Ground and Project CONSULTANTS LTD

128-130 GRAFTON ROAD, LONDON, NW5

4BABasement Impact Assessment:

Land Stability Assessment Report

July 2019

Client:

Eta Bridging Ltd

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128-130 GRAFTON ROAD, LONDON, NW5 4BA

Basement Impact Assessment: Land Stability Assessment

40213-3

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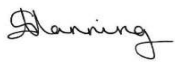
Revision History

Revision	Date	Purpose	Comments
Draft	March 2019	Client Comments	
Final	July 2019	Planning Application	Incorporates Ground Movement Assessment

Signatures and Approvals				
Authors	G Manning O Hawes	 	Date	11/07/19
Checker and Approver	J Smithson		Date	11/07/19

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Contents

1 Introduction

Ground and Project Consultants Ltd has been instructed by Eta Bridging Ltd to undertake a Basement Impact Assessment regarding the land stability, for 128-130 Grafton Road, London, NW5 4BA. The property is located in the Borough of Camden, London in the Gospel Oak ward. Its location is indicated on Figure 1.

Figure 1: Site Location

2 Scope and Objective

A previous screening and scoping report (Report No. 40213-1) was produced by Ground and Project Consultants in September 2017. This report incorporates the subsequent ground investigation data, and assesses the potential for ground movement that could impact on adjacent buildings.

The scope of this report and approach are as follows:

- A review of the existing data supplied by the client has been carried out, including the proposal drawings produced to date, photos of the building and other freely available data such as BGS geological information and purchased environmental data.
- In line with the methodology set out in the London Borough of Camden guidance, CPG4, latest revision:
    - An assessment of the published and encountered geology.
    - Responses to the Screening questions.
    - Development of Scoping Issues.
- A review of the Ground & Water Limited ground investigation data.
- Assessment of the data to develop a ground model and carry out an engineering interpretation and impact assessment of the land stability.

The report has not considered contaminated land aspects of the site.

The report assumes the full involvement of a suitably qualified and experienced Structural Engineer in the design and supervision of the basement construction.

This report and the work to support it, have been carried out by Jon Smithson who is a Director of Ground and Project Consultants Ltd and is a Chartered Geologist (CGeol) with over 30 years' experience.

3 Site Information

i. Site Location

The property at 128-130 Grafton Road, London, NW5 4BA is located on the east side of the road. The property is around 1.4 km north of Regent's Park and 900m north of Camden Locks. The National Grid Reference for the property is TQ 28495 85038. The location of the property is indicated in Figure 1 above.

ii. Site Description

The existing property is a single-storey terraced industrial building/warehouse comprising a ground floor and a mezzanine floor with associated forecourt area / off-street parking for approximately 5 vehicles to the front of the property. It is currently occupied by E & D Scaffolding Co Ltd. The existing building is brick built and is understood to be in overall good condition, with minor signs of distress.

There are no trees on the property with the site comprising hardstanding throughout. However, there are some trees close by to the front of the property immediately to the south and along the road.

The property is bound by residential or commercial/industrial buildings and Grafton Road to the southwest. The property adjoins a four-storey residential scheme on its south-eastern side (no. 126). There is an attached two-storey industrial building "Spring Lighting" on its north-western side (no. 132-134). The property backs onto a five-storey building fronting Spring Place to the northeast which is in commercial/industrial use as a lighting manufacturer.

iii. Topography

The OS map indicates the property is at around 36m AOD. The ground surface at the site and surrounding area is relatively flat.

iv. Proposals

The proposals for the site comprise demolition of the existing structure and construction of a five-storey residential building with a basement and roof terrace. The basement will be approximately 3m deep and expected to be deeper for the lift shaft. The lift shaft is proposed to be set back about 5 to 7m from the perimeter of the basement. The footprint of the basement including sunken terraces is approximately 14.1m wide by 16.8m deep with a resultant area of around 237m^2. The descriptions and dimensions above have been estimated from drawings provided by Redrock Development Group.

v. Geology

The available geological mapping (Ref 1.) indicates that the site lies on the London Clay Formation. The London Clay Formation typically comprises a stiff grey fissured clay, weathering to brown near surface. Concretions of argillaceous limestone in nodular form (claystones) occur throughout the formation. The base of the London Clay Formation is likely to occur at significant depth below the property. An area of worked ground (the hatched area) is indicated close by to the east and north. An area of potential Head Deposits is shown around 300m to the northwest. See Figure 2 below.

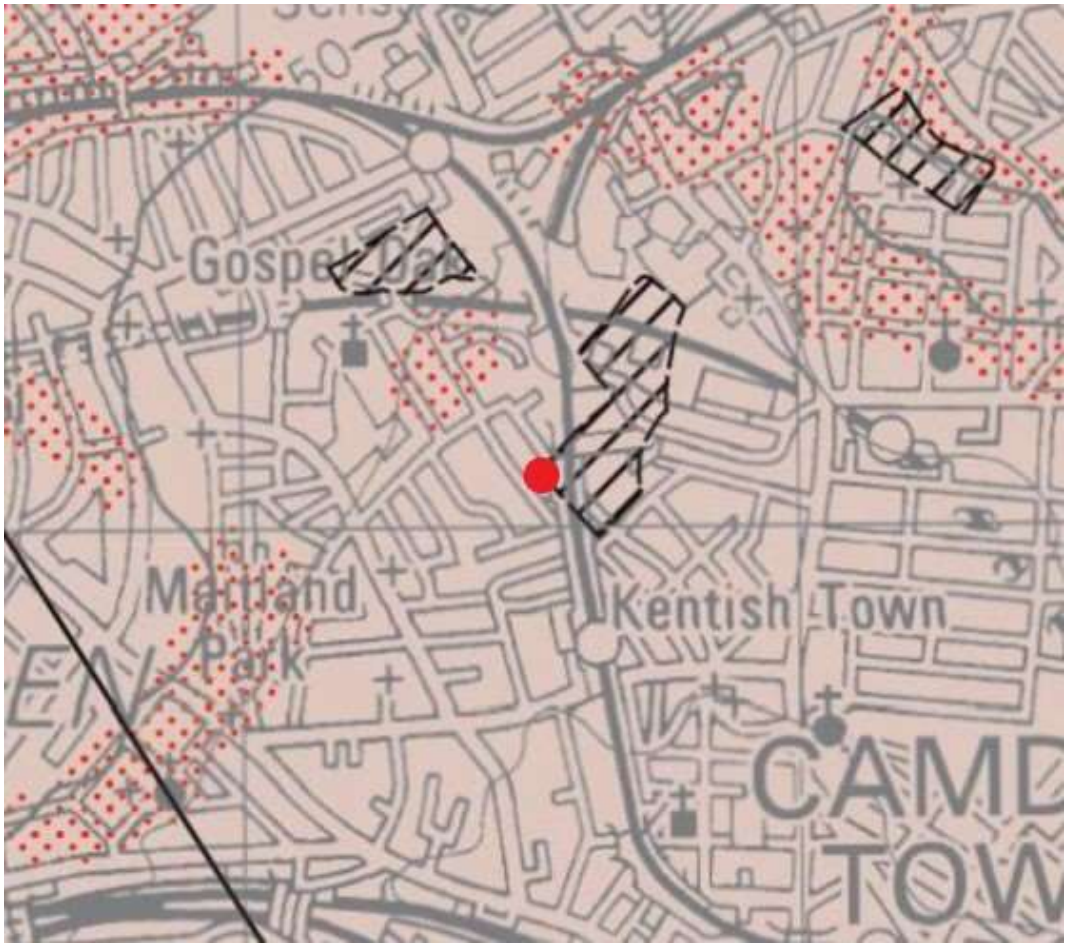

Figure 2: Geology

vi. Hydrology and Hydrogeology

The OS Map indicates that there are no surface water bodies in the near vicinity of the site. The Hampstead Ponds are located approximately 1.4km to the northwest. Tributaries of the 'lost' River Fleet are understood to run in culvert around 100-200m to the east and west of the site.

The underlying London Clay is classified by the Environment Agency as unproductive strata (rock layers with low permeability and negligible significance for water supply or river base flow). The site is not within a source protection zone of a public water supply. There are no ground or surface water abstraction licences within 250m of the site.

4 BIA Screening for Slope/Land Stability

A screening exercise has been carried out as per the guidance in CPG4 as follows:

Question	Answer	Action/ Comment
Question 1: Does the existing site include slopes, natural or manmade, greater than 7 degrees? (approximately 1 in 8)	No. The ground surface at site is relatively level.	None
Question 2: Will the proposed re-profiling of landscaping at site change slopes at the property boundary to more than 7 degrees?	No. It is understood that there are no planned significant changes in surface profile.	None
Question 3: Does the development neighbour land, including railway cuttings and the like, with a slope greater than 7 degrees?	No. There are no railway cuttings in the immediate vicinity. The close by railway line is on a bridge.	None
Question 4: Is the site within a wider hillside setting in which the general slope is greater than 7 degrees?	No. The slope in the area is less than 1 in 50 (2^{o}) based on published Ordnance Survey data. This is confirmed by Figure 16 from the Arup Report.	None
Question 5: Is the London Clay the shallowest strata at the site?	Yes. The geological maps indicate London Clay is the shallowest deposit. There are potential Head deposits indicated to the north. Made Ground is also likely to be present	The engineering significance of the site geology is further discussed in the Scoping assessment.
Question 6: Will any tree/s be felled as part of the proposed development and/or are any works proposed within any tree protection zones where trees are to be retained? (Note that consent is required from LB Camden to undertake work to any tree/s protected by a Tree Protection Order or to tree/s in a Conservation Area if the tree is over certain dimensions).	Possibly. There are no trees on the property, however, there are trees within influencing distance located at the front of neighbouring properties to the south.	The significance of the proximity of trees is further discussed in the Scoping assessment.
Question 7: Is there a history of seasonal shrink-swell subsidence in the local area, and/or evidence of such effects at the site?	None known. It is understood that the existing buildings at site are in good condition given their age and show only minor signs of distress.	The engineering significance of the site geology is further discussed in the Scoping assessment.

Question 8: Is the site within 100m of a watercourse or a potential spring line?	No. Two tributaries to the 'Lost' River Fleet run approximately 100-200m east and west of the property.	No further action as confirmed by the BIA: Groundwater (Ref. 6).
Question 9: Is the site within an area of previously worked ground?	No. However, worked ground is indicated close by the east.	The engineering significance of the site geology is further discussed in the Scoping assessment.
Question 10: Is the site within an aquifer? If so, will the proposed basement extend beneath the water table such that dewatering may be required during construction?	No. The London Clay is non-productive strata.	None
Question 12: Is the site within 5m of a highway or pedestrian right of way?	Yes.	This is further discussed in the Impact Assessment. Health Safety and environmental measures will be required to be integrated into the building contractor's methods of working.
Question 13: Will the proposed basement significantly increase the differential depth of foundations relative to neighbouring properties?	Yes. It is understood that the adjoining properties do not have basements.	This is further discussed in the Scoping Assessment.
Question 14: Is the site over (or within the exclusion zone of) any tunnels, e.g. railway lines?	No. The LNWR main line is overground and around 40m to the east.	None

5 BIA Scoping for Slope/Land Stability

From the screening assessment carried out in Section 4 it is considered, based on the information available at this stage, that the construction of a basement at 128-130 Grafton Road is viable subject to further assessments and appropriate design and construction considerations. The following issues have been carried forward for scoping:

1) London Clay is the shallowest (mapped) strata.
2) Trees are locally present.
3) Shrink and Swell Clays (It is understood that the existing buildings at site are in good condition given their age and show only minor signs of distress. However, the presence of London Clay requires that this issue be further assessed).
4) The local presence of Worked Ground.
5) The site is within 5m of the footway.
6) The neighbouring properties are not known to have basements so that there may be a significant increase of the differential depth of foundations.

A ground investigation and further assessment was recommended.

6 Ground Investigation

A ground investigation was carried out at the site by Ground and Water Ltd on 1st February 2019. The ground investigation comprised two boreholes drilled to 6.45m and 7.10m below ground level (bgl) using a window sampler rig and two foundation inspection pits.

Th ground investigation encountered Made Ground, overlying Head Deposits, overlying the London Clay Formation. Roots were recorded up to 3.0m bgl. No groundwater was encountered. The findings are summarised below.

i. Made Ground

Made Ground was encountered from ground level to a depth of between 0.95m to 1.8m bgl as concrete hardstanding with a thickness of between 0.17m and 0.2m, over sandy gravelly clay with the gravel consisting of fine to coarse flint with rare brick fragments.

ii. Head

- Head deposits were encountered in each of the exploratory holes, excluding WS1, which encountered the thickest Made Ground. The Head was described as sandy silt gravelly clay, with the gravel consisting of fine to coarse flint. The Head was proven to a depth of 2.0m bgl. Only one SPT was performed in the Head Deposits. This was taken at the top of the Head (1m bgl), and gave an 'N' value of 2. One Atterberg test and moisture content test were carried out on a sample of Head deposit obtained from 1.5m bgl. The results indicate a liquid limit of 76%, plastic limit of 25%, plasticity index of 51% and a moisture content of 33%, indicating the Head is clay of very high plasticity and high volume change potential. The Liquidity Index calculated from these tests was 0.16, which indicates a stiff clay. In this case we believe that the single SPT value of 2 was not representative of the Head Deposits, it being performed at the top of the deposit at the interface with the Made Ground. The Liquidity Index is probably a more reliable indicator of undrained shear strength in this case, and therefore we interpret the Head Deposit as being stiff for the purpose of our assessment of ground movement in this report. However, a sensitivity check has also been performed for soft to firm clay.

iii. London Clay Formation

- The London Clay Formation was encountered beneath the Made Ground and Head deposits to the base of the boreholes. It is described as a brownish grey slightly sandy silty clay with sand lenses and selenite crystals recorded in WS1. Low SPT 'N' values of 6 and 8 were measured at 2m bgl, and 11 and 9 at 3m bgl. Below this depth the SPT's increased with depth and were generally between 11

and 22. An SPT gave refusal at 6.7m bgl in WS1, and is suspected to be due to a claystone nodule. This high N value is considered not representative of the stratum. Four Atterberg tests and moisture content tests were carried out on the London Clay Formation. The results indicate a liquid limit of between 70% and 73%, plastic limit of 25% to 28%, plasticity index of between 42% and 48%, and a moisture content of between 30% and 32%. These Atterberg tests indicate the London Clay Formation is clay of very high plasticity and high shrinkage potential. The Liquidity Index calculated from these tests was 0.05 and 0.1, which indicates a stiff clay. In this case we believe that the low SPTs at depths of between 2 and 3m are not a reliable indicator of undrained shear strength. The Liquidity Index is considered to be a more reliable indicator of undrained shear strength in this case. Therefore, we interpret the London Clay as being stiff for the purpose of our assessment of ground movement in this report. However, a sensitivity check has also been performed for soft to firm clay.

Sulphate testing on three samples of the London Clay Formation gave characteristic values of sulphate being 4100mg/l, total sulphur of 0.24% and pH of 7.15.

iv. Groundwater

Groundwater was not encountered during drilling up to 7.1m bgl.

v. Foundation Inspection Pits

The foundation inspection pits encountered a brick wall resting on concrete foundations from 0.35m or 0.70m bgl, with the base extending to 1.15m and 1.00m bgl respectively.

7 Ground Model

The investigation encountered Made Ground, overlying Head, which in turn overlies the London Clay Formation. The Made Ground was consistent with typical Made Ground associated with a building foundation, and no clear evidence of "worked ground" was encountered. It is noted that some SPT results were low, which may reflect some reworking. We have assumed "worked ground" to mean a deeper excavation associated with mineral extraction. The Head comprised stiff silty sandy slightly gravelly clay of very high plasticity with the gravel comprising flint. The London Clay Formation comprised stiff brownish grey silty sandy clay of very high plasticity with sand lenses and selenite crystals. Roots were encountered down to 3.0m bgl. The London Clay Formation has been found to have elevated sulphates and therefore the design sulphate class for the site is DS-4, with an ACEC of AC-3s.

A ground model for use in this BIA has been developed by interpreting the available data and is detailed below. Note that this ground model is not to be used for the detailed design of foundations and basements. The detailed designer should make his own interpretation of the factual data and carry out further ground investigations as necessary.

Strata	Description	Encountered Surface (m bgl)	Characteristic Values	Comments
Hardstanding	Concrete	G.L	N/A	N/A
Made Ground	Sandy gravelly clay with the gravel consisting of fine to coarse flint and brick.	0.17 – 0.20	C' =0 $\phi' = 20^o$	Made Ground is likely to be highly variable and compressible. Not suitable as a founding stratum.
Head	Stiff sandy silt gravelly clay.	0.95 – 1.8	C' =0 $\phi' = 21^o$	Some areas may be soft to firm.
London Clay Formation	Stiff silty slightly sandy clay with sand lenses, selenite crystals and suspected claystones.	1.8 - 2.0	C' =0 $\phi' = 21^o$	Some shallow areas may be soft to firm. Shrinkable soils may be impacted by tree roots. High sulphate content.
Groundwater	N/A	None encountered	N/A	Not encountered due to clay. Some seepages may occur

8 Impact Assessment

There are no apparent major issues that seriously affect the viability of the construction of the new basement. However, the screening exercise, and subsequent assessment of the geological environment of 128-130 Grafton Road, indicate some areas for further discussion in this report with suggested mitigation where appropriate.

Impact Question	Answer and Justification	Impact
Question 5: Is the London Clay the shallowest strata at the site?	No. Head deposits are the shallowest natural strata.	The Head and London Clay Formation have high volume change potential.
Question 6: Will any tree/s be felled as part of the proposed development and/or are any works proposed within any tree protection zones where trees are to be retained?	Yes. There are no trees on the property. However, there are trees within influencing distance located at the front of neighbouring properties to the south. It is not known if these are protected.	Based on the presence of shrinkable soils beneath the site, foundations will require to be deepened below the zone of influence of trees. Measures to minimise damaging roots should be carried out.
Question 7: Is there a history of seasonal shrink-swell subsidence in the local area, and/or evidence of such effects at the site?	None known. It is understood that the existing buildings at site are in good condition given their age and show only minor signs of distress.	The presence of high volume change potential clays indicate that measures to prevent heave should be undertaken.
Question 12: Is the site within 5m of a highway or pedestrian right of way?	Yes.	Safe method of working should be compiled in the Constructors Risk Assessment and Method Statements.
Question 13: Will the proposed basement significantly increase the differential depth of foundations relative to neighbouring properties?	Yes. It is understood that the adjoining properties do not have basements.	Potential for unacceptable ground movements which could adversely affect the adjoining properties. Monitoring before and during construction should be carried out. Design and Construction must be appropriate to the context.

i. Basement Depth and Foundations

The proposals for the site include the construction of a basement. It is anticipated that the basement founding level will be approximately 3m below the current ground level, with a deeper area for the lift shaft set back from the perimeter of the basement. It will be critical to prevent exposed faces collapsing, so as to minimise ground loss into the new excavation. Adequate temporary face support should be provided. In addition, it is recommended that monitoring is carried out prior to construction and during the

excavation and development of the site to reduce the risk to neighbouring properties. The monitoring will need to include threshold and action levels, with appropriate actions and mitigation measures.

An evaluation of allowable bearing pressures accounting for load distribution, foundation shape and size and settlement tolerances should be carried out as part of the design process. Bearing capacity and settlement issues are not within the remit of this report. However, the factual data gained from the ground investigation can be used for such assessments.

ii. Founding strata

Based on the anticipated depths, the basement will be founded in the London Clay Formation. The London Clay Formation is a high plasticity clay and as such has the potential for volume change, which will need to be accounted for in the design of the retaining walls and base slab. The design should also account for the influence of trees off site to the south and seasonal variations in moisture content.

iii. Groundwater

Groundwater was not encountered during the ground investigation and therefore significant groundwater ingress is not expected. However, allowances for a sump pump for any superficial runoff during high rainfall is recommended.

Care should be taken to minimise disturbance to the formation and to avoid softening of the soils by keeping the excavation free from standing water. Softened soils should be excavated and replaced where practicable.

iv. Trees

The presence of trees will need to be accounted for in design and construction, with deepened foundations in proximity to any trees as well as limiting root damage. Appropriate advice should be sought from an arboricultural expert during detailed design and construction.

v. Preliminary Assessment of Ground Movement

A preliminary estimate of ground movements resulting from construction of the basement has been carried out as follows:

- The methodology described in CIRIA C760 (Reference 8) has been adopted.
- The criteria for acceptability of movements is stated by the structural engineer (Ref. 7) as those movements that do not exceed ‘Category 2’ (slight damage) as defined by CIRIA C760.
- Outline Design drawings developed by the architect (Reference 5) have been reviewed and used to inform this assessment.

- Movements have been assessed for the adjoining properties at 126 and 132 Grafton Road, and 10 Spring Place. 10 Spring Place is comprised of two long buildings, one tall and one low, which have been assessed separately.
- The ground has been assumed to be stiff clay, but a sensitivity check has also been performed for soft to firm clay.
- The magnitude of ground movements has been assessed for the excavation in front of the retaining structure, i.e. the basement wall.
- Groundwater was not encountered during the investigation and therefore groundwater lowering, and associated ground settlement, is unlikely to occur.
- London Clay Formation is expected to underlie the site for some considerable depth and therefore water pressures within granular horizons that could give rise to heave of the base are not expected.
- The outline methodology put forward by the Structural Engineer (Ref. 7) for temporary works has been assumed. The side basement walls, adjoining 126 and 132 Grafton Road, involve first underpinning the party walls using a 'hit and miss' approach, and then installing sheet piles to support the ground below existing foundation level. The front wall adjoining the road, and back wall adjoining 10 Spring Place, will be supported by secant piles. The permanent works involve the construction of a stiff reinforced concrete box within the above temporary works.
- It is important to note that CIRIA report C760 is written for embedded retaining walls. Therefore, movement calculations for the excavation of soil and installation of underpins does not strictly apply to C760. There is no recognised method for calculating ground movements due to underpinned basements so C760 is used as a convenient and recognised approach. It is recognised that settlements are generally small where care and appropriate measures are taken in this type of underpinning basement construction.

The following key assumptions have been made:

- The maximum excavation depth is approximately 3m below lower ground floor level.
- A high wall stiffness has been assumed.
- The wall will be propped using stiff closely spaced props in the temporary case both at basement floor and ceiling levels.
- In the permanent case the walls will be part of a stiff box propped at basement floor and ground level.
- For the purposes of the calculations, the width and height of the subject properties have been estimated from aerial images.

The maximum ground movements in both the horizontal and vertical directions are all estimated to be less than 10mm. Based on the estimates of ground movement, the

potential for damage to adjacent buildings has been assessed based on the methodology described in CIRIA C760. None of the adjacent buildings is expected to suffer damage beyond Category 2, as stipulated by the Structural Engineer (Ref. 7). A sensitivity assessment using soft to firm clay, instead of stiff clay, indicated that the predicted damage categories were unchanged. The calculations are provided in Appendix A, and summarised in Table 1 below.

Adjacent Existing Building	Basement Wall Type	Damage Category (Stiff Clay)
126 Grafton Road	Underpin and sheet piles	2 Slight
132 Grafton Road	Underpin and sheet piles	2 Slight
10 Spring Place (Tall)	Secant Piles	1 Very Slight
10 Spring Place (Low)	Secant Piles	1 Very Slight

Table 1 – Summary of Results of Ground Movement and Adjacent Building Damage Assessment

CIRIA C760 Table 6.4, provides a description of the Categories of damage, and a copy of Table 6.4 is provided in Appendix A.

vi. Construction near footpath and highway

The close proximity of the front of the property to the pavement and highway, means that construction related activities will be carried out in areas adjacent to public access. A thorough assessment of risks to the public and the workforce will need to be developed and mitigation measures put in place where risks cannot be eliminated or managed appropriately.

9 Conclusions and Recommendations

The methodology and approach of CPG4 has been followed in developing this BIA with respect to Land stability. It is concluded that the construction of a basement at 128-130 Grafton Road should not have significant impacts on land stability provided that:

- Design of the permanent and temporary works should be carried out by a competent and experienced Structural Engineer, who should assess and approve method statements as appropriate.
- The construction of the basement is carried out by competent and experienced contractors and precautions are taken to maintain the stability of the excavations.
- Care should be taken to minimise the disturbance and damage to trees and their roots.
- Concrete should be designed in accordance with BRE Special Digest 1 accounting for the sulphate pH and groundwater conditions anticipated.
- A preliminary assessment of ground movement has been carried out. This indicates that a design based on limiting movement of the existing structures to 'Category 2' (slight damage), as categorised in Table 1 of BRE 251 and CIRIA report C760, is feasible. However, a detailed assessment of ground movement should be carried out as part of the detailed temporary and permanent works design.

- The assessment of ground movement and damage category in this report relies on good practice to be followed during the detailed design and construction phase, including the following:
    1. Structural surveys to be carried out of the adjacent buildings prior to detailed design and construction;
    2. A detailed design of the temporary and permanent works to limit the damage to Category 2;
    3. A stiff temporary and permanent basement support system;
    4. Good workmanship by the Contractor during construction of both temporary and permanent basement supports;
    5. Installation of support immediately following excavation;
    6. Avoidance of ground loss through the gaps between the piles;
    7. Minimise deterioration of the central soil mass by the use of blinding/ covering with a waterproof membrane;
    8. Avoid overbreak;
    9. Control and appropriate design and selection of dewatering methods to minimise fines removal and drawdown;
    10. All temporary works and surrounding structures are to be monitored during all phases of the works;
    11. Movement trigger levels to be established as part of the detailed design;

12. Appropriate and immediate actions to be taken on trigger level exceedances, as set out in a plan to be prepared by the Contractor and approved by the Structural Engineer.

- It must be noted that the ground movement estimates are calculated values based on the findings and methods of CIRIA C760. Larger movements may be generated if any one or any combination of the above recommendations and/or assumptions are not heeded or if ground conditions are different from those anticipated by the investigation. Previous experience recorded in C760, suggests that ground movements are highly sensitive to prop and wall stiffness. Therefore, the use of stiff props both in the temporary and permanent cases is essential.

- **Note that interpretations made in this report are for the BIA only**. The detailed designer should make his own interpretation of the factual data and carry out further ground investigations as necessary. As previously discussed in Section 6 (ii) and (iii), there was an anomaly between the SPT results and the Atterberg limits that should be further investigated for detailed design. The mapped presence of 'Worked Ground' raises the possibility that the low SPT N values reflect reworked London Clay. It is recommended that the basement excavation is inspected by a suitably qualified and experienced geotechnical engineer during construction.

10 References

1. BGS Geological Map Sheet 256, North London.
2. Ordnance Survey Map, Explorer 173, London North.
3. Arup: Camden Geological, Hydrogeological and Hydrological Study.
4. CPG4: Basements and Lightwells.
5. Redrock Development Group: various proposal drawings
6. Basement Impact Assessment: groundwater, 128 – 130 Grafton Road, NW5 4BA, H Fraser Consulting, 2 April 2019 (DRAFT).
7. Structural Engineer's Construction Method Statement for Planning, 128-130 Grafton Road, NW5 4BA, NP Essex Cons. Co, NP061974
8. CIRIA C760 Guidance on embedded retaining wall design
9. BRE 251 "Assessment of damage in low-rise buildings"

Appendix A – Preliminary Estimates of Ground Movement and Potential Damage Category Assessment

Ground and Project CONSULTANTS LTD

Calculation

Project : Grafton BIA (40213)

Calculation Ref.: 40213/ Calc.1 Rev.0

Prepared By Ollie Hawes

Checked and Approved by: Jon Smithson

Date: 9 July 2019

Preliminary Estimates of Ground Movement and Potential Damage Category Assessment

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Purpose

To estimate the potential ground movements beneath adjacent buildings resulting from construction of the basement. Using these estimates assess the potential for damage to adjacent buildings.

Method

The method is as described in CIRIA C760 "Guidance on embedded retaining wall design"

Damage Categories are assessed as Table 6.4 of CIRIA C760, which are the same as BRE design 251.

Table 6.4 Classification of visible damage to walls (after Burland et al, 1977, Boscardin and Cording, 1989, and Burland, 2001)

Category of damage	Description of typical damage (ease of repair is underlined)	Approximate crack width (mm)	Limiting tensile strain, ε_{lim} (%)
0 Negligible	Hairline cracks of less than about 0.1 mm are classed as negligible	<0.1	0.0 to 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 to 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 to 0.15
3 Moderate	**The cracks require some opening up and can be patched by a mason. Recurrent cracks can be masked by suitable lining. 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 to 15 or a number of cracks >3	0.15 to 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. Services pipes disrupted.	15 to 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 numbers of cracks	

Notes

1 In assessing the degree of damage, account must be taken of its location in the building or structure.

2 Crack width is only one aspect of damage and should not be used on its own as a direct measure of it.

Inputs

1. Proposed building drawings provided by Redrock Development Group: various proposal drawings
2. Existing Buildings, Ground Model described in, "128-130 GRAFTON ROAD, LONDON, NW5 4BA, Basement Impact Assessment", GPCL, July 2019
3. Outline method and sequence of construction as Structural Engineer's Construction Method Statement for Planning, 128-130 Grafton Road, NW5 4BA, NP Essex Cons. Co, NP061974,

Criteria for Acceptability of Movement and Damage

The Structural Engineer's Construction Method Statement sets out the following criteria

"The proposed works to form the basement will be based on a design that limits the movement of the existing structures to 'Category 2' (slight movement) as categorised in table 1 of BRE design 251 and CIRIA report C580." Note that C760 supersedes C580.

Adjacent Building Dimensions Estimate from Google Maps Images below

126 Grafton Road: H=10m, L= 10m, offset from basement wall: 0m

132 Grafton Road H=6m, L=14m, offset from basement wall:0m

Spring Studios, 10 Spring Place (Tall), H=15m, L= 44m, offset from basement wall :5m

Spring Studios, 10 Spring Place (Low), H=3m, L= 49m, offset from basement wall :0m

Calculation Results Summary

The calculations are presented on the attached spreadsheets and summarized in the table below.

Building	Basement Wall Type	Damage Category (Stiff Clay)	Damage Category Sensitivity Check (Soft to Firm Clay)
126 Grafton Road	Underpin and sheet piles	2 Slight	2 Slight
132 Grafton Road	Underpin and sheet piles	2 Slight	2 Slight
10 Spring Place (Tall),	Secant Piles	1 Very Slight	1 Very Slight
10 Spring Place (Low),	Secant Piles	1 Very Slight	1 Very Slight

Conclusion

The anticipated ground movements from basement construction are small and none of the buildings is expected to suffer damage beyond Category 2. This is provided that the basement is constructed in accordance with the Structural Engineer's Construction Method Statement. Amongst other things the assessment relies on the measures stated in the main body of the report to be adopted during the detailed design and construction phase.

Ground and Project CONSULTANTS LTD

Project	Grafton		
Project No.	40213		
Calc Title	Ground Movement for Underpinned Sides Through Stiff Clay		
Date	03 July 2019	**Rev**	0

House Details, Background Data and Assumptions

Calculations based on C760 Pg156 and Figure 6.8 a)

Basement Depth (m)	3.0
Wall Depth (m)	3.0
Adjacent Building 1	126 Grafton Road
Length (m)	10
Height (m)	10
Distance (m)	0
Far Side (m)	10
Adjacent Building 2	132 Grafton Road
Length (m)	14
Height (m)	6
Distance (m)	0
Far Side (m)	14

Movement Calculations for Wall Installation

Horizontal **Distance from wall/wall depth (m)**	**Distance (m)**	**Movement/ Wall Depth (%)**	**Horizontal Movement (mm)**	**Relevance to adjacent properties**
0	0	0.08	2.4	NS
0.1	0.3	0.07	2.1	
0.2	0.6	0.075	2.25	
0.3	0.9	0.06	1.8	
0.4	1.2	0.05	1.5	
0.5	1.5	0.044	1.32	
0.6	1.8	0.04	1.2	
0.7	2.1	0.035	1.05	
0.8	2.4	0.03	0.9	
0.9	2.7	0.2	6	
1	3	0.018	0.54	
1.1	3.3	0.015	0.45	
1.2	3.6	0.012	0.36	
1.3	3.9	0.010	0.3	
1.4	4.2	0.005	0.15	
1.5	4.5	0.000	0	
Vertical **Distance from wall/wall depth (m)**	**Distance (m)**	**Movement/ Wall Depth (%)**	**Vertical Movement (mm)**	**Relevance to adjacent properties**
0	0	0.05	1.5	NS
0.1	0.3	0.048	1.44	
0.2	0.6	0.046	1.38	
0.3	0.9	0.042	1.26	
0.4	1.2	0.04	1.2	
0.5	1.5	0.037	1.11	
0.6	1.8	0.035	1.05	
0.7	2.1	0.032	0.96	
0.8	2.4	0.029	0.87	
0.9	2.7	0.027	0.81	
1	3	0.025	0.75	
1.1	3.3	0.023	0.69	
1.2	3.6	0.02	0.6	
1.3	3.9	0.018	0.54	
1.4	4.2	0.016	0.48	
1.5	4.5	0.014	0.42	
1.6	4.8	0.011	0.33	
1.7	5.1	0.009	0.27	
1.8	5.4	0.007	0.21	
1.9	5.7	0.004	0.12	
2	6	0	0	

Deflection Ratio

	126 Grafton Road	**132 Grafton Road**
Delta	1.5	1.5
dh	2.4	2.4

Ground and Project CONSULTANTS LTD

Project:	Grafton		
Project No.	40213		
Calc Title	Ground Movement for Underpinned Sides Through Stiff Clay		
Date:	03 July 2019	**Rev**	0

Assumptions

Calculations based on C760 Fig. 6.14 b) assume system stiffness =1000, FOS against base heave >3. zero at 3 x excavation depth as Fig. 6.11 a) and b)

High Stiffness	0.0075

Movement Calculations for Excavation

Horizontal **Distance from wall/excavation depth (m)**	**Distance (m)**	**Horizontal Movement/ Wall Depth (%)**	**Horizontal Movement (mm)**	**Relevance to adjacent properties**
0.0	0	0.15	4.5	NS
0.2	0.6	0.1425	4.3	
0.4	1.2	0.135	4.1	
0.6	1.8	0.1275	3.8	
0.8	2.4	0.12	3.6	
1.0	3	0.1125	3.4	
1.2	3.6	0.105	3.2	
1.4	4.2	0.0975	2.9	
1.6	4.8	0.09	2.7	
1.8	5.4	0.0825	2.5	
2.0	6	0.075	2.3	
2.2	6.6	0.0675	2.0	
2.4	7.2	0.06	1.8	
2.6	7.8	0.0525	1.6	
2.8	8.4	0.045	1.4	
3.0	9	0.0375	1.1	
3.2	9.6	0.03	0.9	
3.4	10.2	0.0225	0.7	FS 126
3.6	10.8	0.015	0.4	
3.8	11.4	0.0075	0.2	
4.0	12	0	0.0	
Vertical **Distance from wall/excavation (m) depth**	**Distance (m)**	**Settlement/ Excavation Depth (%)**	**Settlement (mm)**	**Relevance to adjacent properties**
0.0	0	0.04	1.20	NS
0.2	0.6	0.05	1.50	
0.4	1.2	0.07	2.10	
0.6	1.8	0.08	2.40	
0.8	2.4	0.07	2.10	
1.0	3	0.07	2.10	
1.2	3.6	0.06	1.80	
1.4	4.2	0.06	1.80	
1.6	4.8	0.05	1.50	
1.8	5.4	0.04	1.20	
2.0	6	0.035	1.05	
2.2	6.6	0.03	0.90	
2.4	7.2	0.025	0.75	
2.6	7.8	0.02	0.60	
2.8	8.4	0.015	0.45	
3.0	9	0.01	0.30	
3.2	9.6	0.005	0.15	
3.4	10.2	0	0.00	

Deflection Ratio

	126 Grafton Road	**132 Grafton Road**
Delta	2.4	2.4
dh	3.8	4.5

Ground and Project CONSULTANTS LTD

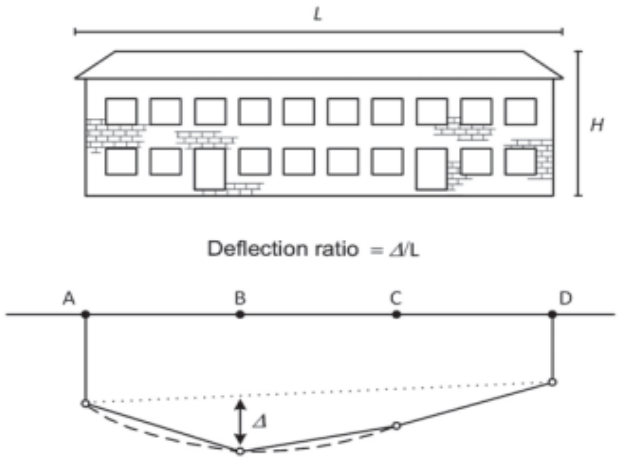
Project:	Grafton		
Project No.	40213		
Calc Title	Ground Movement for Underpinned Sides Through Stiff Clay		
Date:	03 July 2019	**Rev**	0

Combined for Wall Installation and Excavation

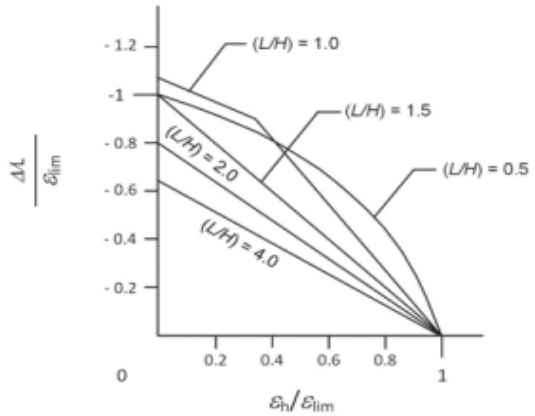
	126 Grafton Road	**132 Grafton Road**
Delta	3.9	3.9
dh	6.2	6.9

Movement Assessment

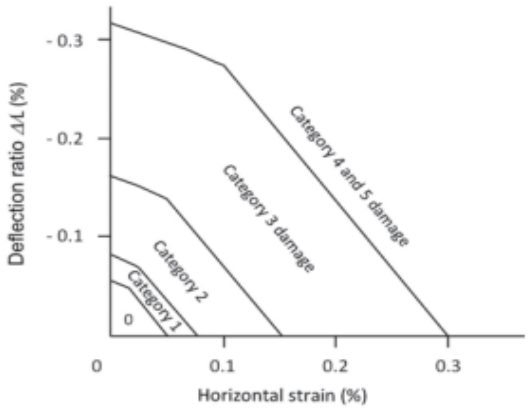
126 Grafton Road			
Horiz Strain (%)	dh/L	0.06	
Deflection Ratio (%)	Delta/L	0.04	
From Graph Fig 6.27©	Damage Category	2 Slight	
From Graph Fig 6.27 (b)	Try elim	0.15	upper limit of damage category Table 6.4
L/H	1.0	Therefore eh/elim	0.4
Reading off Fig 6.27 (b) for closest L/H curve this gives Delta/L/ elim		0.9	
L	10000		
Therefore Delta = L x Reading x elim			
Delta (mm)	13.5		
Delta for combined wall installation and excavation is less :Damage category is confirmed as	Yes - Slight		
132 Grafton Road			
Horiz Strain (%)	dh/L	0.05	
Deflection Ratio (%)	Delta/L	0.03	
From Graph Fig 6.27©	Damage Category	1 V Slight	
From Graph Fig 6.27 (b)	Try elim	0.075	upper limit of damage category Table 6.4
L/H	2.3	Therefore eh/elim	0.7
Reading off Fig 6.27 (b) for closest L/H curve this gives Delta/L/ elim		0.2	
L	14000		
Therefore Delta = L x Reading x elim			
Delta (mm)	2.1		
Delta for combined wall installation and excavation is less : Damage category is confirmed as	No - Slight		



a Definition of deflection ratio



b Influence of horizontal strain on $\Delta/L/\varepsilon_{lim}$



c Relationship between damage category and deflection ratio and horizontal tensile strain for hogging for (*L*/*H*) = 1.0

Note

By adopting values of ε_{lim} associated with various damage categories given in Table 6.4, figure (b) can be developed into an interaction diagram showing the relationship between Δ/L and ε_h for a particular value of *L*/*H* figure (c) shows such a diagram for (*L*/*H*) = 1.0.

Figure 6.27 Relationship between damage category, deflection ratio and horizontal tensile strain (after Burland, 2001)

Ground and Project CONSULTANTS LTD

Project	Grafton		
Project No.	40213		
Calc Title	Ground Movement at Back Side with Secant Piles through Stiff Clay		
Date	03 July 2019	**Rev**	0

House Details, Background Data and Assumptions

Calculations based on C760 Pg156, Figure 6.8 a)

Basement Depth (m)	3.0
Wall Depth (m)	3.0
Adjacent Building 1	Tall 10 Spring Place
Length (m)	44
Height (m)	15
Distance (m)	5
Far Side (m)	49
Adjacent Building 2	Low 10 Spring Place
Length (m)	49
Height (m)	3
Distance (m)	0
Far Side (m)	49

Movement Calculations for Wall Installation

Horizontal Distance from wall/wall depth (m)	Distance (m)	Movement/ Wall Depth (%)	Horizontal Movement (mm)	Relevance to adjacent properties
0.0	0	0.080	2.40	NS Low
0.1	0.3	0.070	2.10	
0.2	0.6	0.075	2.25	
0.3	0.9	0.060	1.80	
0.4	1.2	0.050	1.50	
0.5	1.5	0.044	1.32	
0.6	1.8	0.040	1.20	
0.7	2.1	0.035	1.05	
0.8	2.4	0.030	0.90	
0.9	2.7	0.200	6.00	
1.0	3	0.018	0.54	
1.1	3.3	0.015	0.45	
1.2	3.6	0.012	0.36	
1.3	3.9	0.010	0.30	
1.4	4.2	0.005	0.15	
1.5	4.5	0.000	0.00	
Vertical Distance from wall/wall depth (m)	Distance (m)	Movement/ Wall Depth (%)	Vertical Movement (mm)	Relevance to adjacent properties
0	0	0.05	1.5	NS Low
0.1	0.3	0.048	1.44	
0.2	0.6	0.046	1.38	
0.3	0.9	0.042	1.26	
0.4	1.2	0.04	1.2	
0.5	1.5	0.037	1.11	
0.6	1.8	0.035	1.05	
0.7	2.1	0.032	0.96	
0.8	2.4	0.029	0.87	
0.9	2.7	0.027	0.81	
1	3	0.025	0.75	
1.1	3.3	0.023	0.69	
1.2	3.6	0.020	0.6	
1.3	3.9	0.018	0.54	
1.4	4.2	0.016	0.48	
1.5	4.5	0.014	0.42	
1.6	4.8	0.011	0.33	NS Tall
1.7	5.1	0.009	0.27	
1.8	5.4	0.007	0.21	
1.9	5.7	0.004	0.12	
2	6	0.000	0	

Deflection Ratio

	Tall 10 Spring Place	Low 10 Spring Place
Delta	0.3	1.5
dh	0.0	2.4

Ground and Project CONSULTANTS LTD

Project:	Grafton		
Project No.	40213		
Calc Title	Ground Movement at Back Side with Secant Piles through Soft to Firm Clay		
Date:	03 July 2019	**Rev**	0

Assumptions

Calculations based on C760 Fig. 6.14 b) assume system stiffness =1000, FOS against base heave >3. zero at 3 x excavation depth as Fig. 6.11 a) and b)

High Stiffness	0.0075

Movement Calculations for Excavation

Horizontal **Distance from wall/excavation depth (m)**	**Distance (m)**	**Horizontal Movement/ Wall Depth (%)**	**Horizontal Movement (mm)**	**Relevance to adjacent properties**
0.0	0	0.15	4.5	NS Low
0.2	0.6	0.1425	4.3	
0.4	1.2	0.135	4.1	
0.6	1.8	0.1275	3.8	
0.8	2.4	0.12	3.6	
1.0	3	0.1125	3.4	
1.2	3.6	0.105	3.2	
1.4	4.2	0.0975	2.9	
1.6	4.8	0.09	2.7	NS Tall
1.8	5.4	0.0825	2.5	
2.0	6	0.075	2.3	
2.2	6.6	0.0675	2.0	
2.4	7.2	0.06	1.8	
2.6	7.8	0.0525	1.6	
2.8	8.4	0.045	1.4	
3.0	9	0.0375	1.1	
3.2	9.6	0.03	0.9	
3.4	10.2	0.0225	0.7	
3.6	10.8	0.015	0.4	
3.8	11.4	0.0075	0.2	
4.0	12	0	0.0	
Vertical **Distance from wall/excavation (m) depth**	**Distance (m)**	**Settlement/ Excavation Depth (%)**	**Settlement (mm)**	**Relevance to adjacent properties**
0.0	0	0.04	1.20	NS Low
0.2	0.6	0.05	1.50	
0.4	1.2	0.07	2.10	
0.6	1.8	0.08	2.40	
0.8	2.4	0.07	2.10	
1.0	3	0.07	2.10	
1.2	3.6	0.06	1.80	
1.4	4.2	0.06	1.80	
1.6	4.8	0.05	1.50	NS Tall
1.8	5.4	0.04	1.20	
2.0	6	0.035	1.05	
2.2	6.6	0.03	0.90	
2.4	7.2	0.025	0.75	
2.6	7.8	0.02	0.60	
2.8	8.4	0.015	0.45	
3.0	9	0.01	0.30	

Deflection Ratio

	Tall 10 Spring Place	**Low 10 Spring Place**
Delta	1.2	0.9
dh	2.7	4.5

Ground and Project CONSULTANTS LTD

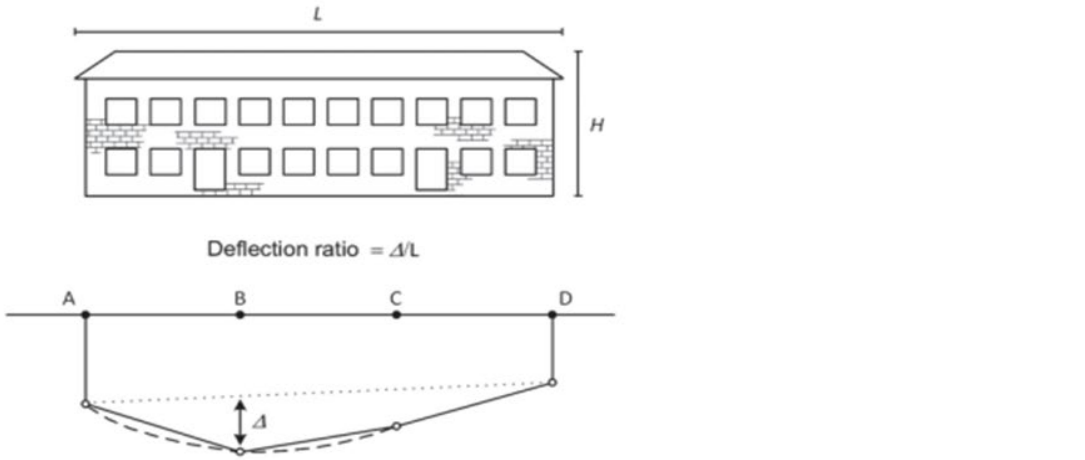
Project:	Grafton		
Project No.	40213		
Calc Title	Ground Movement at Back Side with Secant Piles through Soft to Firm Clay		
Date:	03 July 2019	**Rev**	0

Combined for Wall Installation and Excavation

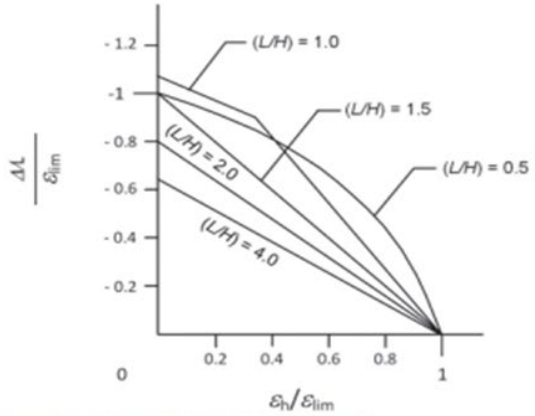
	Tall 10 Spring Place	Low 10 Spring Place
Delta	1.5	2.4
dh	2.7	6.9

Movement Assessment

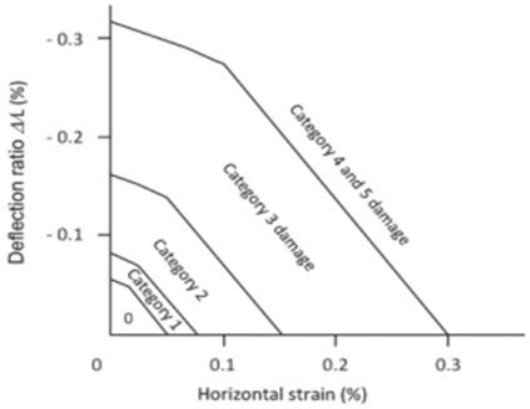
Tall 10 Spring Place			
Horiz Strain (%)	dh/L	0.01	
Deflection Ratio (%)	Delta/L	0.00	
From Graph Fig 6.27©	Damage Category	1 V Slight	
From Graph Fig 6.27 (b)	Try elim	0.075	upper limit of damage category Table 6.4
L/H	2.9	Therefore eh/elim	0.1
Reading off Fig 6.27 (b) for closest L/H curve this gives Delta/L/ elim		0.7	
L	44000		
Therefore Delta = L x Reading x elim			
Delta (mm)	23.1		
Delta for combined wall installation and excavation is less :Damage category is confirmed as	V Slight		
Low 10 Spring Place			
Horiz Strain (%)	dh/L	0.01	
Deflection Ratio (%)	Delta/L	0.00	
From Graph Fig 6.27©	Damage Category	1 V Slight	
From Graph Fig 6.27 (b)	Try elim	0.075	upper limit of damage category Table 6.4
L/H	16.3	Therefore eh/elim	0.2
Reading off Fig 6.27 (b) for closest L/H curve this gives Delta/L/ elim		0.5	
L	49000		
Therefore Delta = L x Reading x elim			
Delta (mm)	18.375		
Delta for combined wall installation and excavation is less : Damage category is confirmed as	V Slight		



a Definition of deflection ratio



b Influence of horizontal strain on $\Delta/L/\varepsilon_{lim}$



c Relationship between damage category and deflection ratio and horizontal tensile strain for hogging for (L/H) = 1.0

Note

By adopting values of ε_{lim} associated with various damage categories given in Table 6.4, figure (b) can be developed into an interaction diagram showing the relationship between Δ/L and ε_h for a particular value of L/H figure (c) shows such a diagram for $(L/H) = 1.0$.

Figure 6.27 Relationship between damage category, deflection ratio and horizontal tensile strain (after Burland, 2001)

Ground and Project CONSULTANTS LTD

Project	Grafton		
Project No.	40213		
Calc Title	Ground Movement for Underpinned Sides Through Soft to Firm Clay		
Date	03 July 2019	**Rev**	0

House Details, Background Data and Assumptions

Calculations based on C760 Pg156, 10mm in 18m depth and zero movement at 1 x wall depth.

Basement Depth (m)	3.0
Wall Depth (m)	3.0
Adjacent Building 1	126 Grafton Road
Length (m)	10
Height (m)	10
Distance (m)	0
Far Side (m)	10
Adjacent Building 2	132 Grafton Road
Length (m)	14
Height (m)	6
Distance (m)	0
Far Side (m)	14

Movement Calculations for Wall Installation

Horizontal **Distance from wall/wall depth (m)**	**Distance (m)**	**Movement/ Wall Depth (%)**	**Horizontal Movement (mm)**	**Relevance to adjacent properties**
0.0	0	0.055	1.65	NS Low
0.2	0.6	0.040	1.20	
0.4	1.2	0.030	0.90	
0.6	1.8	0.020	0.60	
0.8	2.4	0.010	0.30	
1.0	3	0.000	0.00	
Vertical **Distance from wall/wall depth (m)**	**Distance (m)**	**Movement/ Wall Depth (%)**	**Vertical Movement (mm)**	**Relevance to adjacent properties**
0	0	0.055	1.65	NS Low
0.2	0.6	0.04	1.2	
0.4	1.2	0.03	0.9	
0.6	1.8	0.02	0.6	
0.8	2.4	0.01	0.3	
1	3	0	0	

Deflection Ratio

	126 Grafton Road	**132 Grafton Road**
Delta	1.7	1.7
dh	1.7	1.7

Ground and Project CONSULTANTS LTD

Project:	Grafton		
Project No.	40213		
Calc Title	Ground Movement for Underpinned Sides Through Soft to Firm Clay		
Date:	03 July 2019	**Rev**	0

Assumptions

Calculations based on C760 Fig. 6.14 b) assume system stiffness =1000, FOS against base heave >3. zero at 3 x excavation depth as Fig. 6.11 a) and b)

High Stiffness	0.0075

Movement Calculations for Excavation

Horizontal **Distance from wall/excavation depth (m)**	**Distance (m)**	**Horizontal Movement/ Wall Depth (%)**	**Horizontal Movement (mm)**	**Relevance to adjacent properties**
0.0	0	0.2	6.0	NS Low
0.2	0.6	0.1425	4.3	
0.4	1.2	0.135	4.1	
0.6	1.8	0.1275	3.8	
0.8	2.4	0.12	3.6	
1.0	3	0.1125	3.4	
1.2	3.6	0.105	3.2	
1.4	4.2	0.0975	2.9	
1.6	4.8	0.09	2.7	NS Tall
1.8	5.4	0.0825	2.5	
2.0	6	0.075	2.3	
2.2	6.6	0.0675	2.0	
2.4	7.2	0.06	1.8	
2.6	7.8	0.0525	1.6	
2.8	8.4	0.045	1.4	
3.0	9	0	0.0	
Vertical **Distance from wall/excavation (m) depth**	**Distance (m)**	**Settlement/ Excavation Depth (%)**	**Settlement (mm)**	**Relevance to adjacent properties**
0.0	0	0.2	6.00	NS Low
0.2	0.6	0.1425	4.28	
0.4	1.2	0.135	4.05	
0.6	1.8	0.1275	3.83	
0.8	2.4	0.12	3.60	
1.0	3	0.1125	3.38	
1.2	3.6	0.105	3.15	
1.4	4.2	0.0975	2.93	
1.6	4.8	0.09	2.70	NS Tall
1.8	5.4	0.0825	2.48	
2.0	6	0.075	2.25	
2.2	6.6	0.0675	2.03	
2.4	7.2	0.06	1.80	
2.6	7.8	0.0525	1.58	
2.8	8.4	0.045	1.35	
3.0	9	0	0.00	

Deflection Ratio

	126 Grafton Road	**132 Grafton Road**
Delta	6.0	6.0
dh	6.0	6.0

Ground and Project CONSULTANTS LTD

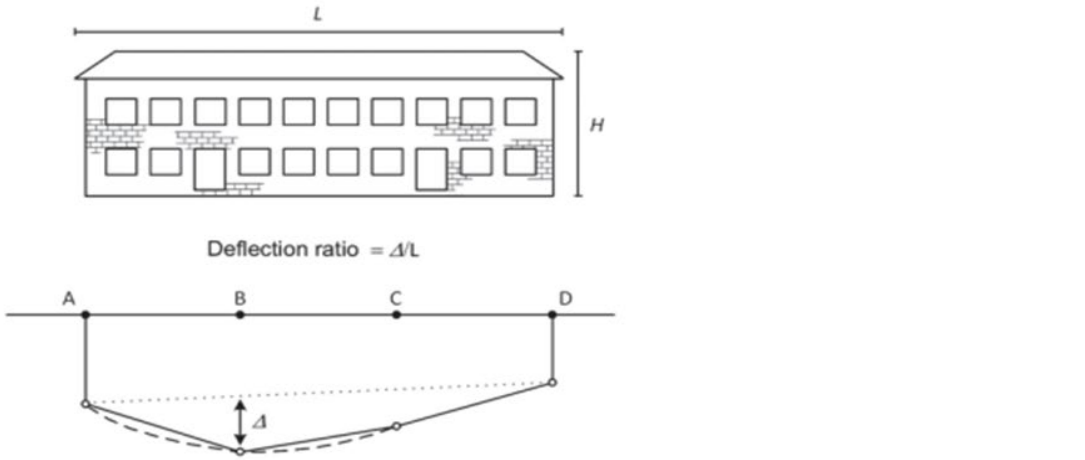
Project:	Grafton		
Project No.	40213		
Calc Title	Ground Movement for Underpinned Sides Through Soft to Firm Clay		
Date:	03 July 2019	**Rev**	0

Combined for Wall Installation and Excavation

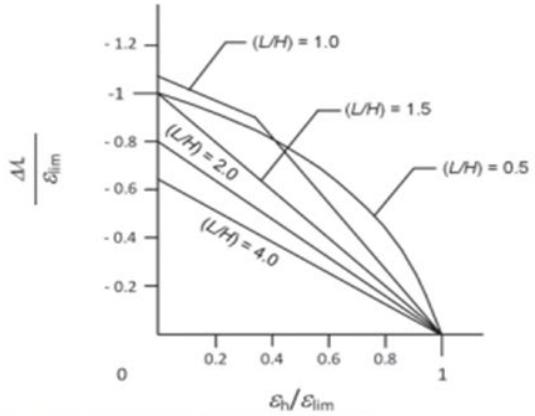
	126 Grafton Road	**132 Grafton Road**
Delta	7.7	7.7
dh	7.7	7.7

Movement Assessment

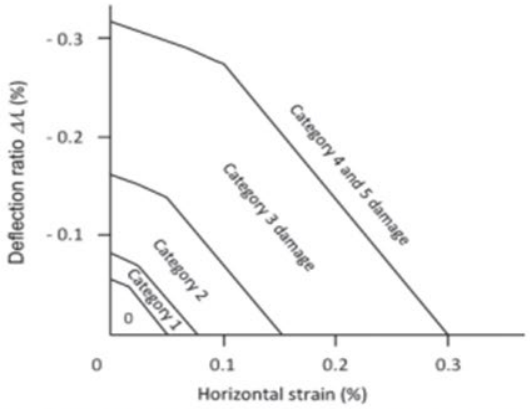
126 Grafton Road			
Horiz Strain (%)	dh/L	0.08	
Deflection Ratio (%)	Delta/L	0.08	
From Graph Fig 6.27©	Damage Category	2 Slight	
From Graph Fig 6.27 (b)	Try elim	0.15	upper limit of damage category Table 6.4
L/H	1.0	Therefore eh/elim	0.5
Reading off Fig 6.27 (b) for closest L/H curve this gives Delta/L/ elim		0.7	
L	10000		
Therefore Delta = L x Reading x elim			
Delta (mm)	10.5		
Delta for combined wall installation and excavation is less :Damage category is confirmed as	Yes - Slight		
132 Grafton Road			
Horiz Strain (%)	dh/L	0.05	
Deflection Ratio (%)	Delta/L	0.05	
From Graph Fig 6.27©	Damage Category	2 Slight	
From Graph Fig 6.27 (b)	Try elim	0.15	upper limit of damage category Table 6.4
L/H	2.3	Therefore eh/elim	0.4
Reading off Fig 6.27 (b) for closest L/H curve this gives Delta/L/ elim		0.5	
L	14000		
Therefore Delta = L x Reading x elim			
Delta (mm)	10.5		
Delta for combined wall installation and excavation is less : Damage category is confirmed as	Yes - Slight		



a Definition of deflection ratio



b Influence of horizontal strain on $\Delta/L/\varepsilon_{lim}$



c Relationship between damage category and deflection ratio and horizontal tensile strain for hogging for (L/H) = 1.0

Note

By adopting values of ε_{lim} associated with various damage categories given in Table 6.4, figure (b) can be developed into an interaction diagram showing the relationship between Δ/L and ε_h for a particular value of L/H figure (c) shows such a diagram for $(L/H) = 1.0$.

Figure 6.27 Relationship between damage category, deflection ratio and horizontal tensile strain (after Burland, 2001)

Ground and Project CONSULTANTS LTD

Project	Grafton		
Project No.	40213		
Calc Title	Ground Movement at Back Side with Secant Piles through Soft to Firm Clay		
Date	03 July 2019	**Rev**	0

House Details, Background Data and Assumptions

Calculations based on C760 Pg155, assuming 10mm in 18m depth and zero movement at 1 x wall depth.

Basement Depth (m)	3.0
Wall Depth (m)	3.0
Adjacent Building 1	Tall 10 Spring Place
Length (m)	44
Height (m)	15
Distance (m)	5
Far Side (m)	49
Adjacent Building 2	Low 10 Spring Place
Length (m)	49
Height (m)	3
Distance (m)	0
Far Side (m)	49

Movement Calculations for Wall Installation

Horizontal **Distance from wall/wall depth (m)**	**Distance (m)**	**Movement/ Wall Depth (%)**	**Horizontal Movement (mm)**	**Relevance to adjacent properties**
0.0	0	0.055	1.65	NS Low
0.2	0.6	0.040	1.20	
0.4	1.2	0.030	0.90	
0.6	1.8	0.020	0.60	
0.8	2.4	0.010	0.30	
1.0	3	0.000	0.00	
Vertical **Distance from wall/wall depth (m)**	**Distance (m)**	**Movement/ Wall Depth (%)**	**Vertical Movement (mm)**	**Relevance to adjacent properties**
0.0	0.0	0.055	1.7	NS Low
0.2	0.6	0.040	1.2	
0.4	1.2	0.030	0.9	
0.6	1.8	0.020	0.6	
0.8	2.4	0.010	0.3	
1.0	3.0	0.000	0.0	

Deflection Ratio

	Tall 10 Spring Place	**Low 10 Spring Place**
Delta	0.0	1.7
dh	0.0	1.7

Ground and Project CONSULTANTS LTD

Project:	Grafton		
Project No.	40213		
Calc Title	Ground Movement at Back Side with Secant Piles through Soft to Firm Clay		
Date:	03 July 2019	**Rev**	0

Assumptions

Calculations based on C760 Fig. 6.14 b) assume system stiffness =1000, FOS against base heave >3. zero at 3 x excavation depth as Fig. 6.11 a) and b)

High Stiffness	0.0075

Movement Calculations for Excavation

Horizontal **Distance from wall/excavation depth (m)**	**Distance (m)**	**Horizontal Movement/ Wall Depth (%)**	**Horizontal Movement (mm)**	**Relevance to adjacent properties**
0.0	0	0.2	6.0	NS Low
0.2	0.6	0.1425	4.3	
0.4	1.2	0.135	4.1	
0.6	1.8	0.1275	3.8	
0.8	2.4	0.12	3.6	
1.0	3	0.1125	3.4	
1.2	3.6	0.105	3.2	
1.4	4.2	0.0975	2.9	
1.6	4.8	0.09	2.7	NS Tall
1.8	5.4	0.0825	2.5	
2.0	6	0.075	2.3	
2.2	6.6	0.0675	2.0	
2.4	7.2	0.06	1.8	
2.6	7.8	0.0525	1.6	
2.8	8.4	0.045	1.4	
3.0	9	0	0.0	
Vertical **Distance from wall/excavation (m) depth**	**Distance (m)**	**Settlement/ Excavation Depth (%)**	**Settlement (mm)**	**Relevance to adjacent properties**
0.0	0	0.2	6.00	NS Low
0.2	0.6	0.1425	4.28	
0.4	1.2	0.135	4.05	
0.6	1.8	0.1275	3.83	
0.8	2.4	0.12	3.60	
1.0	3	0.1125	3.38	
1.2	3.6	0.105	3.15	
1.4	4.2	0.0975	2.93	
1.6	4.8	0.09	2.70	NS Tall
1.8	5.4	0.0825	2.48	
2.0	6	0.075	2.25	
2.2	6.6	0.0675	2.03	
2.4	7.2	0.06	1.80	
2.6	7.8	0.0525	1.58	
2.8	8.4	0.045	1.35	
3.0	9	0	0.00	

Deflection Ratio

	Tall 10 Spring Place	**Low 10 Spring Place**
Delta	2.7	6.0
dh	2.7	6.0

Ground and Project CONSULTANTS LTD

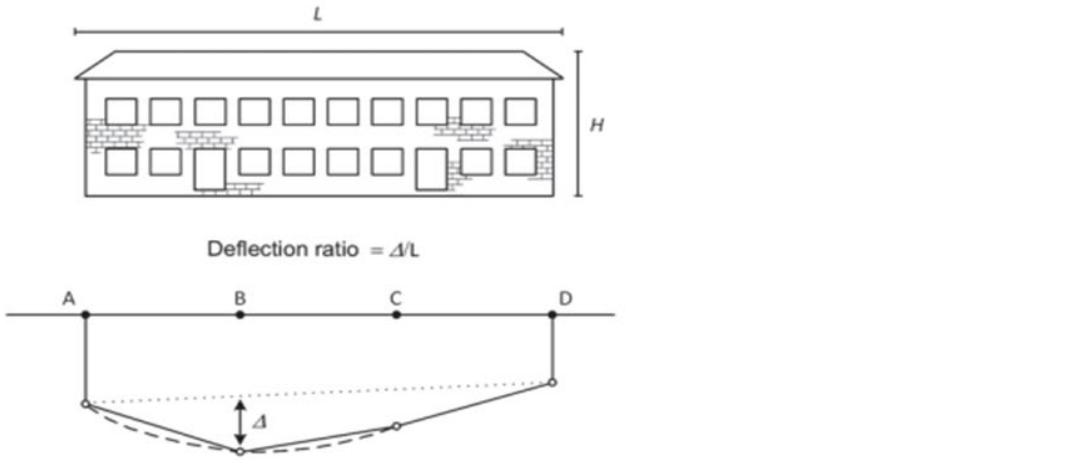
Project:	Grafton		
Project No.	40213		
Calc Title	Ground Movement at Back Side with Secant Piles through Soft to Firm Clay		
Date:	03 July 2019	**Rev**	0

Combined for Wall Installation and Excavation

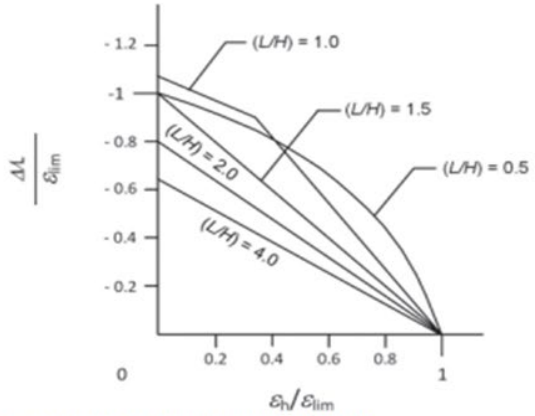
	Tall 10 Spring Place	Low 10 Spring Place
Delta	2.7	7.7
dh	2.7	7.7

Movement Assessment

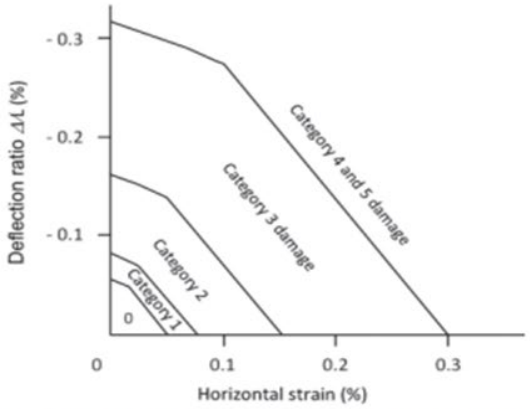
Tall 10 Spring Place			
Horiz Strain (%)	dh/L	0.01	
Deflection Ratio (%)	Delta/L	0.01	
From Graph Fig 6.27©	Damage Category	1 V Slight	
From Graph Fig 6.27 (b)	Try elim	0.075	upper limit of damage category Table 6.4
L/H	2.9	Therefore eh/elim	0.1
Reading off Fig 6.27 (b) for closest L/H curve this gives Delta/L/ elim		0.7	
L	44000		
Therefore Delta = L x Reading x elim			
Delta (mm)	23.1		
Delta for combined wall installation and excavation is less :Damage category is confirmed as	V Slight		
Low 10 Spring Place			
Horiz Strain (%)	dh/L	0.02	
Deflection Ratio (%)	Delta/L	0.02	
From Graph Fig 6.27©	Damage Category	1 V Slight	
From Graph Fig 6.27 (b)	Try elim	0.075	upper limit of damage category Table 6.4
L/H	16.3	Therefore eh/elim	0.2
Reading off Fig 6.27 (b) for closest L/H curve this gives Delta/L/ elim		0.5	
L	49000		
Therefore Delta = L x Reading x elim			
Delta (mm)	18.375		
Delta for combined wall installation and excavation is less : Damage category is confirmed as	V Slight		



a Definition of deflection ratio



b Influence of horizontal strain on $\Delta/L/\varepsilon_{lim}$



c Relationship between damage category and deflection ratio and horizontal tensile strain for hogging for (L/H) = 1.0

Note

By adopting values of ε_{lim} associated with various damage categories given in Table 6.4, figure (b) can be developed into an interaction diagram showing the relationship between Δ/L and ε_h for a particular value of L/H figure (c) shows such a diagram for $(L/H) = 1.0$.

Figure 6.27 Relationship between damage category, deflection ratio and horizontal tensile strain (after Burland, 2001)