Ground Movement Assessment

15 Great James Street

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CONTENTS

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1. INTRODUCTION

Webb Yates Lrd (Webb Yates) were engaged by Marrick Consult to prepare a Ground Movement Assessment (GMA) on behalf of 15 Great James Street Ltd for the proposed redevelopment works at 15 Great James Street, Holborn, London WC1N 3DP.

1.1. Proposed Scheme

The proposed redevelopment works involve the partial demolition of the existing building at 15 Great James Street, extension of its lower ground floor (i.e. installation of underpins/reinforced concrete walls and excavation at the eastern part of the property's footprint) and the construction of the newly planned building layout. The site is bounded by two properties: 14 Great James Street to the south and 16 Great James Street to the north. Great James Street runs along the western boundary of the site, whereas Cockpit Yard can be found to the east.

The preliminary arrangement of the proposed works is shown in Figure 1.1. The proposed excavation footprint (red hatched area) is approximately 9m long and 6m wide. At this stage, the typology of the earth retention system comprises underpins/reinforced concrete walls which are planned to be installed in a hit-and-miss fashion. For the purpose of this GMA, a wall depth and basement excavation depth of 2m have been assumed. It has also been assumed that the proposed earth retention system will be temporarily supported until the permanent works are complete. Figure 1.2 and Figure 1.3 indicate cross sections CC and DD, respectively, indicating the proposed demolition and excavation works as well as the structural elements proposed to be constructed as part of the redevelopment works.

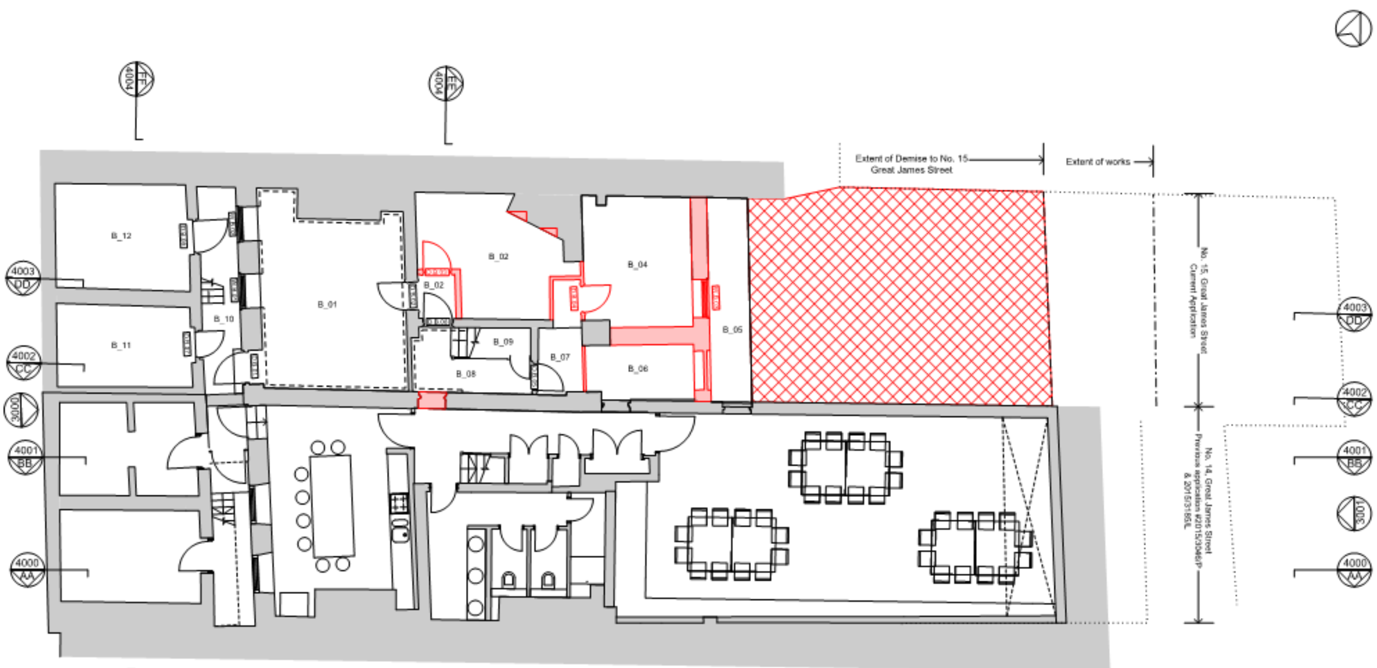
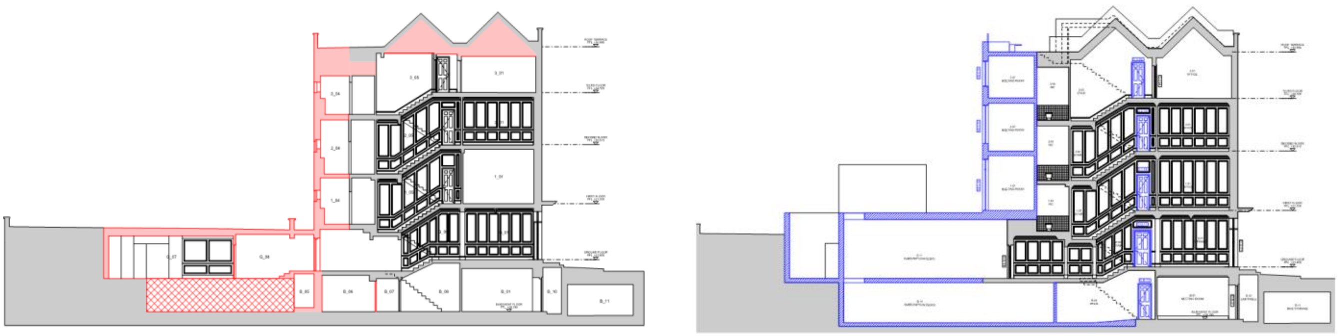
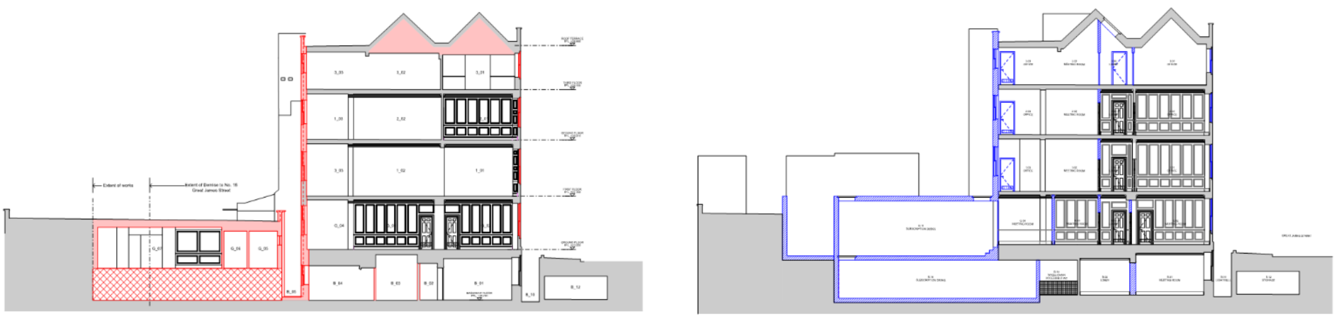


Figure 1.1 Owen Architect's preliminary plan view of proposed works at lower ground floor level. Red hatch indicates the proposed excavation area. Solid red hatches indicate existing structural elements planned to be demolished.



(a) (b)

Figure 1.2 Owen Architects cross section CC - (a) Existing (red indicates excavation and demolition areas) and (b) proposed (blue indicates new structural components) building layout.



(a) (b)

Figure 1.3 Owen Architects cross section DD - (a) Existing (red indicates excavation and demolition areas) and (b) proposed (blue indicates new structural components) building layout.

1.2. Design Assumptions

Due to the proximity of the adjacent buildings it is assumed that the soil retention system will be effectively propped during construction either by one or a combination of the following (or other suitable alternative):

1. Restrained from the top of the proposed wall bending out-of-plane across relatively short spans.
2. Bespoke temporary props/corner bracing/etc.

The following outline construction sequence is proposed:

1. Demolition of selected structural elements of the existing property.
2. Installation of the proposed underpins/reinforced concrete walls in a hit-and-miss fashion.

3. Excavation works carried out at part of the site's footprint and extension of existing lower ground floor's area, with parallel installation of propping as required to maintain stability.
4. Installation of basement slab, ground beams and other substructure elements
5. Installation of ground floor slab followed by the removal of temporary propping system.
6. Construction of remaining superstructure elements.

2. GROUND MOVEMENT ASSESSMENT

2.1. Overview

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. Neighbouring structures may be adversely affected by ground movements precipitated by basement construction. A simplified account of typical sources of ground movement is provided below:

1. Demolition and enabling works:
   - Minor stress relief and (typically) small ground movements associated with removal of permanent building loads during demolition.
   - Ground movements arising primarily from contractor workmanship and adopted means and methods to enable the site to progress with basement works. E.g. shoring of temporary excavations to remove obstructions wall installations, etc.
2. Retaining Wall Installation effects:
   - Ground movements arising from installation of embedded retaining wall elements, such as the proposed underpins/reinforced concrete walls.
   - The development and pattern of ground movements is dependent on the sequence that the works are performed.
3. Bulk excavation to formation:
   - Ground movements arising from stress relief associated with unloading of the ground mass.
   - Ground movements associated with soil-structure interaction between the embedded retaining wall, temporary propping system and retained ground mass.
4. Permanent loading:
   - Ground movements associated with construction of the new superstructure elements to the rear.
   - Redistribution of load paths from temporary works elements to permanent works elements.
   - Long term ground movements associated with soil consolidation and creep.

2.2. Means and Methods

The GMA has been undertaken using proprietary spreadsheets and the commercially available software packages Oasys Pdisp and Xdisp, which consider the three-dimensional ground movement field induced by the proposed works in a simplified way.

Ground movements associated with Item 1 (as described in the previous section) have been omitted in the study presented herein due to the localised and insignificant effects of the demolition works. Ground movements associated with Items 3 & 4 have been evaluated using Oasys Pdisp. In these analyses the soil is assumed to behave as an isotropic, linear elastic medium. Structural forces applied to the foundation and the effects of stress-relief due to excavation are represented by applying equivalent pressures on planes at the surface, or within the elastic half-space representing the foundation soils. Ground movements that are primarily due to contractor workmanship cannot be captured within this assessment.

Ground movements associated with Items 2 & 3 were also evaluated using the empirical normalised displacement curves presented in CIRIA C760. For the installation of the underpins, the curve adopted was "Installation of planar diaphragm wall in stiff clay (CIRIA C760 Fig. 6.9)". For the temporarily propped excavation, the curve adopted was "Excavation in front of high stiffness wall in stiff clay (CIRIA C760 Fig. 6.15)". These curves have been developed from a database of recorded ground movements and they generally represent an upper bound to the data. It is assumed that some effects of workmanship are intrinsically captured within the movement records. Notwithstanding, ground movements due to poor workmanship practices, may induce movements significantly higher than those represented by the empirical ground movement curves. It is assumed that the ground works will be carried out by a competent and experienced groundworks contractor.

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 2.1.

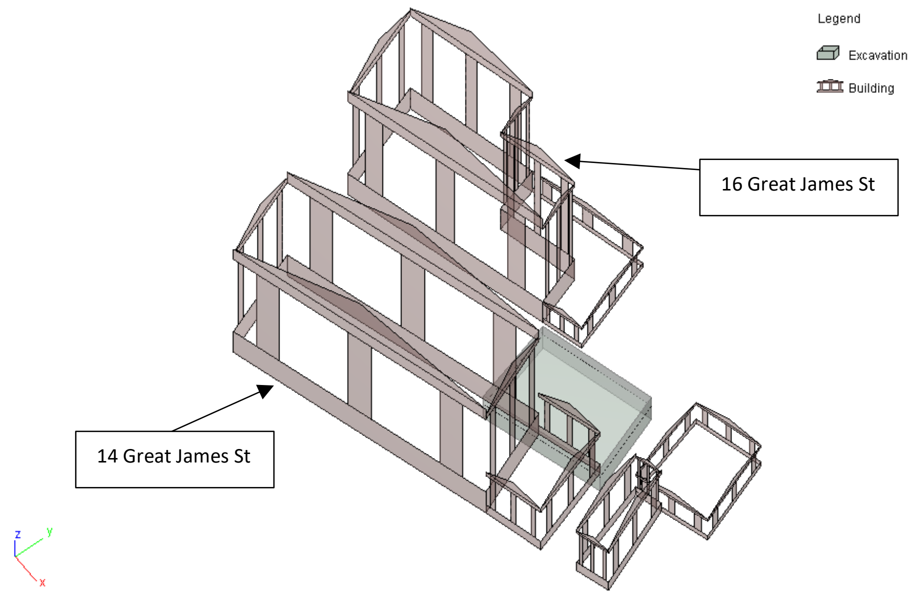


Figure 2.1 Indicative plot of the three-dimensional analytical model produced using the Oasys software suite (soil removed for clarity of presentation). Idealised installation/excavation geometry shown in grey adopted in Xdisp.

2.3. Design Scenarios

The following design scenarios have been evaluated in order to bound the potential ground movements arising from the proposed works.

1. Excavation of the proposed lower ground floor areas simulated as an overburden pressure removal.
2. Wall installation & excavation simulated with the corresponding CIRIA C760 curves.

3. Wall installation & excavation simulated with the corresponding CIRIA C760 curves and application of the structural loads resulting from the redevelopment works.

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 has been incorporated into the analysis by superimposing the long-term ground displacements due to the permanent foundation loads (SLS) evaluated from Pdisp as per Figure 2.1.

Figure 2.1 Proposed building SLS loads implemented in Pdisp.

2.4. Ground Model

An idealised ground model has been evaluated based on publicly available borehole data via the British Geological Society Borehole Viewer. The examined boreholes have been found within a radius of 130m from the site under consideration. The ground surface has been assumed to be at approximately 24mOD and the stratigraphy comprises of Made Ground overlaying Alluvium, River Terrace Deposits and finally London Clay.

The undrained shear strength profile for London Clay was assessed from the SPT N60 blow counts recorded during the cable percussive boring. The undrained shear strength is assumed to be equal to approximately $S_u = 4.5 \times N_{60}$. Table 2.1 summarises the representative ground model adopted for ground movement assessment purposes.

Table 2.1 Summary of ground model and geotechnical parameters adopted for analysis purposes.

Soil Type	Top of stratum [mOD]	Unit weight, γ [kN/m^3]	Undrained shear strength, S_u [kPa]	Undrained Young's Modulus [MPa]	Drained Young's Modulus [MPa]
Made Ground	24.00	18	-	-	10
Alluvium	21.75	18	-	-	7
River Terrace Deposits	20.65	20	-	-	50
London Clay	18.15	20	67.5 + 6.3z [1]	33.8 + 3.1z [1]	27.0 + 2.5z [1]

[1] z refers to the depth in metres below the top of London Clay.

[2] Rigid boundary assumed to 0mOD for analytical purposes.

[3] The stiffness data have been empirically evaluation taking into consideration the nature of the geotechnical/soil-structure interaction mechanisms and levels of anticipated strain within the soil mass.

2.5. Impact Assessment Setup

The potential impact/damage induced on primary wall/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.

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. The zone of influence is therefore assumed to primarily effect the properties at 14 and 16 Great James Street along with the independent parts of 14 and 15 Great James street located along Cockpit Yard, in the east. 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 masonry walls of concern are shown in Figure 2.3 including the wall nomenclature/reference system adopted. 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 as depicted in Figure 2.4. The assessment considers the well-established Burland (1997) damage classification method, as presented and summarised in Figure 2.5. 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.

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.

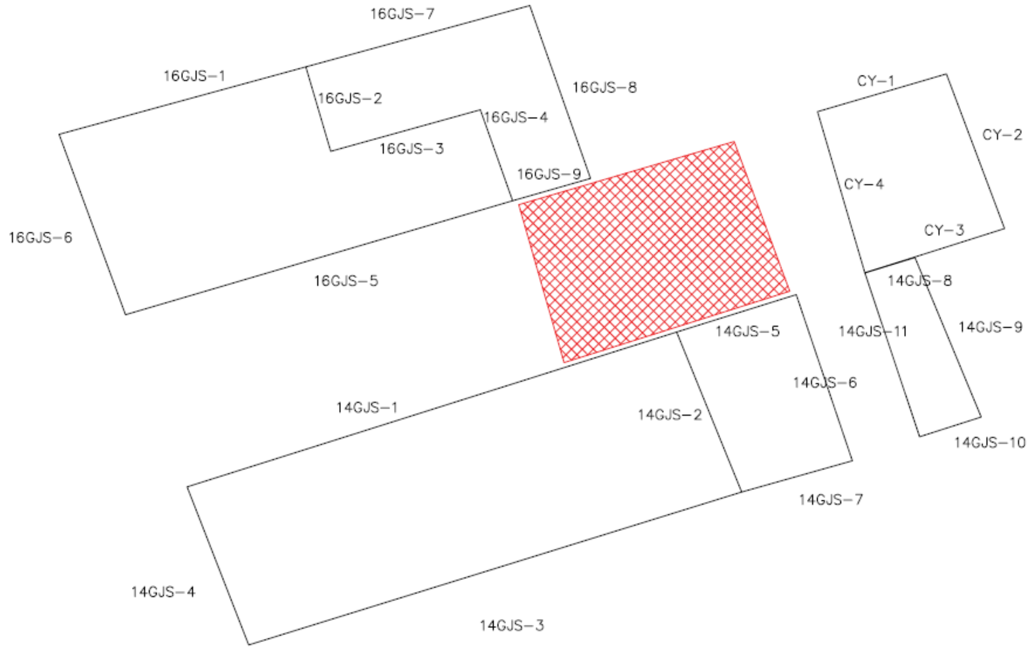


Figure 2.3 Nomenclature for building/masonry wall elements indicated in black and simplified excavation outline adopted in Xdisp indicated with red. Idealised proposed excavation area indicated by red hatch.

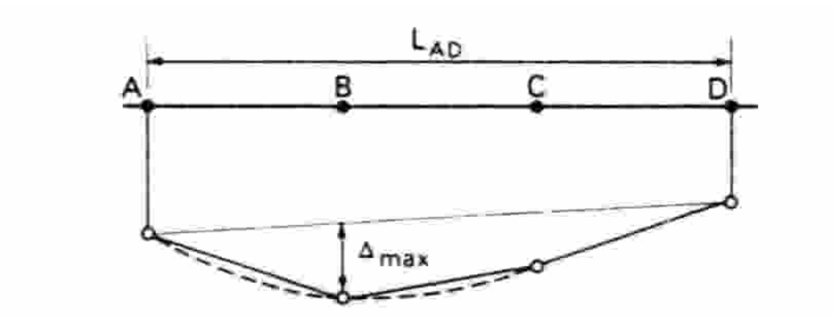


Figure 2.4 Definition of relative deflection Δ and deflection ratio Δ/L.

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 2.5 Damage categorisation - relationship between category of damage and limiting strain ε_{lim}.

2.6. Impact Assessment Outcomes

Figure 2.6 and Figure 2.7 illustrate the vertical and horizontal displacement contours around the construction area for the analysis scenario 3. Vertical and horizontal movements have been calculated to range between 0-12mm and 0-5mm, respectively. The majority of the walls fall within Category 0, representative of a Negligible damage classification, for all analysed scenarios. 1no. Wall CY-1 has been classified as Category 1, representative of Very Slight damage classification, for scenario 3 only. On the basis of the bounding analysis methods, it is assessed that the damage category for the properties adjacent to the proposed basement will not exceed Category 1 – Very Slight.

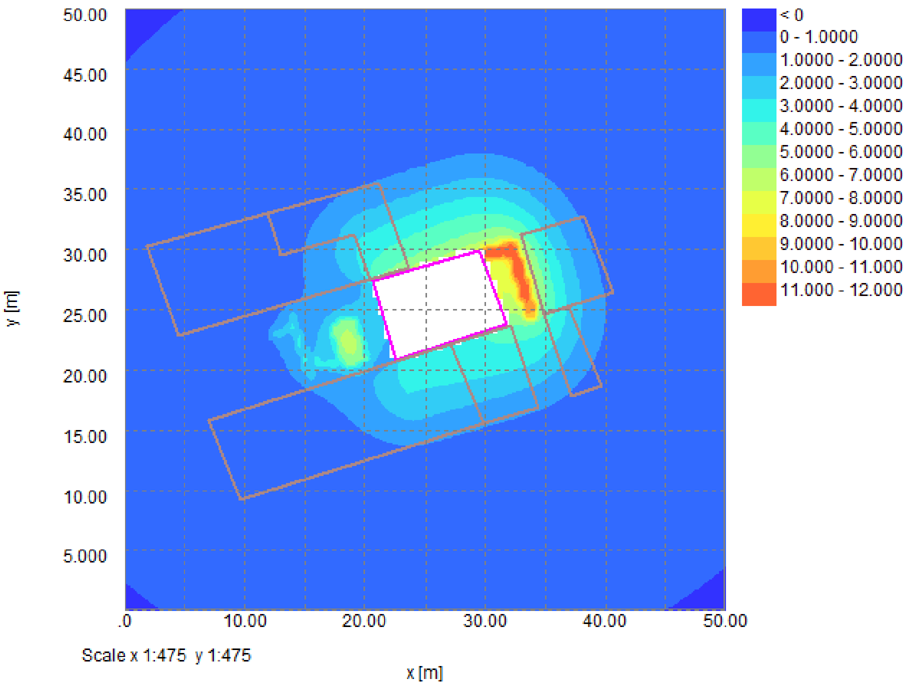


Figure 2.6 Vertical ground surface movements - Scenario 3.

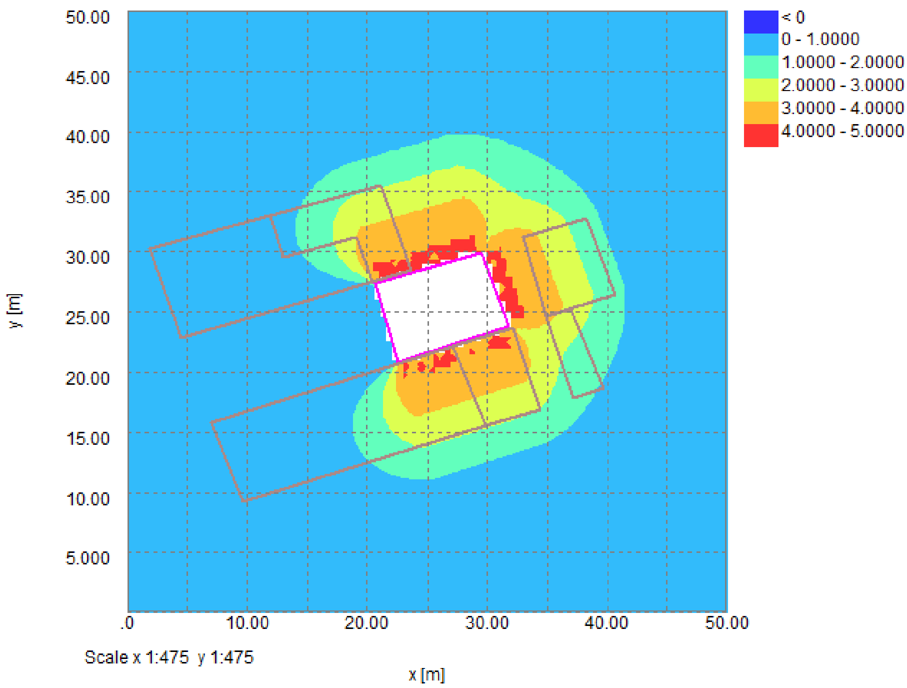


Figure 2.7 Resultant horizontal ground surface movements - Scenario 3.

3. CONCLUSIONS AND SUMMARY

The interaction between the proposed redevelopment works at 15 Great James Street and the adjacent properties has been reviewed. The proposed development construction operations comprise a series of stages, broadly including:

- Demolition of the existing building.
- Installation of underpins/reinforced concrete walls.
- Basement excavation.
- Construction of permanent works elements.

The impact of the excavation stages of construction have been reviewed on the basis of five alternative methods:

1. Excavation of the proposed lower ground floor areas simulated as an overburden pressure removal.
2. Wall installation & excavation simulated with the corresponding CIRIA curves.
3. Wall installation & excavation simulated with the corresponding CIRIA curves and application of the proposed building's loading.

These scenarios have been considered in order to bound the potential ground movements arising from construction operations (i.e. maximum potential heave and settlement). This strategy ensures a robust evaluation of potential impact in light of the bespoke, intricate and workmanship dependent processes adopted for this development.

Vertical and horizontal movements have been calculated to range between 0-12mm and 0-5mm, respectively. The majority of the walls fall within Category 0, representative of a Negligible damage classification, for all analysed scenarios. 1no. Wall CY-1 has been classified as Category 1, representative of Very Slight damage classification, for scenario 3 only. On the basis of the bounding analysis methods, it is assessed that the damage category for the properties adjacent to the proposed basement will not exceed Category 1 – Very Slight.

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. This is in light of the relatively cautious ground model assumptions and simplified greenfield nature of the assessment undertaken.

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.

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.