PROJECT QUAD LIMITED

PROJECT QUAD

GROUND MOVEMENTS REPORT

REVISION 2

March 2015

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DISCLAIMER

REVISION HISTORY

Revision	Date	Description
Rev. 0	February 2015	Issued for comments
Rev 1	March 2015	Minor changes
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EXECUTIVE SUMMARY

It is proposed to refurbish 6-10 Cambridge Terrace and 1-2 Chester Gate and construct a basement underneath the front part of the existing building and under the road to the west. The basement will be constructed by a combination of underpinning techniques and bored piled walls around the perimeter.

A study of ground movements associated with the basement construction and their impact on the adjacent structures has been estimated using empirical methods.

The basement construction would induce ground movements around the excavated area whose potential effects have been assessed with reference to the Category of Damage Chart presented in CIRIA C580. The properties No. 1-2 Chester Gate and N5 Cambridge Terrace would be expected to experience 'very slight' damage, with additional localised cracks around the party wall of No. 1 Chester Gate. No. 1 and 2 Chester Gate is in the same ownership of the site and fit out works on this property will be carried out at a later stage.

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1 INTRODUCTION

The Geotechnical Consulting Group (GCG) have been commissioned by 1 Chester Gate Limited, 2 Chester Gate Limited and Project Quad limited (Project Quad), to assess the impact of the ground movements associated with the Project Quad on the surrounding structures.

The expected movements in the area around the site have been estimated using an empirical approach that is based on field measurements of movements from a number of basement constructions across London (CIRIA C580).

Information on the proposal has been provided by Michael Barclay Partnership, the structural engineers for the project.

2 THE SITE AND THE PROPOSED WORKS

The site is located to the east of Regents Park. It forms an ‘L’ shape spanning over Cambridge Terrace and Chester Gate to include the northern end of a large regency period terrace (6-10 Cambridge Terrace) and the building 1-2 Chester Gate.

The building 1-2 Chester Gate is Grade II Listed and the building No. 6 to 10 Cambridge Terrace is Grade I Listed.

The buildings have a lower ground floor with brick vaults extending outside the wall line above ground.

Figure 1 shows the site location and Figure 2 shows a layout of the site.

The buildings were constructed in 1826 designed by John Nash. It is understood that 7-10 Cambridge Terrace has suffered bomb damage during the Second Word War and fire damage in 1947, following which the structure was demolished. It was reconstructed in 1986 to replicate the original building façade. The new structure was founded on piles and the basement vaults were incorporated within the new basement at the same level. The works also extended to the party wall of No. 6, which was supported on piles, although the rest of the house maintained the original masonry arrangement.

The building 6-10 Cambridge Terrace shares a party wall with the adjacent properties No. 5 Cambridge Terrace to the south. Cambridge Terrace, Chester Gate and Cambridge Terrace Mews bound the site to the west, north and east respectively. There are two storey mews houses along Cambridge Terrace Mews, which are set parallel to Cambridge Terrace at about 14m from the rear of 6-7 Cambridge Terrace (Figure2).

It is proposed to construct a basement underneath No. 8, 9 and 10 Cambridge Terrace, the western part of No. 7 and under the existing vaults along Cambridge Terrace up approximately to the rear pavement line of the Outer Circle. The basement will extend to about 5.8m below the existing lower ground floor level, and will be deepened up to 9m under the northern and middle part of the proposed basement area. Structural works will be carried out on 1-2 Chester Gate at a later stage.

Figure 3 shows a plan of the proposed basement with a mark-up of the excavation depth and a typical cross section.

The basement will be constructed through a combination of underpinning of the existing structures and the installation of bored piles. In the final condition the basement will be a reinforced concrete box with a roof just below the level of the current lower ground floor. Soil will be placed back over the lid of the box outside the vault area.

3 THE SURROUNDING STRUCTURES

The proposed basement construction would induce ground movements inside and outside the proposed basement area. The structures that are likely to be most affected by these are No. 1-2 Chester Gate, to the east of the proposed basement, and No. 5 Cambridge Terrace, immediately to the south of the site.

3.1 No. 1-2 Chester Gate

These houses were built around 1825 designed by John Nash and are Grade II listed.

They are approximately 8m x 10m in plan and are symmetric around their party wall, which is at around 8m to the east of the proposed basement. The houses include four storeys and a lower ground floor, which is believed to extend to the same level of the existing lower ground floor under 6-10 Cambridge Terrace. Figure 4 shows the houses and a plan of the lower ground floor.

The party wall with No. 10 and 9 Cambridge Terrace is believed to be underpinned. This was probably done as part of the 1986 reconstruction works of 7-10 Cambridge Terrace.

These houses are in the same ownership of No. 6-10 Cambridge Terrace and it is understood that fit out works on them are to be progressed separately.

3.2 No. 5 Cambridge Terrace

This is part of the original 1826 terrace. It is a six storey terraced house with a lower ground floor extending over the whole footprint of the property. This structure is approximately 12.5m x 8m in plan (Figure 5). It is believed to have ground bearing masonry walls, but the party wall with No. 6 Cambridge Terrace is believed to be supported on piles, which were installed as part of the 1986 works on No. 6-10 Cambridge Terrace.

The foundation level of the other ground bearing walls is not known with certainty, but, for the purposes of the assessment herein, they will be assumed to be at 0.5m below the level of the existing lower ground floor.

Details on the conditions of the house are unknown, but it is assumed herein that it is in good condition.

4 GROUND CONDITIONS

Detailed information on the ground conditions of the site is provided in the GCG hydrogeological report (GCG 2015).

For the purposes of the analyses herein the ground stratigraphy can be summarised as follows:

Made Ground (Street level)	at +30.5mOD
London Clay	at +28.5mOD
Lambeth Group	at 0mOD
Thanet Sand	at -14mOD
Chalk	at -20mOD

Groundwater at +28.6mOD.

5 GROUND MOVEMENT ANALYSES

5.1 Background

In the area of the new basement the soil will tend to move as a result of the net change of vertical load on the ground. The basement structure should be designed accounting for these movements.

Around the site ground movements during and after the works would be due mainly to:

- the underpinning of the existing foundations,
- piling around the rest of the perimeter of the new basement
- the excavation of the main basement, which would induce a reduction of vertical and lateral stresses in the ground along the excavation boundaries.

The magnitude and distribution of the ground movements inside and outside the excavated area are a function of changes of load in the ground and workmanship. The way that the existing buildings around the site respond to the movements is dependent on their current conditions and the precautions that are taken to reduce the risk of building movements.

The estimated ground movements and their impacts on adjacent houses are discussed below.

5.2 Ground movements around the new basement

5.2.1 *Movements due to underpinning*

Underpinning will be carried out along the perimeter walls of No. 8, 9 and 10 and the façades of No. 6 and 7.

The existing structure 7-10 is currently supported on piles. It is understood that temporary piles will be installed to support the structure during the basement construction. As such, no load will be carried and transferred during the underpinning process except under the party wall with No. 1-2 Chester Gate and under the façade of No. 6 Cambridge Terrace.

Even where the underpinning would involve a transfer of vertical loads from the current to a deeper foundation level, only small net load changes would occur and therefore, generally, most of the underpinning movements are likely to be settlements due to construction effects.

The depth of the underpinning would be approximately 8m and about 7.5m under the party wall with No. 1-2 Chester Gate, which is already underpinned by about 0.5m.

Experience suggests that for relatively shallow underpinning, if the underpinning is carried out with good workmanship and in the dry, the ground movements can be controlled so that these do not exceed 10mm. The settlements would be localised under the underpinned walls and any damage caused by these movements will affect the underpinned walls and should be capable of being repaired afterwards.

It should be noted that perched groundwater was found across the site during the site investigation. This should be accounted for during construction and, if necessary, measures should be taken to ensure that the works can be carried out the in the dry.

5.2.2 *Movements due to installation of piled wall*

Bored pile walls are to be installed around the perimeter of the basement and around the perimeter of the basement plant enclosure. The length would be dictated by the surcharge loads applied by the structures behind and by the vertical loads on the walls. The final pile design has not yet been completed, but, considering the depth of the excavation and assuming that the walls will be propped during construction, for the purposes of the analyses herein the piled walls around the perimeter of the basement will be assumed to be around 15m long.

The installation of bored piles is known to cause ground movements as a consequence of a loss of horizontal support during drilling. Record data on basement construction in London (CIRIA C580) are shown in Figure 6 and can be used to estimate the expected movements.

Records of data on horizontal movements are limited and very scattered and in practice horizontal movements can be ignored. Record data on settlements show a large scatter over a distance of about 0.2 times the wall length behind the wall. Behind that all but a very few measurements show that the settlements are less than 0.02% of the wall length. The movements are highly dependent on the piling method and the care taken. Based on the record data and recent monitoring information (Ball et al., 2014), for the purposes of estimating overall settlements the curve marked on the figure can be used.

For basement walls of 15m the expected settlements are about 3mm at the back of the wall and about 1.5mm at 6m from the wall.

5.2.3 *Movements due to excavation*

The excavation would cause upward ground movements in the excavated area and under the perimeter walls as a result of the vertical change (reduction) of loads on the excavated surface. Behind the retaining walls the ground would tend to settle and move towards the excavation as the walls bend towards the excavation due to the reduction of lateral support to them.

Figure 7 shows empirical data based on the movements of ground behind retaining walls as a result of excavations in typical London ground conditions. The movements depend on the propping sequence and on the depth of the excavation and although there is a considerable scatter, the data lies within an envelope, which can be used to predict the likely upper limit of movement at any particular distance from the excavation. Although the database refers to embedded retaining walls, there is a lack of reliable data on ground movements behind underpinnings so the CIRIA C580 data is typically used also for underpinning.

The main basement will be excavated in front of bored walls and the underpinned walls, which would be propped prior to the start of any significant excavation. Record data referring to stiff support of the walls could therefore be used to estimate the expected movements.

The ground behind the walls would tend to sag and therefore the maximum settlements would occur at a distance behind the retaining walls. The values estimated from the record data occur behind the walls. At the corners ground movements would be restricted to about half of the predicted values.

These would add to any predicted movements due to wall installation or underpinning construction.

Contour plots of the predicted ground movements due to the combined effect of excavation and bored pile installation around the basement area have been constructed and are shown in Figures 8 and 9.

In the long term additional movements would be expected as a result of the net change of vertical load on the ground, which could affect the underpinned walls.

6 DISCUSSION OF THE GROUND MOVEMENT ANALYSES

6.1 Effects of ground movements on the structures around the basement

The basement construction would induce ground movements on the surrounding area that would induce the structures around the basement to settle and move towards it as shown in Figures 8 and 9. The structure No. 7 Cambridge Terrace is supported on piles and therefore it is unlikely to be significantly affected by the induced ground movements. Similarly, there would not be significant effect on the party walls of No. 6 Cambridge Terrace, which are supported on piles. However, it is understood that this structure has other load bearing masonry walls, which are likely to be affected by the movements. Distortions could therefore occur on this structure. This is part of the site and damage would be repaired after the basement works are completed.

6.2 No. 1-2 Chester Gate

The party wall with No. 9-10 Cambridge Terrace would settle during the underpinning process. During excavation, it would tend to move upwards as the ground in the area of the basement swells from the reduction of vertical stress and it would also tend to move towards the excavation due to the loss of horizontal support (although this movement would be restricted by the propping system). These movements could induce cracks at the junctions of the party wall.

Behind the wall, ground would distort during excavation as shown in Figures 8 and 9. The potential damage of these ground movements on the house can be estimated as suggested in CIRIA C580 by looking at the combined effects of the horizontal strains and the deflection ratio, which is the ratio between the maximum distortion of a structure and its length.

Ignoring the effects of underpinning and considering that No 1 Chester Gate is about 8m long, the proposed basement excavation will cause a deflection ratio across this house of about 0.02%, which, in combination with horizontal strains of about 0.06%, is likely to cause a damage to this house that can be classified just within the boundary of Category 1 (“very slight”) in the Category of Damage Chart (CIRIA C580) shown in Figure 10.

Additional cracks would occur around the party wall junctions of No.1 Chester Gate.

No. 2 Chester Gate would tend to tilt towards the new basement and could experience some cracks around the junctions and openings. The potential damage to this house could be classified as Category 1.

6.3 No. 5 Cambridge Terrace

As shown in Figures 8 and 9 the ground movements induced by the basement construction would tend to make this house tilt towards the new basement.

However, it is understood that the party wall with No. 6 is supported on piles and therefore it would not be significantly affected by the induced ground movements. The other walls, which are thought to be ground bearing, would experience some movements, but, given the stiffness of the house and the fact that it is part of a terrace, it is likely to experience some shearing across the walls. The expected potential damage would therefore be cracks around the junctions and the openings. It is not expected to be higher than Category 1.

6.4 Houses on Cambridge Terrace

Figures 8 and 9 show that the predicted ground movements are not expected to extend under these houses except on No.1, which could experience minor distortions. These are unlikely to cause damage higher than Category 0 (‘negligible’).

7 CONCLUSIONS

The impact of the proposed basement construction at No. 6-10 Cambridge Terrace on the surrounding structures has been estimated using empirical methods and experience.

Ground movements would be induced by the basement construction in the area around the site. The ground behind the walls would tend to settle and move horizontally as a result of the installation of retaining walls and basement excavation.

Assuming that the works would be carried out using good workmanship and with control and in dry ground conditions, the induced ground movements are expected to cause damage on the adjacent properties that can be classified as 'very slight' in the Damage Category Chart (CIRIA C580).

The party walls with the adjacent property No. 1-2 Chester Gate would tend to settle during the underpinning process and move back upwards after the basement is excavated and long term movements develop. These would cause additional cracks localised around the wall junctions.

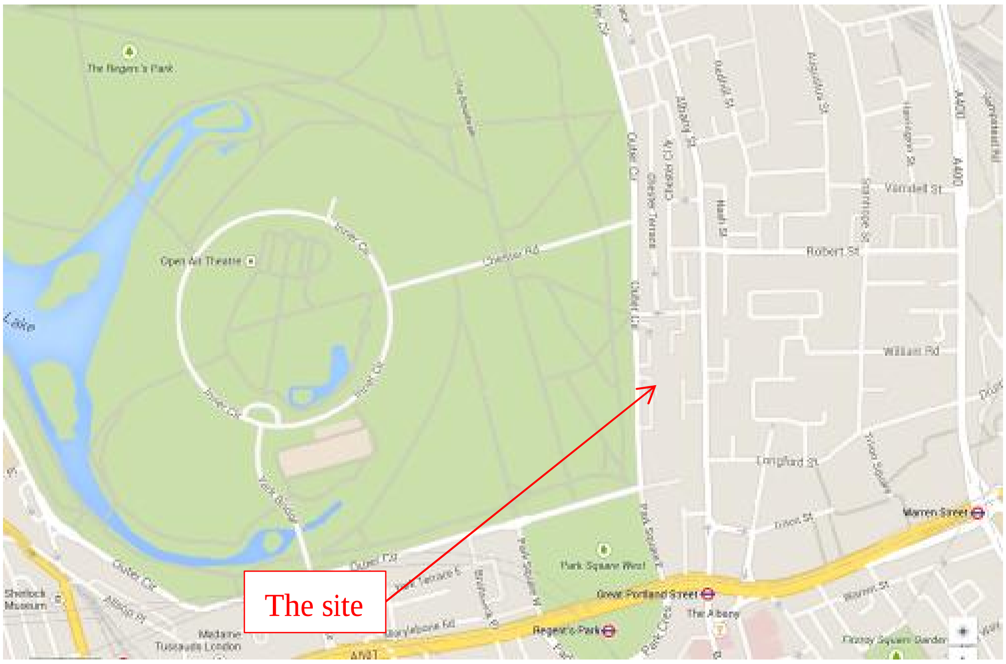
8 REFERENCES

Ball, R, Langdon, N and Creighton, M (2014); **'**Prediction of party wall movements using Ciria report C580'. Ground Engineering, September 2014.

CIRIA C580 Embedded Retaining walls – Guide for economic design

Geotechnical Consulting Group (2015) **-** Project Quad, hydrogeological report

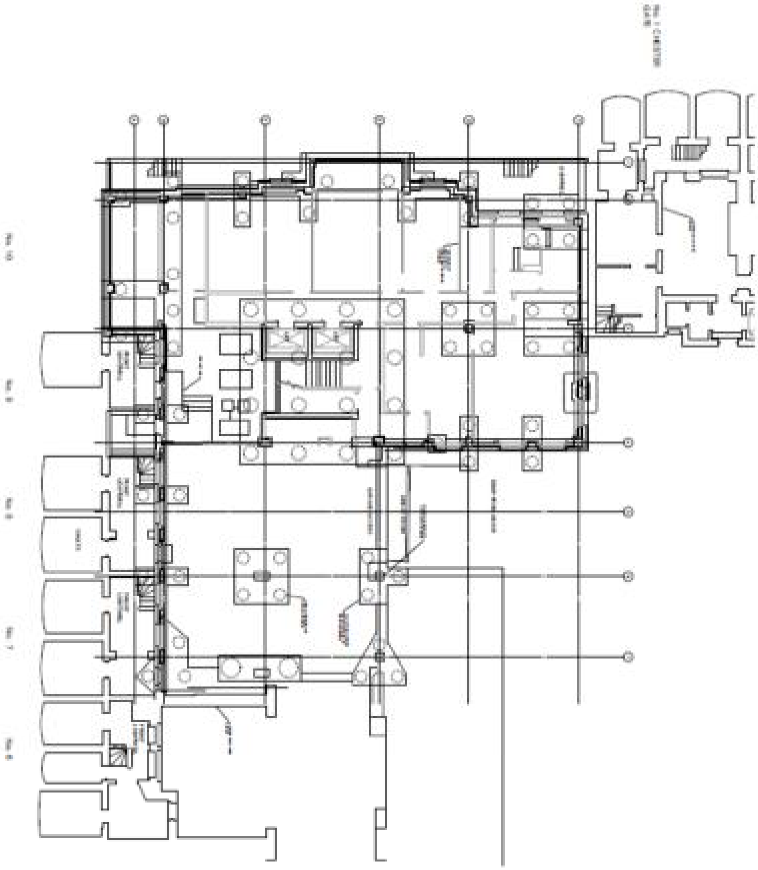
FIGURES



GCG	**Project Quad Limited** Project Quad	**Figure** **1**
	Site location The site	

(a)

(b)



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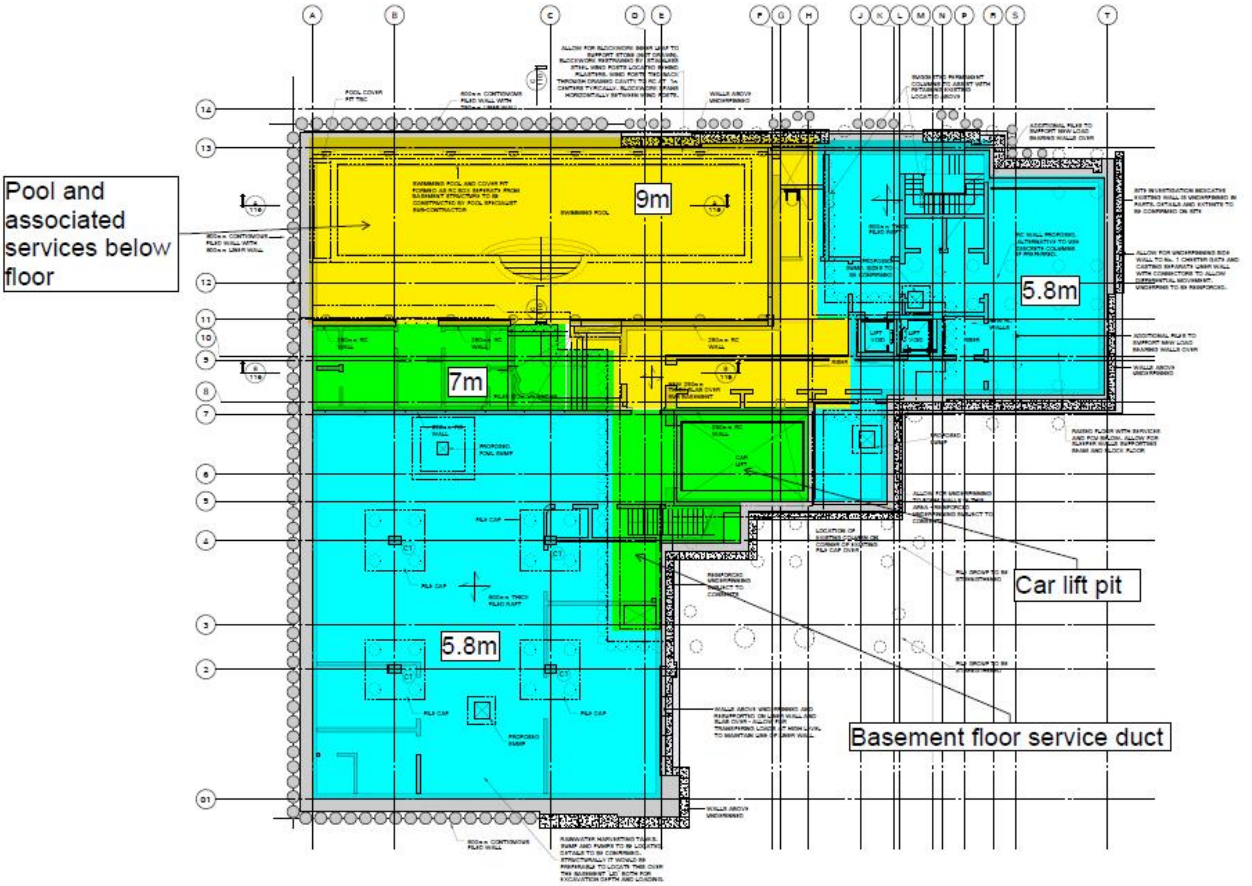
The existing structure

(a) Façade and (b) plan of lower ground floor

Figure

2



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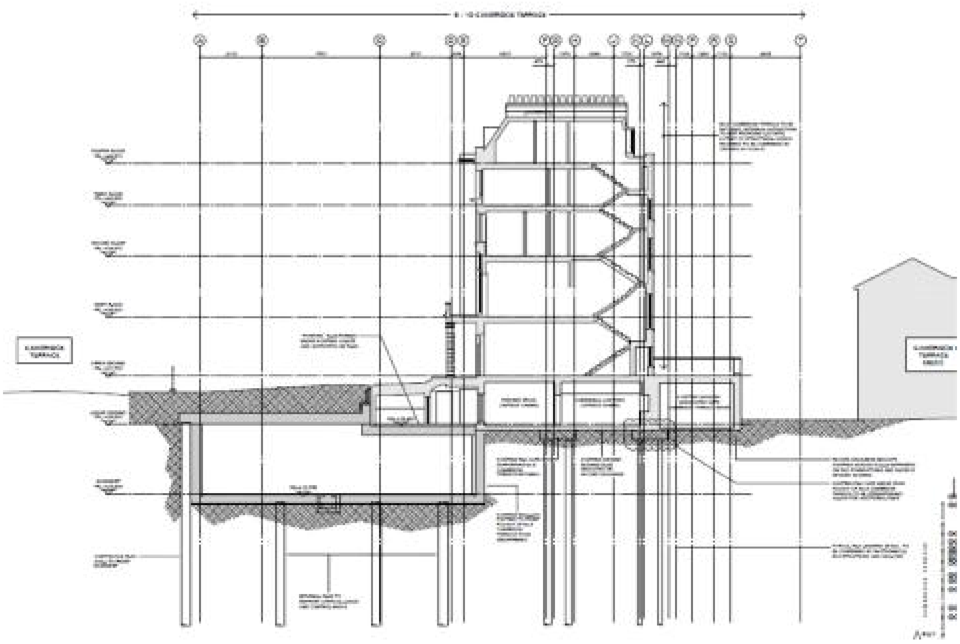
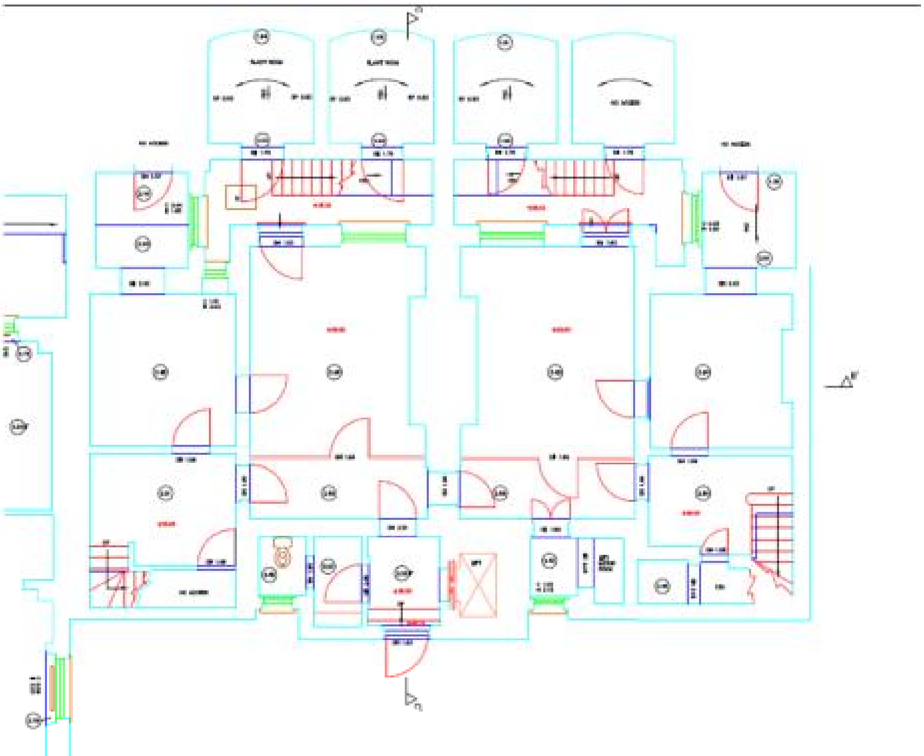


(b)

GCG	**Project Quad Limited** Project Quad	**Figure**
	The proposed structure (a) Plan of basement (b) typical cross section	**3**

(a)

(b)



Project Quad Limited

Project Quad

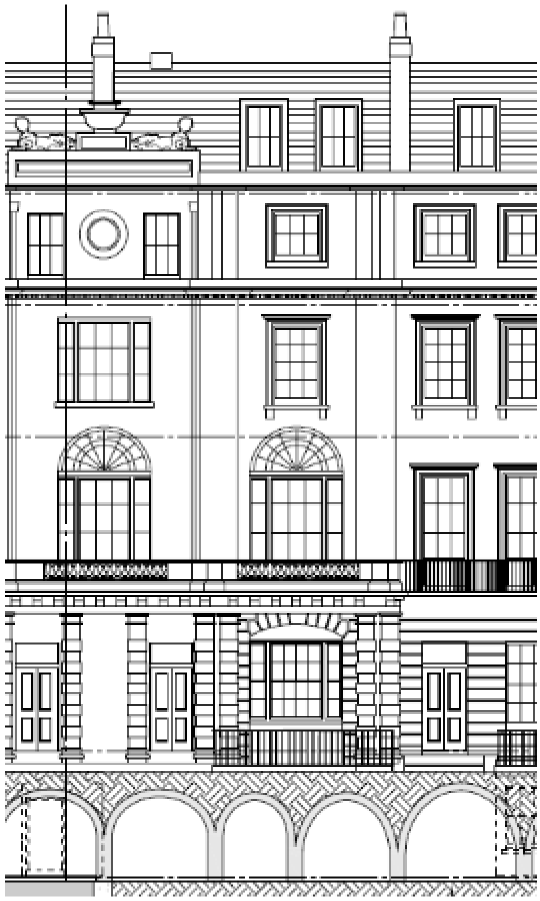
Structures around the basement- 1-2 Chester Gate

(a) Façade (b) plan of lower ground floor

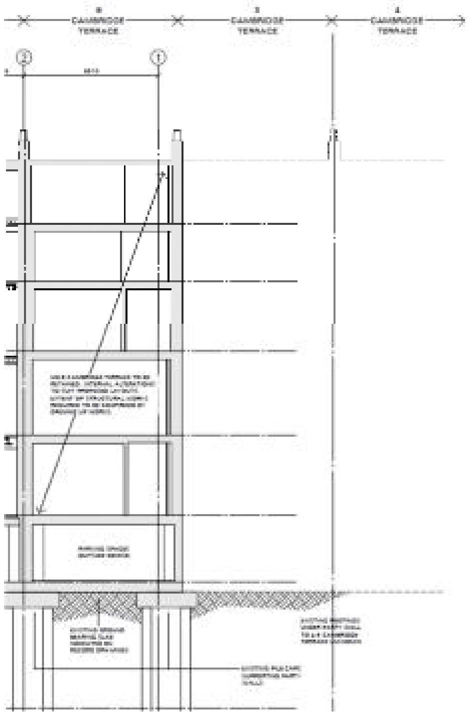
Figure

4

(a)



(b)



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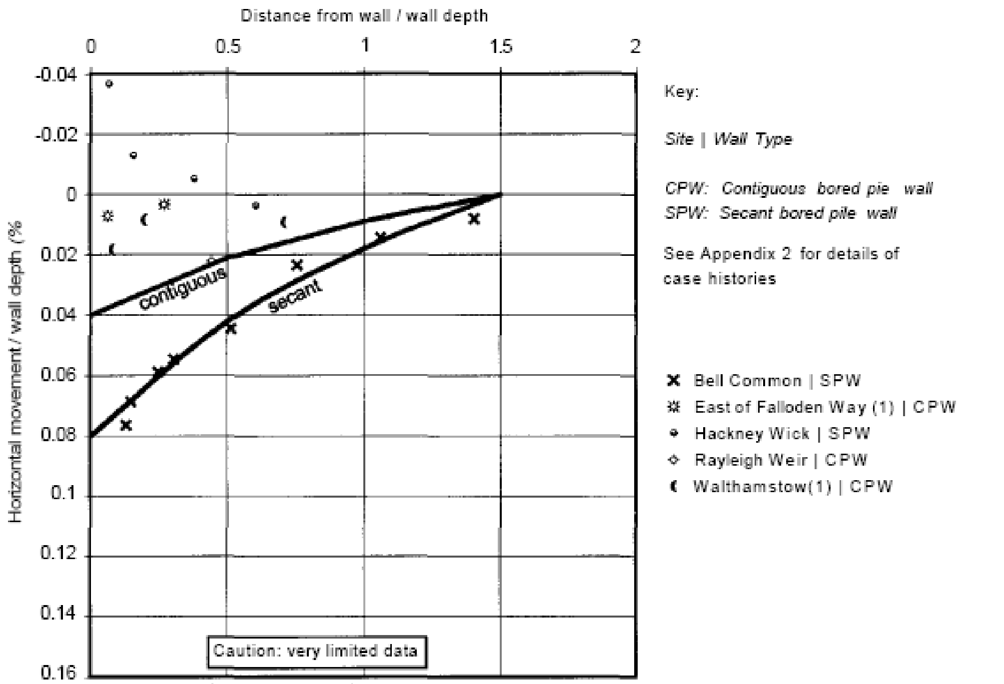
No 5 Cambridge Terrace

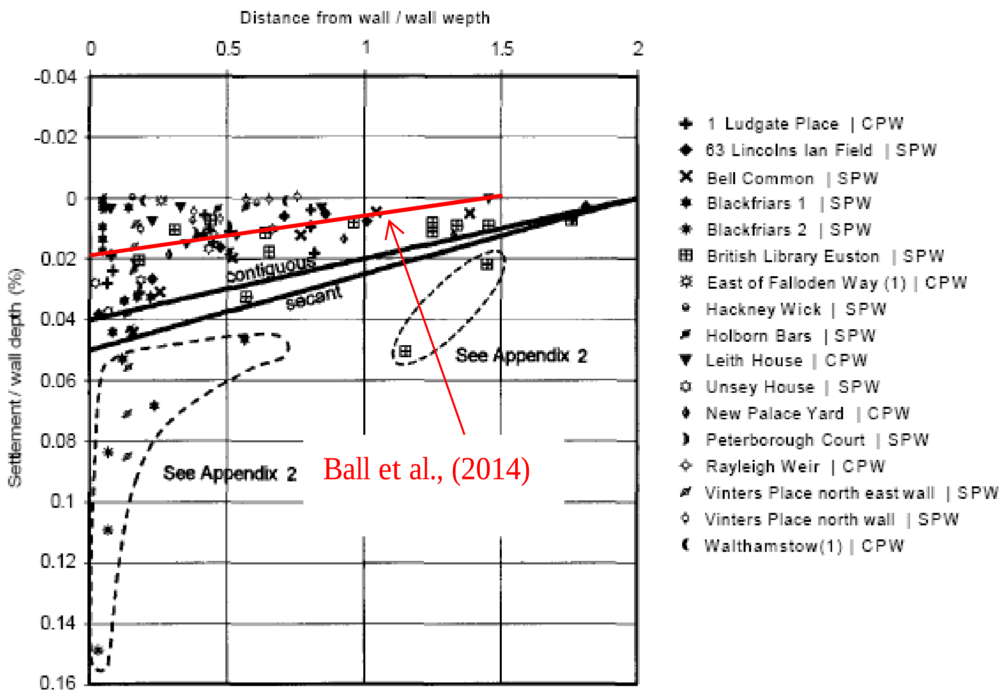
(a) Façade (b) Foundation system

Figure

5

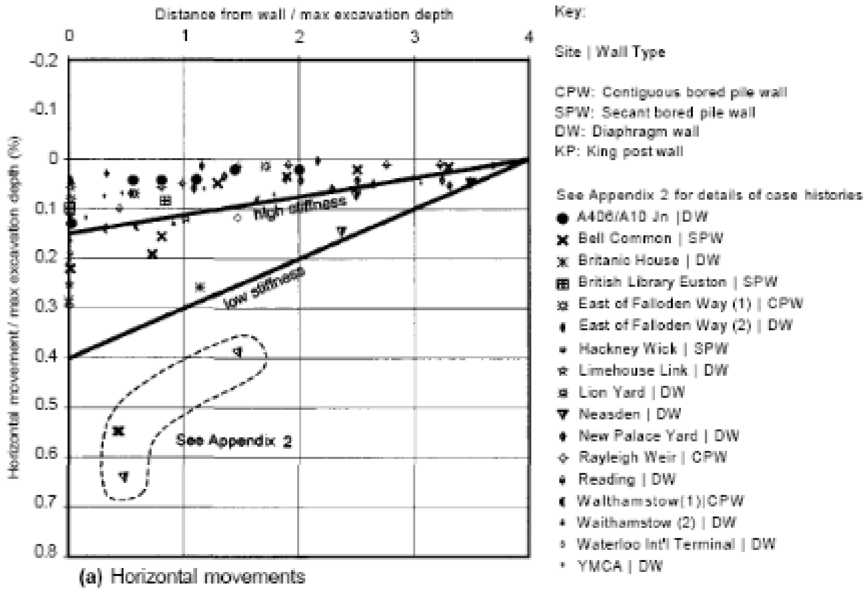


(a) Horizontal movements

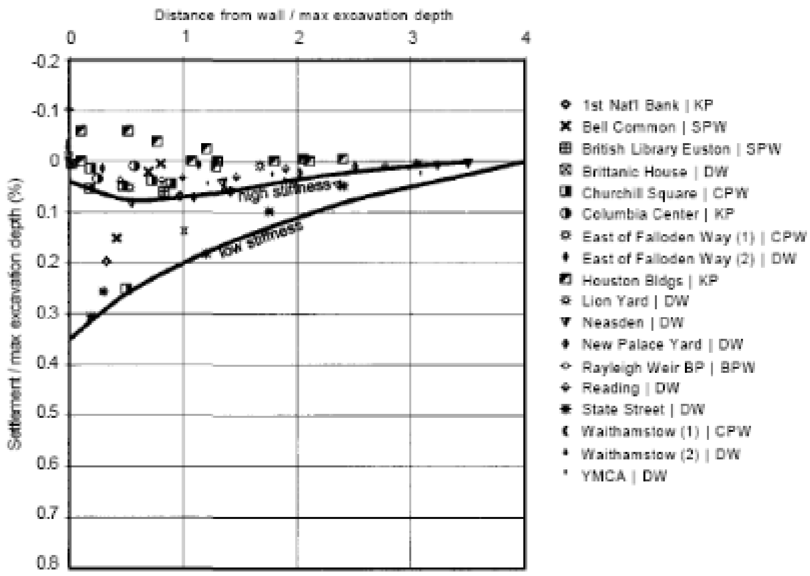


(b) Vertical movements

Project Quad Limited Project Quad		**Figure**
Field measurements of ground movements due to bored pile wall installation in stiff clay (CIRIA C580)		**6**



(a) Horizontal movements



(b) Vertical movements

	Project Quad Limited Project Quad	**Figure**
	Field measurements of ground movements due to excavation in front of wall in stiff clay (CIRIA C580)	**7**

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Ground movements induced around the site

Vertical movements due to basement excavation and installation of bored piles

Figure

8

GCG	**Project Quad Limited** Project Quad	**Figure**
	Ground movements induced around the site Horizontal movements	**9**

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.	

	Project Quad Limited Project Quad	**Figure**
	Damage Category Table, Ciria C580	**10**