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28 Charlotte Street, London

Impact Assessment for Proposed Underpinning Works

For: Anderson Consulting Engineers

Job No: 1013857

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Client:	Anderson Consulting Engineers
Report Title:	Impact Assessment for Proposed Underpinning Works
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1. Introduction

1.1 Context

Cundall Johnston & Partners LLP (Cundall) has been appointed by Anderson Consulting Engineers (ACE) to provide geotechnical engineering advice relating to the formation of a single level of basement at 28 Charlotte Street, London. The development site forms part of a terraced apartment block and impacts to adjoining structures will need to be evaluated in accordance with Camden Planning Guidance on Basements and Lightwells (CPG4).

1.2 Objectives and Scope of Assessment

The report summarises potential ground movements resulting from the formation of a single level of basement at 28 Charlotte Street and evaluates the impact of these movements on adjacent structures at 30 and 32 Charlotte Street.

It should be noted that the Local Authority may require submission of a ‘basement impact assessment’ in connection with the proposed development, and that this report, in itself, will be insufficient for satisfying this requirement.

This report does not consider the stability of existing foundations during the excavation and underpinning works.

1.3 References

This report has been prepared (in part) using information from the following sources:

- ACE (2016) Construction Method Statement for 28 Charlotte Street, Fitzrovia, London, WIT 2NF.
- Burland (1996) Prediction of ground movements and assessment of risk of building damage due to bored tunnelling , Geotechnical Aspects of Underground Construction in Soft Ground, ISBN 9054108568.
- Chelmer (2016) Factual Report on Ground Investigation at 28 Charlotte Street, London, Report Reference FACT/6262-REV1.
- ITA/AITES (2007) Settlement Induced by Tunnelling in Soft Ground, Tunnelling and Underground Space Technology, Volume 22, Pages 119-149.

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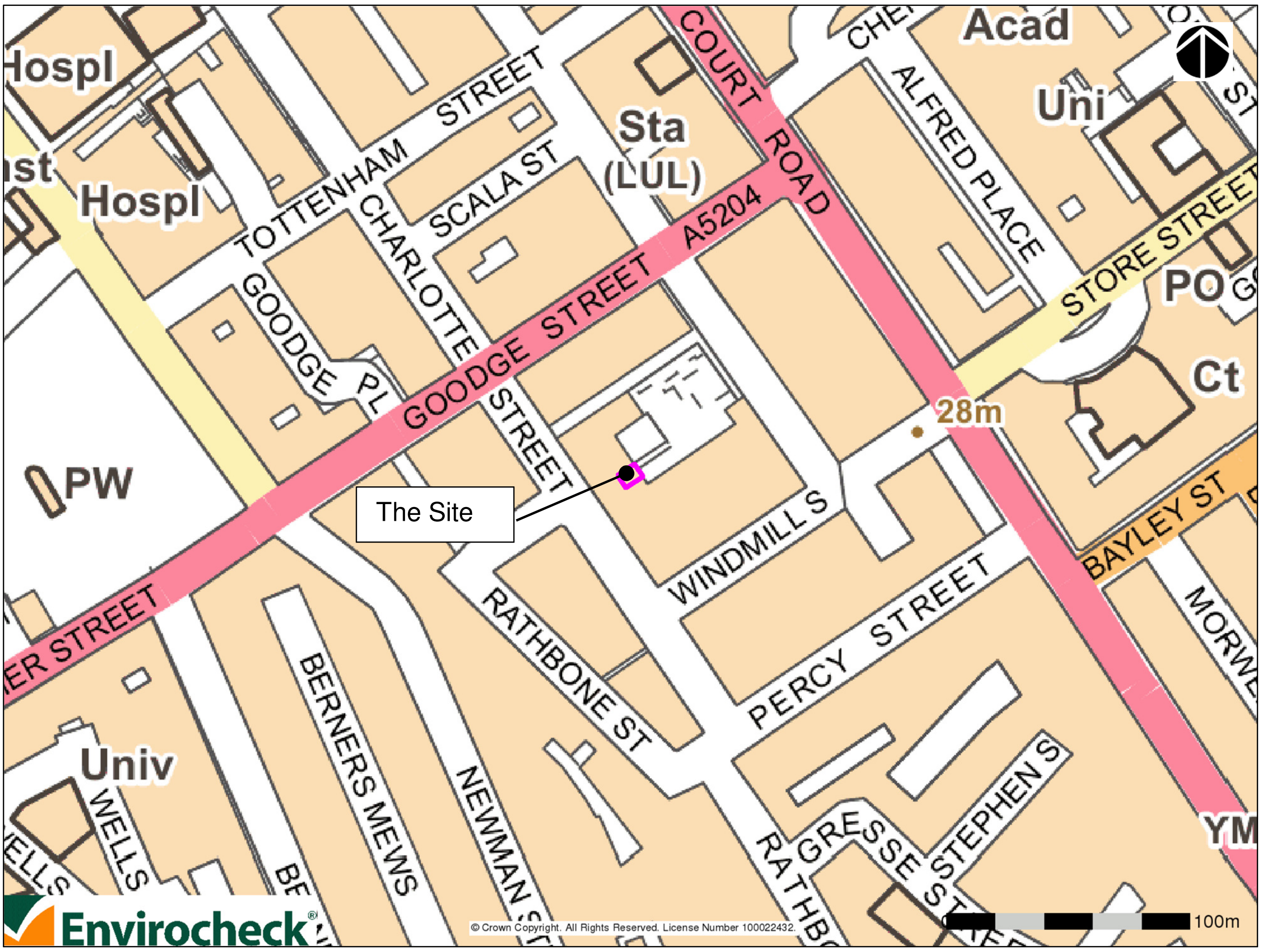
2. The Site

2.1 Site Location

The site is located at the rear of 28 Charlotte Street, London. A site location plan is presented as Figure 1.

Figure 1 – Site Location Plan



2.2 Site Description

The site comprises a two-storey apartment at the rear of a terraced apartment block. The building measures approximately 7m x 10m in plan and is approximately 6.8m in height. The building is adjoined to two similar structures at 30 and 32 Charlotte Street.

A rear view of the site and adjoining apartments is presented as Figure 2.

Figure 2 – Rear View of Site Looking West

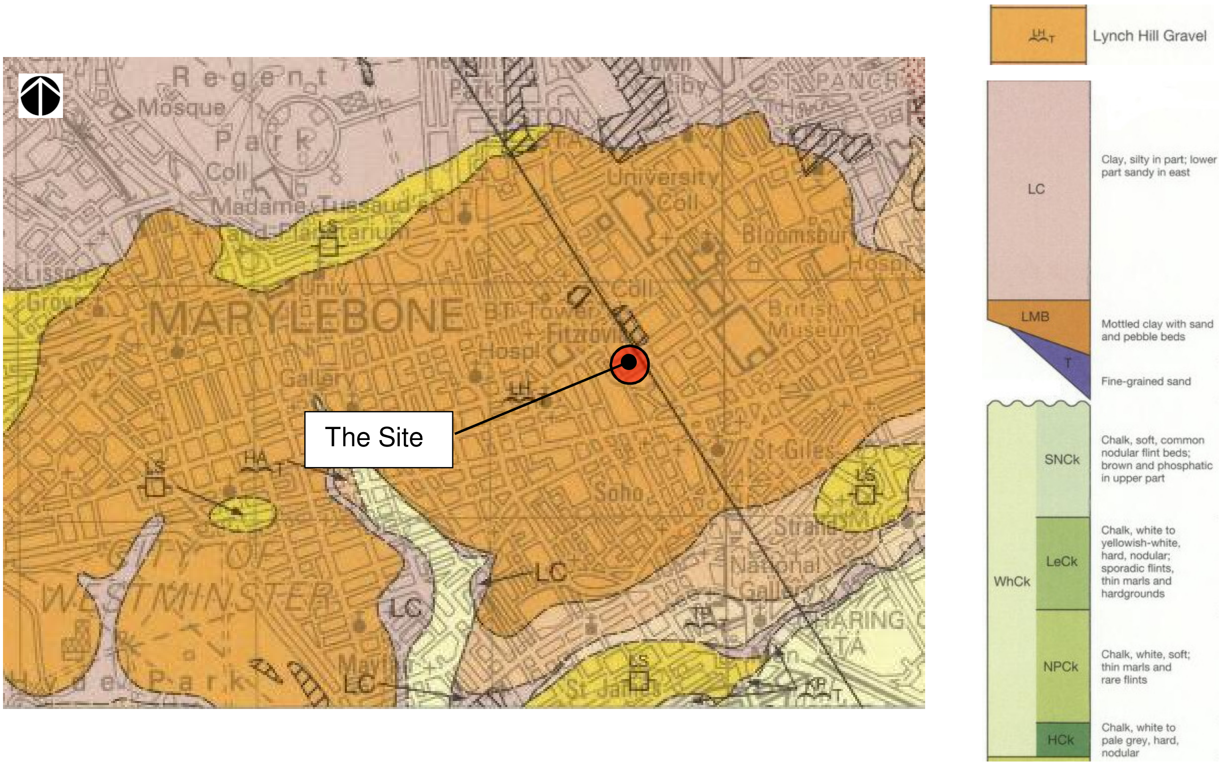
2.3 Ground Conditions

Sheet 256 of the British Geological Survey (England & Wales, Solid & Drift Edition) indicates the site to be underlain by a downward sequence comprising:

- Lynch Hill Gravel.
- London Clay (LC).
- Lambeth Group (LMB).
- Thanet Sand (T).
- White Chalk Subgroup (WhCk)

An extract of the BGS map is presented as Figure 3.

Figure 3 – Extract of BGS Sheet 256



A ground investigation was undertaken in connection with the proposed development in January 2016. These works are reported in Chelmer (2016) and confirm the published geology to be accurate. Further details of the precise soil stratigraphy encountered during the works are presented as Table 1.

Chelmer (2016) suggests groundwater to be located at 5.3m depth. This depth coincides with the top of the locally occurring Lynch Hill Gravel and is below the anticipated depth of basement excavation

Table 1 – Ground Investigation Results

Stratum	Description	Depth to Top of Stratum (m)	Stratum Thickness (m)
Made Ground	Variable silty gravelly SAND to sandy gravelly SILT containing frequent to occasional brick, slate, and concrete fragments	0.0	5.3
Lynch Hill Gravel	Silty gravelly SAND	5.3	2.4
London Clay	Very stiff, silty CLAY	7.7	Not proven

3. Assumed Construction Sequence

Details of the proposed basement construction sequence are provided in ACE (2016) and summarised as follows:

- Stage 1: Break out existing ground floor slab and install load bearing piles from working platform level of +9.93m Site Datum (SD).
- Stage 2: Excavate down to +7.3m SD at centre of basement area. Earthen berms are to be left in place at basement perimeter.
- Stage 3: Cast ground floor slab at centre of basement area.
- Stage 4: Partially remove earthen berms from basement perimeter and form underpinning to existing footings using a one-metre bay width. Propping to be applied to excavated face, as required.
- Stage 5: Apply dry packing to underpinnings and extend ground floor slab to basement perimeter.
- Stage 6: Repeat Stages 4 through 5 for each bay width. It is assumed that bays will be underpinned in a "1, 3, 5, 2, 4," sequence.

Indicative details of the basement extent and underpinning are presented as Figures 4 and 5, respectively.

Figure 4 – Cross Section through Proposed Basement

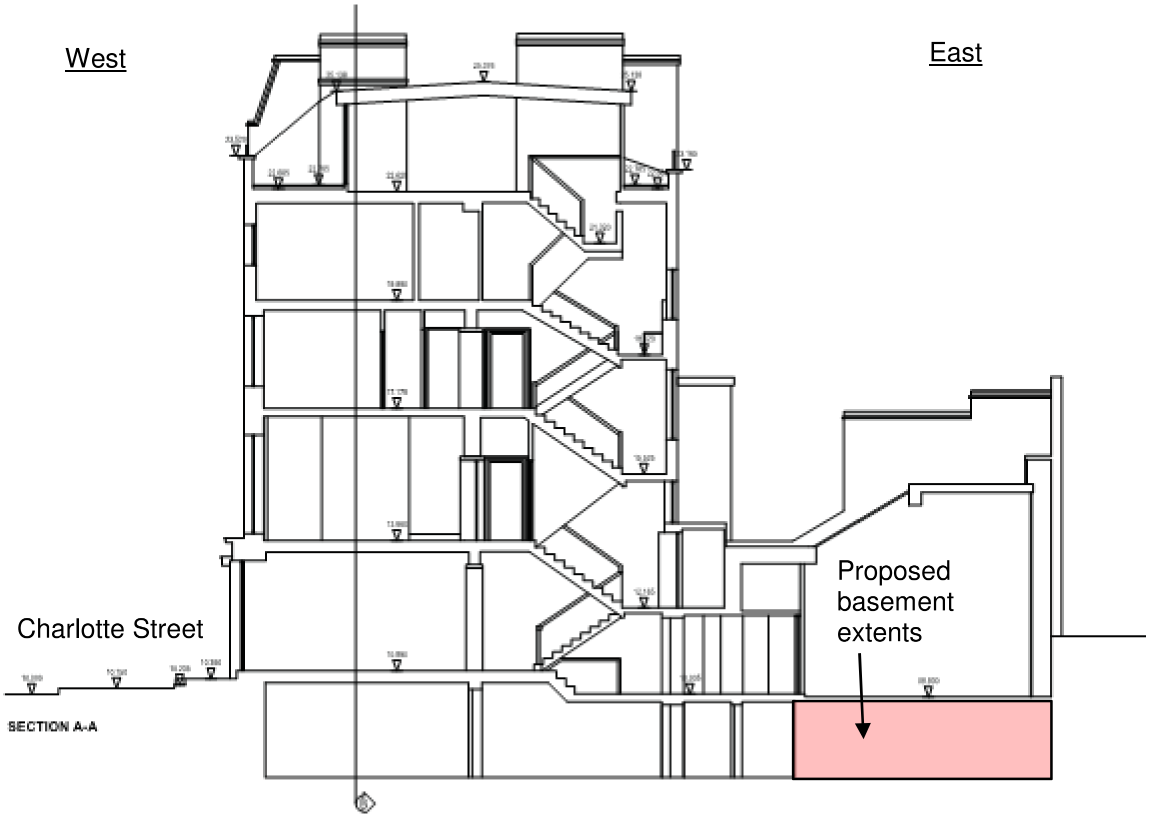
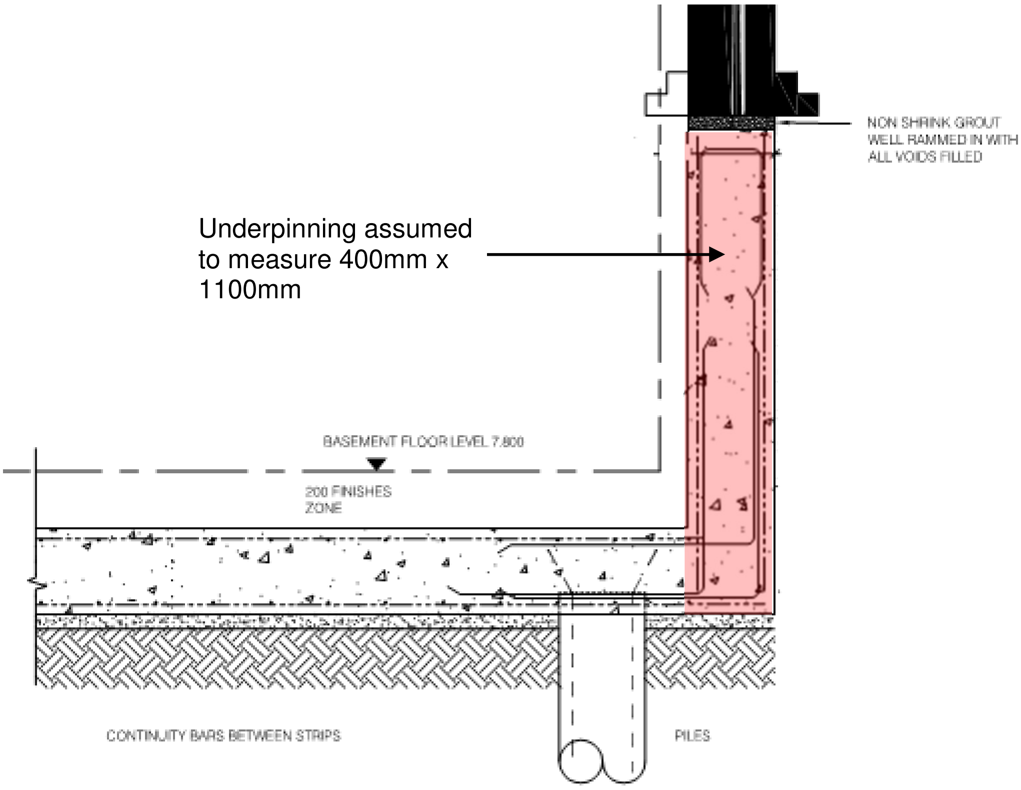


Figure 5 – Indicative Underpinning Detail



4. Method of Analysis

4.1 Ground Movement

In the absence of published case histories, it is assumed that the underpinning works will be similar to tunnelling, in that some soil volume loss will be experienced within the zone of excavation, and that this volume loss will result in horizontal and vertical movement of the overlying soils. It is assumed that the soil volume loss will be limited to 1 %, which is in keeping with the maximum allowable soil volume loss typically specified for tunnelling in granular soil. Refer to ITA/AITES (2007) for further details.

4.2 Impacts to Existing Structures

Impacts of ground movement on existing structures have been evaluated in accordance with Burland (1996). This methodology likens masonry structures to an equivalent beam and classifies damage according to limiting tensile strain (see Table 2).

Table 2 – Burland Damage Classification

Damage Category	Normal Degree of Severity	Limiting Tensile Strain (%)	Typical Damage Manifestation
0	Negligible	0.05	Hairline cracks less than about 0.1mm
1	Very slight	0.075	Fine cracks which are easily treated during normal decoration works. Crack widths are typically between 0.1 and 1.0mm
2	Slight	0.15	Cracks easily filled, with redecoration likely to be required. Exterior cracking may be visible, with doors and windows sticking slightly. Crack widths are typically between 1 and 5mm
3	Moderate	0.3	Cracks may require cutting out and replacement. Doors and windows likely to stick and site services likely to be interrupted. Crack widths typically between 5 and 15mm
4	Severe to very severe	>0.3	Extensive repairs required, with crack widths in excess of 15mm

5. Analysis Results

The analysis results are presented as Appendix A and summarised as Table 3.

Table 3 – Analysis Results

Parameter	Result
Vertical ground movement	6mm
Horizontal ground movement	2mm
Limiting tensile strain in 'sagging' zone	0.057 %
Limiting tensile strain in 'hogging' zone	0.051 %

Based upon the above, the underpinning works are anticipated to result in Category 1 damage to the adjoining buildings. This damage classification is described as being 'very slight' in nature and typically results in crack widths of up to 1.0mm.

6. Conclusions and Recommendations

6.1 Conclusions

The proposed underpinning works are likely to result in 6mm of vertical movement and 2mm of horizontal movement at existing foundation level. This movement is likely to result in Category 1 damage to adjacent structures. This damage classification is described as being 'very slight' in nature and typically results in crack widths of less than 1.0mm. This category of damage is expected to be easily repaired during the course of normal re-decoration works.

6.2 Recommendations

It is recommended that adjacent buildings be subject to visual inspection surveys immediately prior to and upon completion of works and that vertical movement of existing foundations be monitored on a routine basis. Suggested trigger levels and contingency actions for the vertical movement monitoring are presented as Table 4.

Table 4 – Trigger Levels and Contingency Actions for Foundation Movement Monitoring

Trigger Level	Vertical Movement Corresponding to Trigger Level	Contingency Actions
Amber	6mm	• Review method of working and assess possibility of further movement occurring • Increase frequency of monitoring • Undertake visual condition survey of affected area
Red	10mm	• Stop work in affected area • Undertake visual condition survey of affected area

Notwithstanding the analysis results described herein, it is suggested that the following maximum damage criteria be incorporated into the underpinning works contract:

- Settlement of any adjacent foundation shall be limited to 10mm; and
- Damage to any adjacent structure shall be limited to Burland Category 1. This damage classification is described as 'very slight' and is typically associated with crack widths of between 0.1 and 1.0mm.

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APPENDIX A

CALCULATIONS

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JOB NUMBER / FILE	CALCULATION NUMBER	DRAWING REFERENCE
1013857	—	—

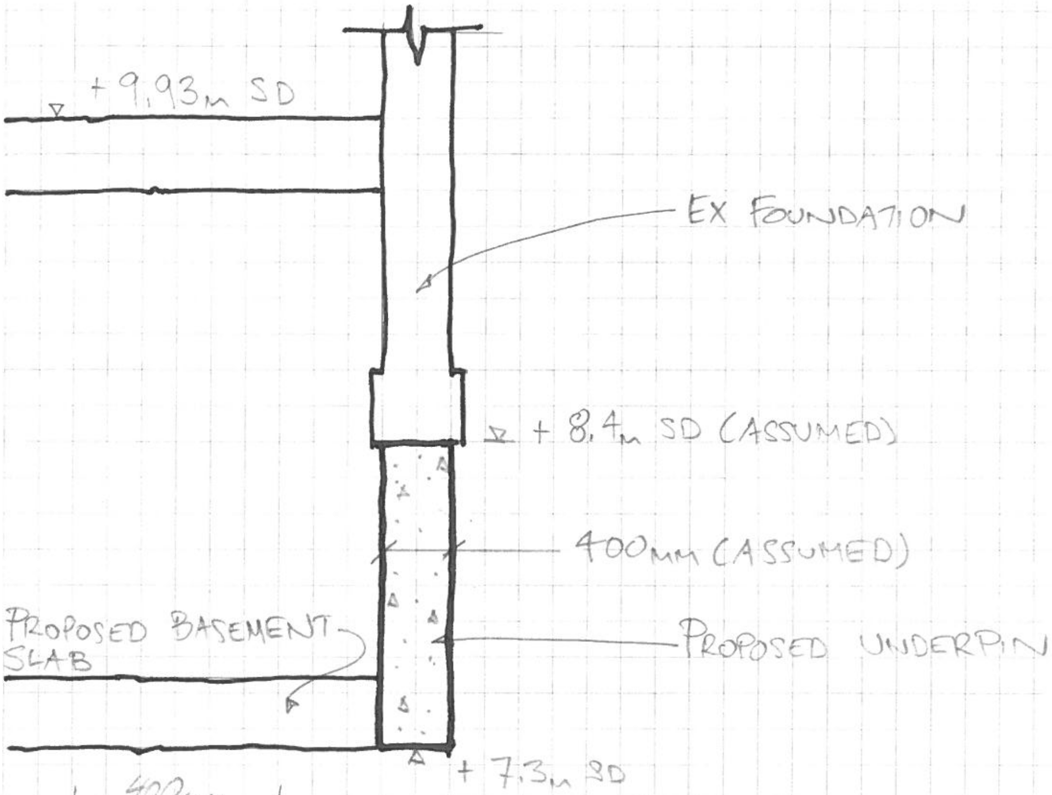
JOB TITLE: 28 CHARLOTTE STREET

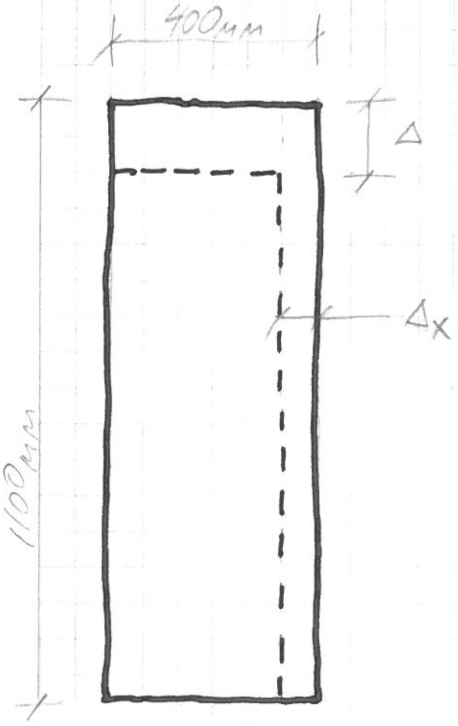
CALCULATION: IMPACT ASSESSMENT FOR GROUND MOVEMENT

REV	CALCULATION BY	DATE	CHECKED BY	VERIFIED BY:
0	JMS	19 AUG 16	JAS	—
1				
2				

CALCULATION DETAIL:

ESTIMATE VERTICAL FOUNDATION MOVEMENT DUE TO UNDERPINNING WORKS





* ASSUME THAT UNDERPINNING WILL RESULT IN 1% VOLUME LOSS

* UNDERPINNING WIDTH = 400mm

* UNDERPINNING HEIGHT = 1100mm

$\therefore h = 2.75\,w$

$\therefore (w)(2.75) = (0.99)(1100)(400)$

$2.75\,w^2 = 435{,}600$

$w = 398\text{mm}$

$\therefore \Delta = 1100 - (2.75)(398) = 5.5\text{mm} \quad (\approx 6.0\text{mm})$

$\Delta x = 400 - 398 = 2.0\text{mm}$

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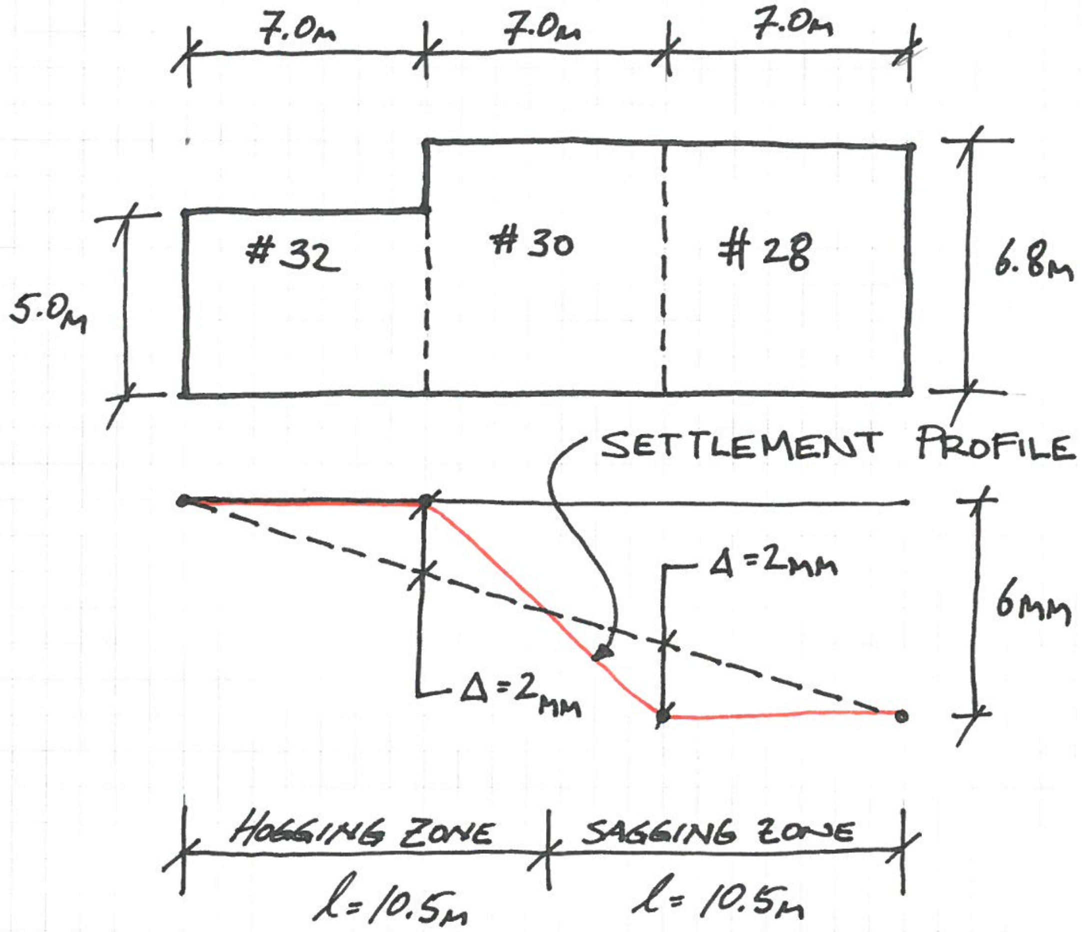
JOB NUMBER / FILE	CALCULATION NUMBER	DRAWING REFERENCE
1013857	–	–

JOB TITLE: 28 CHARLOTTE STREET

CALCULATION: IMPACT ASSESSMENT FOR GROUND MOVEMENT

REV	CALCULATION BY	DATE	CHECKED BY	VERIFIED BY
0				
1				
2				

CALCULATION DETAIL:



FROM BURLAND + WROTH (1974):

$$\frac{\Delta}{l} = \left\{\frac{l}{12t} + \frac{3IE}{2tlHG}\right\}\varepsilon_b \text{ ; AND}$$

$$\frac{\Delta}{l} = \left\{1 + \frac{Hl^2G}{18IE}\right\}\varepsilon_d$$

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JOB NUMBER / FILE	CALCULATION NUMBER	DRAWING REFERENCE
1013857		

JOB TITLE

28 CHARLOTTE STREET

CALCULATION

IMPACT ASSESSMENT FOR GROUND MOVEMENT

REV	CALCULATION BY	DATE	CHECKED BY	VERIFIED BY:
0				
1				
2				

CALCULATION DETAIL:

WHERE :

H = BUILDING HEIGHT

= 6.8m IN SAGGING ZONE

= 5.9m IN HOGGING ZONE

l = BUILDING LENGTH

= 10.5m FOR BOTH SAGGING + HOGGING ZONES

$\frac{E}{G}$ = 2.6 (CONSTANT)

I = SECOND MOMENT OF INERTIA

= $\frac{H^3}{12}$ IN SAGGING ZONE

= $\frac{H^3}{3}$ IN HOGGING ZONE

t = FURTHEST DISTANCE FROM NEUTRAL AXIS TO EDGE OF EQUIVALENT BEAM

= $\frac{H}{2}$ IN SAGGING ZONE

= H IN HOGGING ZONE

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JOB NUMBER / FILE	CALCULATION NUMBER	DRAWING REFERENCE
1013857		

JOB TITLE

28 CHARLOTTE STREET

CALCULATION

IMPACT ASSESSMENT FOR GROUND MOVEMENT

REV	CALCULATION BY	DATE	CHECKED BY	VERIFIED BY
0				
1				
2				

CALCULATION DETAIL:

* FROM BURLAND + WROTH (1974):

LIMITING TENSILE STRAIN IS THE GREATEST OF:

① $\varepsilon_{bt} = \varepsilon_h + \varepsilon_b$; AND

② $\varepsilon_{dt} = 0.35\,\varepsilon_h + \sqrt{(0.65\,\varepsilon_h)^2 + \varepsilon_d^2}$

* ASSUME THAT HORIZONTAL STRAIN $(\varepsilon_h) = \frac{\Delta x}{7.0\text{m}}$

$= \frac{2\text{mm}}{7{,}000\text{mm}}$

$= 0.00029$

$= 0.029\%$

FOR SAGGING ZONE

$I = \frac{H^3}{12} = \frac{(6.8)^3}{12} = 26.2\text{m}^3$

$t = \frac{H}{2} = \frac{6.8}{2} = 3.4\text{m}$

$l = 10.5\text{m}$

$\Delta = 2\text{mm}$

$\therefore \frac{0.002}{10.5} = \left\{ \frac{10.5}{12(3.4)} + \frac{3(26.2)(2.6)}{2(3.4)(10.5)(6.8)} \right\} \varepsilon_b$

$\frac{0.002}{10.5} = \left\{ 0.257 + 0.421 \right\} \varepsilon b$

$\varepsilon_b = 0.00028$

$= 0.028\%$

CUNDALL	JOB NUMBER / FILE: 1013857	CALCULATION NUMBER:	DRAWING REFERENCE:	
JOB TITLE: 28 CHARLOTTE STREET	REV / CALCULATION BY:	DATE:	CHECKED BY:	VERIFIED BY:
	0			
CALCULATION: IMPACT ASSESSMENT FOR GROUND MOVEMENT	1			
	2			

CALCULATION DETAIL:

$$\frac{0.002}{10.5} = \left\{ 1 + \frac{(6.8)(10.5)^2}{18(26.2)(2.6)} \right\} \varepsilon_d$$

$$\frac{0.002}{10.5} = \{ 1 + 0.61 \} \varepsilon_d$$

$$\varepsilon_d = 0.00012$$
$$= 0.012\%$$

$$\varepsilon_{bt} = \varepsilon_h + \varepsilon_b$$
$$= 0.029 + 0.028$$
$$= 0.057\%$$

$$\varepsilon_{dt} = 0.35\varepsilon_h + \sqrt{(0.65\,\varepsilon_h)^2 + \varepsilon_d^2}$$
$$= 0.35(0.029) + \sqrt{[(0.65)(0.029)]^2 + 0.012^2}$$

$$\varepsilon_{dt} = 0.032\%$$

∴ LIMITING TENSILE STRAIN = 0.057%. THIS CORRESPONDS TO DAMAGE CATEGORY 1

CUNDALL	JOB NUMBER / FILE:	CALCULATION NUMBER:	DRAWING REFERENCE:
	1013857		

JOB TITLE:	REV	CALCULATION BY	DATE	CHECKED BY	VERIFIED BY:
28 CHARLOTTE STREET	0				
CALCULATION:	1				
IMPACT ASSESSMENT FOR GROUND MOVEMENT	2				

CALCULATION DETAIL:

FOR HOGGING ZONE

$H = 5.9m$

$I = \frac{H^3}{3} = \frac{(5.9)^3}{3} = 68.5$

$t = H = 5.9m$

$l = 10.5m$

$\Delta = 2.0mm$

$\therefore \frac{0.002}{10.5} = \left\{ \frac{10.5}{12(5.9)} + \frac{3(68.5)(2.6)}{2(5.9)(10.5)(5.9)} \right\} \varepsilon_b$

$\frac{0.002}{10.5} = \{ 0.148 + 0.731 \} \varepsilon_b$

$\varepsilon_b = 0.00022$

$= 0.022\%$

$\frac{0.002}{10.5} = \left\{ 1 + \frac{(5.9)(10.5)^2}{18(68.5)(2.6)} \right\} \varepsilon d$

$\frac{0.002}{10.5} = \{ 1 + 0.203 \} \varepsilon d$

$\varepsilon d = 0.00016$

$= 0.016\%$

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JOB NUMBER / FILE:	CALCULATION NUMBER:	DRAWING REFERENCE:
1013857		

JOB TITLE:
28 CHARLOTTE STREET

CALCULATION:
IMPACT ASSESIMENT FOR GROUND MOVEMENT

REV	CALCULATION BY	DATE	CHECKED BY	VERIFIED BY:
0				
1				
2				

CALCULATION DETAIL:

$$\varepsilon_{bt} = \varepsilon_h + \varepsilon_b$$

$$= 0.029 + 0.022$$

$$= 0.051\,\%$$

$$\varepsilon_{dt} = 0.35\,\varepsilon_h + \sqrt{(0.65\,\varepsilon_h)^2 + \varepsilon_d^2}$$

$$= 0.35(0.029) + \sqrt{[0.65(0.029)]^2 + 0.016^2}$$

$$\varepsilon_{dt} = 0.035\,\%$$

∴ LIMITING TENSILE STRAIN FOR HOGGING ZONE IS 0.051%. THIS CORRESPONDS TO CLASS I DAMAGE