PILE FOUNDATION DESIGN

(Issued subject to mutual agreement of Sub-Contract)

Contract Number

9377

Site Address

Hampstead Green
London

Main Contractor

CAREY LONDON LIMITED

Date	Rev	Designed By	Approved By	Comments / Drawings Rev.s
20/04/16	0	Kayvan Kiany Design Manager	Neil Stone Engineering Manager	
09/05/16	A	Kayvan Kiany Design Manager	Neil Stone Engineering Manager	
16/05/16	B	Kayvan Kiany Design Manager	Neil Stone Engineering Manager	TC piles added

HAMPSTEAD GREEN
BEARING PILE DESIGN REV B

Contents

1.0 Design Brief

The proposed redevelopment of the site involves the installation of piles for the new development at Hampstead Green London. The piles are to be constructed using the continuous flight auger (CFA) technique.

Piles are designed in accordance with BS EN 1997-1:2004, with no requirement for pile load testing.

Piles will be installed to an installation tolerance of 75mm on plan and 1 in 75 verticality.

Tower crane piles have been designed for a FOS of 3 for both compression and tension. (Piles are not being load tested). Piling platform level is 72mOD. Pile cut-off levels are 67.575mOD for piles CP1-CP12 and 68.975mOD for piles CP13-CP24.

The piling will be carried out from a platform level of 72mOD and 74.9mOD.

Pile cut-off levels vary from 65.925mOD to 70.775mOD.

Projection steel shall be provided to platform level. Where a greater projection length is required or bending of bars is not possible, suitable bars will need to be coupled onto the projection steel post trimming (by others).

Pile design requirements are summarised in *Fig.1*

Pile diameter (mm)	SLS Pile Load (kN)	Comb 2 action (kN)	Pile length (m)
400	200-825	215-979	11.4-24.2
400 (Tower Crane)	600		21.4

Fig 1 Pile summary

2.0 Design Input

2.1 Site Investigation

Card Geotechnics Limited Geotechnical and geo-environmental report, rev 4, dated Feb 2015.

2.2 Drawings

Relevant Drawings:	elliottwood Consulting drawings – S/70 Proposed Pile Layout rev C3 S/71 Proposed Pile Layout Schedules rev C2 **S/75 proposed Crane Base Pile Layout**

2.3 Codes & Standards

BS EN 1992-1-1:2004 Eurocode 2: Design of Concrete Structures
ES EN 1997-1:2004 Eurocode 7: Geotechnical Design
BS EN1536: 2010 Execution of Special Geotechnical Work – Bored Piles
CIRIA C654

2.4 Specification

ICE Specification for piling and embedded retaining walls, 2nd Edition (SPERW), 2007.
elliottwood specification for piling works, tender issue dated 2015.

3.0 Design Philosophy & Ground/ Design Model

3.1 Design Philosophy

Design is based on a partial safety factor approach where characteristic pile resistance is calculated in accordance with BS EN 1997-1:2004, Design Approach 1 (section 2.4.7.3.4.2), design by calculation

Design has been checked for Geotechnical and Structural Ultimate Limit States (ULS).

Design is based upon design actions < design resistance.

We have assessed the structure class to be Category 2 (Section 2.1) "Conventional types of structure and foundation with no exceptional risk or difficult soil and loading conditions".

3.2 Site Investigation

The site Investigation Report provided a total of 5 boreholes up to a maximum depth of 30m. Standard Penetration Tests (SPT's) and un-drained triaxial tests have been carried out.

3.3 Soil Model

The soil profile used within the design is illustrated below this profile was developed from a review of the aforementioned site investigation. *See Fig 2*.

Stratum	Design Level (mOD)
MG / Head deposits	**72**
London Clay	**71**

Fig 2 Soil Model

Perched groundwater was encountered within some of the boreholes above the London Clay

3.4 Soil Parameters

A correlation value of 5 has been applied to the SPT results to obtain the equivalent Undrained Shear Strength (kN/m^2) of the Clay. The soil parameters shown in *Fig.3* are subsequently used for the design of the piles. Strength plots Vs depth can also be found in Appendix A.

STRATUM	BEARING PILE DESIGN PARAMETERS		
London CLAY	Bulk Density	γ_b	= 20kN/m^3
Firm to V Stiff CLAY	SPT	'N'	Values as design lines
(fissured silty CLAY)	Cohesion	c_u	Values as design lines, correlation factor = 5
	Adhesion factor	α	= 0.60
	Unit skin friction	q_s	Limited to maximum average 110kPa

Fig 3 Soil Parameters

4.0 Specified Actions

4.1 Compression

Piles have been designed for vertical compression actions as specified on drawings listed in section 2.2.
TC piles have been designed to a factor of safety of 3

4.2 Shear

Piles have been designed for shear actions as specified on drawings listed in section 2.2

The maximum bending moments have been calculated using Broms analysis (1964), as described in section 4.3 of “Piling Engineering” by Ken Fleming et al. Results can be viewed in Appendix C.

4.3 Tension

Working piles are not subject to net tension actions.
TC piles have been designed to a factor of safety of 3 for the 125kN tension load, Ast = 432mm²

$$A_{s\ req} = \frac{1.5 * T * 1000}{0.87 * f_y}$$

4.4 Moments from Tolerances

Piles have been designed as restrained at the head; any additional actions as a result of pile installation tolerances have not been allowed for, these loads are to be accommodated by the substructure.

Factors of safety are applied to the piles geotechnical capacity in order to allow for a number of variables, one of these is the potential load increase for piles that have moved within the piles installation tolerances of 75mm on plan and 1 in 75 verticality. This would be an acceptable situation with no cause for concern.

Any piles that have moved beyond the pile installation tolerances will be reviewed on a case by case basis on receipt of the piles as built survey.

4.5 Heave (desiccation)

Piles have been designed to cater for the effects of possible heave (swell) as a result of desiccation within the top 3m for piles outside of the basement footprint.

4.6 Negative Skin Friction (NSF)

Piles have not been designed for the effects of NSF.

5.0 Bearing Capacity

5.1 Bearing Capacity – Cohesive Soils

Shaft Resistance - Clay (ULS)

Characteristic Shaft Resistance of Stratum	$q_{s;i;k}$	=	$\alpha \times C_{u\ av.}$
Characteristic Shaft Resistance of Pile	$R_{s;k}$	=	$A_{s;i}\ q_{s;i;k}$

Where:

$A_{s;i}$ = π x dia x length of shaft in clay
$C_{u\ av.}$ = Av. Undrained shear strength over length of shaft
α = adhesion

Base Resistance - Clay (ULS)

Characteristic Base Resistance of Stratum	$q_{b;k}$	=	$C_{u\ base} \times N_c$
Characteristic Base Resistance of Pile	$R_{b;k}$	=	$A_b\ q_{b;k}$

Where:

A_b (Area of base) = π x dia^2 x 0.25
N_c (Bearing capacity factor) = 9.0
C_u base = Undrained design shear strength at base

Pile capacity calculations can be found in Appendix B

5.2 Design Check for Geotechnical ULS – Design Approach 1

Combination 1 (STR) used to check concrete stress and combination 2 (GEO) used for pile toe level.

Design Approach 1 Combination 1:

$R_{b;k} = A_b\, q_{b;k}$

$R_{s;k} = A_{s;i}\, q_{s;i;k}$

γ_b = **1.0** (Base)

γ_s = **1.0** (Shaft Compression)

γ_s = **1.0** (Shaft Tension)

γ_{Rd} = **1.4** (Model Factor)

$R_{c;d} = (R_{b;k}/\gamma_b + R_{s;k}/\gamma_s)/\gamma_{Rd}$

$\gamma_G = 1.35$

$\gamma_Q = 1.5$

$\Psi 0 = 0.5\ (Q_{k} > w_{L.})$

$F_{c;d} = G_k.\ \gamma_G + Q_k.\ \gamma_Q + w_{L.}\ \gamma_{Q.}\ \Psi 0$

$\Psi 0 = 0.7\ (Q_{k} < w_{L.})$

$F_{c;d} = G_k.\ \gamma_G + Q_k.\ \gamma_{Q\,.}\ \Psi 0 + w_{L.}\ \gamma_Q$

$F_{c;d} < R_{c;d}$: OK

Design Approach 1 Combination 2:

$R_{b;k} = A_b\, q_{b;k}$

$R_{s;k} = A_{s;i}\, q_{s;i;k}$

γ_b = **2.0** (Base)

γ_s = **1.6** (Shaft Compression)

γ_s = **2.0** (Shaft Tension)

γ_{Rd} = **1.4** (Model Factor)

$R_{c;d} = (R_{b;k}/\gamma_b + R_{s;k}/\gamma_s)/\gamma_{Rd}$

$\gamma_G = 1.0$

$\gamma_Q = 1.3$

$\Psi 0 = 0.5\ (Q_{k} > w_{L.})$

$F_{c;d} = G_k.\ \gamma_G + Q_k.\ \gamma_Q + w_{L.}\ \gamma_{Q.}\ \Psi 0$

$\Psi 0 = 0.7\ (Q_{k} < w_{L.})$

$F_{c;d} = G_k.\ \gamma_G + Q_k.\ \gamma_{Q.}\ \Psi 0 + w_{L.}\ \gamma_Q$

$F_{c;d} < R_{c;d}$: OK

Tension Loads, combination 1 for structural design and combination 2 for geotechnical design.

Design Approach 1 Combination 1:

$\text{Tension} = G_{kt}.\ \gamma_G + Q_{kt}.\ \gamma_Q + w_{Lt.}\ \gamma_{Q.} - (G_k \times 1)$

Design Approach 1 Combination 2:

$\text{Tension} = G_{kt}.\ \gamma_G + Q_{kt}.\ \gamma_Q + w_{Lt.}\ \gamma_{Q.} - (G_k \times 1)$

Where:

$F_{c;d}$	design axial compression load
γ_G	partial factor for permanent action
γ_Q	partial factor for variable action
$R_{c;d}$	design value R_c
$R_{b;k}$	characteristic value for base resistance of pile
γ_b	partial factor for base resistance of pile
$R_{s;k}$	characteristic value for shaft resistance of pile
γ_s	partial factor for shaft resistance of pile
$\gamma_{R;d}$	partial factor for uncertainty in a resistance model
$q_{s;i;k}$	characteristic value of shaft resistance in stratum i
$q_{b;k}$	characteristic value of base resistance in stratum i
$A_{s;i}$	pile shaft surface area in stratum i
G_k	permanent action
Q_k	variable action

5.3 Design Check for Structural ULS – Concrete Compression

Where geotechnical ULS resistances and SLS performance have been satisfied, the structural capacity of the pile is determined in accordance with BS EN 1997-1:2004 and BS EN 1992-1-1:2004, using the Comb 1 (STR).
See appendix E.

6.0 Structural Design

6.1 Structural Parameters

Pile diameters	=	400mm
Concrete, f_{cu}	=	C32/40 N/mm^2 DC-3
Steel f_{yk}	=	500 N/mm^2 [high yield]
Materials factor γ_s	=	1.15 (reinforcement)
Cover	=	75mm

6.2 Reinforcement Design

The reinforcement adopted is calculated from the lateral load analysis. Analysis can be viewed in Appendix D.

Projection steel shall be provided to platform level. Where a greater projection length is required or bending of bars is not possible, suitable bars will need to be coupled onto the projection steel post trimming (by others).

Projection steel has been calculated after BS EN 1992-1-1:2004.

Based on a pile cap strength of 40N/mm² a projection lap lengths will be required, 510mm for H16 bars and 660mm for H20 bars.

Case	Pile diam. (mm)	Lateral Load (kN)	Reinforcement
1	**400**	**25kN**	**4H16x6m in H8 Helical, H8@160 c-c**
2	**400**	**25kN**	**4H20x10m in H8 Helical, H8@160 c-c**
3	**400 (TC) CP1-12**	**25kN**	**4H20x10m in H8 Helical, H8@160 c-c + 1H25: 11m**
4	**400 (TC) CP 13-24**	**25kN**	**4H20x8m in H8 Helical, H8@160 c-c + 1H25: 11m**

Cages for the piles within the basement footprint or with deep pile cut-off levels have been beefed up for constructibility

Fig 4 Reinforcement Summary

7.0 Pile Testing / Validation Requirements

The piles have been designed with the adoption of higher partial factors which negates the requirement for any pile load testing.

Pile settlement criteria of 10mm at DVL has been adopted.
Settlement analysis for a 400mm diameter pile, SLS load of 825kN (24m) can be found in Appendix F.
The analysis was carried out using a method derived by Fleming, W.G.K (1992), Geotechnique 42, No.3.
The settlement at SWL is predicted to be <5mm.

All bearing piles are to be sonic integrity tested. Please note integrity testing to be booked in with Rock & Alluvium (Leatherhead office) by the main contractor allowing 3 working days to mobilise testing sub-contractor.

8.0 Outstanding Issues

None.

Appendix A

Strength Vs Depth Plots

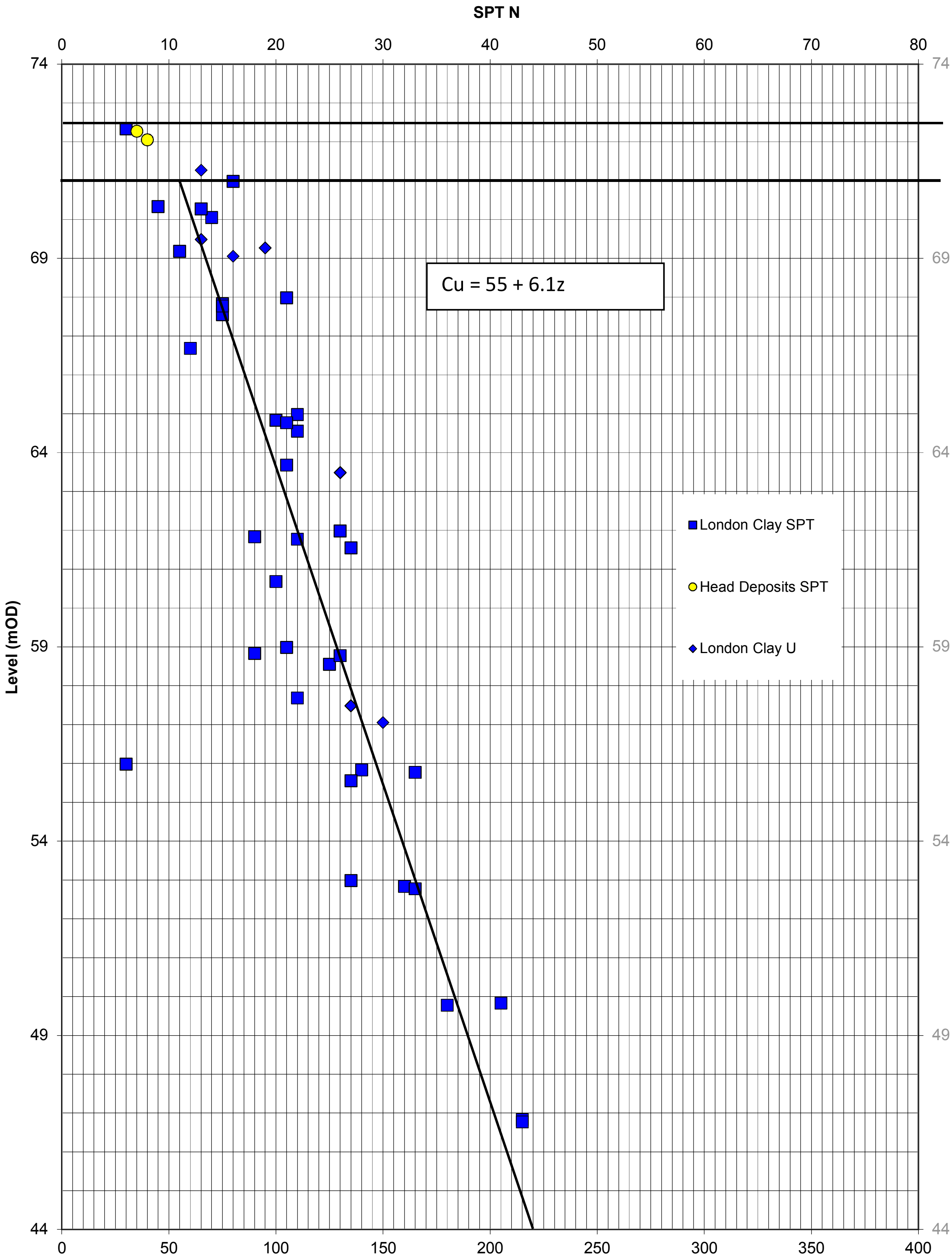
Site Address Hampstead Green

Reference 9377

Date 22/01/2016

Rock & Alluvium
Tel. 01372 389 333
enquiries@rockal.com
www.rockal.com

Cu = 5 * SPT



Design based on site investigation report by CGL dated: Sep 2014

Appendix B

Bearing Pile Design Calculations

Static Pile Design

RA-PG-06-025 (11.07)

Piling Technique: CFA

Site Address : Hampstead Green

Contract No : 9377

Revision : 0

Rock & Alluvium
BRIDGE HOUSE
27 BRIDGE STREET
LEATHERHEAD
SURREY
KT22 8BL
TEL) 01372 389 333
enquiries@rockal.com
www.rockal.com

Comments : 0=72mOD
Load bearing piles outside basement footprint

Model Factor =	1.4		
F of S shaft =	1.6	F of S shaft =	1.2
F of S base =	2	F of S base =	########

Depth Interval
1.00 m

(1)		(2)	S-1	S-2	S-3	S-4	S-5	C-1	C-2	C-3	C-4	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Depth Range		Soil Description	Sand Input Parameters					Clay Input Parameters				N.S.F. Parameter	Bulk Unit Weight	Submerged Unit Weight	Effective o'burden pressure	Unit Skin Friction	Unit Base Resistance	CFA Piles		0.400	size in m	CFA Piles		0.400	size in m
Start	End		SPT 'N'	k_s	Δ $\Delta\Phi$ = 1.00	D/B Ratio (for info)	Nq	C_u Bottom	C_u Grad-ient?	ΔC_u Gradient	Alpha (α)	Beta (β)	(γ)	(γ')	(σ_v')	[1] 225 (q_s)	[2] 15500 (q_b)	Ult. Shaft (Q_s)	Ult. Base (Q_b)	Ult. N.S.F.	Allowable Capacity	Ult. Shaft (Q_s)	Ult. Base (Q_b)	Ult. N.S.F.	Allowable Capacity
m								kN/m²		kN/m²			kN/m³	kN/m³	kN/m²	kN/m²	kN/m²	kN	kN	kN	kN	kN	kN	kN	kN
0.00	1.00	Ignore				3									0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
1.00	2.00	Ignore				5									0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
2.00	3.00	London Clay				8		64.2	y		0.60				0.0	38.5	577.8	48.4	72.6	0.0	48	48	73	0.0	40
3.00	4.00	London Clay				10		73.3	y	9.1	0.60				0.0	41.3	659.7	100.2	82.9	0.0	74	100	83	0.0	84
4.00	5.00	London Clay				13		79.4	y	6.1	0.60				0.0	45.8	714.6	157.8	89.8	0.0	103	158	90	0.0	132
5.00	6.00	London Clay				15		85.5	y	6.1	0.60				0.0	49.5	769.5	220.0	96.7	0.0	133	220	97	0.0	183
6.00	7.00	London Clay				18		91.6	y	6.1	0.60				0.0	53.1	824.4	286.7	103.6	0.0	165	287	104	0.0	239
7.00	8.00	London Clay				20		97.7	y	6.1	0.60				0.0	56.8	879.3	358.1	110.5	0.0	199	358	110	0.0	298
8.00	9.00	London Clay				23		103.8	y	6.1	0.60				0.0	60.5	934.2	434.1	117.4	0.0	236	434	117	0.0	362
9.00	10.00	London Clay				25		109.9	y	6.1	0.60				0.0	64.1	989.1	514.6	124.3	0.0	274	515	124	0.0	429
10.00	11.00	London Clay				28		116.0	y	6.1	0.60				0.0	67.8	1044.0	599.8	131.2	0.0	315	600	131	0.0	500
11.00	12.00	London Clay				30		122.1	y	6.1	0.60				0.0	71.4	1098.9	689.6	138.1	0.0	357	690	138	0.0	575
12.00	13.00	London Clay				33		128.2	y	6.1	0.60				0.0	75.1	1153.8	783.9	145.0	0.0	402	784	145	0.0	653
13.00	14.00	London Clay				35		134.3	y	6.1	0.60				0.0	78.8	1208.7	882.9	151.9	0.0	448	883	152	0.0	736
14.00	15.00	London Clay				38		140.4	y	6.1	0.60				0.0	82.4	1263.6	986.4	158.8	0.0	497	986	159	0.0	822
15.00	16.00	London Clay				40		146.5	y	6.1	0.60				0.0	86.1	1318.5	1094.6	165.7	0.0	548	1095	166	0.0	912
16.00	17.00	London Clay				43		152.6	y	6.1	0.60				0.0	89.7	1373.4	1207.4	172.6	0.0	601	1207	173	0.0	1006
17.00	18.00	London Clay				45		158.7	y	6.1	0.60				0.0	93.4	1428.3	1324.7	179.5	0.0	655	1325	179	0.0	1104
18.00	19.00	London Clay				48		164.8	y	6.1	0.60				0.0	97.1	1483.2	1446.7	186.4	0.0	712	1447	186	0.0	1206
19.00	20.00	London Clay				50		170.9	y	6.1	0.60				0.0	100.7	1538.1	1573.2	193.3	0.0	771	1573	193	0.0	1311
20.00	21.00	London Clay				53		177.0	y	6.1	0.60				0.0	104.4	1593.0	1704.4	200.2	0.0	832	1704	200	0.0	1420
21.00	22.00	London Clay				55		183.1	y	6.1	0.60				0.0	108.0	1647.9	1840.1	207.1	0.0	895	1840	207	0.0	1533
22.00	23.00	London Clay				58		189.2	y	6.1	0.60				0.0	111.7	1702.8	1980.5	214.0	0.0	961	1980	214	0.0	1650
23.00	24.00	London Clay				60		195.3	y	6.1	0.60				0.0	115.4	1757.7	2125.4	220.9	0.0	1028	2125	221	0.0	1771
24.00	25.00	London Clay				63		201.4	y	6.1	0.60				0.0	119.0	1812.6	2275.0	227.8	0.0	1097	2275	228	0.0	1896

Average unit skin in granular soils = 0.0 kN/m²
Average unit skin in cohesive soils = 78.7 kN/m²
Average unit skin in chalk soils = 0.0 kN/m²

[1] Limiting value for unit skin friction per m depth (in kN/m²)
[2] Limiting value for unit base resistance (in kN/m²)

Static Pile Design

RA-PG-06-025 (11.07)

Piling Technique: CFA
Site Address : Hampstead Green

Contract No : 9377 **Revision :** 0

Rock & Alluvium
BRIDGE HOUSE
27 BRIDGE STREET
LEATHERHEAD
SURREY
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TEL) 01372 389 333
enquiries@rockal.com
www.rockal.com

Comments : 0=72mOD
Load Bearing Piles within basement footprint

Model Factor =	1.4		
F of S shaft =	1.6	**F of S shaft =**	1.2
F of S base =	2	**F of S base =**	########

Depth Interval
1.00 m

(1)		(2)	S-1	S-2	S-3	S-4	S-5	C-1	C-2	C-3	C-4	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Depth Range		Soil Description	Sand Input Parameters					Clay Input Parameters				N.S.F. Parameter	Bulk Unit Weight	Submerged Unit Weight	Effective o'burden pressure	Unit Skin Friction	Unit Base Resistance	CFA Piles		0.400	size in m	CFA Piles		0.400	size in m
			SPT 'N'	k_s	Δ ΔΦ = 1.00	D/B Ratio (for info)	Nq	C_u Bottom	C_u Grad-ient?	Δ C_u Gradient	Alpha (α)	Beta (β)	(γ)	(γ')	(σ_v')	[1] 225 (q_s)	[2] 15500 (q_b)	Ult. Shaft (Q_s)	Ult. Base (Q_b)	Ult. N.S.F.	Allowable Capacity	Ult. Shaft (Q_s)	Ult. Base (Q_b)	Ult. N.S.F.	Allowable Capacity
Start m	End							kN/m²		kN/m²			kN/m³	kN/m³	kN/m²	kN/m²	kN/m²	kN	kN	kN	kN	kN	kN	kN	kN
0.00	1.00	Ignore				3									0.0	0.0	0.0	0.0	0.0	0.0	**0**	0	0	0.0	**0**
1.00	2.00	Ignore				5									0.0	0.0	0.0	0.0	0.0	0.0	**0**	0	0	0.0	**0**
2.00	3.00	Ignore				8									0.0	0.0	0.0	0.0	0.0	0.0	**0**	0	0	0.0	**0**
3.00	4.00	Ignore				10									0.0	0.0	0.0	0.0	0.0	0.0	**0**	0	0	0.0	**0**
4.00	5.00	Ignore				13									0.0	0.0	0.0	0.0	0.0	0.0	**0**	0	0	0.0	**0**
5.00	6.00	Ignore				15									0.0	0.0	0.0	0.0	0.0	0.0	**0**	0	0	0.0	**0**
6.00	7.00	London Clay				18		88.6	y		0.60				0.0	53.2	797.4	66.8	100.2	0.0	**66**	67	100	0.0	**56**
7.00	8.00	London Clay				20		97.7	y	9.1	0.60				0.0	55.9	879.3	137.0	110.5	0.0	**101**	137	110	0.0	**114**
8.00	9.00	London Clay				23		103.8	y	6.1	0.60				0.0	60.5	934.2	213.0	117.4	0.0	**137**	213	117	0.0	**178**
9.00	10.00	London Clay				25		109.9	y	6.1	0.60				0.0	64.1	989.1	293.6	124.3	0.0	**175**	294	124	0.0	**245**
10.00	11.00	London Clay				28		116.0	y	6.1	0.60				0.0	67.8	1044.0	378.7	131.2	0.0	**216**	379	131	0.0	**316**
11.00	12.00	London Clay				30		122.1	y	6.1	0.60				0.0	71.4	1098.9	468.5	138.1	0.0	**258**	468	138	0.0	**390**
12.00	13.00	London Clay				33		128.2	y	6.1	0.60				0.0	75.1	1153.8	562.8	145.0	0.0	**303**	563	145	0.0	**469**
13.00	14.00	London Clay				35		134.3	y	6.1	0.60				0.0	78.8	1208.7	661.8	151.9	0.0	**350**	662	152	0.0	**552**
14.00	15.00	London Clay				38		140.4	y	6.1	0.60				0.0	82.4	1263.6	765.4	158.8	0.0	**398**	765	159	0.0	**638**
15.00	16.00	London Clay				40		146.5	y	6.1	0.60				0.0	86.1	1318.5	873.5	165.7	0.0	**449**	874	166	0.0	**728**
16.00	17.00	London Clay				43		152.6	y	6.1	0.60				0.0	89.7	1373.4	986.3	172.6	0.0	**502**	986	173	0.0	**822**
17.00	18.00	London Clay				45		158.7	y	6.1	0.60				0.0	93.4	1428.3	1103.6	179.5	0.0	**557**	1104	179	0.0	**920**
18.00	19.00	London Clay				48		164.8	y	6.1	0.60				0.0	97.1	1483.2	1225.6	186.4	0.0	**614**	1226	186	0.0	**1021**
19.00	20.00	London Clay				50		170.9	y	6.1	0.60				0.0	100.7	1538.1	1352.2	193.3	0.0	**673**	1352	193	0.0	**1127**
20.00	21.00	London Clay				53		177.0	y	6.1	0.60				0.0	104.4	1593.0	1483.3	200.2	0.0	**734**	1483	200	0.0	**1236**
21.00	22.00	London Clay				55		183.1	y	6.1	0.60				0.0	108.0	1647.9	1619.1	207.1	0.0	**797**	1619	207	0.0	**1349**
22.00	23.00	London Clay				58		189.2	y	6.1	0.60				0.0	111.7	1702.8	1759.4	214.0	0.0	**862**	1759	214	0.0	**1466**
23.00	24.00	London Clay				60		195.3	y	6.1	0.60				0.0	115.4	1757.7	1904.4	220.9	0.0	**929**	1904	221	0.0	**1587**
24.00	25.00	London Clay				63		201.4	y	6.1	0.60				0.0	119.0	1812.6	2053.9	227.8	0.0	**998**	2054	228	0.0	**1712**

Average unit skin in granular soils = 0.0 kN/m²
Average unit skin in cohesive soils = 86.0 kN/m²
Average unit skin in chalk soils = 0.0 kN/m²

[1] Limiting value for unit skin friction per m depth (in kN/m²)
[2] Limiting value for unit base resistance (in kN/m²)

Static Pile Design

RA-PG-06-025 (11.07)

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Piling Technique: CFA
Site Address : Hampstead Green
Contract No : 9377
Revision : 0

Comments : 0=72mOD
Tower Crane Piles

F of S shaft =	3	F of S shaft =	1.2
F of S base =	3	F of S base =	########

Depth Interval
1.00 m

Start (1) m	End (1) m	Soil Description (2)	S-1 SPT 'N'	S-2 k_s	S-3 $\Delta\Phi$ = 1.00	S-4 D/B Ratio (for info)	S-5 Nq	C-1 C_u Bottom kN/m²	C-2 C_u Grad-ient?	C-3 ΔC_u Gradient kN/m²	C-4 Alpha (α)	(3) N.S.F. Parameter Beta (β)	(4) Bulk Unit Weight (γ) kN/m³	(5) Submerged Unit Weight (γ') kN/m³	(6) Effective o'burden pressure (σ_v') kN/m²	(7) Unit Skin Friction (q_s) kN/m² [1] 225	(8) Unit Base Resistance (q_b) kN/m² [2] 15500	(9) CFA Piles 0.400 size in m: Ult. Shaft (Q_s) kN	(10) Ult. Base (Q_b) kN	(11) Ult. N.S.F. kN	(12) Allowable Capacity kN	(13) CFA Piles 0.400 size in m: Ult. Shaft (Q_s) kN	(14) Ult. Base (Q_b) kN	(15) Ult. N.S.F. kN	(16) Allowable Capacity kN
0.00	1.00	Ignore				3									0.0	0.0	0.0	0.0	0.0	0.0	**0**	0	0	0.0	**0**
1.00	2.00	Ignore				5									0.0	0.0	0.0	0.0	0.0	0.0	**0**	0	0	0.0	**0**
2.00	3.00	Ignore				8									0.0	0.0	0.0	0.0	0.0	0.0	**0**	0	0	0.0	**0**
3.00	4.00	Ignore				10									0.0	0.0	0.0	0.0	0.0	0.0	**0**	0	0	0.0	**0**
4.00	5.00	Ignore				13									0.0	0.0	0.0	0.0	0.0	0.0	**0**	0	0	0.0	**0**
5.00	6.00	London Clay				15		82.5	y		0.60				0.0	49.5	742.5	62.2	93.3	0.0	**52**	62	93	0.0	**52**
6.00	7.00	London Clay				18		91.6	y	9.1	0.60				0.0	52.2	824.4	127.8	103.6	0.0	**77**	128	104	0.0	**107**
7.00	8.00	London Clay				20		97.7	y	6.1	0.60				0.0	56.8	879.3	199.2	110.5	0.0	**103**	199	110	0.0	**166**
8.00	9.00	London Clay				23		103.8	y	6.1	0.60				0.0	60.5	934.2	275.2	117.4	0.0	**131**	275	117	0.0	**229**
9.00	10.00	London Clay				25		109.9	y	6.1	0.60				0.0	64.1	989.1	355.7	124.3	0.0	**160**	356	124	0.0	**296**
10.00	11.00	London Clay				28		116.0	y	6.1	0.60				0.0	67.8	1044.0	440.9	131.2	0.0	**191**	441	131	0.0	**367**
11.00	12.00	London Clay				30		122.1	y	6.1	0.60				0.0	71.4	1098.9	530.7	138.1	0.0	**223**	531	138	0.0	**442**
12.00	13.00	London Clay				33		128.2	y	6.1	0.60				0.0	75.1	1153.8	625.0	145.0	0.0	**257**	625	145	0.0	**521**
13.00	14.00	London Clay				35		134.3	y	6.1	0.60				0.0	78.8	1208.7	724.0	151.9	0.0	**292**	724	152	0.0	**603**
14.00	15.00	London Clay				38		140.4	y	6.1	0.60				0.0	82.4	1263.6	827.5	158.8	0.0	**329**	828	159	0.0	**690**
15.00	16.00	London Clay				40		146.5	y	6.1	0.60				0.0	86.1	1318.5	935.7	165.7	0.0	**367**	936	166	0.0	**780**
16.00	17.00	London Clay				43		152.6	y	6.1	0.60				0.0	89.7	1373.4	1048.4	172.6	0.0	**407**	1048	173	0.0	**874**
17.00	18.00	London Clay				45		158.7	y	6.1	0.60				0.0	93.4	1428.3	1165.8	179.5	0.0	**448**	1166	179	0.0	**972**
18.00	19.00	London Clay				48		164.8	y	6.1	0.60				0.0	97.1	1483.2	1287.8	186.4	0.0	**491**	1288	186	0.0	**1073**
19.00	20.00	London Clay				50		170.9	y	6.1	0.60				0.0	100.7	1538.1	1414.3	193.3	0.0	**536**	1414	193	0.0	**1179**
20.00	21.00	London Clay				53		177.0	y	6.1	0.60				0.0	104.4	1593.0	1545.5	200.2	0.0	**582**	1545	200	0.0	**1288**
21.00	22.00	London Clay				55		183.1	y	6.1	0.60				0.0	108.0	1647.9	1681.2	207.1	0.0	**629**	1681	207	0.0	**1401**
22.00	23.00	London Clay				58		189.2	y	6.1	0.60				0.0	111.7	1702.8	1821.6	214.0	0.0	**679**	1822	214	0.0	**1518**
23.00	24.00	London Clay				60		195.3	y	6.1	0.60				0.0	115.4	1757.7	1966.5	220.9	0.0	**729**	1967	221	0.0	**1639**
24.00	25.00	London Clay				63		201.4	y	6.1	0.60				0.0	119.0	1812.6	2116.1	227.8	0.0	**781**	2116	228	0.0	**1763**

Average unit skin in granular soils = 0.0 *kN/m²*
Average unit skin in cohesive soils = 84.2 *kN/m²*
Average unit skin in chalk soils = 0.0 *kN/m²*

[1] Limiting value for unit skin friction per m depth (in kN/m²)
[2] Limiting value for unit base resistance (in kN/m²)

Appendix C

Lateral Load Analysis

PROJECT	Hampstead Green
CONTRACT nr	9377
Design Case	400mm Lateral 25kN

Rock & Alluvium

BY	APP	DATE	Sheet
KK			

LAYER	LEVEL OF TOP OF STRATUM FROM COL (m)	SOIL DESCRIPTION	UNIT WEIGHT (kN/m^3)	Cu (kN/m^2)	Phi (^{o})
1	0	London Clay	20	55	
2					
3					
4	-20.0				

Water Level :-	0.0	m	
Pile Size :-	400	mm	
Unfactored Lateral Load at Top :-	25	kN	
Unfactored Moment Applied to Top :-	0	kNm	
F.O.S. on Lateral Pressure :-	3	*To derive reinforcement length- SEE NOTES*	

SUMMARY

Level of max moment (mb COL	Level of bottom of reinforcement (mb COL)	Unfactored max moment (kNm)	
-0.8	**-1.8**	**11.7**	**Divide by 2 for restrained piles**

Level (m)	Factored Lateral Resisting Pressure (kN/m^2)	Shear in Pile (kN)	Moment in Pile (kNm)
0.0	36.667	25.000	0.000
-0.1	47.361	23.319	2.420
-0.2	58.056	21.211	4.650
-0.3	68.750	18.675	6.648
-0.4	79.444	15.711	8.370
-0.5	90.139	12.319	9.775
-0.6	100.833	8.500	10.820
-0.7	111.528	4.253	11.461
-0.8	122.222	0.000	11.656
-0.9	132.917	-5.103	11.405
-1.0	143.611	-10.633	10.621
-1.1	154.306	-16.592	9.264
-1.2	165.000	-22.978	7.289
-1.3	165.000	-29.578	4.661
-1.4	165.000	-22.978	2.033
-1.5	165.000	-16.378	0.066
-1.6	165.000	-9.778	-1.242
-1.7	165.000	-3.178	-1.890
-1.8	165.000	3.422	-1.878

Appendix D

Structural Analysis

PROJECT: **Hampstead Green**	Rock & Alluvium					
TITLE or DESCRIPTION: **400mm Lateral 25kN**	ORIG by	Date	VERIF	Date	Ref. No	SHEET No
	KK				9377	of

REFERENCE | Rev:

EC2 — **Bending and Axial Force to EN 1992-1-1:2004 (EC2)** — Circular Sections (Cast In-situ)

Pile section

	pile diameter	=	400	mm
	design pile diameter h	=	380	mm
	Ac	=	113411	mm^2
4.4.1.3(4)	cover[1] c_{nom}	=	65	mm
	cage diameter d	=	218	mm
	ratio d/h	=	0.6	
	f_{ck}	=	32	MPa
	f_{yk}	=	500	MPa

k_2 = 75 mm

Kf = 1.1 [NA 2.4.2.5 (2)}

Design Actions on pile

Actions N	=	0	kN
Factored Actions N	=	1238	kN
Shear V_{Ed}	=	25	
Ult Shear V_{Ed}	=	37.5	kN
Induced Moment M_i	=	6	kNm
Applied Moment M_{Ed}	=		kNm
Σ Moments M	=	6	kNm
Factored Ult M	=	9	kNm

BM/SF factor 1.5

Using IstructE design charts for circular columns:-

$M/h^3 f_{ck}$ = 0.01 (also checked for M/h3 fck=0.0 for zero vertical load)

Actions N	$N/h^2 f_{ck}$	=	0.00
Factored Actions N	$N/h^2 f_{ck}$	=	0.29

therefore from charts;

$\rho f_{yk} / f_{ck}$ = 0.05 **From charts**

$\rho = 4A_{st} / \pi.h^2$

therefore, adopt greater of;

Area of main steel Ast	=	330	mm^2
main bar dia	=	16	mm
no. main bars	=	4	no.
stirrup dia	=	8	mm
Area of main steel, A_{st}	=	804	mm^2.
Bar spacing (face to face)	=	155	mm

PROJECT: Hampstead Green	Rock & Alluvium					
TITLE or DESCRIPTION: 400mm Lateral 25kN	ORIG by	Date	VERIF	Date	Ref. No	SHEET No
	KK				9377	of

REFERENCE | Rev:

EC2 **Shear to EN 1992-1-1:2004 (EC2)** Circular Sections (Cast In-situ) using helical reinforcement

Pile section

pile dia = 400 mm

pile diameter dnom = 380 mm

Ac = 113411 mm^2

4.4.1.3(4) cover c_{nom} = 65 mm k_2 = 75 mm [NA.4.4.1.3 (4)]

main bar dia = 16 mm

no. main bars = 4 no.

helical dia. = 8 mm

d = 254 mm γ_c = 1.5 (This is adjusted by K_f=1.1 [2.4.2.5 (2)] to give 1.65)

f_{ck} = 32 MPa γ_c = 1.65 α_{cc} = 0.85 [NA.3.1.6 (1)}

f_{yk} = 500 MPa γ_s = 1.15

V_{Ed} = 25 kN SF factor 1.5

Ult V_{Ed} = 37.5 kN

factored actions N_{Ed} = 0 kN Must have as zero if tension load is present as

6.2.2 Check requirement for shear reinforcement

$V_{Rd,c}$ = $[C_{Rd,c}k(100\rho_1 f_{ck})^{1/3}+k_1\sigma_{cp}]b_w d$ CRd,c = 0.18 / γc 0.11

with minimum = $(v_{min}+k_1\sigma_{cp})b_w d$ k = $1+(200/d)^{1/2}$ 1.89 <=2.0

ρ_1 = $A_{sl}/b_w d$ 0 <=0.02

v_{min} = $0.035k^{3/2}f_{ck}^{1/2}$ σ_{cp} = N_{ed}/A_c 0 < $0.2f_{cd}$

0.5131 k_1 = 0.15 [NA.6.2.2(1)]

$V_{Rd,c}$ = **47** kN

Is $V_{Rd,c} > V_{Ed}$ **=>** **YES** Action: ***No shear links needed - provide nominal links as req'd***

6.2.3 Design Shear Reinforcement

Check concrete strut capacity at Cot θ = 2.5 :- cot θ = 2

tan θ = 0.5

6.2.3 (3) exp 6.9 $V_{Rd,max}$ = $\alpha_{cw}.b_w.z.v_1.f_{cd}$ / (Cotθ+tanθ) (6.9) α_{cw} = 1 [NA.1 6.2.3(3)]

z = 0.9d 229 mm

$V_{Rd,max}$ = **300** **kN** v_1 = 0.6 (1-(fck/250)) 0.52 [6.6N]

Is $V_{Rd,max} > V_{Ed}$ **=>** **NA** Action:

Calculation for strut inclination:-

θ = $0.5.\sin^{-1}[(6.54*V_{Ed})/(b_w.d.(1-f_{ck}/250).f_{ck})$

θ = NA rad cot θ = 2.5 > 1.0

Calculate shear reinforcement spacing after Turmo et al (2008);-

$V_{Rd,s}$ = $z.\cot\theta.(A_\Phi/0.5s).f_{ywd}.0.85$ A_Φ = 50.3 mm^2

s = $2.([z.\cot\theta.A_\Phi.fywd.0.85]/V_{Rd,s})$ f_{ywd} = 435 MPa

= **NA** mm

Check maximum shear link spacing:-

is $s_{l,max}$ > 0.75d **YES**

Provide **8** mm helical at nominal pitch **190** mm

Turo, J, *et al*. Shear truss analogy for concrete members of solid and hollow circular cross section. **Eng. Struc.** (2008)

Site Address	**Hampstead Green**
Contract Number	**9377**
Revision	**0**
Date	**09/05/2016**
Designed by	**KK**
Approved by	

Rock & Alluvium

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Heave Reinforcement Calculation

Consider heave as acting over the top 3.0 m.

Allow for 0.5 m of ignored depth due to pile cut-off.

Heave force

Hf = alpha * cu * pi * l * b =	113.1	kN
Where:		
alpha is the soil softening factor =	0.6	
cu is the cohesion within the heave material =	60	kN/m2
pi =	3.142	
l is the length of pile over which the heave force acts =	2.5	m
and b is the pile diameter =	400	mm

Area of steel reinforcement against heave

Asc = Hf * FOS *10^3 * ym / fy =	**390**	**mm2**
Where:		
FOS (from NHBC guidance note) =	1.5	
fy =	500	N/mm2
γm is the material factor of safety from Structural codes =	1.15	

Steel bar length required

USC reqd = Hf * FOS =	**169.7**	**kN**
Where:		
FOS (from NHBC guidance note) =	1.5	
at	6	m
Ultimate Shaft Capacity (USC)	220	kN

Therefore provide the following to protect against heave:

4 No.	H	**16**	bars
		6	m long
	in a H	**8**	helical binder

Other loading conditions affecting steel reinforcement are to be considered seperately.
The piles are designed to protect only themselves from the forces of heave.
Ground beams and slabs should be protected to ensure that heave forces are not transferred to the piles.

Appendix E

Concrete Capacity Check

PROJECT	Hampstead Geen	Rock & Alluvium					
TITLE	EC2 structural Capacity Check	Orig.	Date	Verif.	Date	Ref. No./rev.	Sheet
		KK				9377	
Section	Case 1 - 400mm					Date 09/05/2016	

Based on EC2 Design
Maximum Structural Capacity for 400 mm diameter pile

The Value of design compressive strength of concrete is defined as:

f_{cd} = **$(\alpha_{cc} * f_{ck}) / (y_c * k_f)$** ***Clauses 2.4.2.5 & 3.15***

Therefore for C 32/40 Concrete, characteristic cylinder strength = 32 N/mm^2

Where:
α_{cc} = 0.85
f_{ck} = 32 N/mm^2
y_C = 1.50
k_f = 1.10

Therefore
f_{cd} = 16.48 N/mm^2

Design Axial Resistance of 400 mm diameter pile

$N_{rd} = A_c * f_{cd} + A_s * f_{yd}$

Where:
d_{nom} 380 mm^2
A_c = 113411 mm^2
f_{cd} = 16.48 N/mm^2
A_s Ignore
f_{yd} Ignore

Basing Design on Compressive Strength of Concrete Area alone

$N_{rd} = A_c * f_{cd}$

For a 400 mm diameter pile
A_c = 113411 mm^2

Therefore pile resistance is

N_{rd} =	**1870** kN

Therefore max Com 1 action from schedule is

F_{cd} =	1238	kN	**Total**

Check Compressive Stress on Pile, $N_{rd} > F_{cd}$

Nrd > Fcd therefore no additional compression steel required

Appendix F

Settlement Analysis

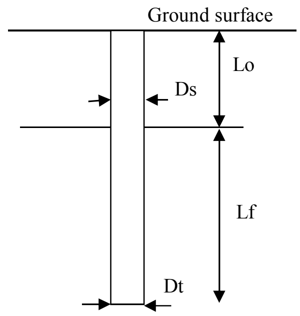
Rock & Alluvium	Project: Hampstead Green	Ref: 9377	
	Design case:		
	400mm pile load 825kN (SLS)	By: KK	Date:
	PPL 72mOD COL 66.7mOD	Chk:	Date:

Cemset v 1.0

Prediction of pile ultimate capacity using the method outlined by Fleming in Geotechnique 42, No 3 pages 411-425

Pile Data

Pile Number			
Pile shaft diameter	Ds	400	mm
Pile base diameter	Db	400	mm
Pile length with no friction	Lo	0	m
Pile length with friction	Lf	18.7	m
Effective Lf length factor	Ke	0.45	
Shaft flexibility factor	Ms	0.0012	
Soil modulus below pile base	Eb	58590	kN/m²
Concrete modulus	Ec	3.10E+07	kN/m²
Ultimate shaft capacity	Us	1904	kN
Ultimate shaft friction	qus	81	kN/m²
Estimated Ultimate End bearing	Ub	220	kN
Ultimate end bearing pressure	qub	1751	kN/m²



Test Data

Load at head	(kN)																		
Head Settlement	(mm)																		
Elastic Settlement	(mm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Predicted Settlement

Load descriptor WL Settlement required for load of 825 kN Predicted settlement at head = 2.1 mm

Projected Data

Load at head	(kN)	0	59	118	177	236	295	354	413	471	530	589	648	707	766	825
Rigid Pile Settlemen	(mm)	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.4
Total settlement	(mm)	0.0	0.1	0.3	0.4	0.6	0.7	0.9	1.0	1.2	1.3	1.5	1.6	1.8	2.0	2.1

(For "Load at Head" applied at base)