timeline for any potential further trigger limit breach. Develop contingency measures e.g. complete detailed design of any additional temporary propping/supports.

   If/when deflection readings reach the amber trigger level threshold, the developed contingency measures will be compiled and issued to the Party Wall Surveyors for review/comment. The Contractor will undertake preparatory works in order to secure required materials, proprietary products and plant/machinery in preparation for the potential event of exceedance of the red trigger level threshold (and requirement for implementation of mitigation/contingency procedures).

3. RED Movements exceeding limit and magnitudes may potentially result in damage to adjacent properties beyond the agreed categorisation. Stop excavation in affected region, inspect the pile wall and neighbouring properties, use the monitored data to reassess damage the damage category of the neighbouring properties. If required implement contingency measures e.g. additional temporary propping.

   In the event of red trigger level exceedance, the works in the area of concern will be halted with immediate effect (on the day the exceedance is recorded). The mitigation measures developed by the Contractor and project team will be implemented in accordance with the relevant submissions provided to the Party Wall Surveyors. The Party Wall Surveyors/advising Engineers and the Building Owner's engineering/consultancy team will meet on site as soon as viable in order to establish an appropriate and effective strategy for progressing the works (including criteria and programme for recommencement of excavation/construction operations).

4.2.3 The proposed trigger limits are summarised in Tables 4.1 and 4.2; horizontal and vertical movement trigger values have been provided. These values should be agreed with all interested parties/stakeholders prior to the start of basement excavation works.

4.2.4 Monitoring data will allow all parties involved in the project to directly compare monitoring results against the trigger values. Depending on the monitored movements of the adjacent properties, as compared to that predicted from the analysis, the data can be used to assist in reviewing working methods so as to avoid consequential damage to neighbouring properties. Identifying deviations in trends can lead to the implementation of predetermined mitigation measures.

4.2.5 Monitoring reading reports should be issued to the party wall surveyors at appropriate intervals over the duration of the works. This should be accompanied by an overview/statement from the temporary works engineer/project structural engineer or specialist monitoring company detailing any actions required.

4.2.6 Two sets of standard trigger limits have been stipulated, one set for 21 Lyncroft Garden and another for 25 Lyncroft Gardens.

Table 4.1: Standard trigger limits (mm) – for monitoring of the earth retention system adjacent to 21 Lyncroft Gardens.

Excavation stage		GREEN	AMBER	RED
Excavation to proposed basement formation level	Horizontal	< 2	2 - 3	> 3
	Vertical	< 3	3 - 5	> 5

Table 4.2: Standard trigger limits (mm) – for monitoring of the earth retention system adjacent to 25 Lyncroft Gardens.

Excavation stage		GREEN	AMBER	RED
Excavation to proposed basement formation level	Horizontal	< 3	3 - 4	> 4
	Vertical	< 4	4 - 6	> 6

5 CONCLUSIONS & SUMMARY

5.1.1 The interaction between the proposed 23 Lyncroft Gardens development and the adjacent neighbouring properties has been reviewed as part of the GMA study presented herein.

5.1.2 The impact of the basement excavation stage of construction has been reviewed utilising the CIRIA C760 ground movement curves for installation and excavation works in stiff clay.

5.1.3 The geology underlying the site comprised 0.5m of Made Ground over London Clay. The strength/stiffness profile of the London Clay was determined from site investigation data of a nearby site due to the lack of in-situ testing on the site examined herein.

5.1.4 The results from the analysis are presented in Figures 3.3 and 3.4.

5.1.5 The assessment results have been found to be nominal. Maximum global vertical and horizontal displacements of 6mm and 4mm, respectively, have been observed for the worst-case scenario representing the long-term effects of the proposed scheme.

5.1.6 The maximum movement induced by the proposed development on the neighbouring properties has been observed on façade 25LG-1 (northern party wall examined herein) which was calculated to undergo maximum vertical and horizontal displacements of 5mm and 2mm, respectively.

5.1.7 All façades have been evaluated to fall within damage *Category 0 – Negligible* based on the Burland damage criteria.

5.1.8 It is noted that the predicted ground movements are considered to be moderately conservative in light of the relatively cautious ground model assumptions and simplified greenfield nature of the assessment undertaken.

5.1.9 The assessment presented herein is dependent and reliant on the works being undertaken by an experienced contractor, high quality workmanship and appropriate supervision of construction means and methods by experienced personnel.

5.1.10 Finally, it is noted that the GMA will be supplemented by a project specific monitoring regime and Action Plan, which will detail lines of responsibility, monitoring trigger levels and appropriate potential mitigation measures.

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