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Dear Isaac,

8 St. CUTHBERTS ROAD – GROUND MOVEMENT ASSESSMENT (GMA)

1. GEOMETRY OF THE SITE

The proposed development involves the demolition of the existing building comprising 2 self-contained units and the subsequent development of a new residential building comprising 4 self-contained units, including the excavation of a single storey basement. The site is located at 8 St. Cuthberts Road, London and the general arrangement of the current ground floor layout is shown in Figure 1.1. The general arrangement of the proposed basement is shown in Figure 1.2 and covers an expanded area (marked in green) with respect to the existing building's footprint (marked in red).

The proposed basement formation level is -4mbgl. Figure 1.3 displays a typical cross section of the proposed basement with mass concrete underpin and contiguous wall locations highlighted in green and blue, respectively.

The site is bounded to the West and North by residential buildings. St Cuthberts Road runs immediately south of the property. The GMA presented herein is concerned with the impact of the proposed development on the properties adjacent to it.

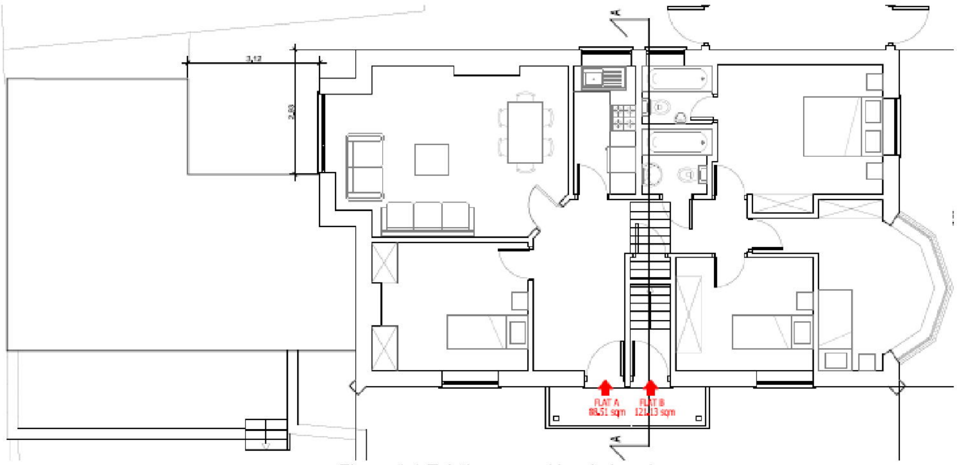

Figure 1.1 Existing ground level plan view

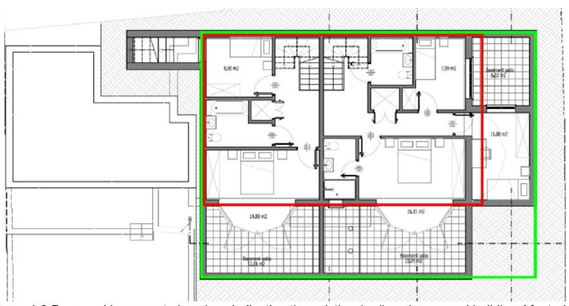

Figure 1.2 Proposed basement plan view, indicating the existing (red) and proposed buildings' footprints

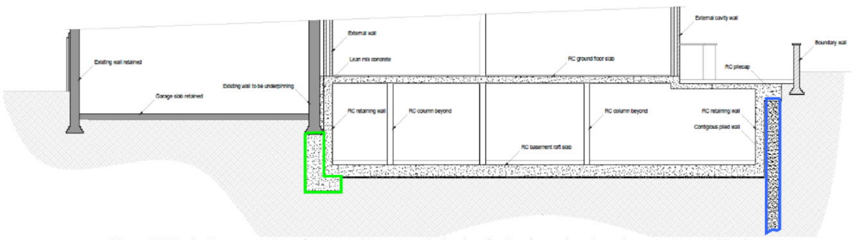

Figure 1.3 Typical cross section of proposed basement indicating footing (green) and contiguous pile wall (blue)

2. PROPOSED UNDER-PINNING WORKS

Part of the West side of the proposed basement is in contact with the adjacent building (see Figure 1.2 and Figure 1.3). Underpinning works will take place to ensure efficient retention during the excavation of the basement, construction phase and design life of the proposed scheme. In addition, underpinning works aim to provide short and long-term stability to the buildings located in the site's proximity.

3. GROUND MOVEMENT ASSESSMENT

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 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 demolition of the existing building, hence ground movements will be induced from overburden removal.

This initial phase will be followed by the installation of a contiguous pile wall on the North, East and South boundaries of the proposed scheme and the installation of underpins on the West boundary of the site. Settlements will be induced around the perimeter of the site within a certain *zone of influence*, resulting in structural deformations of the adjacent buildings. These deformations will then be amplified by the basement bulk excavation works which will follow. 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, the newly published C760 and general principles of elasticity. This procedure comprises the current industry standard/best practice for this type of analytical assessment.

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.

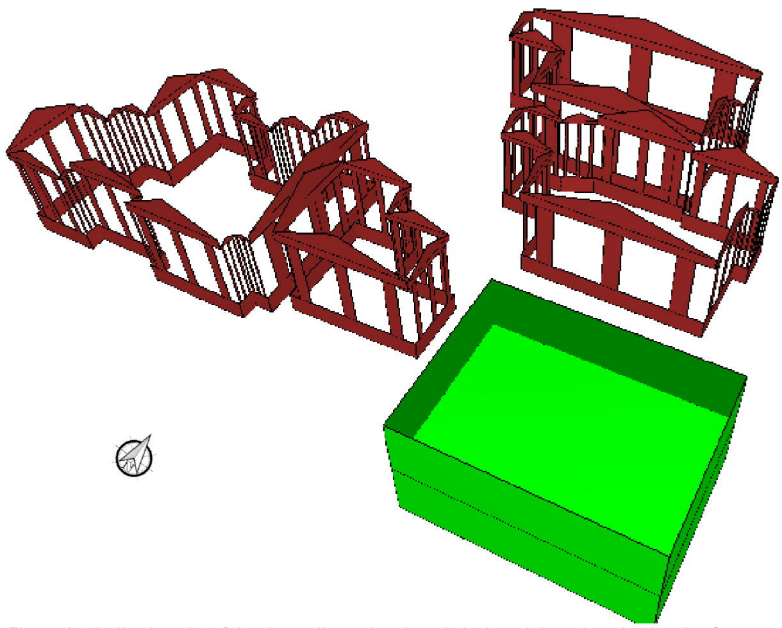

Figure 3.1 Indicative plot of the three-dimensional analytical model produced using the Oasys software suite (soil removed for clarity of presentation). Simplified excavation geometry shown in green.

Ground Model

An idealised ground model has been evaluated based on the site-specific ground investigation which comprised 3 window sample boreholes to 5.5mbgl and 4 hand excavated trial pits.

The thickness of Made Ground was observed in the boreholes to range between 0.4m and 1.5m. It is assessed that proposed basement will be founded at the surface of (or within) the London Clay Formation. Thickness of the London Clay Formation was not proved during the site investigation. For the purposes of the analyses, it is assumed to extend to a depth of 30mbgl.

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

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

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]**
London Clay	1.5 – 30[2]	24.6 + 7.6z[3]	9.8 + 3.0z[3]	7.8 + 2.4z[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 -30 mbgl for analytical purposes (conservative level adopted capturing extensive zone of influence based on development width of around 12m).

3. z is the depth in metres below top of the London Clay, which is assumed to be approx. 1.5m below existing ground level.

Analysis Methods

As outlined previously, three different scenarios have been considered in order to bound the potential ground movements arising from the proposed excavation works.

1. **Existing building demolition**: 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 the existing building's weight (estimated to be approx. -25kPa) imposed by its removal.

   For the short-term analysis, representing the condition immediately following excavation, the soil mass was modelled using undrained stiffness parameters. Drained stiffness parameters were used for capturing the long-term (after the end of construction works and excess pore pressure dissipation) effects of the overburden removal.
2. **Installation of contiguous pile wall/underpins and excavation of basement**: Settlements of the site's proximity and damage to the adjacent buildings were assessed using Oasys Xdisp.

   The horizontal and vertical ground movements due to underpin installation and mass excavation to formation level were evaluated using the normalised CIRIA C580/760 curves for ground movement, as implemented in Oasys Xdisp. Installation of the underpins was modelled by adopting the CIRIA C580/760 curve for *Installation of planar diaphragm wall in stiff clay*.

   This option assumes that the underpinning imposes a ground movement field (resulting from installation and lateral deflection), leading to lateral and vertical components of movement and displacements at foundation level comparable to those measured in the instance of embedded retaining walls.

   Whilst it is acknowledged that the empirical data set is not strictly applicable to the construction technologies adopted, the assessment and associated ground movement mechanisms are representative of the adopted underpinning scenario. This is considered a reasonable approximation in this instance and once again, bounds the solution between settlements and lateral deformations anticipated for the type of construction presented herein, which are inherently subject to satisfactory control of workmanship.

The installation of the contiguous wall was modelled by adopting the CIRIA C580 curve for *Installation of contiguous bored pile wall.* Bulk excavation was evaluated using the CIRIA C580 curve for *Excavation in front of a high stiffness wall in stiff clay*.

As for the demolition stage, short-term loading conditions were considered.

3. **Proposed scheme construction:** The vertical and horizontal displacements induced by the construction of the new scheme were assessed by applying its load on the basement's slab level.

   The long-term loading conditions were considered for this construction stage as well as long-term effects of the 2nd construction phase were also incorporated – including loads imposed by the proposed new structural arrangement.

Impact Assessment

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. 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 both perpendicular and parallel to the proposed basement (covering the key deformation mechanisms).

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.

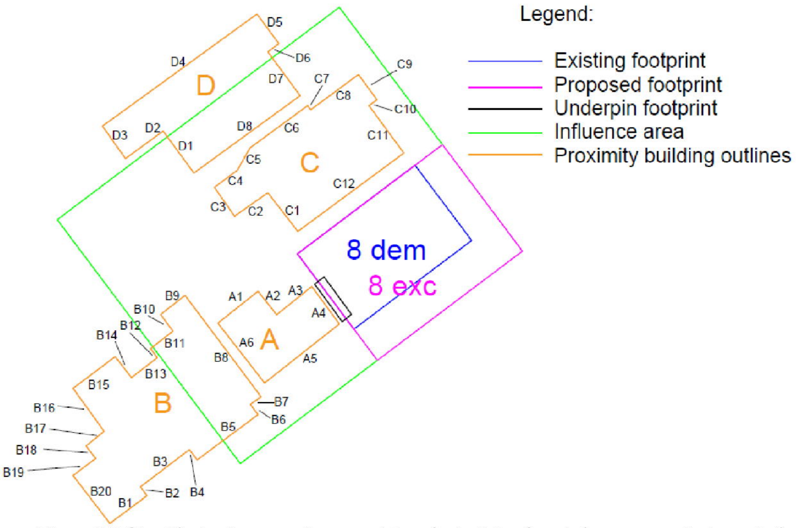

Figure 3.2 Simplified scheme and nomenclature for building façade/masonry wall elements (node/intersect reference numbers noted). Note dem: demolition & exc: excavation.

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 assessed interim (short-term) and long-term phases of construction, arising from a combination of direct tension and bending induced tension mechanisms, as reported in Table 2.2.

Impact Assessment Outcomes

The results from the analysis are presented in Table 2.2 (denoting the evaluated damage categorisation in accordance with the Burland criteria presented herein).

The majority of the façades fall within Category 0, representative of a Negligible damage classification.

A limited number of selected structures/facades have been classified as Category 1, representative of Very Slight.

On the basis of the bounding analysis methods, it is assessed that the damage category for the properties adjacent to 8 St Cuthberts Rd will not exceed Category 1 – Very Slight.

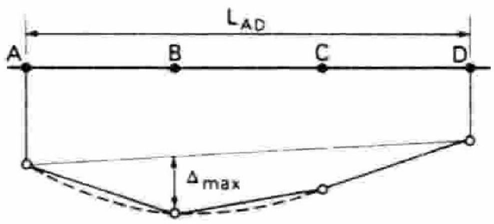

Figure 3.3: Definition of relative deflection Δ and deflection ratio Δ/L.

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 demolition, installation/excavation and long-term condition stages (refer to Figure 3.2 for façade nomenclature)

Wall / façade reference	Damage Category Envelope		
	Demolition	**Installation / Excavation**	**Long term loading**
A1	0 (Negligible)	1 (Very Slight)	1 (Very Slight)
A2	0 (Negligible)	0 (Negligible)	0 (Negligible)
A3	0 (Negligible)	1 (Very Slight)	1 (Very Slight)
A4	0 (Negligible)	0 (Negligible)	0 (Negligible)
A5	0 (Negligible)	1 (Very Slight)	1 (Very Slight)
A6	0 (Negligible)	0 (Negligible)	0 (Negligible)
B1	0 (Negligible)	0 (Negligible)	0 (Negligible)
B2	0 (Negligible)	0 (Negligible)	0 (Negligible)
B3	0 (Negligible)	0 (Negligible)	0 (Negligible)
B4	0 (Negligible)	0 (Negligible)	0 (Negligible)
B5	0 (Negligible)	0 (Negligible)	0 (Negligible)
B6	0 (Negligible)	0 (Negligible)	0 (Negligible)
B7	0 (Negligible)	0 (Negligible)	0 (Negligible)
B8	0 (Negligible)	0 (Negligible)	0 (Negligible)
B9	0 (Negligible)	0 (Negligible)	0 (Negligible)
B10	0 (Negligible)	0 (Negligible)	0 (Negligible)
B11	0 (Negligible)	0 (Negligible)	0 (Negligible)
B12	0 (Negligible)	0 (Negligible)	0 (Negligible)
B13	0 (Negligible)	0 (Negligible)	0 (Negligible)
B14	0 (Negligible)	0 (Negligible)	0 (Negligible)
B15	0 (Negligible)	0 (Negligible)	0 (Negligible)
B16	0 (Negligible)	0 (Negligible)	0 (Negligible)
B17	0 (Negligible)	0 (Negligible)	0 (Negligible)
B18	0 (Negligible)	0 (Negligible)	0 (Negligible)
B19	0 (Negligible)	0 (Negligible)	0 (Negligible)
B20	0 (Negligible)	0 (Negligible)	0 (Negligible)
C1	0 (Negligible)	1 (Very Slight)	1 (Very Slight)
C2	0 (Negligible)	0 (Negligible)	0 (Negligible)
C3	0 (Negligible)	0 (Negligible)	0 (Negligible)
C4	0 (Negligible)	0 (Negligible)	0 (Negligible)
C5	0 (Negligible)	0 (Negligible)	0 (Negligible)
C6	0 (Negligible)	0 (Negligible)	0 (Negligible)
C7	0 (Negligible)	1 (Very Slight)	1 (Very Slight)
C8	0 (Negligible)	0 (Negligible)	0 (Negligible)
C9	0 (Negligible)	1 (Very Slight)	1 (Very Slight)
C10	0 (Negligible)	0 (Negligible)	0 (Negligible)
C11	0 (Negligible)	1 (Very Slight)	1 (Very Slight)
C12	0 (Negligible)	0 (Negligible)	0 (Negligible)
D1	0 (Negligible)	0 (Negligible)	0 (Negligible)
D2	0 (Negligible)	0 (Negligible)	0 (Negligible)
D3	0 (Negligible)	0 (Negligible)	0 (Negligible)
D4	0 (Negligible)	0 (Negligible)	0 (Negligible)
D5	0 (Negligible)	0 (Negligible)	0 (Negligible)
D6	0 (Negligible)	0 (Negligible)	0 (Negligible)
D7	0 (Negligible)	0 (Negligible)	0 (Negligible)
D8	0 (Negligible)	0 (Negligible)	0 (Negligible)

4. DEFLECTION PERFORMANCE CRITERIA

In order to ensure damage classification lower than Category 1 a process of manual scaling was performed of the empirical CIRIA data. The CIRIA excavation curves were scaled by 15% in order to define a wall deflection limit which would satisfy this criterion.

As a result, it is recommended that the horizontal wall deflections should be limited to 5mm to ensure that only Category 1 damage will be experienced by the facades of adjacent buildings.

5. CONCLUSIONS & CLOSING REMARKS

The interaction between the proposed scheme at 8 St Cuthberts Road and the structures on the site proximity has been reviewed as part of the GMA study presented herein.

The proposed development construction operations comprise a series of stages, including the demolition of the existing building, installation of a contiguous pile wall and underpinning system on the western excavation boundary to support the adjacent building's existing foundation, the excavation of a new basement and the construction of a new structure.

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 criteria presented herein). The majority of the facades fall within Category 0, representative of a *Negligible* damage classification. A limited number of structures/facades have been classified as Category 1, representative of *Very Slight* damage classification.

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.

[redacted]

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