A-squared Studio

52 Avenue Road

Ground Movement Assessment – 12 Units

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Project Name	52 Avenue Road
Project Number	1942
Client	DOMVS London
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1942-A2S-XX-XX-RP-Y-0003-00	First Issue	00	PS	21.12.2021
1942-A2S-XX-XX-RP-Y-0003-01	Second Issue Incorporating updated scheme.	01	PS	28.01.2022
1942-A2S-XX-XX-RP-Y-0003-02	Third Issue Including 12-unit scheme.	02	AC	03.05.2022
1942-A2S-XX-XX-RP-Y-0003-03	Fourth Issue Following comments from client	03	AC	05.05.2022
1942-A2S-XX-XX-RP-Y-0003-04	Fifth Issue Updated scheme drawings.	04	AC	09.05.2022

Contents

1. Introduction

A-squared Studio Engineers Ltd (A-squared) has been appointed by Heyne Tillett Steel Ltd (HTS) on behalf of DOMVS London to undertake a Ground Movement Assessment (GMA) for the 52 Avenue Road Basement development in Camden, London.

The A-squared scope comprises an assessment of the potential impact of the proposed development works on the various neighbouring building façades.

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 works at 52 Avenue Road on neighbouring building façades.

The proposed development at 52 Avenue Road comprises demolition of the existing building on site and construction of three structures, housing a total of 12 residential units. A lower ground floor and single storey basement is proposed as part of the development which will reach a maximum depth of circa 9.5 m. The proposed basement perimeter will be retained by concrete contiguous piled wall. The foundation system for the building is currently under design.

The assessment encompasses properties located within the *zone of influence* of the proposed scheme. The GMA assessment is based on *greenfield* ground movements which are unlikely to be exceeded. The adopted assessment methodology provides a robust and conservative assessment, representative of current industry best practice, as detailed in Section 4.

The assessment carried out and described herein aims to:

- Assess the impact of ground movements induced by the proposed works on properties adjacent to the development under consideration.
- Provide performance criteria 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.

2. The Site & Development

2.1. Site Location and Proposed Development

The development site is located at 52 Avenue Road, NW8 6HS as shown in Figure 2.1. The approximate National Grid reference for the site is 527010E, 183850N and the site footprint covers approximately 0.28 hectares. The approximate ground surface elevation at the site is 46m above Ordnance Datum (mOD) and ground surface levels in the surrounding area fall toward the south east by approximately 6m over 275m.

The development site falls within the administrative boundaries of the London Borough of Camden and currently houses a two-storey L-shaped residential building with a large garden.

The current land uses within a 250m radius surrounding the site are summarized in Table 2.1. The existing superstructure is anticipated to comprise of masonry or timber walls, with timber floors and roofing frame with a loadbearing masonry façade. The foundations are expected to be shallow strip footings below the walls and pads underneath any internal columns and core.

The proposed building basement footprint and retaining wall layout are shown in Figure 2.2.

Figure 2.1 Location of the proposed development (boundary marked by the red line)

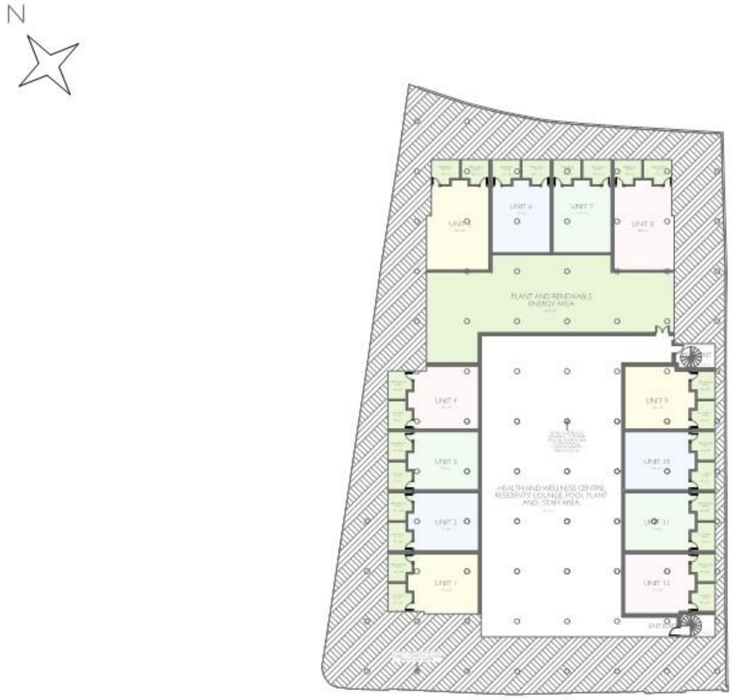


Figure 2.2 Proposed Basement Plan

Table 2.1 Surrounding land uses summary

Bearing from Site	Features directly adjacent to the site boundary	Other identified land uses and key structures
North	57 Elsworthy Road – a three-storey residential property with a garden.	Swiss Cottage School Development & Research Centre – 110m northeast. The UCL Academy – 210m northeast. Marriott Hotel – 250m north.
South	Avenue Road – a single carriageway road of approximately 10m in width.	Residential properties with gardens – 15m south. Electric car charging stations – 110m south closest.
East	50 Avenue Road – a three-storey residential property with a garden.	Primrose Hill public park – 100m east. Wembrook school – 70m south east.
West	Elsworthy Road – a single carriageway road of approximately 10m in width.	81 Avenue Road: a residential property with an outdoor swimming pool – 100m west.

3. Ground Conditions

Site-specific ground investigation works have been completed in support of the production of this GMA. Based on a review of ground investigation data and historical data in the vicinity of the project site, the ground conditions at the site were generally found to comprise the following (in order of succession):

- Made Ground – Grass over topsoil with roots and rootlets.
- London Clay Formation – Stiff bluish to grey fissured silty CLAY.

The above include the strata of engineering interest and significance, taking cognisance of the scale of the proposed development, depth of the proposed basement excavation, and zone of influence.

The ground model adopted for this assessment is presented in Table 3.1. Material strength and stiffness parameters have been derived and assumed from ground investigation data and previous experience in this area of London.

Table 3.1 Ground model and geotechnical parameters adopted for analysis purposes

Stratum	Elevation (mOD)	Thickness (m)	Undrained Young's Modulus, E_u [2](MPa)	Drained Young's Modulus, E' [2](MPa)	Poisson's ratio
Made Ground	+46.00	0.70	-	10	v' = 0.2
London Clay	+45.00	Not Proven	35 + 2.1z	28 + 1.7z	v_u = 0.5 v' = 0.2

1. Ground model based on site specific ground investigation data in the vicinity of the site. This data has been interpreted specifically for the scope of the GMA presented herein.
2. Stiffness data (Eu and E') has been evaluated empirically from in-situ testing data taking into consideration the nature of the geotechnical/soil-structure interaction mechanisms and level of anticipated strain within the soil mass.
3. Rigid boundary was assumed at -43.5 mOD / 89.5 mBGL for analytical purposes.
4. z refers to the depth in metres below the top of the London Clay formation. Lower bound stiffness values have been adopted for GMA purposes only.

4. Impact Assessment Methodology

4.1. Assessment Details

The assessment has been undertaken 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.

Ground movements will arise as a result of various mechanisms which are mobilised as part of the construction works for the proposed scheme. The basement excavations will induce ground movements arising from the overburden removal and installation of the proposed retention system. 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/excavation footprint. A series of three-dimensional models of the proposed scheme have been developed in Oasys Pdisp/Xdisp and combined by means of superposition in order to enable ground movement assessments to be carried out representing the various construction stages. The ground movement displacement fields were separated in two groups (A & B) based on the approach followed, as detailed below:

Group A – Unloading/Loading ground movements

A1. Basement excavation and demolition (short-term).

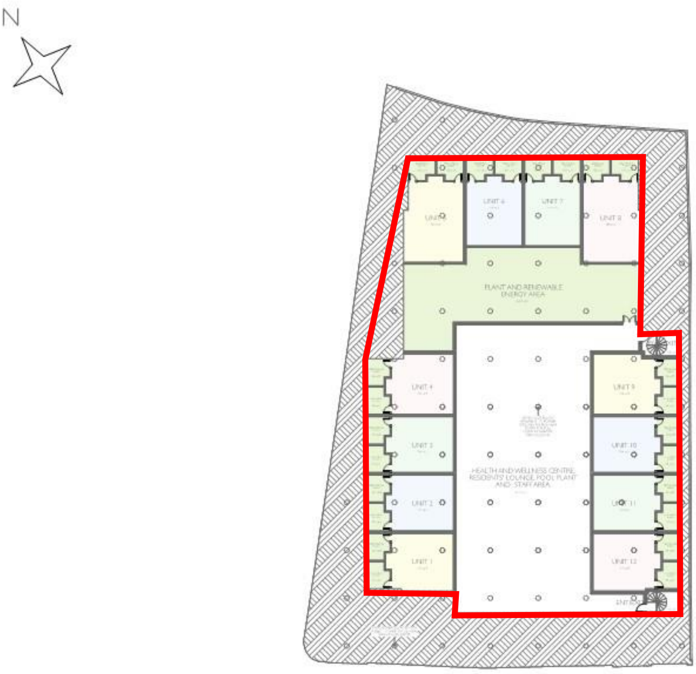
A2. Application of the proposed building loading (long-term).

Group B – CIRIA-based ground movements

B1. Basement excavation and installation of contiguous wall.

B2. Basement excavation, contiguous wall installation and application of the proposed building loading (long-term).

The Group A assessments are based on *greenfield* ground movements evaluated from linear half-space (Pdisp) analyses and focus on vertical ground movements induced by the overburden removal unloading and reloading processes. The modelled excavation footprint has been simplified for the purpose of the analysis. The details are shown below in Figure 4.1.



Excavation boundary marked by red line

Figure 4.1 Simplified excavation for analysis

Excavation unloading pressures have been modelled at the basement formation level representing the removal of approximately 9.5 m (~190 kPa) of overburden to form the basement level as shown in Figure 4.2. The demolition unloading pressure (~32kPa) has been calculated based on the provided existing loading information.

At this stage, the proposed structure foundation system design is currently ongoing. Uniformly distributed loading zones have been modelled at the proposed basement formation level to represent the proposed building loading pressures. Proposed loading pressures of 12 kPa/storey have been adopted for the purpose of this analysis. A total loading pressure of 60 kPa is adopted based on the number of proposed building storeys as shown in Figure 4.3, this is considered to be a reasonable representation of the proposed scheme structural loads.

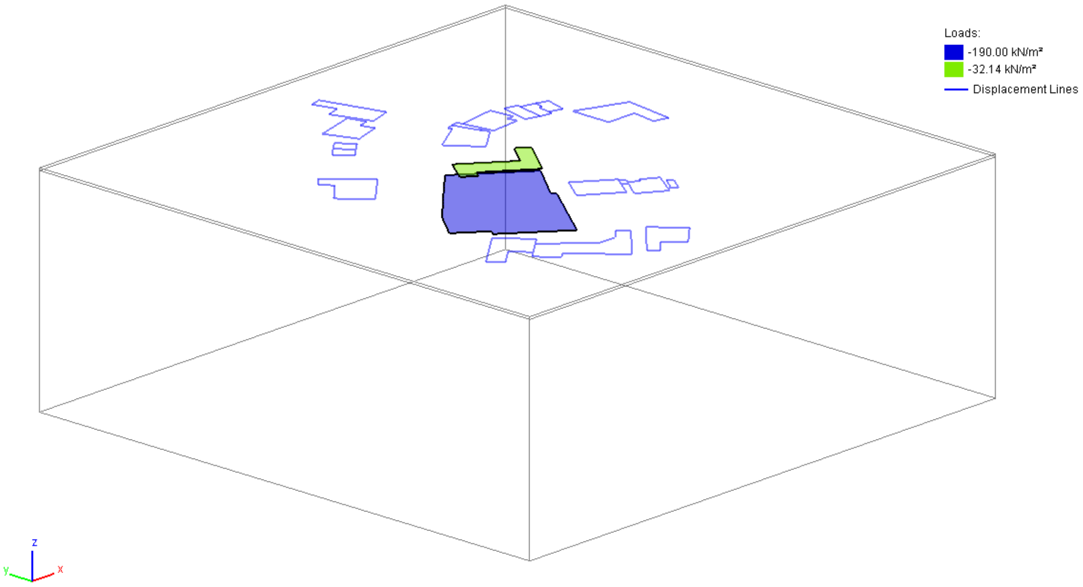


Figure 4.2 Loading in Pdisp – Demolition and Excavation

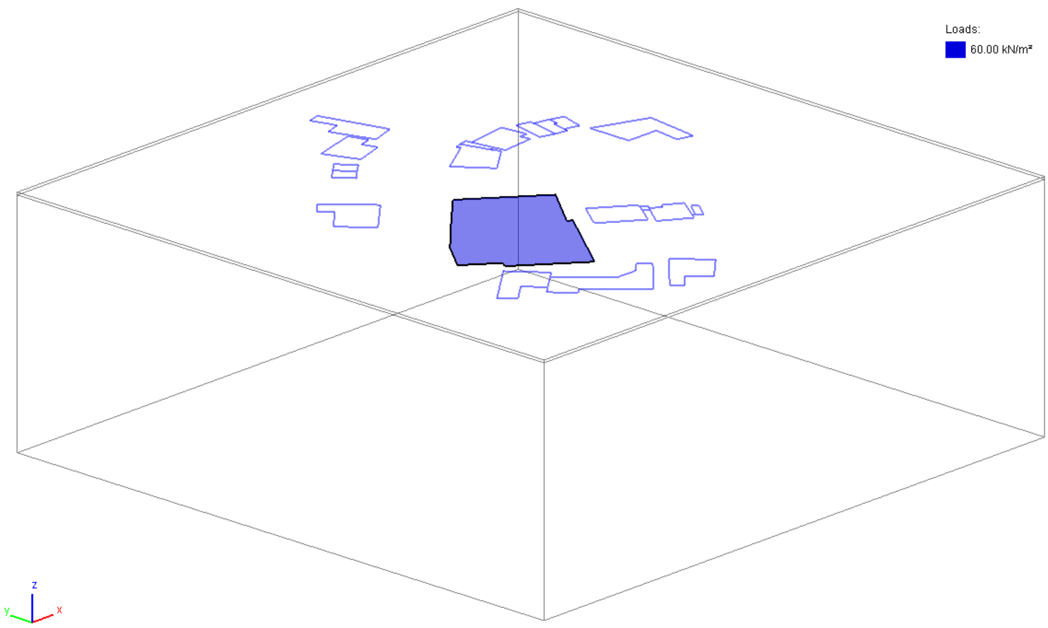


Figure 4.3 Loading in Pdisp – Structural loading stage (basement excavation removed)

The Group B assessments adopt the normalised ground displacement curves reported in CIRIA C760. In addition to the effects arising from the basement excavation, the ground movement effects associated with the installation of the contiguous retaining wall have been considered. The following CIRIA C760 normalised ground movement curves were adopted to assess ground movements due to retention system installation and excavation works:

- *Wall Installation*: Installation of contiguous bored pile wall in stiff clay.
- *Excavation to formation*: Excavation in front of a high stiffness wall in stiff clay.

The contiguous retaining walls have been assumed to be 14.3 m long (from ground level) for the basement formation.

Given the depth of the walls and their proximity to adjacent buildings, it is assumed that suitable construction controls and temporary works, including rigorous monitoring methodologies, will be implemented during the wall installation and basement excavation works on site to reduce the overall impact of the development. Hence the CIRIA curve for the installation of contiguous bored pile wall in stiff clay have been reduced by 70%.

In the B2 assessment, the CIRIA ground movements are combined with the long-term settlements induced by the loading redistribution (evaluated in Pdisp).

The two sets of analyses enabled the evaluation of an envelope of damage classification results, with the worst-case results presented herein. A simplified representative geometry has been adopted for defining the excavation/installation geometry implemented in the 3D modelling efforts, as shown in Figure 4.4.

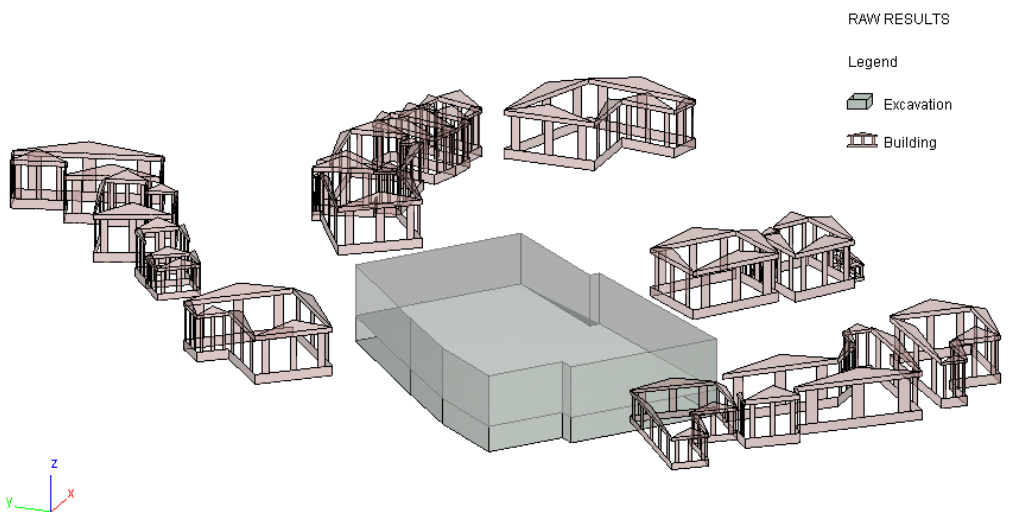


Figure 4.4 Indicative plot of the three-dimensional analytical model using the Oasys XDisp software suite

4.2. Impact Assessment

4.2.1. General

The potential impact/damage induced on primary façade/wall elements of the buildings surrounding the proposed scheme have been evaluated on the basis of the calculated ground movement fields. The masonry walls of concern are shown in Figure 4.5 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 basements (covering the key deformation mechanisms). In total, 97 façades of the neighbouring buildings were considered for the current study and these are grouped in the following manner:

- AR.50.1- AR.50.4 : 50 Avenue Road (wall 1-4)

- ER.56.1- ER.56.6 : 56 Elsworthy Road (wall 1-6)

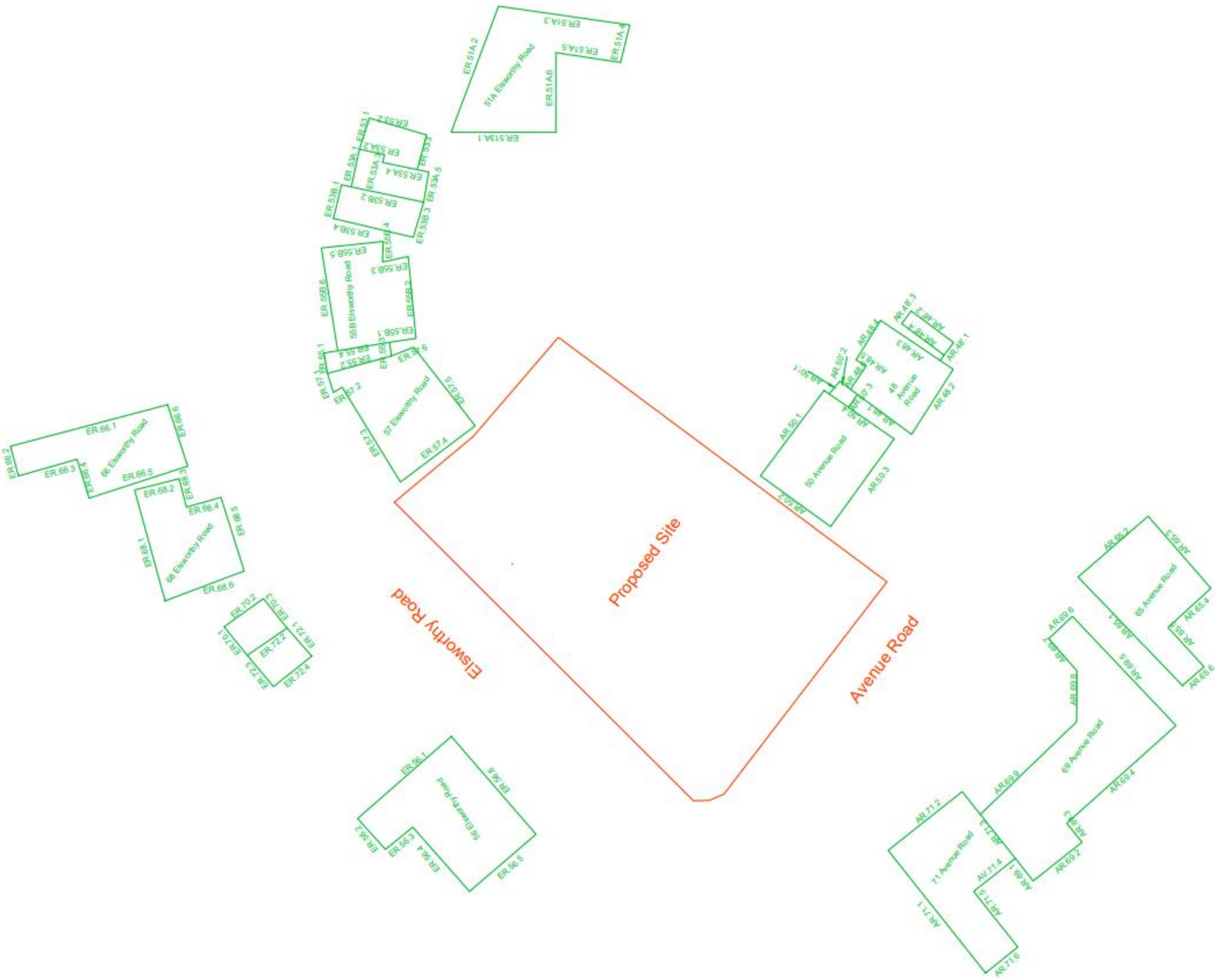


Figure 4.5 Simplified scheme and nomenclature for each building façade/masonry wall element

Each wall has been assumed to behave as an equivalent beam subject to 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 and horizontal extension mechanisms estimated from the analyses. The assessment considers the well-established Burland (1997) damage classification method, as presented and summarised in Figure 4.6 and Figure 4.7. 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 proposed construction stages, 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).

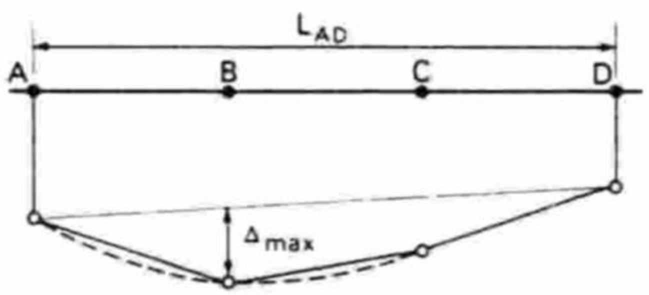


Figure 4.6 Definition of relative deflection Δ and defelction ratio Δ/L

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 4.7 Building damage classificaton – relationship between catergory of damage and limiting strain ε_{lim}

4.2.2. Results

The results of the assessment indicate that one façade will experience a maximum of damage Category 1 – Very Slight throughout the construction works. The affected façades are presented in Table 4.1. The remaining façades are not expected to exceed damage Category 0 – Negligible and are omitted from the table below. Figure 4.8 and Figure 4.9 depict the vertical displacements induced by the proposed basement excavation and structural loading from Pdisp respectively. Figures 4.10, 4.11, 4.12, and 4.13 show vertical to horizontal displacements calculated using CIRIA C760 data sets for B1 and B2 assessments using Xdisp

Table 4.1 Evaluated damage categories resulting from the assessment

Façade Reference	Analysis Scenario			
	A1	A2	B1	B2
AR.50.1	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
AR.50.2	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
AR.50.3	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
AR.50.4	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
AR.50'.1	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
AR.50'.2	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
AR.50'.3	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
AR.48.1	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
AR.48.2	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
AR.48.3	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
AR.48.4	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
AR.48.5	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
AR.48.6	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
AR.48'.1	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible

Façade Reference	Analysis Scenario			
	A1	A2	B1	B2
AR.71.1	Category 0 - Negligible	Category 0 - Negligible	Category 1 – Very Slight	Category 1 – Very Slight
AR.71.2	Category 0 - Negligible	Category 0 - Negligible	Category 0 – Negligible	Category 0 - Negligible
ER.56.1	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
ER.56.5	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
ER.56.6	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
ER.57.3	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
ER.57.4	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible
ER.57.5	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible	Category 0 - Negligible

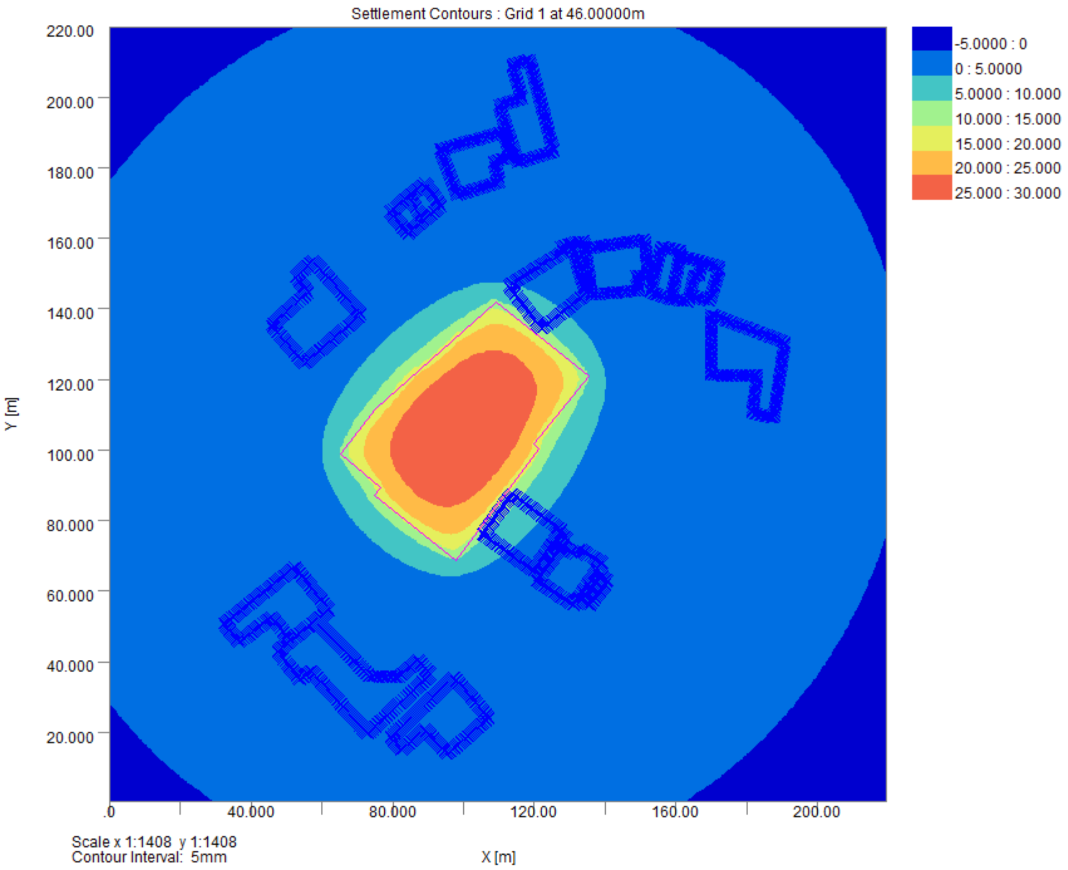


Figure 4.8 Resultant Pdisp vertical displacement contours scenario A1 – demolition and excavation (units in mm)

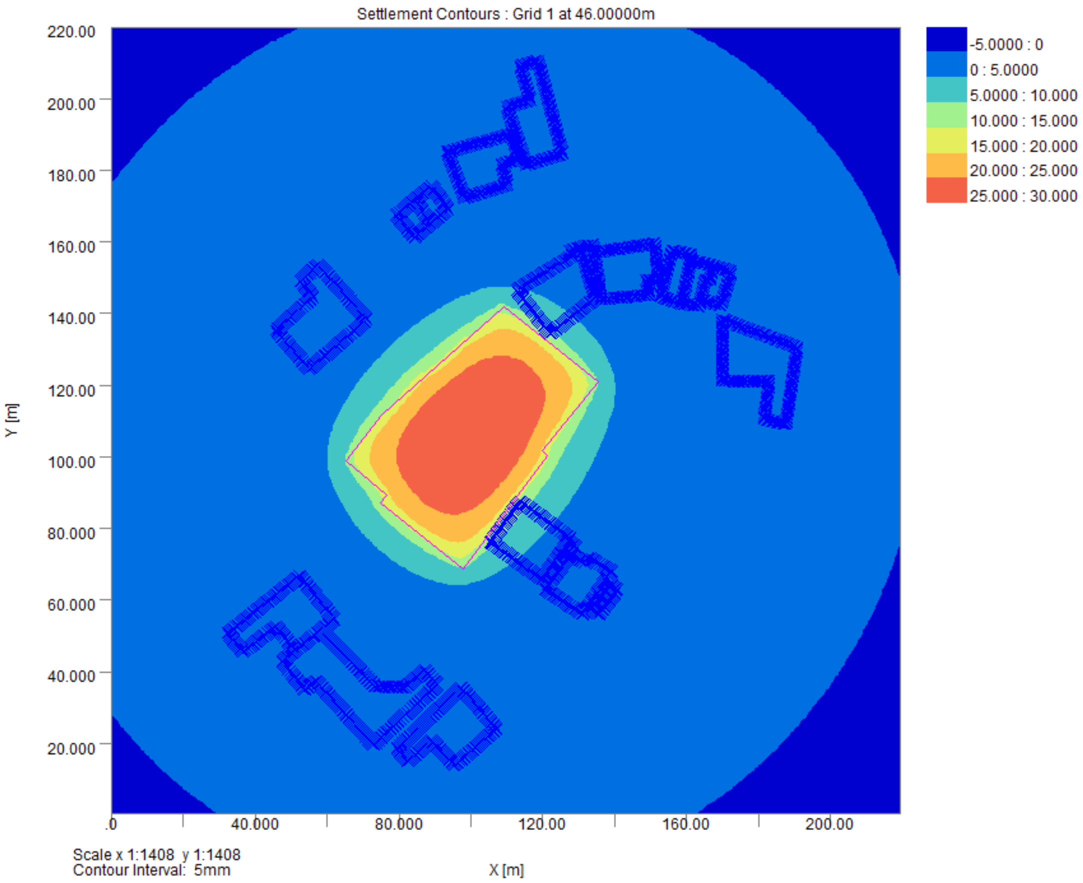


Figure 4.9 Resulstant Pdisp vertical displacment contours scenario A2 – long-term loading (units in mm)

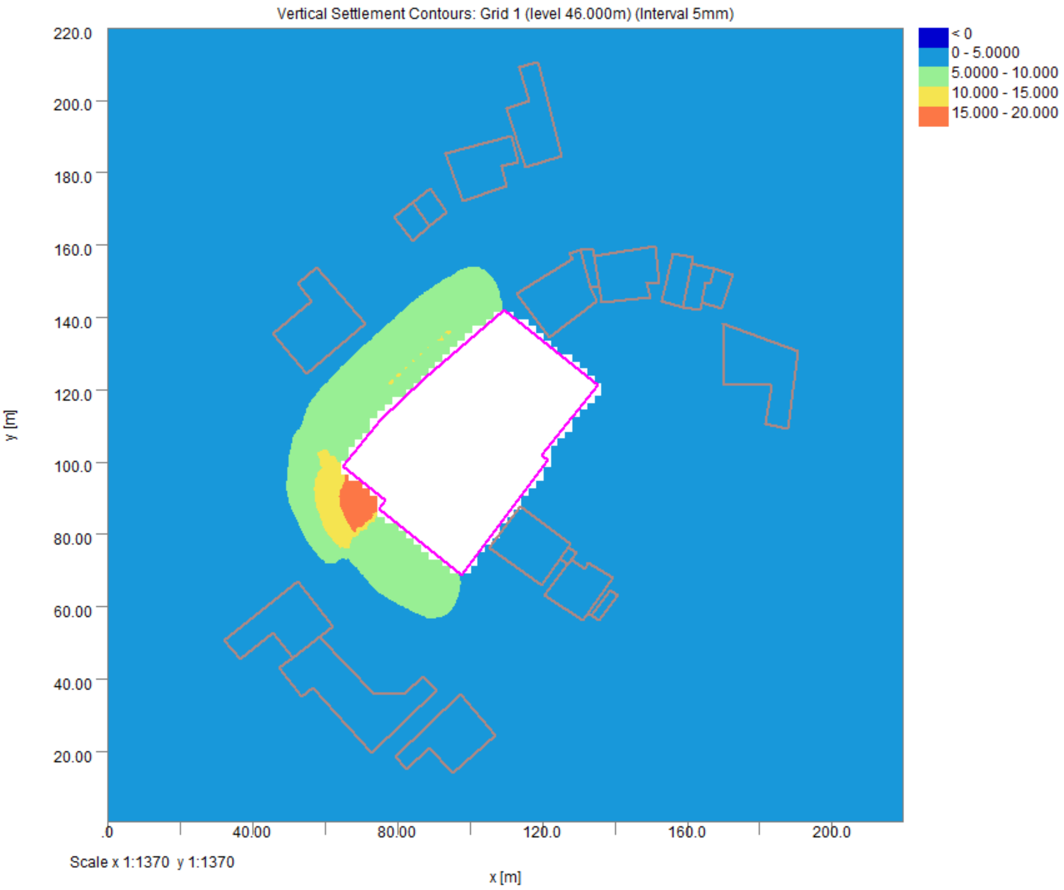


Figure 4.10 Resultant Xdisp vertical displacement contours for scenario B1 (CIRIA C760) – excavation and installation of contiguous piles (units in mm)

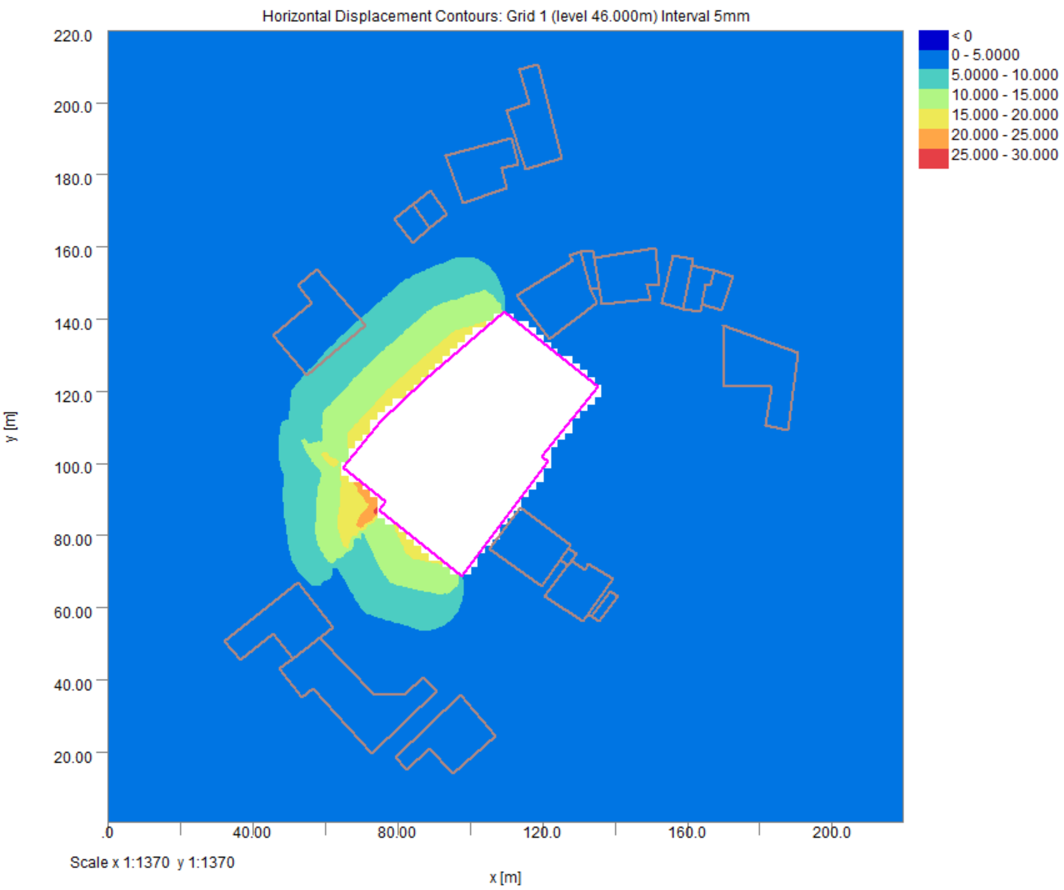


Figure 4.11 Resultant Xdisp horizontal displacement contours for scenario B1 (CIRIA C760) – excavation and installation of contiguous piles (units in mm)

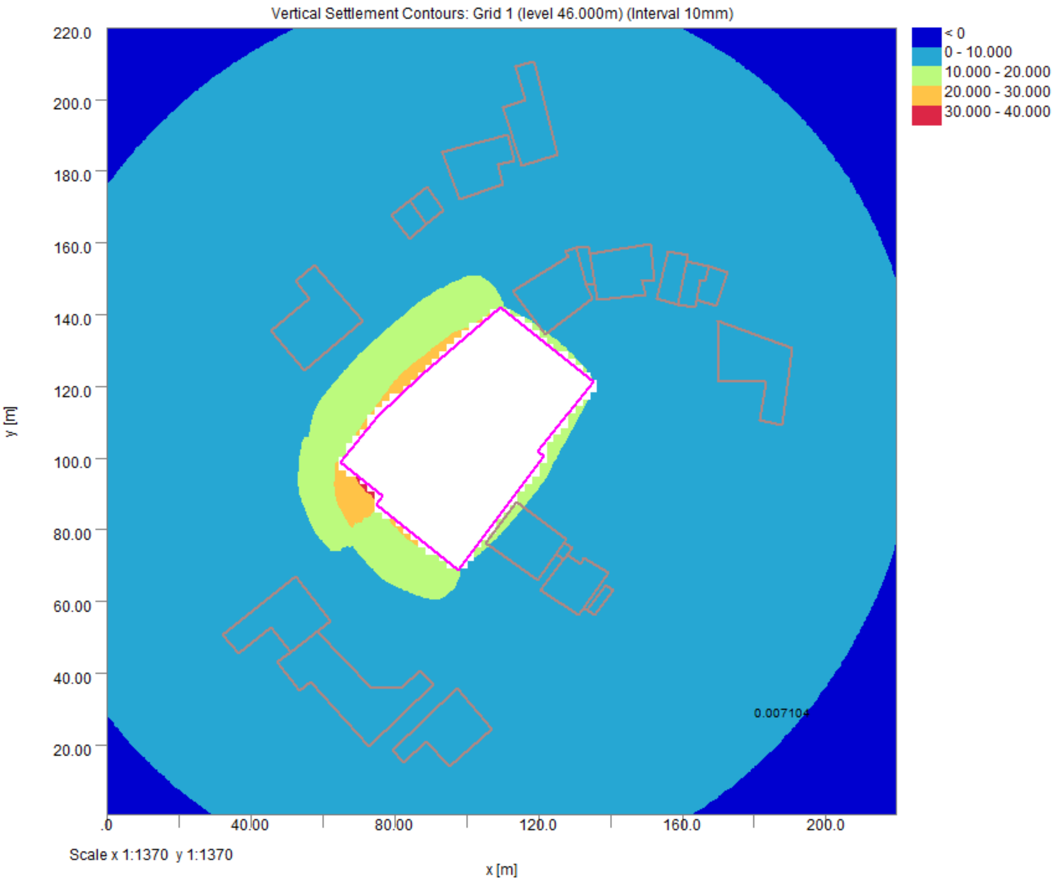


Figure 4.12 Resultant Xdisp vertical displacement contours for scenario B2 (CIRIA C760) – contiguous piles and application of proposed building load

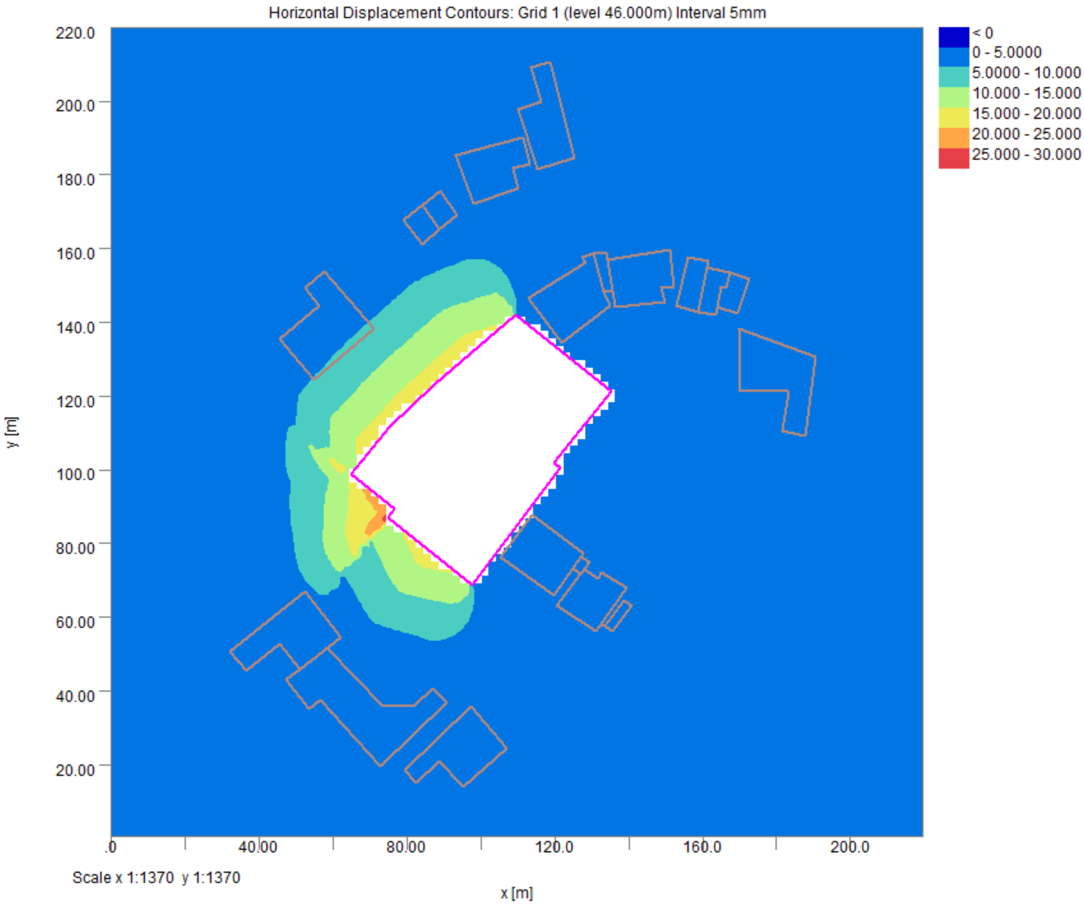


Figure 4.13 Resultant Xdisp horizontal displacement contours for scenario B2 (CIRIA C760) – contiguous piles and application of proposed building load

4.3. Basement Excavation Criteria

A maximum horizontal and vertical movement of 29mm and 20mm is anticipated from the proposed development (horizontal from the basement wall installation and excavation, vertical from combined CIRIA curve + loading effects). The results of this analysis show that all buildings fall within acceptable damage classifications if the ground movements caused by the proposed development are limited to the values presented in Table 4.2.

Table 4.2 Limiting ground movement values for the project at various construction stages

Stage	Maximum Cumulative Ground Movement (mm)	
	Vertical	Horizontal
Excavation	12	22
Installation of retaining wall	8	7

It is recommended that ground movement / earth retention system design and construction movement criteria are developed based on the results presented herein. This will enable the design of the retaining wall and any required temporary propping measures to be undertaken in a holistic fashion, ensuring ground movements are limited to no greater than that presented herein.

Specific wall/façade deflection limits and trigger levels may also be developed as part of the scheme monitoring regime. Such limits and trigger levels should be coordinated with the scheme monitoring specification and monitoring action plan / emergency preparedness plan.

5. Conclusions & Closing Remarks

The interaction between the proposed 52 Avenue Road 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 proposed development involves the excavation of a one to two storey basement and the construction of three 3-storey reinforced concrete superstructures. The embedded retaining wall will be used to form the basement box with temporary props.

The impact of the various construction stages has 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 movement fields using empirical CIRIA curves in Xdisp. In the latter case, a contiguous wall solution (during the installation of the retaining wall) has been considered, utilising the CIRIA C760 ground movement curves for excavation in front of high stiffness walls in stiff clay.

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 construction methodology. Both short-term (undrained) and long-term (drained) conditions have been assessed by adopting the relevant soil stiffness parameters for each case.

In order to best limit ground movements in proximity to sensitive neighbouring buildings, due consideration may be given to suitable means and methods of construction. For example, reducing the extent of temporary excavations during earth removal operations in close proximity to buildings considered to be at most risk of damage.

The results from the GMA (denoting the evaluated damage categorisation in accordance with the Burland criteria described herein) considering neighbouring properties are presented in Table 4.1. It is observed that the maximum damage classification for the neighbouring properties is Category 1 – Very Slight. The maximum permissible retaining wall lateral deflection during excavation of the basement and installation of contiguous walls should be demonstrably limited to 22 mm (7 mm during bulk excavation) in order to ensure the damage classifications stated herein remain valid.

It is noted that the predicted ground movements, the associated wall tensile strains, and the 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 also noted that the GMA will 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. 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.

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

During the design of the embedded retaining walls and temporary propping measures, deflection performance criteria for these design elements should be derived on the basis of the results presented herein to ensure that the maximum damage classification of Category 1 – Very Slight is not breached.

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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