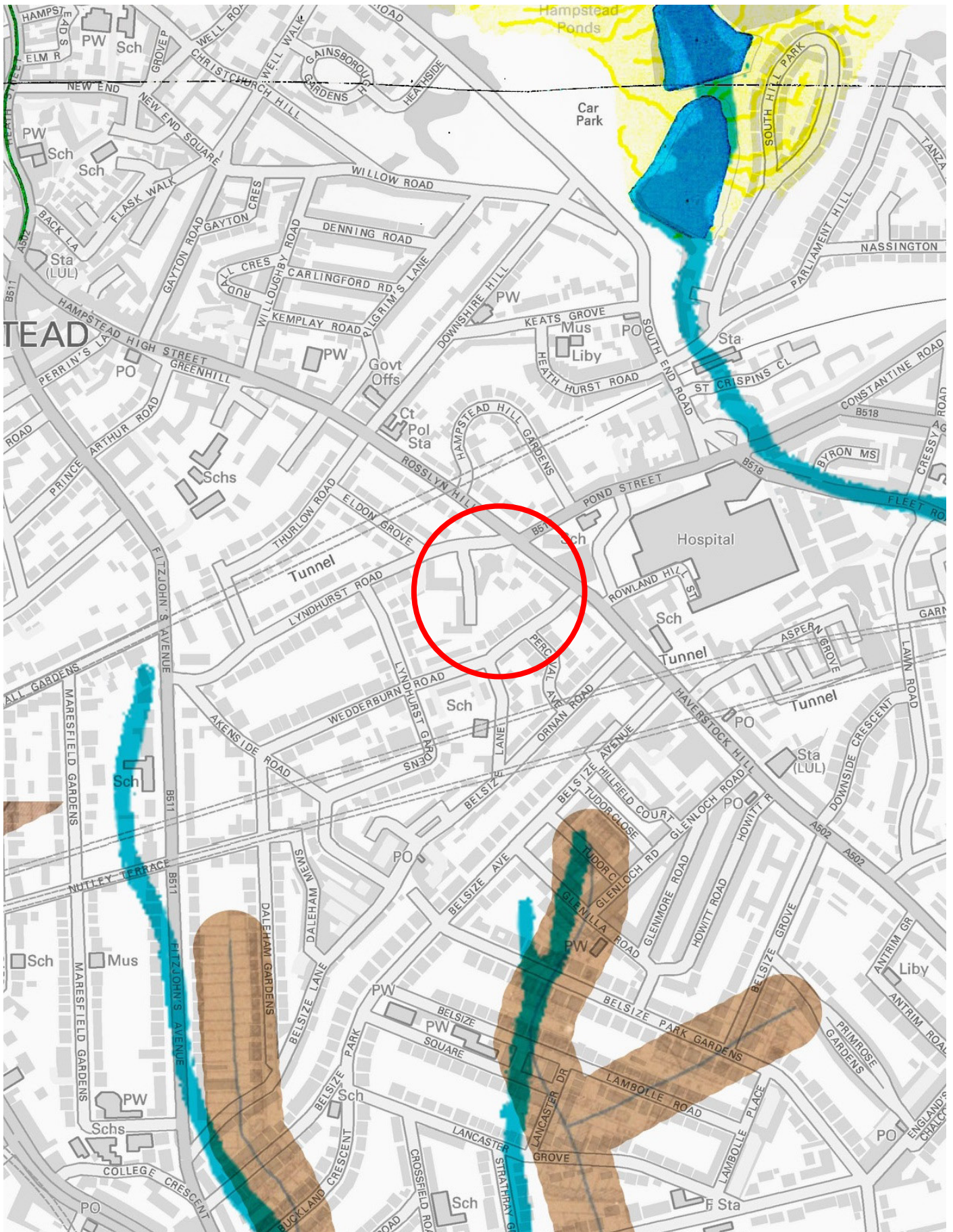


# Old water courses

Tyburn and Fleet



**Appendix H: Technical paper: Prediction of party wall movements using CIRIA report 580.**

# Prediction of party wall movements using Ciria report C580

Richard Ball and Nick Langdon, CGL Card Geotechnics, and Mark Creighton, Galliford Try Construction

## Summary

This paper presents a case study regarding the prediction of party wall movements using Ciria Report C580 – *Embedded retaining walls, guidance for economic design* for the cased small diameter continuous flight auger (CFA) piles that formed the basement box for a site in Pont Street, London.

Installation movements were determined based on Ciria C580 case study data for pile lengths which varied around the perimeter of the basement from 10m to 22m. Extensive monitoring was installed and monitored continuously during construction through 2011 and into 2012. The results are compared to original predictions and it is concluded that installation movement predictions from Ciria guidance can be significantly reduced for controlled contiguous piled wall installations with consequent benefits to party wall negotiations.

## Introduction

Many of the basements currently being constructed in London are directly adjacent to neighbouring properties with basement walls generally formed by piling or by underpinning party wall structures. Consequently they are subject to stringent party wall negotiations, and the calculation of ground movements and consequent prediction of building damage is critical.

This paper describes the construction of a piled two-storey basement in Pont Street, London, and provides a rationale for reducing predicted piled wall installation movements at the analysis stage. Monitoring data is provided demonstrating the veracity of this approach, and back analysis has been undertaken to better understand the relationship between predicted and actual ground movements.

Where basements are constructed using piled perimeter walls, a proportion of ground movement will occur due to the installation of the piles, through ground loss and elastic closure of the pile bore. Current best practice is based on Ciria report C580, which presents a historical data set for vertical and horizontal ground movements caused by piled wall installation, predominantly obtained from the London area.

Ciria C580 recommends an upper bound line for predicting ground movements of 0.04% of the wall depth. In the case of the Pont Street basement, this value gave rise to a prediction of

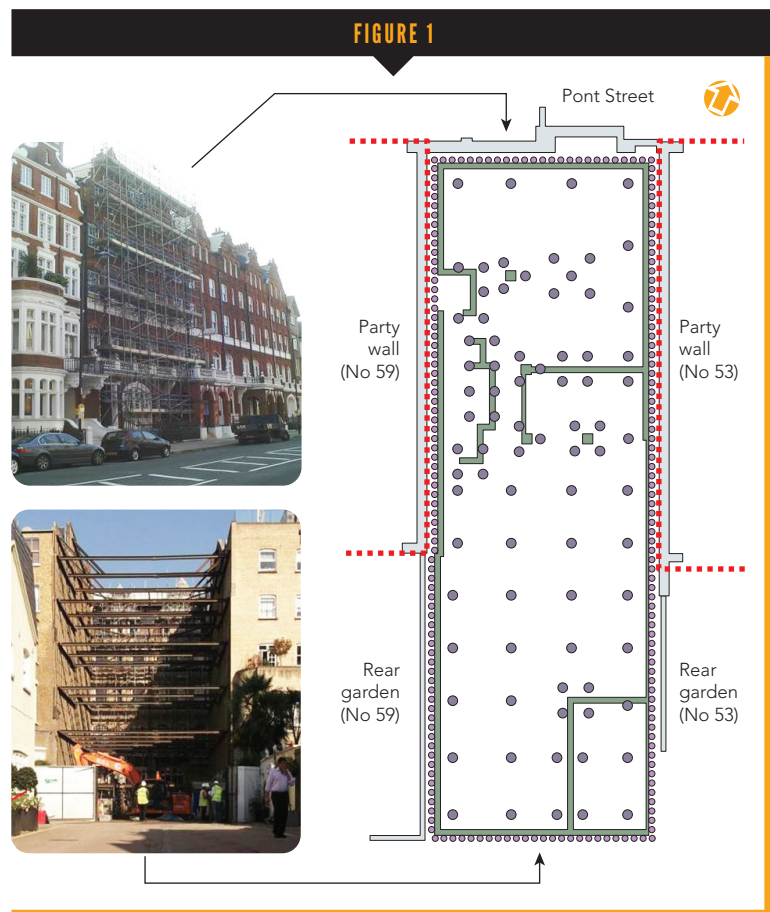
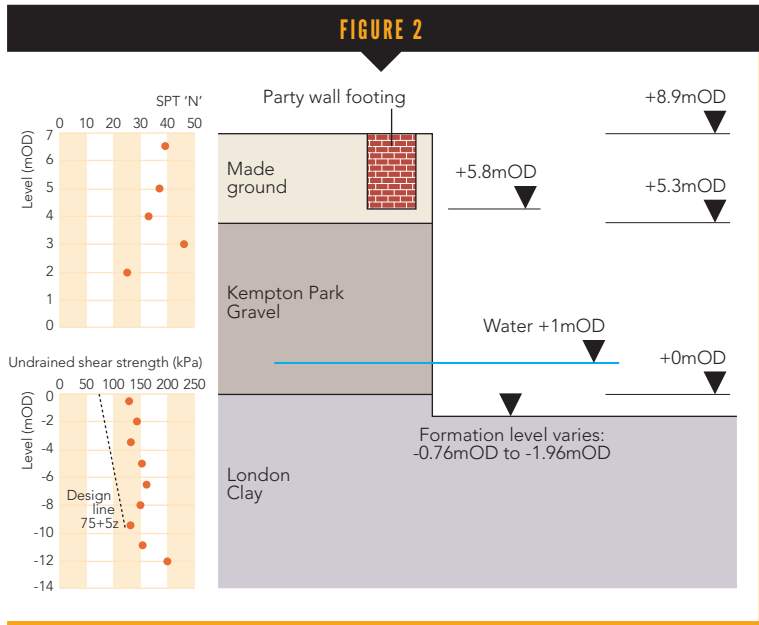


Figure 1 Site views and plan layout

unacceptable ground movements and building damage and this prompted a review.

This case study shows a value of 0.02% to be appropriate for a well-constructed piled wall in typical London ground conditions and presents monitoring data obtained throughout



the development to support this conclusion. It is recognised that good construction control was critical in realising this level of movement.

**Site description**

The site fronts onto Pont Street with Clabon Mews to the south and rear. The site was occupied by two mid-terrace Victorian properties five storeys high with a single basement level and mansard roof (see Figure 1). Party wall properties were of a similar style. The site is long and thin, extending some 40m back from its frontage on Pont Street, with an overall width of 12m.

**Ground conditions**

The ground conditions on site are summarised in Figure 2. They comprised made ground over dense River Terrace Gravels to a depth of 7.5m below the existing ground level, with the London Clay beneath this. Groundwater was recorded at the base of the River Terrace Gravels.

Figure 2  
Conceptual site model  
Figure 3  
Propping scheme (1st level) looking towards Pont Street



Access for the site investigation was severely restricted and intrusive works were limited to a single cable percussion borehole to 20m depth and a series of hand-excavated trial pits. The site investigation data was augmented by CGL Card Geotechnics with historical borehole records, both publicly available and from within CGL's private archive.

In addition, local case studies were consulted for guidance to establish the soil profile and requisite geotechnical design parameters.

Geotechnical design parameters are summarised in Table 1. Parameters for the made ground and gravels were derived from standard penetration testing (SPT) within the borehole, correlating uncorrected "N" values to friction angle based on the relation proposed by Peck et al (1967). The undrained shear strength of the London Clay was established by quick undrained triaxial testing on undisturbed U100 samples and a conservative design line was chosen to fit within the bounds of those published by Patel, 1992. Drained, effective stress parameters were selected with reference to (Burland et al, 2001). Plots of SPT N vs level and undrained shear strength vs level are presented in Figure 2.

**The scheme**

The scheme comprised the demolition of the existing properties while retaining the façade, with the construction of a single new building and double storey basement across the entire site footprint (Figure 3). The basement was excavated to a depth of between 9.7m to 10.9m below existing ground level (Figure 2) within a contiguous piled wall consisting of 300mm diameter

**TABLE 1: GEOTECHNICAL DESIGN PARAMETERS**

Stratum	Design Level (mbgl) [mOD]	gb (kN/m <sup>3</sup> )	Cu (kPa) [c']	f'	Eu (MPa) [E']
Made Ground	0 [7.5]	18	n/a	28	5 + 4z <sup>a</sup>
Kempton Park Gravel	1.7 [5.8]	19	n/a	37	40 + 5z <sup>a</sup>
London Clay	7.5 [0.0]	20	75 + 5z <sup>a</sup> [5]	24	50 + 5z <sup>b</sup> [40 + 4z] <sup>b</sup>

a. z = depth below surface of stratum

b. Based on Burland J B, Standing J R, and Jardine F M (eds), Building response to tunnelling, case studies from construction of the Jubilee Line Extension London, Ciria Special Publication 200



Figure 4 Piling rig at work within basement

bored piles. The wall was propped at capping beam level and at approximate mid-height during construction using hydraulic props pre-loaded to 200kN to 250kN into position to prevent “relaxation” on excavation.

Working room was severely restricted within the basement, (see Figure 4) and piling was undertaken with a 3.6t Klemm 701 rotary rig using a cased segmental flight auger (SFA) system. The SFA system allows restricted headroom working, with 1m long auger segments sequentially added to the auger string to achieve the required pile depth.

The piles were fully cased through the River Terrace Gravels into the top of the London Clay, limiting the potential for ground loss during boring and the casings were rotated into position to reduce ground vibrations. In addition, piles were installed on a “hit one miss three” basis, such that horizontal stress relief/ground movement never occurred concurrently on two adjacent piles.

Negotiations with engineers responsible for safeguarding the party wall (neighbouring) properties were complex given the value and proximity of the neighbouring properties and the number of party wall stakeholders. In total, 19 party wall awards were made and these required predicted building damage arising from ground movements to fall within “Building Damage Category 1” or “very slight” damage in accordance with the classification scheme proposed by Burland (1974), and later modified by Boscardin and Cording (1989). In addition, an extensive monitoring system was required to be included in the construction process with regular monitoring against agreed movement trigger limits.

#### Predicted ground movements

Ground movements due to installation were predicted based on the proposed pile lengths, which varied around the

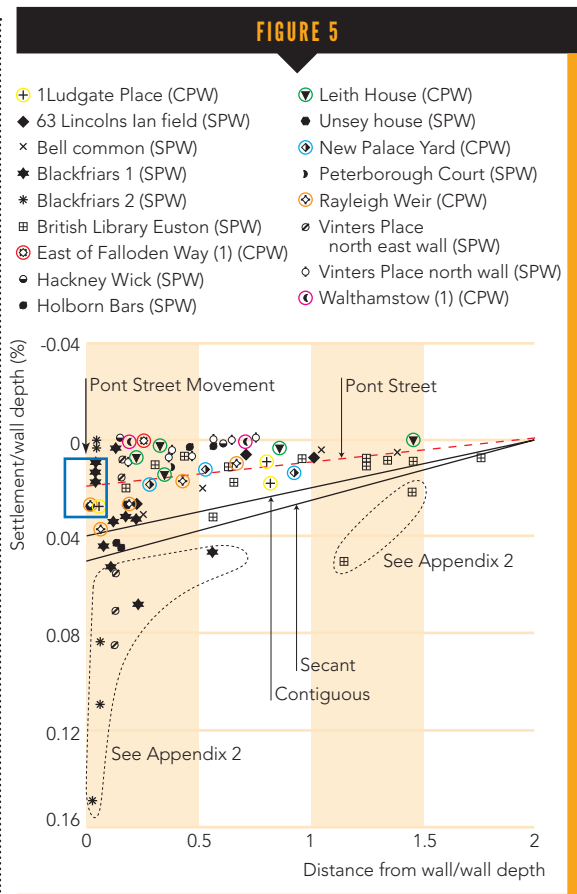


Figure 5 Case study data CIRIA C580 – with authors’ rationalisation

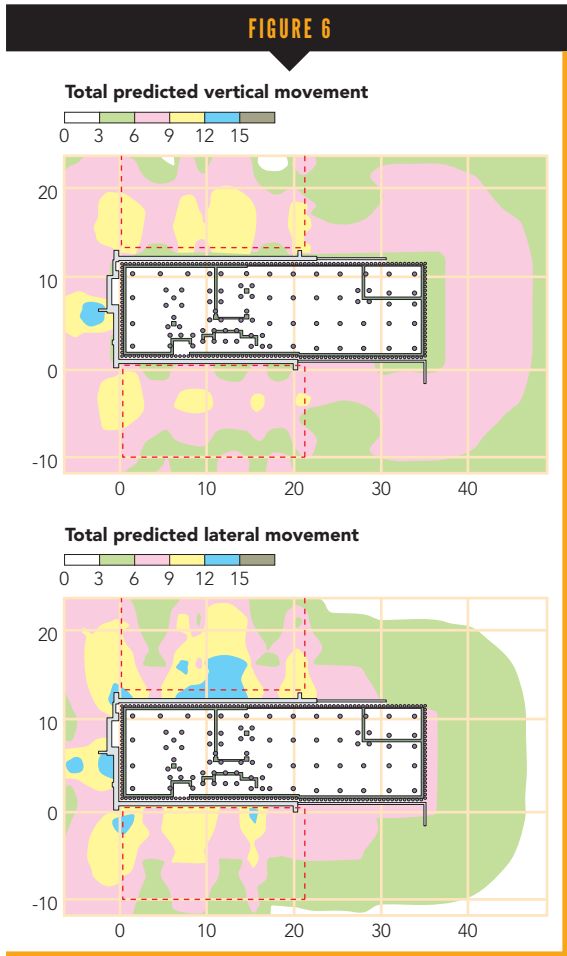


Figure 6 Predicted ground movements (total)

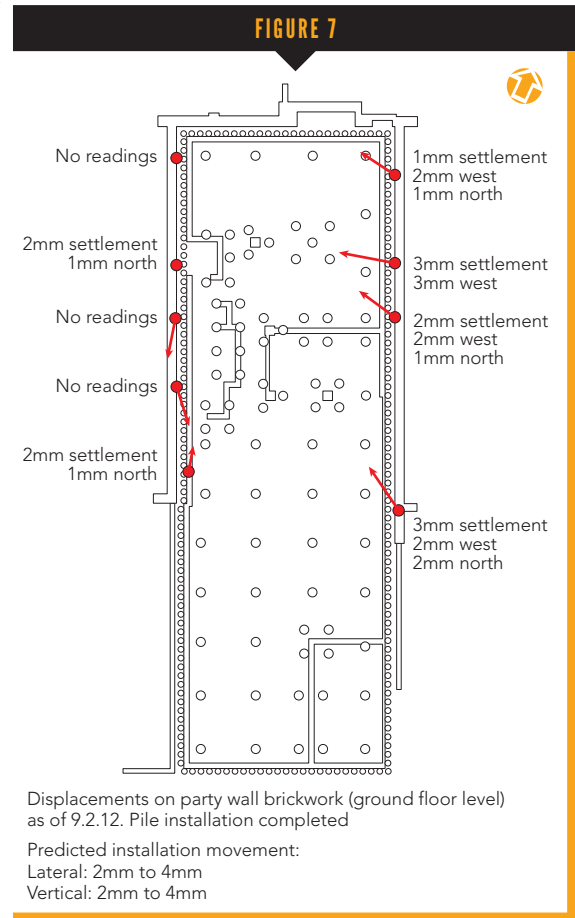


Figure 7 Monitored movements due to pile installation

perimeter of the basement from a general length of 10m, to up to a maximum of 22m where superstructure column loads were picked up on sections of basement wall. These pile lengths resulted in predicted ground movements (based on an installation movement of 0.04% pile length) of between 4mm and 9mm, giving rise to predicted Building Damage Categories in excess of the requisite “Category 1” criterion. This led to a requirement to rationalise and control movements derived from the installation of the piled wall.

Ground movement due to pile installation is thought to occur through ground loss during boring in granular deposits, with a potential additional component of movement derived from vibrational compaction. In clay soils, such as the London Clay, additional movement can potentially be developed by the bores caused by a relaxation of horizontal stresses (Bowles 1988). Given the depth of the London Clay on site, movements within the gravels were more critical and it was considered that these could be considerably reduced by casing through this stratum and by adopting the hit one miss three methodology described above.

Furthermore, the Ciria case study data was reviewed more critically: Ciria C580 compiles case study data from the installation of contiguous and secant piled walls. A total of 26 case studies are reported, and the ground conditions in each

comprise a thickness of superficial deposits (alluvium, Terrace Gravels, made ground, glacial till) overlying the London Clay. The data is not sensitised to the proportion of gravels over the London Clay, and are based rather on “typical” ground conditions. It was considered the Pont Street site was not untypical with regard to the data.

The authors reviewed the case study data published in Ciria C580 and noted that for the installation of contiguous piled walls in ground conditions similar to those at Pont Street, a reasonable argument could be made for halving these movements to 0.02% of the pile length.

The 0.04% design value shown in Ciria C580 was clearly an “upper bound” value for all pile types (see Figure 5). Further to this, the new piles were to be cased through the near surface gravels, which was not a common process during the assembly of the Ciria data from the 1980s and early 1990s.

This argument was adopted for the ground movement analysis, reducing predicted installation movements to between 2mm and 4.5mm, reducing the predicted Building Damage Category to Category 1 and thereby having the potential to satisfy the requirements for party wall agreement.

A stringent monitoring scheme was specified, implemented alongside the controlled piling methodology previously described.

### Geotechnical analysis

Predicted installation ground movements were combined with a retaining wall analysis and heave analysis to determine overall predicted ground movements at the location of the party wall foundations. The results are summarised in Figure 6 and were used to determine trigger limits against which monitoring was undertaken. This data is provided for completeness; however, this paper is concerned primarily with ground movements caused by the installation of the piled walls.

### Monitoring

The site was monitored comprehensively to an accuracy of +/-2mm with a Leica TS30 Motorised Total Station and Leica DNA03 precision digital level. Eighty retro targets were fixed to the party wall structures and the basement capping beam, monitored weekly by an independent surveying company.

### Recorded ground movements

Monitoring results are summarised in Figure 7, from targets installed on the party wall brickwork at approximately ground-floor level. The vectors show movements at the end of basement wall installation and prior to any excavation taking place. Settlement is recorded as being generally between 1mm to 3mm, with lateral movements of a similar order. These values agree well with the predicted installation movements of between 2mm and 4.5mm.

Monitored movements have been normalised by pile length and are summarised in Table 3. Table 3 includes normalised movements accounting for the worst error combination in readings (provided in square brackets), giving the maximum range of normalised movements.

It can be seen from the data presented that normalised installation movements for the site are on average of 0.01% of pile length. Allowing for the worst combination of errors (for example, a systematic error in the monitoring equipment) gives an average of 0.023% pile length. As this is very unlikely, it is considered that the results are generally consistent with the rationalised approach set out by the authors based on 0.02% of wall depth.

### Conclusions

This paper provides a case study demonstrating that with good construction control, piled wall installation movements can be restricted to 0.02% of wall length, providing a significant reduction in predicted ground movements over the commonly adopted upper bound limit of 0.04% as published in Ciria C580.

It is noted in Ciria C580 that “the magnitude of ground movements depends upon the quality of workmanship. Large local ground movements can be expected where construction problems are encountered”.

In this context the authors would suggest that 0.02% wall length for contiguous wall installation is a reasonable design value where construction controls – such as cased CFA piling and hit and miss construction – are put in place from an early stage with rigorous monitoring methodologies set against rationally derived trigger limits. All parties must be made aware of the potential risks to party wall properties, and all construction activities considered within the background of potential ground movements.

**TABLE 2: RECORDED PILE INSTALLATION MOVEMENTS NORMALISED AGAINST PILE LENGTH**

	Horiz/pile length (%)	Vert/pile length (%)
Location	[measurement error +/- 2mm]	
A2	0.006 - [0.023]	0.013 - [0.025]
A4	0.006 - [0.021]	0.012 - [0.023]
E1	0.011 - [0.025]	0.005 - [0.015]
E2	0.014 - [0.025]	0.014 - [0.023]
E2.5	0.012 - [0.027]	0.011 - [0.022]
E4	0.012 - [0.018]	0.013 - [0.022]

### Acknowledgements

The authors would like to thank their colleagues in Galliford Try and CGL together with the other members of the design and construction teams who have assisted in the collation of this data and the successful outcome of the project.

### References

- Gaba et al (2003). Ciria C580, *Embedded retaining walls – guidance for economic design*
- Fernie et al (2003). *Movement and deep basement provision at Knightsbridge Crown Court, Harrods, London, in Ciria Special Publication 199, Response of buildings to excavation-induced ground movements.*
- Peck, RB; Hanson, WE; and Thornburn, TH (1967) *Foundation Engineering*, 2nd edition. John Wiley, New York, p310.
- Patel, D (1992). *Interpretation of results of pile tests in London Clay, Proceedings of the conference of piling in Europe. Institution of Civil Engineers.*
- Burland, JB; Standing, JR; Jardine, FM (2001). *Building response to tunnelling, case studies from construction of the Jubilee Line Extension, London, Volume 1: Projects and Methods, Ciria special publication 200*
- Burland, JB; Wroth, CP (1974). *Settlement of buildings and associated damage, State of the art review. Conf on Settlement of Structures, Cambridge, Pentech Press, London, pp611-654*
- Boscardin, MD; Cording, EG (1989). *Building response to excavation induced settlement. J Geotech Eng, ASCE, 115 (1); pp 1-21.*
- Bowles, JE (1988). *Foundation Analysis and Design, 4th edition, McGraw-Hill International*

**Appendix I: Updated assessment of predicted ground movements and damage assessment for adjacent buildings based on CIRIA report 580 and technical paper.**



Date	JUN 15	Job no.	1693/11	Sheet	0.1
Engineer	RWa				
Checked by	DZ				
Project		No 11 ROSSLYN HILL			

GROUND MOVEMENT PREDICTIONS IN ACCORDANCE WITH CIRIA 580  
 & A TECHNICAL PAPER BY BALL & LANGDON (2014, GROUND  
 ENGINEERING).

THESE CALCULATIONS LOOK AT THE RESULTS OF GROUND  
 MOVEMENTS DUE TO PILES. BALL ET AL STATES CIRIA 580  
 TAKES AN OVER CONSERVATIVE ESTIMATE ON GROUND  
 MOVEMENTS DUE TO THE INSTALLATION OF PILED WALLS.  
 FIGURE 2.8 (ATTACHED) TAKES AN UPPER BOUND LIMIT OF  
 0.04 %. ADDITIONAL EMPIRICAL DATA SET OUT IN BALL  
 SUGGEST TAKING 0.02 % IS MORE REALISTIC

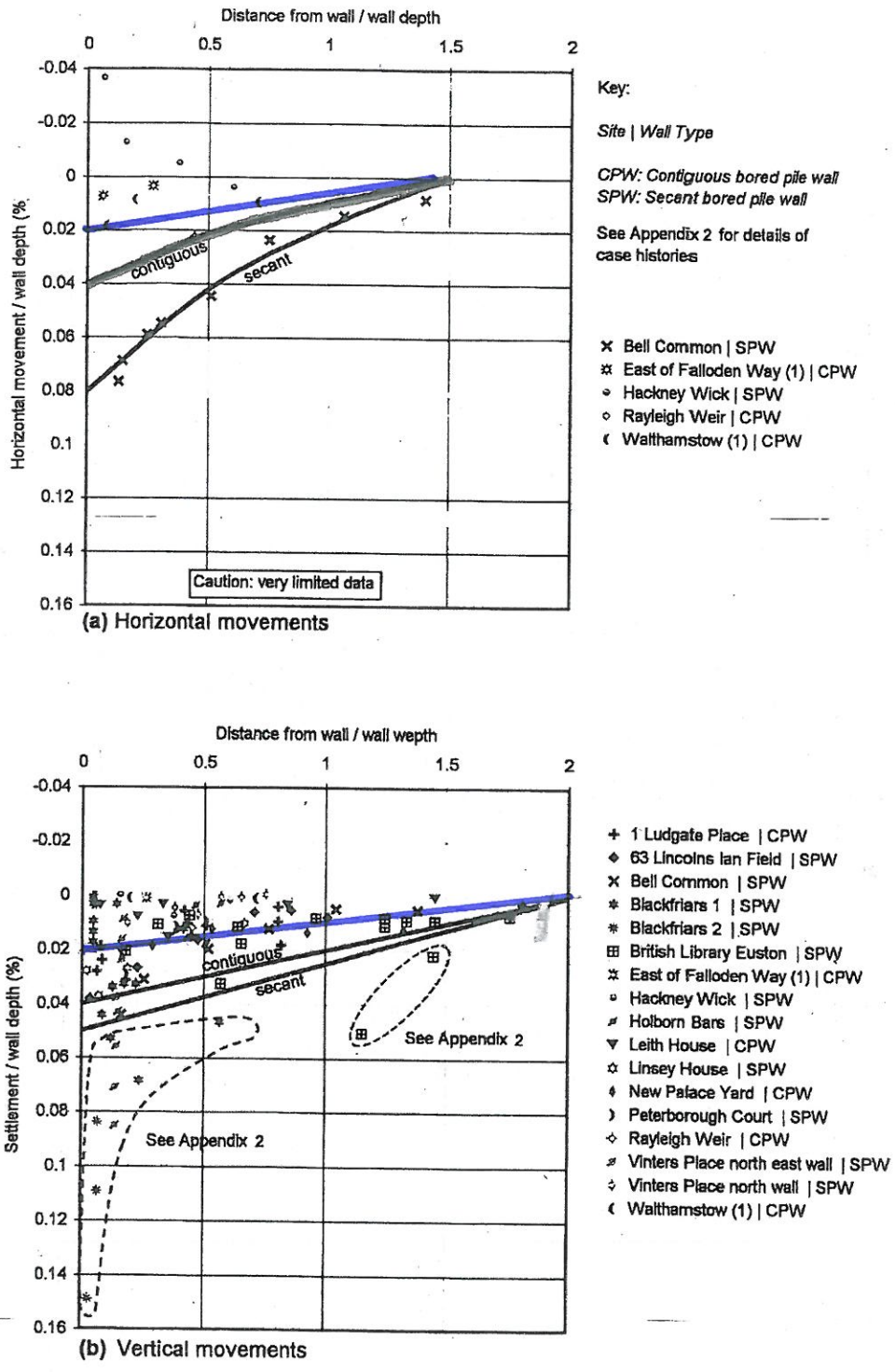
THE MOVEMENTS DUE TO PILED WALLS WILL TAKE THIS  
 INTO CONSIDERATION.

PILE DEPTH = 18m

DISTANCE FROM FACE OF WALL (m)	MOVEMENT DUE TO PILE INSTALLATION	
	HORIZONTAL (mm)	VERTICAL (mm)
0	3.60	3.6
1	3.40	3.40
5	3.10	3.15
10	2.25	2.75
15	1.35	1.8
20	1.05	1.30

Date	MARCH 15	Job no.	1692/01	Sheet	1
Engineer	R. Lee				
Checked by	JL				
Project	No 11 Rosslyn Hill				

B1A



**Figure 2.8** Ground surface movements due to bored pile wall installation in stiff clay

# Alan Baxter

75 Cowcross Street  
 London EC1M 6EL  
 tel 020 7250 1555  
 email aba@alanbaxter.co.uk  
 www.alanbaxter.co.uk

Date JUN 15	Job no.	Sheet
Engineer RWA	1693/11	0.2
Checked by DL		
Project No 11 Rosslyn Hill		

INITIAL GROUND MOVEMENTS DUE TO EXCAVATION OF  
 THE BASEMENT WAS CALCULATED IN ACCORDANCE WITH CIRIA S80.  
 THIS HAS BEEN DONE FOR EACH DEPTH OF BASEMENT.  
 REFER TO FIGURE 2.11

DISTANCE FROM WALL	MOVEMENTS (mm)	
	H	V
0	11.25	1.98
1	10.5	2.00
5	9.00	6.00
10	7.5	4.45
15	6.75	2.00
20	3.75	0.75
25	3.00	0.37
30	0.00	0.00

7.5m DEEP

DISTANCE	MOVEMENT (mm)	
	H	V
0	9.75	1.62
1	7.80	3.90
5	7.15	4.87
10	5.20	2.60
15	3.25	1.30
20	1.3	0

6.5m DEEP

# Alan Baxter

75 Cowcross Street  
 London EC1M 6EL  
 Tel 020 7250 1555  
 email aba@alanbaxter.co.uk  
 www.alanbaxter.co.uk

Date	JUN '15	Job no.	1693/P1	Sheet	0.3
Engineer	RWJ				
Checked by	DZ				
Project	No 11 Koslyn Hill				

DISTANCE FROM WALL

MOVEMENT (mm)  
H V

5.5m DEEP

0	8.25	1.37
1	6.60	4.40
5	6.05	4.70
10	4.40	2.20
15	2.20	0.25
20	1.10	0.00

DISTANCE FROM WALL

MOVEMENT (mm)  
H V

4.5m DEEP

0	6.75	1.12
1	5.89	2.25
5	4.95	3.15
10	2.70	0.45
15	0.65	0.00

DISTANCE FROM WALL

MOVEMENT (mm)  
H V

3.5m DEEP

0	5.3	0.88
1	4.5	2.80
5	3.15	1.75
10	1.4	0.35

Date	14/01/10	Job no.	1693/01	Sheet	-
Engineer	RWA	Checked by	JH		
Project					
Nell Rossignol Hill					

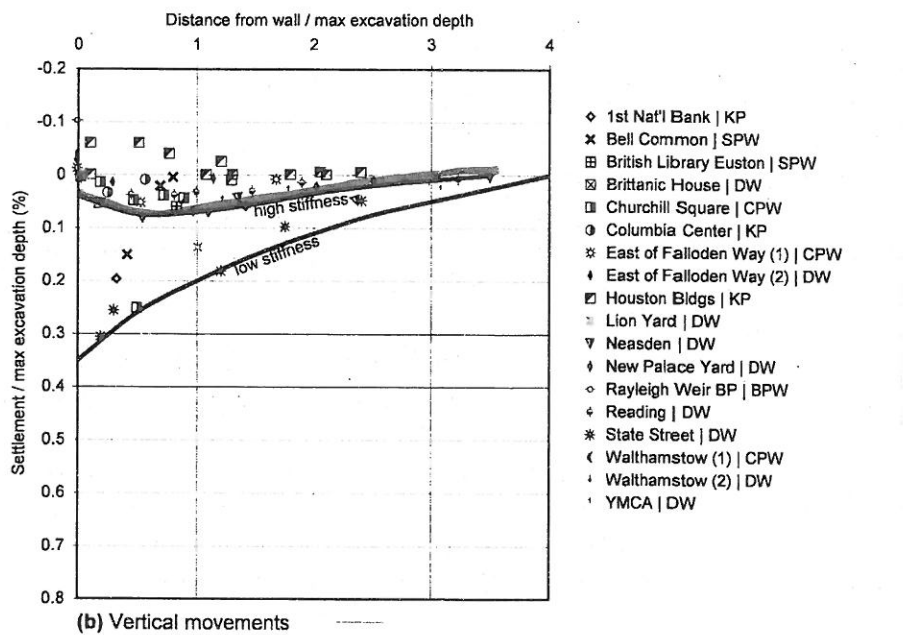
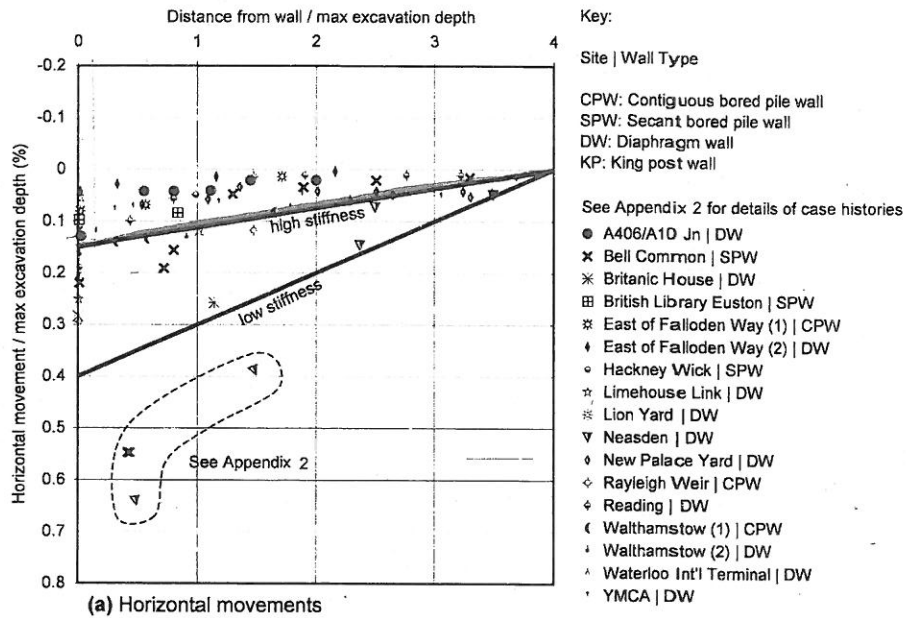


Figure 2.11 Ground surface movements due to excavation in front of wall in stiff clay

# Alan Baxter

75 Cowcross Street  
 London EC1M 6EL  
 tel 020 7250 1555  
 email aba@alanbaxter.co.uk  
 www.alanbaxter.co.uk

Date	Jun 15	Job no.	1693/01	Sheet	0.4
Engineer	RWa				
Checked by	DZ				
Project	No.11 Rosslyn Hill				

THESE MOVEMENTS (DUE TO THE INSTALLATION OF THE PILE WALL & EXCAVATION HAVE BEEN COMBINED) THE MOVEMENTS HAVE BEEN PLOTTED AS CONTOURS TO ALLOW THE DUE TO DAMAGE CATEGORY TO BE DETERMINED.

## COMBINED MOVEMENTS

DISTANCE	MOVEMENT (mm)	
	H	V
0	14.85	5.48
1	13.9	5.4
5	12.1	9.15
10	9.75	7.2
15	8.1	3.8
20	4.83	2.05
25	3	0.00

7.5m DEEP

DISTANCE	MOVEMENT (mm)	
	H	V
0	13.35	5.22
1	11.2	2.5
5	10.25	8.02
10	7.45	5.35
15	4.6	3.1
20	2.38	1.3

6.5m DEEP

# Alan Baxter

75 Cowcross Street  
London EC1M 6EL  
tel 020 7250 1555  
email aba@alanbaxter.co.uk  
www.alanbaxter.co.uk

Date JUN 15	Job no.	Sheet
Engineer RWA	1693/11	0.5
Checked by DZ		
Project No 11 Rosslyn Hill		

DISTANCE

MOVEMENT (MM)

5.5m DEEP

	H	V
0	11.85	4.98
1	10	7.8
5	9.15	7.85
10	6.65	4.95
15	3.55	2.08
20	2.18	1.3

DISTANCE

MOVEMENT (MM)

4.5m DEEP

	H	V
0	10.35	4.73
1	9.29	5.65
5	8.05	6.37
10	4.95	3.2
15	1.8	1.8
20	1.08	0.00

# Alan Baxter

75 Cowcross Street  
London EC1M 6EL  
tel 020 7250 1555  
email aba@alanbaxter.co.uk  
www.alanbaxter.co.uk

Date	JUN 15	Job no.	1693/11	Sheet	0.6
Engineer	RWA				
Checked by	DZ				
Project	No.11 Rosslyn Hill				

DISTANCE

MOVEMENT

3.5m DEEP

	H	V
0	8.9	4.48
1	7.9	6.2
5	6.25	4.9
10	3.65	3.1
15	1.35	1.8
20	1.08	1.3

FROM THE COMBINED MOVEMENTS THE DAMAGE  
CATEGORY CAN THEN BE DETERMINED.



# Alan Baxter

75 Cowcross Street  
 London EC1M 6EL  
 tel 020 7250 1555  
 email aba@alanbaxter.co.uk  
 www.alanbaxter.co.uk

Date	JUN 15	Job no.	1693/11	Sheet	0.7
Engineer	R. Khan				
Checked by	DZ				
Project		No. 11 ROSSLYN HILL			

## VERTICAL STRAINS DUE TO MOVEMENTS

	$\Delta$ mm	$L$ m	$\Delta/L$ %
LYNDHURST	3.5 mm	17.	0.029
ROSSLYN	0.9 mm	8	0.01
GARAGES	2.5 mm	5	0.05

## HORIZONTAL STRAIN DUE TO MOVEMENTS

		$\Delta s_h$	$\Delta s_h/L$ %
LYNDHURST	@ 1m $\Delta h_e = 10.5$ mm	@ 15m $\Delta h_z = 6.75$ mm $\Rightarrow$ 3.5 mm	0.031
ROSSLYN	@ 1m $\Delta h_e = 3$ mm	@ 10m $\Delta h_z = 1.5$ mm $\Rightarrow$ 1.5 mm	0.015
GARAGES	@ 1m $\Delta h_e = 1.5$ mm	@ 6m $\Delta h_e = 9$ mm $\Rightarrow$ 2.5 mm	0.050

FROM TABLE 2.5.

LYNDHURST HALL	= BURLAND DAMAGE CAT	0 NEGIGIBLE
No. 11 ROSSLYN	= BURLAND DAMAGE CAT	0 NEGIGIBLE
GARAGES	= BURLAND DAMAGE CAT	1 VERY SLIGHT

**Appendix J: Plan and sections showing relationship between Lyndhurst Hall and proposed basement extensions.**