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35 TEMPLEWOOD AVENUE – GROUND MOVEMENT ASSESSMENT (GMA)

1. GEOMETRY OF THE SITE

The proposed development involves the construction of a new single storey basement, which will deepen and locally extend the footprint of the existing basement at 35 Templewood Avenue. The general arrangement of the proposed basement which covers the entire footprint of 35 Templewood Avenue is shown in Figure 2.1. Figures Figure 2.2 & Figure 2.3 display cross sections of the proposed development, with the new basement proposal beneath the existing ground floor shown clearly.

The existing lower ground floor (which is present over much of the existing building footprint) formation level is at around 111mOD and the proposed excavation slab formation level is 107.5mOD. Figure 2.2 & Figure 2.3 display typical long/cross sections of the proposed development with proposed footing locations highlighted in green.

The site is bounded to the east and west by Templewood Avenue and the Schrieber Building, respectively. West Heath Rd site to the north of the site with 33 Templewood Avenue to the south. The GMA presented herein is concerned with the impact of the proposed development on the properties immediately adjacent, namely the Schrieber Building and 33 Templewood Avenue.

2. PROPOSED UNDER-PINNING WORKS

The proposed basement is to be constructed by means of underpinning techniques, Figure 2.1 displays a sketch of the underpinning methodology, in the following indicative key construction stages:

1. Establish site, repair any existing cracks & install monitoring equipment.
2. Install temporary propping to existing walls just above ground floor level.
3. Demolish existing ground floor structure.
4. Underpin perimeter walls in sequence.
5. Underpin internal walls in sequence.
6. Excavate to intermediate level and install temporary propping to underpins.
7. Excavate to formation level and place blinding.
8. Install buried drainage, heave board and cast basement slab.
9. Remove temporary props when basement slab has gained sufficient strength.
10. Install new ground floor structure.

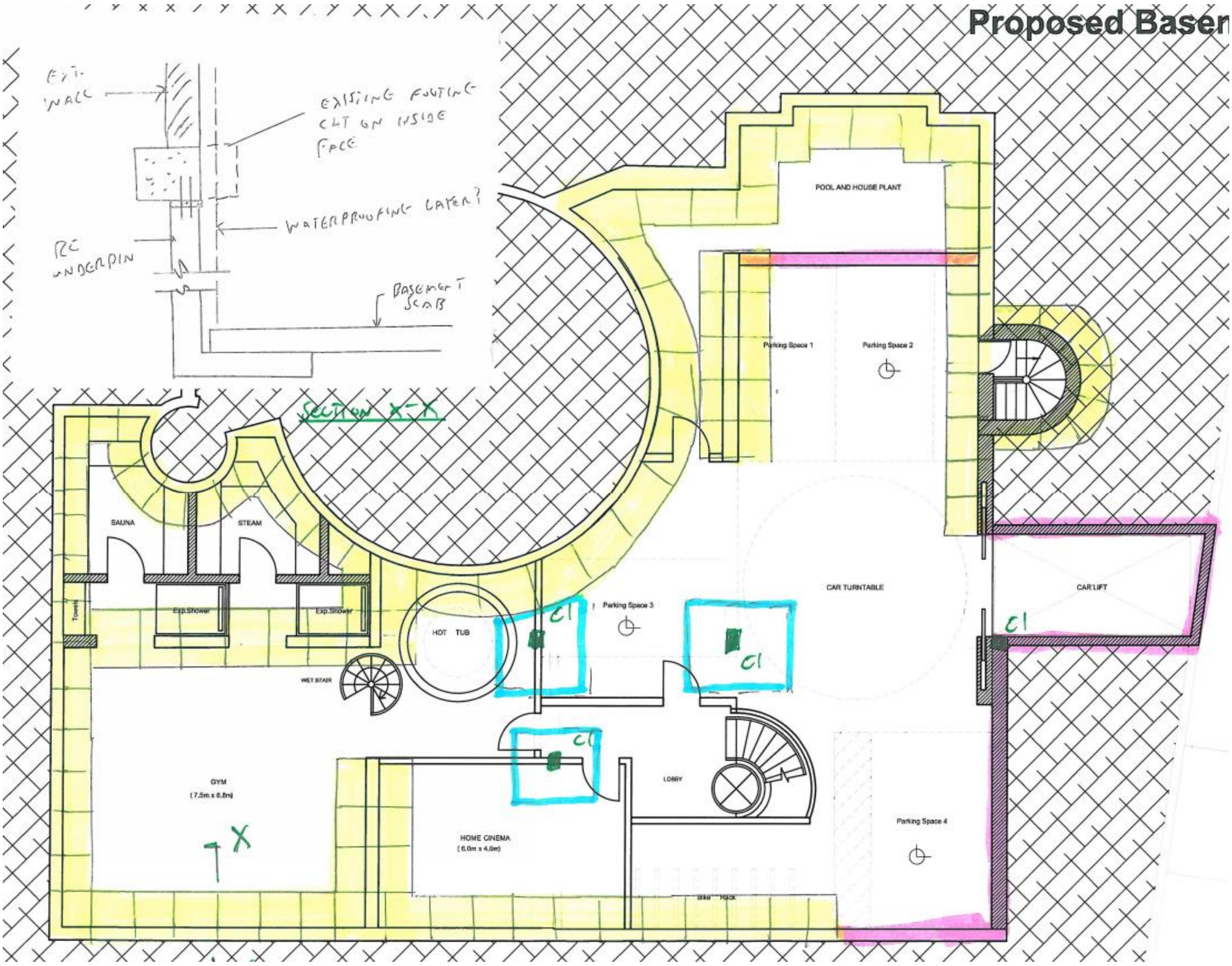

Figure 2.1: Proposed basement layout – Option A.

Figure 2.2: Typical long section

Figure 2.3: Typical cross section

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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 removal of the existing ground floor structure having installed temporary propping to the existing walls. This initial strip phase will be followed by basement excavation operations and the underpinning of the masonry perimeter walls and application of the permanent works building loadings. Areas outside the existing building footprint will comprise reinforced concrete cantilever walls. The basement excavation process and underpinning will induce ground movements arising from the overburden removal. 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 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.

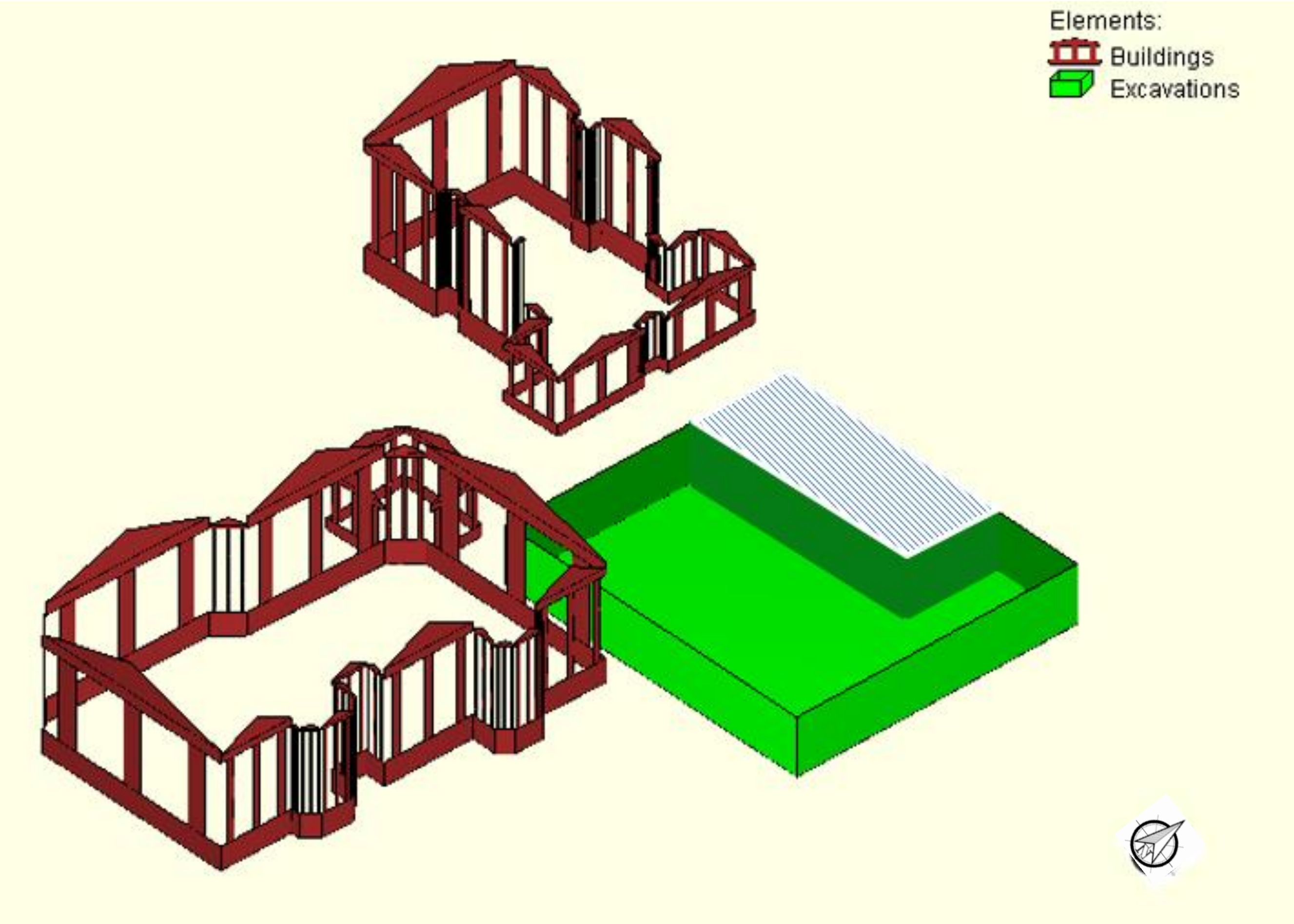

Figure 3.1: Indicative plot of the three-dimensional analytical model produced using the Oasys software suite (soil removed for clarity of presentation). Simplified excavation geometry shown in green.

Ground Model

An idealised ground model has been evaluated based on the site-specific ground investigation which comprised 2no window sample boreholes to 6.0mbgl and 1no hand excavated trial pit.

The thickness of Made Ground was observed in the boreholes to be typically less than 1m thick. It is assessed that the buildings adjacent to the proposed development site will be founded at the surface of (or within) the Bagshot Formation. The thickness of the Bagshot Formation was not proven during the site investigation.

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)**	**Drained Young's Modulus, E' (MPa)**
Bagshot Formation	0.7 - 1.0	45 + 9.5 z[1]	20.3 + 4.3 z[1]	16.2 + 3.4 z[1]

Notes: 1. z is the depth in metres below top of the Bagshot Formation, which is assumed to be approx. 1.0m below existing ground level.

2. *Rigid boundary* assumed at -30 mbgl for analytical purposes (conservative level adopted capturing extensive zone of influence based on development width of around 10-12m).

3. 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.

Analysis Methods

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

1. In the first option (*Method 1*), the *worst-case* heave condition was assessed by assuming that no lateral or downward ground movement takes place during the underpinning operations (effectively assuming a wished into place underpin solution).

   Heave movements arising from the proposed basement excavation were assessed using Oasys Pdisp.

   The proposed excavation and associated heave was modelled by applying an upward (unloading) stress at the formation level, which is equivalent to the total stress relief (approx. -80 kPa) imposed by the proposed depth of excavation beneath the existing basement.

   For the short term analysis, representing the condition immediately following excavation, the soil mass was modelled using undrained stiffness parameters.

   In the long term (representing the condition some time after the building works are complete and excess pore pressures have dissipated), relaxation of the soil was captured by using drained soil parameters. The effect of increased building loads, associated with the proposed renovation works, were also incorporated in this phase.

   Figure 2.2 shows the geometry and intensity of the footing loads as applied in the Pdisp model. The permanent building loads were evaluated on the basis of an indicative load takedown based on the proposed floor arrangements provided.

   Note that only those loads adjacent to the neighbouring properties have been modelled – the remainder are considered to be out with the zone of influence. In addition, the applied foundation loading has been taken conservatively as the allowable bearing pressure of 150kPa upon which the foundations have been sized.

2. The second option (*Method 2*) assesses horizontal movements and ground settlements (as opposed to heave evaluated in Option 1) imposed by the proposed excavation and underpinning works.

   The horizontal and vertical ground movements due to underpin installation and mass excavation to formation level were evaluated using the normalised CIRIA C580 curves for ground movement, as implemented in Oasys Xdisp. Installation was modelled by adopting the CIRIA C580 curve for *Installation of planar diaphragm wall in stiff clay*. Bulk excavation was evaluated using the CIRIA C580 curve for *Excavation in front of a high stiffness 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 maximum potential heave, settlements and lateral deformations anticipated for the type of construction presented herein, which are inherently subject to satisfactory control of workmanship.

   As for Method 1, short term and long term phases were considered. The proposed building loads were also incorporated.

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 3.3, 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.

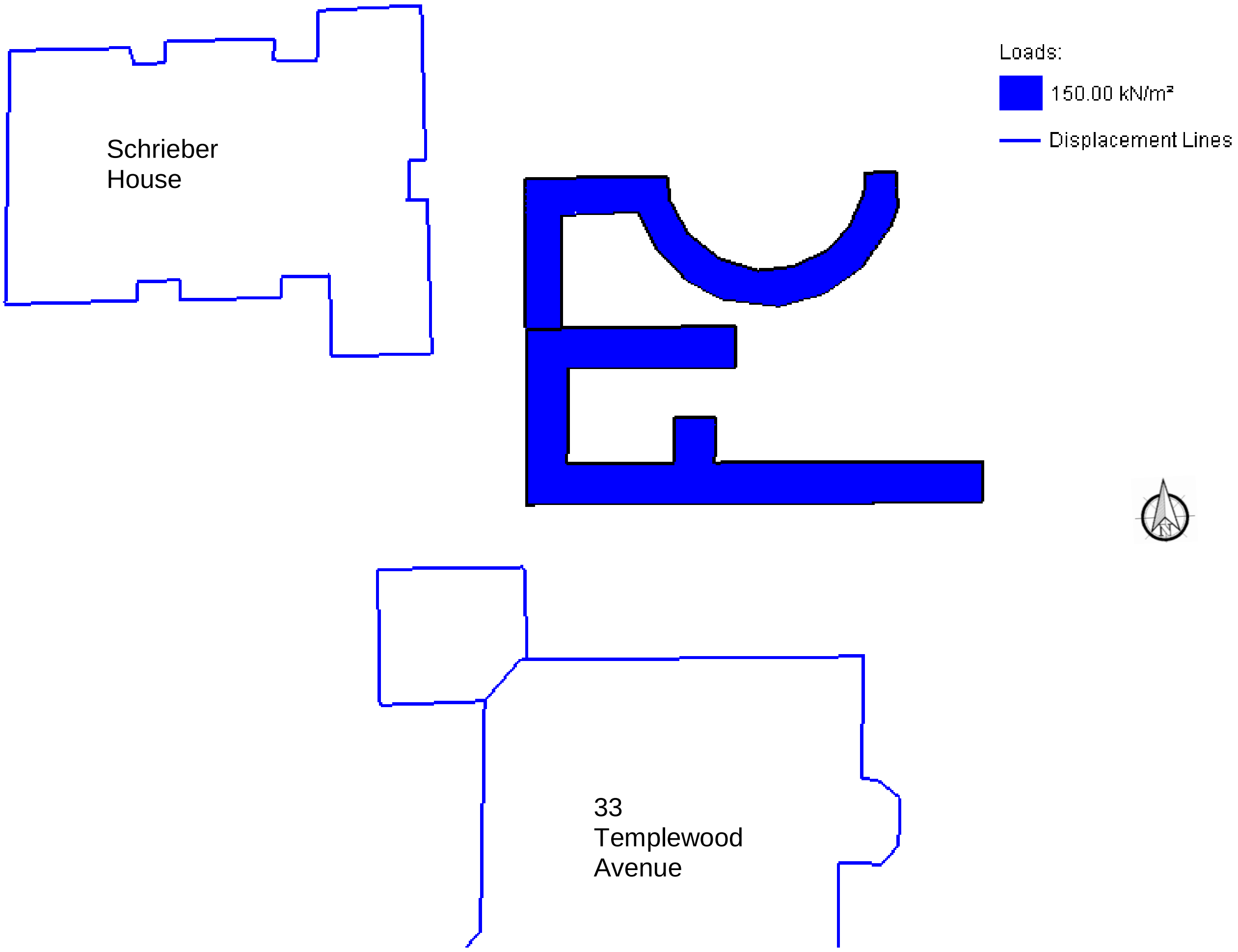

Figure 3.2: Long term phase loading regime model with adjacent properties.

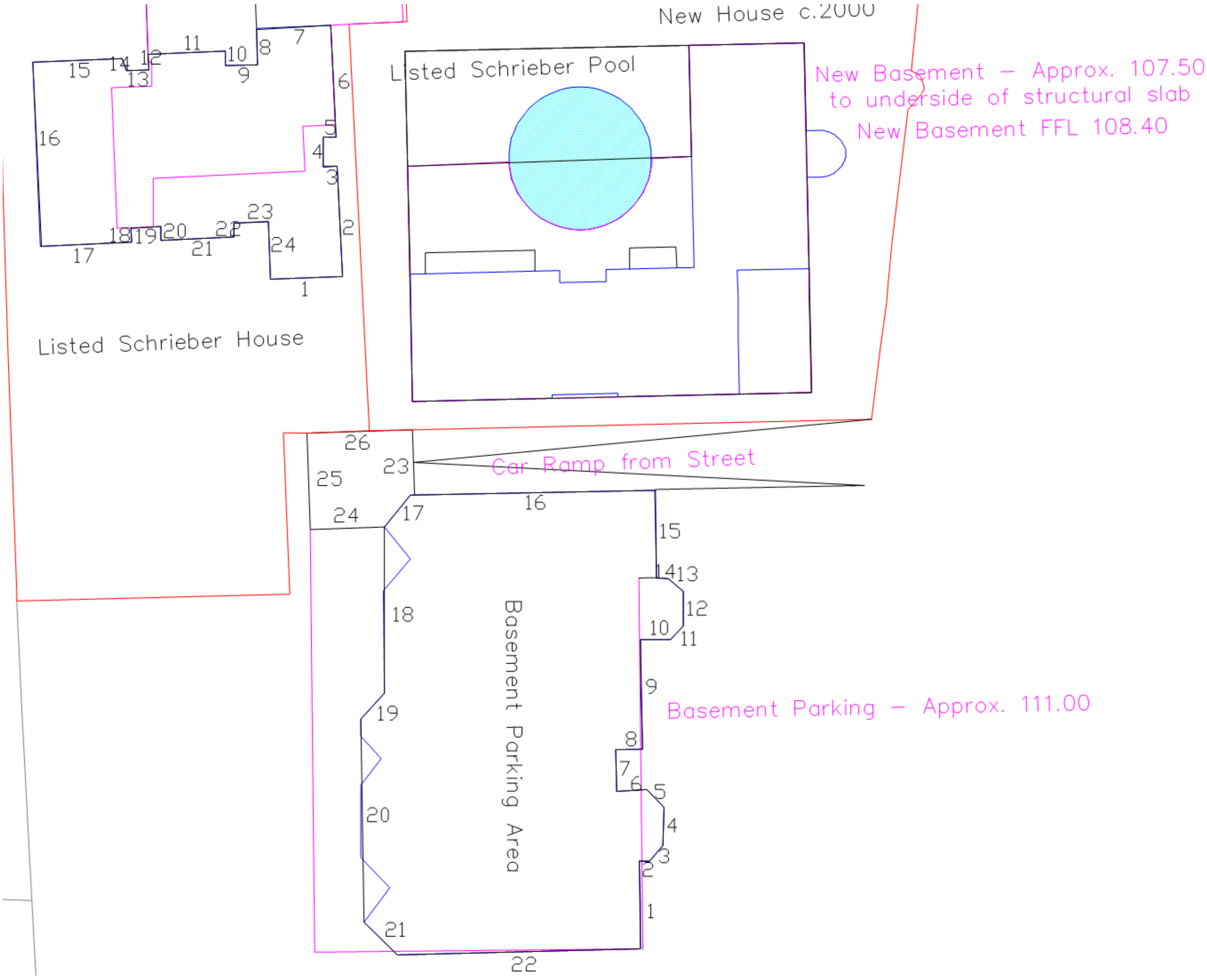

Figure 3.3: Simplified scheme and nomenclature for building façade/masonry wall elements (node/intersect reference numbers noted).

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 3.4 & Figure 3.5. 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 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.

<u>Impact Assessment Outcomes</u>

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 damage classification.

No façades have been classified as Category 2 (slight) or higher.

On the basis of the bounding analysis methods, it is assessed that the damage category for the properties adjacent to 35 Templewood Avenue will not exceed Category 1 – very slight.

Table 3.2: Evaluated damage categories for strip/excavation and long term condition stages (refer to Figure 3.3 for wall nomenclature)

Method 1

Building	Wall/façade reference	Damage Category Envelope	
		Excavation	Long term
Schrieber Building	1	0 (Negligible)	0 (Negligible)
Schrieber Building	2	0 (Negligible)	0 (Negligible)
Schrieber Building	3	0 (Negligible)	0 (Negligible)
Schrieber Building	4	0 (Negligible)	0 (Negligible)
Schrieber Building	5	0 (Negligible)	0 (Negligible)
Schrieber Building	6	0 (Negligible)	0 (Negligible)
Schrieber Building	7	0 (Negligible)	0 (Negligible)
Schrieber Building	8	0 (Negligible)	0 (Negligible)
Schrieber Building	9	0 (Negligible)	0 (Negligible)
Schrieber Building	10	0 (Negligible)	0 (Negligible)
Schrieber Building	11	0 (Negligible)	0 (Negligible)
Schrieber Building	12	0 (Negligible)	0 (Negligible)
Schrieber Building	13	0 (Negligible)	0 (Negligible)
Schrieber Building	14	0 (Negligible)	0 (Negligible)
Schrieber Building	15	0 (Negligible)	0 (Negligible)
Schrieber Building	16	0 (Negligible)	0 (Negligible)
Schrieber Building	17	0 (Negligible)	0 (Negligible)

Schrieber Building	18	0 (Negligible)	0 (Negligible)
Schrieber Building	19	0 (Negligible)	0 (Negligible)
Schrieber Building	20	0 (Negligible)	0 (Negligible)
Schrieber Building	21	0 (Negligible)	0 (Negligible)
Schrieber Building	22	0 (Negligible)	0 (Negligible)
Schrieber Building	23	0 (Negligible)	0 (Negligible)
Schrieber Building	24	0 (Negligible)	0 (Negligible)
33 Templewood Ave	1	0 (Negligible)	0 (Negligible)
33 Templewood Ave	2	0 (Negligible)	0 (Negligible)
33 Templewood Ave	3	0 (Negligible)	0 (Negligible)
33 Templewood Ave	4	0 (Negligible)	0 (Negligible)
33 Templewood Ave	5	0 (Negligible)	0 (Negligible)
33 Templewood Ave	6	0 (Negligible)	0 (Negligible)
33 Templewood Ave	7	0 (Negligible)	0 (Negligible)
33 Templewood Ave	8	0 (Negligible)	0 (Negligible)
33 Templewood Ave	9	0 (Negligible)	0 (Negligible)
33 Templewood Ave	10	0 (Negligible)	0 (Negligible)
33 Templewood Ave	11	0 (Negligible)	0 (Negligible)
33 Templewood Ave	12	0 (Negligible)	0 (Negligible)
33 Templewood Ave	13	0 (Negligible)	0 (Negligible)
33 Templewood Ave	14	0 (Negligible)	0 (Negligible)
33 Templewood Ave	15	0 (Negligible)	0 (Negligible)
33 Templewood Ave	16	0 (Negligible)	0 (Negligible)
33 Templewood Ave	17	0 (Negligible)	0 (Negligible)
33 Templewood Ave	18	0 (Negligible)	0 (Negligible)

33 Templewood Ave	19	0 (Negligible)	0 (Negligible)
33 Templewood Ave	20	0 (Negligible)	0 (Negligible)
33 Templewood Ave	21	0 (Negligible)	0 (Negligible)
33 Templewood Ave	22	0 (Negligible)	0 (Negligible)
33 Templewood Ave	23	0 (Negligible)	0 (Negligible)
33 Templewood Ave	24	0 (Negligible)	0 (Negligible)
33 Templewood Ave	25	0 (Negligible)	0 (Negligible)
33 Templewood Ave	26	0 (Negligible)	0 (Negligible)

Method 2

Building	Wall/façade reference	Damage Category Envelope	
		Excavation	Long term
Schrieber Building	1	1 (Very Slight)	1 (Very Slight)
Schrieber Building	2	1 (Very Slight)	1 (Very Slight)
Schrieber Building	3	0 (Negligible)	0 (Negligible)
Schrieber Building	4	0 (Negligible)	0 (Negligible)
Schrieber Building	5	0 (Negligible)	0 (Negligible)
Schrieber Building	6	0 (Negligible)	0 (Negligible)
Schrieber Building	7	0 (Negligible)	0 (Negligible)
Schrieber Building	8	0 (Negligible)	0 (Negligible)
Schrieber Building	9	0 (Negligible)	0 (Negligible)
Schrieber Building	10	0 (Negligible)	0 (Negligible)
Schrieber Building	11	0 (Negligible)	0 (Negligible)
Schrieber Building	12	0 (Negligible)	0 (Negligible)
Schrieber Building	13	0 (Negligible)	0 (Negligible)

Schrieber Building	14	0 (Negligible)	0 (Negligible)
Schrieber Building	15	0 (Negligible)	0 (Negligible)
Schrieber Building	16	0 (Negligible)	0 (Negligible)
Schrieber Building	17	0 (Negligible)	0 (Negligible)
Schrieber Building	18	0 (Negligible)	0 (Negligible)
Schrieber Building	19	0 (Negligible)	0 (Negligible)
Schrieber Building	20	0 (Negligible)	0 (Negligible)
Schrieber Building	21	0 (Negligible)	0 (Negligible)
Schrieber Building	22	0 (Negligible)	0 (Negligible)
Schrieber Building	23	0 (Negligible)	0 (Negligible)
Schrieber Building	24	0 (Negligible)	0 (Negligible)
33 Templewood Ave	1	0 (Negligible)	0 (Negligible)
33 Templewood Ave	2	0 (Negligible)	0 (Negligible)
33 Templewood Ave	3	0 (Negligible)	0 (Negligible)
33 Templewood Ave	4	0 (Negligible)	0 (Negligible)
33 Templewood Ave	5	0 (Negligible)	0 (Negligible)
33 Templewood Ave	6	0 (Negligible)	0 (Negligible)
33 Templewood Ave	7	0 (Negligible)	0 (Negligible)
33 Templewood Ave	8	0 (Negligible)	0 (Negligible)
33 Templewood Ave	9	0 (Negligible)	0 (Negligible)
33 Templewood Ave	10	0 (Negligible)	0 (Negligible)
33 Templewood Ave	11	0 (Negligible)	0 (Negligible)
33 Templewood Ave	12	0 (Negligible)	0 (Negligible)
33 Templewood Ave	13	0 (Negligible)	0 (Negligible)
33 Templewood Ave	14	0 (Negligible)	0 (Negligible)

33 Templewood Ave	15	0 (Negligible)	0 (Negligible)
33 Templewood Ave	16	0 (Negligible)	0 (Negligible)
33 Templewood Ave	17	0 (Negligible)	0 (Negligible)
33 Templewood Ave	18	0 (Negligible)	0 (Negligible)
33 Templewood Ave	19	0 (Negligible)	0 (Negligible)
33 Templewood Ave	20	0 (Negligible)	0 (Negligible)
33 Templewood Ave	21	0 (Negligible)	0 (Negligible)
33 Templewood Ave	22	0 (Negligible)	0 (Negligible)
33 Templewood Ave	23	1 (Very Slight)	1 (Very Slight)
33 Templewood Ave	24	0 (Negligible)	0 (Negligible)
33 Templewood Ave	25	0 (Negligible)	0 (Negligible)
33 Templewood Ave	26	0 (Negligible)	0 (Negligible)

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}.

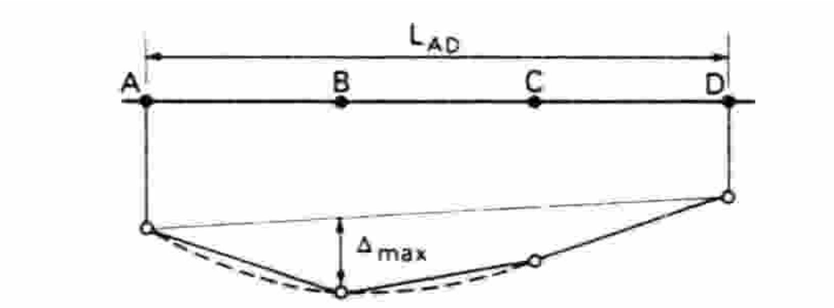

Figure 3.5: Definition of relative deflection Δ and deflection ratio Δ/L.

4. ADDITIONAL GMA ELEMENTS

In addition to the analysis relating to the neighboring properties, two additional items have been assessed. These are the listed Schreiber swimming pool which is within the footprint of the existing 35 Templewood Avenue property and the adjacent roadways, respectively.

Figure 4.1: Additional analysis elements displayed in green.

The idealized geometries adopted for the analysis of the swimming pool and roadway/pavement, are shown in green in Figure 4.1.

Listed swimming pool assessment

The results yielded by these analyses indicate that the swimming pool is expected to be subject to no greater than Category 1 damage (Very Slight), based on the classification system after Burland et al. 1977 and Boscardin and Cording 1989. In order to ensure that this damage classification is not exceeded the following performance criteria must be adhered to:

- Maximum horizontal deflection of the mass concrete underpinning around the swimming pool of 5mm.

Adjacent roadway assessment

W Heath Road and Templewood Avenue run adjacent to the site under consideration in the North and East, respectively. The impact of underpinning and excavation works on these roads has also been assessed in terms of maximum vertical and horizontal deflections at a number of locations. Soil displacements were monitored along the green lines drawn on the streets (see Figure 4.1). Lines running both parallel (segments 1 & 2) and perpendicular (segments 3-6) to the streets were defined to capture the effects more accurately.

The assessments found that all recorded displacements at these locations were <1mm. Thus it can be reasonably concluded that the effect of the proposed works on W Heath Road and Templewood Avenue are negligible.

5. CONCLUSIONS & CLOSING REMARKS

The interaction between the proposed 35 Templewood Avenue development, the Schrieber Building and 33 Templewood Avenue has been reviewed as part of the GMA study presented herein.

The proposed development construction operations comprise a series of stages, including strip of the existing ground floor structure/temporary propping of existing walls, basement deepening/excavation and construction of the proposed elements. The impact of the excavation stages of construction have been reviewed on the basis of two alternative methods (i.e. evaluating the effects of unloading/overburden removal using Pdisp (Method 1) and the excavation effect using empirical CIRIA ground movement curves in Xdisp (Method 2)). The 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 underpinning processes adopted.

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 facades 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* damage classification – no damage category higher than this has been assessed.

In addition to the above, assessments were carried out to quantify the potential impact of the proposed development on both the listed Schrieber swimming pool and the adjacent roadways, respectively. It was found that in order to ensure a damage classification of no greater than Category 1 (*Very Slight*) for the swimming pool, the horizontal deflection of the underpinning system in this location must be limited to within 5mm. The ground movements at both W Heath Road and Templewood Avenue were found to be negligible.

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.

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