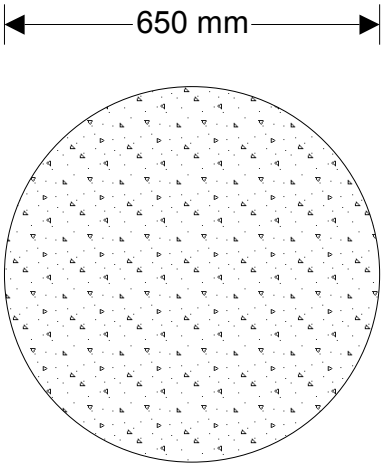
PILE ANALYSIS

In accordance with EN 1997-1:2004 incorporating Corrigendum dated February 2009 and the recommended values



Pile details

Installation method;	Drilled
Shape;	650 mm diameter
Length;	L = **5000** mm

Material details

Material;	Concrete
Concrete strength class;	C40/50
Part. factor, concrete (EN1992-1-1 cl. 2.4.2.4(1));	γ_C = **1.50**
Coefficient α_{cc} (EN1992-1-1 cl. 3.1.6(1));	α_{cc} = **1.00**
Characteristic compression cylinder strength;	f_{ck} = **40** N/mm^2
Design comp. strength (EN1992-1-1 cl. 3.1.6(1));	$f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C$ = **26.7** N/mm^2
Mean value of cyl. strength (EN1992-1-1 Table 3.1);	$f_{cm} = f_{ck}$ + 8 MPa = **48.0** N/mm^2
Secant mod. of elasticity (EN1992-1-1 Table 3.1); kN/mm^2	E_{cm} = 22000 MPa $\times$ (f_{cm} / 10 MPa)$^{0.3}$ = **35.2**
Modulus of elasticity;	E = E_{cm} = **35.2** kN/mm^2

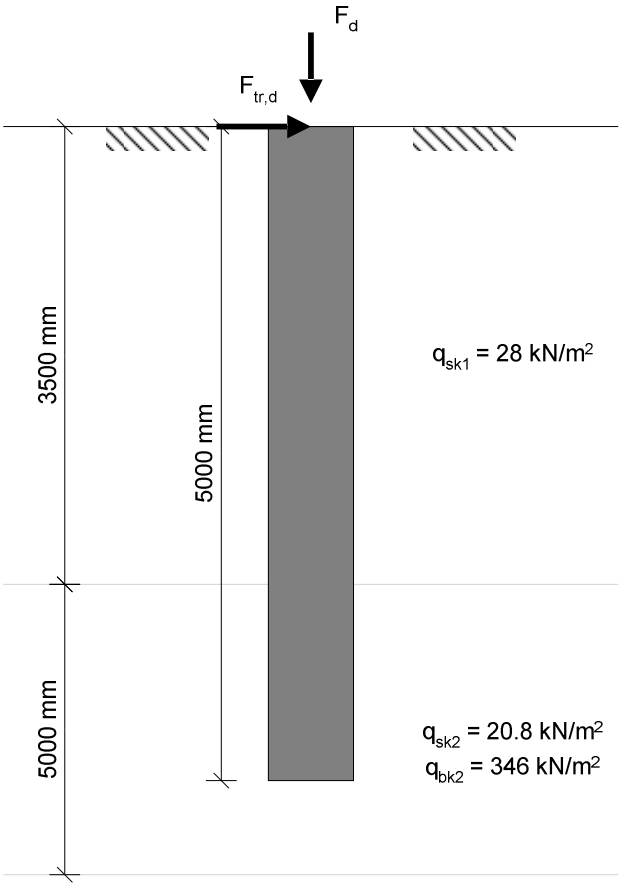
Geometric properties

Pile section depth; h = **650** mm

Bearing area; $A_{bearing} = \pi \times h^2 / 4 =$ **0.332** m^2

Pile perimeter; $Perim_{pile} = \pi \times h =$ **2.042** m

Moment of inertia; $I = \pi \times h^4 / 64 =$ **876241** cm^4



q_{ski} = Characteristic value, shaft resistance, q_{bki} = Characteristic value, base

Stratum details

Stratum	Geomaterial	Thickness, $t_{stratai}$ (mm)	Characteristic value, base, q_{bki} (kN/m^2)	Characteristic value, shaft, q_{ski} (kN/m^2)
1	Cohesionless	3500	-	28
2	Cohesive	5000	346	20.8

Action details

Characteristic perm. unfav. action, compression;	$G_{c,k,unfav}$ = **35** kN
Characteristic perm. fav. action, compression;	$G_{c,k,fav}$ = **0** kN
Characteristic variable unfav. action, compression;	$Q_{c,k}$ = **15** kN
Characteristic perm. unfav. action, tension;	$G_{t,k,unfav}$ = **0** kN
Characteristic perm. fav. action, tension;	$G_{t,k,fav}$ = **0** kN
Characteristic variable unfav. action, tension;	$Q_{t,k}$ = **0** kN
Characteristic unfavourable perm. lateral action;	$G_{tr,k,unfav}$ = **15** kN
Characteristic favourable permanent lateral action;	$G_{tr,k,fav}$ = **0** kN
Characteristic variable lateral action;	$Q_{tr,k}$ = **42** kN

Geotechnical partial and model factors:

Design approach 2:

Model factor on axial resistance;	γ_{model} = **1.40**
Permanent unfavourable, A1 (Table A.3);	$\gamma_{G,unfav,A1}$ = **1.35**
Permanent favourable, A1 (2);	$\gamma_{G,fav,A1}$ = **1.00**
Variable unfavourable, A1 (Table A.3);	$\gamma_{Q,A1}$ = **1.50**

Characteristic axial resistance

Characteristic axial base resistance;	$R_{bk} = A_{bearing} \times q_{bk}$ = **114.8** kN
Characteristic axial shaft resistance per stratum	
Stratum 1;	$R_{sk1} = q_{sk1} \times Perim_{pile} \times t_{strata1}$ =**200.1** kN
Stratum 2;	$R_{sk2} = q_{sk2} \times Perim_{pile} \times (L - D_{strata2})$ =**63.7** kN
Characteristic total axial shaft resistance;	$R_{sk} = R_{sk1} + R_{sk2}$ = **263.8** kN

Axial compressive resistance

Load combination 1: A1 + M1 + R2

Design compression action;	$F_{c,d,C1} = \gamma_{G,unfav,A1} \times G_{c,k,unfav} - \gamma_{G,fav,A1} \times G_{c,k,fav} + \gamma_{Q,A1} \times Q_{c,k}$ = **69.8** kN
Partial resistance factor, bearing (Table A.7);	$\gamma_{b,R2}$ = **1.10**
Partial resistance factor, shaft (Table A.7);	$\gamma_{s,R2}$ = **1.10**
Design compressive resistance;	$R_{c,d,C1} = (R_{bk} / \gamma_{b,R2} + R_{sk} / \gamma_{s,R2}) / \gamma_{model}$ = **245.9** kN
	$F_{c,d,C1} / R_{c,d,C1}$ = **0.284**

PASS - Design compressive resistance exceeds design load

Lateral analysis properties

Pile head fixity;	Free
Eccentricity of applied action;	e_{actual} = **0** mm
Lateral action duration;	Long-term

Lateral stratum details

Overburden pressure, $p_{ozSi} = \sum_{i=1}^{n} \gamma'_i \times t_{stratai}$

Stratum	Characteristic cohesion, $c_{i,k}$ (kN/m^2)	Characteristic friction angle, $\phi_{i,k}$ (degrees)	Characteristic unit weight of soil, $\gamma_{i,k}$ (kN/m^3)	Characteristic overburden pressure, $p_{ozSi,k}$ (kN/m^2)
1	0	22	18	63
2	0	1	21.4	170

Load combination 1: A1 + M1 + R2

Partial factors:

Angle of shearing resistance (Table A.4); $\gamma_{\phi',M1}$ = **1.00**

Effective cohesion (Table A.4); $\gamma_{c',M1}$ = **1.00**

Undrained shear strength (Table A.4); $\gamma_{cu,M1}$ = **1.00**

Weight density (Table A.4); $\gamma_{\gamma,M1}$ = **1.00**

Lateral resistance factor; $\gamma_{tr,R2}$ = **1.10**

Stratum	Design cohesion, $c_{i,d}$ (kN/m^2)	Design friction angle, $\phi_{i,d}$ (degrees)	Design unit weight of soil, $\gamma_{i,d}$ (kN/m^3)	Design overburden pressure, $p_{ozSi,d}$ (kN/m^2)
1	0	22	18	63
2	0	1	21.4	170

Resisting soil is divided into 10 segments to determine lateral resistance

From iteration, assume depth of point of rotation; X = **3053** mm

Distance from lateral action to ground; $e = e_{actual}$ = **0** mm

Segment 1 properties:

Depth to base of segment from ground; $z_{Kq1} = 1 \times L / 10$ = **500** mm

Depth to base of segment from top of stratum; $z_{Kc1} = z_{Kq1} - D_{strata1}$ = **500** mm

Depth to pile width ratio for K_q; z_{Kq1} / h = **0.8**

Depth to pile width ratio for K_c; z_{Kc1} / h = **0.8**

Effective overburden pressure; $p_{oz1} = p_{ozS0,d} + (z_{Kq1} - D_{strata1}) \times \gamma'_{1,d}$ = **9** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); K_{q1} = **3.15**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); K_{c1} = **10.05**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z1} = p_{oz1} \times K_{q1} + c'_{1,d} \times K_{c1}$ = **28.358** kN/m^2

Unit passive resistance at mid-height; $p_{z1,m} = (p_{z1} + p_{z0}) / 2$ = **14.179** kN/m^2

Segment lateral point load; $P_{LatS1} = L / 10 \times p_{z1,m} \times h$ = **4.6** kN

Segment moment about applied load; $M_{trS1} = P_{LatS1} \times (e + (1 - 0.5) \times L / 10)$ = **1.2** kNm

Segment moment about X; $M_{XS1} = P_{LatS1} \times (X - (1 - 0.5) \times L / 10)$ = **12.9** kNm

Segment 2 properties:

Depth to base of segment from ground; $z_{Kq2} = 2 \times L / 10 =$ **1000** mm

Depth to base of segment from top of stratum; $z_{Kc2} = z_{Kq2} - D_{strata1} =$ **1000** mm

Depth to pile width ratio for K_q; $z_{Kq2} / h =$ **1.5**

Depth to pile width ratio for K_c; $z_{Kc2} / h =$ **1.5**

Effective overburden pressure; $p_{oz2} = p_{ozS0,d} + (z_{Kq2} - D_{strata1}) \times \gamma'_{1,d} =$ **18** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); $K_{q2} =$ **3.56**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); $K_{c2} =$ **13.31**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z2} = p_{oz2} \times K_{q2} + c'_{1,d} \times K_{c2} =$ **64.051** kN/m^2

Unit passive resistance at mid-height; $p_{z2,m} = (p_{z2} + p_{z1}) / 2 =$ **46.205** kN/m^2

Segment lateral point load; $P_{LatS2} = L / 10 \times p_{z2,m} \times h =$ **15** kN

Segment moment about applied load; $M_{trS2} = P_{LatS2} \times (e + (2 - 0.5) \times L / 10) =$ **11.3** kNm

Segment moment about X; $M_{XS2} = P_{LatS2} \times (X - (2 - 0.5) \times L / 10) =$ **34.6** kNm

Segment 3 properties:

Depth to base of segment from ground; $z_{Kq3} = 3 \times L / 10 =$ **1500** mm

Depth to base of segment from top of stratum; $z_{Kc3} = z_{Kq3} - D_{strata1} =$ **1500** mm

Depth to pile width ratio for K_q; $z_{Kq3} / h =$ **2.3**

Depth to pile width ratio for K_c; $z_{Kc3} / h =$ **2.3**

Effective overburden pressure; $p_{oz3} = p_{ozS0,d} + (z_{Kq3} - D_{strata1}) \times \gamma'_{1,d} =$ **27** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); $K_{q3} =$ **3.89**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); $K_{c3} =$ **15.59**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z3} = p_{oz3} \times K_{q3} + c'_{1,d} \times K_{c3} =$ **105.068** kN/m^2

Unit passive resistance at mid-height; $p_{z3,m} = (p_{z3} + p_{z2}) / 2 =$ **84.559** kN/m^2

Segment lateral point load; $P_{LatS3} = L / 10 \times p_{z3,m} \times h =$ **27.5** kN

Segment moment about applied load; $M_{trS3} = P_{LatS3} \times (e + (3 - 0.5) \times L / 10) =$ **34.4** kNm

Segment moment about X; $M_{XS3} = P_{LatS3} \times (X - (3 - 0.5) \times L / 10) =$ **49.5** kNm

Segment 4 properties:

Depth to base of segment from ground; $z_{Kq4} = 4 \times L / 10 =$ **2000** mm

Depth to base of segment from top of stratum; $z_{Kc4} = z_{Kq4} - D_{strata1} =$ **2000** mm

Depth to pile width ratio for K_q; $z_{Kq4} / h =$ **3.1**

Depth to pile width ratio for K_c; $z_{Kc4} / h =$ **3.1**

Effective overburden pressure; $p_{oz4} = p_{ozS0,d} + (z_{Kq4} - D_{strata1}) \times \gamma'_{1,d} =$ **36** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); $K_{q4} =$ **4.17**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); $K_{c4} =$ **17.27**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z4} = p_{oz4} \times K_{q4} + c'_{1,d} \times K_{c4} =$ **150.073** kN/m^2

Unit passive resistance at mid-height; $p_{z4,m} = (p_{z4} + p_{z3}) / 2 =$ **127.570** kN/m^2

Segment lateral point load; $P_{LatS4} = L / 10 \times p_{z4,m} \times h =$ **41.5** kN

Segment moment about applied load; $M_{trS4} = P_{LatS4} \times (e + (4 - 0.5) \times L / 10) =$ **72.6** kNm

Segment moment about X; $M_{XS4} = P_{LatS4} \times (X - (4 - 0.5) \times L / 10) =$ **54** kNm

Segment 5 properties:

Depth to base of segment from ground; $z_{Kq5} = 5 \times L / 10 =$ **2500** mm

Depth to base of segment from top of stratum; $z_{Kc5} = z_{Kq5} - D_{strata1} =$ **2500** mm

Depth to pile width ratio for K_q; $z_{Kq5} / h =$ **3.8**

Depth to pile width ratio for K_c; $z_{Kc5} / h =$ **3.8**

Effective overburden pressure; $p_{oz5} = p_{ozS0,d} + (z_{Kq5} - D_{strata1}) \times \gamma'_{1,d} =$ **45** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); $K_{q5} =$ **4.4**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); $K_{c5} =$ **18.57**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z5} = p_{oz5} \times K_{q5} + c'_{1,d} \times K_{c5} =$ **198.142** kN/m^2

Unit passive resistance at mid-height; $p_{z5,m} = (p_{z5} + p_{z4}) / 2 =$ **174.107** kN/m^2

Segment lateral point load; $P_{LatS5} = L / 10 \times p_{z5,m} \times h =$ **56.6** kN

Segment moment about applied load; $M_{trS5} = P_{LatS5} \times (e + (5 - 0.5) \times L / 10) =$ **127.3** kNm

Segment moment about X; $M_{XS5} = P_{LatS5} \times (X - (5 - 0.5) \times L / 10) =$ **45.4** kNm

Segment 6 properties:

Depth to base of segment from ground; $z_{Kq6} = 6 \times L / 10 =$ **3000** mm

Depth to base of segment from top of stratum; $z_{Kc6} = z_{Kq6} - D_{strata1} =$ **3000** mm

Depth to pile width ratio for K_q; $z_{Kq6} / h =$ **4.6**

Depth to pile width ratio for K_c; $z_{Kc6} / h =$ **4.6**

Effective overburden pressure; $p_{oz6} = p_{ozS0,d} + (z_{Kq6} - D_{strata1}) \times \gamma'_{1,d} =$ **54** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); $K_{q6} =$ **4.6**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); $K_{c6} =$ **19.6**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z6} = p_{oz6} \times K_{q6} + c'_{1,d} \times K_{c6} =$ **248.616** kN/m^2

Unit passive resistance at mid-height; $p_{z6,m} = (p_{z6} + p_{z5}) / 2 =$ **223.379** kN/m^2

Segment lateral point load; $P_{LatS6} = L / 10 \times p_{z6,m} \times h =$ **72.6** kN

Segment moment about applied load; $M_{trS6} = P_{LatS6} \times (e + (6 - 0.5) \times L / 10) =$ **199.6** kNm

Segment moment about X; $M_{XS6} = P_{LatS6} \times (X - (6 - 0.5) \times L / 10) =$ **22** kNm

Segment 7 properties:

Depth to base of segment from ground; $z_{Kq7} = 7 \times L / 10 =$ **3500** mm

Depth to base of segment from top of stratum; $z_{Kc7} = z_{Kq7} - D_{strata1} =$ **3500** mm

Depth to pile width ratio for K_q; $z_{Kq7} / h =$ **5.4**

Depth to pile width ratio for K_c; $z_{Kc7} / h =$ **5.4**

Effective overburden pressure; $p_{oz7} = p_{ozS0,d} + (z_{Kq7} - D_{strata1}) \times \gamma'_{1,d} =$ **63** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); $K_{q7} =$ **4.78**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); $K_{c7} =$ **20.43**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z7} = p_{oz7} \times K_{q7} + c'_{1,d} \times K_{c7} =$ **301.013** kN/m^2

Unit passive resistance at mid-height; $p_{z7,m} = (p_{z7} + p_{z6}) / 2 =$ **274.814** kN/m^2

Approximate calculation applying the unit passive resistance at mid-height above and below X:

Segment (above X) lateral point load; $P_{LatS7t} = (X - 6 \times L / 10) \times h \times p_{z7,m} =$ **9.4** kN

Segment (above X) moment about applied load; $M_{trS7t} = P_{LatS7t} \times (e + X - (X - (6 \times L / 10)) / 2) =$ **28.5** kNm

Segment (above X) moment about X; $M_{XS7t} = P_{LatS7t} \times ((X - (6 \times L / 10)) / 2) =$ **0.2** kNm

Segment (below X) lateral point load; $P_{LatS7b} = -(7 \times L / 10 - X) \times h \times p_{z7,m} =$ **-79.9** kN

Segment (below X) moment about applied load; $M_{trS7b} = P_{LatS7b} \times (e + X + (7 \times L / 10 - X) / 2) =$ **-261.8** kNm

Segment (below X) moment about X; $M_{XS7b} = P_{LatS7b} \times ((X - (7 \times L / 10)) / 2) =$ **17.9** kNm

Segment 8 properties:

Depth to base of segment from ground; $z_{Kq8} = 8 \times L / 10 =$ **4000** mm

Depth to base of segment from top of stratum; $z_{Kc8} = z_{Kq8} - D_{strata2} =$ **500** mm

Depth to pile width ratio for K_q; $z_{Kq8} / h =$ **6.2**

Depth to pile width ratio for K_c; $z_{Kc8} / h =$ **0.8**

Effective overburden pressure; $p_{oz8} = p_{ozS1,d} + (z_{Kq8} - D_{strata2}) \times \gamma'_{2,d} =$ **73.7** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); $K_{q8} =$ **0.1**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); $K_{c8} =$ **4.58**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z8} = p_{oz8} \times K_{q8} + c'_{2,d} \times K_{c8} =$ **7.409** kN/m^2

Unit passive resistance at mid-height; $p_{z8,m} = (p_{z8} + p_{z7}) / 2 =$ **154.211** kN/m^2

Segment lateral point load; $P_{LatS8} = -L / 10 \times p_{z8,m} \times h =$ **-50.1** kN

Segment moment about applied load; $M_{trS8} = P_{LatS8} \times (e + (8 - 0.5) \times L / 10) =$ **-187.9** kNm

Segment moment about X; $M_{XS8} = P_{LatS8} \times (X - (8 - 0.5) \times L / 10) =$ **34.9** kNm

Segment 9 properties:

Depth to base of segment from ground; $z_{Kq9} = 9 \times L / 10 =$ **4500** mm

Depth to base of segment from top of stratum; $z_{Kc9} = z_{Kq9} - D_{strata2} =$ **1000** mm

Depth to pile width ratio for K_q; $z_{Kq9} / h =$ **6.9**

Depth to pile width ratio for K_c; $z_{Kc9} / h =$ **1.5**

Effective overburden pressure; $p_{oz9} = p_{ozS1,d} + (z_{Kq9} - D_{strata2}) \times \gamma'_{2,d} =$ **84.4** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); $K_{q9} =$ **0.1**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); $K_{c9} =$ **5.55**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z9} = p_{oz9} \times K_{q9} + c'_{2,d} \times K_{c9} =$ **8.574** kN/m^2

Unit passive resistance at mid-height; $p_{z9,m} = (p_{z9} + p_{z8}) / 2 =$ **7.991** kN/m^2

Segment lateral point load; $P_{LatS9} = -L / 10 \times p_{z9,m} \times h =$ **-2.6** kN

Segment moment about applied load; $M_{trS9} = P_{LatS9} \times (e + (9 - 0.5) \times L / 10) =$ **-11** kNm

Segment moment about X; $M_{XS9} = P_{LatS9} \times (X - (9 - 0.5) \times L / 10) =$ **3.1** kNm

Segment 10 properties:

Depth to base of segment from ground; $z_{Kq10} = 10 \times L / 10 =$ **5000** mm

Depth to base of segment from top of stratum; $z_{Kc10} = z_{Kq10} - D_{strata2} =$ **1500** mm

Depth to pile width ratio for K_q; $z_{Kq10} / h =$ **7.7**

Depth to pile width ratio for K_c; $z_{Kc10} / h =$ **2.3**

Effective overburden pressure; $p_{oz10} = p_{ozS1,d} + (z_{Kq10} - D_{strata2}) \times \gamma'_{2,d} =$ **95.1** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); K_{q10} = **0.1**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); K_{c10} = **6.14**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z10} = p_{oz10} \times K_{q10} + c'_{2,d} \times K_{c10}$ = **9.757** kN/m^2

Unit passive resistance at mid-height; $p_{z10,m} = (p_{z10} + p_{z9}) / 2$ = **9.165** kN/m^2

Segment lateral point load; $P_{LatS10} = -L / 10 \times p_{z10,m} \times h$ = **-3** kN

Segment moment about applied load; $M_{trS10} = P_{LatS10} \times (e + (10 - 0.5) \times L / 10)$ = **-14.1** kNm

Segment moment about X; $M_{XS10} = P_{LatS10} \times (X - (10 - 0.5) \times L / 10)$ = **5.1** kNm

Sum of moments about point of load application near zero;

$\Sigma M_{tr} = M_{trS1} + M_{trS2} + M_{trS3} + M_{trS4} + M_{trS5} + M_{trS6} + M_{trS7t} + M_{trS7b} + M_{trS8} + M_{trS9} + M_{trS10}$ = **-0** kNm

Sum of moments about point of rotation;

$\Sigma M_X = M_{XS1} + M_{XS2} + M_{XS3} + M_{XS4} + M_{XS5} + M_{XS6} + M_{XS7t} + M_{XS7b} + M_{XS8} + M_{XS9} + M_{XS10}$ = **279.7** kNm

Calculated soil lateral resist. (Tomlinson Eqn 7.52); $R_{tr,calc} = \Sigma M_X / (e + X)$ = **91.6** kN

Design lateral action; $F_{tr,d,C1} = \gamma_{G,unfav,A1} \times G_{tr,k,unfav} - \gamma_{G,fav,A1} \times G_{tr,k,fav} + \gamma_{Q,A1} \times Q_{tr,k}$ = **83.3** kN

Design lateral resistance; $R_{tr,d,C1} = R_{tr,calc} / \gamma_{tr,R2}$ = **83.3** kN

$F_{tr,d,C1} / R_{tr,d,C1}$ = **1**

PASS - Design lateral resistance exceeds lateral load

Lateral deflection analysis (Characteristic values)

Resisting soil is divided into 10 segments to determine lateral resistance

From iteration, assume depth of point of rotation; X = **3053** mm

Distance from lateral action to ground; $e = e_{actual}$ = **0** mm

Segment 1 properties:

Depth to base of segment from ground; z_{Kq1}= 1 × L / 10 = **500** mm

Depth to base of segment from top of stratum; $z_{Kc1} = z_{Kq1} - D_{strata1}$ = **500** mm

Depth to pile width ratio for K_q; z_{Kq1} / h = **0.8**

Depth to pile width ratio for K_c; z_{Kc1} / h = **0.8**

Effective overburden pressure; $p_{oz1} = p_{ozS0,k} + (z_{Kq1} - D_{strata1}) \times \gamma'_{1,k}$ = **9** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); K_{q1} = **3.15**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); K_{c1} = **10.05**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z1} = p_{oz1} \times K_{q1} + c'_{1,k} \times K_{c1}$ = **28.358** kN/m^2

Unit passive resistance at mid-height; $p_{z1,m} = (p_{z1} + p_{z0}) / 2$ = **14.179** kN/m^2

Segment lateral point load; $P_{LatS1} = L / 10 \times p_{z1,m} \times h$ = **4.6** kN

Segment moment about applied load; $M_{trS1} = P_{LatS1} \times (e + (1 - 0.5) \times L / 10)$ = **1.2** kNm

Segment moment about X; $M_{XS1} = P_{LatS1} \times (X - (1 - 0.5) \times L / 10)$ = **12.9** kNm

Segment 2 properties:

Depth to base of segment from ground;	$z_{Kq2} = 2 \times L / 10 =$ **1000** mm
Depth to base of segment from top of stratum;	$z_{Kc2} = z_{Kq2} - D_{strata1} =$ **1000** mm
Depth to pile width ratio for K_q;	$z_{Kq2} / h =$ **1.5**
Depth to pile width ratio for K_c;	$z_{Kc2} / h =$ **1.5**
Effective overburden pressure;	$p_{oz2} = p_{ozS0,k} + (z_{Kq2} - D_{strata1}) \times \gamma'_{1,k} =$ **18** kN/m^2
Brinch Hansen coefficient, K_q (Tomlison Fig 7.37);	$K_{q2} =$ **3.56**
Brinch Hansen coefficient, K_c (Tomlison Fig 7.37);	$K_{c2} =$ **13.31**
Unit passive resist. at base (Tomlinson Eqn 7.49);	$p_{z2} = p_{oz2} \times K_{q2} + c'_{1,k} \times K_{c2} =$ **64.051** kN/m^2
Unit passive resistance at mid-height;	$p_{z2,m} = (p_{z2} + p_{z1}) / 2 =$ **46.205** kN/m^2
Segment lateral point load;	$P_{LatS2} = L / 10 \times p_{z2,m} \times h =$ **15** kN
Segment moment about applied load;	$M_{trS2} = P_{LatS2} \times (e + (2 - 0.5) \times L / 10) =$ **11.3** kNm
Segment moment about X;	$M_{XS2} = P_{LatS2} \times (X - (2 - 0.5) \times L / 10) =$ **34.6** kNm
Segment 3 properties:	
Depth to base of segment from ground;	$z_{Kq3} = 3 \times L / 10 =$ **1500** mm
Depth to base of segment from top of stratum;	$z_{Kc3} = z_{Kq3} - D_{strata1} =$ **1500** mm
Depth to pile width ratio for K_q;	$z_{Kq3} / h =$ **2.3**
Depth to pile width ratio for K_c;	$z_{Kc3} / h =$ **2.3**
Effective overburden pressure;	$p_{oz3} = p_{ozS0,k} + (z_{Kq3} - D_{strata1}) \times \gamma'_{1,k} =$ **27** kN/m^2
Brinch Hansen coefficient, K_q (Tomlison Fig 7.37);	$K_{q3} =$ **3.89**
Brinch Hansen coefficient, K_c (Tomlison Fig 7.37);	$K_{c3} =$ **15.59**
Unit passive resist. at base (Tomlinson Eqn 7.49);	$p_{z3} = p_{oz3} \times K_{q3} + c'_{1,k} \times K_{c3} =$ **105.068** kN/m^2
Unit passive resistance at mid-height;	$p_{z3,m} = (p_{z3} + p_{z2}) / 2 =$ **84.559** kN/m^2
Segment lateral point load;	$P_{LatS3} = L / 10 \times p_{z3,m} \times h =$ **27.5** kN
Segment moment about applied load;	$M_{trS3} = P_{LatS3} \times (e + (3 - 0.5) \times L / 10) =$ **34.4** kNm
Segment moment about X;	$M_{XS3} = P_{LatS3} \times (X - (3 - 0.5) \times L / 10) =$ **49.5** kNm
Segment 4 properties:	
Depth to base of segment from ground;	$z_{Kq4} = 4 \times L / 10 =$ **2000** mm
Depth to base of segment from top of stratum;	$z_{Kc4} = z_{Kq4} - D_{strata1} =$ **2000** mm
Depth to pile width ratio for K_q;	$z_{Kq4} / h =$ **3.1**
Depth to pile width ratio for K_c;	$z_{Kc4} / h =$ **3.1**
Effective overburden pressure;	$p_{oz4} = p_{ozS0,k} + (z_{Kq4} - D_{strata1}) \times \gamma'_{1,k} =$ **36** kN/m^2
Brinch Hansen coefficient, K_q (Tomlison Fig 7.37);	$K_{q4} =$ **4.17**
Brinch Hansen coefficient, K_c (Tomlison Fig 7.37);	$K_{c4} =$ **17.27**
Unit passive resist. at base (Tomlinson Eqn 7.49);	$p_{z4} = p_{oz4} \times K_{q4} + c'_{1,k} \times K_{c4} =$ **150.073** kN/m^2
Unit passive resistance at mid-height;	$p_{z4,m} = (p_{z4} + p_{z3}) / 2 =$ **127.570** kN/m^2
Segment lateral point load;	$P_{LatS4} = L / 10 \times p_{z4,m} \times h =$ **41.5** kN
Segment moment about applied load;	$M_{trS4} = P_{LatS4} \times (e + (4 - 0.5) \times L / 10) =$ **72.6** kNm
Segment moment about X;	$M_{XS4} = P_{LatS4} \times (X - (4 - 0.5) \times L / 10) =$ **54** kNm
Segment 5 properties:	

Depth to base of segment from ground; $z_{Kq5} = 5 \times L / 10 =$ **2500** mm

Depth to base of segment from top of stratum; $z_{Kc5} = z_{Kq5} - D_{strata1} =$ **2500** mm

Depth to pile width ratio for K_q; $z_{Kq5} / h =$ **3.8**

Depth to pile width ratio for K_c; $z_{Kc5} / h =$ **3.8**

Effective overburden pressure; $p_{oz5} = p_{ozS0,k} + (z_{Kq5} - D_{strata1}) \times \gamma'_{1,k} =$ **45** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); $K_{q5} =$ **4.4**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); $K_{c5} =$ **18.57**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z5} = p_{oz5} \times K_{q5} + c'_{1,k} \times K_{c5} =$ **198.142** kN/m^2

Unit passive resistance at mid-height; $p_{z5,m} = (p_{z5} + p_{z4}) / 2 =$ **174.107** kN/m^2

Segment lateral point load; $P_{LatS5} = L / 10 \times p_{z5,m} \times h =$ **56.6** kN

Segment moment about applied load; $M_{trS5} = P_{LatS5} \times (e + (5 - 0.5) \times L / 10) =$ **127.3** kNm

Segment moment about X; $M_{XS5} = P_{LatS5} \times (X - (5 - 0.5) \times L / 10) =$ **45.4** kNm

Segment 6 properties:

Depth to base of segment from ground; $z_{Kq6} = 6 \times L / 10 =$ **3000** mm

Depth to base of segment from top of stratum; $z_{Kc6} = z_{Kq6} - D_{strata1} =$ **3000** mm

Depth to pile width ratio for K_q; $z_{Kq6} / h =$ **4.6**

Depth to pile width ratio for K_c; $z_{Kc6} / h =$ **4.6**

Effective overburden pressure; $p_{oz6} = p_{ozS0,k} + (z_{Kq6} - D_{strata1}) \times \gamma'_{1,k} =$ **54** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); $K_{q6} =$ **4.6**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); $K_{c6} =$ **19.6**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z6} = p_{oz6} \times K_{q6} + c'_{1,k} \times K_{c6} =$ **248.616** kN/m^2

Unit passive resistance at mid-height; $p_{z6,m} = (p_{z6} + p_{z5}) / 2 =$ **223.379** kN/m^2

Segment lateral point load; $P_{LatS6} = L / 10 \times p_{z6,m} \times h =$ **72.6** kN

Segment moment about applied load; $M_{trS6} = P_{LatS6} \times (e + (6 - 0.5) \times L / 10) =$ **199.6** kNm

Segment moment about X; $M_{XS6} = P_{LatS6} \times (X - (6 - 0.5) \times L / 10) =$ **22** kNm

Segment 7 properties:

Depth to base of segment from ground; $z_{Kq7} = 7 \times L / 10 =$ **3500** mm

Depth to base of segment from top of stratum; $z_{Kc7} = z_{Kq7} - D_{strata1} =$ **3500** mm

Depth to pile width ratio for K_q; $z_{Kq7} / h =$ **5.4**

Depth to pile width ratio for K_c; $z_{Kc7} / h =$ **5.4**

Effective overburden pressure; $p_{oz7} = p_{ozS0,k} + (z_{Kq7} - D_{strata1}) \times \gamma'_{1,k} =$ **63** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); $K_{q7} =$ **4.78**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); $K_{c7} =$ **20.43**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z7} = p_{oz7} \times K_{q7} + c'_{1,k} \times K_{c7} =$ **301.013** kN/m^2

Unit passive resistance at mid-height; $p_{z7,m} = (p_{z7} + p_{z6}) / 2 =$ **274.814** kN/m^2

Approximate calculation applying the unit passive resistance at mid-height above and below X:

Segment (above X) lateral point load; $P_{LatS7t} = (X - 6 \times L / 10) \times h \times p_{z7,m} =$ **9.4** kN

Segment (above X) moment about applied load; $M_{trS7t} = P_{LatS7t} \times (e + X - (X - (6 \times L / 10)) / 2) =$ **28.5** kNm

Segment (above X) moment about X; $M_{XS7t} = P_{LatS7t} \times ((X - (6 \times L / 10)) / 2) =$ **0.2** kNm

Segment (below X) lateral point load; $P_{LatS7b} = -(7 \times L / 10 - X) \times h \times p_{z7,m} =$ **-79.9** kN

Segment (below X) moment about applied load; $M_{trS7b} = P_{LatS7b} \times (e + X + (7 \times L / 10 - X) / 2) =$ **-261.8** kNm

Segment (below X) moment about X; $M_{XS7b} = P_{LatS7b} \times ((X - (7 \times L / 10)) / 2) =$ **17.9** kNm

Segment 8 properties:

Depth to base of segment from ground; $z_{Kq8} = 8 \times L / 10 =$ **4000** mm

Depth to base of segment from top of stratum; $z_{Kc8} = z_{Kq8} - D_{strata2} =$ **500** mm

Depth to pile width ratio for K_q; $z_{Kq8} / h =$ **6.2**

Depth to pile width ratio for K_c; $z_{Kc8} / h =$ **0.8**

Effective overburden pressure; $p_{oz8} = p_{ozS1,k} + (z_{Kq8} - D_{strata2}) \times \gamma'_{2,k} =$ **73.7** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); $K_{q8} =$ **0.1**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); $K_{c8} =$ **4.58**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z8} = p_{oz8} \times K_{q8} + c'_{2,k} \times K_{c8} =$ **7.409** kN/m^2

Unit passive resistance at mid-height; $p_{z8,m} = (p_{z8} + p_{z7}) / 2 =$ **154.211** kN/m^2

Segment lateral point load; $P_{LatS8} = -L / 10 \times p_{z8,m} \times h =$ **-50.1** kN

Segment moment about applied load; $M_{trS8} = P_{LatS8} \times (e + (8 - 0.5) \times L / 10) =$ **-187.9** kNm

Segment moment about X; $M_{XS8} = P_{LatS8} \times (X - (8 - 0.5) \times L / 10) =$ **34.9** kNm

Segment 9 properties:

Depth to base of segment from ground; $z_{Kq9} = 9 \times L / 10 =$ **4500** mm

Depth to base of segment from top of stratum; $z_{Kc9} = z_{Kq9} - D_{strata2} =$ **1000** mm

Depth to pile width ratio for K_q; $z_{Kq9} / h =$ **6.9**

Depth to pile width ratio for K_c; $z_{Kc9} / h =$ **1.5**

Effective overburden pressure; $p_{oz9} = p_{ozS1,k} + (z_{Kq9} - D_{strata2}) \times \gamma'_{2,k} =$ **84.4** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); $K_{q9} =$ **0.1**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); $K_{c9} =$ **5.55**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z9} = p_{oz9} \times K_{q9} + c'_{2,k} \times K_{c9} =$ **8.574** kN/m^2

Unit passive resistance at mid-height; $p_{z9,m} = (p_{z9} + p_{z8}) / 2 =$ **7.991** kN/m^2

Segment lateral point load; $P_{LatS9} = -L / 10 \times p_{z9,m} \times h =$ **-2.6** kN

Segment moment about applied load; $M_{trS9} = P_{LatS9} \times (e + (9 - 0.5) \times L / 10) =$ **-11** kNm

Segment moment about X; $M_{XS9} = P_{LatS9} \times (X - (9 - 0.5) \times L / 10) =$ **3.1** kNm

Segment 10 properties:

Depth to base of segment from ground; $z_{Kq10} = 10 \times L / 10 =$ **5000** mm

Depth to base of segment from top of stratum; $z_{Kc10} = z_{Kq10} - D_{strata2} =$ **1500** mm

Depth to pile width ratio for K_q; $z_{Kq10} / h =$ **7.7**

Depth to pile width ratio for K_c; $z_{Kc10} / h =$ **2.3**

Effective overburden pressure; $p_{oz10} = p_{ozS1,k} + (z_{Kq10} - D_{strata2}) \times \gamma'_{2,k} =$ **95.1** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); $K_{q10} =$ **0.1**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); $K_{c10} =$ **6.14**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z10} = p_{oz10} \times K_{q10} + c'_{2,k} \times K_{c10}$ = **9.757** kN/m^2

Unit passive resistance at mid-height; $p_{z10,m} = (p_{z10} + p_{z9}) / 2$ = **9.165** kN/m^2

Segment lateral point load; $P_{LatS10} = -L / 10 \times p_{z10,m} \times h$ = **-3** kN

Segment moment about applied load; $M_{trS10} = P_{LatS10} \times (e + (10 - 0.5) \times L / 10)$ = **-14.1** kNm

Segment moment about X; $M_{XS10} = P_{LatS10} \times (X - (10 - 0.5) \times L / 10)$ = **5.1** kNm

Sum of moments about point of load application near zero;

$\Sigma M_{tr} = M_{trS1} + M_{trS2} + M_{trS3} + M_{trS4} + M_{trS5} + M_{trS6} + M_{trS7t} + M_{trS7b} + M_{trS8} + M_{trS9} + M_{trS10}$ = **-0** kNm

Sum of moments about point of rotation;

$\Sigma M_X = M_{XS1} + M_{XS2} + M_{XS3} + M_{XS4} + M_{XS5} + M_{XS6} + M_{XS7t} + M_{XS7b} + M_{XS8} + M_{XS9} + M_{XS10}$ = **279.7** kNm

Calculated soil lateral resist. (Tomlinson Eqn 7.52); $R_{tr,calc} = \Sigma M_X / (e + X)$ = **91.6** kN

Lateral deflection

Characteristic lateral action; $F_{tr,k} = G_{tr,k,unfav} - G_{tr,k,fav} + Q_{tr,k}$ = **57** kN

Virtual point of fixity, from iteration; $V_{zf} = R_{tr,calc} - P_{LatS1} - P_{LatS2} - P_{LatS3} - P_{LatS4} - R \times P_{LatS5}$ = **0** kN

$z_f = (4 + R) \times L / 10$ = **2027** mm

Actual lateral deflection at top of pile; $\delta_{Lat} = (F_{tr,k} \times (e + z_f)^3) / (3 \times E \times I)$ = **0.51** mm

Allowable lateral deflection; $\delta_{LatAllow}$ = **25** mm

$\delta_{Lat} / \delta_{LatAllow}$ = **0.021**

PASS - Allowable lateral deflection exceeds actual lateral deflection

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