UCL – New Students Centre

Bearing Pile Design

Geotechnical Design Report

Report reference: P230-des-02 C00

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1. Executive Summary – Bearing Pile Design Requirements

- These calculations cover the design of the bearing piles for the UCL New Students Centre development at Gordon Street
- 115nr 600mm and 5nr 900mm nominal diameter bearing piles are required to support the new structure.
- Bearing piles to be constructed using a rotary bored technique.
- Piles have been designed to Eurocode 7 taking account of permanent, leading variable, accompanying variable and transverse actions (as specified by the engineer).
- Design is based on a piling platform level of **24.2mOD.**
- Design Chemical classification = **DC-3**
- Design is based on a minimum characteristic concrete strength of **37N/mm^2 @ 28 days (C30/37)** for piled foundations.
- Piles have been designed as fully restrained by the substructure.
- Reinforcement will be provided to a projection length in accordance with EC2.

The following summary table is based on pile design to EC7.

Pile diameter (mm)	Applied compression load (kN) (SLS)	Tension load (kN)	Piling Platform Level (mOD)	Design toe level (mOD)	Indicative pile length (m)
600	250 to 2200	0 to 1300	24.2	10 to -7.0	14.2 to 31.2
900	2800 to 3900	0	24.2	-1.5 to -7.5	25.7 to 31.7

Table 1 *Pile design summary*

Note: See Section 8 for reinforcement summary

1.1. CDM Risks

A full CDM design assessment is located in Appendix **B**.

2. Project summary

Keltbray Piling has been appointed by Mace to design and construct rotary bored bearing piles for the development at UCL (Gordon Street) New Student Centre.

These works comprise the installation of 600mm or 900mm diameter thin wall rotary bearing piles from a piling platform level of **24.2mOD**. The temporary casing will be installed until a seal is achieved into the London Clay (nominally after 1.0m penetration). The top of the London Clay is expected at 18.0mOD and therefore 7.0m of temporary casing is envisaged.

2.1. Description of site and surroundings

As shown in Figure 1, the site is bound by Bloomsbury theatre to the north and Gordon Street to the east. The site is bounded to the south by a row of Georgian terraced housing and to the west by university buildings belonging to UCL. The site is currently surrounded by secure steel fencing along the eastern boundary.

The site was previously occupied by All Saint's Church which was destroyed by bombing during the Second World War. Since that time the only known development within the confines of the site has been temporary offices and university lecture rooms.

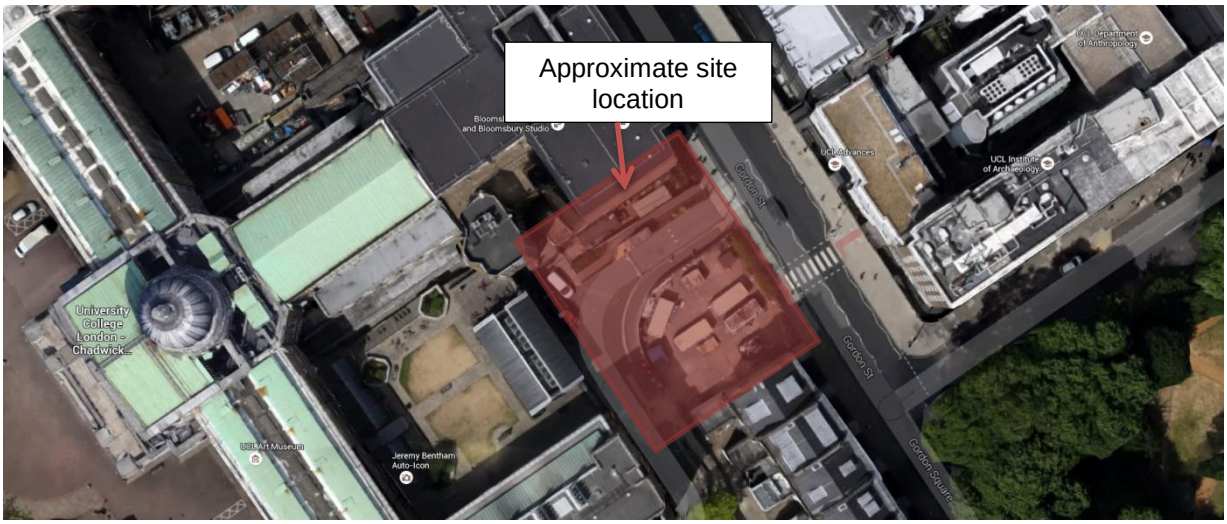


Figure 1: *Site Location: UCL Gordon Street, London (Source: http:// maps.google.com)*

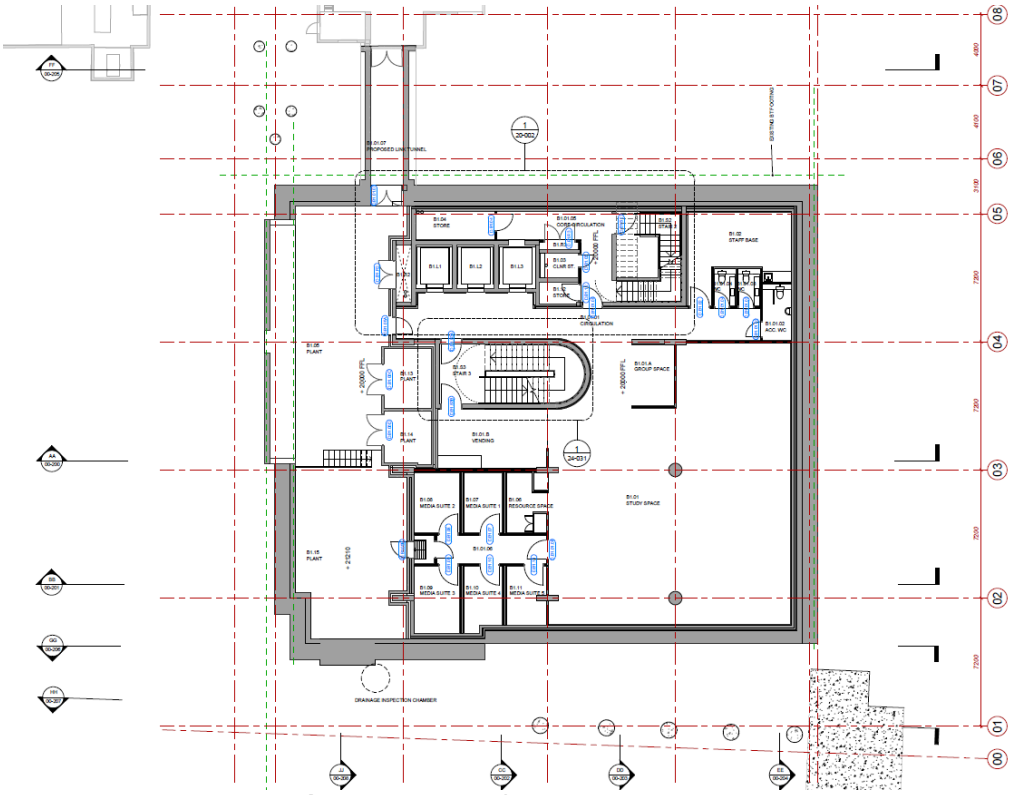


Figure 2: *General Arrangement*

3. Piling Specification – Key Requirements

- Design is in accordance with Curtins Specification 031-51-0200-SP-S-00008-XX revision P01 and ICE SPERW:2007.
- Design is based on Eurocode 7 and its associated UK National Annex.
- Pile design life of 60 years.
- All bearing piles to be tested using Sonic Echo method.
- **DC-3** concrete classification.
- Piles to be bored and concreted within 12 hours.
- Plan positional tolerance = 75mm
- Pile verticality tolerance = 1 in 75mm
- Minimum concrete cube compressive strength at 28 days = 37N/mm^2

3.1 Information to be provided / clarified by the Clients Engineer

- Acceptance of the basis for this design by all parties and any qualifications therein
- Acceptance of loading assumptions as detailed in section 5
- Load Split of 70% Permanent : 30% Variable
- Maximum Pile settlement = 15mm at SLS

4. Ground Conditions

4.1. Description of investigations and ground conditions

The design has been carried out based on the results of a ground investigation, undertaken by Soil Mechanics (Report No. D6056 Rev.1, dated March 2007), comprising:

- 4 No. Cable Percussion Boreholes to a maximum depth of 40.50m.
- Standard penetration testing (SPT) were carried out at regular intervals in the cable percussive boreholes with disturbed and undisturbed samples recovered (U100's) for subsequent laboratory testing.
- Laboratory testing included:
  - Particle size distribution
  - Moisture Content and Atterberg limits determination
  - Chemical testing
  - Undrained triaxial testing (consolidated and unconsolidated)
  - One dimensional consolidation testing

The existing ground level is approximately 24.2 mOD. The ground conditions generally comprise of sand and gravel (Lynch Hill Gravel) over the London Clay Formation and Lambeth Group.

The boreholes have been plotted against level and are located within Appendix **A**.

Detailed consideration of the ground engineering properties as presented in the site investigation report has been undertaken. The soil descriptions in the following sections have been interpreted from the results of the ground investigation.

Made Ground
The Made Ground is generally described as brown sandy gravel. Sand is fine to medium and gravel is sub-angular to sub-rounded fine to coarse. Occasional cobble size fragments of brick and concrete were encountered.

Lynch Hill Gravel
The Lynch Hill Gravel comprises medium dense to locally dense sand and gravel. The gravel is typically described as sub-angular to sub-rounded fine to coarse flint. Standard Penetration Test (SPT) 'N' values in this stratum typically range between 'N' = 17 and 50. The lower values of 'N' = 17, in the lower parts of the deposit reflects the interface with the London Clay, beneath.

London Clay
Boreholes encountered the surface of the London Clay at an elevation of approximately 18.0 mOD, which is about 6.2m below existing ground level. The London Clay comprised of fissured dark grey clay, with strength ranging from stiff to very stiff. The thickness of the London Clay Formation is about 8m and therefore extends to an elevation **of 10.0mOD.**

Lambeth Group
The Lambeth Group was encountered below the London Clay between 10.5m OD and 5.5m OD. It is described as very stiff fissured and locally laminated mottled light blue and red brown clay. Some possible shell fragments were encountered with size ranging from silt size particles **to 1-3mm.**

Thanet Sand Formation
Thanet Sand was encountered between -10.5 to -11.5 m OD and is described as dense, fine to medium sand with occasional lenses of soft brown clay. Extrapolated SPT N-values are in the range of 64 to 300.

4.2. Groundwater

During the site investigation, possible seepage was found in one borehole at 5m bgl. Nevertheless, since water was added at 3m bgl to aid with the drilling, this can be misleading. No groundwater strikes were encountered in any other boreholes. Groundwater monitoring reported in the SI showed GWL at 4.9 – 5.5 mbgl. The groundwater level therefore is conservatively assumed to be at 19.5mOD for the purposes of design.

4.3. Design Stratigraphy

A review of the ground investigation information has found the ground conditions to be reasonably consistent across the site; therefore, the following single design stratigraphy has been adopted for the purposes of design:

Stratum	Design level of stratum (mOD)	Thickness (m)
Made Ground	24.2	3.2
Lynch Hill Gravel	21.0	3.0
London Clay	18.0	8.0
Lambeth Group	10.0	21.0
Thanet Sand	-11.0	Not proven

Table 2 *Design Stratigraphy profile*

4.4. Geotechnical Design Parameters

The site investigation information has been reviewed to select appropriate geotechnical parameters to allow design of the bearing piles. A summary of these geotechnical design parameters is provided in Table 3.

The undrained shear strength (c_u) profile within the London Clay has been derived from the results of undrained triaxial testing and in situ SPTs. SPT 'N' results have been correlated to the triaxial data provided to provide a site specific correlation factor (f) of 5.5 in the London Clay and 6.0 in the Lambeth Group as shown in Figure 3.

The moderately conservative design line equation in the London Clay is given as follows:

$$c_u = \begin{cases} 70 + 15z, & \text{from } 18.0\text{mOD to } 10.0\text{mOD} \\ 200 + 13.3z, & \text{from } 10.0\text{mOD to } -11.5\text{mOD} \\ 485 & \text{below } -11.5\text{mOD} \end{cases}$$

Where z = depth below top of the corresponding stratum.

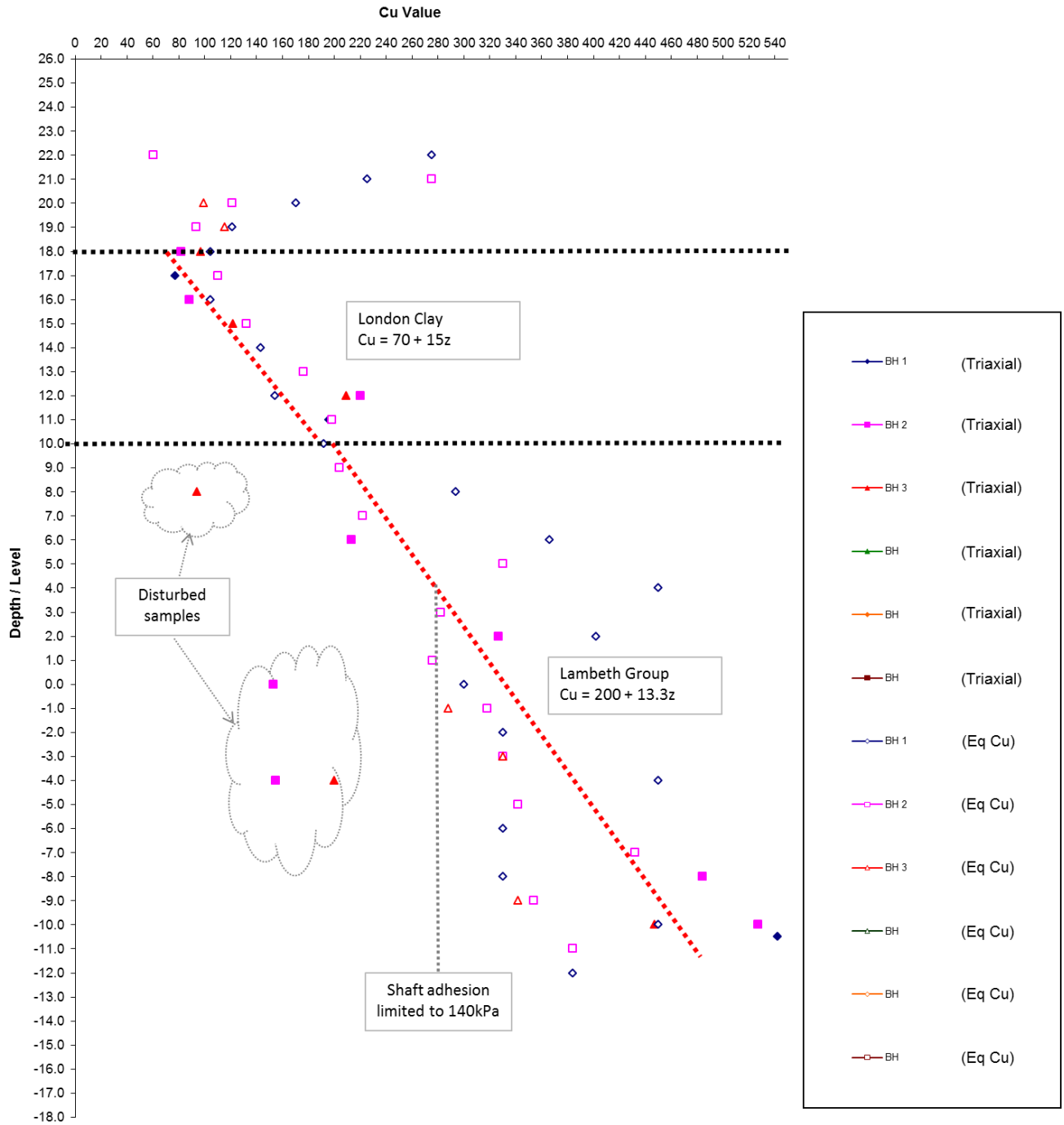


Figure 3: *Plot of undrained shear strength and correlated SPT'N' value against Level (mOD)*

The soil parameters as shown below are subsequently used for design of the piles.

STRATUM	BEARING PILE DESIGN PARAMETERS		
Made Ground	Bulk density	γb	= 18kN/m^3 (Skin friction contribution ignored)
Lynch Hill Gravel	Bulk density SPT Friction angle Shaft friction Coeff Bearing Capacity factor Unit end bearing	γb 'N' 'Φ' k_s N_q q_b	= 20kN/m^3 = 17-50 = 38° = 0.7 = 200 = N/A
London Clay	Bulk density SPT Cohesion (within basement) Adhesion factor Unit skin friction End bearing coefficient	γb 'N' c_u α q_s N_c	= 20kN/m^3 = values as per design line (Figure 3) = values as per design lines (Figure 3) = 0.5 = 110kPa (average) over pile shaft not exceeded* = 9.0
Lambeth Group	Bulk density SPT Cohesion (within basement) Adhesion factor Unit skin friction End bearing coefficient	γb 'N' c_u α q_s N_c	= 20kN/m^3 = values as per design line (Figure 3) = values as per design lines (Figure 3) = 0.5 = 110kPa (average) over pile shaft not exceeded* = 9.0

Table 3 *Summary of design soil parameters for bearing piles*

Note: LDSA 2009 guidelines set a maximum average of 110 kPa over the pile shaft in the London Clay. For this design, this is adopted for the total length of the pile shaft in the London Clay and the Lambeth Group.

5. Design Methodology

5.1. Design philosophy

Piles will be installed from a single piling platform level across the site at **24.2 mOD.**

The design has been based on 600mm and 900mm nominal diameter rotary bored thin wall casing bearing piles. The diameter for the bearing piles is 610/572mm and 910/876mm representing the cased and tool diameters respectively.

All piles will be installed based on the adoption of the higher model factor (1.40) as no preliminary pile tests are to be undertaken. The higher partial safety factors are to be used for the shaft friction (1.60) and end bearing resistances (2.00) as no load testing is proposed.

The serviceability performance of the piles has been checked to confirm that the expected pile performance meets the Clients specification.

5.2. Design Approach to EC7

The design is based on Eurocode 7 adopting a design approach based on empirical calculations taking into account partial safety factors on shaft friction, end bearing and an additional model factor.

The fundamental principles of an EC7 design approach is that applied loads (actions) are factored up and design reactions (resistances) are factored down.

In summary design is to ensure for combination 1 & 2 to design approach 1:

Design actions < Design resistance

Design is based on a partial safety factor approach whereby 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.

The design has been checked for Geotechnical (GEO) and Structural (STR) Ultimate Limit States (ULS) with additional checks based on sensitivity analysis for the Serviceability Limit State (SLS) as per clause 2.4.6.1(6) P.

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".

6. Design Actions – SLS to ULS

Design has been checked for Geotechnical (GEO) ultimate limit state analysis based on the following:

- Piles are designed in accordance with current Eurocode Standards, as per Curtin's piling specification.
- Piles have been designed with no requirement for load testing.

The piles have been divided into 6 load cases based on their tension loads which determine the reinforcement design see table 7.

The following serviceability limit state actions have been specified by the Engineer:

Pile dia (mm)	Pile nr	Total Vert. load (kN)	Total tension (kN)	Total shear (kN)
600	115	250 to 2200	0 to 1300	7 to 31
900	5	2800 to 3900	0	39 to 55

Table 4 *SLS loads*

6.1. Compression Actions

In accordance with design to EC7, design actions acting on the piles from the SLS values provided by the engineer have been factored up for combination 1 & 2 using the partial safety factors outlined in EC0, Table NA.A1.2 as stated below.

Load Conversion Factors - SLS to ULS				
Action Type	**Action Split**		**Com 1**	**Com 2**
Permanent	n/a		1.35	1.00
Leading Variable	n/a		1.50	1.30
Accomp Variable	**AVA**	**Wind**	$\psi_{0,1}$	0.5
Accomp Variable	**AVA**	**Imposed**	$\psi_{0,1}$	0.7

Table 5 *Compressive Actions (SLS)*

Design resistances have been calculated based on the following partial safety factors:

Partial factor for Pile Resistance			
Combination 1		**Combination 2**	
+ Shaft	1.00	**+ Shaft**	1.60
Base	1.00	**Base**	2.00
- Shaft	1.00	**- Shaft**	2.00
Model factor	1.40		

Table 6 *Partial factors for pile resistances*

From experience, design combination 2 governs the geotechnical requirements in design.

The partial safety factor for resistance on the pile shaft has been taken as 1.60 and 2.0 on the base on the basis that no working load tests will be carried out and a model factor of 1.40.

6.2. Tension Actions

Piles are subject up to 1300kN total SLS tension.

A Factor of Safety of 3.0 has been used for the tensile geotechnical capacity of the piles as specified by Curtins (“*Pile Schedule, 031-51-0200-DR-S-00008-ZZ”)*

6.3. Transverse Actions

Piles have been designed for transverse actions (horizontal loads) and the design also consider the action imposed as a result of installed verticality tolerance where individual piles have been design to an equivalent lateral load of:

Lateral Load (SLS) = Vertical Load (SLS) / 75

Transverse loads (SLS) have been input into the calculation with the design effects of the actions factored up to ULS values.

Lateral loading induces a moment within the pile, resisted by the passive earth pressure. Design calculations have been completed using the single pile design function within WALLAP (version 5.04) with the appropriate maximum moment and shear forces taken forward to calculation as discussed in section 6.4 of this document.

Single pile analyses are located in Appendix **D.**

At this stage no allowance has been made in the design for additional lateral loads or moments induced as a result of temporary loading effects (e.g. local excavations adjacent to the piles).

6.4. Moments and tolerances

Pile design has been based on full restraint at the head by the substructure and hence no allowance has been made for eccentric moments caused by allowable installation tolerances:

NB A pile tolerance of 75mm on plan and 1 in 75 verticality has been allowed for.

A WALLAP analysis has been completed for piles subject to moments due to applied horizontal forces in order to determine the bending moment and shear force profiles with depth. See section 8.5 for further details.

6.5. Heave

Tension applied to piles from short term heave has been calculated based on Terzaghi’s 1-D consolidation theory. A minimum steel reinforcement of 6B20 is adequate for the short term heave which equates to less than 6 months based on the consolidation rates taken from the SI. It is assumed that the basement slab will be constructed within 6 months from the installation of the piles and that any heave induced tension after that has been taken into account by the Engineer and given through the pile loads specified in the pile schedule.

Negative Skin Friction (NSF)
The site investigation has been reviewed and no allowance has been made in the design for the potential effects of negative skin friction.

7. Calculation of Design Ultimate Resistances for Bearing Piles

7.1. Design Resistance for Cohesionless Soils (e.g. Lynch Hill Gravel)

Pile capacity calculations within cohesionless soils have been based on the following:

Shaft Resistance – Cohesionless strata (ULS)

Characteristic Shaft Resistance of Stratum $q_{s;i;k} = K_s \tan \delta \times \overline{\sigma_v}'$
Where shaft friction factor K_s = values as per Table 2

Characteristic Shaft Resistance of Pile $R_{s;k} = A_{s;i}\, q_{s;i;k}$

Where:
$\underline{A}_s$ = π x dia x length of shaft in clay
$\overline{\sigma_v}'$ = Average effective vertical stress

Base Resistance – Cohesionless strata (ULS)

Characteristic Base Resistance of Stratum $q_{b;k} = \overline{\sigma_v}' \times N_q$
Characteristic Base Resistance of Pile $R_{b;k} = A_b \times q_{ub}$

Where:
A_b (Area of base) = π x dia^2 x 0.25
N_q = Bearing capacity factor (after Berezantsev)

7.2. Design Resistance for Cohesive Soils (e.g. London Clay & Lambeth Group clay)

The following calculations were used in calculating the bearing capacity within the London Clay and Lambeth Group clay.

Shaft Resistance - Cohesive strata (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 = π x dia x length of shaft in clay
$C_{u\ av.}$ = Av. Undrained shear strength over length of shaft
α = 0.50 (London clay)

NB Ultimate shaft friction has been limited to a maximum value of 140kPa in the London Clay with the average value over the pile shaft length not exceeding 110kPa as with LDSA 2009 guidelines.

Base Resistance - Cohesive strata (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 (London Clay)
C_u base = Undrained design shear strength at base

Notation

$F_{c;d}$	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

A Geotechnical Summary can be found in Appendix C

7.3. Serviceability Limit State (SLS) Analysis

Design calculations have been undertaken to model the expected performance of the bearing piles under load.

Settlement analysis has been completed using the method described by Flemming, W.G.K (1992) and is summarised in Table 7 below:

Pile Dia. (mm)	Design SWL (kN)	Pile toe level (mOD)	Est. settlement (mm)
600	2200	-8.0	<15mm
900	3900	-7.5	<15mm

Table 7 *Summary of Settlement Analysis*

Note: Full Analysis is included in Appendix G

8. Structural Design

Reinforcement design has been completed on the basis of the reinforced concrete design code BS EN 1992-1-1:2004

8.1. Structural Parameters

Pile diameters	=	600/572mm or 900/876mm
Design Concrete strength, f_{cu}	=	37 N/mm^2 (DC-3)
Steel f_y	=	500 N/mm^2 [high yield] BS EN 1992-1-1:2004
Load factor	=	1.50 (100% variable load)
Materials factor	=	1.15 (reinforcement)
Minimum Concrete Cover	=	75mm

8.2. Reinforcement Design Summary

- Reinforcement is provided to cater for the applied tensile and lateral loads, heave induced loads and loads applied due to positional tolerances
- Pile projection has been calculated in accordance with BS EN 1992-1-1:2004
- De-bonding foam is to be provided to assist in breaking the piles down
- All reinforcement calculations have been undertaken in accordance with BS EN 1992-1-1:2004
- Where necessary reinforcement cages may be stiffened in order to facilitate installation

8.3. Compression

The axial compressive stress of concrete has been checked in accordance with BS EN 1992-1-1:2004 where:

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

$$\boldsymbol{f_{cd}} = (\propto_{cc} * \boldsymbol{f_{ck}}) \Big/ (\boldsymbol{y_c} * \boldsymbol{k_f})$$

Appendix **F** presents a calculation to prove a 600mm diameter pile is capable of supporting the max specified pile load (2200kN) and that a 900mm diameter pile is capable of supporting the max specified load (3900kN) in this project based on a 70/30 load split permanent to variable.

8.4. Tension

Allowance has been made in the design for piles subject to tension loading in accordance with section 6.2 on the following basis.

$$As\ req = \frac{1.5\ x\ Tension\ load\ x\ 1000}{0.87\ x\ fy}$$

Tension will be carried by the reinforcement cage. The computer software OASYS AdSec is used for the structural design. The section is designed to be under maximum design bending and maximum design tension simultaneously (conservative approach).

8.5. Pile Section Design for Bending & Shear

Horizontal forces are specified by the engineer to be 1% of the pile design vertical load and a minimum of 5kN. Single pile analyses performed on Wallap simulates the distribution of the generated Bending moment and shear force in each pile as a result of the lateral load applied at the pile's CoL. Maximum values of these are given in the table below.

Design calculations for reinforcement required due to bending have been completed using Oasys Adsec. Example calculations are given in Appendix E.

Shear calculations are based on the method described by Turo, J, et al (2008) Shear truss analogy for concrete members of solid and hollow circular cross section.

Pile dia. (mm)	Design cage case	Applied dead comp. load (kN) (SLS)*	Max Tension load unfactored (kN)	Bending moment unfactored (kNm) (resulting from applied lateral load)	Lateral Load unfactored (kN)
600	1	0	500	12	31
600	2	0	700	12	31
600	3	0	900	12	31
600	4	0	1300	12	31
600	5	0	0	<10	22
900	6	0	0	45	55

Table 8 *Pile loading summary*

**Note: Applied compressive load (favourable for structural analysis) is considered 0kN for all piles (reasonably conservative approach)*

8.6. Steel projection

Steel projections have been calculated in accordance with EC2 cl. 8.4.3 with the expression:

$$l_{b,rqd} = (\emptyset/_4)(\sigma_{sd}/_{f_{bd}})$$

Where:
Ø = Bar diameter
σ_{sd} = design stress of the bar at the position from where the anchorage is measured
f_{bd} = design ultimate bond stress = 2.25 x η_1 x η_1 x f_{ctd}

f_{ctd} = 1.41MPa
therefore f_{bd} = 3.18MPa

For cages with 20mm diameter bars:

$$l_{b,rqd} = (20/_4)\left(435/_{3.18}\right) = 685mm$$

For cages with 25mm diameter bars:

$$l_{b,rqd} = \left(25/_4\right)\left(435/_{3.18}\right) = 856mm$$

For cages with 32mm diameter bars:

$$l_{b,rqd} = \left({}^{32}/_{4}\right)\left({}^{435}/_{3.18}\right) = 1096mm$$

Due to tension loads governing design cases, the design anchorage length has been calculated in accordance with EC2 Cl. 8.4.4:

$$l_{bd} = \alpha 1\alpha 2\alpha 3\alpha 4\alpha 5 l_{b,rqd}$$

EC2 Table 8.2 all alpha values are equal to 1.0 except α2 which is 0.7 for the 20mm and 25mm bars and 0.8 for the 32mm bars.

Hence for cages with 20mm diameter bars:

L_{bd} = 0.7 x 685 = 480mm

Hence for cages with 25mm diameter bars:

L_{bd} = 0.7 x 856 = 600mm

Hence for cages with 32mm diameter bars:

L_{bd} = 0.8 x 1096 = 875mm

A summary of the required reinforcement cages is provided in Table 8 below.

Design cage case	Nr main bar	Main bar dia. (mm)	Shear helicals (mm)	Cage toe level (mOD)	Projection (mm)
1	**7**	**20**	**B8@300**	4.5 to 8.0	480
2	**6**	**25**	**B8@300**	2.5 to 4.0	600
3	**7**	**25**	**B8@300**	0.0 to 1.5	600
4	**6**	**32**	**B8@300**	-4.5 to -1.0	875
5	**6**	**20**	**B8@300**	10.0 to 15.0	480
6	**7**	**25**	**B10@450**	15.6	600

Table 9 *Reinforcement Design Summary*

Note: Actual projection length may be increased to suit site works

8.7. Design Concrete Classification

Design is based on design concrete classification level **DC-3** in accordance with the project specification.

9. Reference Documents

1. *BS EN1536: 2010 – Execution of special geotechnical work – Bored Piles*
2. *BS EN 1997-1:2004 – Eurocode 7 Geotechnical Design*
3. *NA to BS EN 1991:2004 – UK National annex to Eurocode 7: Geotechnical Design*
4. *BS EN 1992-1-1:2004 Eurocode 2: Design of concrete structures*
5. *BS4449: 2005 Steel for reinforced concrete*
6. *BRE Special Digest 1: 2005 3rd Edition*
7. *Specification for Piling and Embedded Retaining Wall (SPERW) 2007*
8. *The Concrete Centre, How to Design Concrete Structures using Eurocode 2 (Bond, A.J., Brooker, O., Harris, A.J., Harrison, T., Moss, R.M., Narayanan, R.S., and Webster, R., 2006)*
9. *London District Surveyors Association, "Foundations: No1. Guidance Notes for the Design of Straight Shafted Bored Piles in London Clay: 2009*
10. *Flemming W.J.K (1992). A new method for single pile settlement prediction and analysis*

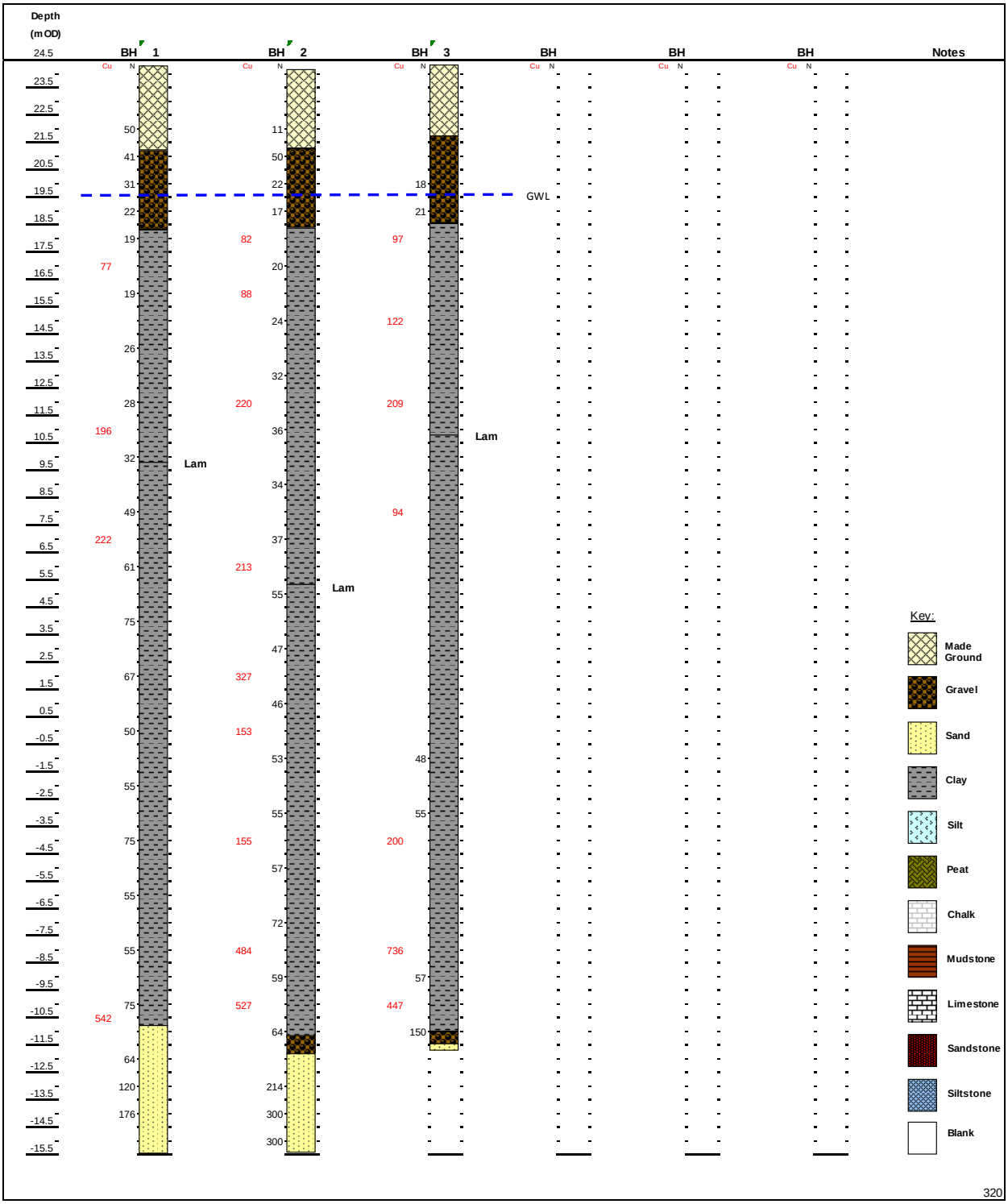
9.1. Drawing References

Drawing Title	Drawing No	Revision
Pile Layout	031− 51− 0200− DR− S− 00100− ZZ	P4
Pile Schedule	031-51-0200-DR-S-00008-ZZ_iss2	P2
GA Basement Level 2	031-51-0200-DR-S-00101-B2_iss5	P5
Capping Beam and Ground Beams	031-51-0200-DR-S-00113-00_iss5	P5
Soil mechanics, factual report on ground investigation	D6056	1,March 2007
Curtins Specification: Piling	SP-S-00008-XX	P01
Curtins Specification: Concrete Mixes	SP-S-00004-XX	P01
Phase 2 Intrusive Investigation	EB1029/AJS/2872	July 2013

Table 10 *List of drawings used in design*

A. Borehole profile vs Level (mOD)

keltbray Piling



Keltbray Piling

B. Designers' Risk Assessment

keltbray Piling

Risk level action	
Risk level	**Action required**
Low	Check that no further risks can be eliminated by design modifications. Proceed with design.
Med	Consider alternative design or construction method. If alternatives are not available, specify precautions to be adopted. List residual hazards in risk register.
High	Seek alternative solutions. If alternatives are not available, specify precautions to be adopted and advise manager. List residual hazards in risk register.

Severity category			
Score	**Health & Safety**	**Environmental**	**Technical**
1	Minor injury / inconvenience. Minor delay to work.	Short term local damage.	Design approval required.
2	Minor injury.	Medium term local damage. Short term regional damage.	Onerous performance specification.
3	Reportable / Lost time injury.	Long term local damage. Regional damage.	Complex design solution. Variable soil.
4	Major injury / illness. Long term effects.	Long term widespread damage.	Limited site investigation data. Highly variable soil.
5	Fatalities.	Widespread permanent damage.	Catastrophic element failure.

Risk matrix					
Severity score	**Likelihood score**				
	1	**2**	**3**	**4**	**5**
1	Low	Low	Low	Med	Med
2	Low	Low	Med	Med	High
3	Low	Med	Med	High	High
4	Med	Med	High	High	High
5	Med	High	High	High	High

							Pre RCMs				Post RCMs			
Risk no.	**Date**	**By**	**H&S/ Env/ Tech**	**Activity**	**Hazard**	**Cause**	**Likelihood**	**Severity**	**Risk rating**	**Risk control measures (RCMs)**	**Likelihood**	**Severity**	**Risk rating**	**Residual hazards**
1	17-03-15	AM	Tech	Pile Design	Piles are inadequately designed	Unknown construction levels	3	4	High	Design is checked after piling platform checks. Piling mat level qualified in tender.	1	1	Low	
2	17-03-15	AM	Tech	Pile Design	Design is incorrect	Poor information.	4	4	High	Design has been based on a moderately conservative design line and lower bound correlation to SPT'N'. Factor of safety in accordance with ICE SPERW 2007. Contractor shall satisfy himself that the ground conditions on site / pile diameter / capacity chosen to be kept within the scope of the site investigation	1	1	Low	
3	17-03-15	AM	Tech	Piling mat design, preparation and maintenance	Overturning rig / instability	Incorrect design of mat thickness / poor maintenance of mat / inadequate removal of soft spots / variable ground conditions	4	4	High	Detailed design of piling mat provided / removal of soft spots / continuous and adequate maintenance of mat	1	1	Low	
4	17-03-15	AM	Tech	Pile Construction	Exposure to spoil / ground containing hazardous substances / deterioration of concrete	Existence of hazardous substances in the ground	4	4	High	Potential contamination to be assessed and controlled by a competent contractor / concrete to be designed to account for potential contamination	1	1	Low	
5	13-03-15	AM	Ops	Travelling up/down ramps	Rig overturning	Platform instability, insufficient design or width	3	5	High	Ensure piling platform is designed and installed and tested to specification.	1	1	Low	

6	17-03-15	AM	Tech	Pile Construction	Ground loss / structural integrity of the pile compromised associated with bore stability	Piling method not suitable for the ground conditions encountered	3	2	Med	Works to be undertaken by a competent contractor using normal site procedures / contractor should satisfy himself that the piling methods are suitable for ground conditions	1	1	Low	
7	17-03-15	AM	Tech/ Ops	Pile Construction	Water strike into open bore	Insufficient penetration of casing into London Clay	2	3	Med	Clay level to be inspected and checked during construction and works to be undertaken by a competent contractor.	1	1	Low	
8	18-4-16	AM	Tech	Pile Construction	Operations affecting existing structures	Insufficient information on the extent of the existing structures	2	2	Med	Drawings and information on existing structures to be provided by the Engineer before works commence on site	1	1	Low	

keltbray Piling

C. Bearing Capacity Calculations and Geotechnical Summary

Lynch Hill Gravel

EC7 Design Approach - Alternative Design Method

PILE CAPACITIES IN COHESIONLESS SOILS

Effective Stress & Pile Input Parameters		
Pile Dia.	900	mm
p.p.l.	24.20	m OD
Cut-off	21.73	m OD
Top of Stratum	21.00	m OD
Finished g.l.	21.00	m OD

Partial factor for Pile Resistance			
Combination 1		Combination 2	
+ Shaft	1.00	+ Shaft	1.60
Base	1.00	Base	2.00
- Shaft	1.00	- Shaft	2.00
Model factor		1.40	

Load Conversion Factors - ULS to SLS			
Load Type	Load Split	Com 1	Com 2
Permanent	70%	1.35	1.00
Variable	30%	1.50	1.30

Design Notes

Stratum Ref-	River Terrace Gravels								
Top of Stratum	21.00	m OD		Overburden Unit Wt.	18.00	kN/m^3		Water Level	19.50	m OD
Initial Qus:	0	kN		Limiting base stress	15000	kN/m^2		Limiting shaft stress	200	kN/m^2
delta/phi	1.00			Limiting phi	38	degs		Limiting N_q	200	
								Minimum Design FoS on Shaft Friction		1.20

Bore (m)	Unit Wt. (kN/m^3)	SPT N	delta (degs)	k	Nq	p.w.p. (kN/m^2)	p (kN/m^2)	p' (kN/m^2)	qus (kN/m^2)	Qus (kN)	qub (kN/m^2)	Qub (kN)	Design Comp Resist R_{cd} (Com 1) kN	Design Comp Resist R_{cd} (Com 2) kN	Max unFact Loads kN Comp	Max unFact Loads kN Tension	Toe m OD
3.20	20.0	20	33.0	0.7	55	0	0.0	0.0	0	0	0	0	0	0	0	0	21.00
3.70	20.0	20	33.0	0.7	55	0	10.0	10.0	5	3	0	0	2	1	1	1	20.50
4.20	20.0	20	33.0	0.7	55	0	20.0	20.0	9	13	0	0	9	6	5	5	20.00
4.70	20.0	20	33.0	0.7	55	0	30.0	30.0	14	29	0	0	21	13	12	11	19.50
5.20	20.0	20	33.0	0.7	55	5	40.0	35.1	16	50	1935	1231	915	42	42	19	19.00
5.70	20.0	10	33.0	0.7	55	10	50.0	40.2	18	74	2216	1410	1060	62	62	28	18.50
6.20	20.0	20	33.0	0.7	55	15	60.0	45.3	21	101	2497	1588	1207	85	85	39	18.00
6.70	20.0	20	33.0	0.7	55	20	70.0	50.4	23	132	2778	1767	1357	110	110	51	17.50

London Clay/Lambeth Group

keltbray Piling

EC7 Design Approach - Alternative Design Method

PILE CAPACITIES IN COHESIVE SOILS

Pile Dia. :	572	mm			Overburden :	6.200	m
p.p.l.:	24.200	m OD	Cut-off :	14.325 m OD	Initial Qus:	0	kN (resulting from overburden)

Partial factor for Pile Resistance			
Set R1 (Comb 1)		Set R4 (Comb 2)	
+ Shaft	1.00	+ Shaft	1.60
Base	1.00	Base	2.00
- Shaft	1.00	- Shaft	2.00
Model factor		1.40	

Pile Design Factors	London Clay
Adhesion	0.50
End Bearing, N_c	9.0
Max. Adhesion	140 kN/m2
Pile Design Factors	Lambeth Group
Adhesion	0.50
End Bearing, N_c	9.0
Max. Adhesion	140 kN/m2

Load Conversion Factors - ULS to SLS			
Load Type	Load Split	Com 1	Com 2
Permanent	70%	1.35	1.00
Variable	30%	1.50	1.30

Design Notes

Shear Strength Profile							
Depth m	6.200		14.200		14.21		34.21
Cu kN/m^2	70		190		200		466
Gradient		15.00		1000.00		13.30	

Minimum Design FoS on Shaft Friction 1.20

Depth (m)	Cohesion (kN/m^2)	Adhesion (kN/m^2)	dQus (kN)	QuS (kN)	Qub (kN)	Qult (kN)	Design Comp Resist R_{cd} (Com 1) kN	Design Comp Resist R_{cd} (Com 2) kN	Max unFct Load Comp kN	Max unFct Load Tension kN	Level (m OD)
6.20	70	35	0	0	0	0	0	0		0	18.00
6.70	78	39	0	0	0	0	0	0	#VALUE!	0	17.50
7.20	85	43	0	0	0	0	0	0	#VALUE!	0	17.00
7.70	93	46	0	0	0	0	0	0	#VALUE!	0	16.50
8.20	100	50	0	0	0	0	0	0	#VALUE!	0	16.00
8.70	108	54	0	0	0	0	0	0	#VALUE!	0	15.50
9.20	115	58	0	0	0	0	0	0	#VALUE!	0	15.00
9.70	123	61	0	0	0	0	0	0	#VALUE!	0	14.50
10.20	130	65	60	0	301	301	215	0	0	0	14.00
10.70	138	69	63	60	318	378	270	45	41	20	13.50
11.20	145	73	67	124	335	459	328	92	84	41	13.00
11.70	153	76	70	190	353	543	388	142	130	63	12.50
12.20	160	80	74	261	370	631	450	194	178	87	12.00
12.70	168	84	77	334	387	722	515	249	228	111	11.50
13.20	175	88	80	411	405	816	583	328	301	137	11.00
13.70	183	91	84	491	422	913	652	370	340	164	10.50
14.20	190	95	87	575	439	1014	725	414	379	192	10.00
14.70	197	98	90	662	455	1117	798	458	420	221	9.50
15.20	203	102	93	752	470	1222	873	504	462	251	9.00
15.70	210	105	96	845	486	1330	950	550	505	282	8.50
16.20	217	108	99	940	501	1441	1030	599	549	313	8.00
16.70	223	112	102	1039	516	1555	1111	648	595	346	7.50
17.20	230	115	105	1141	532	1673	1195	699	642	380	7.00
17.70	237	118	108	1246	547	1793	1281	752	689	415	6.50
18.20	243	122	111	1353	562	1916	1369	805	739	451	6.00
18.70	250	125	114	1464	578	2042	1459	860	789	488	5.50
19.20	257	128	117	1578	593	2171	1551	916	841	526	5.00
19.70	263	132	120	1695	609	2303	1645	974	894	565	4.50
20.20	270	135	123	1814	624	2438	1742	1033	948	605	4.00
20.70	276	138	125	1937	639	2576	1840	1093	1003	646	3.50
21.20	283	140	126	2062	655	2717	1941	1154	1059	687	3.00
21.70	290	140	126	2188	670	2858	2041	1216	1116	729	2.50
22.20	296	140	126	2314	685	2999	2142	1278	1172	771	2.00
22.70	303	140	126	2439	701	3140	2243	1339	1229	813	1.50
23.20	310	140	126	2565	716	3282	2344	1401	1285	855	1.00
23.70	316	140	126	2691	732	3423	2445	1463	1342	897	0.50
24.20	323	140	126	2817	747	3564	2546	1524	1398	939	0.00
24.70	330	140	126	2943	762	3705	2646	1586	1455	981	-0.50
25.20	336	140	126	3068	778	3846	2747	1648	1512	1023	-1.00
25.70	343	140	126	3194	793	3987	2848	1709	1568	1065	-1.50
26.20	350	140	126	3320	809	4129	2949	1771	1625	1107	-2.00
26.70	356	140	126	3446	824	4270	3050	1833	1681	1149	-2.50
27.20	363	140	126	3572	839	4411	3151	1894	1738	1191	-3.00
27.70	370	140	126	3697	855	4552	3251	1956	1794	1232	-3.50
28.20	376	140	126	3823	870	4693	3352	2018	1851	1274	-4.00
28.70	383	140	126	3949	885	4834	3453	2079	1907	1316	-4.50
29.20	390	140	126	4075	901	4976	3554	2141	1964	1358	-5.00
29.70	396	140	126	4201	916	5117	3655	2202	2021	1400	-5.50
30.20	403	140	126	4326	932	5258	3756	2264	2077	1442	-6.00
30.70	409	140	126	4452	947	5399	3856	2326	2134	1484	-6.50
31.20	416	140	126	4578	962	5540	3957	2387	2190	1526	-7.00

keltbray Piling

EC7 Design Approach - Alternative Design Method

PILE CAPACITIES IN COHESIVE SOILS

Pile Dia. :	572	mm			Overburden :	6.200	m
p.p.l.:	24.200	m OD	Cut-off :	13.325	m OD	Initial Qus:	0	kN (resulting from overburden)

Partial factor for Pile Resistance			
Set R1 (Comb 1)		Set R4 (Comb 2)	
+ Shaft	1.00	+ Shaft	1.60
Base	1.00	Base	2.00
- Shaft	1.00	- Shaft	2.00
Model factor		1.40	

Pile Design Factors	London Clay
Adhesion	0.50
End Bearing, N_c	9.0
Max. Adhesion	140 kN/m2
Pile Design Factors	Lambeth Group
Adhesion	0.50
End Bearing, N_c	9.0
Max. Adhesion	140 kN/m2

Load Conversion Factors - ULS to SLS			
Load Type	Load Split	Com 1	Com 2
Permanent	70%	1.35	1.00
Variable	30%	1.50	1.30

Design Notes

Shear Strength Profile							
Depth m	6.200		14.200		14.21		34.21
Cu kN/m^2	70		190		200		466
Gradient		15.00		1000.00		13.30	

Minimum Design FoS on Shaft Friction 1.20

Depth (m)	Cohesion (kN/m^2)	Adhesion (kN/m^2)	dQus (kN)	QuS (kN)	Qub (kN)	Qult (kN)	Design Comp Resist R_{cd} (Com 1) kN	Design Comp Resist R_{cd} (Com 2) kN	Max unFct Load Comp kN	Max unFct Load Tension kN	Level (m OD)
6.20	70	35	0	0	0	0	0	0		0	18.00
6.70	78	39	0	0	0	0	0	0	#VALUE!	0	17.50
7.20	85	43	0	0	0	0	0	0	#VALUE!	0	17.00
7.70	93	46	0	0	0	0	0	0	#VALUE!	0	16.50
8.20	100	50	0	0	0	0	0	0	#VALUE!	0	16.00
8.70	108	54	0	0	0	0	0	0	#VALUE!	0	15.50
9.20	115	58	0	0	0	0	0	0	#VALUE!	0	15.00
9.70	123	61	0	0	0	0	0	0	#VALUE!	0	14.50
10.20	130	65	0	0	0	0	0	0	#VALUE!	0	14.00
10.70	138	69	0	0	0	0	0	0	#VALUE!	0	13.50
11.20	145	73	67	0	335	335	240	0	0	0	13.00
11.70	153	76	70	67	353	420	300	50	46	22	12.50
12.20	160	80	74	137	370	507	362	102	94	46	12.00
12.70	168	84	77	211	387	598	427	157	144	70	11.50
13.20	175	88	80	288	405	692	494	214	196	96	11.00
13.70	183	91	84	368	422	790	564	274	251	123	10.50
14.20	190	95	87	451	439	891	636	358	329	150	10.00
14.70	197	98	90	538	455	993	709	403	370	179	9.50
15.20	203	102	93	628	470	1098	785	448	411	209	9.00
15.70	210	105	96	721	486	1207	862	495	454	240	8.50
16.20	217	108	99	817	501	1318	941	544	499	272	8.00
16.70	223	112	102	916	516	1432	1023	593	544	305	7.50
17.20	230	115	105	1017	532	1549	1107	644	591	339	7.00
17.70	237	118	108	1122	547	1669	1192	696	639	374	6.50
18.20	243	122	111	1230	562	1792	1280	750	688	410	6.00
18.70	250	125	114	1341	578	1919	1370	805	738	447	5.50
19.20	257	128	117	1454	593	2048	1463	861	790	485	5.00
19.70	263	132	120	1571	609	2180	1557	919	843	524	4.50
20.20	270	135	123	1691	624	2315	1653	978	897	564	4.00
20.70	276	138	125	1814	639	2453	1752	1038	952	605	3.50
21.20	283	140	126	1939	655	2593	1852	1099	1009	646	3.00
21.70	290	140	126	2064	670	2734	1953	1161	1065	688	2.50
22.20	296	140	126	2190	685	2876	2054	1223	1122	730	2.00
22.70	303	140	126	2316	701	3017	2155	1284	1178	772	1.50
23.20	310	140	126	2442	716	3158	2256	1346	1235	814	1.00
23.70	316	140	126	2568	732	3299	2357	1408	1291	856	0.50
24.20	323	140	126	2693	747	3440	2457	1469	1348	898	0.00
24.70	330	140	126	2819	762	3581	2558	1531	1404	940	-0.50
25.20	336	140	126	2945	778	3723	2659	1592	1461	982	-1.00
25.70	343	140	126	3071	793	3864	2760	1654	1518	1024	-1.50
26.20	350	140	126	3196	809	4005	2861	1716	1574	1065	-2.00
26.70	356	140	126	3322	824	4146	2962	1777	1631	1107	-2.50
27.20	363	140	126	3448	839	4287	3062	1839	1687	1149	-3.00
27.70	370	140	126	3574	855	4429	3163	1901	1744	1191	-3.50
28.20	376	140	126	3700	870	4570	3264	1962	1800	1233	-4.00
28.70	383	140	126	3825	885	4711	3365	2024	1857	1275	-4.50
29.20	390	140	126	3951	901	4852	3466	2086	1913	1317	-5.00
29.70	396	140	126	4077	916	4993	3567	2147	1970	1359	-5.50
30.20	403	140	126	4203	932	5134	3667	2209	2027	1401	-6.00
30.70	409	140	126	4329	947	5276	3768	2271	2083	1443	-6.50
31.20	416	140	126	4454	962	5417	3869	2332	2140	1485	-7.00

keltbray Piling

EC7 Design Approach - Alternative Design Method

PILE CAPACITIES IN COHESIVE SOILS

Pile Dia. :	572	mm			Overburden :	6.200	m
p.p.l.:	24.200	m OD	Cut-off :	21.732	m OD	Initial Qus:	68	kN (resulting from overburden)

Partial factor for Pile Resistance			
Set R1 (Comb 1)		Set R4 (Comb 2)	
+ Shaft	1.00	+ Shaft	1.60
Base	1.00	Base	2.00
- Shaft	1.00	- Shaft	2.00
Model factor		1.40	

Pile Design Factors	London Clay
Adhesion	0.50
End Bearing, N_c	9.0
Max. Adhesion	140 kN/m2
Pile Design Factors	**Lambeth Group**
Adhesion	0.50
End Bearing, N_c	9.0
Max. Adhesion	140 kN/m2

Load Conversion Factors - ULS to SLS			
Load Type	Load Split	Com 1	Com 2
Permanent	70%	1.35	1.00
Variable	30%	1.50	1.30

Design Notes

Shear Strength Profile							
Depth m	6.200		14.200		14.21		34.21
Cu kN/m^2	70		190		200		466
Gradient		15.00		1000.00		13.30	

Minimum Design FoS on Shaft Friction 1.20

Depth (m)	Cohesion (kN/m^2)	Adhesion (kN/m^2)	dQus (kN)	QuS (kN)	Qub (kN)	Qult (kN)	Design Comp Resist R_{cd} (Com 1) kN	Design Comp Resist R_{cd} (Com 2) kN	Max unFct Load Comp kN	Max unFct Load Tension kN	Level (m OD)
6.20	70	35	33	68	162	230	164	88	81	23	18.00
6.70	78	39	37	101	179	280	200	94	84	34	17.50
7.20	85	43	40	138	197	334	239	128	115	46	17.00
7.70	93	46	43	178	214	391	280	132	121	59	16.50
8.20	100	50	47	221	231	452	323	181	166	74	16.00
8.70	108	54	50	267	249	516	369	208	191	89	15.50
9.20	115	58	53	317	266	583	417	237	217	106	15.00
9.70	123	61	57	371	283	654	467	267	245	124	14.50
10.20	130	65	60	427	301	728	520	298	274	142	14.00
10.70	138	69	63	487	318	805	575	331	304	162	13.50
11.20	145	73	67	551	335	886	633	366	336	184	13.00
11.70	153	76	70	618	353	970	693	402	369	206	12.50
12.20	160	80	74	688	370	1058	756	439	403	229	12.00
12.70	168	84	77	762	387	1149	821	478	439	254	11.50
13.20	175	88	80	838	405	1243	888	519	476	279	11.00
13.70	183	91	84	919	422	1341	958	561	515	306	10.50
14.20	190	95	87	1002	439	1442	1030	604	555	334	10.00
14.70	197	98	90	1089	455	1544	1103	649	595	363	9.50
15.20	203	102	93	1179	470	1649	1178	694	637	393	9.00
15.70	210	105	96	1272	486	1758	1255	741	680	424	8.50
16.20	217	108	99	1368	501	1869	1335	790	724	456	8.00
16.70	223	112	102	1467	516	1983	1416	839	770	489	7.50
17.20	230	115	105	1568	532	2100	1500	890	817	523	7.00
17.70	237	118	108	1673	547	2220	1586	942	865	558	6.50
18.20	243	122	111	1781	562	2343	1674	996	914	594	6.00
18.70	250	125	114	1892	578	2469	1764	1051	964	631	5.50
19.20	257	128	117	2005	593	2599	1856	1107	1016	668	5.00
19.70	263	132	120	2122	609	2731	1951	1165	1069	707	4.50
20.20	270	135	123	2242	624	2866	2047	1224	1123	747	4.00
20.70	276	138	125	2365	639	3004	2146	1284	1178	788	3.50
21.20	283	140	126	2490	655	3144	2246	1345	1234	830	3.00
21.70	290	140	126	2615	670	3285	2347	1407	1291	872	2.50
22.20	296	140	126	2741	685	3427	2448	1469	1347	914	2.00
22.70	303	140	126	2867	701	3568	2548	1530	1404	956	1.50
23.20	310	140	126	2993	716	3709	2649	1592	1460	998	1.00
23.70	316	140	126	3118	732	3850	2750	1653	1517	1039	0.50
24.20	323	140	126	3244	747	3991	2851	1715	1574	1081	0.00
24.70	330	140	126	3370	762	4132	2952	1777	1630	1123	-0.50
25.20	336	140	126	3496	778	4274	3053	1838	1687	1165	-1.00
25.70	343	140	126	3622	793	4415	3153	1900	1743	1207	-1.50
26.20	350	140	126	3747	809	4556	3254	1962	1800	1249	-2.00
26.70	356	140	126	3873	824	4697	3355	2023	1856	1291	-2.50
27.20	363	140	126	3999	839	4838	3456	2085	1913	1333	-3.00
27.70	370	140	126	4125	855	4979	3557	2147	1969	1375	-3.50
28.20	376	140	126	4251	870	5121	3658	2208	2026	1417	-4.00
28.70	383	140	126	4376	885	5262	3758	2270	2083	1459	-4.50
29.20	390	140	126	4502	901	5403	3859	2332	2139	1501	-5.00
29.70	396	140	126	4628	916	5544	3960	2393	2196	1543	-5.50
30.20	403	140	126	4754	932	5685	4061	2455	2252	1585	-6.00
30.70	409	140	126	4880	947	5826	4162	2517	2309	1627	-6.50
31.20	416	140	126	5005	962	5968	4263	2578	2365	1668	-7.00

keltbray Piling

EC7 Design Approach - Alternative Design Method

PILE CAPACITIES IN COHESIVE SOILS

Pile Dia. :	876	mm			Overburden :	6.200	m
p.p.l.:	24.200	m OD	Cut-off :	21.732	m OD	Initial Qus:	101	kN (resulting from overburden)

Partial factor for Pile Resistance			
Set R1 (Comb 1)		Set R4 (Comb 2)	
+ Shaft	1.00	+ Shaft	1.60
Base	1.00	Base	2.00
- Shaft	1.00	- Shaft	2.00
Model factor		1.40	

Pile Design Factors	London Clay
Adhesion	0.50
End Bearing, N_c	9.0
Max. Adhesion	140 kN/m2
Pile Design Factors	**Lambeth Group**
Adhesion	0.50
End Bearing, N_c	9.0
Max. Adhesion	140 kN/m2

Load Conversion Factors - ULS to SLS			
Load Type	Load Split	Com 1	Com 2
Permanent	70%	1.35	1.00
Variable	30%	1.50	1.30

Design Notes

Shear Strength Profile							
Depth m	6.200		14.200		14.21		34.21
Cu kN/m^2	70		190		200		466
Gradient		15.00		1000.00		13.30	

Minimum Design FoS on Shaft Friction 1.20

Depth (m)	Cohesion (kN/m^2)	Adhesion (kN/m^2)	dQus (kN)	QuS (kN)	Qub (kN)	Qult (kN)	Design Comp Resist R_{cd} (Com 1) kN	Design Comp Resist R_{cd} (Com 2) kN	Max unFct Load Comp kN	Max unFct Load Tension kN	Level (m OD)
6.20	70	35	51	101	380	481	343	181	166	34	18.00
6.70	78	39	56	152	420	572	409	142	126	51	17.50
7.20	85	43	61	208	461	669	478	194	173	69	17.00
7.70	93	46	66	269	502	770	550	200	183	90	16.50
8.20	100	50	71	335	542	877	627	249	229	112	16.00
8.70	108	54	77	406	583	989	707	302	277	135	15.50
9.20	115	58	82	483	624	1107	790	359	330	161	15.00
9.70	123	61	87	565	664	1229	878	420	385	188	14.50
10.20	130	65	92	651	705	1357	969	543	498	217	14.00
10.70	138	69	97	743	746	1489	1064	598	549	248	13.50
11.20	145	73	102	841	787	1627	1162	656	602	280	13.00
11.70	153	76	108	943	827	1770	1264	716	657	314	12.50
12.20	160	80	113	1050	868	1918	1370	779	715	350	12.00
12.70	168	84	118	1163	909	2072	1480	844	774	388	11.50
13.20	175	88	123	1281	949	2230	1593	911	836	427	11.00
13.70	183	91	128	1404	990	2394	1710	980	899	468	10.50
14.20	190	95	133	1532	1031	2563	1830	1052	965	511	10.00
14.70	197	98	138	1665	1067	2732	1951	1124	1031	555	9.50
15.20	203	102	142	1803	1103	2905	2075	1199	1100	601	9.00
15.70	210	105	147	1945	1139	3084	2203	1275	1170	648	8.50
16.20	217	108	151	2092	1175	3266	2333	1353	1242	697	8.00
16.70	223	112	156	2243	1211	3454	2467	1434	1315	748	7.50
17.20	230	115	160	2399	1247	3646	2604	1516	1391	800	7.00
17.70	237	118	165	2559	1283	3842	2745	1601	1469	853	6.50
18.20	243	122	170	2724	1319	4043	2888	1687	1548	908	6.00
18.70	250	125	174	2894	1355	4249	3035	1776	1629	965	5.50
19.20	257	128	179	3068	1391	4459	3185	1867	1712	1023	5.00
19.70	263	132	183	3247	1427	4674	3339	1959	1797	1082	4.50
20.20	270	135	188	3430	1463	4894	3495	2054	1884	1143	4.00
20.70	276	138	191	3618	1500	5118	3655	2151	1973	1206	3.50
21.20	283	140	193	3809	1536	5345	3818	2249	2063	1270	3.00
21.70	290	140	193	4002	1572	5574	3981	2348	2154	1334	2.50
22.20	296	140	193	4195	1608	5803	4145	2447	2245	1398	2.00
22.70	303	140	193	4387	1644	6031	4308	2546	2336	1462	1.50
23.20	310	140	193	4580	1680	6260	4471	2645	2426	1527	1.00
23.70	316	140	193	4773	1716	6489	4635	2744	2517	1591	0.50
24.20	323	140	193	4965	1752	6717	4798	2842	2608	1655	0.00
24.70	330	140	193	5158	1788	6946	4961	2941	2698	1719	-0.50
25.20	336	140	193	5351	1824	7175	5125	3040	2789	1784	-1.00
25.70	343	140	193	5543	1860	7404	5288	3139	2880	1848	-1.50
26.20	350	140	193	5736	1896	7632	5452	3238	2971	1912	-2.00
26.70	356	140	193	5929	1932	7861	5615	3337	3061	1976	-2.50
27.20	363	140	193	6121	1968	8090	5778	3436	3152	2040	-3.00
27.70	370	140	193	6314	2005	8318	5942	3535	3243	2105	-3.50
28.20	376	140	193	6506	2041	8547	6105	3633	3333	2169	-4.00
28.70	383	140	193	6699	2077	8776	6268	3732	3424	2233	-4.50
29.20	390	140	193	6892	2113	9004	6432	3831	3515	2297	-5.00
29.70	396	140	193	7084	2149	9233	6595	3930	3606	2361	-5.50
30.20	403	140	193	7277	2185	9462	6759	4029	3696	2426	-6.00
30.70	409	140	193	7470	2221	9691	6922	4128	3787	2490	-6.50
31.20	416	140	193	7662	2257	9919	7085	4227	3878	2554	-7.00

keltbray Piling

Pile No	PPL (m OD)	CoL (mOD)	ULS Combination 1 Load (kN)	ULS Combination 2 Load (kN)	SLS Tension Load (kN)	Compression Toe Level (mOD)	Tension Toe Level (mOD)	Design Toe Level (mOD)
PL001	24.20	21.732	767	600	None	**10.00**	**#N/A**	**10.00**
PL002	24.20	21.732	2302	1799	None	**-1.00**	**#N/A**	**-1.00**
PL003	24.20	21.832	1465	1145	None	**4.50**	**#N/A**	**4.50**
PL004	24.20	21.732	767	600	None	**10.00**	**#N/A**	**10.00**
PL005	24.20	21.732	2302	1799	None	**-1.00**	**#N/A**	**-1.00**
PL006	24.20	14.825	698	545	400	**8.50**	**6.50**	**6.50**
PL007	24.20	14.825	2232	1744	1300	**-2.00**	**-4.50**	**-4.50**
PL008	24.20	14.825	1395	1090	800	**3.50**	**1.50**	**1.50**
PL009	24.20	14.825	628	491	900	**9.00**	**0.00**	**0.00**
PL010	24.20	14.825	558	436	800	**9.50**	**1.50**	**1.50**
PL011	24.20	14.825	767	600	1100	**7.50**	**-2.00**	**-2.00**
PL012	24.20	14.825	488	382	700	**10.00**	**2.50**	**2.50**
PL013	24.20	18.275	1604	1254	None	**3.50**	**#N/A**	**3.50**
PL014	24.20	14.325	1883	1472	None	**0.00**	**#N/A**	**0.00**
PL015	24.20	14.325	1883	1472	None	**0.00**	**#N/A**	**0.00**
PL016	24.20	14.325	2093	1635	None	**-1.00**	**#N/A**	**-1.00**
PL017	24.20	14.325	2093	1635	None	**-1.00**	**#N/A**	**-1.00**
PL018	24.20	14.325	1744	1363	None	**1.00**	**#N/A**	**1.00**
PL019	24.20	14.325	1744	1363	None	**1.00**	**#N/A**	**1.00**
PL020	24.20	14.825	628	491	900	**9.00**	**0.00**	**0.00**
PL021	24.20	18.275	1604	1254	None	**3.50**	**#N/A**	**3.50**
PL022	24.20	14.325	1883	1472	None	**0.00**	**#N/A**	**0.00**
PL023	24.20	14.325	1883	1472	None	**0.00**	**#N/A**	**0.00**
PL024	24.20	14.325	2093	1635	None	**-1.00**	**#N/A**	**-1.00**
PL025	24.20	14.325	2093	1635	None	**-1.00**	**#N/A**	**-1.00**
PL026	24.20	14.325	1744	1363	None	**1.00**	**#N/A**	**1.00**
PL027	24.20	14.325	1744	1363	None	**1.00**	**#N/A**	**1.00**
PL028	24.20	13.875	2232	1744	None	**-2.50**	**#N/A**	**-2.50**
PL029	24.20	13.875	2232	1744	None	**-2.50**	**#N/A**	**-2.50**
PL030	24.20	13.875	2232	1744	None	**-2.50**	**#N/A**	**-2.50**
PL031	24.20	14.325	1883	1472	None	**0.00**	**#N/A**	**0.00**
PL032	24.20	14.325	1883	1472	None	**0.00**	**#N/A**	**0.00**
PL033	24.20	14.325	2093	1635	None	**-1.00**	**#N/A**	**-1.00**
PL034	24.20	14.325	2093	1635	None	**-1.00**	**#N/A**	**-1.00**
PL035	24.20	14.325	1744	1363	None	**1.00**	**#N/A**	**1.00**
PL036	24.20	14.325	1744	1363	None	**1.00**	**#N/A**	**1.00**
PL037	24.20	14.825	1465	1145	None	**3.00**	**#N/A**	**3.00**
PL038	24.20	14.825	907	709	1300	**6.50**	**-4.50**	**-4.50**
PL039	24.20	13.875	2232	1744	None	**-2.50**	**#N/A**	**-2.50**
PL040	24.20	13.875	2232	1744	None	**-2.50**	**#N/A**	**-2.50**

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PL041	24.20	14.825	419	327	600	**11.00**	**4.00**	**4.00**
PL042	24.20	14.825	349	273	500	**11.00**	**5.00**	**5.00**
PL043	24.20	14.825	1325	1036	None	**3.50**	**#N/A**	**3.50**
PL044	24.20	13.875	2232	1744	None	**-2.50**	**#N/A**	**-2.50**
PL045	24.20	13.325	2511	1962	1100	**-4.00**	**-2.50**	**-4.00**
PL046	24.20	13.325	2930	2289	500	**-7.00**	**4.50**	**-7.00**
PL047	24.20	13.875	2232	1744	None	**-2.50**	**#N/A**	**-2.50**
PL048	24.20	13.875	2232	1744	None	**-2.50**	**#N/A**	**-2.50**
PL049	24.20	13.325	1535	1199	None	**2.00**	**#N/A**	**2.00**
PL050	24.20	13.325	3069	2398	500	**-8.00**	**4.50**	**-8.00**
PL051	24.20	13.325	1883	1472	None	**-0.50**	**#N/A**	**-0.50**
PL052	24.20	13.325	2930	2289	500	**-7.00**	**4.50**	**-7.00**
PL053	24.20	13.325	1883	1472	None	**-0.50**	**#N/A**	**-0.50**
PL054	24.20	14.325	2023	1581	None	**-0.50**	**#N/A**	**-0.50**
PL055	24.20	14.325	2023	1581	None	**-0.50**	**#N/A**	**-0.50**
PL056	24.20	12.925	977	763	1200	**5.50**	**-4.00**	**-4.00**
PL057	24.20	22.460	4255	3325	None	**-2.50**	**#N/A**	**-2.50**
PL058	24.20	13.875	2232	1744	None	**-2.50**	**#N/A**	**-2.50**
PL059	24.20	13.875	2232	1744	None	**-2.50**	**#N/A**	**-2.50**
PL060	24.20	13.875	2232	1744	None	**-2.50**	**#N/A**	**-2.50**
PL061	24.20	13.325	2511	1962	250	**-4.00**	**8.00**	**-4.00**
PL062	24.20	13.325	1535	1199	None	**2.00**	**#N/A**	**2.00**
PL063	24.20	13.325	2511	1962	None	**-4.00**	**#N/A**	**-4.00**
PL064	24.20	13.325	1883	1472	None	**-0.50**	**#N/A**	**-0.50**
PL065	24.20	13.325	1883	1472	None	**-0.50**	**#N/A**	**-0.50**
PL066	24.20	14.325	2023	1581	None	**-0.50**	**#N/A**	**-0.50**
PL067	24.20	14.325	2023	1581	None	**-0.50**	**#N/A**	**-0.50**
PL068	24.20	14.825	1186	927	None	**4.50**	**#N/A**	**4.50**
PL069	24.20	14.825	2232	1744	None	**-2.00**	**#N/A**	**-2.00**
PL070	24.20	14.825	2232	1744	None	**-2.00**	**#N/A**	**-2.00**
PL071	24.20	14.825	2232	1744	None	**-2.00**	**#N/A**	**-2.00**
PL072	24.20	13.325	1535	1199	None	**2.00**	**#N/A**	**2.00**
PL073	24.20	13.325	1535	1199	None	**2.00**	**#N/A**	**2.00**
PL074	24.20	13.325	1883	1472	None	**-0.50**	**#N/A**	**-0.50**
PL075	24.20	13.325	1883	1472	None	**-0.50**	**#N/A**	**-0.50**
PL076	24.20	14.325	2023	1581	None	**-0.50**	**#N/A**	**-0.50**
PL077	24.20	14.325	2023	1581	None	**-0.50**	**#N/A**	**-0.50**
PL078	24.20	13.325	977	763	1200	**5.50**	**-4.00**	**-4.00**
PL079	24.20	22.460	5441	4251	None	**-7.50**	**#N/A**	**-7.50**
PL080	24.20	14.825	349	273	450	**11.00**	**6.00**	**6.00**
PL081	24.20	14.825	419	327	600	**11.00**	**4.00**	**4.00**
PL082	24.20	14.825	2232	1744	None	**-2.00**	**#N/A**	**-2.00**
PL083	24.20	14.825	2232	1744	None	**-2.00**	**#N/A**	**-2.00**

PL084	24.20	14.825	2232	1744	None	**-2.00**	**#N/A**	**-2.00**
PL085	24.20	14.325	2023	1581	None	**-0.50**	**#N/A**	**-0.50**
PL086	24.20	14.325	2023	1581	None	**-0.50**	**#N/A**	**-0.50**
PL087	24.20	14.325	2023	1581	None	**-0.50**	**#N/A**	**-0.50**
PL088	24.20	14.325	2023	1581	None	**-0.50**	**#N/A**	**-0.50**
PL089	24.20	14.325	1604	1254	None	**2.00**	**#N/A**	**2.00**
PL090	24.20	14.325	1604	1254	None	**2.00**	**#N/A**	**2.00**
PL091	24.20	14.825	2232	1744	None	**-2.00**	**#N/A**	**-2.00**
PL092	24.20	14.825	2232	1744	None	**-2.00**	**#N/A**	**-2.00**
PL093	24.20	14.825	2232	1744	None	**-2.00**	**#N/A**	**-2.00**
PL094	24.20	14.825	907	709	1300	**6.50**	**-4.50**	**-4.50**
PL095	24.20	14.825	907	709	1300	**6.50**	**-4.50**	**-4.50**
PL096	24.20	22.460	5441	4251	None	**-7.50**	**#N/A**	**-7.50**
PL097	24.20	14.325	2023	1581	None	**-0.50**	**#N/A**	**-0.50**
PL098	24.20	14.325	2023	1581	None	**-0.50**	**#N/A**	**-0.50**
PL099	24.20	14.325	2023	1581	None	**-0.50**	**#N/A**	**-0.50**
PL100	24.20	14.325	2023	1581	None	**-0.50**	**#N/A**	**-0.50**
PL101	24.20	14.325	1604	1254	None	**2.00**	**#N/A**	**2.00**
PL102	24.20	14.325	1604	1254	None	**2.00**	**#N/A**	**2.00**
PL103	24.20	14.825	2232	1744	None	**-2.00**	**#N/A**	**-2.00**
PL104	24.20	14.825	2232	1744	None	**-2.00**	**#N/A**	**-2.00**
PL105	24.20	14.825	2232	1744	None	**-2.00**	**#N/A**	**-2.00**
PL106	24.20	14.325	2023	1581	None	**-0.50**	**#N/A**	**-0.50**
PL107	24.20	14.325	2023	1581	None	**-0.50**	**#N/A**	**-0.50**
PL108	24.20	14.325	2023	1581	None	**-0.50**	**#N/A**	**-0.50**
PL109	24.20	14.325	2023	1581	None	**-0.50**	**#N/A**	**-0.50**
PL110	24.20	14.325	1604	1254	None	**2.00**	**#N/A**	**2.00**
PL111	24.20	14.325	1604	1254	None	**2.00**	**#N/A**	**2.00**
PL112	24.20	22.460	5092	3979	None	**-6.00**	**#N/A**	**-6.00**
PL113	24.20	14.825	837	654	900	**7.00**	**0.00**	**0.00**
PL114	24.20	14.825	907	709	1300	**6.50**	**-4.50**	**-4.50**
PL115	24.20	14.825	628	491	900	**9.00**	**0.00**	**0.00**
PL116	24.20	14.825	907	709	1300	**6.50**	**-4.50**	**-4.50**
PL117	24.20	14.825	628	491	900	**9.00**	**0.00**	**0.00**
PL118	24.20	14.825	698	545	1000	**8.50**	**-1.00**	**-1.00**
PL119	24.20	14.825	558	436	800	**9.50**	**1.50**	**1.50**
PL120	24.20	22.460	3906	3052	None	**-1.50**	**#N/A**	**-1.50**

D. Single Pile Analyses

Units: kN,m

INPUT DATA

SOIL PROFILE

Stratum no.	Elevation of top of stratum	Soil types - Active side	Passive side
1	14.82	5 LC - dr	5 LC - dr
2	10.00	7 LAM - dr	7 LAM - dr

SOIL PROPERTIES

No.	Soil type / Description	Bulk density kN/m3	Young's Modulus Eh,kN/m2 (dEh/dy)	At rest coeff. Ko (dKo/dy)	Consol state. NC/OC (Nu)	Active limit Ka (Kac)	Passive limit Kp (Kpc)	Cohesion kN/m2 (dc/dy)
	(Datum elev.)							
1	MG	18.00	10000	0.500	OC (0.200)	0.000 (0.000)	5.026 (0.000)	
2	Not defined							
3	Lynch Hill GRAV	20.00	60000	0.500	OC (0.200)	0.000 (0.000)	9.255 (0.000)	
4	Not defined							
5	LC - dr (18.00)	20.00	45500 (9750)	1.000	OC (0.200)	0.000 (0.000)	3.411 (5.416)	5.000d
6	Not defined							
7	LAM - dr (10.00)	20.00	116000 (7714)	1.000	OC (0.200)	0.000 (0.000)	3.627 (5.634)	5.000d

Additional soil parameters associated with Ka and Kp

No.	Soil type / Description	--- parameters for Ka --- Soil friction angle	Wall adhesion coeff.	Back-fill angle	--- parameters for Kp --- Soil friction angle	Wall adhesion coeff.	Back-fill angle
1	MG	0.00	0.000	0.00	30.00	1.000	0.00
2	Not defined						
3	Lynch Hill GRAV	0.00	0.000	0.00	38.00	1.000	0.00
4	Not defined						
5	LC - dr	0.00	0.000	0.00	24.00	1.000	0.00
6	Not defined						
7	LAM - dr	0.00	0.000	0.00	25.00	1.000	0.00

GROUND WATER CONDITIONS

Density of water = 10.00 kN/m3

	Active side	Passive side
Initial water table elevation	14.82	14.82

Automatic water pressure balancing at toe of pile : No

PILE PROPERTIES

Type of structure = Single Pile
Pile diameter = 0.60 m
Elevation of toe of pile = -6.50
Maximum finite element length = 1.20 m
Pile diameter = 0.60 m
Youngs modulus of pile E = 2.0000E+07 kN/m2
Moment of inertia of pile I = 6.3617E-03 m4
E.I = 127235 kN.m2
Yield Moment of pile = Not defined

HORIZONTAL and MOMENT LOADS/RESTRAINTS

Load no.	Elevation	Horizontal load kN	Moment load kN.m	Moment restraint kN.m/rad	Partial factor/ Category
1	14.82	30.70	0	100000	1.00 -

CONSTRUCTION STAGES

Construction stage no.	Stage description
1	Apply load no.1 at elevation 14.82 The effect of strut/anchor stiffness at this elevation will be included while applying this load

FACTORS OF SAFETY and ANALYSIS OPTIONS

Limit State options: Serviceability Limit State
All loads and soil strengths are unfactored

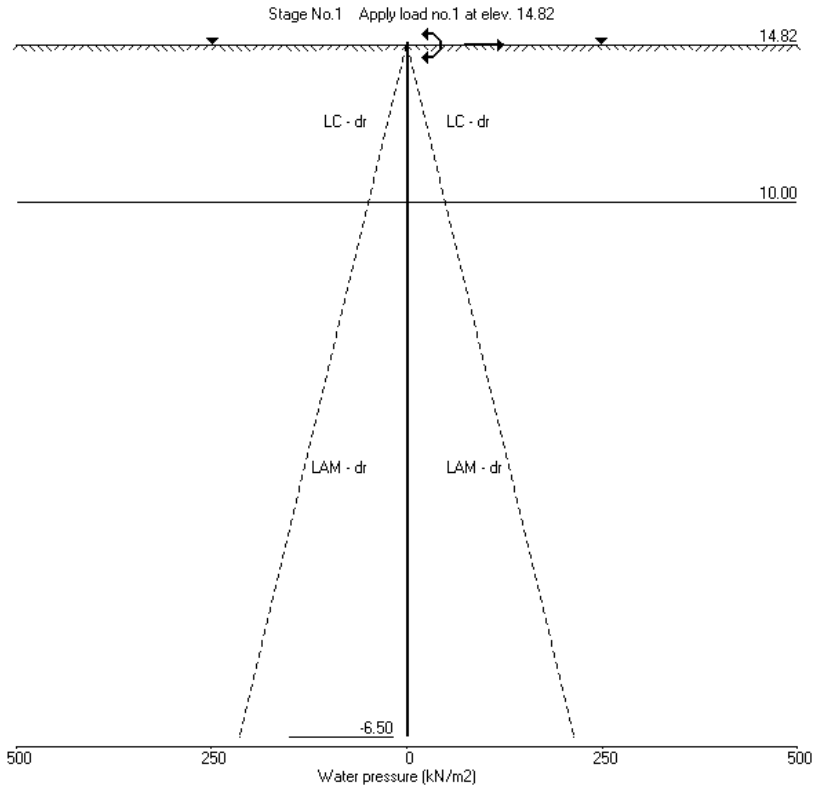
Parameters for undrained strata:
Minimum equivalent fluid density = 5.00 kN/m3
Maximum depth of water filled tension crack = 0.00 m

Bending moment and displacement calculation:
Method - Subgrade reaction model using Influence Coefficients

OUTPUT OPTIONS

Stage no.	Stage description	Output options - Displacement Bending mom. Shear force	Active, Passive pressures	Graph. output
1	Apply load no.1 at elev. 14.82	No	No	No
*	Summary output	Yes	-	Yes

Units: kN,m



KELTBRAY PILING | Sheet No.
Program: WALLAP Version 6.05 Revision A46.B59.R49 | Job No. P230
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Data filename/Run ID: 600mm - 14.825 CoL |
Student Centre UCL | Date:14-04-2016
600mm bearing | Checked :

Units: kN,m

Stage No. 1 Apply load no.1 at elevation 14.82
The effect of strut/anchor stiffness at this elevation
will be included while applying this load

BENDING MOMENT and DISPLACEMENT ANALYSIS of Single Pile

Analysis options

Pile diameter = 0.60m
Subgrade reaction model - Boussinesq Influence coefficients
Soil deformations are elastic until the active or passive limit is reached

Rigid boundaries: Active side 20.00 from pile
Passive side 20.00 from pile

Limit State: Serviceability Limit State

Node no.	Y coord	Nett pressure kN/m2	Pile disp. m	Pile rotation rad.	Shear force kN	Bending moment kN.m	Strut forces kN	Applied moments kN.m
1	14.82	-35.31	0.000	1.26E-04	30.7	-12.6	-30.7	-12.6
2	14.01	-31.02	0.000	1.51E-04	14.5	4.8		
3	13.20	-19.31	0.000	1.01E-04	2.3	11.0		
4	12.00	1.13	-0.000	2.45E-05	-4.3	5.3		
5	11.00	3.89	-0.000	-1.93E-06	-2.8	1.4		
6	10.00	2.46	-0.000	-6.60E-06	-0.9	-0.2		
		2.31	-0.000	-6.60E-06	-0.9	-0.2		
7	9.20	0.95	-0.000	-4.49E-06	-0.1	-0.5		
8	8.40	0.13	-0.000	-1.96E-06	0.2	-0.3		
9	7.20	-0.20	0.000	1.30E-08	0.2	-0.1		
10	6.00	-0.11	0.000	2.79E-07	0.0	0.0		
11	4.80	-0.01	0.000	1.08E-07	-0.0	0.0		
12	3.60	0.01	-0.000	4.38E-09	-0.0	0.0		
13	2.40	0.01	-0.000	-1.21E-08	-0.0	-0.0		
14	1.20	0.00	-0.000	-4.83E-09	0.0	-0.0		
15	0.00	-0.00	0.000	-1.65E-10	0.0	-0.0		
16	-1.20	-0.00	0.000	5.11E-10	0.0	0.0		
17	-2.40	-0.00	0.000	1.78E-10	-0.0	0.0		
18	-3.60	0.00	-0.000	-2.35E-12	-0.0	0.0		
19	-4.80	0.00	-0.000	-2.04E-11	-0.0	-0.0		
20	-5.65	0.00	-0.000	-1.04E-11	0.0	-0.0		
21	-6.50	-0.00	0.000	-6.11E-12	-0.0	-0.0		

Node no.	Y coord	ACTIVE side: Effective stresses: Water press. kN/m2	Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
1	14.82	0.00	0.00	0.00	81.24	0.00	0.00a	120858
2	14.01	8.12	8.12	0.00	164.40	0.00	8.12a	133380
3	13.20	16.25	16.25	0.00	247.55	6.59	22.84	145903
4	12.00	28.25	28.25	0.00	370.36	28.82	57.07	138845
5	11.00	38.25	38.25	0.00	472.70	40.19	78.44	151862
6	10.00	48.25	48.25	0.00	575.05	49.48	97.73	164878
		48.25	48.25	0.00	609.53	49.41	97.66	154865
7	9.20	56.25	56.25	0.00	696.58	56.73	112.98	163104
8	8.40	64.25	64.25	0.00	783.64	64.32	128.57	171343
9	7.20	76.25	76.25	0.00	914.21	76.15	152.40	192677
10	6.00	88.25	88.25	0.00	1044.79	88.20	176.45	205639
11	4.80	100.25	100.25	0.00	1175.36	100.24	200.49	218601
12	3.60	112.25	112.25	0.00	1305.94	112.25	224.50	230498
13	2.40	124.25	124.25	0.00	1436.52	124.25	248.50	243401

(continued)

Stage No.1 Apply load no.1 at elevation 14.82
The effect of strut/anchor stiffness at this elevation
will be included while applying this load

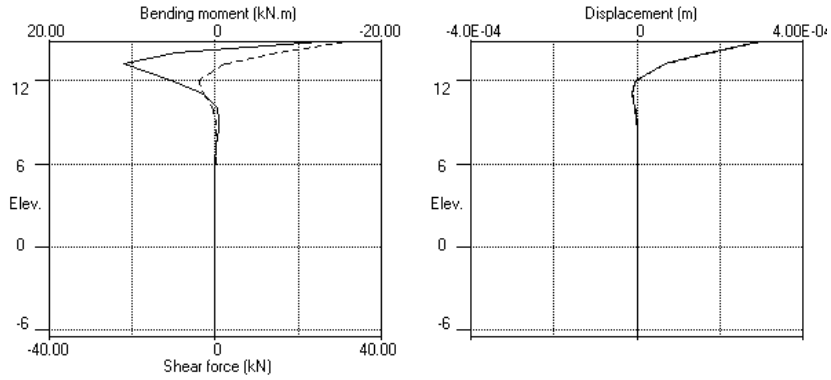
Node no.	Y coord	ACTIVE side: Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
14	1.20	136.25	136.25	0.00	1567.09	136.25	272.50	256303
15	0.00	148.25	148.25	0.00	1697.67	148.25	296.50	272614
16	-1.20	160.25	160.25	0.00	1828.25	160.25	320.50	285680
17	-2.40	172.25	172.25	0.00	1958.82	172.25	344.50	298745
18	-3.60	184.25	184.25	0.00	2089.40	184.25	368.50	319813
19	-4.80	196.25	196.25	0.00	2219.97	196.25	392.50	333214
20	-5.65	204.75	204.75	0.00	2312.47	204.75	409.50	342706
21	-6.50	213.25	213.25	0.00	2404.96	213.25	426.50	864219

Node no.	Y coord	PASSIVE side: Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
1	14.82	0.00	0.00	0.00	81.24	35.31	35.31	120858
2	14.01	8.12	8.12	0.00	164.40	31.02	39.15	133380
3	13.20	16.25	16.25	0.00	247.55	25.91	42.16	145903
4	12.00	28.25	28.25	0.00	370.36	27.68	55.93	138845
5	11.00	38.25	38.25	0.00	472.70	36.31	74.56	151862
6	10.00	48.25	48.25	0.00	575.05	47.02	95.27	164878
		48.25	48.25	0.00	609.53	47.09	95.34	154865
7	9.20	56.25	56.25	0.00	696.58	55.77	112.02	163104
8	8.40	64.25	64.25	0.00	783.64	64.18	128.43	171343
9	7.20	76.25	76.25	0.00	914.21	76.35	152.60	192677
10	6.00	88.25	88.25	0.00	1044.79	88.30	176.55	205639
11	4.80	100.25	100.25	0.00	1175.36	100.26	200.51	218601
12	3.60	112.25	112.25	0.00	1305.94	112.25	224.50	230498
13	2.40	124.25	124.25	0.00	1436.52	124.25	248.50	243401
14	1.20	136.25	136.25	0.00	1567.09	136.25	272.50	256303
15	0.00	148.25	148.25	0.00	1697.67	148.25	296.50	272614
16	-1.20	160.25	160.25	0.00	1828.25	160.25	320.50	285680
17	-2.40	172.25	172.25	0.00	1958.82	172.25	344.50	298745
18	-3.60	184.25	184.25	0.00	2089.40	184.25	368.50	319813
19	-4.80	196.25	196.25	0.00	2219.97	196.25	392.50	333214
20	-5.65	204.75	204.75	0.00	2312.47	204.75	409.50	342706
21	-6.50	213.25	213.25	0.00	2404.96	213.25	426.50	864219

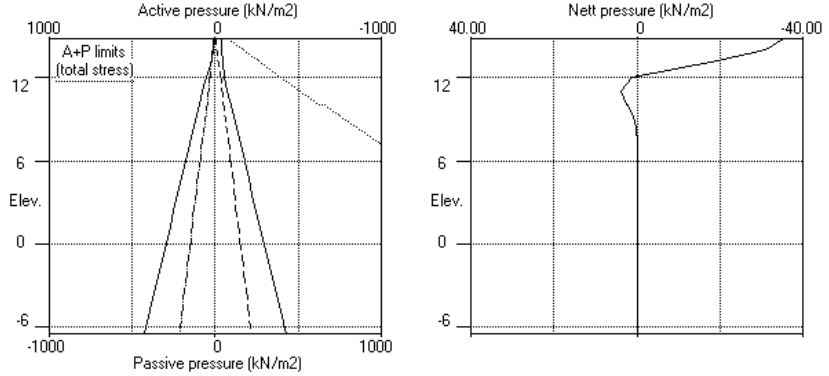
Note: 8.12a Soil pressure at active limit
123.45p Soil pressure at passive limit

Units: kN,m

Stage No.1 Apply load no.1 at elev. 14.82



Stage No.1 Apply load no.1 at elev. 14.82



Units: kN,m

Summary of results

LIMIT STATE PARAMETERS

Limit State: Serviceability Limit State
All loads and soil strengths are unfactored

BENDING MOMENT and DISPLACEMENT ANALYSIS of Single Pile

Analysis options

Pile diameter = 0.60m
Subgrade reaction model - Boussinesq Influence coefficients
Soil deformations are elastic until the active or passive limit is reached

Rigid boundaries: Active side 20.00 from pile
Passive side 20.00 from pile

Limit State: Serviceability Limit State

Bending moment, shear force and displacement envelopes

Node no.	Y coord	Displacement maximum	Displacement minimum	Bending moment maximum	Bending moment minimum	Shear force maximum	Shear force minimum
		m	m	kN.m	kN.m	kN	kN
1	14.82	0.000	0.000	0.0	-12.6	30.7	0.0
2	14.01	0.000	0.000	4.8	0.0	14.5	0.0
3	13.20	0.000	0.000	11.0	0.0	2.3	0.0
4	12.00	0.000	-0.000	5.3	0.0	0.0	-4.3
5	11.00	0.000	-0.000	1.4	0.0	0.0	-2.8
6	10.00	0.000	-0.000	0.0	-0.2	0.0	-0.9
7	9.20	0.000	-0.000	0.0	-0.5	0.0	-0.1
8	8.40	0.000	-0.000	0.0	-0.3	0.2	0.0
9	7.20	0.000	0.000	0.0	-0.1	0.2	0.0
10	6.00	0.000	0.000	0.0	0.0	0.0	0.0
11	4.80	0.000	0.000	0.0	0.0	0.0	-0.0
12	3.60	0.000	-0.000	0.0	0.0	0.0	-0.0
13	2.40	0.000	-0.000	0.0	-0.0	0.0	-0.0
14	1.20	0.000	-0.000	0.0	-0.0	0.0	0.0
15	0.00	0.000	0.000	0.0	-0.0	0.0	0.0
16	-1.20	0.000	0.000	0.0	0.0	0.0	0.0
17	-2.40	0.000	0.000	0.0	0.0	0.0	-0.0
18	-3.60	0.000	-0.000	0.0	0.0	0.0	-0.0
19	-4.80	0.000	-0.000	0.0	-0.0	0.0	-0.0
20	-5.65	0.000	-0.000	0.0	-0.0	0.0	0.0
21	-6.50	0.000	0.000	0.0	-0.0	0.0	-0.0

Maximum and minimum bending moment and shear force at each stage

Stage no.	Bending moment maximum	Bending moment elev.	Bending moment minimum	Bending moment elev.	Shear force maximum	Shear force elev.	Shear force minimum	Shear force elev.
	kN.m		kN.m		kN		kN	
1	11.0	13.20	-12.6	14.82	30.7	14.82	-4.3	12.00

Maximum and minimum displacement at each stage

Stage no.	Displacement maximum	Displacement elev.	Displacement minimum	Displacement elev.	Stage description
	m		m		
1	0.000	14.82	-0.000	11.00	Apply load no.1 at elev. 14.82

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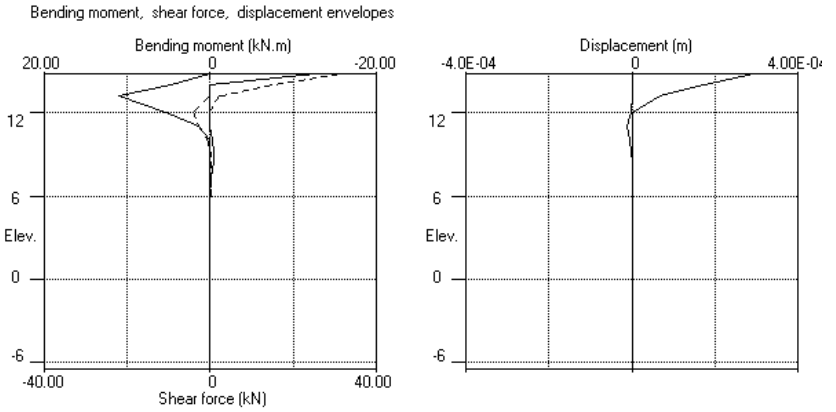
Student Centre UCL | Date:14-04-2016
600mm bearing | Checked :

Units: kN,m



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Program: WALLAP Version 6.05 Revision A46.B59.R49 | Job No. P230
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Data filename/Run ID: 600mm - 21.732 CoL |
Student Centre UCL | Date:14-04-2016
600mm bearing | Checked :

Units: kN,m

INPUT DATA

SOIL PROFILE

Stratum no.	Elevation of top of stratum	Soil types Active side	Passive side
1	21.73	3 Lynch Hill GRAV	3 Lynch Hill GRAV
2	18.00	5 LC - dr	5 LC - dr
3	10.00	7 LAM - dr	7 LAM - dr

SOIL PROPERTIES

No.	Soil type -- Description (Datum elev.)	Bulk density kN/m3	Young's Modulus Eh,kN/m2 (dEh/dy)	At rest coeff. Ko (dKo/dy)	Consol state. NC/OC (Nu)	Active limit Ka (Kac)	Passive limit Kp (Kpc)	Cohesion kN/m2 (dc/dy)
1	MG	18.00	10000	0.500	OC (0.200)	0.000 (0.000)	5.026 (0.000)	
2	Not defined							
3	Lynch Hill GRAV	20.00	60000	0.500	OC (0.200)	0.000 (0.000)	9.255 (0.000)	
4	Not defined							
5	LC - dr (18.00)	20.00	45500 (9750)	1.000	OC (0.200)	0.000 (0.000)	3.411 (5.416)	5.000d
6	Not defined							
7	LAM - dr (10.00)	20.00	116000 (7714)	1.000	OC (0.200)	0.000 (0.000)	3.627 (5.634)	5.000d

Additional soil parameters associated with Ka and Kp

No.	Soil type ------- Description	--- parameters for Ka --- Soil friction angle	Wall adhesion coeff.	Back-fill angle	--- parameters for Kp --- Soil friction angle	Wall adhesion coeff.	Back-fill angle
1	MG	0.00	0.000	0.00	30.00	1.000	0.00
2	Not defined						
3	Lynch Hill GRAV	0.00	0.000	0.00	38.00	1.000	0.00
4	Not defined						
5	LC - dr	0.00	0.000	0.00	24.00	1.000	0.00
6	Not defined						
7	LAM - dr	0.00	0.000	0.00	25.00	1.000	0.00

GROUND WATER CONDITIONS

Density of water = 10.00 kN/m3

	Active side	Passive side
Initial water table elevation	21.73	21.73

Automatic water pressure balancing at toe of pile : No

PILE PROPERTIES

Type of structure = Single Pile
Pile diameter = 0.60 m
Elevation of toe of pile = -6.50
Maximum finite element length = 1.20 m
Pile diameter = 0.60 m
Youngs modulus of pile E = 2.0000E+07 kN/m2
Moment of inertia of pile I = 6.3617E-03 m4
E.I = 127235 kN.m2
Yield Moment of pile = Not defined

HORIZONTAL and MOMENT LOADS/RESTRAINTS

Load no.	Elevation	Horizontal load kN	Moment load kN.m	Moment restraint kN.m/rad	Partial factor/ Category
1	21.73	23.00	0	50000	1.00 -

CONSTRUCTION STAGES

Construction stage no.	Stage description
1	Apply load no.1 at elevation 21.73 The effect of strut/anchor stiffness at this elevation will be included while applying this load

FACTORS OF SAFETY and ANALYSIS OPTIONS

Limit State options: Serviceability Limit State
All loads and soil strengths are unfactored

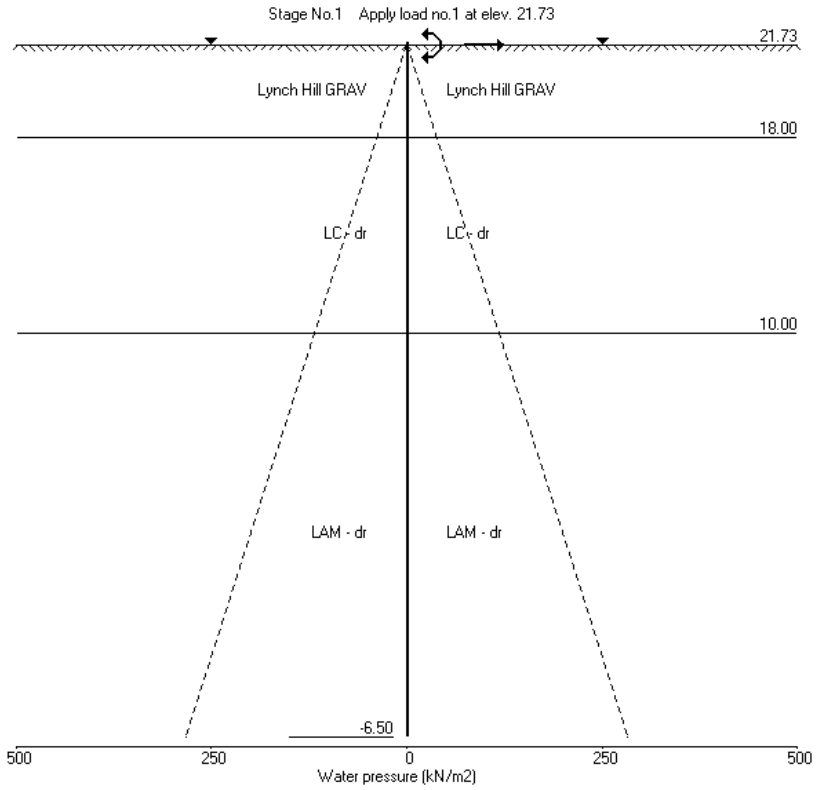
Parameters for undrained strata:
Minimum equivalent fluid density = 5.00 kN/m3
Maximum depth of water filled tension crack = 0.00 m

Bending moment and displacement calculation:
Method - Subgrade reaction model using Influence Coefficients

OUTPUT OPTIONS

Stage no.	Stage description	Output options: Displacement Bending mom. Shear force	Active, Passive pressures	Graph. output
1	Apply load no.1 at elev. 21.73	No	No	No
*	Summary output	Yes	-	Yes

Units: kN,m



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Program: WALLAP Version 6.05 Revision A46.B59.R49 | Job No. P230
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Data filename/Run ID: 600mm - 21.732 CoL |
Student Centre UCL | Date:14-04-2016
600mm bearing | Checked :

Units: kN,m

Stage No. 1 Apply load no.1 at elevation 21.73
The effect of strut/anchor stiffness at this elevation
will be included while applying this load

BENDING MOMENT and DISPLACEMENT ANALYSIS of Single Pile

Analysis options

Pile diameter = 0.60m
Subgrade reaction model - Boussinesq Influence coefficients
Soil deformations are elastic until the active or passive limit is reached

Rigid boundaries: Active side 20.00 from pile
Passive side 20.00 from pile

Limit State: Serviceability Limit State

Node no.	Y coord	Nett pressure kN/m2	Pile disp. m	Pile rotation rad.	Shear force kN	Bending moment kN.m	Strut forces kN	Applied moments kN.m
1	21.73	0.00	0.000	2.05E-04	23.0	-10.3	-23.0	-10.3
2	21.07	-31.65	0.000	2.19E-04	16.7	4.9		
3	20.40	-22.51	0.000	1.75E-04	5.9	11.7		
4	19.20	-3.98	0.000	7.40E-05	-3.7	9.9		
5	18.00	3.55	-0.000	9.43E-06	-3.8	3.8		
		2.69	-0.000	9.43E-06	-3.8	3.8		
6	16.80	2.86	-0.000	-9.90E-06	-1.8	0.3		
7	15.60	1.34	-0.000	-8.37E-06	-0.3	-0.7		
8	14.40	0.17	-0.000	-3.08E-06	0.2	-0.5		
9	13.20	-0.21	0.000	-2.01E-07	0.2	-0.1		
10	12.00	-0.16	0.000	4.30E-07	0.1	0.0		
11	11.00	-0.06	0.000	2.82E-07	0.0	0.0		
12	10.00	-0.00	0.000	9.36E-08	-0.0	0.0		
13	9.20	0.01	-0.000	1.31E-08	-0.0	0.0		
14	8.40	0.01	-0.000	-1.43E-08	-0.0	0.0		
15	7.20	0.00	-0.000	-1.35E-08	-0.0	-0.0		
16	6.00	0.00	-0.000	-3.63E-09	0.0	-0.0		
17	4.80	-0.00	0.000	3.89E-10	0.0	-0.0		
18	3.60	-0.00	0.000	6.22E-10	0.0	0.0		
19	2.40	-0.00	0.000	1.75E-10	-0.0	0.0		
20	1.20	0.00	-0.000	-1.52E-11	-0.0	0.0		
21	0.00	0.00	-0.000	-2.59E-11	-0.0	-0.0		
22	-1.20	0.00	-0.000	-6.52E-12	0.0	-0.0		
23	-2.40	-0.00	0.000	9.20E-13	0.0	-0.0		
24	-3.60	-0.00	0.000	9.93E-13	0.0	0.0		
25	-4.80	0.00	-0.000	1.90E-13	-0.0	0.0		
26	-5.65	0.00	-0.000	-8.05E-15	-0.0	0.0		
27	-6.50	0.00	-0.000	-4.29E-14	-0.0	-0.0		

Node no.	Y coord	ACTIVE side: Effective stresses: Water press. kN/m2	Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
1	21.73	0.00	0.00	0.00	0.00	0.00	0.00	93445
2	21.07	6.64	6.68	0.00	185.47	0.00	6.64a	93445
3	20.40	13.30	13.34	0.00	370.38	0.00	13.30a	93445
4	19.20	25.30	25.34	0.00	703.56	10.68	35.98	93445
5	18.00	37.30	37.34	0.00	1036.73	20.44	57.74	77271
		37.30	37.34	0.00	463.39	38.69	75.99	58598
6	16.80	49.30	49.34	0.00	586.20	50.77	100.07	73665
7	15.60	61.30	61.34	0.00	709.01	62.01	123.31	88733

(continued)

Stage No.1 Apply load no.1 at elevation 21.73
The effect of strut/anchor stiffness at this elevation
will be included while applying this load

Node no.	Y coord	ACTIVE side: Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
8	14.40	73.30	73.34	0.00	831.83	73.43	146.73	103801
9	13.20	85.30	85.34	0.00	954.64	85.24	170.54	123815
10	12.00	97.30	97.34	0.00	1077.45	97.26	194.56	139510
11	11.00	107.30	107.34	0.00	1179.79	107.31	214.61	152589
12	10.00	117.30	117.34	0.00	1282.14	117.34	234.64	165668
		117.30	117.34	0.00	1361.33	117.34	234.64	155608
13	9.20	125.30	125.34	0.00	1448.38	125.35	250.65	162674
14	8.40	133.30	133.34	0.00	1535.43	133.34	266.64	170891
15	7.20	145.30	145.34	0.00	1666.00	145.34	290.64	183217
16	6.00	157.30	157.34	0.00	1796.58	157.34	314.64	195542
17	4.80	169.30	169.34	0.00	1927.16	169.34	338.64	219777
18	3.60	181.30	181.34	0.00	2057.73	181.34	362.64	232809
19	2.40	193.30	193.34	0.00	2188.31	193.34	386.64	245841
20	1.20	205.30	205.34	0.00	2318.89	205.34	410.64	264605
21	0.00	217.30	217.34	0.00	2449.46	217.34	434.64	277926
22	-1.20	229.30	229.34	0.00	2580.04	229.34	458.64	291246
23	-2.40	241.30	241.34	0.00	2710.61	241.34	482.64	303682
24	-3.60	253.30	253.34	0.00	2841.19	253.34	506.64	316964
25	-4.80	265.30	265.34	0.00	2971.77	265.34	530.64	322434
26	-5.65	273.80	273.84	0.00	3064.26	273.84	547.64	331619
27	-6.50	282.30	282.34	0.00	3156.75	282.34	564.64	340804

Node no.	Y coord	PASSIVE side: Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
1	21.73	0.00	0.00	0.00	0.00	0.00	0.00	93445
2	21.07	6.64	6.68	0.00	185.47	31.65	38.29	93445
3	20.40	13.30	13.34	0.00	370.38	22.51	35.81	93445
4	19.20	25.30	25.34	0.00	703.56	14.66	39.96	93445
5	18.00	37.30	37.34	0.00	1036.73	16.90	54.20	77271
		37.30	37.34	0.00	463.39	35.99	73.29	58598
6	16.80	49.30	49.34	0.00	586.20	47.91	97.21	73665
7	15.60	61.30	61.34	0.00	709.01	60.67	121.97	88733
8	14.40	73.30	73.34	0.00	831.83	73.25	146.55	103801
9	13.20	85.30	85.34	0.00	954.64	85.44	170.74	123815
10	12.00	97.30	97.34	0.00	1077.45	97.42	194.72	139510
11	11.00	107.30	107.34	0.00	1179.79	107.37	214.67	152589
12	10.00	117.30	117.34	0.00	1282.14	117.34	234.64	165668
		117.30	117.34	0.00	1361.33	117.34	234.64	155608
13	9.20	125.30	125.34	0.00	1448.38	125.33	250.63	162674
14	8.40	133.30	133.34	0.00	1535.43	133.34	266.64	170891
15	7.20	145.30	145.34	0.00	1666.00	145.34	290.64	183217
16	6.00	157.30	157.34	0.00	1796.58	157.34	314.64	195542
17	4.80	169.30	169.34	0.00	1927.16	169.34	338.64	219777
18	3.60	181.30	181.34	0.00	2057.73	181.34	362.64	232809
19	2.40	193.30	193.34	0.00	2188.31	193.34	386.64	245841
20	1.20	205.30	205.34	0.00	2318.89	205.34	410.64	264605
21	0.00	217.30	217.34	0.00	2449.46	217.34	434.64	277926
22	-1.20	229.30	229.34	0.00	2580.04	229.34	458.64	291246
23	-2.40	241.30	241.34	0.00	2710.61	241.34	482.64	303682

Run ID. 600mm - 21.732 CoL | Sheet No.
Student Centre UCL | Date:14-04-2016
600mm bearing | Checked :

(continued)

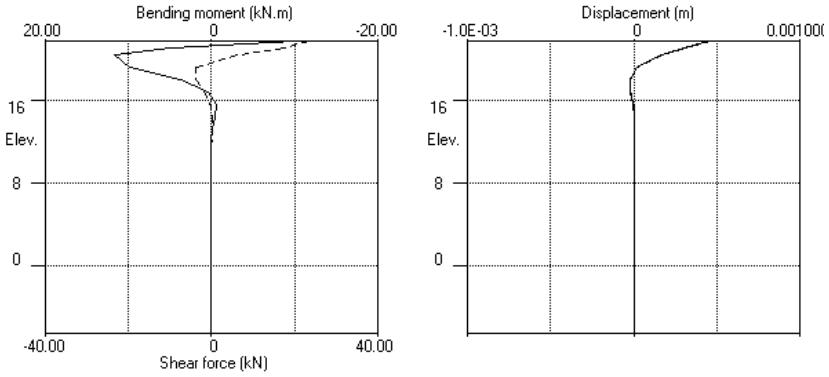
Stage No.1 Apply load no.1 at elevation 21.73
The effect of strut/anchor stiffness at this elevation
will be included while applying this load

Node no.	Y coord	PASSIVE side: Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
24	-3.60	253.30	253.34	0.00	2841.19	253.34	506.64	316964
25	-4.80	265.30	265.34	0.00	2971.77	265.34	530.64	322434
26	-5.65	273.80	273.84	0.00	3064.26	273.84	547.64	331619
27	-6.50	282.30	282.34	0.00	3156.75	282.34	564.64	340804

Note: 13.30a Soil pressure at active limit
123.45p Soil pressure at passive limit

Units: kN,m

Stage No.1 Apply load no.1 at elev. 21.73



KELTBRAY PILING | Sheet No.
Program: WALLAP Version 6.05 Revision A46.B59.R49 | Job No. P230
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Data filename/Run ID: 600mm - 21.732 CoL |
Student Centre UCL | Date:14-04-2016
600mm bearing | Checked :

Units: kN,m

Summary of results

LIMIT STATE PARAMETERS

Limit State: Serviceability Limit State
All loads and soil strengths are unfactored

BENDING MOMENT and DISPLACEMENT ANALYSIS of Single Pile

Analysis options

Pile diameter = 0.60m
Subgrade reaction model - Boussinesq Influence coefficients
Soil deformations are elastic until the active or passive limit is reached

Rigid boundaries: Active side 20.00 from pile
Passive side 20.00 from pile

Limit State: Serviceability Limit State

Bending moment, shear force and displacement envelopes

Node no.	Y coord	Displacement maximum	Displacement minimum	Bending moment maximum	Bending moment minimum	Shear force maximum	Shear force minimum
		m	m	kN.m	kN.m	kN	kN
1	21.73	0.000	0.000	0.0	-10.3	23.0	0.0
2	21.07	0.000	0.000	4.9	0.0	16.7	0.0
3	20.40	0.000	0.000	11.7	0.0	5.9	0.0
4	19.20	0.000	0.000	9.9	0.0	0.0	-3.7
5	18.00	0.000	-0.000	3.8	0.0	0.0	-3.8
6	16.80	0.000	-0.000	0.3	0.0	0.0	-1.8
7	15.60	0.000	-0.000	0.0	-0.7	0.0	-0.3
8	14.40	0.000	-0.000	0.0	-0.5	0.2	0.0
9	13.20	0.000	0.000	0.0	-0.1	0.2	0.0
10	12.00	0.000	0.000	0.0	0.0	0.1	0.0
11	11.00	0.000	0.000	0.0	0.0	0.0	0.0
12	10.00	0.000	0.000	0.0	0.0	0.0	-0.0
13	9.20	0.000	-0.000	0.0	0.0	0.0	-0.0
14	8.40	0.000	-0.000	0.0	0.0	0.0	-0.0
15	7.20	0.000	-0.000	0.0	-0.0	0.0	-0.0
16	6.00	0.000	-0.000	0.0	-0.0	0.0	0.0
17	4.80	0.000	0.000	0.0	-0.0	0.0	0.0
18	3.60	0.000	0.000	0.0	0.0	0.0	0.0
19	2.40	0.000	0.000	0.0	0.0	0.0	-0.0
20	1.20	0.000	-0.000	0.0	0.0	0.0	-0.0
21	0.00	0.000	-0.000	0.0	-0.0	0.0	-0.0
22	-1.20	0.000	-0.000	0.0	-0.0	0.0	0.0
23	-2.40	0.000	0.000	0.0	-0.0	0.0	0.0
24	-3.60	0.000	0.000	0.0	0.0	0.0	0.0
25	-4.80	0.000	-0.000	0.0	0.0	0.0	-0.0
26	-5.65	0.000	-0.000	0.0	0.0	0.0	-0.0
27	-6.50	0.000	-0.000	0.0	-0.0	0.0	-0.0

Maximum and minimum bending moment and shear force at each stage

Stage no.	Bending moment maximum	Bending moment elev.	Bending moment minimum	Bending moment elev.	Shear force maximum	Shear force elev.	Shear force minimum	Shear force elev.
	kN.m		kN.m		kN		kN	
1	11.7	20.40	-10.3	21.73	23.0	21.73	-3.8	18.00

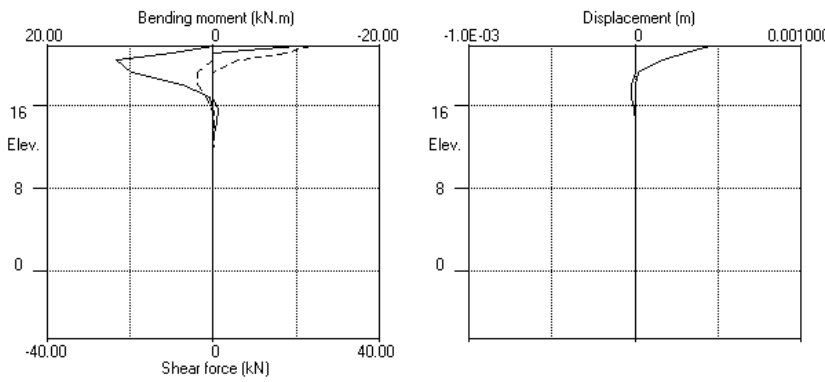
Summary of results (continued)

Maximum and minimum displacement at each stage

Stage no.	Displacement maximum m	elev.	minimum m	elev.	Stage description
1	0.000	21.73	-0.000	18.00	Apply load no.1 at elev. 21.73

Units: kN,m

Bending moment, shear force, displacement envelopes



Units: kN,m

INPUT DATA

SOIL PROFILE

Stratum no.	Elevation of top of stratum	Soil types Active side	Passive side
1	22.46	1 MG	1 MG
2	21.50	3 Lynch Hill GRAV	3 Lynch Hill GRAV
3	18.00	5 LC - dr	5 LC - dr
4	10.00	7 LAM - dr	7 LAM - dr

SOIL PROPERTIES

No.	Soil type -- Description (Datum elev.)	Bulk density kN/m3	Young's Modulus Eh,kN/m2 (dEh/dy)	At rest coeff. Ko (dKo/dy)	Consol state. NC/OC (Nu)	Active limit Ka (Kac)	Passive limit Kp (Kpc)	Cohesion kN/m2 (dc/dy)
1	MG	18.00	10000	0.500	OC (0.200)	0.000 (0.000)	5.026 (0.000)	
2	Not defined							
3	Lynch Hill GRAV	20.00	60000	0.500	OC (0.200)	0.000 (0.000)	9.255 (0.000)	
4	Not defined							
5	LC - dr (18.00)	20.00	45500 (9750)	1.000	OC (0.200)	0.000 (0.000)	3.411 (5.416)	5.000d
6	Not defined							
7	LAM - dr (10.00)	20.00	116000 (7714)	1.000	OC (0.200)	0.000 (0.000)	3.627 (5.634)	5.000d

Additional soil parameters associated with Ka and Kp

No.	Soil type Description	--- parameters for Ka --- Soil friction angle	Wall adhesion coeff.	Back-fill angle	--- parameters for Kp --- Soil friction angle	Wall adhesion coeff.	Back-fill angle
1	MG	0.00	0.000	0.00	30.00	1.000	0.00
2	Not defined						
3	Lynch Hill GRAV	0.00	0.000	0.00	38.00	1.000	0.00
4	Not defined						
5	LC - dr	0.00	0.000	0.00	24.00	1.000	0.00
6	Not defined						
7	LAM - dr	0.00	0.000	0.00	25.00	1.000	0.00

GROUND WATER CONDITIONS

Density of water = 10.00 kN/m3

	Active side	Passive side
Initial water table elevation	22.46	22.46

Automatic water pressure balancing at toe of pile : No

PILE PROPERTIES

Type of structure = Single Pile
Pile diameter = 0.90 m
Elevation of toe of pile = -1.00
Maximum finite element length = 1.20 m
Pile diameter = 0.90 m
Youngs modulus of pile E = 2.0000E+07 kN/m2
Moment of inertia of pile I = 0.032206 m4
E.I = 644120 kN.m2
Yield Moment of pile = Not defined

HORIZONTAL and MOMENT LOADS/RESTRAINTS

Load no.	Elevation	Horizontal load kN	Moment load kN.m	Moment restraint kN.m/rad	Partial factor/ Category
1	22.46	55.00	0	200000	1.00 -

CONSTRUCTION STAGES

Construction stage no.	Stage description
1	Apply load no.1 at elevation 22.46 The effect of strut/anchor stiffness at this elevation will be included while applying this load

FACTORS OF SAFETY and ANALYSIS OPTIONS

Limit State options: Serviceability Limit State
All loads and soil strengths are unfactored

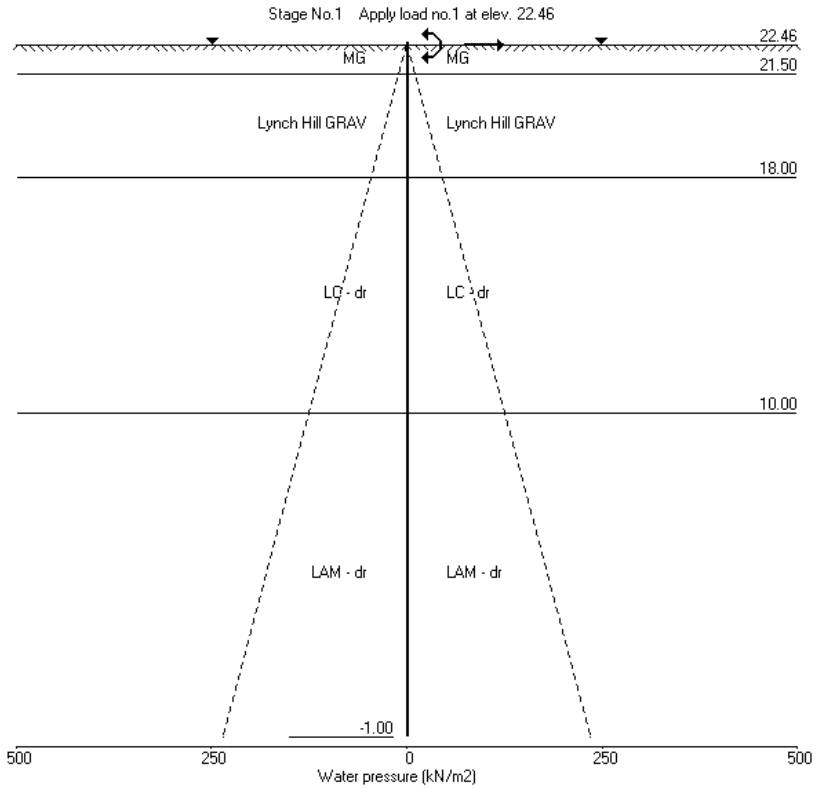
Parameters for undrained strata:
Minimum equivalent fluid density = 5.00 kN/m3
Maximum depth of water filled tension crack = 0.00 m

Bending moment and displacement calculation:
Method - Subgrade reaction model using Influence Coefficients

OUTPUT OPTIONS

Stage no.	Stage description	Output options Displacement Bending mom. Shear force	Active, Passive pressures	Graph. output
1	Apply load no.1 at elev. 22.46	No	No	No
*	Summary output	Yes	-	Yes

Units: kN,m



KELTBRAY PILING | Sheet No.
Program: WALLAP Version 6.05 Revision A46.B59.R49 | Job No. P230
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Data filename/Run ID: 900mm - 22.460 coL |
Student Centre UCL | Date:14-04-2016
900mm bearing | Checked :

Units: kN,m

Stage No. 1 Apply load no.1 at elevation 22.46
The effect of strut/anchor stiffness at this elevation
will be included while applying this load

BENDING MOMENT and DISPLACEMENT ANALYSIS of Single Pile

Analysis options

Pile diameter = 0.90m
Subgrade reaction model - Boussinesq Influence coefficients
Soil deformations are elastic until the active or passive limit is reached

Rigid boundaries: Active side 20.00 from pile
Passive side 20.00 from pile

Limit State: Serviceability Limit State

Node no.	Y coord	Nett pressure kN/m2	Pile disp. m	Pile rotation rad.	Shear force kN	Bending moment kN.m	Strut forces kN	Applied moments kN.m
1	22.46	0.00	0.001	2.16E-04	55.0	-43.4	-55.0	-43.4
2	21.50	-9.86	0.001	2.42E-04	50.7	8.9		
		-39.98	0.001	2.42E-04	50.7	8.9		
3	20.35	-28.32	0.000	1.96E-04	15.4	42.3		
4	19.20	-12.94	0.000	1.18E-04	-6.0	45.1		
5	18.00	0.21	-0.000	4.91E-05	-12.8	29.5		
		0.16	-0.000	4.91E-05	-12.8	29.5		
6	16.80	3.72	-0.000	8.31E-06	-10.7	14.3		
7	15.60	4.20	-0.000	-8.47E-06	-6.5	3.8		
8	14.40	2.96	-0.000	-1.08E-05	-2.6	-1.3		
9	13.20	1.39	-0.000	-7.37E-06	-0.2	-2.4		
10	12.00	0.28	-0.000	-3.38E-06	0.7	-1.8		
11	11.00	-0.17	0.000	-1.12E-06	0.7	-1.1		
12	10.00	-0.30	0.000	3.42E-08	0.5	-0.4		
		-0.28	0.000	3.42E-08	0.5	-0.4		
13	9.20	-0.25	0.000	3.79E-07	0.3	-0.1		
14	8.40	-0.18	0.000	4.26E-07	0.1	0.0		
15	7.20	-0.07	0.000	2.83E-07	0.0	0.1		
16	6.00	-0.01	0.000	1.15E-07	-0.0	0.1		
17	4.80	0.01	-0.000	1.78E-08	-0.0	0.0		
18	3.60	0.01	-0.000	-1.51E-08	-0.0	0.0		
19	2.40	0.01	-0.000	-1.57E-08	-0.0	-0.0		
20	1.20	0.00	-0.000	-8.44E-09	0.0	-0.0		
21	0.10	-0.00	0.000	-3.89E-09	0.0	-0.0		
22	-1.00	-0.00	0.000	-2.60E-09	0.0	-0.0		

Node no.	Y coord	ACTIVE side: Effective stresses: Water press. kN/m2	Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
1	22.46	0.00	0.00	0.00	0.00	0.00	0.00	11241
2	21.50	9.60	7.68	0.00	115.80	0.00	9.60a	11241
		9.60	7.68	0.00	213.23	0.00	9.60a	67444
3	20.35	21.10	19.18	0.00	532.53	0.00	21.10a	67444
4	19.20	32.60	30.68	0.00	851.82	8.87	41.47	67444
5	18.00	44.60	42.68	0.00	1185.00	21.45	66.05	58322
		44.60	42.68	0.00	518.04	42.76	87.36	44228
6	16.80	56.60	54.68	0.00	640.85	56.54	113.14	55600
7	15.60	68.60	66.68	0.00	763.67	68.78	137.38	66973
8	14.40	80.60	78.68	0.00	886.48	80.16	160.76	78346
9	13.20	92.60	90.68	0.00	1009.29	91.37	183.97	89719

(continued)

Stage No.1 Apply load no.1 at elevation 22.46
The effect of strut/anchor stiffness at this elevation
will be included while applying this load

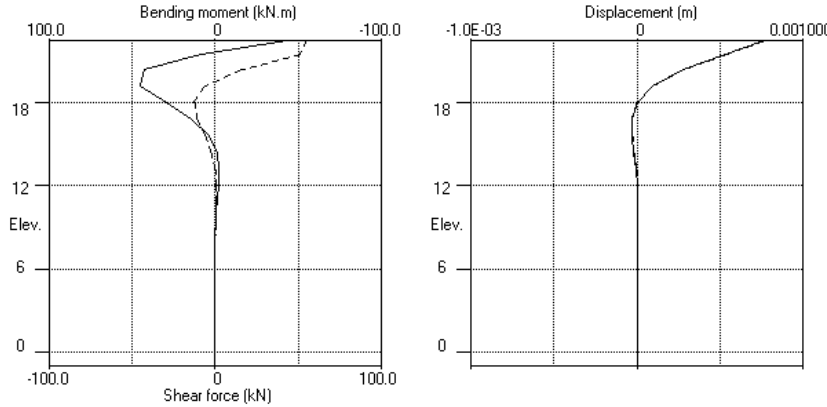
Node no.	Y coord	ACTIVE side: Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
10	12.00	104.60	102.68	0.00	1132.10	102.82	207.42	101092
11	11.00	114.60	112.68	0.00	1234.44	112.59	227.19	112728
12	10.00	124.60	122.68	0.00	1336.79	122.53	247.13	122390
		124.60	122.68	0.00	1419.43	122.54	247.14	114957
13	9.20	132.60	130.68	0.00	1506.48	130.55	263.15	121073
14	8.40	140.60	138.68	0.00	1593.53	138.59	279.19	127189
15	7.20	152.60	150.68	0.00	1724.11	150.64	303.24	136363
16	6.00	164.60	162.68	0.00	1854.69	162.68	327.28	145536
17	4.80	176.60	174.68	0.00	1985.26	174.69	351.29	157328
18	3.60	188.60	186.68	0.00	2115.84	186.69	375.29	166656
19	2.40	200.60	198.68	0.00	2246.42	198.68	399.28	175985
20	1.20	212.60	210.68	0.00	2376.99	210.68	423.28	185314
21	0.10	223.60	221.68	0.00	2496.69	221.68	445.28	283081
22	-1.00	234.60	232.68	0.00	2616.38	232.68	467.28	295568

Node no.	Y coord	PASSIVE side: Water press. kN/m2	Effective stresses: Vertic -al kN/m2	Active limit kN/m2	Passive limit kN/m2	Earth pressure kN/m2	Total earth pressure kN/m2	Coeff. of subgrade reaction kN/m3
1	22.46	0.00	0.00	0.00	0.00	0.00	0.00	11241
2	21.50	9.60	7.68	0.00	115.80	9.86	19.46	11241
		9.60	7.68	0.00	213.23	39.98	49.58	67444
3	20.35	21.10	19.18	0.00	532.53	28.32	49.42	67444
4	19.20	32.60	30.68	0.00	851.82	21.81	54.41	67444
5	18.00	44.60	42.68	0.00	1185.00	21.23	65.83	58322
		44.60	42.68	0.00	518.04	42.60	87.20	44228
6	16.80	56.60	54.68	0.00	640.85	52.82	109.42	55600
7	15.60	68.60	66.68	0.00	763.67	64.58	133.18	66973
8	14.40	80.60	78.68	0.00	886.48	77.20	157.80	78346
9	13.20	92.60	90.68	0.00	1009.29	89.99	182.59	89719
10	12.00	104.60	102.68	0.00	1132.10	102.54	207.14	101092
11	11.00	114.60	112.68	0.00	1234.44	112.77	227.37	112728
12	10.00	124.60	122.68	0.00	1336.79	122.83	247.43	122390
		124.60	122.68	0.00	1419.43	122.82	247.42	114957
13	9.20	132.60	130.68	0.00	1506.48	130.81	263.41	121073
14	8.40	140.60	138.68	0.00	1593.53	138.77	279.37	127189
15	7.20	152.60	150.68	0.00	1724.11	150.72	303.32	136363
16	6.00	164.60	162.68	0.00	1854.69	162.68	327.28	145536
17	4.80	176.60	174.68	0.00	1985.26	174.67	351.27	157328
18	3.60	188.60	186.68	0.00	2115.84	186.67	375.27	166656
19	2.40	200.60	198.68	0.00	2246.42	198.68	399.28	175985
20	1.20	212.60	210.68	0.00	2376.99	210.68	423.28	185314
21	0.10	223.60	221.68	0.00	2496.69	221.68	445.28	283081
22	-1.00	234.60	232.68	0.00	2616.38	232.68	467.28	295568

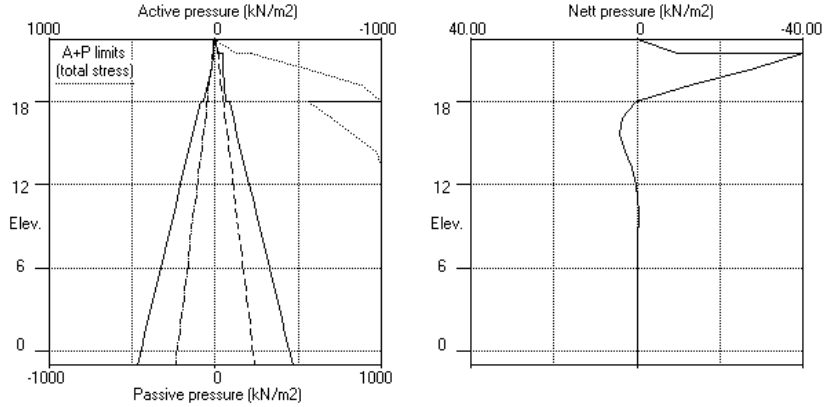
Note: 21.10a Soil pressure at active limit
123.45p Soil pressure at passive limit

Units: kN,m

Stage No.1 Apply load no.1 at elev. 22.46



Stage No.1 Apply load no.1 at elev. 22.46



Units: kN,m

Summary of results

LIMIT STATE PARAMETERS

Limit State: Serviceability Limit State
All loads and soil strengths are unfactored

BENDING MOMENT and DISPLACEMENT ANALYSIS of Single Pile

Analysis options

Pile diameter = 0.90m
Subgrade reaction model - Boussinesq Influence coefficients
Soil deformations are elastic until the active or passive limit is reached

Rigid boundaries: Active side 20.00 from pile
Passive side 20.00 from pile

Limit State: Serviceability Limit State

Bending moment, shear force and displacement envelopes

Node no.	Y coord	Displacement maximum	Displacement minimum	Bending moment maximum	Bending moment minimum	Shear force maximum	Shear force minimum
		m	m	kN.m	kN.m	kN	kN
1	22.46	0.001	0.000	0.0	-43.4	55.0	0.0
2	21.50	0.001	0.000	8.9	0.0	50.7	0.0
3	20.35	0.000	0.000	42.3	0.0	15.4	0.0
4	19.20	0.000	0.000	45.1	0.0	0.0	-6.0
5	18.00	0.000	-0.000	29.5	0.0	0.0	-12.8
6	16.80	0.000	-0.000	14.3	0.0	0.0	-10.7
7	15.60	0.000	-0.000	3.8	0.0	0.0	-6.5
8	14.40	0.000	-0.000	0.0	-1.3	0.0	-2.6
9	13.20	0.000	-0.000	0.0	-2.4	0.0	-0.2
10	12.00	0.000	-0.000	0.0	-1.8	0.7	0.0
11	11.00	0.000	0.000	0.0	-1.1	0.7	0.0
12	10.00	0.000	0.000	0.0	-0.4	0.5	0.0
13	9.20	0.000	0.000	0.0	-0.1	0.3	0.0
14	8.40	0.000	0.000	0.0	0.0	0.1	0.0
15	7.20	0.000	0.000	0.1	0.0	0.0	0.0
16	6.00	0.000	0.000	0.1	0.0	0.0	-0.0
17	4.80	0.000	-0.000	0.0	0.0	0.0	-0.0
18	3.60	0.000	-0.000	0.0	0.0	0.0	-0.0
19	2.40	0.000	-0.000	0.0	-0.0	0.0	-0.0
20	1.20	0.000	-0.000	0.0	-0.0	0.0	0.0
21	0.10	0.000	0.000	0.0	-0.0	0.0	0.0
22	-1.00	0.000	0.000	0.0	-0.0	0.0	0.0

Maximum and minimum bending moment and shear force at each stage

Stage no.	Bending moment maximum	Bending moment elev.	Bending moment minimum	Bending moment elev.	Shear force maximum	Shear force elev.	Shear force minimum	Shear force elev.
	kN.m		kN.m		kN		kN	
1	45.1	19.20	-43.4	22.46	55.0	22.46	-12.8	18.00

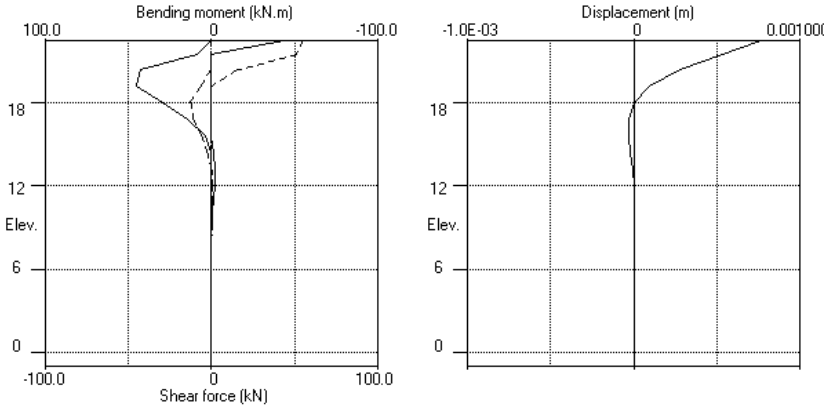
Maximum and minimum displacement at each stage

Stage no.	Displacement maximum	Displacement elev.	Displacement minimum	Displacement elev.	Stage description
	m		m		
1	0.001	22.46	-0.000	16.80	Apply load no.1 at elev. 22.46

Summary of results (continued)

Units: kN,m

Bending moment, shear force, displacement envelopes



Keltbray Piling

Keltbray Piling

E. Structural Calculations to EC2

Bending moment capacity of piles (Adsec)

Shear links of piles

Keltbray Piling

Adsec

UCL Bearing piles

General Specification

Code of Practice	EN 1992-1-1:2004 Eurocode 2
Country	United Kingdom
Bending Axes	Biaxial

Section 1 Details

Definition

Name	Section 1
Type	Concrete
Material	C30/37
Origin	Centre
Dimensions	
Diameter	600.0mm
Section Area	282700.mm^2
Reinforcement Area	1885.mm^2
Reinforcement	0.6667%

Section Nodes

Node	Y [mm]	Z [mm]
1	0.0	301.3
2	67.04	293.7
3	130.7	271.4
4	187.8	235.5
5	235.5	187.8
6	271.4	130.7
7	293.7	67.04
8	301.3	-13.17E-6
9	293.7	-67.04
10	271.4	-130.7
11	235.5	-187.8
12	187.8	-235.5
13	130.7	-271.4
14	67.04	-293.7
15	-26.34E-6	-301.3
16	-67.04	-293.7
17	-130.7	-271.4
18	-187.8	-235.5
19	-235.5	-187.8
20	-271.4	-130.7
21	-293.7	-67.04
22	-301.3	3.593E-6
23	-293.7	67.04
24	-271.4	130.7
25	-235.5	187.8
26	-187.8	235.5
27	-130.7	271.4
28	-67.04	293.7

Cover and Links

Cover	75.00mm
Link Size	10.00mm
Link Material	500B

Bars

Bar	Y	Z	Diameter	Material	Type	Pre-stress Force	Pre-stress Strain	Appl. loads include/exclude pre-stress
	[mm]	[mm]	[mm]			[kN]		
1	205.0	0.0	20.00	500B	Steel			
2	102.5	177.5	20.00	500B	Steel			
3	-102.5	177.5	20.00	500B	Steel			
4	-205.0	206.9E-9	20.00	500B	Steel			
5	-102.5	-177.5	20.00	500B	Steel			
6	102.5	-177.5	20.00	500B	Steel			

Elastic Properties

Effective properties of the section, ignoring reinforcement.

Geometric Centroid	y	0.0mm
	z	0.0mm
Area		282700.mm^2
Second Moments of Area	I_{yy}	6.362E+9mm^4
	I_{zz}	6.362E+9mm^4
	I_{yz}	0.0mm^4
Principal Second Moments of Area	I_{uu}	6.362E+9mm^4
	I_{zz}	6.362E+9mm^4
	Angle	0.0°
Shear Area Factor	k_y	0.8571
	k_z	0.8571
Torsion Constant		12.72E+9mm^4
Section Modulus	Z_y	21.21E+6mm^3
	Z_z	21.21E+6mm^3
Plastic Modulus	Z_{py}	36.00E+6mm^3
	Z_{pz}	36.00E+6mm^3
Radius of Gyration	R_y	150.0mm
	R_z	150.0mm

Properties of gross section, including reinforcement.

Geometric Centroid	y	99.55E-9mm
	z	0.0mm
EA		9.599E+6kN
EI	EI_{yy}	215500.kNm^2
	EI_{zz}	215500.kNm^2
	EI_{yz}	0.0kNm^2
Principal EI	EI_{uu}	215500.kNm^2
	EI_{zz}	215500.kNm^2
	Angle	90.00°

Section Material Properties

Type		Concrete
Name		C30/37
Weight		Normal Weight
Density	ρ	2.400t/m^3
Cylinder Strength	f_{ck}	30000.kPa
Tensile Strength	f_{ctm}	2896.kPa
Elastic Modulus (short term)	E	32.84E+6kPa
Poisson's Ratio	ν	0.2000
Coeff. Thermal Expansion	α	10.00E-6/°C
Partial Safety Factor	$\gamma_{mc,ULS}$	1.500

Bar	Y	Z	Diameter	Material	Type	Pre-stress Force	Pre-stress Strain	Appl. loads include/exclude pre-stress
	[mm]	[mm]	[mm]			[kN]		

	$\gamma_{mc,SLS}$	1.000
Maximum Strain		0.003500[-]
Plateau Strain		0.002000[-]
ULS Compression Curve		Parabola-rect.
ULS Tension Curve		No-tension
SLS Compression Curve		Fig 3.2
SLS Tension Curve		Interpolated
Aggregate Size		20.00mm

Reinforcement Properties

Name		500B
f_y		500000.kPa
Modulus		200.0E+6kPa
Partial Safety Factor	$\gamma_{ms,ULS}$	1.150
	$\gamma_{ms,SLS}$	1.000
Maximum Strain		0.05000[-]
Stress/Strain Curve		Elastic-plastic

Loading

Reference Point

All loading acts through the Reference Point.
All strain planes are defined relative to the Reference Point.

Definition		Geometric Centroid
Reference Point Coordinates	y	0.0mm
	z	0.0mm

Ultimate Charts

N/M Coordinates

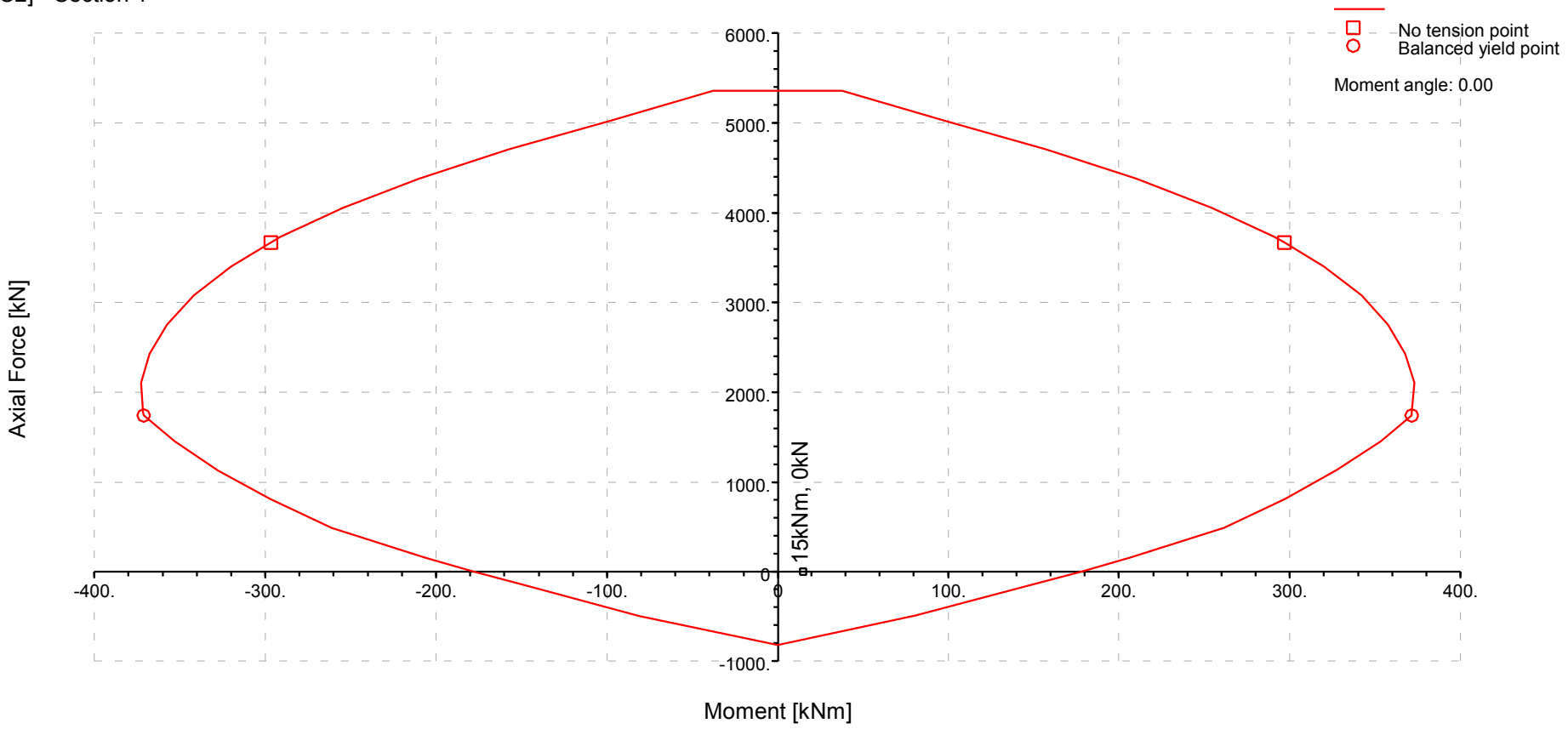
N/M [EC2] - Section 1

Moment angle: 0.00

	M [kNm]	N [kN]	Notes
1	-372.7	2106.	
2	-371.5	1780.	
3	-371.2	1743.	Balanced yield point
4	-353.2	1456.	
5	-327.4	1131.	
6	-297.1	805.8	
7	-261.4	481.1	
8	-206.8	156.1	
9	-177.9	-0.04130	
10	-145.4	-168.8	
11	-81.02	-493.8	
12	-0.4559	-818.0	
13	0.2928	-818.6	
14	81.06	-493.6	
15	145.4	-169.0	
16	177.9	0.002498	
17	206.8	156.1	
18	261.4	481.0	
19	297.1	805.8	
20	327.5	1131.	
21	353.2	1456.	
22	371.2	1743.	Balanced yield point
23	371.5	1780.	

	M [kNm]	N [kN]	Notes
24	372.7	2106.	
25	367.6	2430.	
26	357.5	2755.	
27	341.9	3080.	
28	319.8	3405.	
29	296.8	3669.	No tension point
30	290.9	3730.	
31	254.5	4055.	
32	210.3	4380.	
33	157.5	4704.	
34	97.35	5029.	
35	37.99	5354.	
36	-37.99	5354.	
37	-97.35	5029.	
38	-157.5	4704.	
39	-210.3	4380.	
40	-254.5	4055.	
41	-290.9	3730.	
42	-296.8	3669.	No tension point
43	-319.8	3405.	
44	-341.9	3080.	
45	-357.5	2755.	
46	-367.6	2430.	
47	-372.7	2106.	

N/M [EC2] - Section 1



UCL Bearing piles

General Specification

Code of Practice	EN 1992-1-1:2004 Eurocode 2
Country	United Kingdom
Bending Axes	Biaxial

Section 1 Details

Definition

Name	Section 1
Type	Concrete
Material	C30/37
Origin	Centre
Dimensions	
Diameter	600.0mm
Section Area	282700.mm^2
Reinforcement Area	4825.mm^2
Reinforcement	1.707%

Section Nodes

Node	Y [mm]	Z [mm]
1	0.0	301.3
2	67.04	293.7
3	130.7	271.4
4	187.8	235.5
5	235.5	187.8
6	271.4	130.7
7	293.7	67.04
8	301.3	-13.17E-6
9	293.7	-67.04
10	271.4	-130.7
11	235.5	-187.8
12	187.8	-235.5
13	130.7	-271.4
14	67.04	-293.7
15	-26.34E-6	-301.3
16	-67.04	-293.7
17	-130.7	-271.4
18	-187.8	-235.5
19	-235.5	-187.8
20	-271.4	-130.7
21	-293.7	-67.04
22	-301.3	3.593E-6
23	-293.7	67.04
24	-271.4	130.7
25	-235.5	187.8
26	-187.8	235.5
27	-130.7	271.4
28	-67.04	293.7

Cover and Links

Cover	75.00mm
Link Size	10.00mm
Link Material	500B

Bars

Bar	Y	Z	Diameter	Material	Type	Pre-stress Force	Pre-stress Strain	Appl. loads include/exclude pre-stress
	[mm]	[mm]	[mm]			[kN]		
1	199.0	0.0	32.00	500B - Copy	Steel			
2	99.50	172.3	32.00	500B - Copy	Steel			
3	-99.50	172.3	32.00	500B - Copy	Steel			
4	-199.0	5.904E-6	32.00	500B - Copy	Steel			
5	-99.50	-172.3	32.00	500B - Copy	Steel			
6	99.50	-172.3	32.00	500B - Copy	Steel			

Elastic Properties

Effective properties of the section, ignoring reinforcement.

Geometric Centroid	y	0.0mm
	z	0.0mm
Area		282700.mm^2
Second Moments of Area	I_{yy}	6.362E+9mm^4
	I_{zz}	6.362E+9mm^4
	I_{yz}	0.0mm^4
Principal Second Moments of Area	I_{uu}	6.362E+9mm^4
	I_{zz}	6.362E+9mm^4
	Angle	0.0°
Shear Area Factor	k_y	0.8571
	k_z	0.8571
Torsion Constant		12.72E+9mm^4
Section Modulus	Z_y	21.21E+6mm^3
	Z_z	21.21E+6mm^3
Plastic Modulus	Z_{py}	36.00E+6mm^3
	Z_{pz}	36.00E+6mm^3
Radius of Gyration	R_y	150.0mm
	R_z	150.0mm

Properties of gross section, including reinforcement.

Geometric Centroid	y	-189.4E-9mm
	z	378.8E-9mm
EA		10.09E+6kN
EI	EI_{yy}	224900.kNm^2
	EI_{zz}	224900.kNm^2
	EI_{yz}	-238.9E-6kNm^2
Principal EI	EI_{uu}	224900.kNm^2
	EI_{zz}	224900.kNm^2
	Angle	-45.00°

Section Material Properties

Type		Concrete
Name		C30/37
Weight		Normal Weight
Density	ρ	2.400t/m^3
Cylinder Strength	f_{ck}	30000.kPa
Tensile Strength	f_{ctm}	2896.kPa
Elastic Modulus (short term)	E	32.84E+6kPa
Poisson's Ratio	ν	0.2000
Coeff. Thermal Expansion	α	10.00E-6/°C
Partial Safety Factor	$\gamma_{mc,ULS}$	1.500

Bar	Y	Z	Diameter	Material	Type	Pre-stress Force	Pre-stress Strain	Appl. loads include/exclude pre-stress
	[mm]	[mm]	[mm]			[kN]		

	$\gamma_{mc,SLS}$	1.000
Maximum Strain		0.003500[-]
Plateau Strain		0.002000[-]
ULS Compression Curve		Parabola-rect.
ULS Tension Curve		No-tension
SLS Compression Curve		Fig 3.2
SLS Tension Curve		Interpolated
Aggregate Size		20.00mm

Reinforcement Properties

Name		500B - Copy
f_y		500000.kPa
Modulus		200.0E+6kPa
Partial Safety Factor	$\gamma_{ms,ULS}$	1.150
	$\gamma_{ms,SLS}$	1.000
Maximum Strain		0.05556[-]
Stress/Strain Curve		Elastic-plastic

Loading

Reference Point

All loading acts through the Reference Point.
All strain planes are defined relative to the Reference Point.

Definition		Geometric Centroid
Reference Point Coordinates	y	0.0mm
	z	0.0mm

Ultimate Charts

N/M Coordinates

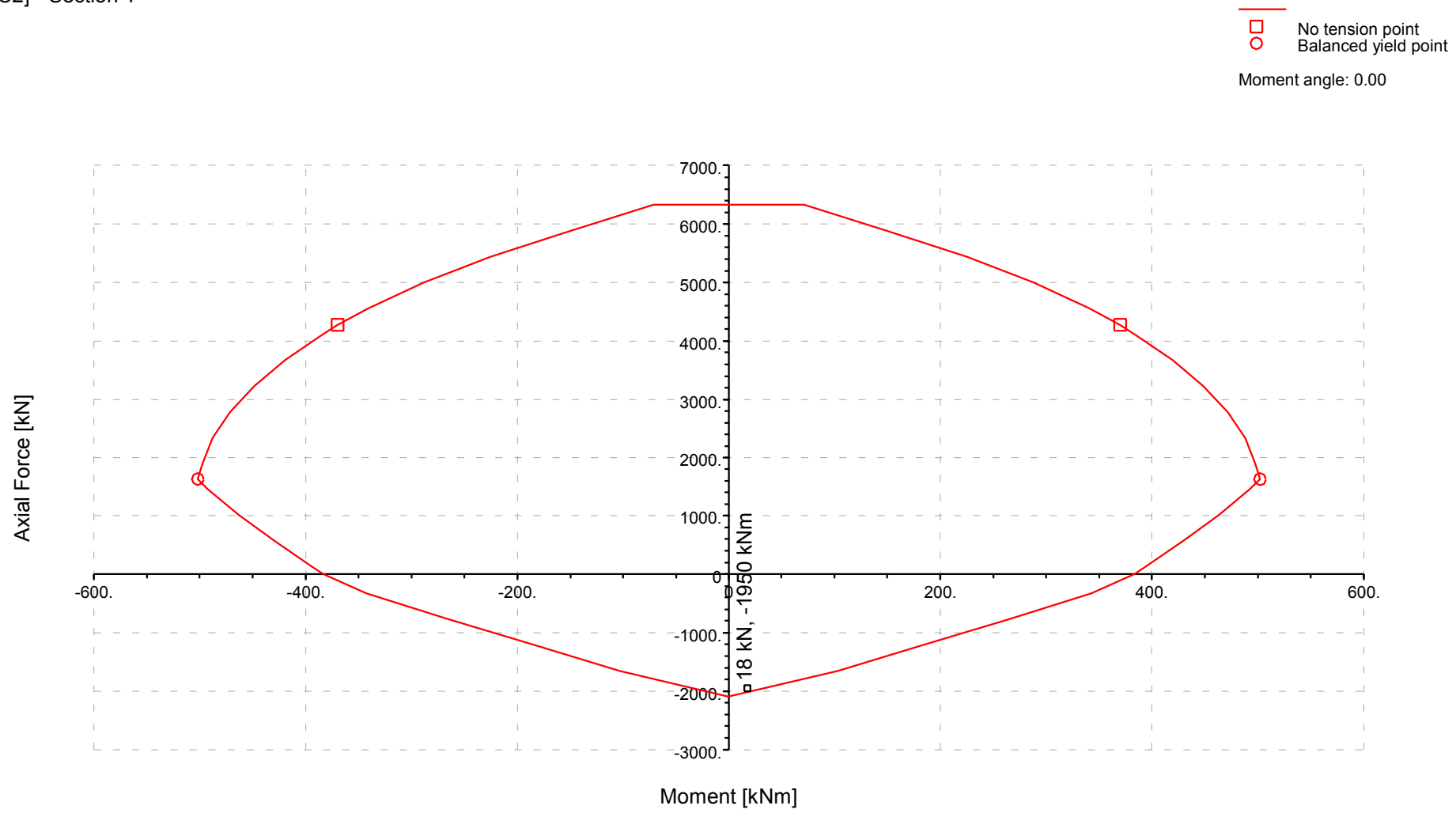
N/M [EC2] - Section 1

Moment angle: 0.00

	M [kNm]	N [kN]	Notes
1	-497.2	1898.	
2	-502.0	1622.	Balanced yield point
3	-492.3	1453.	
4	-462.9	1010.	
5	-429.3	565.9	
6	-393.5	122.3	
7	-383.5	0.1444	
8	-342.6	-321.4	
9	-266.0	-764.6	
10	-185.0	-1208.	
11	-102.9	-1652.	
12	-0.7028	-2096.	
13	102.9	-1652.	
14	185.0	-1208.	
15	266.0	-764.8	
16	342.6	-321.3	
17	383.5	0.1308	
18	393.5	122.3	
19	429.3	565.9	
20	462.9	1010.	
21	492.3	1453.	
22	502.0	1622.	Balanced yield point
23	497.2	1898.	

	M [kNm]	N [kN]	Notes
24	487.9	2341.	
25	471.2	2784.	
26	448.0	3228.	
27	419.4	3672.	
28	384.0	4115.	
29	369.6	4271.	No tension point
30	340.7	4559.	
31	288.1	5002.	
32	225.6	5445.	
33	148.5	5890.	
34	71.11	6333.	
35	-71.10	6333.	
36	-148.5	5890.	
37	-225.6	5445.	
38	-288.1	5002.	
39	-340.7	4559.	
40	-369.6	4271.	No tension point
41	-384.0	4115.	
42	-419.4	3672.	
43	-448.0	3228.	
44	-471.2	2784.	
45	-487.9	2341.	
46	-497.2	1898.	

N/M [EC2] - Section 1



UCL Bearing piles

General Specification

Code of Practice	EN 1992-1-1:2004 Eurocode 2
Country	United Kingdom
Bending Axes	Biaxial

Section 1 Details

Definition

Name	Section 1
Type	Concrete
Material	C30/37
Origin	Centre
Dimensions	
Diameter	600.0mm
Section Area	282700.mm^2
Reinforcement Area	3436.mm^2
Reinforcement	1.215%

Section Nodes

Node	Y [mm]	Z [mm]
1	0.0	301.3
2	67.04	293.7
3	130.7	271.4
4	187.8	235.5
5	235.5	187.8
6	271.4	130.7
7	293.7	67.04
8	301.3	-13.17E-6
9	293.7	-67.04
10	271.4	-130.7
11	235.5	-187.8
12	187.8	-235.5
13	130.7	-271.4
14	67.04	-293.7
15	-26.34E-6	-301.3
16	-67.04	-293.7
17	-130.7	-271.4
18	-187.8	-235.5
19	-235.5	-187.8
20	-271.4	-130.7
21	-293.7	-67.04
22	-301.3	3.593E-6
23	-293.7	67.04
24	-271.4	130.7
25	-235.5	187.8
26	-187.8	235.5
27	-130.7	271.4
28	-67.04	293.7

Cover and Links

Cover	75.00mm
Link Size	10.00mm
Link Material	500B

Bars

Bar	Y	Z	Diameter	Material	Type	Pre-stress Force	Pre-stress Strain	Appl. loads include/exclude pre-stress
	[mm]	[mm]	[mm]			[kN]		
1	202.5	0.0	25.00	500B - Copy	Steel			
2	126.3	158.3	25.00	500B - Copy	Steel			
3	-45.06	197.4	25.00	500B - Copy	Steel			
4	-182.4	87.86	25.00	500B - Copy	Steel			
5	-182.4	-87.86	25.00	500B - Copy	Steel			
6	-45.06	-197.4	25.00	500B - Copy	Steel			
7	126.3	-158.3	25.00	500B - Copy	Steel			

Elastic Properties

Effective properties of the section, ignoring reinforcement.

Geometric Centroid	y	0.0mm
	z	0.0mm
Area		282700.mm^2
Second Moments of Area	I_{yy}	6.362E+9mm^4
	I_{zz}	6.362E+9mm^4
	I_{yz}	0.0mm^4
Principal Second Moments of Area	I_{uu}	6.362E+9mm^4
	I_{zz}	6.362E+9mm^4
	Angle	0.0°
Shear Area Factor	k_y	0.8571
	k_z	0.8571
Torsion Constant		12.72E+9mm^4
Section Modulus	Z_y	21.21E+6mm^3
	Z_z	21.21E+6mm^3
Plastic Modulus	Z_{py}	36.00E+6mm^3
	Z_{pz}	36.00E+6mm^3
Radius of Gyration	R_y	150.0mm
	R_z	150.0mm

Properties of gross section, including reinforcement.

Geometric Centroid	y	-193.9E-9mm
	z	0.0mm
EA		9.859E+6kN
EI	EI_{yy}	220700.kNm^2
	EI_{zz}	220700.kNm^2
	EI_{yz}	0.0kNm^2
Principal EI	EI_{uu}	220700.kNm^2
	EI_{zz}	220700.kNm^2
	Angle	0.0°

Section Material Properties

Type		Concrete
Name		C30/37
Weight		Normal Weight
Density	ρ	2.400t/m^3
Cylinder Strength	f_{ck}	30000.kPa
Tensile Strength	f_{ctm}	2896.kPa
Elastic Modulus (short term)	E	32.84E+6kPa
Poisson's Ratio	ν	0.2000
Coeff. Thermal Expansion	α	10.00E-6/°C
Partial Safety Factor	$\gamma_{mc,ULS}$	1.500

Bar	Y	Z	Diameter	Material	Type	Pre-stress Force	Pre-stress Strain	Appl. loads include/exclude pre-stress
	[mm]	[mm]	[mm]			[kN]		

	$\gamma_{mc,SLS}$	1.000
Maximum Strain		0.003500[-]
Plateau Strain		0.002000[-]
ULS Compression Curve		Parabola-rect.
ULS Tension Curve		No-tension
SLS Compression Curve		Fig 3.2
SLS Tension Curve		Interpolated
Aggregate Size		20.00mm

Reinforcement Properties

Name		500B - Copy
f_y		500000.kPa
Modulus		200.0E+6kPa
Partial Safety Factor	$\gamma_{ms,ULS}$	1.150
	$\gamma_{ms,SLS}$	1.000
Maximum Strain		0.05000[-]
Stress/Strain Curve		Elastic-plastic

Loading

Reference Point

All loading acts through the Reference Point.
All strain planes are defined relative to the Reference Point.

Definition		Geometric Centroid
Reference Point Coordinates	y	0.0mm
	z	0.0mm

Ultimate Charts

N/M Coordinates

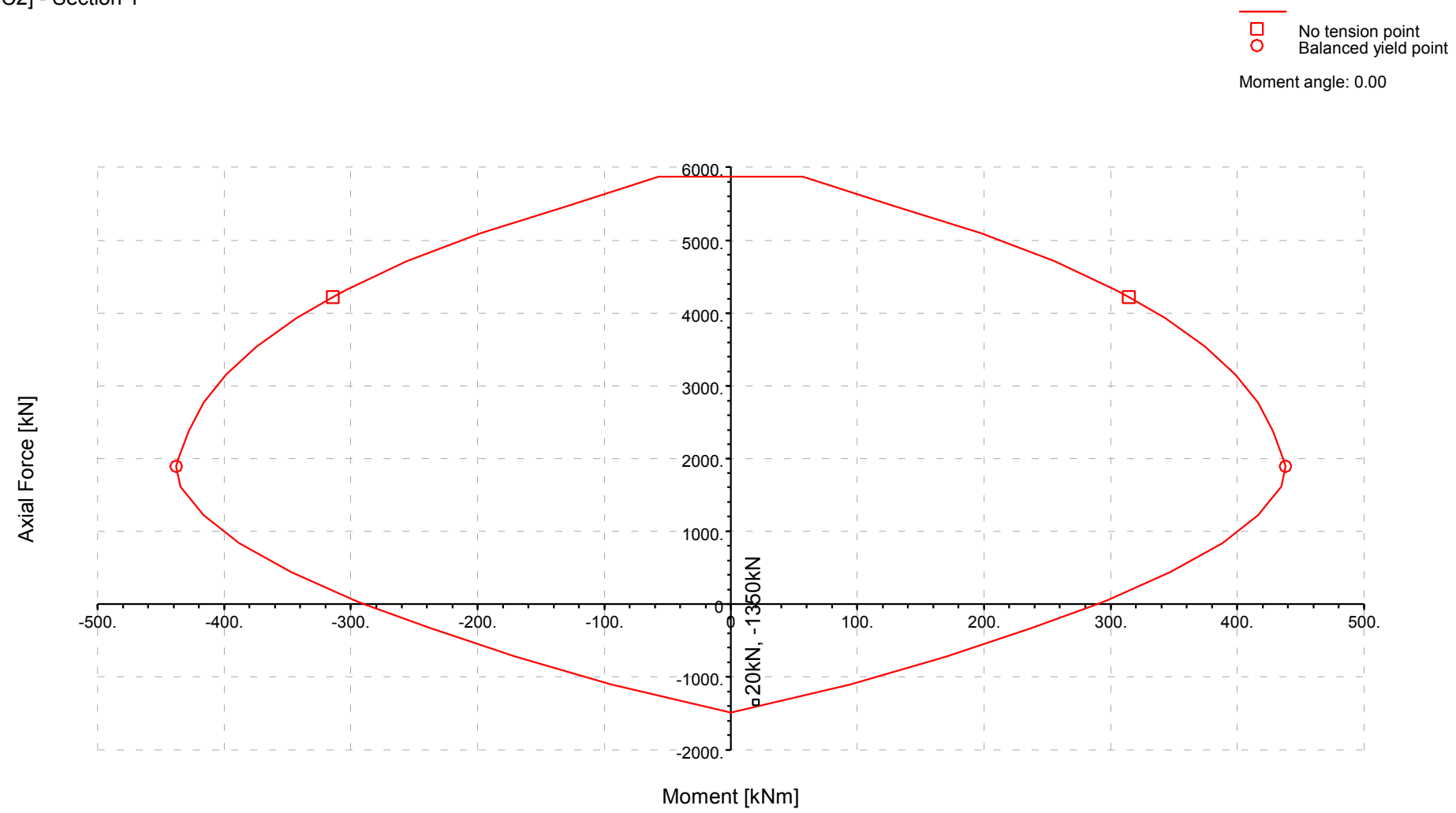
N/M [EC2] - Section 1

Moment angle: 0.00

	M [kNm]	N [kN]	Notes
1	-436.3	1995.	
2	-438.0	1891.	
3	-434.7	1608.	
4	-416.3	1220.	
5	-388.1	833.1	
6	-347.2	445.5	
7	-298.3	56.86	
8	-289.8	-0.09309	
9	-238.2	-330.6	
10	-170.5	-717.5	
11	-94.32	-1105.	
12	-0.4231	-1493.	
13	94.34	-1105.	
14	170.5	-717.5	
15	238.3	-329.6	
16	289.8	-0.1798	
17	298.5	57.67	
18	347.2	445.3	
19	388.1	832.8	
20	416.3	1220.	
21	434.7	1608.	
22	438.0	1891.	
23	436.3	1995.	

	M [kNm]	N [kN]	Notes
24	428.2	2383.	
25	416.5	2771.	
26	398.7	3158.	
27	374.3	3546.	
28	343.1	3933.	
29	314.5	4225.	
30	304.0	4321.	
31	256.2	4708.	
32	197.9	5096.	
33	127.9	5483.	
34	57.01	5871.	
35	-57.03	5871.	
36	-127.9	5483.	
37	-197.9	5096.	
38	-256.1	4709.	
39	-303.9	4321.	
40	-314.5	4225.	
41	-343.1	3933.	
42	-374.3	3546.	
43	-398.7	3158.	
44	-416.5	2770.	
45	-428.2	2383.	
46	-436.3	1995.	

N/M [EC2] - Section 1



UCL Bearing piles

General Specification

Code of Practice	EN 1992-1-1:2004 Eurocode 2
Country	United Kingdom
Bending Axes	Biaxial

Section 1 Details

Definition

Name	Section 1
Type	Concrete
Material	C30/37
Origin	Centre
Dimensions	
Diameter	900.0mm
Section Area	636200.mm^2
Reinforcement Area	3436.mm^2
Reinforcement	0.5401%

Section Nodes

Node	Y [mm]	Z [mm]
1	0.0	451.1
2	78.34	444.3
3	154.3	423.9
4	225.6	390.7
5	290.0	345.6
6	345.6	290.0
7	390.7	225.6
8	423.9	154.3
9	444.3	78.34
10	451.1	-19.72E-6
11	444.3	-78.34
12	423.9	-154.3
13	390.7	-225.6
14	345.6	-290.0
15	290.0	-345.6
16	225.6	-390.7
17	154.3	-423.9
18	78.34	-444.3
19	-39.44E-6	-451.1
20	-78.34	-444.3
21	-154.3	-423.9
22	-225.6	-390.7
23	-290.0	-345.6
24	-345.6	-290.0
25	-390.7	-225.6
26	-423.9	-154.3
27	-444.3	-78.34
28	-451.1	220.5E-6
29	-444.3	78.34
30	-423.9	154.3
31	-390.7	225.6
32	-345.6	290.0
33	-290.0	345.6
34	-225.6	390.7
35	-154.3	423.9
36	-78.34	444.3

Cover and Links

Node	Y [mm]	Z [mm]

Cover 75.00mm
Link Size 10.00mm
Link Material 500B

Bars

Bar	Y [mm]	Z [mm]	Diameter [mm]	Material	Type	Pre-stress Force [kN]	Pre-stress Strain	Appl. loads include/exclude pre-stress
1	352.5	0.0	25.00	500B	Steel			
2	219.8	275.6	25.00	500B	Steel			
3	-78.44	343.7	25.00	500B	Steel			
4	-317.6	152.9	25.00	500B	Steel			
5	-317.6	-152.9	25.00	500B	Steel			
6	-78.44	-343.7	25.00	500B	Steel			
7	219.8	-275.6	25.00	500B	Steel			

Elastic Properties

Effective properties of the section, ignoring reinforcement.

Geometric Centroid	y	0.0mm
	z	0.0mm
Area		636200.mm^2
Second Moments of Area	I_{yy}	32.21E+9mm^4
	I_{zz}	32.21E+9mm^4
	I_{yz}	0.0mm^4
Principal Second Moments of Area	I_{uu}	32.21E+9mm^4
	I_{zz}	32.21E+9mm^4
	Angle	0.0°
Shear Area Factor	k_y	0.8571
	k_z	0.8571
Torsion Constant		64.41E+9mm^4
Section Modulus	Z_y	71.57E+6mm^3
	Z_z	71.57E+6mm^3
Plastic Modulus	Z_{py}	121.5E+6mm^3
	Z_{pz}	121.5E+6mm^3
Radius of Gyration	R_y	225.0mm
	R_z	225.0mm

Properties of gross section, including reinforcement.

Geometric Centroid	y	0.0mm
	z	-356.2E-9mm
EA		21.46E+6kN
EI	EI_{yy}	1.093E+6kNm^2
	EI_{zz}	1.093E+6kNm^2
	EI_{yz}	-477.8E-6kNm^2
Principal EI	EI_{uu}	1.093E+6kNm^2
	EI_{zz}	1.093E+6kNm^2
	Angle	-45.00°

Section Material Properties

Type		Concrete
Name		C30/37
Weight		Normal Weight
Density	ρ	2.400t/m^3

Bar	Y	Z	Diameter	Material	Type	Pre-stress Force	Pre-stress Strain	Appl. loads include/exclude pre-stress
	[mm]	[mm]	[mm]			[kN]		

Cylinder Strength	f_{ck}	30000.kPa
Tensile Strength	f_{ctm}	2896.kPa
Elastic Modulus (short term)	E	32.84E+6kPa
Poisson's Ratio	ν	0.2000
Coeff. Thermal Expansion	α	10.00E-6/°C
Partial Safety Factor	$\gamma_{mc,ULS}$	1.500
	$\gamma_{mc,SLS}$	1.000
Maximum Strain		0.003500[-]
Plateau Strain		0.002000[-]
ULS Compression Curve		Parabola-rect.
ULS Tension Curve		No-tension
SLS Compression Curve		Fig 3.2
SLS Tension Curve		Interpolated
Aggregate Size		20.00mm

Reinforcement Properties

Name		500B
f_y		500000.kPa
Modulus		200.0E+6kPa
Partial Safety Factor	$\gamma_{ms,ULS}$	1.150
	$\gamma_{ms,SLS}$	1.000
Maximum Strain		0.05000[-]
Stress/Strain Curve		Elastic-plastic

Loading

Reference Point

All loading acts through the Reference Point.
All strain planes are defined relative to the Reference Point.

Definition		Geometric Centroid
Reference Point Coordinates	y	0.0mm
	z	0.0mm

Ultimate Charts

N/M Coordinates

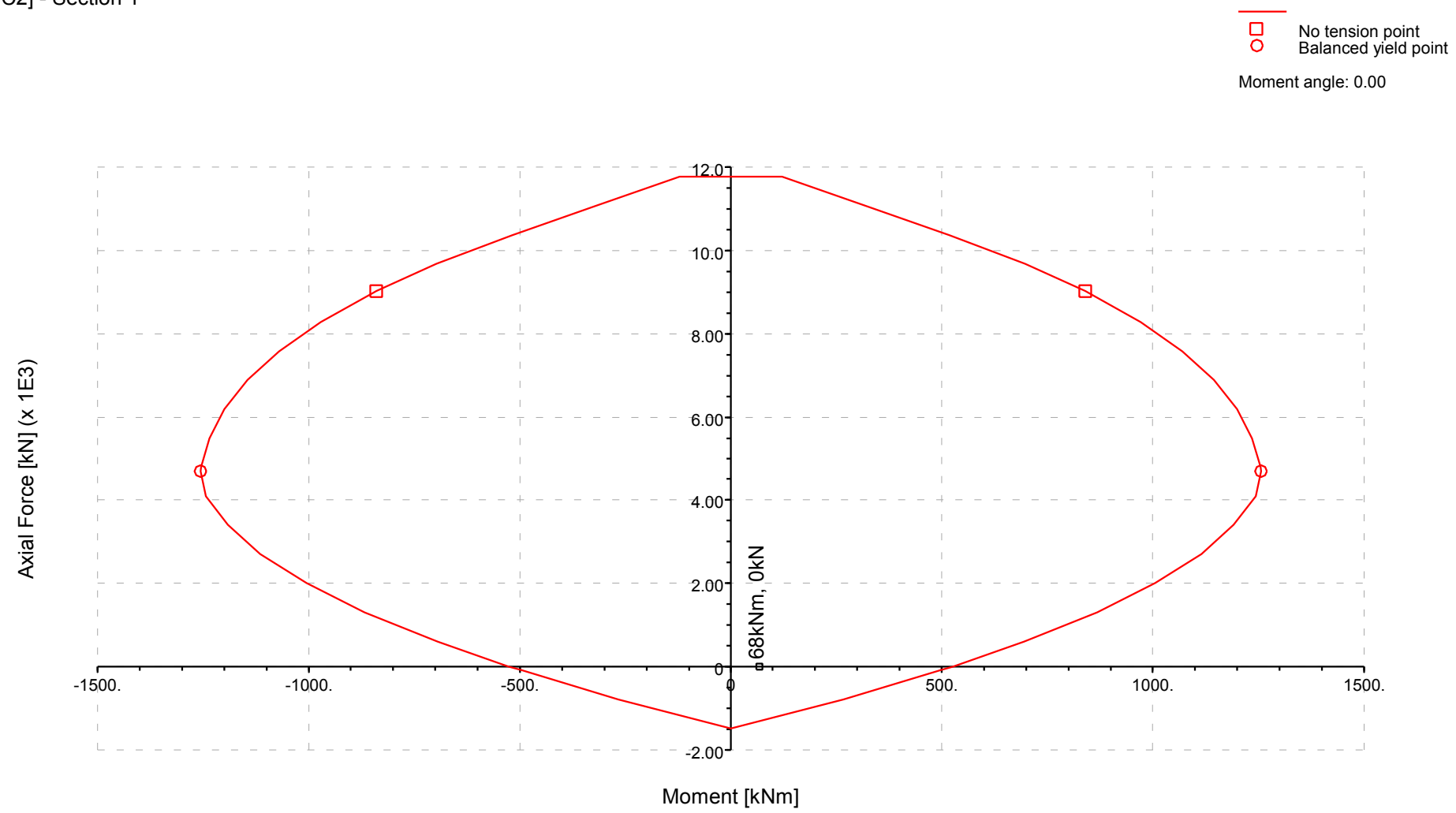
N/M [EC2] - Section 1

Moment angle: 0.00

	M [kNm]	N [kN]	Notes
1	-1255.	4796.	
2	-1256.	4694.	
3	-1243.	4096.	
4	-1191.	3397.	
5	-1115.	2699.	
6	-1005.	2000.	
7	-867.6	1300.	
8	-694.6	603.2	
9	-526.4	0.6728	
10	-496.3	-95.72	
11	-266.7	-794.7	
12	-0.6207	-1493.	
13	267.2	-793.6	
14	496.9	-93.84	
15	526.2	0.1113	

	M [kNm]	N [kN]	Notes
16	694.7	603.6	
17	868.0	1302.	
18	1005.	2000.	
19	1115.	2699.	
20	1191.	3397.	
21	1243.	4096.	
22	1256.	4694.	
23	1255.	4796.	
24	1235.	5493.	
25	1200.	6191.	
26	1145.	6890.	
27	1070.	7590.	
28	971.4	8287.	
29	848.9	8985.	
30	839.4	9033.	
31	697.8	9684.	
32	518.5	10380.	
33	321.0	11080.	
34	122.5	11780.	
35	-122.6	11780.	
36	-321.0	11080.	
37	-518.5	10380.	
38	-697.8	9684.	
39	-839.4	9033.	
40	-848.9	8985.	
41	-971.3	8288.	
42	-1070.	7588.	
43	-1145.	6890.	
44	-1200.	6191.	
45	-1235.	5493.	
46	-1255.	4796.	

N/M [EC2] - Section 1



UCL Bearing piles

General Specification

Code of Practice	EN 1992-1-1:2004 Eurocode 2
Country	United Kingdom
Bending Axes	Biaxial

Section 1 Details

Definition

Name	Section 1
Type	Concrete
Material	C30/37
Origin	Centre
Dimensions	
Diameter	600.0mm
Section Area	282700.mm^2
Reinforcement Area	2945.mm^2
Reinforcement	1.042%

Section Nodes

Node	Y [mm]	Z [mm]
1	0.0	301.3
2	67.04	293.7
3	130.7	271.4
4	187.8	235.5
5	235.5	187.8
6	271.4	130.7
7	293.7	67.04
8	301.3	-13.17E-6
9	293.7	-67.04
10	271.4	-130.7
11	235.5	-187.8
12	187.8	-235.5
13	130.7	-271.4
14	67.04	-293.7
15	-26.34E-6	-301.3
16	-67.04	-293.7
17	-130.7	-271.4
18	-187.8	-235.5
19	-235.5	-187.8
20	-271.4	-130.7
21	-293.7	-67.04
22	-301.3	3.593E-6
23	-293.7	67.04
24	-271.4	130.7
25	-235.5	187.8
26	-187.8	235.5
27	-130.7	271.4
28	-67.04	293.7

Cover and Links

Cover	75.00mm
Link Size	10.00mm
Link Material	500B

Bars

Bar	Y	Z	Diameter	Material	Type	Pre-stress Force	Pre-stress Strain	Appl. loads include/exclude pre-stress
	[mm]	[mm]	[mm]			[kN]		
1	202.5	0.0	25.00	500B	Steel			
2	101.3	175.4	25.00	500B	Steel			
3	-101.3	175.4	25.00	500B	Steel			
4	-202.5	4.086E-6	25.00	500B	Steel			
5	-101.3	-175.4	25.00	500B	Steel			
6	101.3	-175.4	25.00	500B	Steel			

Elastic Properties

Effective properties of the section, ignoring reinforcement.

Geometric Centroid	y	0.0mm
	z	0.0mm
Area		282700.mm^2
Second Moments of Area	I_{yy}	6.362E+9mm^4
	I_{zz}	6.362E+9mm^4
	I_{yz}	0.0mm^4
Principal Second Moments of Area	I_{uu}	6.362E+9mm^4
	I_{zz}	6.362E+9mm^4
	Angle	0.0°
Shear Area Factor	k_y	0.8571
	k_z	0.8571
Torsion Constant		12.72E+9mm^4
Section Modulus	Z_y	21.21E+6mm^3
	Z_z	21.21E+6mm^3
Plastic Modulus	Z_{py}	36.00E+6mm^3
	Z_{pz}	36.00E+6mm^3
Radius of Gyration	R_y	150.0mm
	R_z	150.0mm

Properties of gross section, including reinforcement.

Geometric Centroid	y	195.5E-9mm
	z	0.0mm
EA		9.777E+6kN
EI	EI_{yy}	219000.kNm^2
	EI_{zz}	219000.kNm^2
	EI_{yz}	-119.5E-6kNm^2
Principal EI	EI_{uu}	219000.kNm^2
	EI_{zz}	219000.kNm^2
	Angle	-45.00°

Section Material Properties

Type		Concrete
Name		C30/37
Weight		Normal Weight
Density	ρ	2.400t/m^3
Cylinder Strength	f_{ck}	30000.kPa
Tensile Strength	f_{ctm}	2896.kPa
Elastic Modulus (short term)	E	32.84E+6kPa
Poisson's Ratio	ν	0.2000
Coeff. Thermal Expansion	α	10.00E-6/°C
Partial Safety Factor	$\gamma_{mc,ULS}$	1.500

Bar	Y	Z	Diameter	Material	Type	Pre-stress Force	Pre-stress Strain	Appl. loads include/exclude pre-stress
	[mm]	[mm]	[mm]			[kN]		

	$\gamma_{mc,SLS}$	1.000
Maximum Strain		0.003500[-]
Plateau Strain		0.002000[-]
ULS Compression Curve		Parabola-rect.
ULS Tension Curve		No-tension
SLS Compression Curve		Fig 3.2
SLS Tension Curve		Interpolated
Aggregate Size		20.00mm

Reinforcement Properties

Name		500B
f_y		500000.kPa
Modulus		200.0E+6kPa
Partial Safety Factor	$\gamma_{ms,ULS}$	1.150
	$\gamma_{ms,SLS}$	1.000
Maximum Strain		0.05000[-]
Stress/Strain Curve		Elastic-plastic

Loading

Reference Point

All loading acts through the Reference Point.
All strain planes are defined relative to the Reference Point.

Definition		Geometric Centroid
Reference Point Coordinates	y	0.0mm
	z	0.0mm

Ultimate Charts

N/M Coordinates

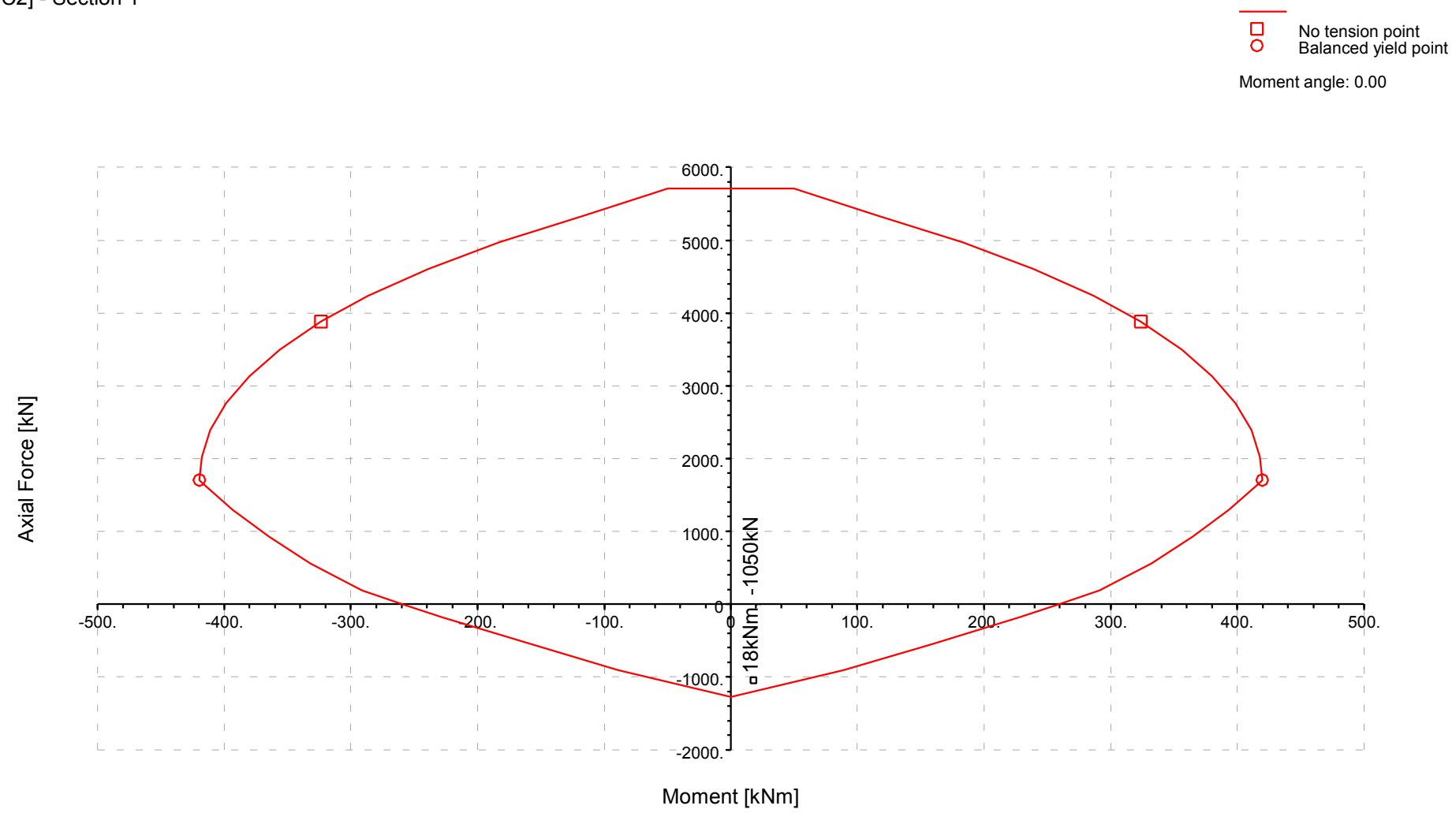
N/M [EC2] - Section 1

Moment angle: 0.00

	M [kNm]	N [kN]	Notes
1	-417.6	2030.	
2	-419.4	1702.	Balanced yield point
3	-417.3	1663.	
4	-393.5	1295.	
5	-364.5	927.0	
6	-332.1	559.4	
7	-291.4	191.6	
8	-259.6	0.4447	
9	-228.4	-176.1	
10	-159.7	-543.6	
11	-89.12	-911.5	
12	-0.4113	-1279.	
13	0.3911	-1279.	
14	89.11	-911.6	
15	159.7	-543.8	
16	228.5	-175.9	
17	259.6	0.1289	
18	291.4	191.6	
19	332.1	559.3	
20	364.5	927.0	
21	393.5	1295.	
22	417.3	1663.	
23	419.4	1702.	Balanced yield point

	M [kNm]	N [kN]	Notes
24	417.6	2030.	
25	411.2	2398.	
26	398.3	2766.	
27	380.3	3133.	
28	356.2	3501.	
29	325.2	3869.	
30	323.7	3885.	No tension point
31	286.5	4237.	
32	239.2	4604.	
33	183.2	4972.	
34	116.1	5340.	
35	50.20	5707.	
36	-50.20	5707.	
37	-116.1	5340.	
38	-183.2	4972.	
39	-239.2	4604.	
40	-286.5	4237.	
41	-323.7	3885.	No tension point
42	-325.2	3869.	
43	-356.2	3501.	
44	-380.3	3133.	
45	-398.3	2766.	
46	-411.2	2398.	
47	-417.6	2030.	

N/M [EC2] - Section 1



UCL Bearing piles

General Specification

Code of Practice	EN 1992-1-1:2004 Eurocode 2
Country	United Kingdom
Bending Axes	Biaxial

Loading

Reference Point

All loading acts through the Reference Point.
All strain planes are defined relative to the Reference Point.

Definition		Geometric Centroid
Reference Point Coordinates	y	0.0mm
	z	0.0mm

Ultimate Charts

N/M Coordinates

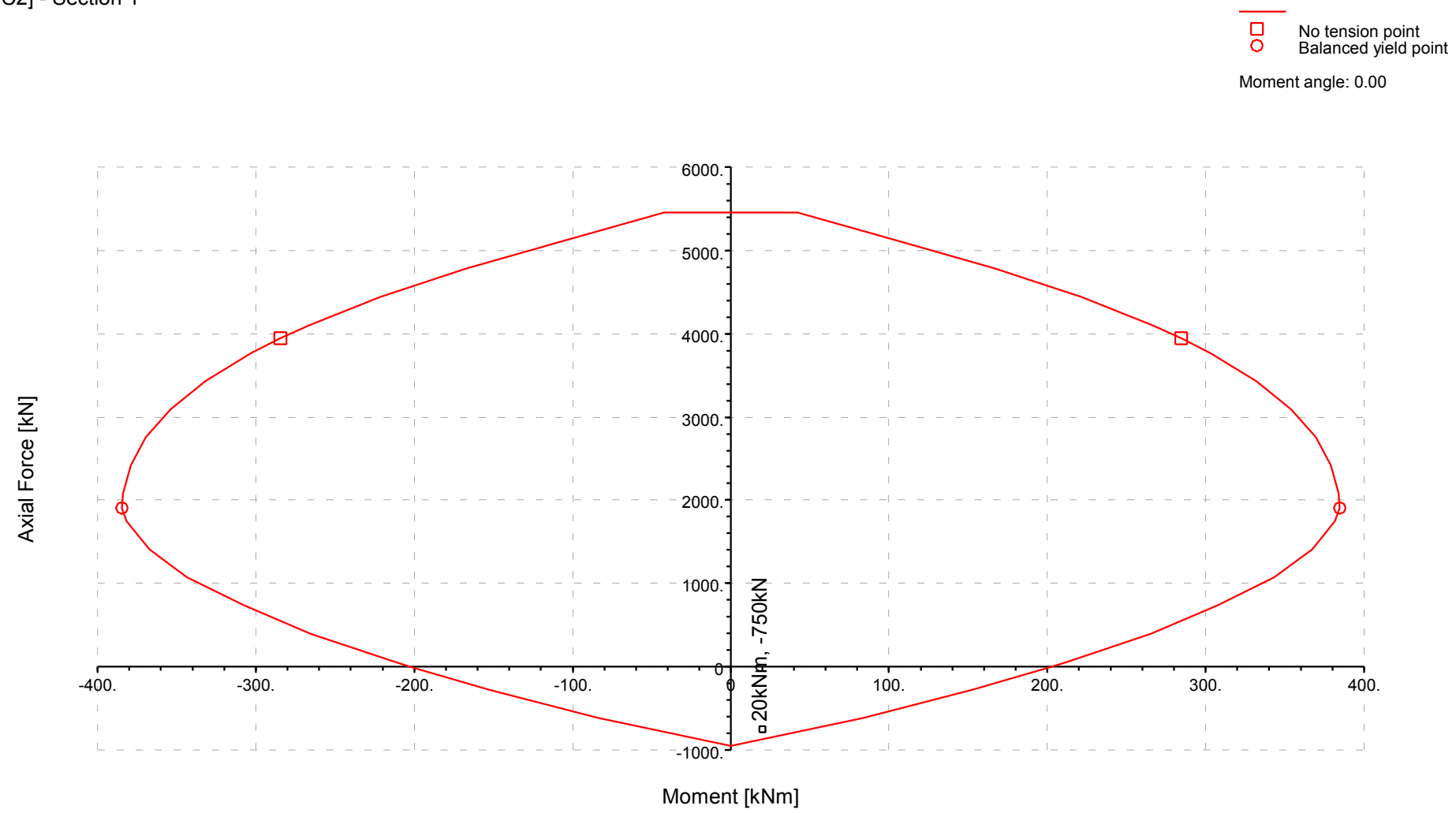
N/M [EC2] - Section 1

Moment angle: 0.00

	M [kNm]	N [kN]	Notes
1	-383.7	2084.	
2	-384.7	1904.	
3	-381.6	1746.	
4	-367.2	1408.	
5	-343.5	1070.	
6	-307.7	732.8	
7	-265.5	395.1	
8	-212.5	57.53	
9	-203.0	-0.08033	
10	-152.5	-279.8	
11	-84.01	-618.1	
12	-0.3594	-954.9	
13	84.11	-617.7	
14	152.5	-280.0	
15	203.0	0.005694	
16	212.5	57.68	
17	265.5	395.2	
18	307.7	732.8	
19	343.4	1070.	
20	367.2	1408.	
21	381.6	1746.	
22	384.7	1904.	
23	383.7	2084.	
24	379.1	2420.	
25	369.6	2758.	
26	353.8	3096.	
27	331.8	3434.	
28	302.8	3771.	
29	284.6	3949.	
30	266.2	4109.	
31	221.7	4446.	

	M [kNm]	N [kN]	Notes
32	167.2	4784.	
33	105.0	5121.	
34	42.41	5459.	
35	-42.40	5459.	
36	-105.0	5121.	
37	-167.2	4784.	
38	-221.7	4446.	
39	-266.2	4109.	
40	-284.6	3949.	
41	-302.8	3771.	
42	-331.8	3433.	
43	-353.8	3096.	
44	-369.6	2758.	
45	-379.1	2421.	
46	-383.7	2084.	

N/M [EC2] - Section 1



Keltbray Piling

Shear reinforcement

keltbray Piling

PROJECT: P230 UCL	keltbray Piling				
TITLE or DESCRIPTION: **BEARING PILES 600mm**	ORIG by	Date	VERIF	Date	Ref. No	SHEET No
	AM	15/04/2016				of

REFERENCE | Rev:

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

Pile section

	pile dia d_{nom}	=	600	mm			
	design pile diameter	=	600	mm			
	Ac	=	282743	mm^2			
4.4.1.3(4)	cover c_{nom}	=	75	mm	k_2 =	75 mm	[NA.1 4.4.1.3 (4)]
	main bar dia	=	20	mm			
	no. main bars	=	6	no.			
	helical dia.	=	8	mm			
	d	=	425	mm	γ_c = 1.5 (This is adjusted by K_f=1.1 [2.4.2.5 (2)] to give 1.65)		
	f_{ck}	=	30	MPa	γ_c = 1.65	α_{cc} = 0.85	[NA.1 3.1.6 (1)}
	f_{yk}	=	500	MPa	γ_s = 1.15		
	Ult V_{Ed}	=	31	kN	SF factor	1.5	
	Ult V_{Ed}	=	46.5	kN			
	factored action: N_{Ed}	=	0	kN			

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 = $1+(200/d)^{1/2}$ = 1.69 <=2.0

ρ_1 = $A_{sl}/b_w d$ = 0 <=0.02

v_{min} = $0.035k^{3/2}f_{ck}^{1/2}$ = 0.4196 — σ_{cp} = N_{ed}/A_c = 0 < $0.2f_{cd}$

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

$V_{Rd,c}$ = **105** 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 = 1

tan θ = 1

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 = 383 mm

$V_{Rd,max}$ = **937 kN** — v_1 = 0.6 (1-(fck/250)) = 0.53 [6.6N]

Is $V_{Rd,c}$ > 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 = 1 > 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	**315**	mm

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

keltbray Piling

PROJECT: P230 UCL	keltbray Piling				
TITLE or DESCRIPTION: **BEARING PILES 900mm**	ORIG by	Date	VERIF	Date	Ref. No	SHEET No
	AM	15/04/2016				of

REFERENCE | Rev:

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

Pile section

pile dia d_{nom}	=	900	mm
design pile diameter	=	900	mm
Ac	=	636173	mm^2
4.4.1.3(4) cover c_{nom}	=	75	mm
main bar dia	=	25	mm
no. main bars	=	7	no.
helical dia.	=	10	mm
d	=	666	mm
f_{ck}	=	30	MPa
f_{yk}	=	500	MPa
Ult V_{Ed}	=	55	kN
Ult V_{Ed}	=	82.5	kN
factored action: N_{Ed}	=	0	kN

k_2 = 75 mm [NA.1 4.4.1.3 (4)]

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

γ_c = 1.65 α_{cc} = 0.85 [NA.1 3.1.6 (1)}

γ_s = 1.15

SF factor 1.5

6.2.2 Check requirement for shear reinforcement

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

with minimum = $(v_{min}+k_1\sigma_{cp})b_w d$

v_{min} = $0.035k^{3/2}f_{ck}^{1/2}$ 0.3692

CRd,c	=	0.18 / γc	0.11
k	=	$1+(200/d)^{1/2}$	1.55 <=2.0
ρ_1	=	$A_{sl}/b_w d$	0 <=0.02
σ_{cp}	=	N_{ed}/A_c	0 < $0.2f_{cd}$
k_1	=	0.15	[NA.1 6.2.2(1)]

$V_{Rd,c}$ = **207** 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 :-

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

$V_{Rd,max}$ = **1519 kN**

cot θ	=	2.5	
tan θ	=	0.4	
α_{cw}	=	1	[NA.1 6.2.3(3)]
z	=	0.9d	600 mm
v_1	=	0.6 (1-(fck/250)	0.53 [6.6N]

Is $V_{Rd,c} > V_{Ed}$ => **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);-

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

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

= **NA** mm

A_Φ = 78.5 mm^2

f_{ywd} = 435 MPa

Check maximum shear link spacing:-

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

Provide	**10**	mm helical at nominal pitch	**495**	mm

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

Keltbray Piling

F. Concrete Compressive Strength Check to Eurocode 2

keltbray Piling

PROJECT	UCL							
TITLE	EC2 Structural Capacity Check	Orig.	Date	Verif.	Date	Ref. No./rev.		Sheet
		AM	########					
Section						Date	11/04/2016	

Based on EC2 Design
Maximum Structural Capacity for 900 mm diameter pile

1) 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 30/37 Concrete, characteristic cylinder strength = 30 N/mm^2

Where:

α_{cc} =	0.85	
f_{ck} =	30	N/mm^2
y_C =	1.50	
k_f =	1.10	

Therefore

f_{cd} = 15.45 N/mm^2

Design Axial Resistance of 900 mm diameter pile

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

Where:

d_{nom}	855	mm^2
A_c =	574146	mm^2
f_{cd} =	15.45	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 900 mm diameter pile

A_c = 574146 mm^2

Therefore

N_{rd} = 8873 kN

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

Partial Factors on Actions - A1 set of factors

γ_g =	1.35
γ_q =	1.50

Total Action (Unfactored)

DL + LL + WL = 3900 kN

Split	70%	**Permanent**
	30%	**Variable**

Therefore

G_k	3686	kN	**Permanent**
Q_k	1755	kN	**Variable**

$F_{cd} = (G_k * \gamma_g) + (Q_k * \gamma_q)$

Therefore

F_{cd} = 5441 kN Total

Nrd > Fcd therefore no additional compression steel required

keltbray Piling

PROJECT	UCL							
TITLE	EC2 Structural Capacity Check	Orig.	Date	Verif.	Date	Ref. No./rev.		Sheet
Section						Date	11/04/2016	

Based on EC2 Design
Maximum Structural Capacity for 600 mm diameter pile

1) 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 30/37 Concrete, characteristic cylinder strength = 30 N/mm^2

Where:

α_{cc} =	0.85	
f_{ck} =	30	N/mm^2
y_C =	1.50	
k_f =	1.10	

Therefore

f_{cd} = 15.45 N/mm^2

Design Axial Resistance of 600 mm diameter pile

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

Where:

d_{nom}	570	mm^2
A_c =	255176	mm^2
f_{cd} =	15.45	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 600 mm diameter pile

A_c = 255176 mm^2

Therefore

N_{rd} = 3944 kN

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

Partial Factors on Actions - A1 set of factors

γ_g =	1.35
γ_q =	1.50

Total Action (Unfactored)

DL + LL + WL = 2200 kN

Split 70% **Permanent**
30% **Variable**

Therefore

G_k	2079	kN	**Permanent**
Q_k	990	kN	**Variable**

$F_{cd} = (G_k * \gamma_g) + (Q_k * \gamma_q)$

Therefore

F_{cd} = 3069 kN Total

Nrd > Fcd therefore no additional compression steel required

G. Settlement Analysis

keltbray Piling

LOADTEST

Cemset ®
Pile settlement analysis
Version 3.11

UCL 600mm Pile

Page:
Calc by:
Checked:
Date: 18/04/2016
Lead no:
Rev:

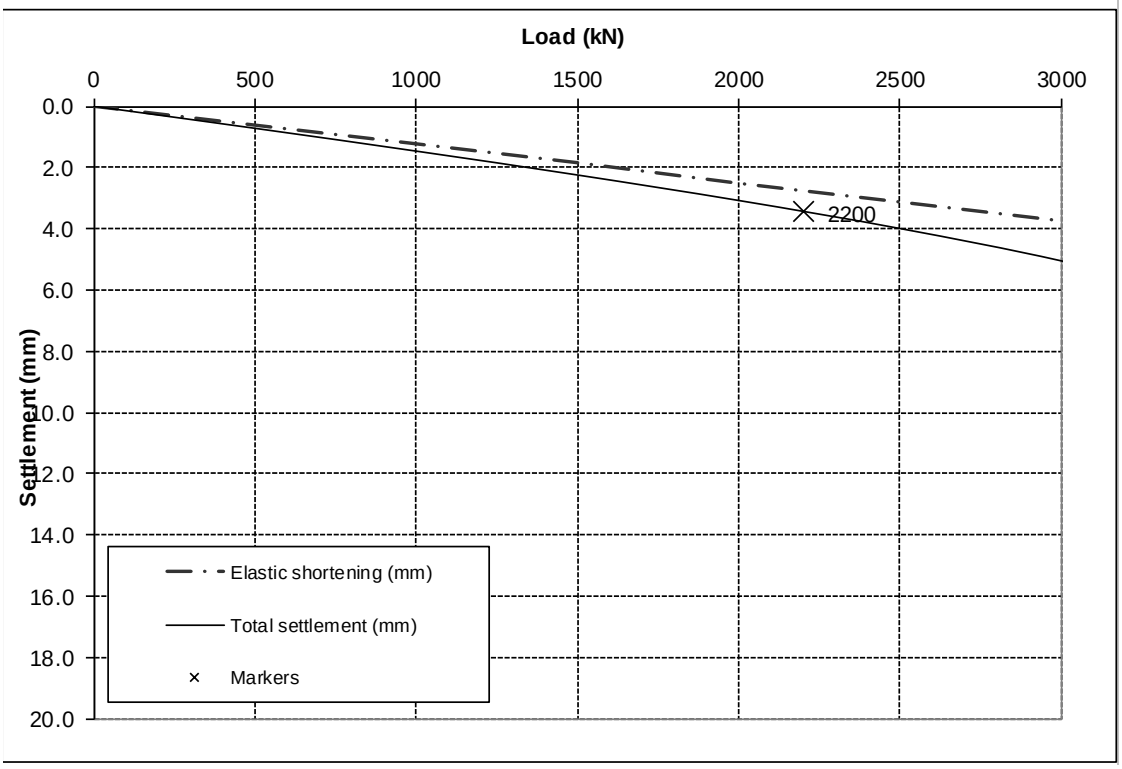
Axes, Markers | Plot Shaft | Plot Base

Input data

Pile shaft diameter	572	mm	Concrete modulus	3.00E+07	kN/m^2
Pile base diameter	572	mm	Soil elastic modulus at base	67000	kN/m^2
Shaft free length	0.0	m	Shaft flexibility factor Ms	0.0015	
Shaft friction length	21.3	m	Friction centroid Ke	0.45	
Ultimate shaft friction	4832	kN	Load Increment	500	kN
Ultimate end bearing	1008	kN	Working load (optional)		kN

Output

Load (kN)	% Ultimate capacity	Elastic shortening (mm)	Total settlement (mm)	Load (kN)	% Ultimate capacity	Elastic shortening (mm)	Total settlement (mm)
0	0.0	0.0	0.0	5500	94.2	7.9	54.9
500	8.6	0.6	0.7	6000	102.7	9.2	999.0
1000	17.1	1.2	1.5	6500	111.3	10.6	999.0
1500	25.7	1.9	2.2	7000	119.9	12.0	999.0
2000	34.2	2.5	3.1	7500	128.4	13.4	999.0
2500	42.8	3.1	4.0	8000	137.0	14.8	999.0
3000	51.4	3.7	5.0	8500	145.5	16.2	999.0
3500	59.9	4.4	6.4	9000	154.1	17.5	999.0
4000	68.5	5.0	8.2	9500	162.7	18.9	999.0
4500	77.1	5.6	11.6	10000	171.2	20.3	999.0
5000	85.6	6.5	19.8	10500	179.8	21.7	999.0



keltbray Piling

Cemset ®
Pile settlement analysis
Version 3.11

UCL 900mm Piles

Page:
Calc by:
Checked:
Date: 18/04/2016
Lead no:
Rev:

Axes, Markers | Plot Shaft | Plot Base

Input data

Pile shaft diameter	876	mm	Concrete modulus	3.00E+07	kN/m^2
Pile base diameter	876	mm	Soil elastic modulus at base	67000	kN/m^2
Shaft free length	0.7	m	Shaft flexibility factor Ms	0.0015	
Shaft friction length	29.2	m	Friction centroid Ke	0.45	
Ultimate shaft friction	7855	kN	Load Increment	500	kN
Ultimate end bearing	2293	kN	Working load (optional)		kN

Output

Load (kN)	%Ultimate capacity	Elastic shortening (mm)	Total settlement (mm)	Load (kN)	%Ultimate capacity	Elastic shortening (mm)	Total settlement (mm)
0	0.0	0.0	0.0	5500	54.2	4.2	6.9
500	4.9	0.4	0.5	6000	59.1	4.6	8.1
1000	9.9	0.8	1.0	6500	64.1	5.0	9.6
1500	14.8	1.1	1.5	7000	69.0	5.4	11.7
2000	19.7	1.5	2.0	7500	73.9	5.7	14.8
2500	24.6	1.9	2.5	8000	78.8	6.3	19.8
3000	29.6	2.3	3.1	8500	83.8	7.1	28.6
3500	34.5	2.7	3.7	9000	88.7	7.9	45.4
4000	39.4	3.1	4.3	9500	93.6	8.7	88.5
4500	44.3	3.4	5.1	10000	98.5	9.6	422.8
5000	49.3	3.8	5.9	10500	103.5	10.4	999.0