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GROUND MOVEMENT ASSESSMENT (GMA) REPORT

46 COMPAYNE GARDENS
HAMPSTEAD
LONDON
NW6 3RY

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APPENDIX 3 – P-DISP & X-DISP INPUT/OUTPUT DATA FOR SCENARIO 2

EXECUTIVE SUMMARY

Dovid Katz commissioned Jomas Associates Ltd to undertake a Ground Movement Assessment (buildings) at the site located at 46 Compayne Gardens, Hampstead, London, NW6 3RY. The salient details of this commission are summarised in the table below.

Executive Summary	
Current Site Use	3-storey semi-detached residential property.
Proposed Site Use/Works	It is proposed to form a basement under the entire footprint of the existing building and projecting slightly beyond the rear façade. The nearest adjacent structures are approx. 0m to the west and 1.5m to the east of the site.
Ground Conditions	The results of a ground investigation revealed a ground profile comprising Made Ground, overlying London Clay Formation. During drilling a groundwater seepage was noted in WS2 at 7.0m bgl. No groundwater was reported in WS1, TP1 or TP2. 1No. return groundwater monitoring visit was undertaken and reported groundwater at 1.32m bgl in WS2, however, WS1 was dry to its base at 4.15mbgl. The groundwater reported in WS2 is not considered to represent a true groundwater body as the London Clay Formation is an unproductive stratum.
Ground Movement Assessment	The Ground Movement Assessment results indicate minimal impact on adjacent properties as a result of the proposed works. The obtained damage categories vary between Category 0 - (Negligible) and Category 1 - (Very Slight) for all analysed scenarios, with respect to the Burland structural damage assessment criteria. These results are within the typical acceptable limits of anticipated structural damage for developments within the London Borough of Camden.

It should be noted that the table above is an executive summary of the findings of this report and is for briefing purposes only. Reference should be made to the main report for detailed information and analysis.

1 INTRODUCTION

1.1 Terms of Reference

1.1.1 Dovid Katz ("The Client") has commissioned Jomas Associates Ltd ('Jomas'), to undertake an assessment of the impact of the proposed development at a site referred to as 46 Compayne Gardens, Hampstead, London, NW6 3RY, on neighbouring buildings. The assessment will inform the planning, design and construction strategies for the site.

1.1.2 To this end, a Ground Movement Assessment (GMA) was undertaken in accordance with Jomas' proposal dated 30th May 2023.

1.2 Proposed Development

1.2.1 It is understood that it is proposed to form a basement under the entire footprint of the existing building and projecting beyond the rear façade.

1.3 Objectives

1.3.1 The GMA encompasses the assessment of the potential structural damage induced to neighbouring properties as a result of the proposed development.

1.4 Supplied Documentation

1.4.1 A number of reports, plans and documents were previously prepared by, or supplied to Jomas Associates to support the analysis required for the GMA. Table 1.1 details the documents supplied:

Table 1.1: Supplied Reports

Title	Author	Reference	Date
Stage 1 & 2 Basement Impact Assessment (Screening & Scoping) for 46 Compayne Gardens, Hampstead NW6 3RY	Jomas Associates Ltd	P4094J2580/SC v2.0	February 2024
Ground Investigation and Basement Impact Assessment for 46 Compayne Gardens, Hampstead, NW6 3RY	Jomas Associates Ltd	P4094J2580/SC v2.0	February 2024
Proposed Plans	UPP Planning	46CG_Proposed Design-Rev 3	August 2023
Proposed Basement and Ground Floor Plan – Reactions Mark-up	Articlus Ltd	AR-SK-1001	September 2023

1.5 Limitations

1.5.1 Jomas Associates Ltd ('Jomas') has prepared this report for the sole use of Dovid Katz, 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. 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 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 every effort has been made to ensure the accuracy of the data supplied, and any 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.

1.5.6 This assessment excludes consideration of impact to buried utilities, highways, railways, tunnels or other assets unless otherwise stated.

2 EXISTING INFORMATION

2.1 Site Information

2.1.1 The site location plan is appended to this report in Appendix 1.

Table 2.1: Site Information

Name of Site	-
Address of Site	46 Compayne Gardens Hampstead London NW6 3RY
Approx. National Grid Ref.	525915 184501
Site Area (Approx.)	0.06ha
Site Occupation	Residential
Local Authority	London Borough of Camden
Proposed Site Use	Residential.
Proposed Works	The development will include excavation to form a single-level basement beneath the existing building footprint and extending slightly beyond the rear façade.
Nearest Structures	The nearest adjacent structures are approx. 0m to the west and 1.5m to the east of the site.

Figure 2.1: Satellite view of the site – Approximate site boundary indicated by the red line

2.2 Site Layout

2.2.1 A site walkover survey was undertaken by Jomas on the 8th June 2022.

Table 2.2: Site Description

Area	Item	Details
On-site:	**Current Uses:**	Site consists of a three-storey semi-detached building split into several residential flats. There is also a driveway and rear garden. It is understood that there is an existing small cellar, though access was not permitted at the time of the walkover.
	Evidence of historic uses:	No evidence of historic uses observed on site.
	Surfaces:	The driveway, side access and small area to rear are brick covered. The rear garden is predominantly lawn with vegetated boundaries. A small soft-landscaped area is also present in the south-west of site next to the driveway.
	Vegetation:	Trees located along west and north boundaries of rear garden.
	Topography/Slope Stability:	The site is observed to be level.
	Drainage:	Site appears to be connected to normal drainage facilities with no issues noted.
	Services:	Site appears to be connected to usual residential services which are in use.
	Controlled waters:	No controlled waters were observed on site.
	Tanks:	No tanks were observed on site.
Neighbouring land:	**North:**	Vegetated area – possible park/garden.
	East:	Residential.
	South:	Compayne Gardens (road) and residential.
	West:	Residential.

2.3 Summary of Ground Conditions

2.3.1 A ground investigation was carried out by Jomas Associates on 23rd June 2022, comprising 2No. windowless sample boreholes, 2No. hand-excavated trial pits, return groundwater monitoring and laboratory geotechnical testing (report ref. P4094J2580/SC v2.0, dated February 2024).

2.3.2 The ground investigation encountered a sequence comprising Made Ground overlying solid geology of the London Clay Formation, as summarised in Table 2.3 below.

Table 2.3: Ground Conditions Encountered

Stratum and Description	Encountered from (mbgl)	Base of strata (mbgl)	Thickness range (m)
Grass or brick paving over brown locally mottled orangish brown slightly sandy very gravelly clay. Sand is coarse. Gravel consists of fine to coarse sub-angular to rounded flint with occasional fine sub-angular brick. (MADE GROUND)	0.0	>0.8 - 1.1	>0.8 - 1.1
Firm** light brown mottled orangish brown very gravelly CLAY. Gravel consists of medium to coarse sub-rounded flint. (LONDON CLAY FORMATION) *Encountered in WS2 only.*	1.1	1.7	0.6
Firm to stiff** orangish-brown to greyish brown becoming grey silty CLAY with occasional selenite crystals. (LONDON CLAY FORMATION)	1.1 – 1.7	>8.0 [Base not proven]	>6.9 [Thickness not proven]

***Consistency estimated using semi-empirical correlations with SPT N-values, Plasticity Indices and published literature*

2.3.3 During drilling a groundwater seepage was noted in WS2 at 7.0m bgl. No groundwater was reported in WS1, TP1 or TP2.

2.3.4 1No. return groundwater monitoring visit was undertaken on 4th July 2022, as summarised below.

Table 2.4: Groundwater Monitoring Summary

Exploratory Hole ID	Depth Encountered (m bgl)	Depth base of well (m bgl)	Stratum
WS1	Dry	4.15	N/A
WS2	1.32	6.26	London Clay Formation

2.3.5 The groundwater reported in WS2 is not considered to represent a true groundwater body as the London Clay Formation is an unproductive stratum, and it is considered to be perched. This is corroborated by the absence of groundwater in WS1 and is therefore considered to be perched water, perhaps surface water that has infiltrated the well-space and been unable to drain away.

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 are associated with the proposed works, providing a simplified account of the following.

- Installation works:
  - Ground movements associated with the installation of the underpin wall around the basement perimeter.
- Basement excavation:
  - Ground movements associated with overburden removal (heave) due to excavation works.
  - Ground movement associated with soil-structure interaction between the retaining walls and retained ground mass.
  - Ground Movements from the imposed line loads around perimeter.
- Long-term ground movements:
  - Ground movements associated with loading of the soil resulting from the proposed structure construction.

3.2 Methodology

3.2.1 The GMA has been carried out using the commercially available software packages P-Disp and X-Disp, produced by Oasys Software. These packages consider the three-dimensional ground movement field induced by proposed excavation and construction works.

3.2.2 For the purposes of the 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 of surrounding anthropogenic structures have not been considered, i.e. the inherent stiffness of the structures under consideration has not been taken into account.

3.2.4 Wall installation effects have been modelled with the application of CIRIA C760 *Installation of planar diaphragm wall in stiff clay* for the underpin wall. Whilst the empirical data set for diaphragm wall installation is not strictly compatible with the construction technologies adopted in underpinning works, it has been 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 satisfactory and conservative approximation. The toe of the envisaged underpin wall has been assumed to be at 3.0m bgl.

3.2.5 The excavation effects have been modelled with the application of the CIRIA C760 *Excavation in front of high stiffness wall in stiff clay*. The excavation height adopted for the basement is 3.0m bgl.

3.2.6 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 due to excavation in front of the underpin retaining wall based on the CIRIA C760 *excavation in front of high stiffness wall in stiff clay* empirical data set.

3.2.7 A uniformly distributed load of -57kPa representing 3.0m of excavation has been applied over the proposed basement footprint to assess the overburden removal / soil heave mechanism.

3.2.8 The proposed building will be supported by a combination of underpins and RC walls around the perimeter, as well as a 3x3m pad and 800mm diameter beams in the basement footprint. A structural loading plan has been provided and is included in Appendix 1. Line loads of between 40.1kN/m and 218.5kN/m have been applied to represent the induced proposed building loads on the perimeter walls. Line loads of between 132kN/m and 638kN/m have been applied to represent the induced proposed building loads on the proposed strips/beams within the basement footprint. A point load of 895kN has been applied to the proposed 3x3m pad.

3.2.9 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.

3.2.10 The scenarios simulated for the assessment presented herein have encompassed the following ground movements aspects.

- **Scenario 1**: Installation of underpin wall and application of line loads only (short-term).
- **Scenario 2**: Installation of underpin wall, excavation of proposed basement (CIRIA) and application of all structural loads (long-term).

3.2.11 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.

3.2.12 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. The structural walls of concern are shown in Figure 3.1.

3.2.13 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.

3.2.14 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.

3.2.15 Potential damage categories are 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: Neighbouring buildings within zone of influence (excavation indicated in grey)

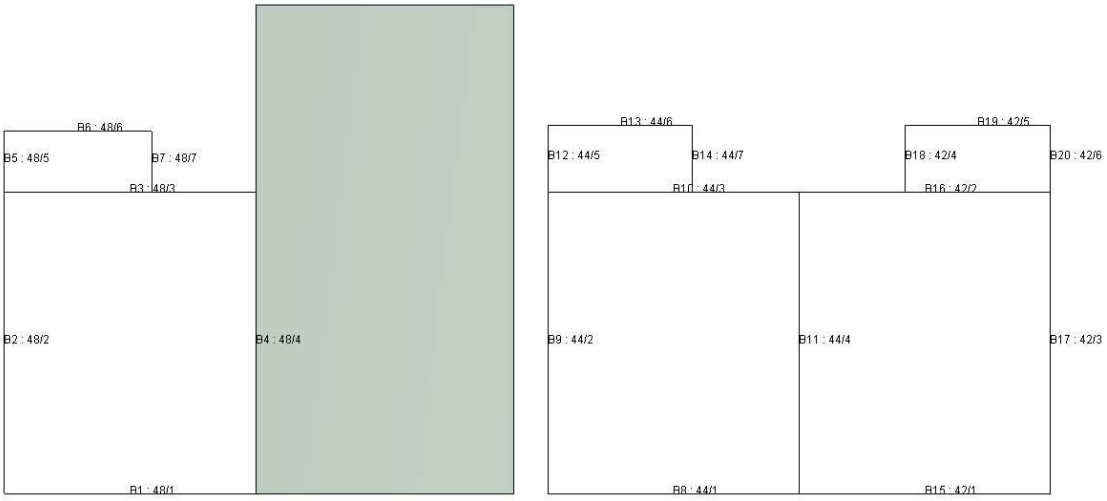


Figure 3.2: Definition of relative deflection Δ and deflection ratio Δ/L.

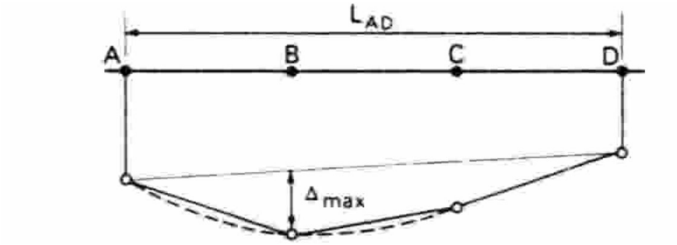


Figure 3.3: Damage categorisation – relationship between category of damage and limiting strain ε_{lim}.

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	

3.3 Ground Model

3.3.1 The stratigraphy discussed herein is based on Ground Investigation & Basement Impact Assessment for 46 Compayne Gardens, Hampstead NW6 3RY, produced by Jomas (v2.0, February 2024).

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

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

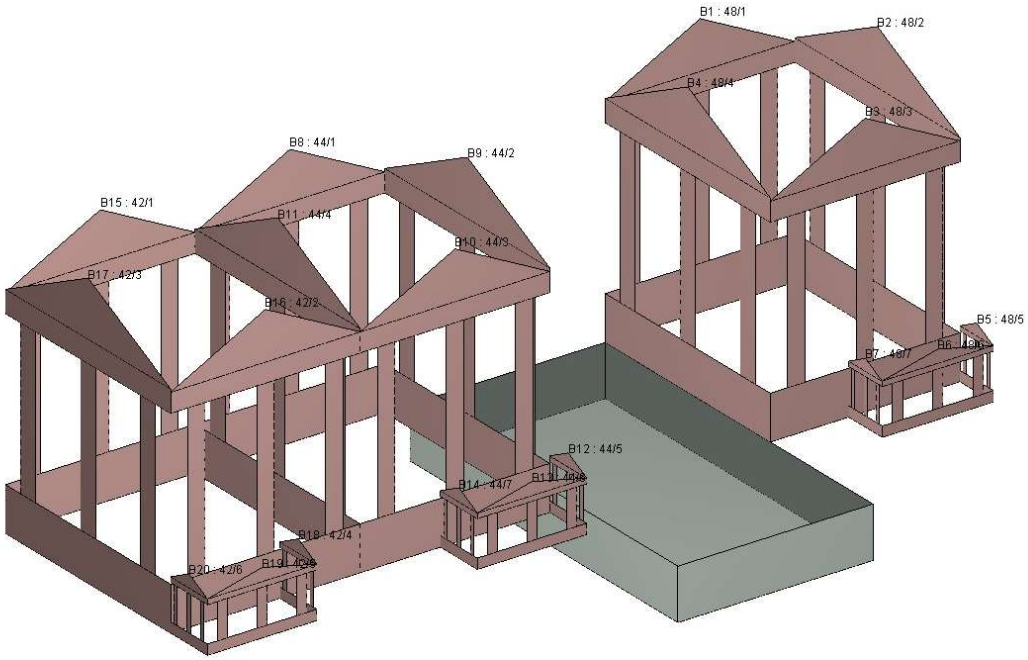
Stratum	Top of Stratum (m AOD)	Undrained Young's Modulus E_u (kPa) [1)]
Made Ground	0.0	9000
London Clay Formation 1	-1.0	18000
London Clay Formation 2	-3.0	21600
London Clay Formation 3	-4.0	23400
London Clay Formation 4	-5.0	27000
London Clay Formation 5	-6.0	28800
London Clay Formation 6	-7.0	30600
London Clay Formation 7	-8.0	32400
Rigid Boundary	-9.0	-
Groundwater Level	-8.9	-

1) Based on the Relationship postulated by Jardine where Eu = 400Cu for the London Clay Formation.

3.4 Impact Assessment Outcome

3.4.1 A perspective view of the XDisp 3D model is depicted in Figure 3.4.

Figure 3.4: Perspective view of XDisp 3d model indicating the excavation zones and neighbouring properties.



3.4.2 The initial assessment results indicate minimal impact on adjacent properties as a result of the proposed works. The obtained damage categories generally vary between *Category 0 (Negligible)* and *Category 1 (Very Slight)* for both analysed scenarios, with respect to the Burland structural damage assessment criteria. The exception being façade 48/3 which marginally falls into *Category 2 (Slight)* for Scenario 1. Table 3.2 presents the assessment results.

Table 3.2: Evaluated damage categories from XDisp

Façade Reference	Scenario 1	Scenario 2
48/1	0 (Negligible)	0 (Negligible)
48/2	0 (Negligible)	0 (Negligible)
48/3	2 (Slight)	1 (Very Slight)
48/4	0 (Negligible)	0 (Negligible)
48/5	0 (Negligible)	0 (Negligible)
48/6	0 (Negligible)	0 (Negligible)
48/7	0 (Negligible)	0 (Negligible)
44/1	0 (Negligible)	1 (Very Slight)
44/2	0 (Negligible)	0 (Negligible)
44/3	0 (Negligible)	1 (Very Slight)
44/4	0 (Negligible)	0 (Negligible)
44/5	0 (Negligible)	0 (Negligible)
44/6	0 (Negligible)	1 (Very Slight)
44/7	0 (Negligible)	0 (Negligible)
42/1	0 (Negligible)	0 (Negligible)
42/2	0 (Negligible)	0 (Negligible)
42/3	0 (Negligible)	0 (Negligible)
42/4	0 (Negligible)	0 (Negligible)
42/5	0 (Negligible)	0 (Negligible)
42/6	0 (Negligible)	0 (Negligible)

3.4.3 Figures 3.5 and 3.6 depict the vertical and horizontal resultant ground surface movements, respectively calculated for Scenario 1. The empirical data shows a maximum settlement of 8mm and horizontal movement of 1.5mm at the perimeter of the excavation footprint. Figure 3.7 presents the building damage resultant from Scenario 1 as modelled in XDisp.

Figure 3.5: Ground surface movements - Vertical - Scenario 1

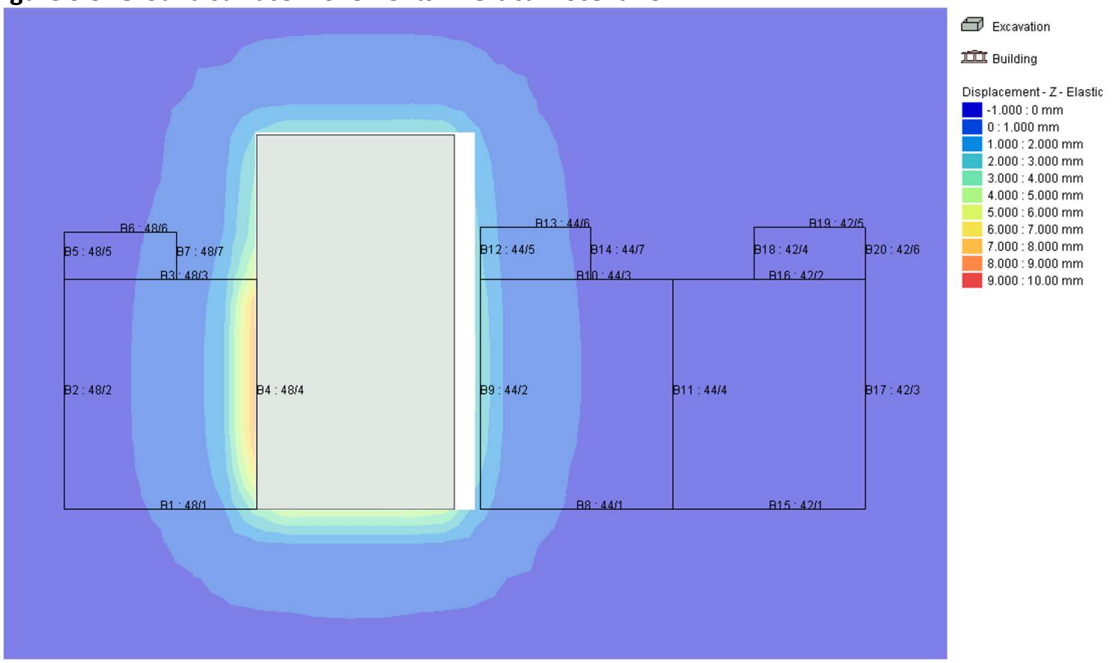


Figure 3.6: Ground surface movements - Horizontal - Scenario 1

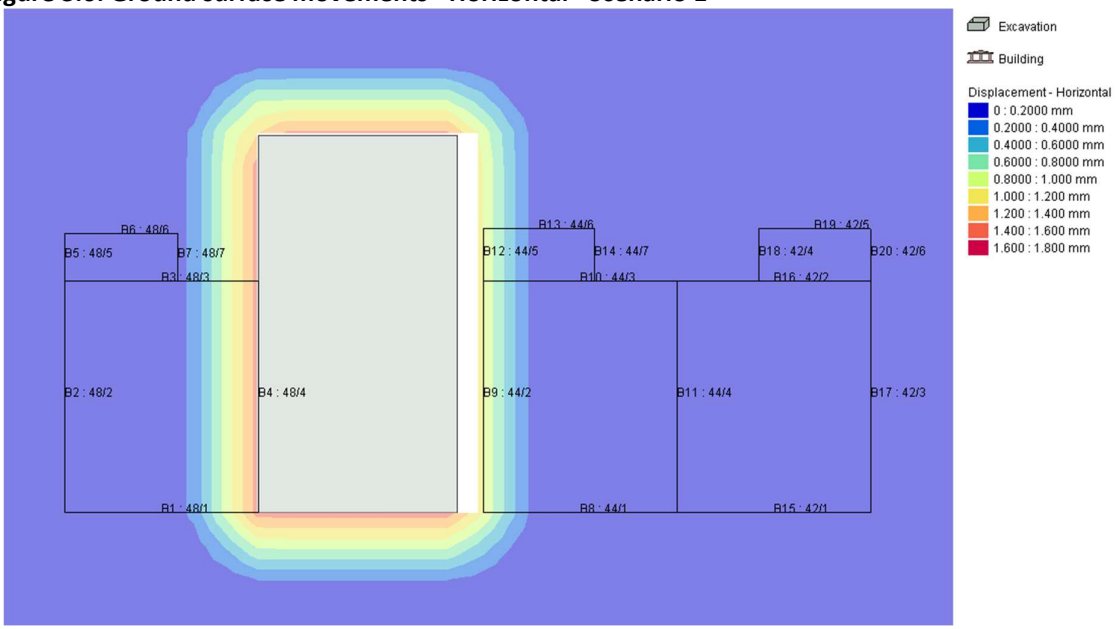
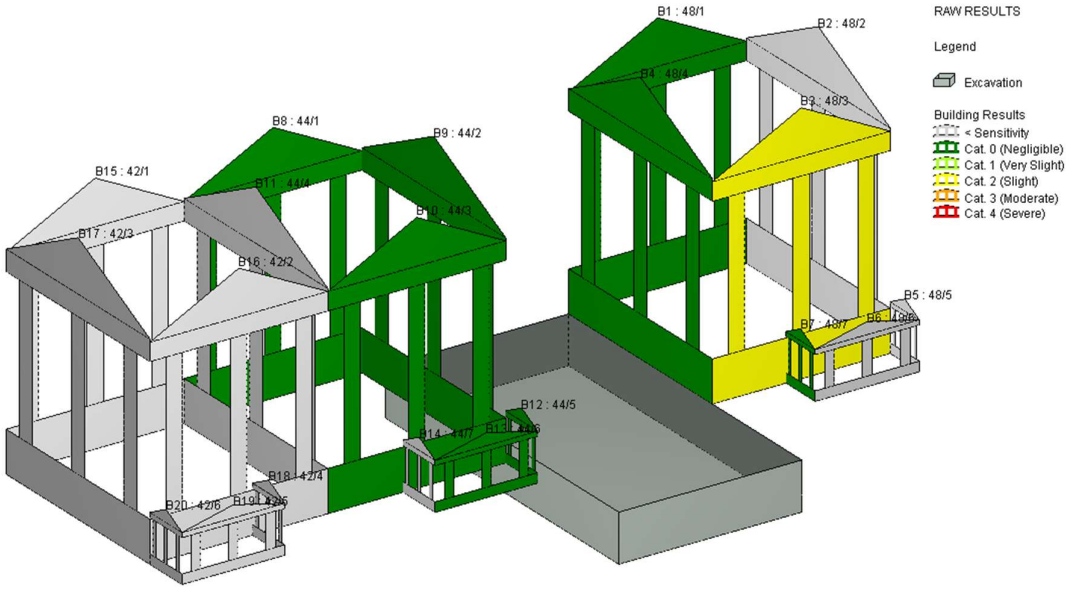


Figure 3.7: Building Damage - Scenario 1



3.4.4 Figures 3.8 and 3.9 depict the vertical and horizontal resultant ground surface movements, respectively calculated for Scenario 2. The empirical data shows a maximum settlement of 8.6mm and horizontal movement of 5.6mm at the perimeter of the excavation footprint. Figure 3.10 presents the building damage resultant from Scenario 2 as modelled in XDisp.

Figure 3.8: Ground surface movements - Vertical - Scenario 2

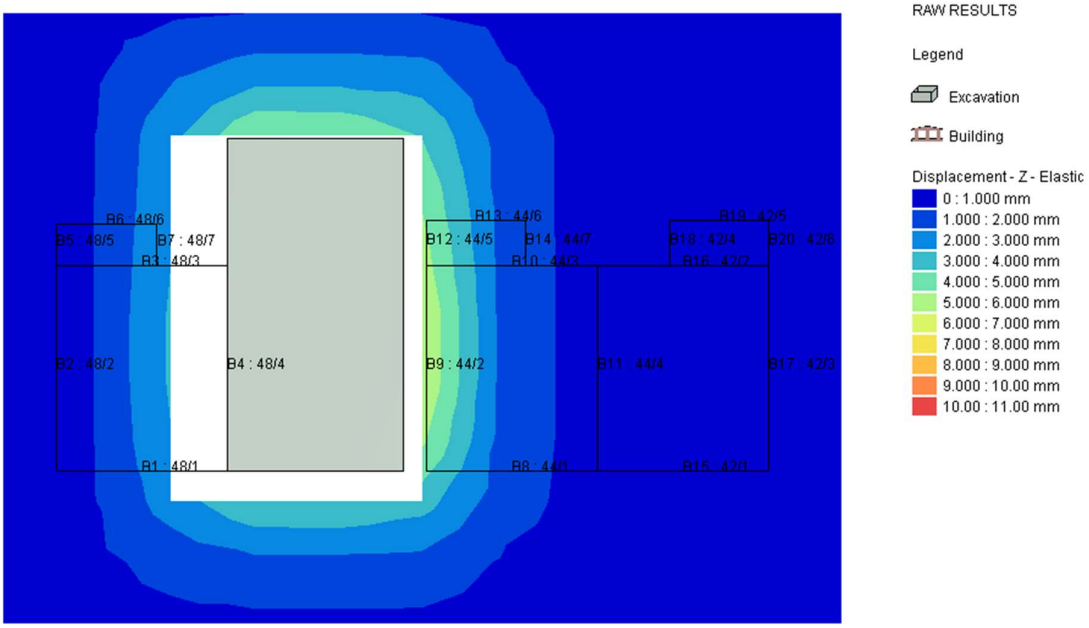


Figure 3.9: Ground surface movements – Horizontal - Scenario 2

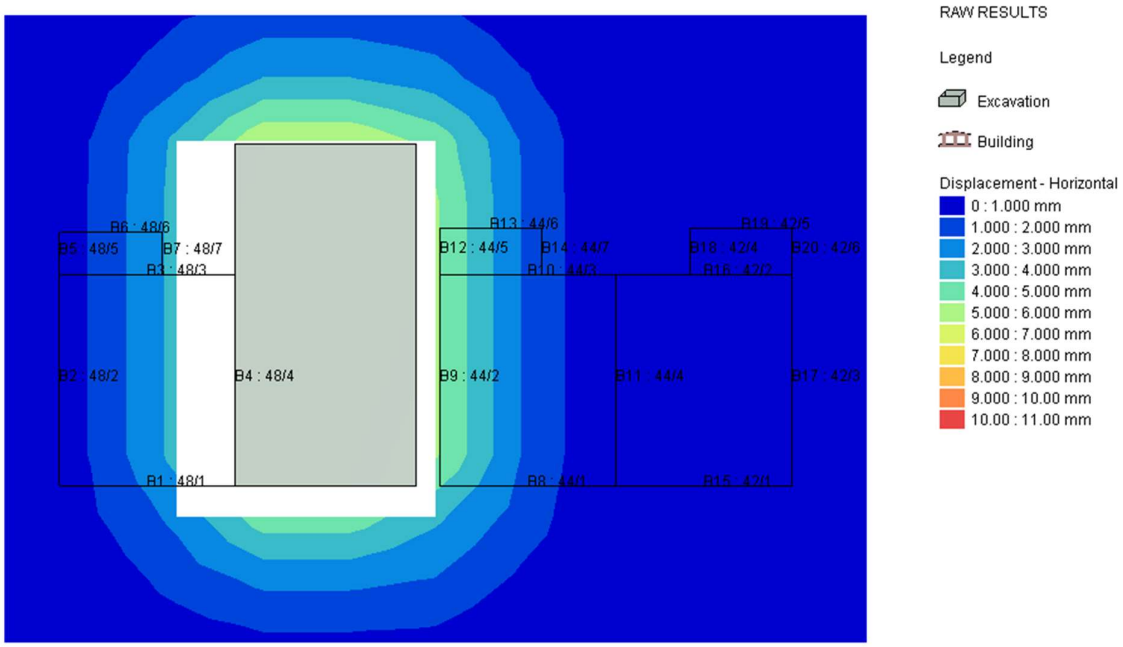
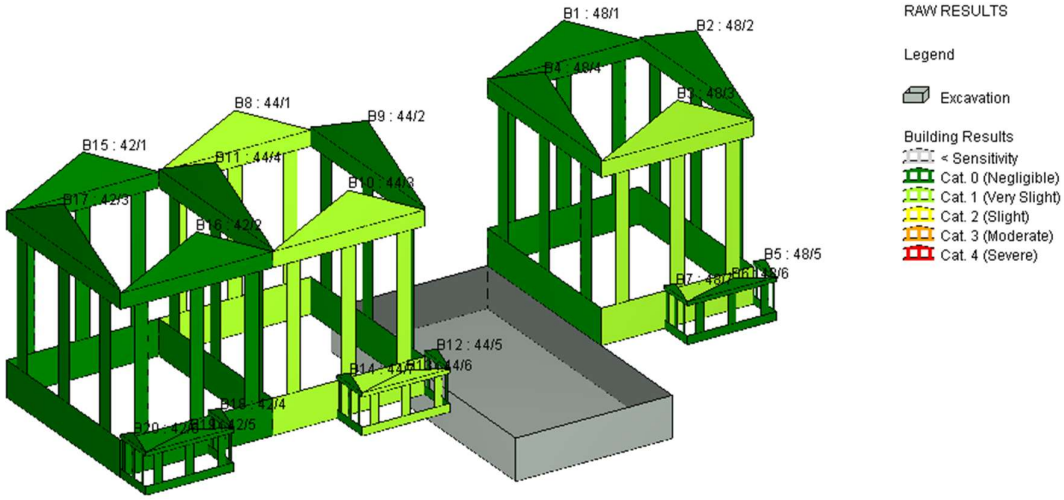


Figure 3.10: Building Damage - Scenario 2



3.5 Acceptable Movement Limits

3.5.1 As summarised in Table 3.2, with the exception of façade 48/3 in Scenario 1, the results are within the acceptable limits of anticipated structural damage for developments within the London Borough of Camden.

3.5.2 In order to keep this façade limited to *Category 1 – Very Slight*, the horizontal movement from the "*Installation of planar diaphragm wall in stiff clay*" surface movement curve modelled in XDisp has been scaled to 80%.

3.5.3 Scenario 1 has been re-modelled using this reduced curve as presented in Figures 3.11, 3.12 and 3.13. The empirical data shows a maximum settlement of 8mm and horizontal movement of 1.2mm at the perimeter of the excavation footprint.

3.5.4 The ground movements due to installation of underpins must be limited by the contractor during the installation process. The reduction in the ground movement curves has been applied to assess the maximum allowable movement and the contractor must use suitable means and methods coupled with monitoring to limit the deflection of the wall so that no unacceptable damage is caused to the neighbouring properties.

3.5.5 The vertical movement curve has not been altered and therefore Figure 3.11 is the same as Figure 3.5.

Figure 3.11: Ground surface movements - Vertical - Scenario 1

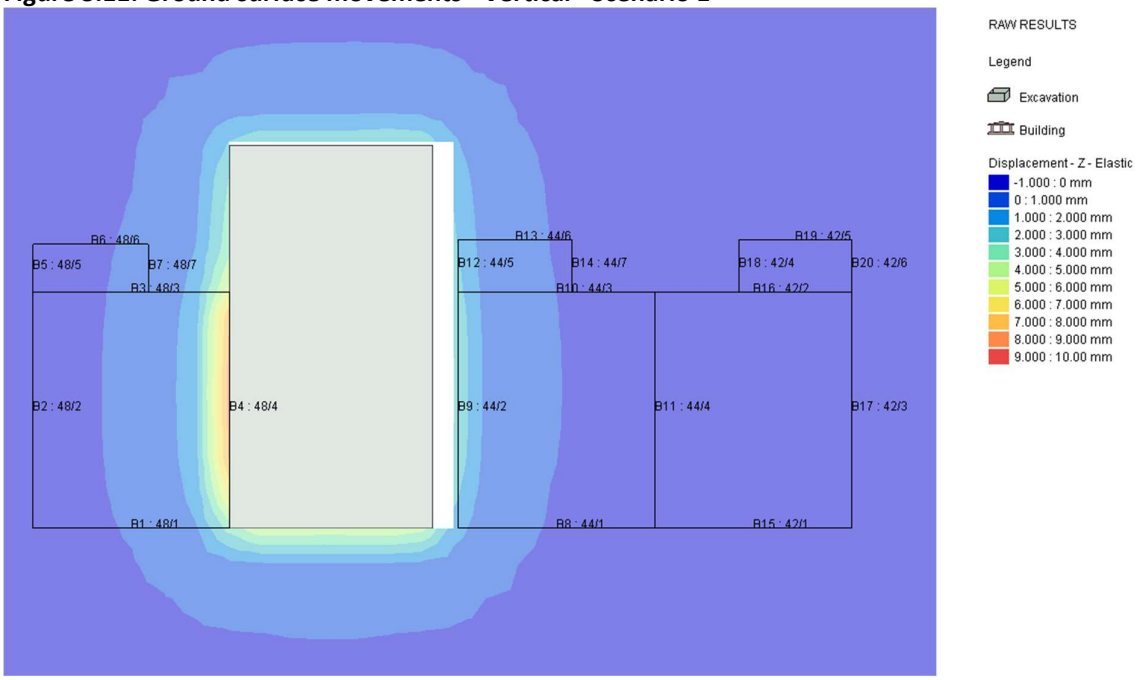


Figure 3.12: Ground surface movements - Horizontal - Scenario 1 (CIRIA Curve reduced to 80%)

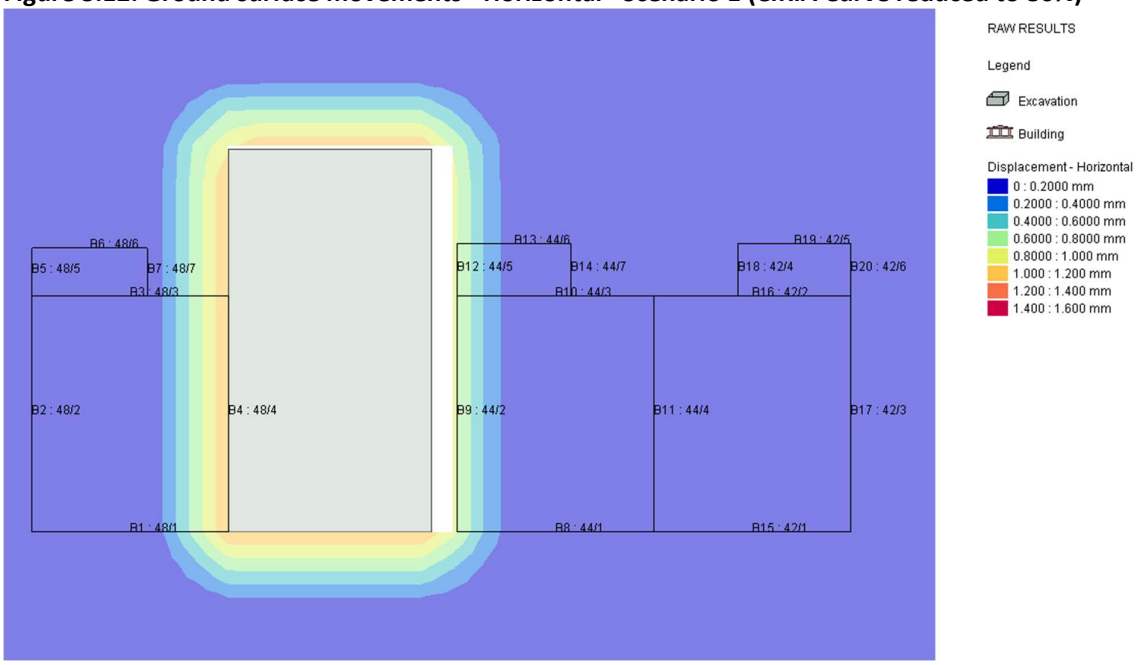
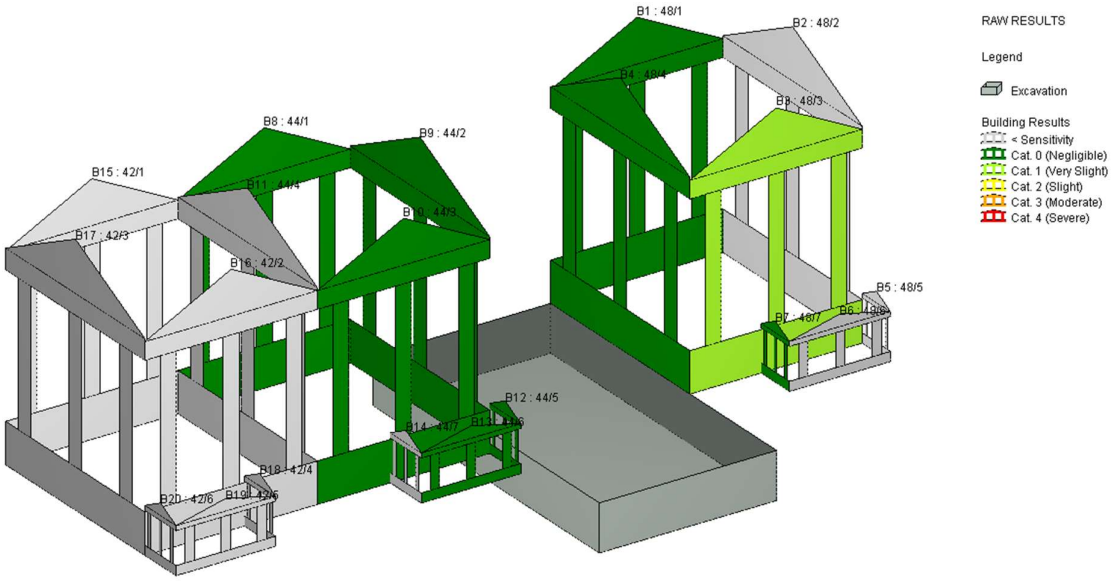


Figure 3.13: Building Damage - Scenario 1 (With horizontal CIRIA curve reduced to 80%)



3.5.6 The results of this analysis show that all buildings will fall within the acceptable damage classification (i.e. not exceeding *Category 1 – Very Slight*), if the ground movements caused by the wall installation and excavation and scheme construction are limited to the values presented in Table 3.3 below. The values in the table represent the worst-case ground movements and consider the reduction of installation horizontal movement curve in XDisp to 80%.

3.5.7 It is noted that the GMA should be supplemented by a project-specific monitoring regime and Action Plan, which will delineate lines of responsibility, trigger levels in accordance with those presented in this GMA and appropriate mitigation measures.

Table 3.3: Maximum Cumulative Ground Movement from XDisp

Scenario	Maximum Cumulative Ground Movement (mm)	
	Vertical	Horizontal
1	8.0	1.2
2	8.6	5.6

4 CONCLUSIONS AND SUMMARY

4.1.1 The interaction between the proposed redevelopment works and the neighbouring properties has been reviewed as part of the Ground Movement Assessment (GMA) study presented herein.

4.1.2 The impact of the basement excavation stage of construction has been assessed with Oasys PDisp and XDisp. Ground movements arising by wall installation effects have been taken into consideration with respect to CIRIA C760 empirical data sets. Ground movements arising by the proposed excavation works have been assessed as an overburden removal mechanism and with respect to CIRIA C760 empirical data sets.

4.1.3 The geology found within the site under consideration comprises Made Ground to a depth of ~1.0m followed by competent London Clay Formation proven to a depth of 8.0m from the site investigation.

4.1.4 The scenarios simulated for the assessment presented herein have encompassed the following ground movements aspects.

- **Scenario 1**: Installation of underpin wall and application of line loads only (short-term).
- **Scenario 2**: Installation of underpin wall, excavation of proposed basement (CIRIA) and application of all structural loads (long-term).

4.1.5 The results from the analysis are presented in Figures 3.8 to 3.13.

4.1.6 Maximum vertical and resultant horizontal displacements of 8.6mm and 5.6mm respectively at basement footprint, have been observed for the worst-case scenario representing the long-term effects of the proposed scheme.

4.1.7 All façades have been evaluated to fall within damage *Category 0 (Negligible) and Category 1 (Very Slight)* based on the Burland damage criteria, which is within the acceptable limits of anticipated structural damage for developments within the London Borough of Camden. In the short

4.1.8 The design of the underpinning/earth retention system will need to be coordinated closely with the findings and performance criteria presented within this report, in particular the excavation performance criteria presented in Section 3.5.

4.1.9 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.

4.1.10 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.

4.1.11 It is recommended that this GMA be supplemented by a project specific monitoring regime and Action Plan, which will delineate lines of responsibility, monitor trigger

levels and appropriate mitigation measures. Condition surveys of the relevant structures should be carried out before and after the proposed works.

5 REFERENCES

British Standards Institution BS 5930:2015+A1:2020 Code of practice for ground investigations. BSI: London

CIRIA Report C760 (2017) Guidance on embedded retaining wall design. CIRIA: London

Tomlinson M.J (2001): Foundation Design and Construction 7th Edition. Pearson prentice Hall: Harlow

APPENDICES

APPENDIX 1 – FIGURES

APPENDIX 2 – P-DISP & X-DISP INPUT/OUTPUT DATA FOR SCENARIO 1

APPENDIX 3 – P-DISP & X-DISP INPUT/OUTPUT DATA FOR SCENARIO 2

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