GROUND MOVEMENT ANALYSIS REPORT

for the site at

38 GLENLOCH ROAD, CAMDEN LONDON NW3 4DN

on behalf of

NW3 PROPERTIES

Report Reference: GWPR2718/GIR/August 2018		Status: FINAL
Issue:	Prepared By:	Verified By:
V1.00 August 2018		
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File Reference: Ground and Water/Project Files/ GWPR2718 38 Glenloch Road, London N1 8JQ		

CONTENTS

FIGURES

APPENDICES

1.0 INTRODUCTION

1.1 General

Ground and Water Limited were instructed by NW3 Properties on the 11th July 2018 to undertake a Ground Movement Assessment at 38 Glenloch Road, London N1 8JQ. The scope of the investigation was detailed within the email between the client and Ground and Water Limited, dated 12th July 2018.

1.2 Aims of the Investigation

The aim of the investigation was understood to be to supply the client and their designers with information regarding the ground conditions underlying the site to assist them in preparing an appropriate scheme for development.

The investigation was to be undertaken to provide the client with a **Ground Movement Analysis, as a supplement to the Ground Investigation Report and Basement Impact Assessment prepared by Jomas Associates Ltd, referenced P1207J1245, dated in January 2018** and the **Construction Methodology Statement in Support of Planning Application, December 2017 Rev. P1, prepared by Rob Markovits, Ref. 172904.**

This Ground Movement Analysis report should be read in conjunction with the Ground Investigation Report, Basement Impact Assessment and Construction Methodology Statement (CMS).

A full scale Desk Study, intrusive ground investigation and full scale geotechnical or contamination assessment were not part of the remit of this report. The findings of the GI-BIA report, relevant to the Ground Movement Analysis are however discussed and assessed in this report.

1.3 Conditions and Limitations

This report has been prepared based on the terms, conditions and limitations outlined within Appendix A.

This report was based on the following documents. Total reliance has been placed on these reports and no liability can be taken for their short comings.

- Desk Study, Ground Investigation & Basement Impact Assessment Report, prepared by Jonas Associates Limited, January 2018, referenced P1207J1245.
- Construction Methodology Statement in Support of Planning Application, December 2017 Rev. P1, prepared by Rob Markovits, Ref. 172904.

This Ground Movement Analysis report should be read in conjunction with these documents.

2.0 SITE SETTING

2.1 Site Location

The site comprised a 0.01ha rectangular shaped plot of land, oriented in a north-west to south-east direction, located on the north-western side of Glenloch Road, ~15m north-east of its junction with Tudor Close. The site was located within the London Borough of Camden, north London.

The approximate National Grid Reference for the site was TQ 27173 84967. A site location plan is provided within Figure 1. A plan showing the site development area is given within Figure 2.

2.2 Site Description

The site currently consists of an unoccupied residential building, in terrace-arrangement, with a rear garden. The property contained an existing lower ground floor / basement beneath part of the building, to a depth of approximately ~3.00m bgl.

An aerial view of the site showing an approximate site boundary is given in Figure 3. An existing plan and section view of the site can be seen in Figures 4 and 5.

2.3 Proposed Development

At the time of reporting, August 2018, the proposed development was understood to comprise the extension of the lower ground floor, to form a single storey basement, demolition of the rear load bearing masonry, extension of the rear ground floor and some alterations to the existing interior design. The basement is going to be formed to an approximate total depth of 3.50m bgl (front and rear).

A plan and a section view of the proposed development are shown in Figures 6 and 7.

2.4 Geology

The BGS Geological Map for the area (North London Sheet No. 256 Solid and Drift 1:50,000) indicated that the site was underlain by bedrock deposits of the London Clay Formation. No areas of Made Ground were noted within 250m of the site.

A BGS borehole located ~228m north-west of the site revealed Made Ground to a depth of ~1.22m bgl, overlying clay for the remaining depth of the borehole, a depth of ~6.10m bgl.

London Clay Formation

The London Clay Formation comprises stiff grey fissured clay, weathering to brown near surface. Concretions of argillaceous limestone in nodular form (Claystones) occur throughout the formation. Crystals of gypsum (Selenite) are often found within the weathered part of the London Clay Formation, and precautions against sulphate attack to concrete are sometimes required. The lowest part of the formation is a sandy bed with black rounded gravel and occasional layers of sandstone and is known as the Basement Bed.

2.5 Slope Stability and Subterranean Developments

The building was situated within an area where slope instability problems were unlikely to be present. According to the report prepared by Jomas Associates Ltd, no special actions are required to avoid problems due to landslides. No special ground investigation are required, and increased construction costs or increased financial risks are unlikely due to potential problems with landslides.

The LUL Northern Line runs approximately 200m to the East of the site. As these were not within a close proximity the client was not required to advise London Underground asset protection department to check alignments and agreed works will not affect any existing tunnels or access shafts. No other underground structures, tunnels or vaults are expected near the proposed works.

2.6 Hydrogeology and Hydrology

A study of the aquifer maps on the DEFRA website and information within the report prepared by Jomas Associates Ltd revealed the site to be located on **Unproductive Strata**, associated with the bedrock deposits of the London Clay Formation. No designation was given for superficial deposits due to their likely absence.

Superficial (Drift) deposits are permeable unconsolidated (loose) deposits, for example, sands and gravels. The bedrock is described as solid permeable formations e.g. sandstone, chalk and limestone.

Unproductive Strata are rock layers with low permeability that have negligible significance for water supply or river base flow. These were formerly classified as non-aquifers.

Examination within the DEFRA website showed that the site did **not** fall within a Groundwater Source Protection Zone as classified in the Policy and Practice for the Protection of Groundwater.

A culvert was recorded to be present 27m east of the site. This culvert channels surface waters draining from the Hampstead Ponds, located 1km north of the site, to the River Thames, located ~ 6km south of the site.

The nearest visible surface water feature comprised a pond, located within Hampstead Heath, ~800m north of the site.

From analysis of hydrogeological and topographical maps, groundwater was anticipated to be encountered at depth (>6.00m below existing ground level (bgl)) and it was considered that the groundwater was flowing in a south / south easterly direction, in alignment with local topography. Isolated pockets of groundwater may be perched within any Made Ground, confined by the London Clay Formation, encountered beneath the site.

Examination of Environment Agency records demonstrates that the site was situated within a **Flood Zone 1**, i.e. an area with low probability of flooding from rivers and sea. In addition, the RoFRAS rate was Very Low, based on the report prepared by Jomas Associates Ltd.

2.7 Radon

BRE 211 (2015) Map 5 of the London, Sussex and west Kent area indicated that the site **was not** located within an area where mandatory protection measures against the ingress of radon were likely to be required. A risk assessment was not required.

2.8 Review of the Desk Study, Ground Investigation & Basement Impact Assessment Report prepared by Jomas Associates Limited, January 2018.

A brief review of the findings of the Desk Study, Ground Investigation & Basement Impact Assessment Report prepared by Jomas Associates Limited, January 2018 is carried out in this section, **with a focus predominantly on the geotechnical parts of concern for the Ground Movement Analysis.**

Summarising the historical mapping review in terms of features and development that have occurred suggested the site was undeveloped land, located within the Belsize Park area in 1871. By 1915, a residential building has been built on site and Glenloch Road has been constructed. No significant changes have occurred on site to the present day.

The surrounding area has been in use almost exclusively for residential properties, with the only significant industrial use being a garage 200m north of site, shown on maps dating 1951 - 1989.

Summary of the important additional features within the Desk Study and Screening of the report prepared by Jomas Associates Limited, relevant to this report

- The site was not within the catchment of the pond chains of Hampstead Heath.

- The proposed development is to extend an existing basement. The new basement will extend out under an existing rear external space which is covered entirely by hard surfacing (paving slabs).

- There is no reason to believe that more water than at present will be or could be discharged to the ground.

- No surface water features were present within 250m of site.

- A stepped slope will be constructed at the rear of the basement, stepping up to existing ground levels at the rear. However, it is assumed that the design of the stepped slope will take into account the risks of failure associated with the construction of the basement.

- No trees will be felled as part of this development and it is not considered likely that works will be undertaken in any root protection zones.

- The site is directly underlain by the London Clay Formation. The site is reported to be in area at moderate risk from shrink-swell clays. No evidence of structural stress caused by seasonal shrink swell was noted during the walkover.

- A culvert is present ~27m east of the site.

- The basement will extend into Unproductive strata, and it is therefore unlikely that a high groundwater table will be present. Some perched water might be encountered.

- It is likely that the basement foundations will increase the differential depth of foundations relative to neighbouring properties however this is dependent on the type and depth of foundations used at the neighbouring properties and this is currently unknown.

  The site was attached to terraced three-storey housing to the east and west of the site. A site walkover was carried out by Ground and Water Ltd. Based on information gathered so far, it was considered that no basement (or at least basement covering the full footprint of the building) was present within 40 Glenloch Road. A lower ground floor was present within 36 Glenloch Road (Light well). Based on similar potential construction with the existing partial basement however, it was considered highly unlikely that this would cover the entire plot. In conclusion, a maximum differential depth of ~3.50m is expected to be created in most areas of the plots of concern.

In addition, based on the CMS, the party walls are to be underpinned in order to accommodate the full proposed basement. This also comprises the worst case scenario for the Ground Movement Analysis.

Results of the Intrusive Ground Investigation

The site works were undertaken on the 14th November 2017 and comprised the drilling of 1No. Windowless Sampler Borehole to a depth of 5.45m bgl and 4No. hand excavated trial pits (TP1 – TP3, TP4a, TP4b) / foundation exposures to depths of between 0.74 - 1.65m bgl / bbl.

A combined ground gas / groundwater monitoring well was installed within WS2, to a depth of 5.00m bgl.

Foundation Exposures – Ground Conditions

TP1 was excavated in the west corner of the basement. The pit was extended to 0.85m bbl (metres below basement level), exposing four brick "steps" of 0.05m width each. The first step was measured to 0.43m depth; the remaining steps stepped down depths of between 0.07m and 0.09m. A fifth step of concrete stepped out 0.15m and was proven as the base of the foundation at 0.85mbbl. The footing was resting on soils of the London Clay Formation, described as soft to firm light brown clay.

TP2 was excavated inside the west corner of the rear room of the building an extended to 1.65mbgl. No step out was observed but the brick wall was followed down to the base of the pit. No natural ground was proved in this pit. The ground conditions comprised laminate floor boards to 0.05m bgl over Made Ground, described as soft to firm light brown sandy gravelly clay. The gravel was abundant, fine to coarse, sub-angular to angular flint, brick and concrete.

TP3 was formed in the rear hallway on the northern side of the house. The base of the foundation was found at 0.95mbgl, with the foundations found to be of brickwork to 0.80mbgl over a concrete base that stepped out by 0.14m. Concrete was recorded to 0.30m bgl, overlying Made Ground, which comprised a light brown gravelly clay. The gravel was abundant, fine to coarse, sub-angular to angular flint, brick and concrete.

TP4a was formed at the rear of the house along a garden wall and adjacent to the building. The exposed garden wall footing was recorded as a 1.30mbgl of brick over concrete. The concrete stepped out to at least 0.16m but the base was not proven. TP4b was formed at the rear of the house along a garden wall and adjacent to the building. The exposed building foundations were recorded as a 0.62mbgl of brick over concrete. The concrete stepped out by 0.02m but the base could not be proven. Laminate floors over concrete were recorded to 0.06m bgl, underlain by Made Ground to 0.60m bgl. The Made Ground comprised soft to firm light brown gravelly clay. The gravel was frequent, fine to coarse, sub-angular to angular brick, flint and concrete. Soils, most likely comprising Made Ground was recorded below, for the remaining depth of the pit, a depth of 1.25m bgl. The soils comprised a firm to stiff light brown clay with rootlets, over pink to brown clayey slightly gravelly sand. The sand was coarse grained with fine to medium angular clinker fragments.

Windowless Sampler Borehole – Ground Conditions

Made Ground

A paving slab over reinforced concrete were recorded in WS2, from ground level to a depth of 0.20m bgl. Soils described as Made Ground were recorded below, comprising light brown low strength gravelly clay. The gravel was frequent, fine to coarse, sub-angular to angular flint, brick and concrete.

London Clay Formation
Soils described as representative of the London Clay Formation were recorded from 1.30m bgl, for the remaining depth of the borehole, a depth of 5.45m bgl. The soils were described as a light brown with blue veins clay.

Groundwater
No groundwater was recorded during the ground investigation. Four return monitoring visits were carried out. Groundwater in WS2 was recorded, at depths of between 2.42 – 4.16m bgl during three of the visits and dry during one visit.

The report also mentioned that given the recorded geology and the lack of groundwater reported during drilling, it was likely that the water levels recorded during monitoring did not represent a true groundwater level, and it was more likely due to surface water ingress into the well.

Geotechnical In-Situ Testing
Standard Penetration Tests were carried out within WS2, at 1m intervals. An SPT N value of 6 was recorded within the Made Ground. SPT N values of between 6 – 12 were recorded within the soils of the London Clay Formation, resulting to low to medium equivalent undrained shear strengths (Cu), (30 – 60 kPa).

It should be noted that an SPT N value of 6 was recorded at 1.00 – 1.45m bgl, with the London Clay Formation encountered at 1.30m bgl, increasing to 10 from 2.00m bgl. Therefore, the low N value was considered to be representative for both the Made Ground and the shallower soils of the London Clay Formation until 2.00m bgl.

Geotechnical Laboratory Testing
Atterberg Limit Tests were carried out within samples of the Made Ground and the London Clay Formation. A modified Plasticity Index of 33.92%, indicating a medium volume change potential, was recorded within the sample of Made Ground tested.

Modified Plasticity Indices of between 37.20% – 59.00% were recorded within the samples of the London Clay Formation tested, indicating a Medium to High volume change potential in accordance with NHBC Chapter 4.2 and BRE240 Standards.

Consistency Index calculations carried out by Ground and Water Ltd, based on the geotechnical laboratory results of the ground investigation, indicated the soils to be stiff (Consistency Indices between 0.83 – 0.92).

Foundation Recommendations
The ground investigation report suggested a bearing capacity of ~90kPa at depths of ~3.00 – 3.50m bgl. It was not part of the remit of this report to comment additionally on ground conditions and foundation recommendations.

Geological Impact
At the depths that the basement would be constructed at the London Clay is unlikely to be prone to

seasonal shrinkage and swelling that arises due to changing water content in the soil. This is due to a lack of significant vegetation capable of removing water within the zone of influence; the extensive hard cover minimising the amount of water entering the ground and the lack of proven groundwater. Given the recorded geology and the lack of groundwater reported during drilling it is likely that the water levels recorded during monitoring does not represent a true groundwater level, and it likely due to surface water ingress into the well.

Hydrology and Hydrogeology Impact
The risk of flooding from groundwater was considered to be low. The proposed basement was unlikely to have a detectable impact on the local groundwater regime. Appropriate water proofing measures should be included within the whole of the proposed basement wall/floor design as a precaution.

The information available suggested that the site lies in an area that is not at risk of surface water flooding. Flooding via this source is therefore considered to be low.

Impact of Basement on adjacent Properties and Pavement
The report mentioned that unavoidable lateral ground movements associated with the basement excavations must be controlled during temporary and permanent works so as not to impact adversely on the stability of the surrounding ground, any associated services and structures. It is recommended that the site is supported by suitably designed temporary support. This will ensure that the adjacent land is adequately supported in the temporary and permanent construction. Alternatively, the excavation should proceed in a manner that maintains the integrity of the ground on all sides.

The Basement Impact Assessment report stated that it would be necessary to ensure that the basements are designed in accordance with the NHBC Standards and take due cognisance of the potential impacts highlighted above. This may be achieved by ensuring best practice engineering and design of the proposed scheme by competent persons and in full accordance with the Construction (Design and Management) Regulations.

A ground movement analysis is undertaken by Ground and Water Limited within the following sections, in order to supplement and further assess the basement impact on the neighbouring properties.

3.0 GROUND MOVEMENT ANALYSIS

3.1 Assessment of Ground Movement

At the time of reporting, August 2018, the proposed development was understood to comprise the extension of the lower ground floor, to form a single storey basement, demolition of the rear load bearing masonry, extension of the rear ground floor and some alterations to the existing interior design. The new basement is going to be formed to an approximate total depth of 3.50m bgl. (front and rear).

The basement will consist of reinforced concrete cantilevering retaining walls. These will be designed to resist the lateral loads around the perimeter of the basement. The basement floor structure will comprise a reinforced concrete slab. The retaining walls will also mainly transfer vertical loads to the ground.

According to CIRIA C760 estimating ground movements in the vicinity of excavations is very complex due to the variety of factors involved. It is also mentioned that ground movements around the excavation can be controlled and minimised by adopting specific measures, which are discussed at the end of this section.

Ground movements can be approximated using available monitoring data presented within CIRIA Report C760 in conjunction with engineering judgement.

CIRIA C760 states that it is not possible to distinguish between walls embedded in competent (stiff) ground retaining some soft and firm clays from those wholly embedded in soft to firm clays from research to date. However, the totality of the data provides an upper bound to observed experience which the vast majority of ground movements will fall into, including soft clays and alluvium. Therefore, using engineering judgement, we have produced design lines based on a conservative, moderate and actual case in firm clays.

The site was attached to terraced three-storey housing to the east and west of the site. A site walkover was carried out. Based on information gathered so far, it was considered that no basement (or at least basement covering the full footprint of the building) was present within 40 Glenloch Road. A lower ground floor was present within 36 Glenloch Road (Light well). Based on similar potential construction with the existing partial basement however, it was considered highly unlikely that this would cover the entire plot. In conclusion, a maximum differential depth of ~3.50m is expected to be created in most areas of the plots of concern.

Based on the maximum depth of excavation, structures within a ~12.2m (vertical movements) - ~14m (horizontal movements) radius of the proposed basement were considered likely to be influenced by the proposed development.

Parameters of Surrounding Properties			
Property	Approximate Distance to Closest Wall (m)	Approximate Length (m)	Approximate Height (m) (Based on the excavation depth measurement points and ground level)
40 Glenloch Road	0.00	7.30	12.00
36 Glenloch Road	0.00	7.30	12.00
34 Glenloch Road	7.30	6.40	12.00

- The magnitude of ground movements has been assessed for the excavation of the underpinned retaining wall structure.
- It is important to note that CIRIA Reports C580/760 were written for embedded retaining walls. Therefore, movement calculations for the excavation of soil and installation of the underpinnings does not strictly apply to C580/760.

The following parameters have been used to inform this assessment:

- The maximum differential basement excavation depth is approximately ~3.50m bgl (front and rear)
- The method of basement construction will be underpinning;
- A high wall stiffness has been considered;
- In the permanent case the wall will always be propped at high level;
- The assessed buildings were estimated to be ~12.0m high based on ground level and the maximum excavation depth.
- Soils comprising Made Ground, over a firm clay has been proved.
- Analysis has been undertaken using soft to firm clays, for conservatism.

Based on reference to CIRIA Report C760 the following ground movements have been developed based on of the excavation of soils to form the basement.

Ground Movement Analysis (Soft to Firm Clay)							
Property	Approx. Horizontal Ground Movement at Closest Wall (mm)	Approx. Horizontal Ground Movement at Furthest Wall (mm)	Horizontal Strain (%)	Approx. Vertical Ground Movement at Closest Wall (mm)	Approx. Vertical Ground Movement at Furthest Wall (mm)	Vertical Deflection Ratio (%)	Category of Damage
Conservative Line							
40 Glenloch Road	5.25	2.51	0.03750	8.75	3.50	0.109589	Slight
36 Glenloch Road	5.25	2.51	0.03750	8.75	3.50	0.109589	Slight
34 Glenloch Road	2.51	0.11	0.03750	3.50	0.00	0.025	Negligible
Moderate Line							
40 Glenloch Road	5.25	2.51	0.03750	5.60	3.50	0.054795	Very Slight
36 Glenloch Road	5.25	2.51	0.03750	5.60	3.50	0.054795	Very Slight
34 Glenloch Road	2.51	0.11	0.03750	3.50	0.00	0.023438	Negligible
Realistic Line							
40 Glenloch Road	5.25	2.51	0.03750	3.50	1.75	0.041096	Very Slight
36 Glenloch Road	5.25	2.51	0.03750	3.50	1.75	0.041096	Very Slight
34 Glenloch Road	2.51	0.11	0.03750	1.75	0.00	0.015625	Negligible

The Ground Movement Spreadsheets and Calculations can be seen within Appendix B. Figures of the graphs used for the analysis can be seen in Figure 8.

In terms of building damage assessment and with reference to Table 2.5 of CIRIA Report C580 (after Burland et al, 1977), the 'Description of typical damage' given the calculated movements it is likely that the damage assessment will fall into Category 2, 'Slight' (for a conservative assessment, which is not likely to occur), to Category 0, 'Negligible'. For moderate and realistic situations, the damage assessment fell within Category 1 'Very Slight' to Category 0 'Negligible'. Calculations for the potential damage at each property can be seen within Appendix B.

Contour plots showing the horizontal and vertical ground movement due to the construction of the basement can be seen within Figures 9 - 10.

- **The size of the developments used to provide the case histories for C580/760 are significantly greater than the scale of works proposed. In practice, the range of ground movements (relative to the excavation depth and the building dimensions) is therefore likely to be much smaller for this development.**

- **CIRIA Report C760 strongly advises that ground movements are influenced by the quality of workmanship. The party wall act will apply to this development and will reinforce good workmanship. The act provides an effective mechanism for ensuring that structural integrity of the neighbouring properties is maintained throughout the construction phase. Amongst other procedures, monitoring proposals will ensure that the actual wall movements are controlled and kept within acceptable limits.**

Underpinning is understood to involve a 'hit and miss' approach in stages so each 'panel' is separated by 3-5 others from the next open one. It will be important that the building contractor is closely supervised and is experienced in this type of construction. It will be critical to prevent exposed faces from collapse or significant ground loss into the new excavation and temporary face support should be maintained where practicable. The nature and presence of basements/cellars in the adjoining properties is not known at this stage. Most ground movement should occur during excavation of the basement and construction so the adequacy of temporary support will be critical in limiting ground movements. A number of factors will assist in limiting ground movements:

- Most ground movement will occur during excavation and construction so the adequacy of temporary support will be critical in limiting ground movements;
- The speed of propping and support is key to limiting ground movements;
- Good workmanship will contribute to minimising ground movements
    - Ensuring that adequate propping is in place at all times during construction;
    - Minimise deterioration of the central soil mass by the use of blinding/covering with a waterproof membrane;
    - Installation of the first (stiff) support quickly and early in the construction sequence for each underpin panel;
    - Control dewatering to minimise fines removal and drawdown;
    - Avoid overbreak.
    - Avoid leaving ground unsupported.

APPENDIX A
Conditions and Limitations

The ground is a product of continuing natural and artificial processes. As a result, the ground will exhibit a variety of characteristics that vary from place to place across a site, and also with time. Whilst a ground investigation will mitigate to a greater or lesser degree against the resulting risk from variation, the risks cannot be eliminated.

The report has been prepared on the basis of information, data and materials which were available at the time of writing. Accordingly any conclusions, opinions or judgements made in the report should not be regarded as definitive or relied upon to the exclusion of other information, opinions and judgements.

The investigation, interpretations, and recommendations given in this report were prepared for the sole benefit of the client in accordance with their brief; as such these do not necessarily address all aspects of ground behaviour at the site. No liability is accepted for any reliance placed on it by others unless specifically agreed in writing.

Any decisions made by you, or by any organisation, agency or person who has read, received or been provided with information contained in the report ("you" or "the Recipient") are decisions of the Recipient and we will not make, or be deemed to make, any decisions on behalf of any Recipient. We will not be liable for the consequences of any such decisions.

Current regulations and good practice were used in the preparation of this report. An appropriately qualified person must review the recommendations given in this report at the time of preparation of the scheme design to ensure that any recommendations given remain valid in light of changes in regulation and practice, or additional information obtained regarding the site.

Any Recipient must take into account any other factors apart from the Report of which they and their experts and advisers are or should be aware. The information, data, conclusions, opinions and judgements set out in the report may relate to certain contexts and may not be suitable in other contexts. It is your responsibility to ensure that you do not use the information we provide in the wrong context.

This report is based on readily available geological records, the recorded physical investigation, the strata observed in the works, together with the results of completed site and laboratory tests. Whilst skill and care has been taken to interpret these conditions likely between or below investigation points, the possibility of other characteristics not revealed cannot be discounted, for which no liability can be accepted. The impact of our assessment on other aspects of the development required evaluation by other involved parties.

The opinions expressed cannot be absolute due to the limitations of time and resources within the context of the agreed brief and the possibility of unrecorded previous in ground activities. The ground conditions have been sampled or monitored in recorded locations and tests for some of the more common chemicals generally expected. Other concentrations of types of chemicals may exist. It was not part of the scope of this report to comment on environment/contaminated land considerations.

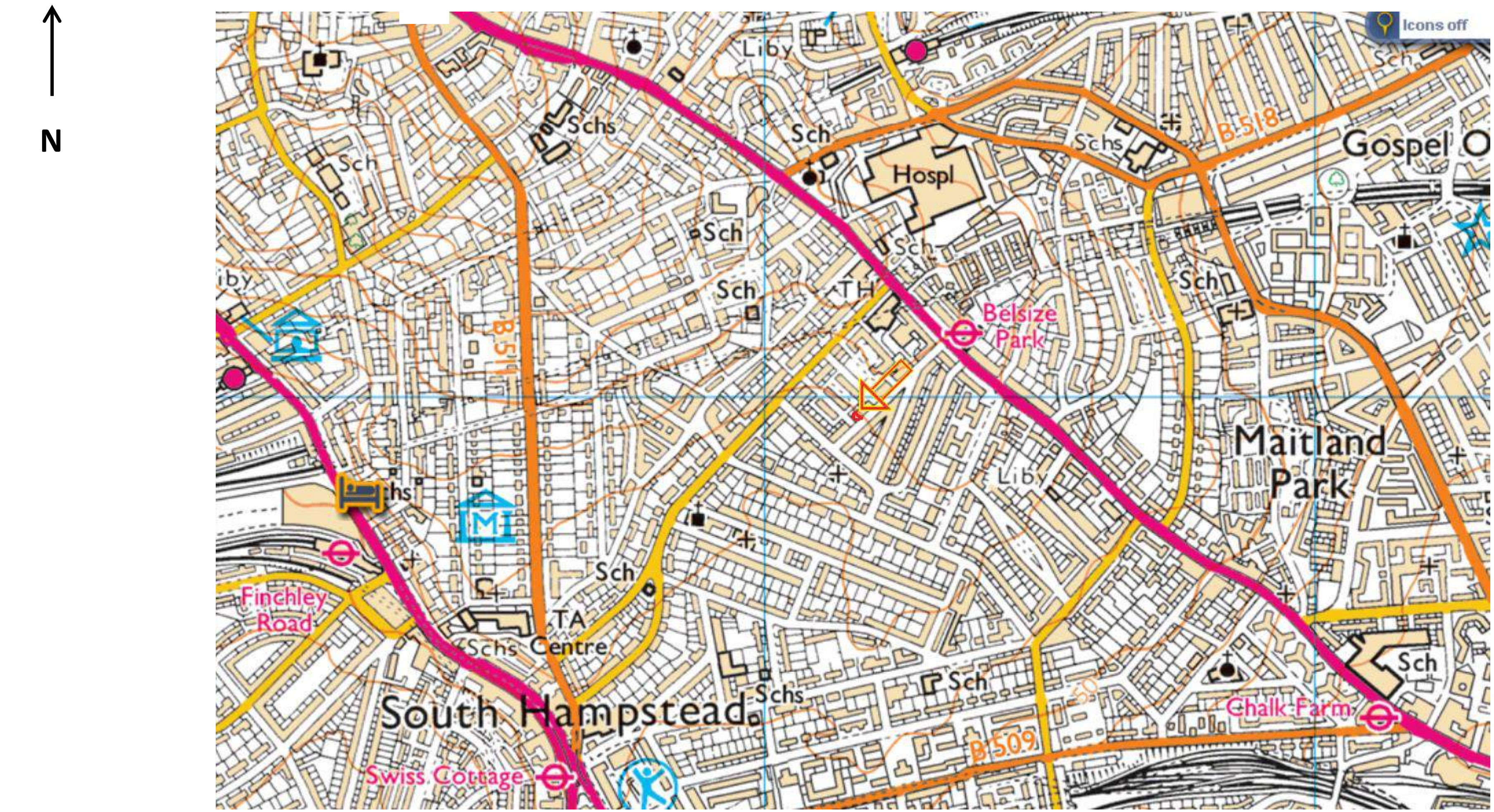
The conclusions and recommendations relate to 38 Glenloch Road, Camden NW3 4DN.

Trial hole is a generic term used to describe a method of direct investigation. The term trial pit, borehole or window sampler borehole implies the specific technique used to produce a trial hole.

The depth to roots and/or of desiccation may vary from that found during the investigation. The client is responsible for establishing the depth to roots and/or of desiccation on a plot-by-plot basis prior to the construction of foundations. Where trees are mentioned in the text this means existing trees, recently removed trees (approximately 15 years to full recovery on cohesive soils) and those planned as part of the site landscaping.

Only our client may rely on this report and should this report or any information contained in it be provided to any third party we accept no responsibility to the third party for the contents of this report save to the extent expressly outlined by us in writing in a reliance letter addressed from us to the third party.

Recipients are not permitted to publish this report outside of their organisation without our express written consent.



APPROXIMATE SITE BOUNDARY

NOT TO SCALE

Project: 38 Glenloch Road, Camden NW3 4DN		**Figure 1**
Client: NW3 Properties	**Date:** August 2018	ground&water
Site Location Plan	**Ref:** GWPR2718	

N

APPROXIMATE SITE BOUNDARY

NOT TO SCALE

Project: 38 Glenloch Road, Camden NW3 4DN		**Figure 2**
Client: NW3 Properties	**Date:** August 2018	ground&water
Site Development Area	**Ref:** GWPR2718	

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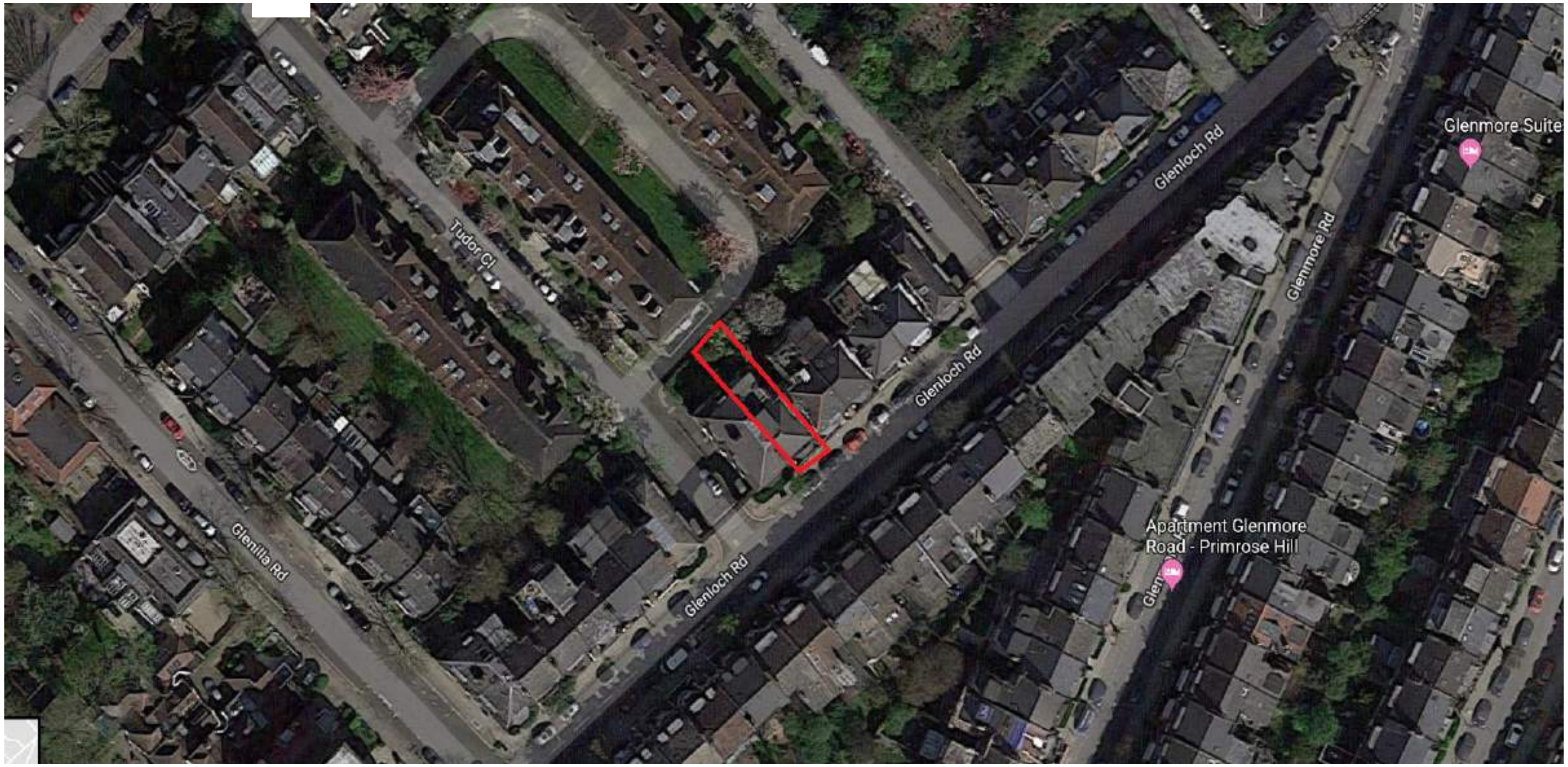
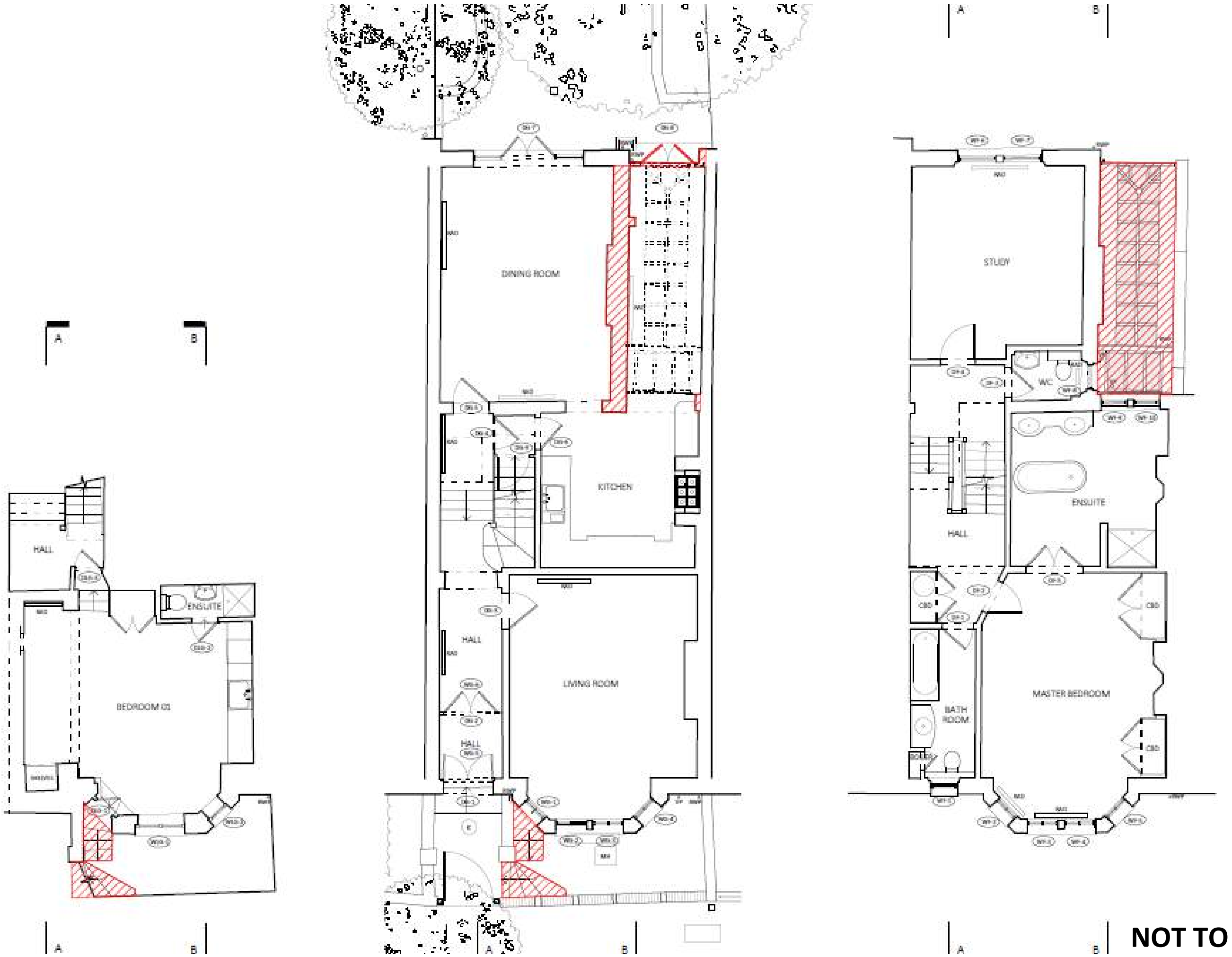


APPROXIMATE SITE BOUNDARY

NOT TO SCALE

Project: 38 Glenloch Road, Camden NW3 4DN		Figure 3
Client: NW3 Properties	Date: August 2018	ground&water
Aerial View of Site	Ref: GWPR2718	



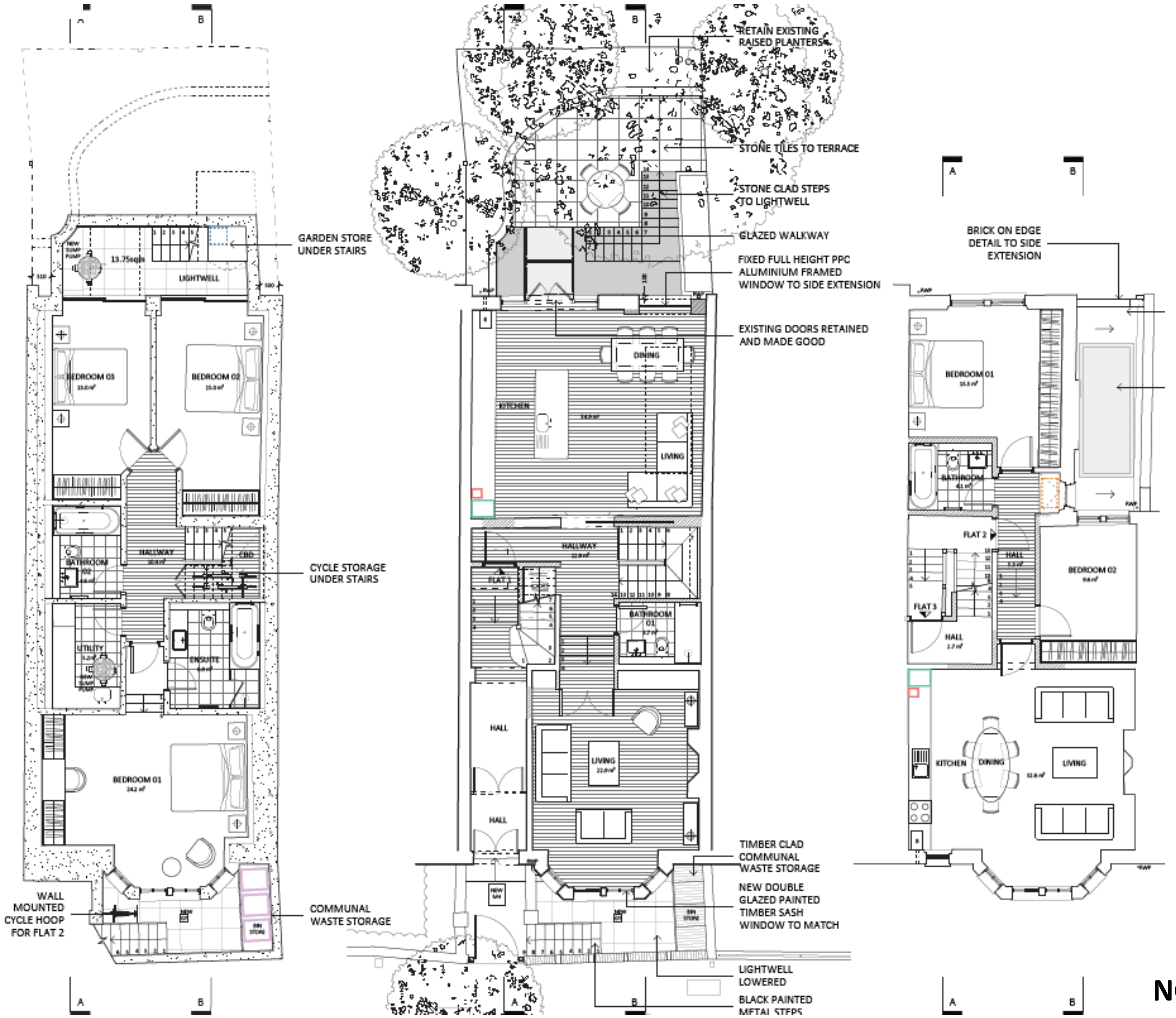
Project: 38 Glenloch Road, Camden NW3 4DN		**Figure 4**
Client: NW3 Properties	**Date:** August 2018	ground&water
Existing Development - Plan View	**Ref:** GWPR2718	

SECTION B-B

SECTION A-A

NOT TO SCALE

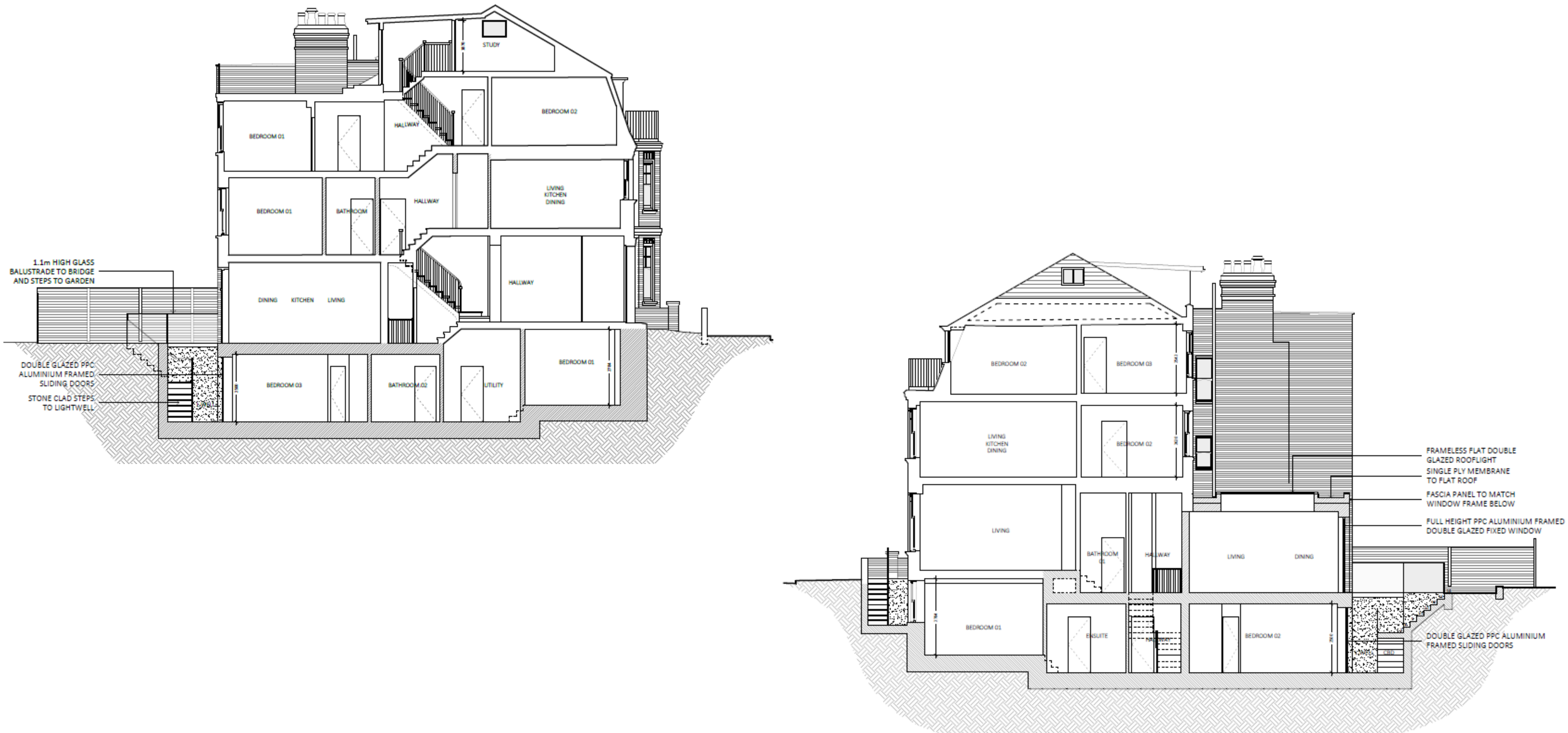
Project: 38 Glenloch Road, Camden NW3 4DN	**Figure 5**
Client: NW3 Properties — **Date:** August 2018	ground&water
Existing Development - Section View — **Ref:** GWPR2718	



NOT TO SCALE

Project: 38 Glenloch Road, Camden NW3 4DN	**Figure 6**
Client: NW3 Properties	**Date:** August 2018
Proposed Development – Plan View	**Ref:** GWPR2718

ground&water

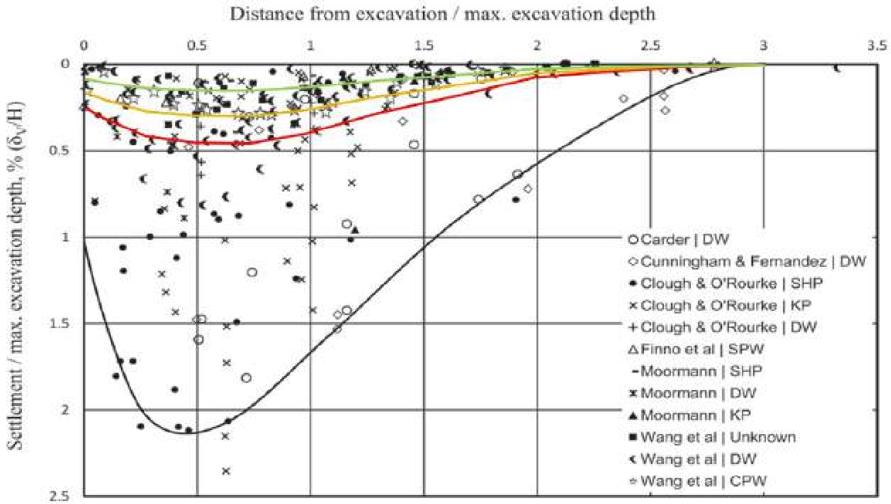


SECTION B-B

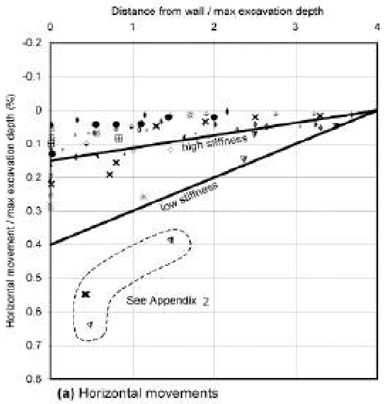
Project: 38 Glenloch Road, Camden NW3 4DN	**Figure 7**
Client: NW3 Properties — **Date:** August 2018	ground&water
Proposed Development – Section View — **Ref:** GWPR2718	

Max Excavation Depth 3.5

Property	Distance	Distance/Max Excavation Depth	Settlement / Max Excavation Depth (%) Read off graph: Conservative	Moderate	Realistic	Settlement (m): Conservative	Moderate	Realistic	Settlement (mm): Conservative	Moderate	Realistic	Horizontal Movement: Distance/Max Excavation Depth	%	(mm)
	0	0	0.25	0.16	0.1	0.00875	0.0056	0.0035	8.75	5.6	3.5	0	0.15	5.25
	1.825	0.521428571	0.45	0.25	0.17	0.01575	0.00875	0.00595	15.75	8.75	5.95	0.521428571	0.130446	4.56563
	3.65	1.042857143	0.36	0.24	0.16	0.0126	0.0084	0.0056	12.6	8.4	5.6	1.042857143	0.110893	3.88125
	5.475	1.564285714	0.19	0.15	0.11	0.00665	0.00525	0.00385	6.65	5.25	3.85	1.564285714	0.091339	3.19688
40	7.3	2.085714286	0.1	0.1	0.05	0.0035	0.0035	0.00175	3.5	3.5	1.75	2.085714286	0.071786	2.5125
	0	0	0.25	0.16	0.1	0.00875	0.0056	0.0035	8.75	5.6	3.5	0	0.15	5.25
	1.825	0.521428571	0.45	0.25	0.17	0.01575	0.00875	0.00595	15.75	8.75	5.95	0.521428571	0.130446	4.56563
	3.65	1.042857143	0.36	0.24	0.16	0.0126	0.0084	0.0056	12.6	8.4	5.6	1.042857143	0.110893	3.88125
	5.475	1.564285714	0.19	0.15	0.11	0.00665	0.00525	0.00385	6.65	5.25	3.85	1.564285714	0.091339	3.19688
36	7.3	2.085714286	0.1	0.1	0.05	0.0035	0.0035	0.00175	3.5	3.5	1.75	2.085714286	0.071786	2.5125
	7.3	2.085714286	0.1	0.1	0.05	0.0035	0.0035	0.00175	3.5	3.5	1.75	2.085714286	0.071786	2.5125
	8.9	2.542857143	0.1	0.05	0	0.0035	0.00175	0	3.5	1.75	0	2.542857143	0.054643	1.9125
	10.5	3	0	0	0	0	0	0	0	0	0	3	0.0375	1.3125
	12.1	3.457142857	0	0	0	0	0	0	0	0	0	3.457142857	0.020357	0.7125
34	13.7	3.914285714	0	0	0	0	0	0	0	0	0	3.914285714	0.003214	0.1125



a Normalised settlements due to excavation in soft to firm clay

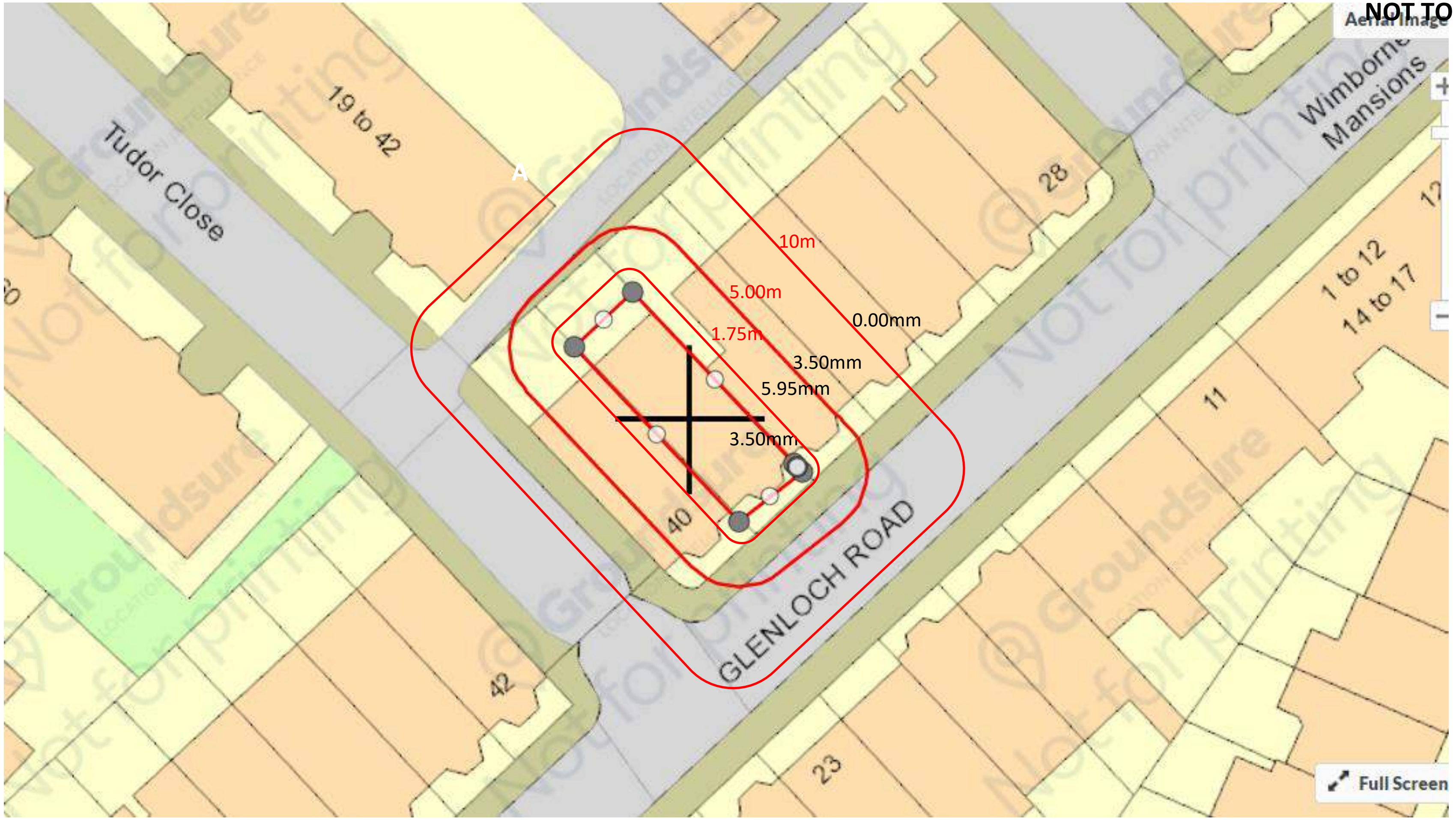


CIRIA C760 does not cover Horizontal Movements for soft - firm clays.
Therefore, these were derived from stiff clay results.

Project: 38 Glenloch Road, Camden NW3 4DN	**Figure 8**
Client: NW3 Properties	**Date:** August 2018
Vertical and Horizontal Ground Movements due to excavation in Soft – Firm Clay	**Ref:** GWPR2718

ground&water

NOT TO SCALE



APPROXIMATE SITE BOUNDARY

Project: 38 Glenloch Road, Camden, London NW3 4DN	**Figure 9**
Client: NW3 Properties — **Date:** August 2018	ground&water
Vertical Ground Movement – Contour Plot Soft to Firm Clay - Realistic — **Ref:** GWPR2718	

NOT TO SCALE

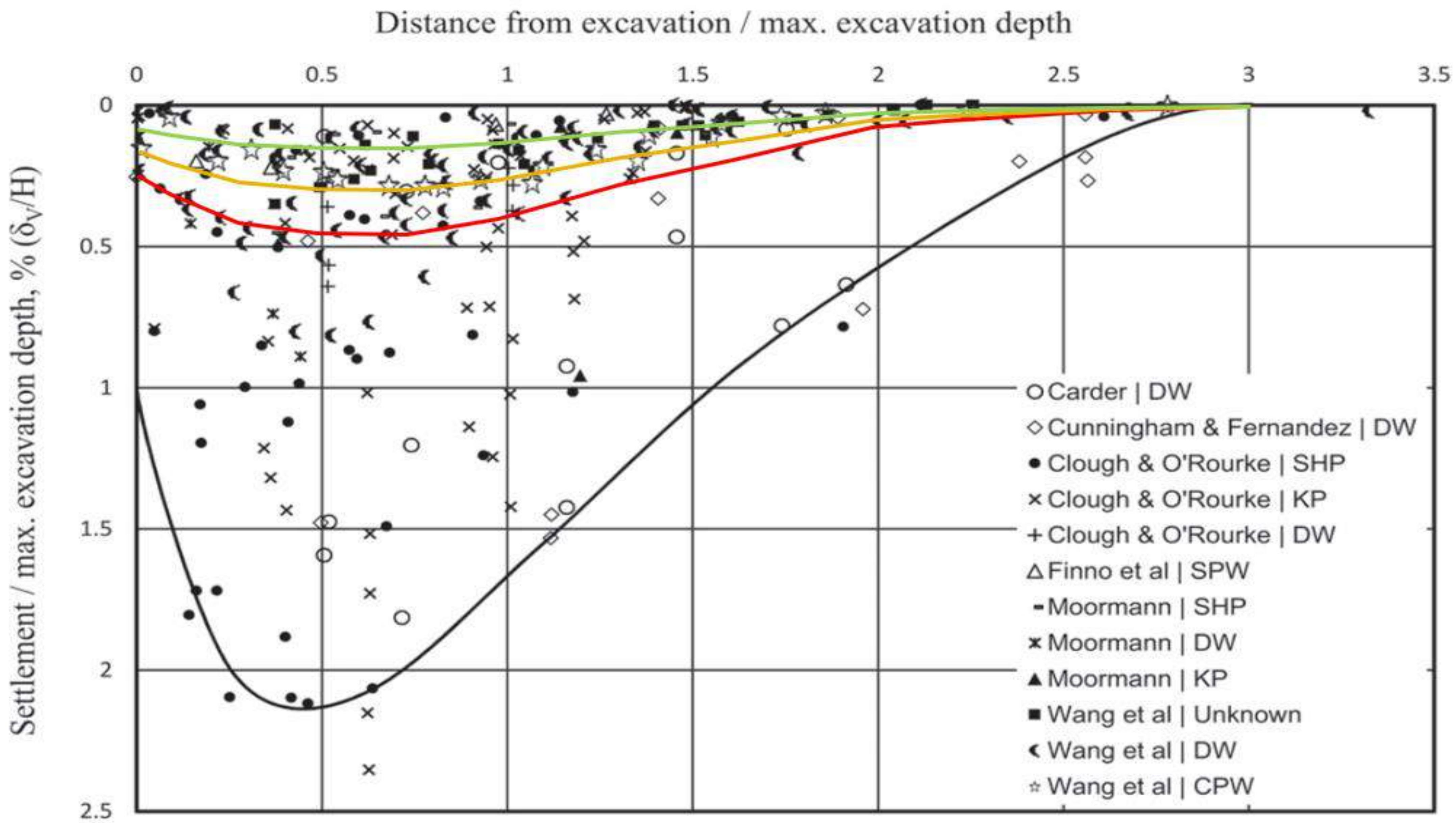
APPROXIMATE SITE BOUNDARY

Project: 38 Glenloch Road, Camden, London NW3 4DN		**Figure 10**
Client: NW3 Properties	**Date:** August 2018	ground&water
Horizontal Ground Movement – Contour Plot **Soft to Firm Clay - Realistic**	**Ref:** GWPR2718	

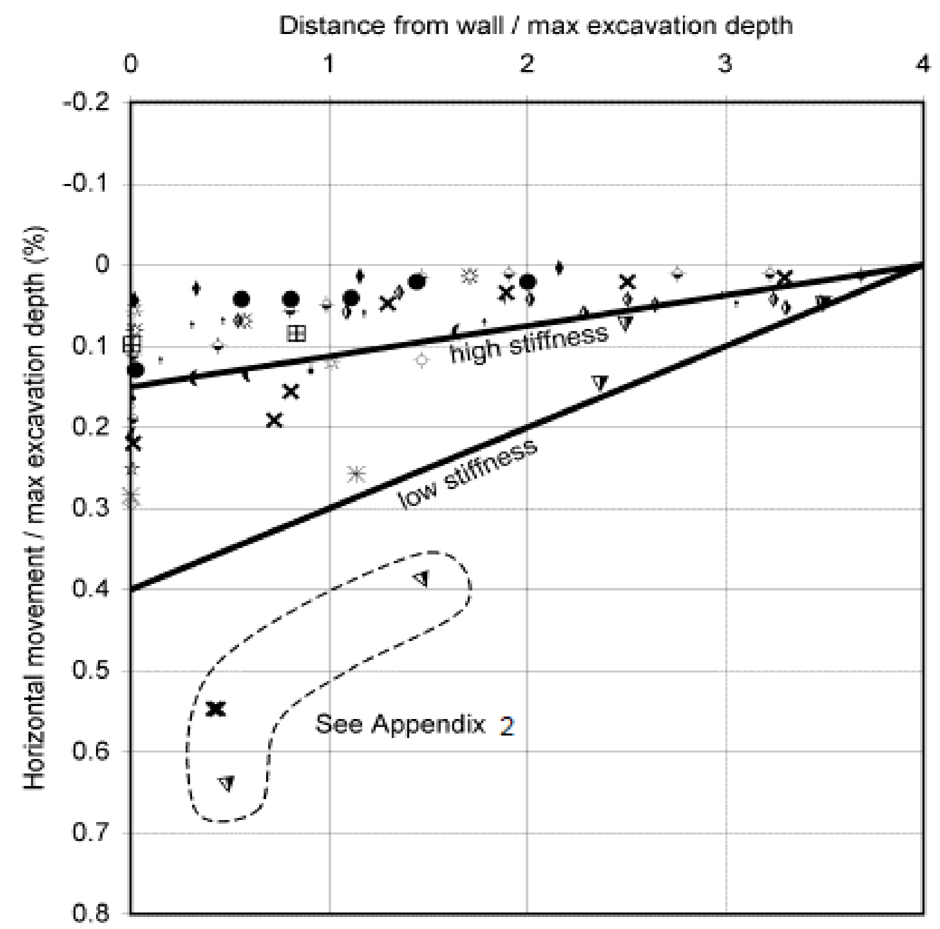
APPENDIX B
Ground Movement Assessment Calculations

Max Excavation Depth 3.5

Property	Distance	Distance/Max Excavation Depth	Settlement / Max Excavation Depth (%) Read off graph: Conservative	Moderate	Realistic	Settlement (m): Conservative	Moderate	Realistic	Settlement (mm): Conservative	Moderate	Realistic	Horizontal Movement: Distance/Max Excavation Depth	%	(mm)
	0	0	0.25	0.16	0.1	0.00875	0.0056	0.0035	8.75	5.6	3.5	0	0.15	5.25
	1.825	0.521428571	0.45	0.25	0.17	0.01575	0.00875	0.00595	15.75	8.75	5.95	0.521428571	0.130446	4.56563
	3.65	1.042857143	0.36	0.24	0.16	0.0126	0.0084	0.0056	12.6	8.4	5.6	1.042857143	0.110893	3.88125
	5.475	1.564285714	0.19	0.15	0.11	0.00665	0.00525	0.00385	6.65	5.25	3.85	1.564285714	0.091339	3.19688
40	7.3	2.085714286	0.1	0.1	0.05	0.0035	0.0035	0.00175	3.5	3.5	1.75	2.085714286	0.071786	2.5125
	0	0	0.25	0.16	0.1	0.00875	0.0056	0.0035	8.75	5.6	3.5	0	0.15	5.25
	1.825	0.521428571	0.45	0.25	0.17	0.01575	0.00875	0.00595	15.75	8.75	5.95	0.521428571	0.130446	4.56563
	3.65	1.042857143	0.36	0.24	0.16	0.0126	0.0084	0.0056	12.6	8.4	5.6	1.042857143	0.110893	3.88125
	5.475	1.564285714	0.19	0.15	0.11	0.00665	0.00525	0.00385	6.65	5.25	3.85	1.564285714	0.091339	3.19688
36	7.3	2.085714286	0.1	0.1	0.05	0.0035	0.0035	0.00175	3.5	3.5	1.75	2.085714286	0.071786	2.5125
	7.3	2.085714286	0.1	0.1	0.05	0.0035	0.0035	0.00175	3.5	3.5	1.75	2.085714286	0.071786	2.5125
	8.9	2.542857143	0.1	0.05	0	0.0035	0.00175	0	3.5	1.75	0	2.542857143	0.054643	1.9125
	10.5	3	0	0	0	0	0	0	0	0	0	3	0.0375	1.3125
	12.1	3.457142857	0	0	0	0	0	0	0	0	0	3.457142857	0.020357	0.7125
34	13.7	3.914285714	0	0	0	0	0	0	0	0	0	3.914285714	0.003214	0.1125



a Normalised settlements due to excavation in soft to firm clay

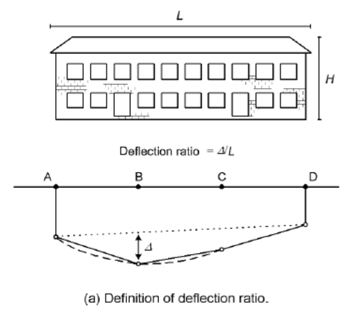


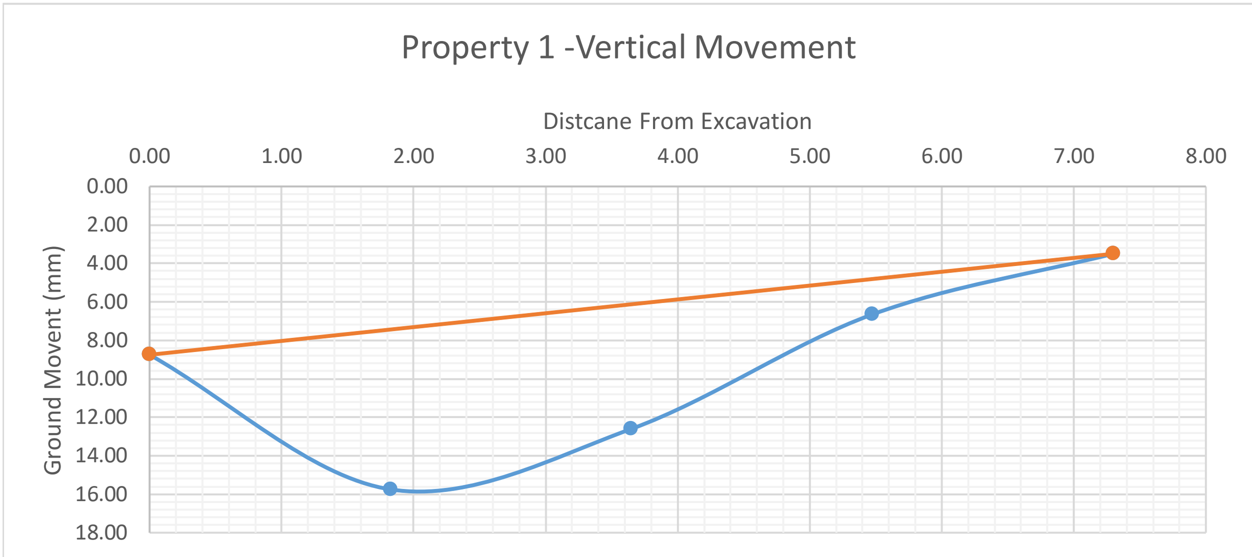
(a) Horizontal movements

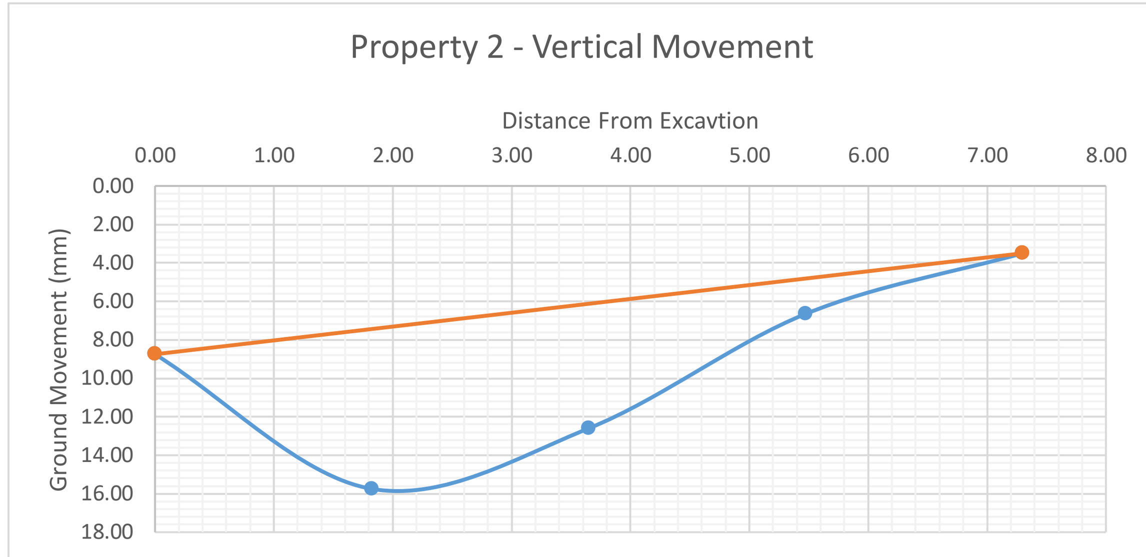
CIRIA C760 does not cover Horizontal Movements for soft - firm clays.
Therefore, these were derived from stiff clay results.

Potential Damage to Building

Soft to firm clays - Conservative







Neighbouring Property 1 No. 40

	m	mm
L	7.30	7300
H	12.00	12000
L/H	0.61	

Verticle Deflection (Δ)	8	mm	from graph (max difference between blue and orange line)
Defelction Ratio (Δ/L)	0.109589	%	
Horizontal Movement (δh)	2.74	mm	difference between horizontal movement at nearest and farthest walls
Horzontal Strain (Ɛh) = δh/L	0.03750	%	

Neighbouring Property 2 No. 36

	m	mm
L	7.30	7300
H	12.00	12000
L/H	0.61	

Verticle Deflection (Δ)	8	mm	from graph (max difference between blue and orange line)
Defelction Ratio (Δ/L)	0.109589	%	
Horizontal Movement (δh)	2.74		difference between horizontal movement at nearest and farthest walls
Horzontal Strain (Ɛh) = δh/L	0.03750	%	

CATEGORY OF DAMAGE Damage category limits are given in Table 2.5 (below) you will also need Fig 2.18 (also shown below).

Property 1:

L/H	0.61	
Negligible damage limit (Ɛlim)	**0.05**	
(Δ/L)/(Ɛlim)	2.191780822	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'negligible' category - no need to plot points
(Ɛh)/(Ɛlim)	0.75	
Very Slight damage limit (Ɛlim)	**0.075**	
(Δ/L)/(Ɛlim)	1.461187215	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'very slight' category - no need to plot points
(Ɛh)/(Ɛlim)	0.5	
Slight damage limit (Ɛlim)	**0.15**	
(Δ/L)/(Ɛlim)	0.730593607	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'slight' category - no need to plot points below
(Ɛh)/(Ɛlim)	0.25	
Moderate damage limit (Ɛlim)	**0.3**	
(Δ/L)/(Ɛlim)	0.365296804	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'moderate' category - if the point is not below, damage is 'severe'
(Ɛh)/(Ɛlim)	0.125	

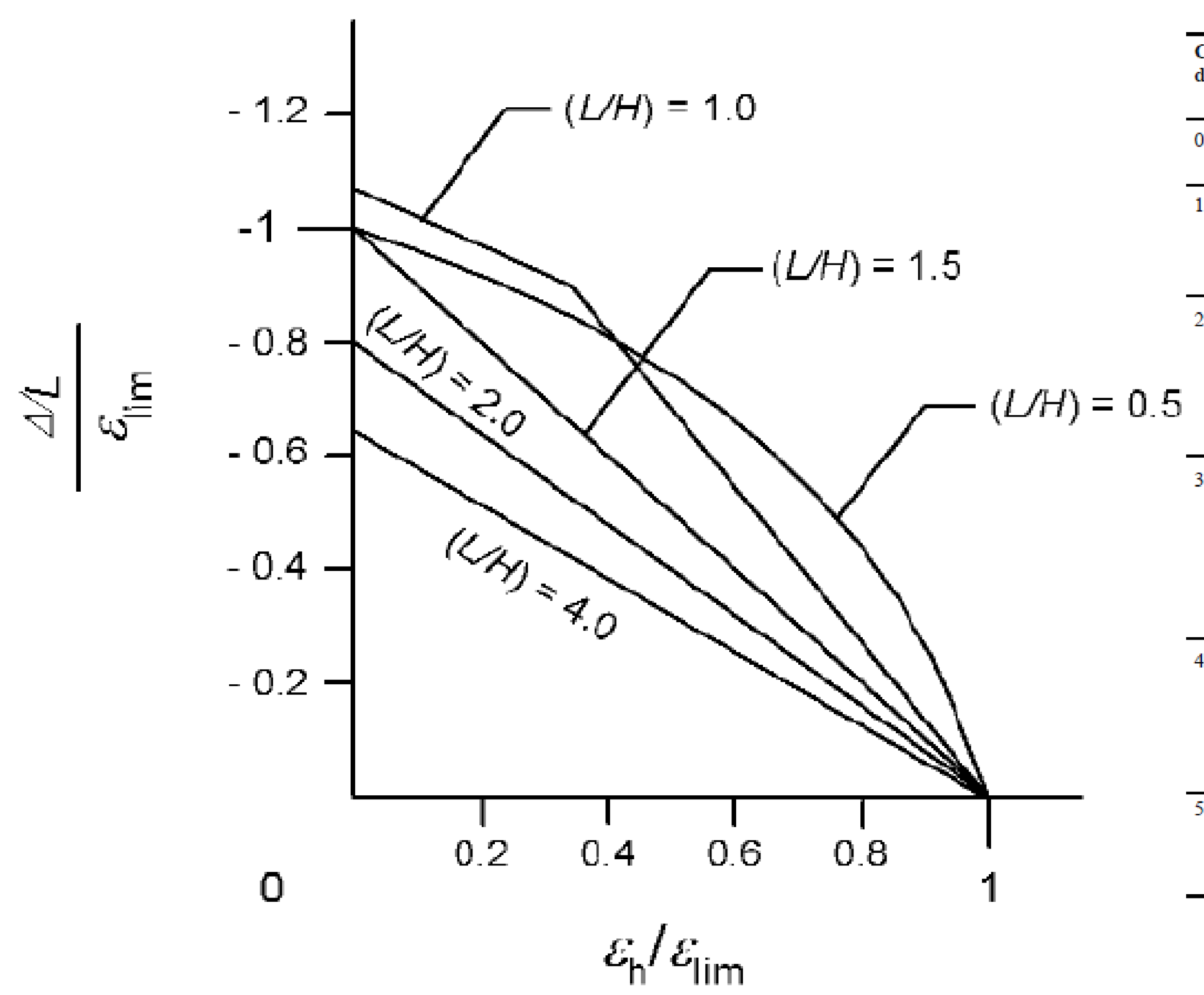
Calculated Category of Damage Slight

Property 2:

L/H	0.61	
Negligible damage limit (Ɛlim)	**0.05**	
(Δ/L)/(Ɛlim)	2.191780822	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'negligible' category - no need to plot points below
(Ɛh)/(Ɛlim)	0.75	
Very Slight damage limit (Ɛlim)	**0.075**	
(Δ/L)/(Ɛlim)	1.461187215	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'very slight' category - no need to plot points below
(Ɛh)/(Ɛlim)	0.5	
Slight damage limit (Ɛlim)	**0.15**	
(Δ/L)/(Ɛlim)	0.730593607	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'slight' category - no need to plot points below
(Ɛh)/(Ɛlim)	0.25	
Moderate damage limit (Ɛlim)	**0.3**	
(Δ/L)/(Ɛlim)	0.365296804	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'moderate' category - if the point is not below, damage is 'severe'
(Ɛh)/(Ɛlim)	0.125	

Calculated Category of Damage Slight

Fig 2.18 (b)



(b) Influence of horizontal strain on $\Delta L / \varepsilon_{lim}$ (after Burland, 2001)

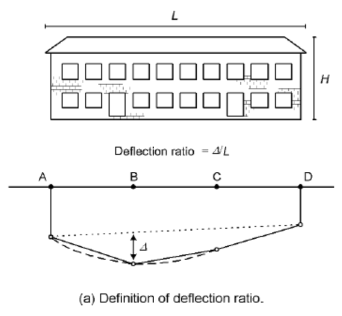
Table 2.5

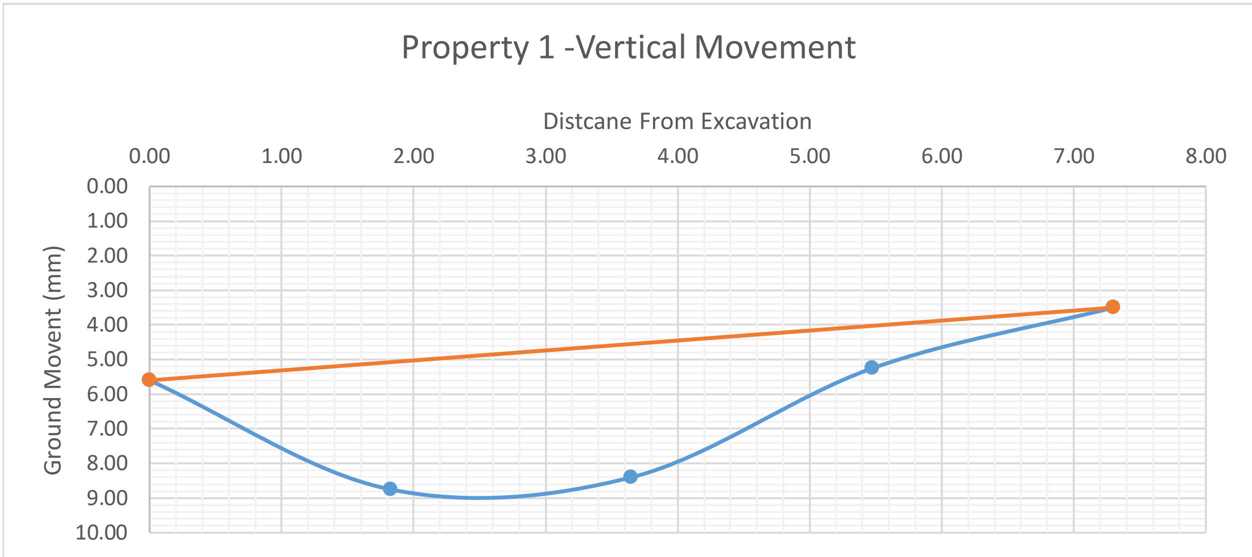
Table 2.5 *Classification of visible damage to walls (after Burland et al, 1977, Boscardin and Cording, 1989; and Burland, 2001)*

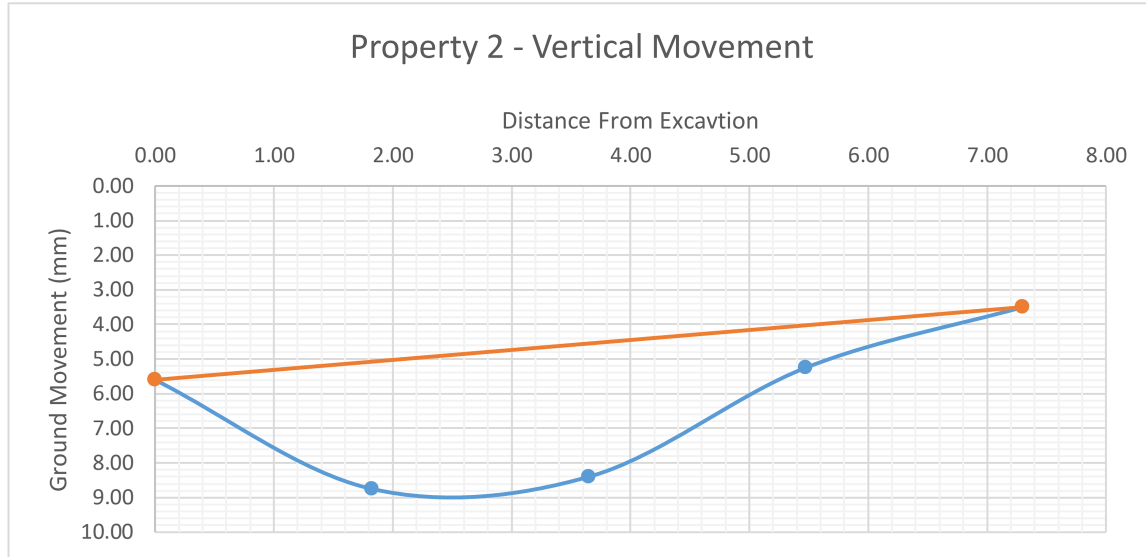
Category of damage	Description of typical damage (ease of repair is underlined)	Approximate crack width (mm)	Limiting tensile strain ε_{lim} (per cent)
0 Negligible	Hairline cracks of less than about 0.1 mm are classed as negligible.	< 0.1	0.0–0.05
1 Very slight	Fine cracks that can easily be treated 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. Weathertightness 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, floor 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.	

Potential Damage to Building

Soft to firm clays - Moderate







Neighbouring Property 1 No. 40

	m	mm
L	7.30	7300
H	12.00	12000
L/H	0.61	

Verticle Deflection (Δ)	4 mm	from graph (max difference between blue and orange line)
Defelction Ratio (Δ/L)	0.054795 %	
Horizontal Movement (δh)	2.74 mm	difference between horizontal movement at nearest and farthest walls
Horzontal Strain (Ɛh) = δh/L	0.03750 %	

Neighbouring Property 2 No. 36

	m	mm
L	7.30	7300
H	12.00	12000
L/H	0.61	

Verticle Deflection (Δ)	4 mm	from graph (max difference between blue and orange line)
Defelction Ratio (Δ/L)	0.054795 %	
Horizontal Movement (δh)	2.74	difference between horizontal movement at nearest and farthest walls
Horzontal Strain (Ɛh) = δh/L	0.03750 %	

CATEGORY OF DAMAGE Damage category limits are given in Table 2.5 (below) you will also need Fig 2.18 (also shown below).

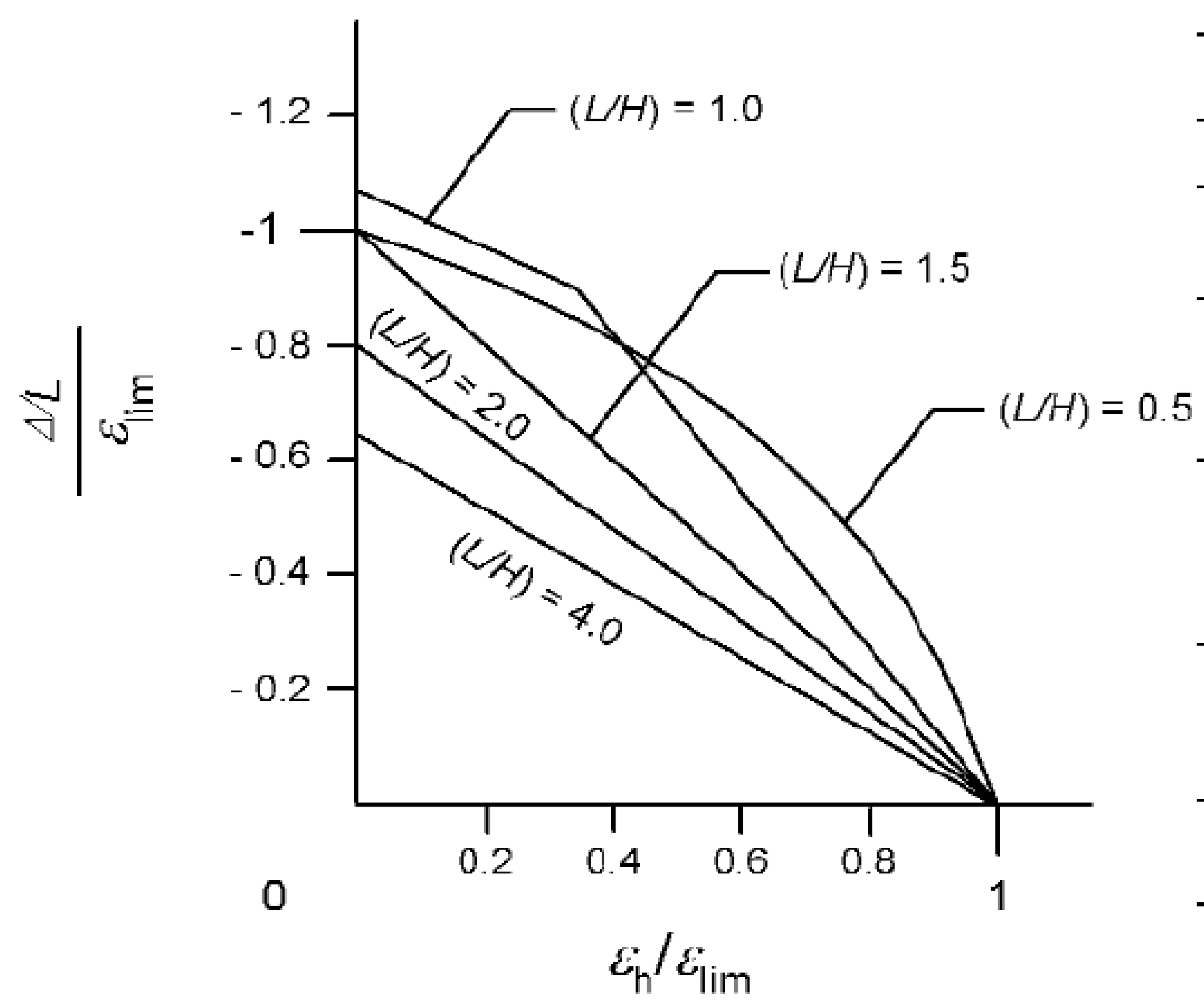
Property 1

L/H	0.61	
Negligible damage limit (Ɛlim)	**0.05**	
(Δ/L)/(Ɛlim) (Ɛh)/(Ɛlim)	1.095890411 0.75	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'negligible' category - no need to plot points
Very Slight damage limit (Ɛlim)	**0.075**	
(Δ/L)/(Ɛlim) (Ɛh)/(Ɛlim)	0.730593607 0.5	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'very slight' category - no need to plot points
Slight damage limit (Ɛlim)	**0.15**	
(Δ/L)/(Ɛlim) (Ɛh)/(Ɛlim)	0.365296804 0.25	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'slight' category - no need to plot points below
Moderate damage limit (Ɛlim)	**0.3**	
(Δ/L)/(Ɛlim) (Ɛh)/(Ɛlim)	0.182648402 0.125	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'moderate' category - if the point is not below, damage is 'severe'
Calculated Category of Damage	Very Slight	

Property 2

L/H	0.61	
Negligible damage limit (Ɛlim)	**0.05**	
(Δ/L)/(Ɛlim) (Ɛh)/(Ɛlim)	1.095890411 0.75	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'negligible' category - no need to plot points below
Very Slight damage limit (Ɛlim)	**0.075**	
(Δ/L)/(Ɛlim) (Ɛh)/(Ɛlim)	0.730593607 0.5	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'very slight' category - no need to plot points below
Slight damage limit (Ɛlim)	**0.15**	
(Δ/L)/(Ɛlim) (Ɛh)/(Ɛlim)	0.365296804 0.25	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'slight' category - no need to plot points below
Moderate damage limit (Ɛlim)	**0.3**	
(Δ/L)/(Ɛlim) (Ɛh)/(Ɛlim)	0.182648402 0.125	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'moderate' category - if the point is not below, damage is 'severe'
Calculated Category of Damage	Very Slight	

Fig 2.18 (b)



(b) Influence of horizontal strain on $\Delta L / \varepsilon_{lim}$ (after Burland, 2001)

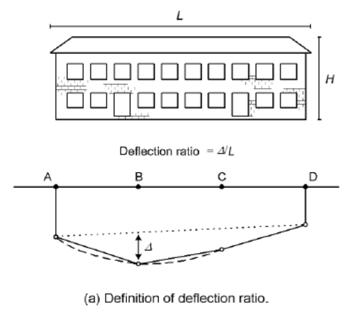
Table 2.5

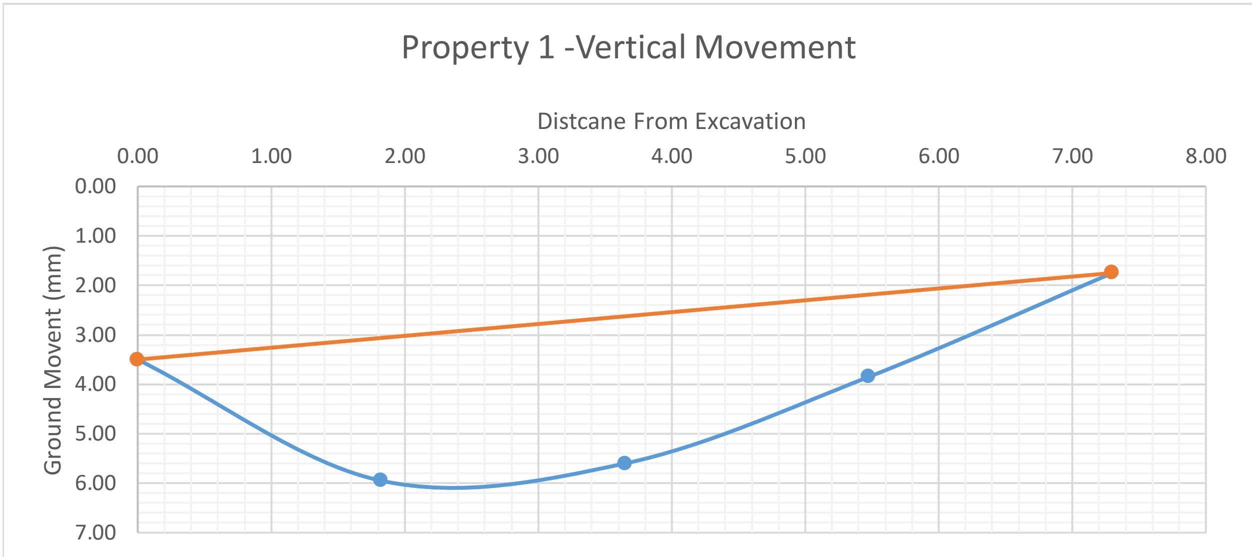
Table 2.5 *Classification of visible damage to walls (after Burland et al, 1977, Boscardin and Cording, 1989; and Burland, 2001)*

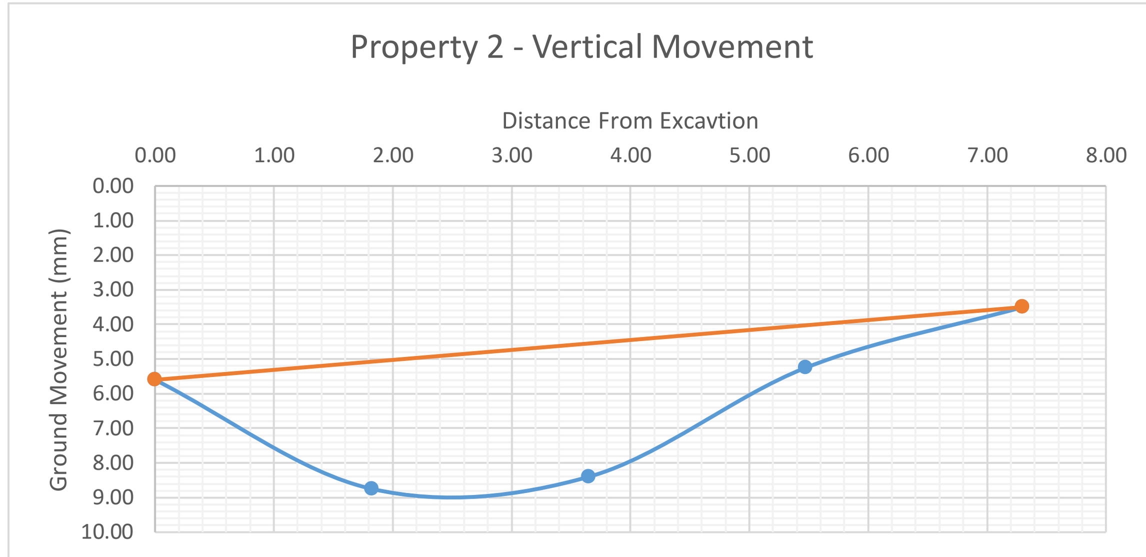
Category of damage	Description of typical damage (ease of repair is underlined)	Approximate crack width (mm)	Limiting tensile strain ε_{lim} (per cent)
0 Negligible	Hairline cracks of less than about 0.1 mm are classed as negligible.	< 0.1	0.0–0.05
1 Very slight	Fine cracks that can easily be treated 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. Weathertightness 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, floor 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.	

Potential Damage to Building

Soft to firm clays - Realistic







Neighbouring Property 1 No. 40

	m	mm
L	7.30	7300
H	12.00	12000
L/H	0.61	

Verticle Deflection (Δ)	3 mm	from graph (max difference between blue and orange line)
Defelction Ratio (Δ/L)	0.041096 %	
Horizontal Movement (δh)	2.74 mm	difference between horizontal movement at nearest and farthest walls
Horzontal Strain (Ɛh) = δh/L	0.03750 %	

Neighbouring Property 2 No. 36

	m	mm
L	7.30	7300
H	12.00	12000
L/H	0.61	

Verticle Deflection (Δ)	3 mm	from graph (max difference between blue and orange line)
Defelction Ratio (Δ/L)	0.041096 %	
Horizontal Movement (δh)	2.74	difference between horizontal movement at nearest and farthest walls
Horzontal Strain (Ɛh) = δh/L	0.03750 %	

CATEGORY OF DAMAGE Damage category limits are given in Table 2.5 (below) you will also need Fig 2.18 (also shown below).

Property 1

L/H	0.61	
Negligible damage limit (Ɛlim)	**0.05**	
(Δ/L)/(Ɛlim)	0.821917808	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'negligible' category - no need to plot points
(Ɛh)/(Ɛlim)	0.75	
Very Slight damage limit (Ɛlim)	**0.075**	
(Δ/L)/(Ɛlim)	0.547945205	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'very slight' category - no need to plot points
(Ɛh)/(Ɛlim)	0.5	
Slight damage limit (Ɛlim)	**0.15**	
(Δ/L)/(Ɛlim)	0.273972603	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'slight' category - no need to plot points below
(Ɛh)/(Ɛlim)	0.25	
Moderate damage limit (Ɛlim)	**0.3**	
(Δ/L)/(Ɛlim)	0.136986301	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'moderate' category - if the point is not below, damage is 'severe'
(Ɛh)/(Ɛlim)	0.125	

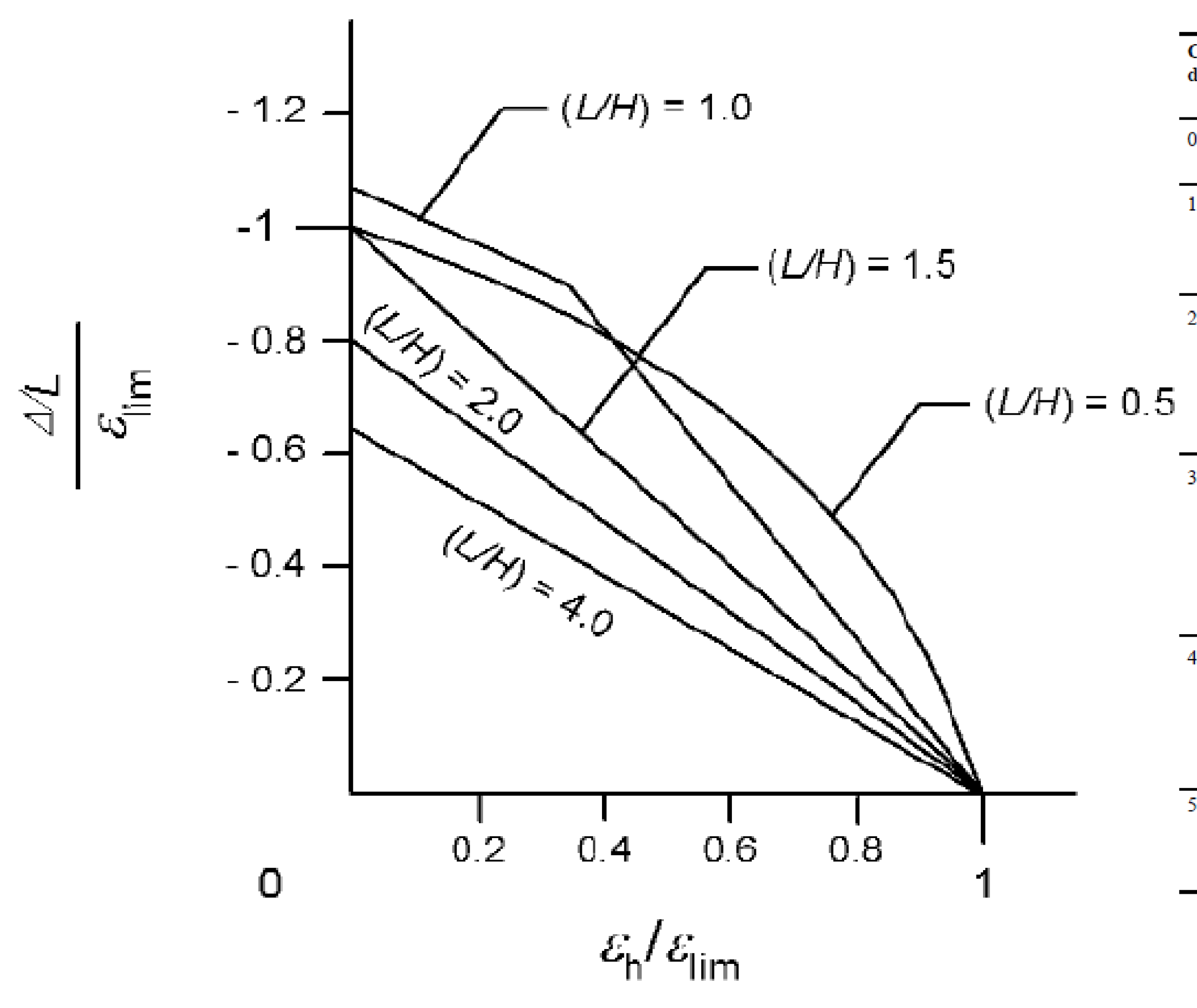
Calculated Category of Damage Very Slight

Property 2

L/H	0.61	
Negligible damage limit (Ɛlim)	**0.05**	
(Δ/L)/(Ɛlim)	0.821917808	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'negligible' category - no need to plot points below
(Ɛh)/(Ɛlim)	0.75	
Very Slight damage limit (Ɛlim)	**0.075**	
(Δ/L)/(Ɛlim)	0.547945205	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'very slight' category - no need to plot points below
(Ɛh)/(Ɛlim)	0.5	
Slight damage limit (Ɛlim)	**0.15**	
(Δ/L)/(Ɛlim)	0.273972603	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'slight' category - no need to plot points below
(Ɛh)/(Ɛlim)	0.25	
Moderate damage limit (Ɛlim)	**0.3**	
(Δ/L)/(Ɛlim)	0.136986301	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'moderate' category - if the point is not below, damage is 'severe'
(Ɛh)/(Ɛlim)	0.125	

Calculated Category of Damage Very Slight

Fig 2.18 (b)



(b) Influence of horizontal strain on $\Delta L / \varepsilon_{lim}$ (after Burland, 2001)

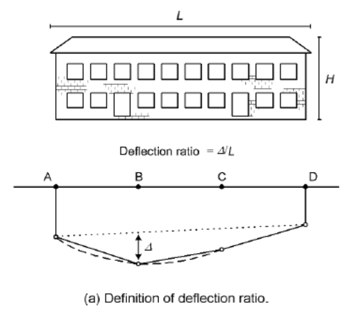
Table 2.5

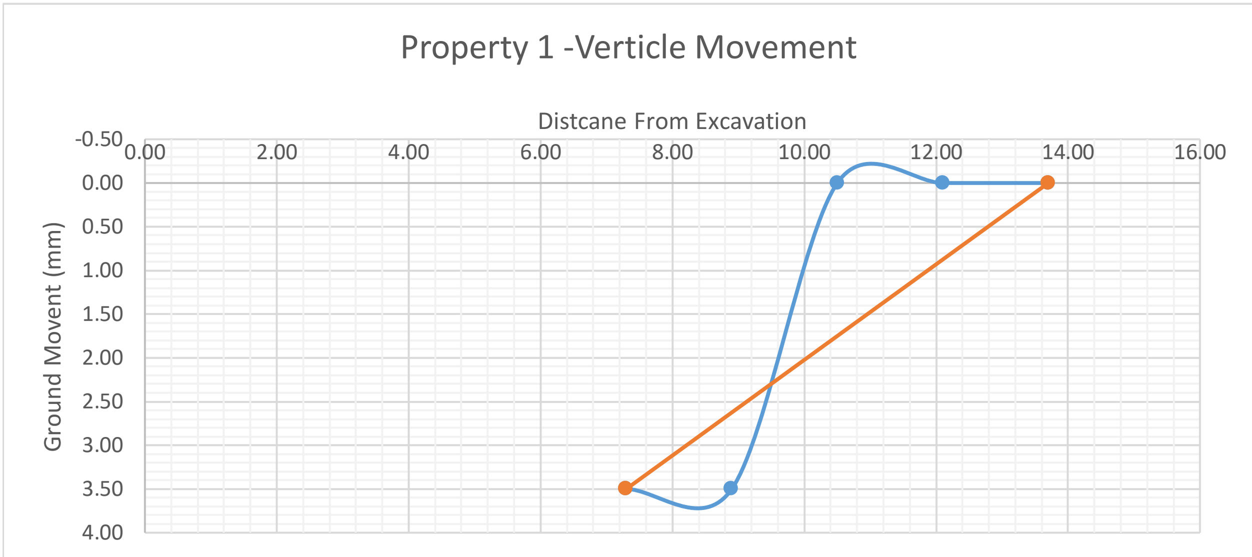
Table 2.5 *Classification of visible damage to walls (after Burland et al, 1977, Boscardin and Cording, 1989; and Burland, 2001)*

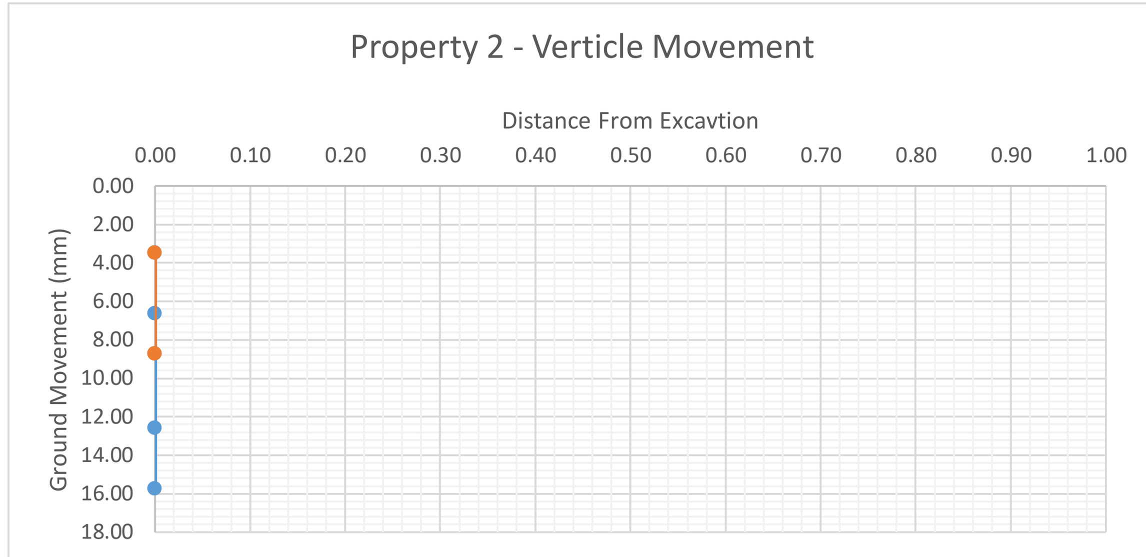
Category of damage	Description of typical damage (ease of repair is underlined)	Approximate crack width (mm)	Limiting tensile strain ε_{lim} (per cent)
0 Negligible	Hairline cracks of less than about 0.1 mm are classed as negligible.	< 0.1	0.0–0.05
1 Very slight	<u>Fine cracks that can easily be treated during normal decoration.</u> Perhaps isolated slight fracture in building. Cracks in external brickwork visible on inspection.	< 1	0.05–0.075
2 Slight	<u>Cracks easily filled. Redecoration probably required.</u> Several slight fractures showing inside of building. Cracks are visible externally and <u>some repointing may be required externally</u> to ensure weathertightness. Doors and windows may stick slightly.	< 5	0.075–0.15
3 Moderate	<u>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.</u> Doors and windows sticking. Service pipes may fracture. Weathertightness often impaired.	5–15 or a number of cracks > 3	0.15–0.3
4 Severe	<u>Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows.</u> Windows and frames distorted, floor 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	<u>This requires a major repair involving partial or complete rebuilding.</u> Beams lose bearings, walls lean badly and require shoring. Windows broken with distortion. Danger of instability.	usually > 25 but depends on number of cracks.	

Potential Damage to Building

Soft to firm clays - Conservative







Neighbouring Property 1 No. 34

	m	mm
L	6.40	6400
H	12.00	12000
L/H	0.53	

Verticle Deflection (Δ)	1.6	mm	from graph (max difference between blue and orange line)
Defelction Ratio (Δ/L)	0.025000	%	
Horizontal Movement (δh)	2.40	mm	difference between horizontal movement at nearest and farthest walls
Horzontal Strain (Ɛh) = δh/L	0.03750	%	

Neighbouring Property 2 No. 0

	m	mm
L	0.00	0
H	0.00	0
L/H	#DIV/0!	

Verticle Deflection (Δ)	8	mm	from graph (max difference between blue and orange line)
Defelction Ratio (Δ/L)	#DIV/0!	%	
Horizontal Movement (δh)	0.00		difference between horizontal movement at nearest and farthest walls
Horzontal Strain (Ɛh) = δh/L	#DIV/0!	%	

CATEGORY OF DAMAGE Damage category limits are given in Table 2.5 (below) you will also need Fig 2.18 (also shown below).

Property 1

L/H 0.53

Negligible damage limit (Ɛlim) 0.05

(Δ/L)/(Ɛlim)	0.5	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'negligible' category - no need to plot points
(Ɛh)/(Ɛlim)	0.75	

Very Slight damage limit (Ɛlim) 0.075

(Δ/L)/(Ɛlim)	0.333333333	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'very slight' category - no need to plot points
(Ɛh)/(Ɛlim)	0.5	

Slight damage limit (Ɛlim) 0.15

(Δ/L)/(Ɛlim)	0.166666667	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'slight' category - no need to plot points below
(Ɛh)/(Ɛlim)	0.25	

Moderate damage limit (Ɛlim) 0.3

(Δ/L)/(Ɛlim)	0.083333333	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'moderate' category - if the point is not below, damage is 'severe'
(Ɛh)/(Ɛlim)	0.125	

Calculated Category of Damage Negligible

Property 2

L/H #DIV/0!

Negligible damage limit (Ɛlim) 0.05

(Δ/L)/(Ɛlim)	#DIV/0!	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'negligible' category - no need to plot points below
(Ɛh)/(Ɛlim)	#DIV/0!	

Very Slight damage limit (Ɛlim) 0.075

(Δ/L)/(Ɛlim)	#DIV/0!	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'very slight' category - no need to plot points below
(Ɛh)/(Ɛlim)	#DIV/0!	

Slight damage limit (Ɛlim) 0.15

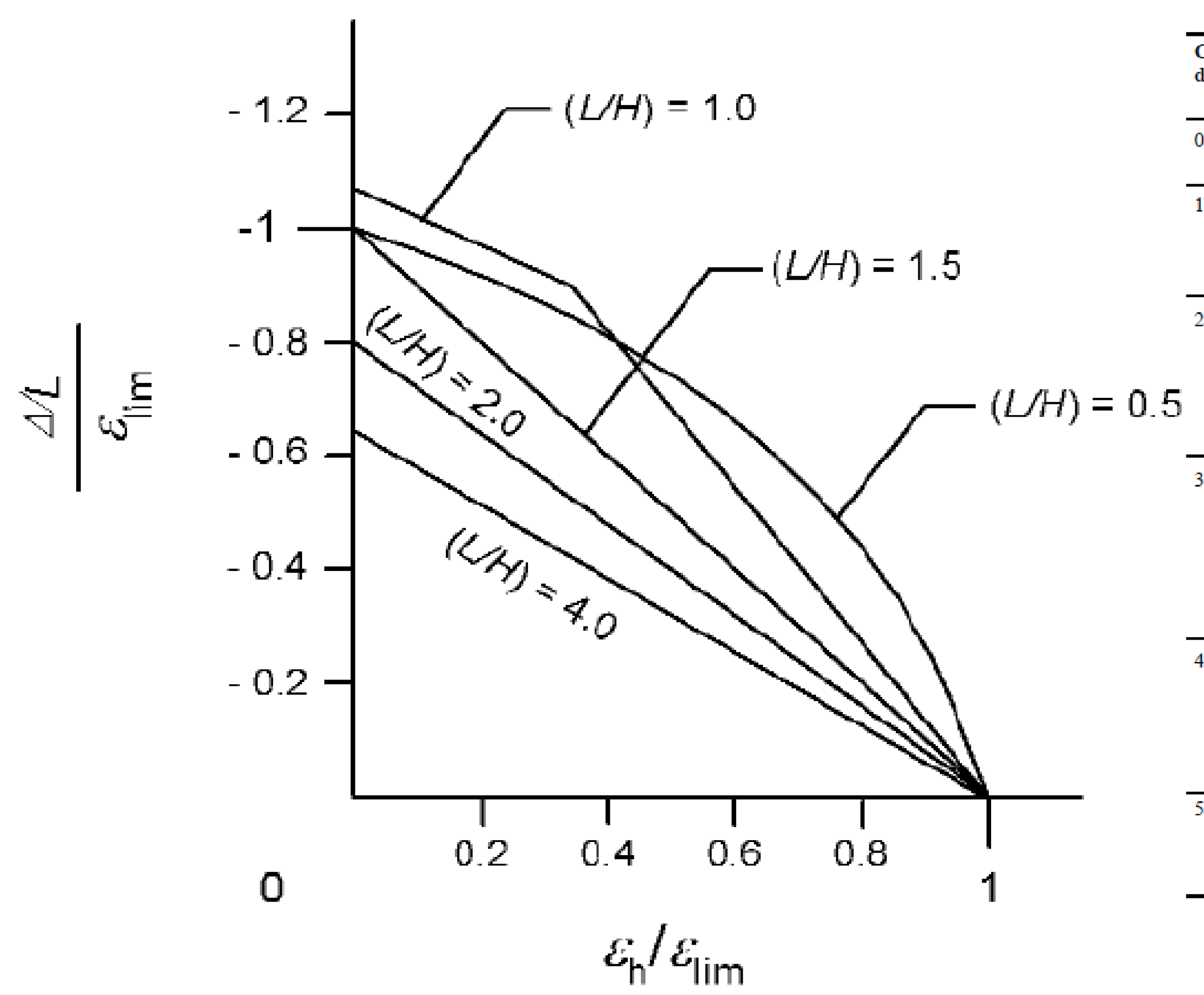
(Δ/L)/(Ɛlim)	#DIV/0!	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'slight' category - no need to plot points below
(Ɛh)/(Ɛlim)	#DIV/0!	

Moderate damage limit (Ɛlim) 0.3

(Δ/L)/(Ɛlim)	#DIV/0!	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'moderate' category - if the point is not below, damage is 'severe'
(Ɛh)/(Ɛlim)	#DIV/0!	

Calculated Category of Damage

Fig 2.18 (b)



(b) Influence of horizontal strain on Δ/L / ε_{lim} (after Burland, 2001)

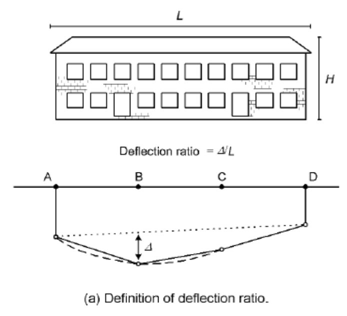
Table 2.5

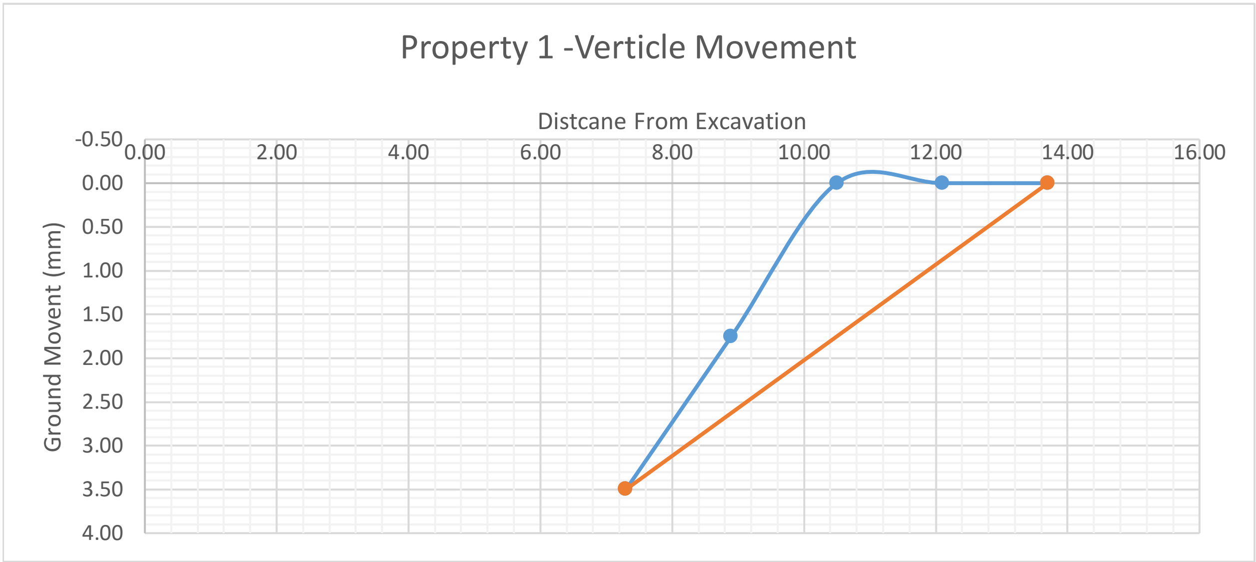
Table 2.5 *Classification of visible damage to walls (after Burland et al, 1977, Boscardin and Cording, 1989; and Burland, 2001)*

Category of damage	Description of typical damage (ease of repair is underlined)	Approximate crack width (mm)	Limiting tensile strain ε_{lim} (per cent)
0 Negligible	Hairline cracks of less than about 0.1 mm are classed 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. Weathertightness 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, floor 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.	

Potential Damage to Building

Soft to firm clays - Moderate





Neighbouring Property 1 No. 34

	m	mm
L	6.40	6400
H	12.00	12000
L/H	0.53	

Verticle Deflection (Δ)	1.5	mm	from graph (max difference between blue and orange line)
Defelction Ratio (Δ/L)	0.023438	%	
Horizontal Movement (δh)	2.40	mm	difference between horizontal movement at nearest and farthest walls
Horzontal Strain (Ɛh) = δh/L	0.03750	%	

Neighbouring Property 2 No. 0

	m	mm
L	0.00	0
H	0.00	0
L/H	#DIV/0!	

Verticle Deflection (Δ)	8	mm	from graph (max difference between blue and orange line)
Defelction Ratio (Δ/L)	#DIV/0!	%	
Horizontal Movement (δh)	0.00		difference between horizontal movement at nearest and farthest walls
Horzontal Strain (Ɛh) = δh/L	#DIV/0!	%	

CATEGORY OF DAMAGE Damage category limits are given in Table 2.5 (below) you will also need Fig 2.18 (also shown below).

Property 1

L/H	0.53	
Negligible damage limit (Ɛlim)	**0.05**	
(Δ/L)/(Ɛlim)	0.46875	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'negligible' category - no need to plot points
(Ɛh)/(Ɛlim)	0.75	
Very Slight damage limit (Ɛlim)	**0.075**	
(Δ/L)/(Ɛlim)	0.3125	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'very slight' category - no need to plot points
(Ɛh)/(Ɛlim)	0.5	
Slight damage limit (Ɛlim)	**0.15**	
(Δ/L)/(Ɛlim)	0.15625	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'slight' category - no need to plot points below
(Ɛh)/(Ɛlim)	0.25	
Moderate damage limit (Ɛlim)	**0.3**	
(Δ/L)/(Ɛlim)	0.078125	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'moderate' category - if the point is not below, damage is 'severe'
(Ɛh)/(Ɛlim)	0.125	

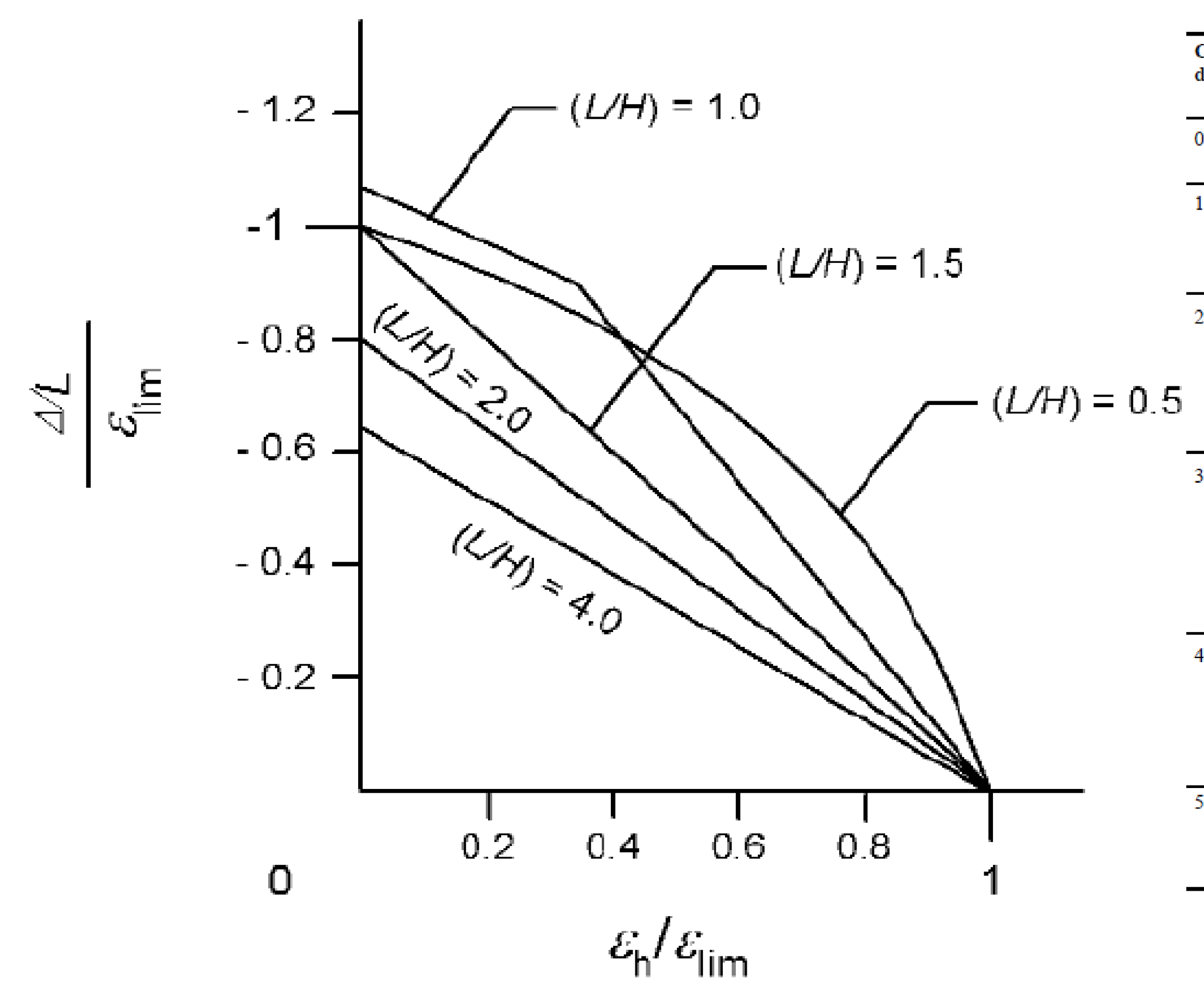
Calculated Category of Damage Negligible

Property 2

L/H	#DIV/0!	
Negligible damage limit (Ɛlim)	**0.05**	
(Δ/L)/(Ɛlim)	#DIV/0!	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'negligible' category - no need to plot points below
(Ɛh)/(Ɛlim)	#DIV/0!	
Very Slight damage limit (Ɛlim)	**0.075**	
(Δ/L)/(Ɛlim)	#DIV/0!	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'very slight' category - no need to plot points below
(Ɛh)/(Ɛlim)	#DIV/0!	
Slight damage limit (Ɛlim)	**0.15**	
(Δ/L)/(Ɛlim)	#DIV/0!	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'slight' category - no need to plot points below
(Ɛh)/(Ɛlim)	#DIV/0!	
Moderate damage limit (Ɛlim)	**0.3**	
(Δ/L)/(Ɛlim)	#DIV/0!	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'moderate' category - if the point is not below, damage is 'severe'
(Ɛh)/(Ɛlim)	#DIV/0!	

Calculated Category of Damage

Fig 2.18 (b)



(b) Influence of horizontal strain on $\Delta L / \varepsilon_{lim}$
(after Burland, 2001)

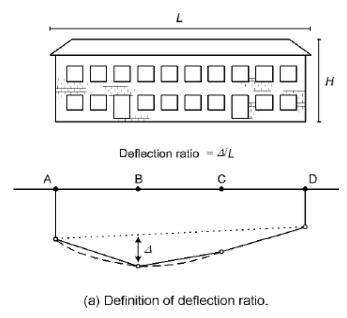
Table 2.5

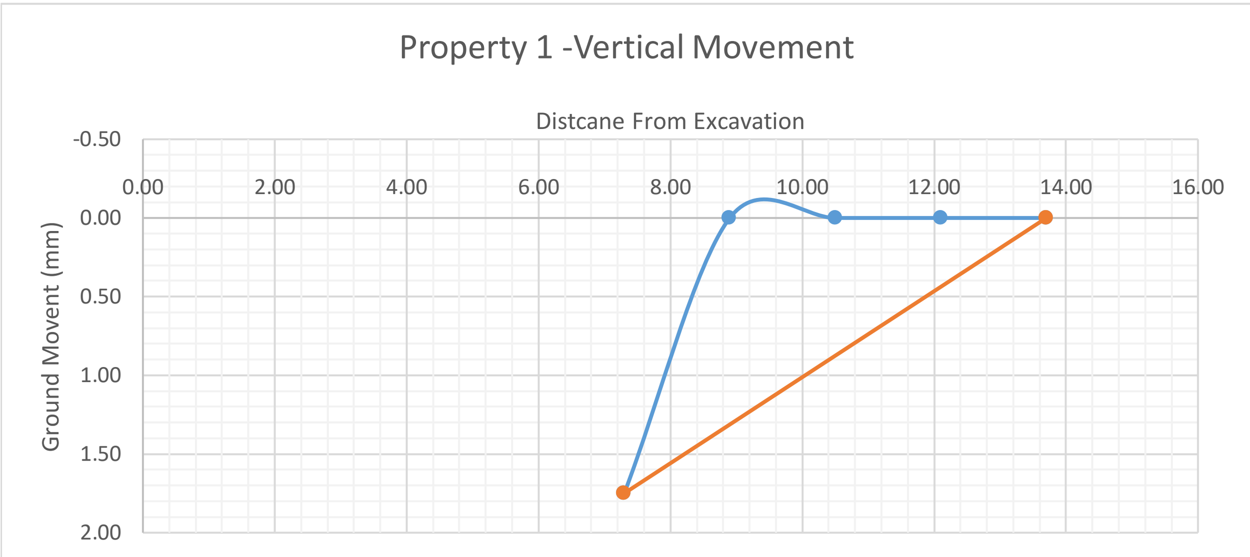
Table 2.5 *Classification of visible damage to walls (after Burland* et al*, 1977, Boscardin and Cording, 1989; and Burland, 2001)*

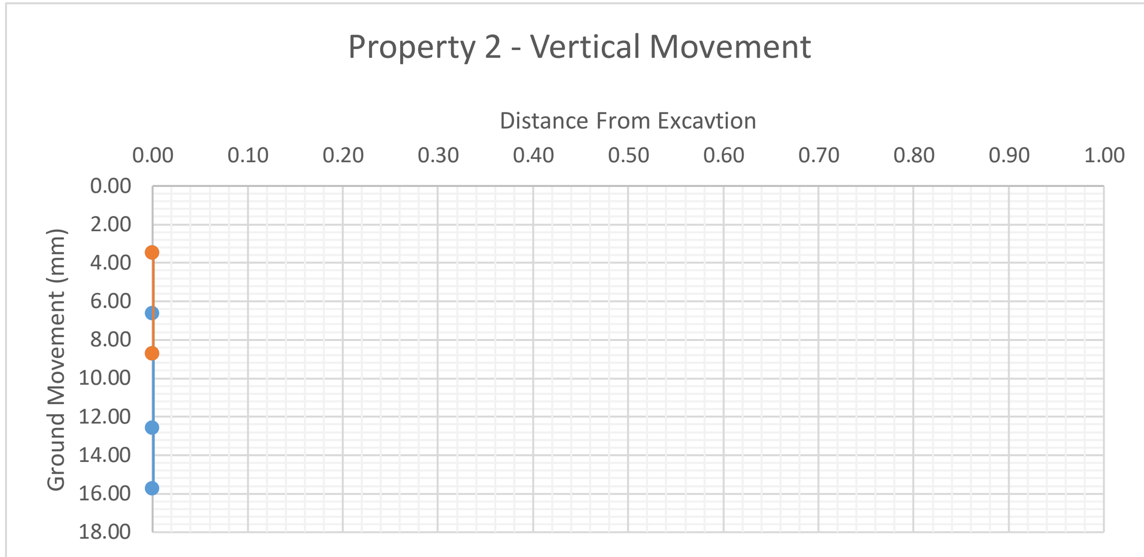
Category of damage	Description of typical damage (ease of repair is underlined)	Approximate crack width (mm)	Limiting tensile strain ε_{lim} (per cent)
0 Negligible	Hairline cracks of less than about 0.1 mm are classed as negligible.	< 0.1	0.0–0.05
1 Very slight	Fine cracks that can easily be treated 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. Weathertightness 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, floor 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.	

Potential Damage to Building

Soft to firm clays - Realsitic







Neighbouring Property 1 No. 34

	m	mm
L	6.40	6400
H	12.00	12000

L/H	0.53		
Verticle Deflection (Δ)	1	mm	from graph (max difference between blue and orange line)
Defelction Ratio (Δ/L)	0.015625	%	
Horizontal Movement (δh)	2.40	mm	difference between horizontal movement at nearest and farthest walls
Horzontal Strain (Ɛh) = δh/L	0.03750	%	

Neighbouring Property 2 No. 0

	m	mm
L	0.00	0
H	0.00	0

L/H	#DIV/0!		
Verticle Deflection (Δ)		mm	from graph (max difference between blue and orange line)
Defelction Ratio (Δ/L)	#DIV/0!	%	
Horizontal Movement (δh)	0.00		difference between horizontal movement at nearest and farthest walls
Horzontal Strain (Ɛh) = δh/L	#DIV/0!	%	

CATEGORY OF DAMAGE Damage category limits are given in Table 2.5 (below) you will also need Fig 2.18 (also shown below).

Property 1

L/H	0.53	
Negligible damage limit (Ɛlim)	**0.05**	
(Δ/L)/(Ɛlim)	0.3125	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'negligible' category - no need to plot points
(Ɛh)/(Ɛlim)	0.75	
Very Slight damage limit (Ɛlim)	**0.075**	
(Δ/L)/(Ɛlim)	0.208333333	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'very slight' category - no need to plot points
(Ɛh)/(Ɛlim)	0.5	
Slight damage limit (Ɛlim)	**0.15**	
(Δ/L)/(Ɛlim)	0.104166667	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'slight' category - no need to plot points below
(Ɛh)/(Ɛlim)	0.25	
Moderate damage limit (Ɛlim)	**0.3**	
(Δ/L)/(Ɛlim)	0.052083333	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'moderate' category - if the point is not below, damage is 'severe'
(Ɛh)/(Ɛlim)	0.125	

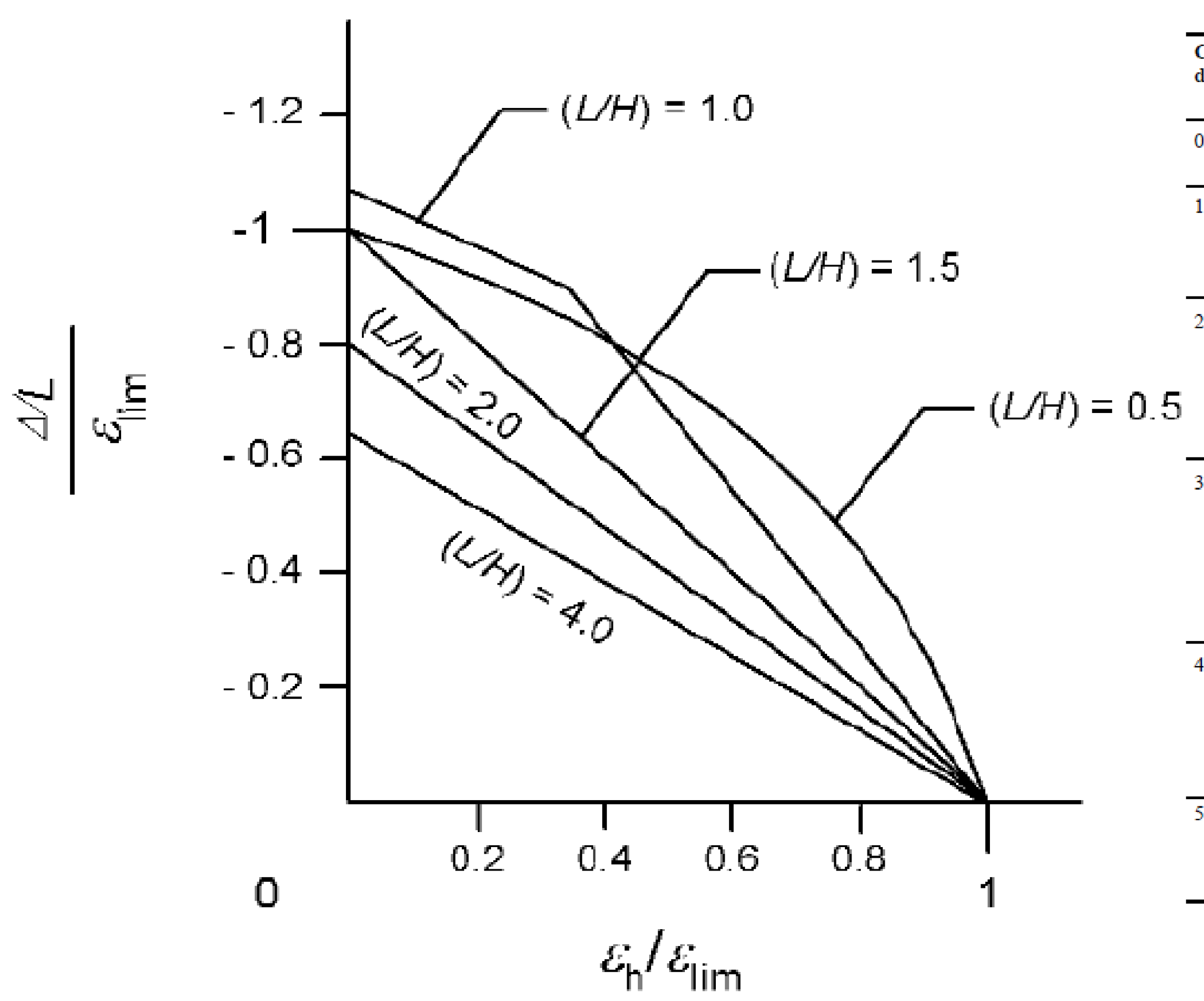
Calculated Category of Damage Negligible

Property 2

L/H	#DIV/0!	
Negligible damage limit (Ɛlim)	**0.05**	
(Δ/L)/(Ɛlim)	#DIV/0!	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'negligible' category - no need to plot points below
(Ɛh)/(Ɛlim)	#DIV/0!	
Very Slight damage limit (Ɛlim)	**0.075**	
(Δ/L)/(Ɛlim)	#DIV/0!	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'very slight' category - no need to plot points below
(Ɛh)/(Ɛlim)	#DIV/0!	
Slight damage limit (Ɛlim)	**0.15**	
(Δ/L)/(Ɛlim)	#DIV/0!	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'slight' category - no need to plot points below
(Ɛh)/(Ɛlim)	#DIV/0!	
Moderate damage limit (Ɛlim)	**0.3**	
(Δ/L)/(Ɛlim)	#DIV/0!	Plot this point on fig2.18 (b) if the plotted point is below the appropriate L/H line then damage falls into 'moderate' category - if the point is not below, damage is 'severe'
(Ɛh)/(Ɛlim)	#DIV/0!	

Calculated Category of Damage

Fig 2.18 (b)



(b) Influence of horizontal strain on Δ/L / ε_{lim} (after Burland, 2001)

Table 2.5

Table 2.5 *Classification of visible damage to walls (after Burland et al, 1977, Boscardin and Cording, 1989; and Burland, 2001)*

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0 Negligible	Hairline cracks of less than about 0.1 mm are classed as negligible.	< 0.1	0.0–0.05
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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.	