Technical Note

A-squared | Studio

Project	72 Maresfield Gardens
Project no.	0537
Subject	Ground movement assessment

Status	Date	Ref	Rev	Issued by	Checked by	
For Issue	17-01-2018	0537-TN-01-00	00	A. Kyparissis	P. Smith	[redacted]

1. Introduction

A-squared Studio Engineers Ltd (A-squared) have been appointed by Multilateral Structural Design Ltd to assess the stability of the load bearing masonry basement walls upon removal of the existing basement slab (allowing basement deepening to take place), for the proposed redevelopment of 72 Maresfield Gardens.

The proposed development involves the demolition of the existing basement slab and the deepening of the existing basement by approximately 400mm.

This technical note presents the findings of the ground movement assessment analysis which has been carried out in order to detrmine the likely impact of the proposed works on the neighbouring properties. This ground movement assessment has been calibrated with the deflections assessed in 0537-TN-02-00 which assessed the stability of the basement walls in the temporary condition. The results presented herein are based on a propped basement deepening construction sequence – ensuring lateral restaint of the existing walls is maintained during the process of slab removal/installation.

2. Proposed works

The proposed development involves the demolition of an existing basement slab and the deepening of the existing basement. The site is located at 72 Maresfield Gardens, London and Figure 2.1 depicts the proposed basement level with respect to the existing basement level, marked with a dashed line.

The effect of the proposed deepening of the existing basement by 400 mm and subsequent wall deflections on the neighbouring properties are detailed in this note.

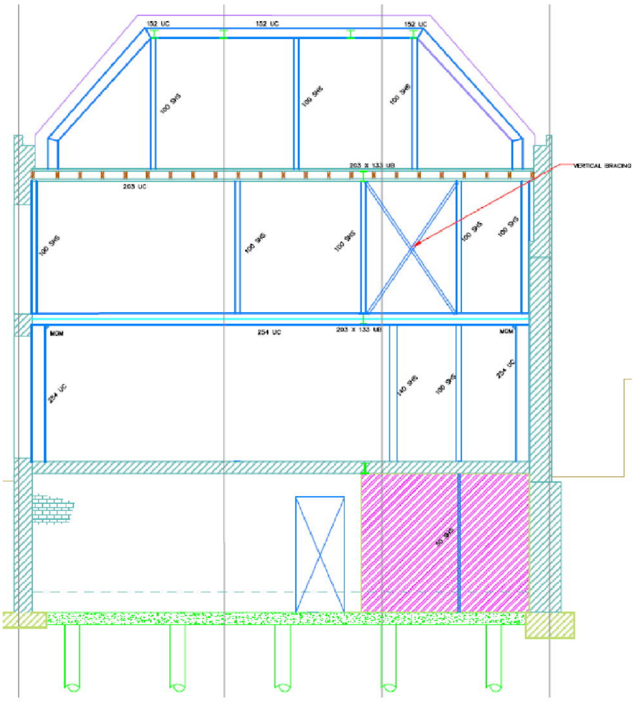

Figure 2.1 Existing (dashed line) and proposed (marked with green) basement levels.

3. Ground movement assessment

<u>Assessment Details</u>

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 works.

Ground movements will arise as a result of various mechanisms which are mobilised as part of the implementation of the proposed scheme. In the first instance, the works will involve the removal of the basement slab and the excavation of the existing basement, hence ground movements will be induced from overburden removal.

This temporary condition will be followed by the redistribution of loads around the perimeter of the building – allowing for the scheme intent to be achieved. Settlements will be induced around the perimeter of the site within a certain zone of influence, resulting in structural deformations of the adjacent buildings. The permanent condition loading will partially reinstate a portion of the removed overburden, yielding settlements across the foundation system.

These ground movements will extend over a given zone of influence surrounding the building footprint. The assessment presented herein adopts the normalised ground displacement curves reported in CIRIA

C580/C760 and general principles of elasticity. This procedure comprises the current industry standard/best practice for this type of analytical assessment.

These normalised ground displacement curves have been calibrated with the wall stability assessment presented in 0537-TN-02-00 in order to envelope the results of the Plaxis analyses.

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.

Ground Model

An idealised ground model has been evaluated based on the site-specific ground investigation which comprised 4 windowless sample boreholes to 4.45 mbgl and 9 hand excavated trial pits.

The thickness of Made Ground was observed in the boreholes to range between 0.9 m and 2.65 m. The proposed basement will be founded within the Claygate formation. The thickness of the latter was not proved during the site investigation. For the purposes of this analysis, it is assumed that a gradual stiffness transition occurs from Claygate to London Clay takes place and extends to a depth of 25mbgl.

Table 3.1 summarises the representative ground model adopted for ground movement assessment purposes.

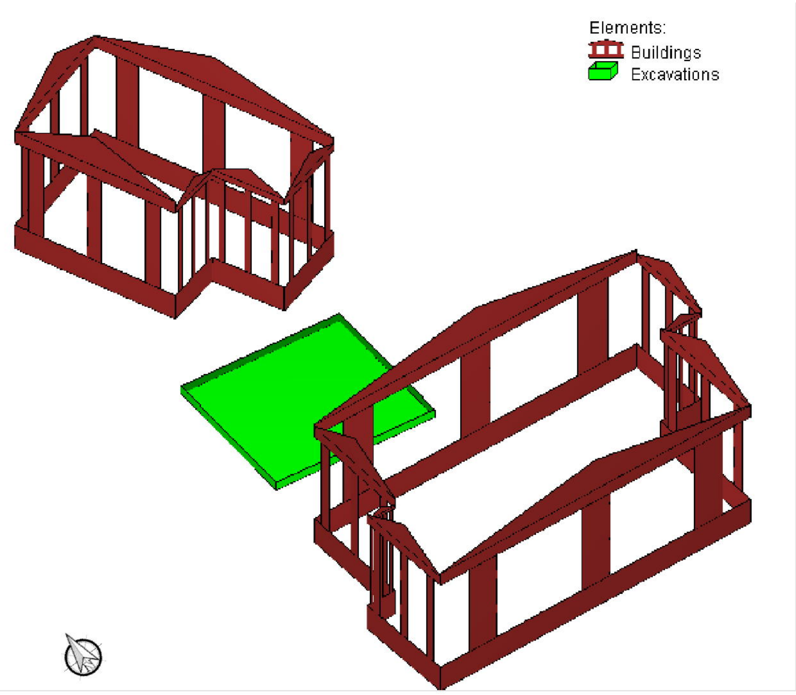

Figure 3.1 Indicative plot of the three-dimensional analytical model produced using the Oasys software suite. Soil removed for clarity of presentation.

Table 3.1 Summary of ground model and geotechnical parameters adopted for the analysis.

Stratum	Top of stratum [mbgl]	Assumed Undrained Strength, S_u [kPa]	Undrained Young's Modulus, E_u [MPa] [1]	Drained Young's Modulus, E' [MPa] [1]
Made ground	0 – 2.65	-	-	10
Claygate/London Clay	2.65 – 25 [2]	22.5 + 9.5 z [3]	9 + 3.8 z [3]	7.2 + 3 z [3]

Notes: 1. The stiffness data (E_u and E') has been evaluated empirically taking into consideration the nature of the geotechnical/soil-structure interaction mechanisms and level of anticipated strain within the soil mass.

2. *Rigid boundary* assumed at -25 mbgl for analytical purposes.

3. z is the depth in metres below top of the London Clay.

Analysis Methods

Two different scenarios have been considered in order to bound the potential ground movements arising from the proposed excavation works.

1. **Basement excavation:** Heave movements arising from the overburden removal were assessed using Oasys Pdisp.

   The associated heave was modelled by applying an upward (unloading) stress at the formation level, which is equivalent to weight of the existing basement slab and soil mass removal. Drained stiffness parameters were used for capturing the effects of the overburden removal as the building is founded on the Claygate layer (all soil behaviour has been conservatively considered to perform in a drained manner).

   The possible effects of this excavation to the adjacent buildings was assessed using Xdisp and the incorporated Burland (1997) criteria.

2. **Redistribution of permanent loads:** Vertical and horizontal displacements induced by the redistribution of permanent loads were applied on representative 1 m wide strips around the perimeter of the building, in an effort to simulate the long-term loading condition.

   The relative potential damage to the neighbouring buildings was again examined with the Burland (1997) criteria. In addition, the basement excavation effects were also incorporated in the analysis by adopting the CIRIA C580/760 curve for *Excavation of a high stiffness wall in stiff clay*. This curve was calibrated in order to align with the detailed vertical and horizontal ground movements obtained by the Plaxis 2D model, reported in the accompanying technical note, 0537-TN-02-00.

Impact Assessment

The potential impact/damage induced on primary façade/wall elements of neighbouring properties within the zone of influence of the proposed works has been evaluated on the basis of the calculated ground movement field. The masonry walls of concern are shown in Figure 3.2, including the wall nomenclature/reference system adopted. The arrangement is based on the currently available survey information and presents a reasonable array of primary structures.

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

Tensile strains induced within the building masonry walls have been evaluated based on the deflection ratios Δ/L estimated from the analyses. The assessment considers the well-established Burland (1997) damage classification method, as presented and summarised in Figure 3.3 & Figure 3.4. 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 typology.

Potential damage categories are directly related to the tensile strains induced by the phases of construction, arising from a combination of direct tension and bending induced tension mechanisms, as reported in Table 3.2.

A selective range of results from the above analyses can be found in APPENDIX A.

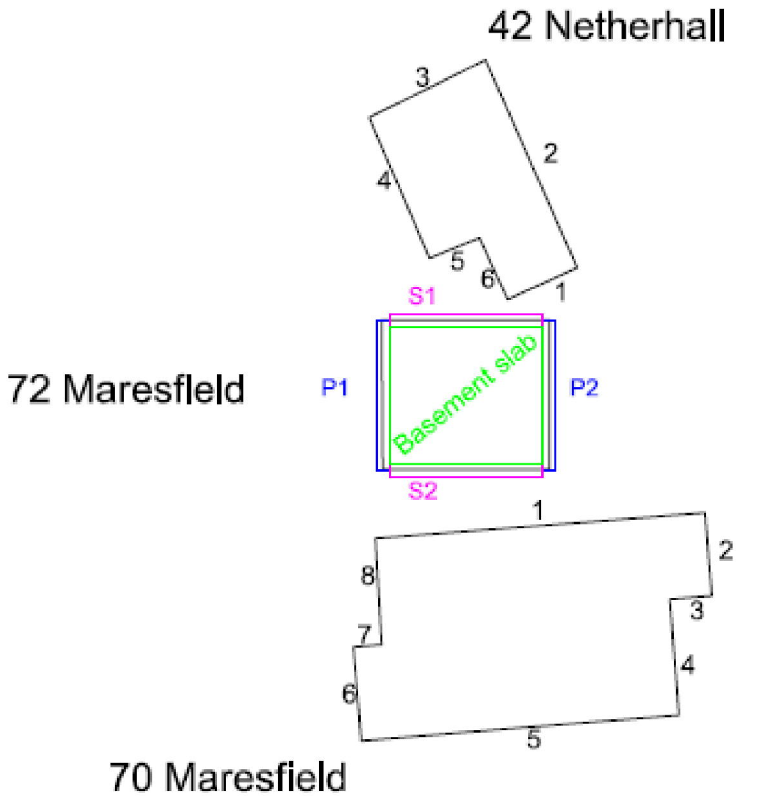

Figure 3.2 Simplified scheme and nomenclature for building facade/masonry wall elements (reference number noted). Loading strips indicated in blue and magenta (P1, P2, S1, S2). Basement slab loading area indicated in green.

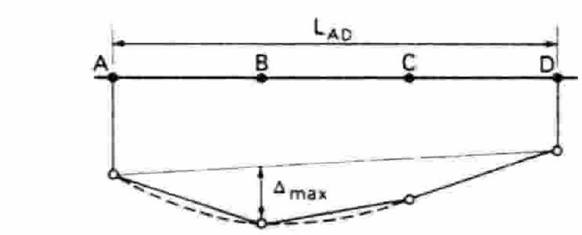

Figure 3.3 Definition of relative deflection Δ and deflection ratio Δ/L.

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

Table 3.2 Evaluated damage categories for excavation and permanent loading stages. Refer to Figure 3.2 for façade nomenclature.

Wall / façade reference	Damage Category Envelope	
	Excavation	Permanent condition
70Mares-1	0 (Negligible)	0 (Negligible)
70Mares-2	0 (Negligible)	0 (Negligible)
70Mares-3	0 (Negligible)	0 (Negligible)
70Mares-4	0 (Negligible)	0 (Negligible)
70Mares-5	0 (Negligible)	0 (Negligible)
70Mares-6	0 (Negligible)	0 (Negligible)
70Mares-7	0 (Negligible)	0 (Negligible)
70Mares-8	0 (Negligible)	0 (Negligible)
42Nether-1	0 (Negligible)	0 (Negligible)
42Nether-2	0 (Negligible)	0 (Negligible)
42Nether-3	0 (Negligible)	0 (Negligible)
42Nether-4	0 (Negligible)	0 (Negligible)
42Nether-5	0 (Negligible)	0 (Negligible)
42Nether-6	0 (Negligible)	0 (Negligible)

4. Concluding remarks

The interaction between the proposed scheme at 72 Maresfield Gardens and the structures within the zone of influence of the proposed works has been reviewed as part of the GMA study presented herein.

The proposed development construction operations comprise two stages, including the deepening of the existing basement and the redistribution of the permanent loads imposed by existing building.

The impact assessment was carried out for each key construction phase in order to account for all primary ground deformation mechanisms while incorporating empirical CIRIA ground movement curves in Oasys Xdisp.

The results from the analysis are presented in Table 3.2 (denoting the evaluated damage categorisation in accordance with the Burland (1997) criteria presented herein). All of the facades fall within Category 0, representative of a Negligible damage classification. Namely, the following displacements should be considered as trigger values for the construction stages analysed herein:

- Maximum absolute horizontal displacement: 5 mm
- Maximum absolute vertical displacement: 6 mm

It is noted that the predicted ground movements, the associated wall tensile strains and level of damage categorisation are considered to be moderately conservative in view of the relatively cautious ground model assumptions 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, monitor trigger levels 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.

APPENDIX A

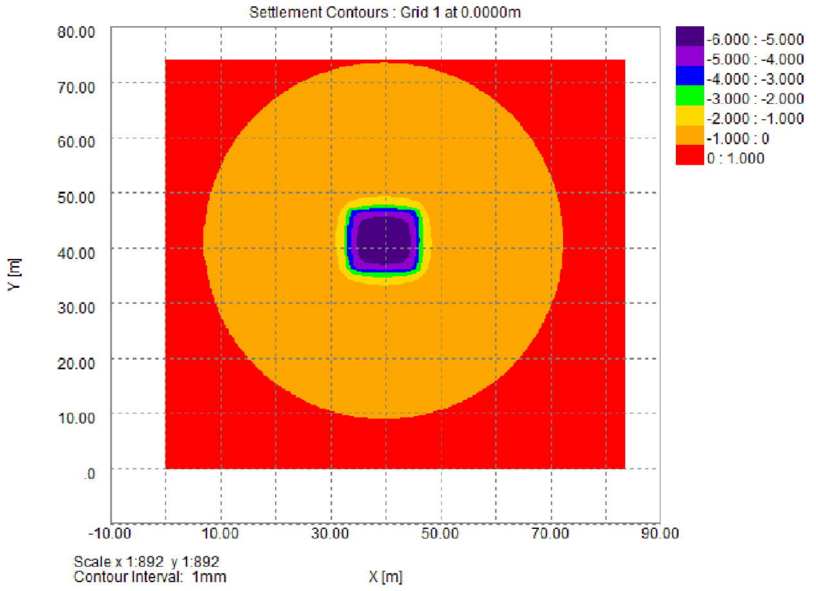

Figure A.1 Surface settlement contours resulting from the soil excavation (negative values indicate heave)

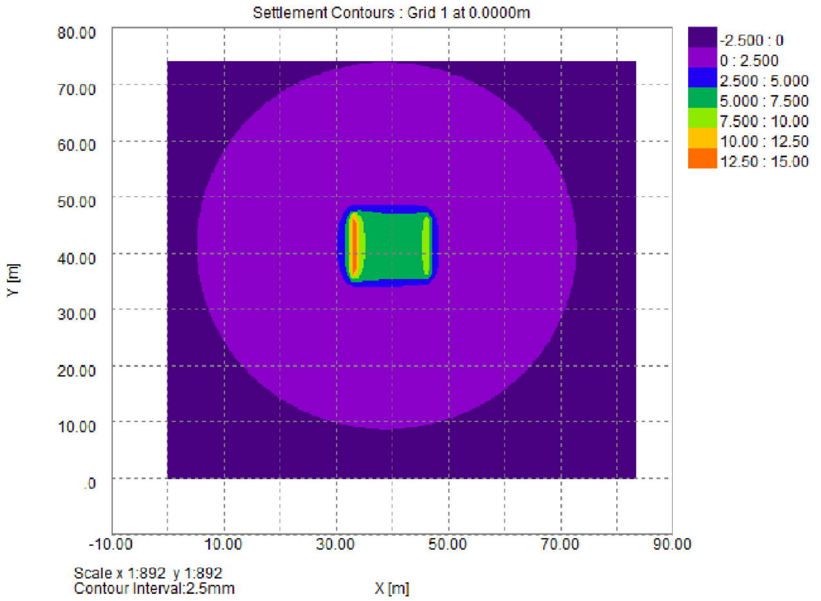

Figure A.2 Surface settlement contours resulting from the permanent condition (positive values indicate settlements)

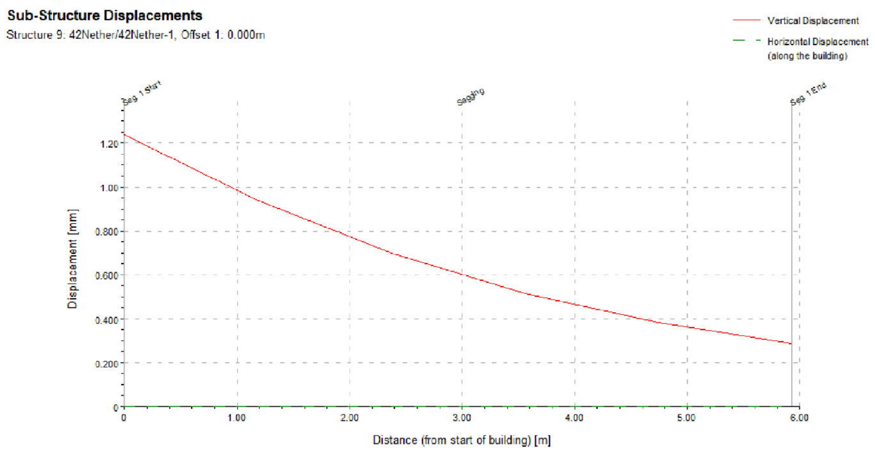

Figure A.3 Façade 42Nether-1 settlement results extracted from excavation analysis

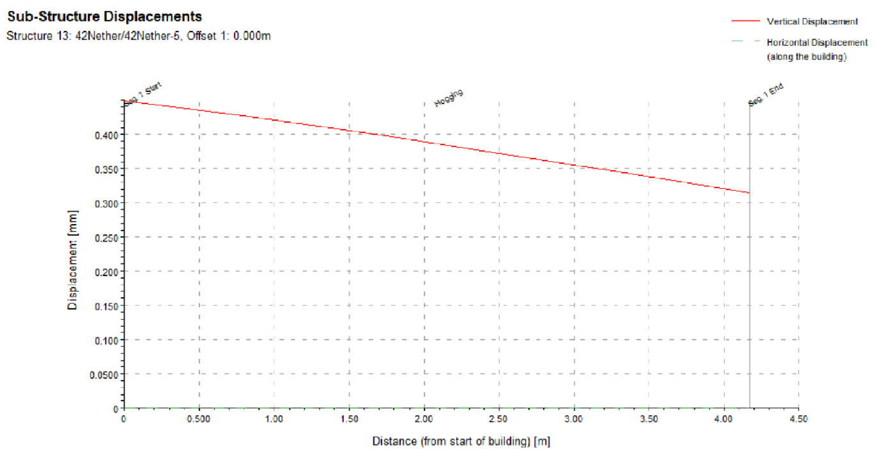

Figure A.4 Façade 42Nether-5 settlement results extracted from excavation analysis

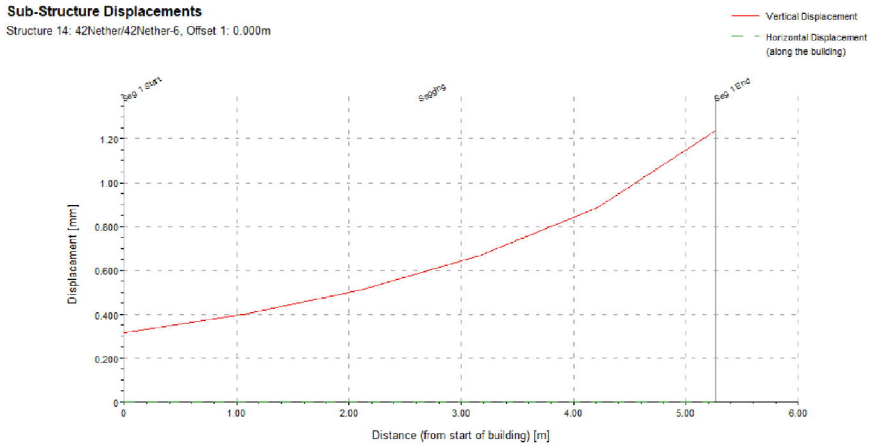

Figure A.5 Façade 42Nether-6 settlement results extracted from excavation analysis

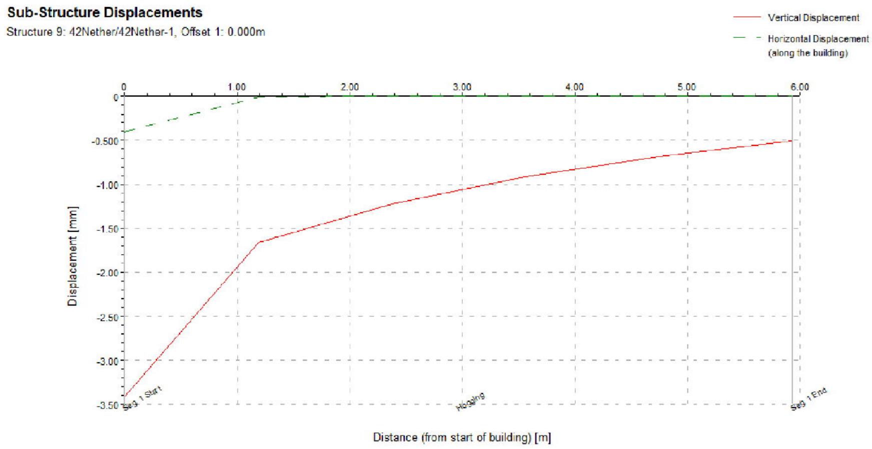

Figure A.6 Façade 42Nether-1 settlement results extracted from permanent condition analysis

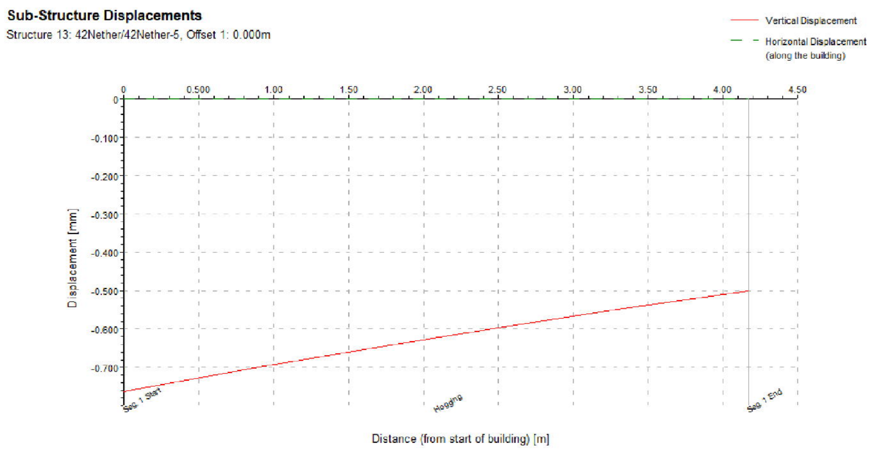

Figure A.7 Façade 42Nether-5 settlement results extracted from permanent condition analysis

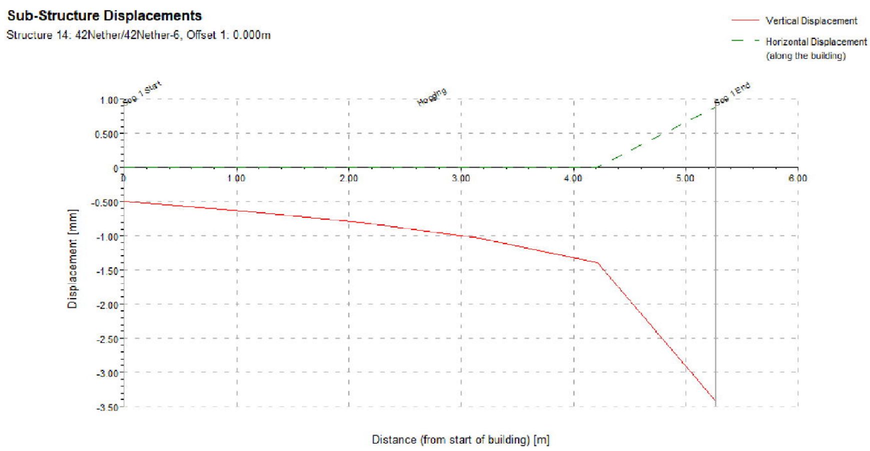

Figure A.8 Façade 42Nether-6 settlement results extracted from permanent condition analysis

Technical Note

A-squared | Studio

Project 72 Maresfield Gardens

Project no. 0537

Subject Basement wall stability assessment

Status	Date	Ref	Rev	Issued by	Checked	[redacted]
For Issue	12-01-2018	0537-TN-02-00	00	A. Kyparissis	P. Smith	

1. Introduction

A-squared Studio Engineers Ltd (A-squared) have been appointed by Multilateral Structural Design Ltd to assess the stability of the load bearing masonry basement walls upon removal of the existing basement slab (allowing basement deepening to take place), for the proposed redevelopment of 72 Maresfield Gardens.

The proposed development involves the demolition of the existing basement slab and the deepening of the existing basement by approximately 400mm. Figure 2.1 depicts the proposed basement level with respect to the existing basement level marked with a dashed line.

This technical note presents the findings of a 2D finite element analysis which has been carried out in order to inform the ongoing scheme development and ensure stability of the load bearing masonry wall is maintained during the proposed works.

2. Proposed construction sequence

It is proposed that the existing basement slab will be removed, allowing basement deepening works to take place.

Upon completion of the deepening works the top of the proposed new basement slab will be approximately 400mm lower than that of the existing.

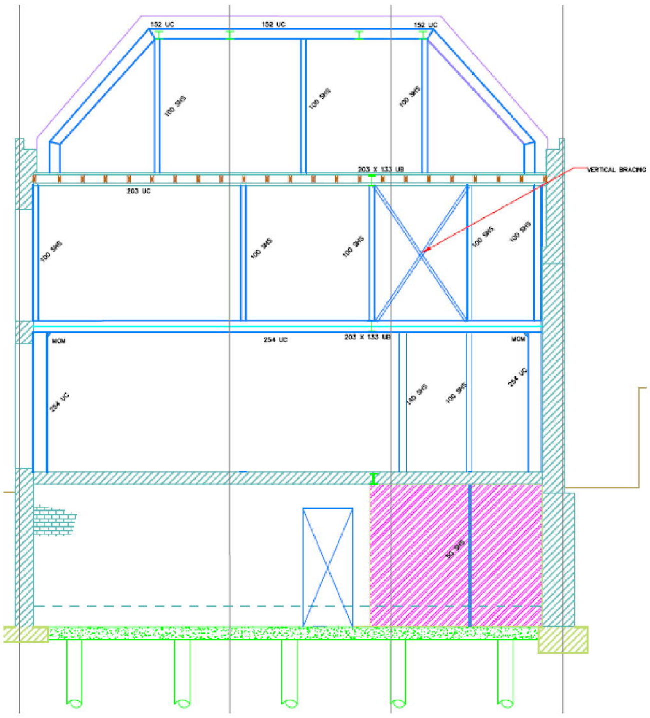

Figure 2.1 Existing (blue dashed line) and proposed (marked with green) basement levels.

3. Basement wall stability analysis

A two-dimensional finite element model was implemented in order to examine the stability of the basement walls during the proposed excavation. The study was conducted with the commercially available software Plaxis 2D.

The geometry adopted in the model is depicted in Figure 3.1 and the dimensions of the wall were assessed based on the drawings provided and ground investigation findings (primarily the trial pits). The soil parameters used in this study are presented in Table 3.1.

Table 3.1 Geotechnical parameters adopted for the soil in the current analysis

Stratum	Bulk unit weight, γ_b [kN/m^3]	Young's modulus, E' [MPa]	Cohesion, c' [kPa]	Angle of shearing resistance, φ' [°]
Made ground	18	10	0	25
Claygate	20	50	0	30

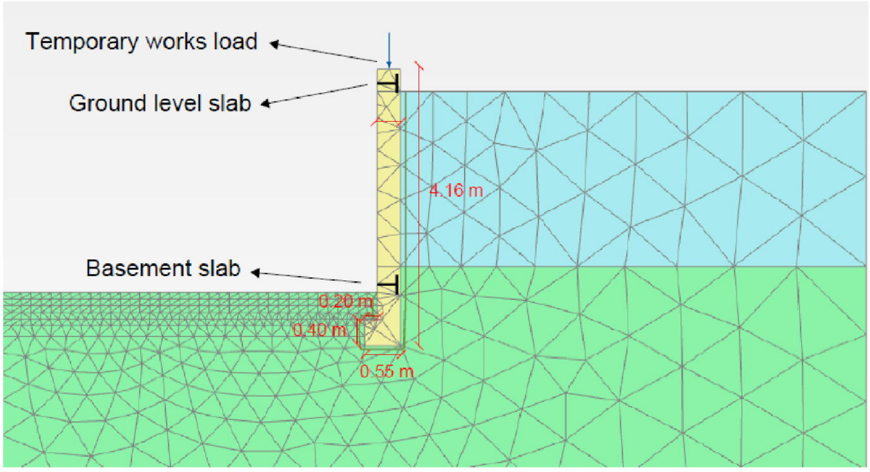

Figure 3.1 Sketch of 2D model used for the basement wall stability assessment.

The excavation process was modelled with a number of layers of finite thickness of approximately 100 mm – this allowed a more accurate assessment of the stability of the wall with the gradual/increasing removal of the soil in front (in order to achieve the 400mm basement level lowering). The mobilised instability mechanism is presented in the indicative contour plot in Figure 3.2.

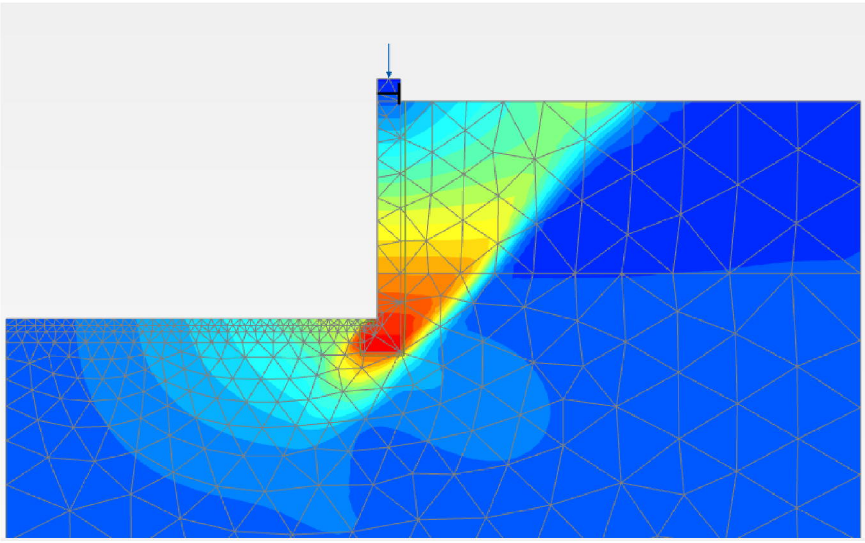

Figure 3.2 Horizontal displacements obtained during the basement excavation.

As an alternative, an indicative propping system was introduced to the model in order to restrain the wall laterally during demolition and excavation in the temporary condition – as is depicted in Figure 3.3. A prop stiffness of EA = 458 × 10^3 kN and a spacing of 3 m were assumed as nominal parameters for this model (representative of an indicative 150mm deep section, adopted for viability review overview purposes only). The propping system was introduced to the model, positioned just above the existing basement slab, prior to the removal of the slab; the proposed construction sequence then followed. As a result of this additional lateral restraint, the maximum horizontal displacements were limited to approximately 1 mm. In addition, a global geotechnical factor of safety of 1.7 was obtained with this solution, which by inspection complies with EC7 Design Approach 1 Combination 2 checks.

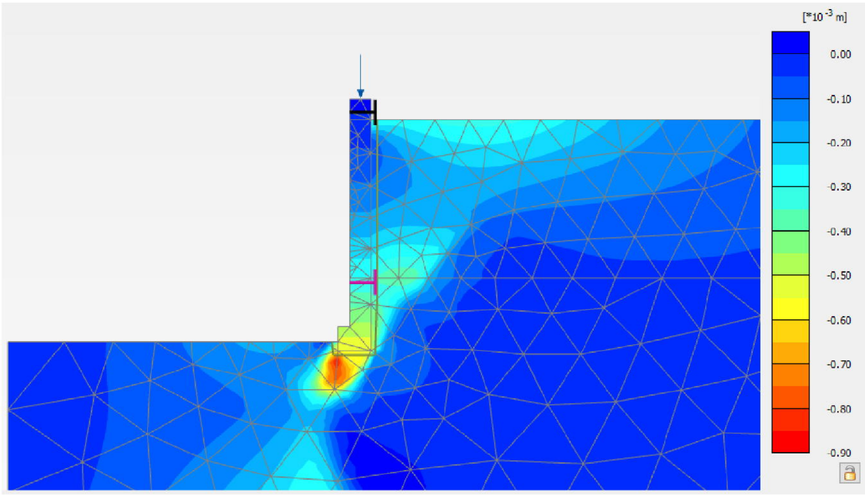

Figure 3.3 Horizontal displacements obtained during the propped basement excavation.

4. Concluding remarks

The stability of the basement wall has been assessed in order to inform the ongoing design development of the proposed deepening works at 72 Maresfields Gardens, as presented herein.

A 2D finite element model was developed in order to examine the vertical and horizontal deformations induced by the proposed works. A representative geometry was adopted within the model based on a series of drawings current at the time of the assessment and the findings of the site-specific ground investigation.

Initially, the proposed construction sequence was implemented which comprised the removal of the existing basement slab, followed by the proposed basement deepening (equating to 400 mm excavation). It was observed that the basement wall is unstable in this unpropped condition once excavation extends below the top of the current wall footing (as a result of the removal of the existing lateral restraint/slab and further reduction in passive resistance arising from the excavation operation).

Therefore, a propping system was introduced to the model prior to the initiation of the proposed construction sequence, which resulted in decreased lateral soil deformations and increased overall global stability to an acceptable factor of safety.

Based on the findings presented herein, it is recommended that the lower portion of the existing masonry wall is propped just above existing slab level prior to removal of the slab and subsequent deepening works. Once the new basement slab has been cast and reached the required design strength, the temporary propping measures may be removed. The propping system will need to be designed accordingly by the specialist contractor, taking cognisance of the nature and characteristics of the existing masonry wall and any potential requirements for load redistribution.