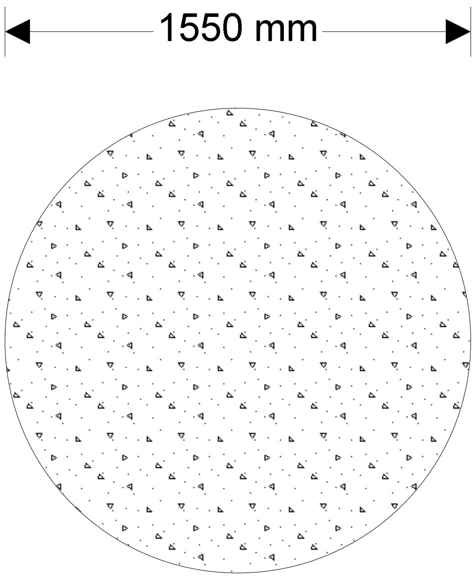
Pile Analysis

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



Pile details

Installation method; Drilled

Shape; 1550 mm diameter

Length; L = **16000** mm

Material details

Material; Concrete

Concrete strength class; C25/30

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} = **25** N/mm^2

Design comp. strength (EN1992-1-1 cl. 3.1.6(1)); $f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C$ = **16.7** N/mm^2

Mean value of cyl. strength (EN1992-1-1 Table 3.1); $f_{cm} = f_{ck} + 8$ MPa = **33.0** N/mm^2

Secant mod. of elasticity (EN1992-1-1 Table 3.1); $E_{cm} = 22000\text{ MPa} \times (f_{cm} / 10\text{ MPa})^{0.3}$ = **31.5** kN/mm^2

Modulus of elasticity; $E = E_{cm}$ = **31.5** kN/mm^2

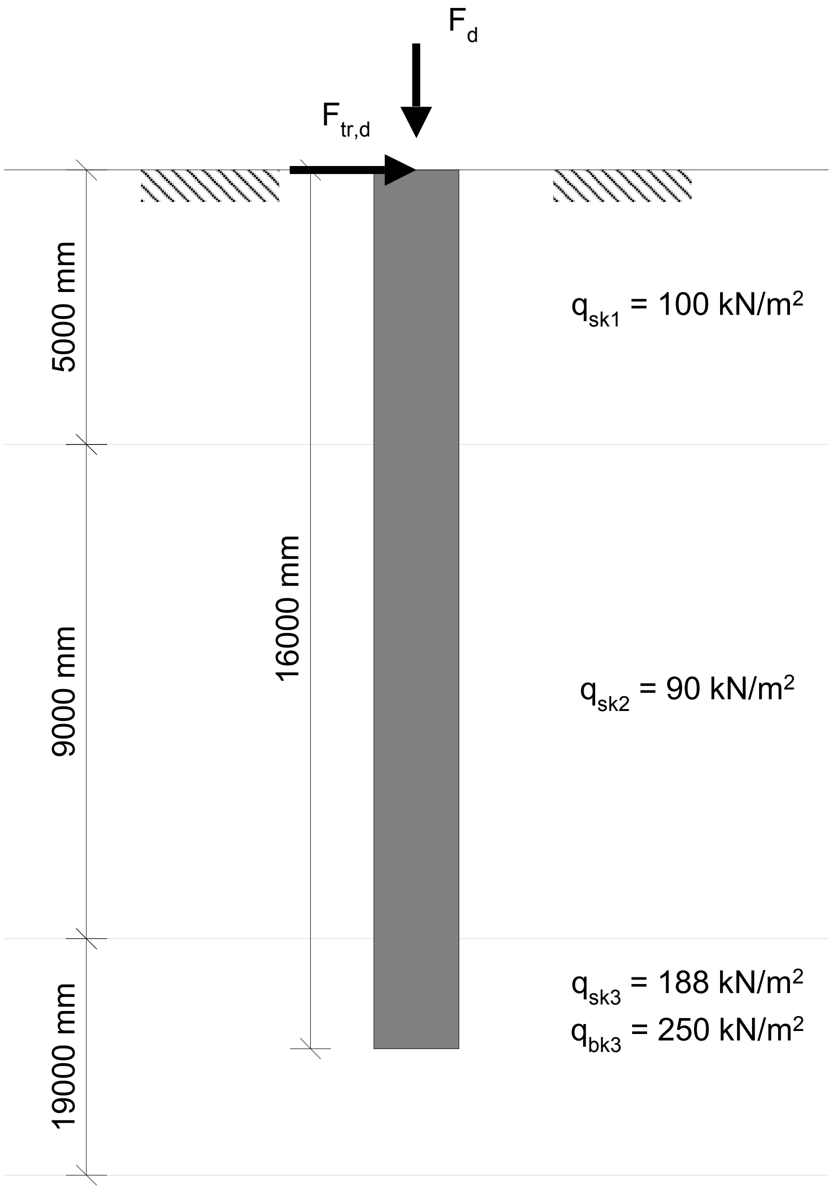
Geometric properties

Pile section depth; h = **1550** mm

Bearing area; $A_{bearing} = \pi \times h^2 / 4 =$ **1.887** m^2

Pile perimeter; $Perim_{pile} = \pi \times h =$ **4.869** m

Moment of inertia; $I = \pi \times h^4 / 64 =$ **28333269** 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	Cohesive	5000	-	100
2	Cohesionless	9000	-	90
3	Cohesive	19000	250	188

Action details

Characteristic perm. unfav. action, compression; $G_{c,k,unfav}$ = **1500** kN

Characteristic perm. fav. action, compression; $G_{c,k,fav}$ = **0** kN

Characteristic variable unfav. action, compression; $Q_{c,k}$ = **550** 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; $G_{tr,k,unfav}$ = **1000** kN

Characteristic favourable permanent lateral action; $G_{tr,k,fav}$ = **0** kN

Characteristic variable lateral action; $Q_{tr,k}$ = **200** kN

Geotechnical partial and model factors:

Design approach 1:

Model factor on axial resistance; γ_{model} = **1.00**

Permanent unfavourable, A1 (Table A.3); $\gamma_{G,unfav,A1}$ = **1.35**

Permanent favourable, A1 (1); $\gamma_{G,fav,A1}$ = **1.00**

Variable unfavourable, A1 (Table A.3); $\gamma_{Q,A1}$ = **1.50**

Permanent unfavourable, A2 (Table A.3); $\gamma_{G,unfav,A2}$ = **1.00**

Permanent favourable, A2 (Table A.3); $\gamma_{G,fav,A2}$ = **1.00**

Variable unfavourable, A2 (Table A.3); $\gamma_{Q,A2}$ = **1.30**

Characteristic axial resistance

Characteristic axial base resistance; $R_{bk} = A_{bearing} \times q_{bk}$ = **471.7** kN

Characteristic axial shaft resistance per stratum

Stratum 1; $R_{sk1} = q_{sk1} \times Perim_{pile} \times t_{strata1}$ =**2434.7** kN

Stratum 2; $R_{sk2} = q_{sk2} \times Perim_{pile} \times t_{strata2}$ =**3944.3** kN

Stratum 3; $R_{sk3} = q_{sk3} \times Perim_{pile} \times (L - D_{strata3})$ =**1830.9** kN

Characteristic total axial shaft resistance; $R_{sk} = R_{sk1} + R_{sk2} + R_{sk3}$ = **8209.9** kN

Axial compressive resistance

Load combination 1: A1 + M1 + R1

Design compression action; $F_{c,d,C1} = \gamma_{G,unfav,A1} \times G_{c,k,unfav} - \gamma_{G,fav,A1} \times G_{c,k,fav} + \gamma_{Q,A1} \times Q_{c,k}$ = **2850** kN

Partial resistance factor, bearing (Table A.7); $\gamma_{b,R1}$ = **1.25**

Partial resistance factor, shaft (Table A.7); $\gamma_{s,R1}$ = **1.00**

Design compressive resistance; $R_{c,d,C1} = (R_{bk} / \gamma_{b,R1} + R_{sk} / \gamma_{s,R1}) / \gamma_{model}$ = **8587.3** kN

$F_{c,d,C1} / R_{c,d,C1}$ = **0.332**

PASS - Design compressive resistance exceeds design load

Load combination 2: A2 + M1 + R4

Design compression action; $F_{c,d,C2} = \gamma_{G,unfav,A2} \times G_{c,k,unfav} - \gamma_{G,fav,A2} \times G_{c,k,fav} + \gamma_{Q,A2} \times Q_{c,k}$ = **2215** kN

Partial resistance factor, bearing (Table A.7); $\gamma_{b,R4}$ = **1.60**

Partial resistance factor, shaft (Table A.7); $\gamma_{s,R4}$ = **1.30**

Design compressive resistance; $R_{c,d,C2} = (R_{bk} / \gamma_{b,R4} + R_{sk} / \gamma_{s,R4}) / \gamma_{model}$ = **6610.2** kN

$F_{c,d,C2} / R_{c,d,C2}$ = **0.335**

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, $\square_{i,k}$ (degrees)	Characteristic unit weight of soil, $\square_{i,k}$ (kN/m^3)	Characteristic overburden pressure, $p_{ozSi,k}$ (kN/m^2)
1	50	10	10	50
2	0	35	12	158
3	150	12	11	367

Load combination 1: A1 + M1 + R1

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; $\gamma_{tr,R1}$ = **1.00**

Stratum	Design	Design friction	Design unit	Design

	cohesion, $c_{i,d}$ (kN/m^2)	angle, □$_{i,d}$ (degrees)	weight of soil, □$_{i,d}$ (kN/m^3)	overburden pressure, $p_{ozSi,d}$ (kN/m^2)
1	50	10	10	50
2	0	35	12	158
3	150	12	11	367

Resisting soil is divided into 10 segments to determine lateral resistance

From iteration, assume depth of point of rotation; X = **11952** mm

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

<u>Segment 1 properties:</u>

Depth to base of segment from ground; $z_{Kq1} = 1 \times L / 10$ = **1600** mm

Depth to base of segment from top of stratum; $z_{Kc1} = z_{Kq1} - D_{strata1}$ = **1600** mm

Depth to pile width ratio for K_q; z_{Kq1} / h = **1**

Depth to pile width ratio for K_c; z_{Kc1} / h = **1**

Effective overburden pressure; $p_{oz1} = p_{ozS0,d} + (z_{Kq1} - D_{strata1}) \times \gamma'_{1,d}$ = **16** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); K_{q1} = **1.11**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); K_{c1} = **6.85**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z1} = p_{oz1} \times K_{q1} + c'_{1,d} \times K_{c1}$ = **360.182** kN/m^2

Unit passive resistance at mid-height; $p_{z1,m} = (p_{z1} + p_{z0}) / 2$ = **180.091** kN/m^2

Segment lateral point load; $P_{LatS1} = L / 10 \times p_{z1,m} \times h$ = **446.6** kN

Segment moment about applied load; $M_{trS1} = P_{LatS1} \times (e + (1 - 0.5) \times L / 10)$ = **357.3** kNm

Segment moment about X; $M_{XS1} = P_{LatS1} \times (X - (1 - 0.5) \times L / 10)$ = **4980.6** kNm

<u>Segment 2 properties:</u>

Depth to base of segment from ground; $z_{Kq2} = 2 \times L / 10$ = **3200** mm

Depth to base of segment from top of stratum; $z_{Kc2} = z_{Kq2} - D_{strata1}$ = **3200** mm

Depth to pile width ratio for K_q; z_{Kq2} / h = **2.1**

Depth to pile width ratio for K_c; z_{Kc2} / h = **2.1**

Effective overburden pressure; $p_{oz2} = p_{ozS0,d} + (z_{Kq2} - D_{strata1}) \times \gamma'_{1,d}$ = **32** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); K_{q2} = **1.22**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); K_{c2} = **8.51**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z2} = p_{oz2} \times K_{q2} + c'_{1,d} \times K_{c2}$ = **464.435** kN/m^2

Unit passive resistance at mid-height; $p_{z2,m} = (p_{z2} + p_{z1}) / 2$ = **412.308** kN/m^2

Segment lateral point load; $P_{LatS2} = L / 10 \times p_{z2,m} \times h$ = **1022.5** kN

Segment moment about applied load; $M_{trS2} = P_{LatS2} \times (e + (2 - 0.5) \times L / 10)$ = **2454.1** kNm

Segment moment about X; $M_{XS2} = P_{LatS2} \times (X - (2 - 0.5) \times L / 10)$ = **9766.9** kNm

<u>Segment 3 properties:</u>

Depth to base of segment from ground; $z_{Kq3} = 3 \times L / 10$ = **4800** mm

Depth to base of segment from top of stratum; $z_{Kc3} = z_{Kq3} - D_{strata1}$ = **4800** mm

Depth to pile width ratio for K_q; z_{Kq3} / h = **3.1**

Depth to pile width ratio for K_c; z_{Kc3} / h = **3.1**

Effective overburden pressure; $p_{oz3} = p_{ozS0,d} + (z_{Kq3} - D_{strata1}) \times \gamma'_{1,d}$ = **48** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); K_{q3} = **1.3**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); K_{c3} = **9.48**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z3} = p_{oz3} \times K_{q3} + c'_{1,d} \times K_{c3}$ = **536.679** kN/m^2

Unit passive resistance at mid-height; $p_{z3,m} = (p_{z3} + p_{z2}) / 2$ = **500.557** kN/m^2

Segment lateral point load; $P_{LatS3} = L / 10 \times p_{z3,m} \times h$ = **1241.4** kN

Segment moment about applied load; $M_{trS3} = P_{LatS3} \times (e + (3 - 0.5) \times L / 10)$ = **4965.5** kNm

Segment moment about X; $M_{XS3} = P_{LatS3} \times (X - (3 - 0.5) \times L / 10)$ = **9871.1** kNm

Segment 4 properties:

Depth to base of segment from ground; $z_{Kq4} = 4 \times L / 10$ = **6400** mm

Depth to base of segment from top of stratum; $z_{Kc4} = z_{Kq4} - D_{strata2}$ = **1400** mm

Depth to pile width ratio for K_q; z_{Kq4} / h = **4.1**

Depth to pile width ratio for K_c; z_{Kc4} / h = **0.9**

Effective overburden pressure; $p_{oz4} = p_{ozS1,d} + (z_{Kq4} - D_{strata2}) \times \gamma'_{2,d}$ = **66.8** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); K_{q4} = **13.27**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); K_{c4} = **21.57**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z4} = p_{oz4} \times K_{q4} + c'_{2,d} \times K_{c4}$ = **886.587** kN/m^2

Unit passive resistance at mid-height; $p_{z4,m} = (p_{z4} + p_{z3}) / 2$ = **711.633** kN/m^2

Segment lateral point load; $P_{LatS4} = L / 10 \times p_{z4,m} \times h$ = **1764.8** kN

Segment moment about applied load; $M_{trS4} = P_{LatS4} \times (e + (4 - 0.5) \times L / 10)$ = **9883.2** kNm

Segment moment about X; $M_{XS4} = P_{LatS4} \times (X - (4 - 0.5) \times L / 10)$ = **11209.9**
kNm

Segment 5 properties:

Depth to base of segment from ground; $z_{Kq5} = 5 \times L / 10$ = **8000** mm

Depth to base of segment from top of stratum; $z_{Kc5} = z_{Kq5} - D_{strata2}$ = **3000** mm

Depth to pile width ratio for K_q; z_{Kq5} / h = **5.2**

Depth to pile width ratio for K_c; z_{Kc5} / h = **1.9**

Effective overburden pressure; $p_{oz5} = p_{ozS1,d} + (z_{Kq5} - D_{strata2}) \times \gamma'_{2,d}$ = **86** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); K_{q5} = **14.42**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); K_{c5} = **32.86**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z5} = p_{oz5} \times K_{q5} + c'_{2,d} \times K_{c5}$ = **1240.486** kN/m^2

Unit passive resistance at mid-height; $p_{z5,m} = (p_{z5} + p_{z4}) / 2$ = **1063.537** kN/m^2

Segment lateral point load; $P_{LatS5} = L / 10 \times p_{z5,m} \times h$ = **2637.6** kN

Segment moment about applied load; $M_{trS5} = P_{LatS5} \times (e + (5 - 0.5) \times L / 10)$ = **18990.5**
kNm

Segment moment about X; $M_{XS5} = P_{LatS5} \times (X - (5 - 0.5) \times L / 10)$ = **12533** kNm

Segment 6 properties:

Depth to base of segment from ground; $z_{Kq6} = 6 \times L / 10$ = **9600** mm

Depth to base of segment from top of stratum; $z_{Kc6} = z_{Kq6} - D_{strata2}$ = **4600** mm

Depth to pile width ratio for K_q; z_{Kq6} / h = **6.2**

Depth to pile width ratio for K_c; z_{Kc6} / h = **3**

Effective overburden pressure; $p_{oz6} = p_{ozS1,d} + (z_{Kq6} - D_{strata2}) \times \gamma'_{2,d}$ = **105.2** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); K_{q6} = **15.46**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); K_{c6} = **41.79**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z6} = p_{oz6} \times K_{q6} + c'_{2,d} \times K_{c6}$ = **1626.576** kN/m^2

Unit passive resistance at mid-height; $p_{z6,m} = (p_{z6} + p_{z5}) / 2$ = **1433.531** kN/m^2

Segment lateral point load; $P_{LatS6} = L / 10 \times p_{z6,m} \times h$ = **3555.2** kN

Segment moment about applied load; $M_{trS6} = P_{LatS6} \times (e + (6 - 0.5) \times L / 10)$ = **31285.4** kNm

Segment moment about X; $M_{XS6} = P_{LatS6} \times (X - (6 - 0.5) \times L / 10)$ = **11204.9** kNm

<u>Segment 7 properties:</u>

Depth to base of segment from ground; $z_{Kq7} = 7 \times L / 10$ = **11200** mm

Depth to base of segment from top of stratum; $z_{Kc7} = z_{Kq7} - D_{strata2}$ = **6200** mm

Depth to pile width ratio for K_q; z_{Kq7} / h = **7.2**

Depth to pile width ratio for K_c; z_{Kc7} / h = **4**

Effective overburden pressure; $p_{oz7} = p_{ozS1,d} + (z_{Kq7} - D_{strata2}) \times \gamma'_{2,d}$ = **124.4** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); K_{q7} = **16.4**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); K_{c7} = **49.03**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z7} = p_{oz7} \times K_{q7} + c'_{2,d} \times K_{c7}$ = **2040.284** kN/m^2

Unit passive resistance at mid-height; $p_{z7,m} = (p_{z7} + p_{z6}) / 2$ = **1833.430** kN/m^2

Segment lateral point load; $P_{LatS7} = L / 10 \times p_{z7,m} \times h$ = **4546.9** kN

Segment moment about applied load; $M_{trS7} = P_{LatS7} \times (e + (7 - 0.5) \times L / 10)$ = **47287.8** kNm

Segment moment about X; $M_{XS7} = P_{LatS7} \times (X - (7 - 0.5) \times L / 10)$ = **7055.6** kNm

<u>Segment 8 properties:</u>

Depth to base of segment from ground; $z_{Kq8} = 8 \times L / 10$ = **12800** mm

Depth to base of segment from top of stratum; $z_{Kc8} = z_{Kq8} - D_{strata2}$ = **7800** mm

Depth to pile width ratio for K_q; z_{Kq8} / h = **8.3**

Depth to pile width ratio for K_c; z_{Kc8} / h = **5**

Effective overburden pressure; $p_{oz8} = p_{ozS1,d} + (z_{Kq8} - D_{strata2}) \times \gamma'_{2,d}$ = **143.6** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); K_{q8} = **17.26**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); K_{c8} = **55.01**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z8} = p_{oz8} \times K_{q8} + c'_{2,d} \times K_{c8}$ = **2477.864** kN/m^2

Unit passive resistance at mid-height; $p_{z8,m} = (p_{z8} + p_{z7}) / 2$ = **2259.074** kN/m^2

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

Segment (above X) lateral point load; $P_{LatS8t} = (X - 7 \times L / 10) \times h \times p_{z8,m}$ = **2632.2** kN

Segment (above X) moment about applied load; $M_{trS8t} = P_{LatS8t} \times (e + X - (X - (7 \times L / 10)) / 2)$ = **30470.5** kNm

Segment (above X) moment about X; $M_{XS8t} = P_{LatS8t} \times ((X - (7 \times L / 10)) / 2)$ = **989.4** kNm

Segment (below X) lateral point load; $P_{LatS8b} = -(8 \times L / 10 - X) \times h \times p_{z8,m}$ = **-2970.3** kN

Segment (below X) moment about applied load; $M_{trS8b} = P_{LatS8b} \times (e + X + (8 \times L / 10 - X) / 2)$ = **-36759.5** kNm

Segment (below X) moment about X; $M_{XS8b} = P_{LatS8b} \times ((X - (8 \times L / 10)) / 2)$ = **1259.8** kNm

Segment 9 properties:

Depth to base of segment from ground; $z_{Kq9} = 9 \times L / 10$ = **14400** mm

Depth to base of segment from top of stratum; $z_{Kc9} = z_{Kq9} - D_{strata3}$ = **400** mm

Depth to pile width ratio for K_q; z_{Kq9} / h = **9.3**

Depth to pile width ratio for K_c; z_{Kc9} / h = **0.3**

Effective overburden pressure; $p_{oz9} = p_{ozS2,d} + (z_{Kq9} - D_{strata3}) \times \gamma'_{3,d}$ = **162.4** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); K_{q9} = **2.01**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); K_{c9} = **4.87**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z9} = p_{oz9} \times K_{q9} + c'_{3,d} \times K_{c9}$ = **1055.889** kN/m^2

Unit passive resistance at mid-height; $p_{z9,m} = (p_{z9} + p_{z8}) / 2$ = **1766.876** kN/m^2

Segment lateral point load; $P_{LatS9} = -L / 10 \times p_{z9,m} \times h$ = **-4381.9** kN

Segment moment about applied load; $M_{trS9} = P_{LatS9} \times (e + (9 - 0.5) \times L / 10)$ = **-59593.2** kNm

Segment moment about X; $M_{XS9} = P_{LatS9} \times (X - (9 - 0.5) \times L / 10)$ = **7222.5** kNm

Segment 10 properties:

Depth to base of segment from ground; $z_{Kq10} = 10 \times L / 10$ = **16000** mm

Depth to base of segment from top of stratum; $z_{Kc10} = z_{Kq10} - D_{strata3}$ = **2000** mm

Depth to pile width ratio for K_q; z_{Kq10} / h = **10.3**

Depth to pile width ratio for K_c; z_{Kc10} / h = **1.3**

Effective overburden pressure; $p_{oz10} = p_{ozS2,d} + (z_{Kq10} - D_{strata3}) \times \gamma'_{3,d}$ = **180** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); K_{q10} = **2.04**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); K_{c10} = **7.97**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z10} = p_{oz10} \times K_{q10} + c'_{3,d} \times K_{c10}$ = **1562.015** kN/m^2

Unit passive resistance at mid-height; $p_{z10,m} = (p_{z10} + p_{z9}) / 2$ = **1308.952** kN/m^2

Segment lateral point load; $P_{LatS10} = -L / 10 \times p_{z10,m} \times h$ = **-3246.2** kN

Segment moment about applied load; $M_{trS10} = P_{LatS10} \times (e + (10 - 0.5) \times L / 10)$ = **-49342.3** kNm

Segment moment about X; $M_{XS10} = P_{LatS10} \times (X - (10 - 0.5) \times L / 10)$ = **10544.5** kNm

Sum of moments about point of load application near zero;

$\Sigma M_{tr} = M_{trS1} + M_{trS2} + M_{trS3} + M_{trS4} + M_{trS5} + M_{trS6} + M_{trS7} + M_{trS8t} + M_{trS8b} + M_{trS9} + M_{trS10}$ = **-1** kNm

Sum of moments about point of rotation;

$\Sigma M_X = M_{XS1} + M_{XS2} + M_{XS3} + M_{XS4} + M_{XS5} + M_{XS6} + M_{XS7} + M_{XS8t} + M_{XS8b} + M_{XS9} + M_{XS10}$ = **86638.2** kNm

Calculated soil lateral resist. (Tomlinson Eqn 7.52); $R_{tr,calc} = \Sigma M_X / (e + X)$ = **7249** kN

Design lateral action; $F_{tr,d,C1} = \gamma_{G,unfav,A1} \times G_{tr,k,unfav} - \gamma_{G,fav,A1} \times G_{tr,k,fav} + \gamma_{Q,A1} \times Q_{tr,k}$ = **1650** kN

Design lateral resistance; $R_{tr,d,C1} = R_{tr,calc} / \gamma_{tr,R1}$ = **7249** kN

$F_{tr,d,C1} / R_{tr,d,C1}$ = **0.228**

PASS - Design lateral resistance exceeds lateral load

Load combination 2: A2 + M2 + R4

Partial factors:

Angle of shearing resistance (Table A.4); $\gamma_{\phi',M2}$ = **1.25**

Effective cohesion (Table A.4); $\gamma_{c',M2}$ = **1.25**

Undrained shear strength (Table A.4); $\gamma_{cu,M2}$ = **1.40**

Weight density (Table A.4); $\gamma_{\gamma,M2}$ = **1.00**

Lateral resistance factor; $\gamma_{tr,R4}$ = **1.00**

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	40	8	10	50
2	0	29.3	12	158
3	120	9.7	11	367

Resisting soil is divided into 10 segments to determine lateral resistance

From iteration, assume depth of point of rotation; X = **12089** mm

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

<u>Segment 1 properties:</u>

Depth to base of segment from ground; $z_{Kq1} = 1 \times L / 10$ = **1600** mm

Depth to base of segment from top of stratum; $z_{Kc1} = z_{Kq1} - D_{strata1}$ = **1600** mm

Depth to pile width ratio for K_q; z_{Kq1} / h = **1**

Depth to pile width ratio for K_c; z_{Kc1} / h = **1**

Effective overburden pressure; $p_{oz1} = p_{ozS0,d} + (z_{Kq1} - D_{strata1}) \times \gamma'_{1,d}$ = **16** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); K_{q1} = **0.85**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); K_{c1} = **6.37**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z1} = p_{oz1} \times K_{q1} + c'_{1,d} \times K_{c1}$ = **268.276** kN/m^2

Unit passive resistance at mid-height; $p_{z1,m} = (p_{z1} + p_{z0}) / 2$ = **134.138** kN/m^2

Segment lateral point load; $P_{LatS1} = L / 10 \times p_{z1,m} \times h$ = **332.7** kN

Segment moment about applied load; $M_{trS1} = P_{LatS1} \times (e + (1 - 0.5) \times L / 10)$ = **266.1** kNm

Segment moment about X; $M_{XS1} = P_{LatS1} \times (X - (1 - 0.5) \times L / 10)$ = **3755.5** kNm

<u>Segment 2 properties:</u>

Depth to base of segment from ground; $z_{Kq2} = 2 \times L / 10$ = **3200** mm

Depth to base of segment from top of stratum; $z_{Kc2} = z_{Kq2} - D_{strata1}$ = **3200** mm

Depth to pile width ratio for K_q; z_{Kq2} / h = **2.1**

Depth to pile width ratio for K_c; z_{Kc2} / h = **2.1**

Effective overburden pressure; $p_{oz2} = p_{ozS0,d} + (z_{Kq2} - D_{strata1}) \times \gamma'_{1,d}$ = **32** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37);	K_{q2} = **0.93**
Brinch Hansen coefficient, K_c (Tomlison Fig 7.37);	K_{c2} = **7.85**
Unit passive resist. at base (Tomlinson Eqn 7.49);	$p_{z2} = p_{oz2} \times K_{q2} + c'_{1,d} \times K_{c2}$ = **343.619** kN/m^2
Unit passive resistance at mid-height;	$p_{z2,m} = (p_{z2} + p_{z1}) / 2$ = **305.947** kN/m^2
Segment lateral point load;	$P_{LatS2} = L / 10 \times p_{z2,m} \times h$ = **758.7** kN
Segment moment about applied load;	$M_{trS2} = P_{LatS2} \times (e + (2 - 0.5) \times L / 10)$ = **1821** kNm
Segment moment about X;	$M_{XS2} = P_{LatS2} \times (X - (2 - 0.5)\times L / 10)$ = **7351.7** kNm

<u>Segment 3 properties:</u>

Depth to base of segment from ground;	$z_{Kq3} = 3 \times L / 10$ = **4800** mm
Depth to base of segment from top of stratum;	$z_{Kc3} = z_{Kq3} - D_{strata1}$ = **4800** mm
Depth to pile width ratio for K_q;	z_{Kq3} / h = **3.1**
Depth to pile width ratio for K_c;	z_{Kc3} / h = **3.1**
Effective overburden pressure;	$p_{oz3} = p_{ozS0,d} + (z_{Kq3} - D_{strata1}) \times \gamma'_{1,d}$ = **48** kN/m^2
Brinch Hansen coefficient, K_q (Tomlison Fig 7.37);	K_{q3} = **0.99**
Brinch Hansen coefficient, K_c (Tomlison Fig 7.37);	K_{c3} = **8.7**
Unit passive resist. at base (Tomlinson Eqn 7.49);	$p_{z3} = p_{oz3} \times K_{q3} + c'_{1,d} \times K_{c3}$ = **395.655** kN/m^2
Unit passive resistance at mid-height;	$p_{z3,m} = (p_{z3} + p_{z2}) / 2$ = **369.637** kN/m^2
Segment lateral point load;	$P_{LatS3} = L / 10 \times p_{z3,m} \times h$ = **916.7** kN
Segment moment about applied load;	$M_{trS3} = P_{LatS3} \times (e + (3 - 0.5) \times L / 10)$ = **3666.8** kNm
Segment moment about X;	$M_{XS3} = P_{LatS3} \times (X - (3 - 0.5)\times L / 10)$ = **7415.4** kNm

<u>Segment 4 properties:</u>

Depth to base of segment from ground;	$z_{Kq4} = 4 \times L / 10$ = **6400** mm
Depth to base of segment from top of stratum;	$z_{Kc4} = z_{Kq4} - D_{strata2}$ = **1400** mm
Depth to pile width ratio for K_q;	z_{Kq4} / h = **4.1**
Depth to pile width ratio for K_c;	z_{Kc4} / h = **0.9**
Effective overburden pressure;	$p_{oz4} = p_{ozS1,d} + (z_{Kq4} - D_{strata2}) \times \gamma'_{2,d}$ = **66.8** kN/m^2
Brinch Hansen coefficient, K_q (Tomlison Fig 7.37);	K_{q4} = **8.17**
Brinch Hansen coefficient, K_c (Tomlison Fig 7.37);	K_{c4} = **15.42**
Unit passive resist. at base (Tomlinson Eqn 7.49);	$p_{z4} = p_{oz4} \times K_{q4} + c'_{2,d} \times K_{c4}$ = **546.014** kN/m^2
Unit passive resistance at mid-height;	$p_{z4,m} = (p_{z4} + p_{z3}) / 2$ = **470.834** kN/m^2
Segment lateral point load;	$P_{LatS4} = L / 10 \times p_{z4,m} \times h$ = **1167.7** kN
Segment moment about applied load;	$M_{trS4} = P_{LatS4} \times (e + (4 - 0.5) \times L / 10)$ = **6538.9** kNm
Segment moment about X;	$M_{XS4} = P_{LatS4} \times (X - (4 - 0.5)\times L / 10)$ = **7577.3** kNm

<u>Segment 5 properties:</u>

Depth to base of segment from ground;	$z_{Kq5} = 5 \times L / 10$ = **8000** mm
Depth to base of segment from top of stratum;	$z_{Kc5} = z_{Kq5} - D_{strata2}$ = **3000** mm
Depth to pile width ratio for K_q;	z_{Kq5} / h = **5.2**
Depth to pile width ratio for K_c;	z_{Kc5} / h = **1.9**
Effective overburden pressure;	$p_{oz5} = p_{ozS1,d} + (z_{Kq5} - D_{strata2}) \times \gamma'_{2,d}$ = **86** kN/m^2
Brinch Hansen coefficient, K_q (Tomlison Fig 7.37);	K_{q5} = **8.76**
Brinch Hansen coefficient, K_c (Tomlison Fig 7.37);	K_{c5} = **22.24**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z5} = p_{oz5} \times K_{q5} + c'_{2,d} \times K_{c5}$ = **753.091** kN/m^2

Unit passive resistance at mid-height; $p_{z5,m} = (p_{z5} + p_{z4}) / 2$ = **649.552** kN/m^2

Segment lateral point load; $P_{LatS5} = L / 10 \times p_{z5,m} \times h$ = **1610.9** kN

Segment moment about applied load; $M_{trS5} = P_{LatS5} \times (e + (5 - 0.5) \times L / 10)$ = **11598.4** kNm

Segment moment about X; $M_{XS5} = P_{LatS5} \times (X - (5 - 0.5)\times L / 10)$ = **7876.1** kNm

<u>Segment 6 properties:</u>

Depth to base of segment from ground; $z_{Kq6} = 6 \times L / 10$ = **9600** mm

Depth to base of segment from top of stratum; $z_{Kc6} = z_{Kq6} - D_{strata2}$ = **4600** mm

Depth to pile width ratio for K_q; z_{Kq6} / h = **6.2**

Depth to pile width ratio for K_c; z_{Kc6} / h = **3**

Effective overburden pressure; $p_{oz6} = p_{ozS1,d} + (z_{Kq6} - D_{strata2}) \times \gamma'_{2,d}$ = **105.2** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); K_{q6} = **9.26**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); K_{c6} = **27.11**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z6} = p_{oz6} \times K_{q6} + c'_{2,d} \times K_{c6}$ = **974.190** kN/m^2

Unit passive resistance at mid-height; $p_{z6,m} = (p_{z6} + p_{z5}) / 2$ = **863.640** kN/m^2

Segment lateral point load; $P_{LatS6} = L / 10 \times p_{z6,m} \times h$ = **2141.8** kN

Segment moment about applied load; $M_{trS6} = P_{LatS6} \times (e + (6 - 0.5) \times L / 10)$ = **18848.1** kNm

Segment moment about X; $M_{XS6} = P_{LatS6} \times (X - (6 - 0.5)\times L / 10)$ = **7045** kNm

<u>Segment 7 properties:</u>

Depth to base of segment from ground; $z_{Kq7} = 7 \times L / 10$ = **11200** mm

Depth to base of segment from top of stratum; $z_{Kc7} = z_{Kq7} - D_{strata2}$ = **6200** mm

Depth to pile width ratio for K_q; z_{Kq7} / h = **7.2**

Depth to pile width ratio for K_c; z_{Kc7} / h = **4**

Effective overburden pressure; $p_{oz7} = p_{ozS1,d} + (z_{Kq7} - D_{strata2}) \times \gamma'_{2,d}$ = **124.4** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); K_{q7} = **9.7**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); K_{c7} = **30.76**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z7} = p_{oz7} \times K_{q7} + c'_{2,d} \times K_{c7}$ = **1206.625** kN/m^2

Unit passive resistance at mid-height; $p_{z7,m} = (p_{z7} + p_{z6}) / 2$ = **1090.408** kN/m^2

Segment lateral point load; $P_{LatS7} = L / 10 \times p_{z7,m} \times h$ = **2704.2** kN

Segment moment about applied load; $M_{trS7} = P_{LatS7} \times (e + (7 - 0.5) \times L / 10)$ = **28123.8** kNm

Segment moment about X; $M_{XS7} = P_{LatS7} \times (X - (7 - 0.5)\times L / 10)$ = **4568.1** kNm

<u>Segment 8 properties:</u>

Depth to base of segment from ground; $z_{Kq8} = 8 \times L / 10$ = **12800** mm

Depth to base of segment from top of stratum; $z_{Kc8} = z_{Kq8} - D_{strata2}$ = **7800** mm

Depth to pile width ratio for K_q; z_{Kq8} / h = **8.3**

Depth to pile width ratio for K_c; z_{Kc8} / h = **5**

Effective overburden pressure; $p_{oz8} = p_{ozS1,d} + (z_{Kq8} - D_{strata2}) \times \gamma'_{2,d}$ = **143.6** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); K_{q8} = **10.09**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); K_{c8} = **33.6**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z8} = p_{oz8} \times K_{q8} + c'_{2,d} \times K_{c8}$ = **1448.356** kN/m^2

Unit passive resistance at mid-height; $p_{z8,m} = (p_{z8} + p_{z7}) / 2$ = **1327.491** kN/m^2

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

Segment (above X) lateral point load; $P_{LatS8t} = (X - 7 \times L / 10) \times h \times p_{z8,m}$ = **1829.7** kN

Segment (above X) moment about applied load; $M_{trS8t} = P_{LatS8t} \times (e + X - (X - (7 \times L / 10)) / 2)$ = **21306.7** kNm

Segment (above X) moment about X; $M_{XS8t} = P_{LatS8t} \times ((X - (7 \times L / 10)) / 2)$ = **813.6** kNm

Segment (below X) lateral point load; $P_{LatS8b} = -(8 \times L / 10 - X) \times h \times p_{z8,m}$ = **-1462.4** kN

Segment (below X) moment about applied load; $M_{trS8b} = P_{LatS8b} \times (e + X + (8 \times L / 10 - X) / 2)$ = **-18199.4** kNm

Segment (below X) moment about X; $M_{XS8b} = P_{LatS8b} \times ((X - (8 \times L / 10)) / 2)$ = **519.7** kNm

<u>Segment 9 properties:</u>

Depth to base of segment from ground; $z_{Kq9} = 9 \times L / 10$ = **14400** mm

Depth to base of segment from top of stratum; $z_{Kc9} = z_{Kq9} - D_{strata3}$ = **400** mm

Depth to pile width ratio for K_q; z_{Kq9} / h = **9.3**

Depth to pile width ratio for K_c; z_{Kc9} / h = **0.3**

Effective overburden pressure; $p_{oz9} = p_{ozS2,d} + (z_{Kq9} - D_{strata3}) \times \gamma'_{3,d}$ = **162.4** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); K_{q9} = **1.49**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); K_{c9} = **4.51**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z9} = p_{oz9} \times K_{q9} + c'_{3,d} \times K_{c9}$ = **783.427** kN/m^2

Unit passive resistance at mid-height; $p_{z9,m} = (p_{z9} + p_{z8}) / 2$ = **1115.892** kN/m^2

Segment lateral point load; $P_{LatS9} = -L / 10 \times p_{z9,m} \times h$ = **-2767.4** kN

Segment moment about applied load; $M_{trS9} = P_{LatS9} \times (e + (9 - 0.5) \times L / 10)$ = **-37636.8** kNm

Segment moment about X; $M_{XS9} = P_{LatS9} \times (X - (9 - 0.5) \times L / 10)$ = **4180.8** kNm

<u>Segment 10 properties:</u>

Depth to base of segment from ground; $z_{Kq10} = 10 \times L / 10$ = **16000** mm

Depth to base of segment from top of stratum; $z_{Kc10} = z_{Kq10} - D_{strata3}$ = **2000** mm

Depth to pile width ratio for K_q; z_{Kq10} / h = **10.3**

Depth to pile width ratio for K_c; z_{Kc10} / h = **1.3**

Effective overburden pressure; $p_{oz10} = p_{ozS2,d} + (z_{Kq10} - D_{strata3}) \times \gamma'_{3,d}$ = **180** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); K_{q10} = **1.51**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); K_{c10} = **7.26**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z10} = p_{oz10} \times K_{q10} + c'_{3,d} \times K_{c10}$ = **1144.326** kN/m^2

Unit passive resistance at mid-height; $p_{z10,m} = (p_{z10} + p_{z9}) / 2$ = **963.877** kN/m^2

Segment lateral point load; $P_{LatS10} = -L / 10 \times p_{z10,m} \times h$ = **-2390.4** kN

Segment moment about applied load; $M_{trS10} = P_{LatS10} \times (e + (10 - 0.5) \times L / 10)$ = **-36334.3** kNm

Segment moment about X; $M_{XS10} = P_{LatS10} \times (X - (10 - 0.5) \times L / 10)$ = **7436** kNm

Sum of moments about point of load application near zero;

$\Sigma M_{tr} = M_{trS1} + M_{trS2} + M_{trS3} + M_{trS4} + M_{trS5} + M_{trS6} + M_{trS7} + M_{trS8t} + M_{trS8b} + M_{trS9} + M_{trS10}$ = **-1** kNm

Sum of moments about point of rotation; $\Sigma M_X = M_{XS1} + M_{XS2} + M_{XS3} + M_{XS4} + M_{XS5} + M_{XS6} + M_{XS7} + M_{XS8t} + M_{XS8b} + M_{XS9} + M_{XS10}$ = **58539.2** kNm

Calculated soil lateral resist. (Tomlinson Eqn 7.52); $R_{tr,calc} = \Sigma M_X / (e + X)$ = **4842.3** kN

Design lateral action; $F_{tr,d,C2} = \gamma_{G,unfav,A2} \times G_{tr,k,unfav} - \gamma_{G,fav,A2} \times G_{tr,k,fav} + \gamma_{Q,A2} \times Q_{tr,k}$ = **1260** kN

Design lateral resistance; $R_{tr,d,C2} = R_{tr,calc} / \gamma_{tr,R4}$ = **4842.3** kN

$F_{tr,d,C2} / R_{tr,d,C2}$ = **0.26**

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 = **11952** mm

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

Segment 1 properties:

Depth to base of segment from ground; $z_{Kq1} = 1 \times L / 10$ = **1600** mm

Depth to base of segment from top of stratum; $z_{Kc1} = z_{Kq1} - D_{strata1}$ = **1600** mm

Depth to pile width ratio for K_q; z_{Kq1} / h = **1**

Depth to pile width ratio for K_c; z_{Kc1} / h = **1**

Effective overburden pressure; $p_{oz1} = p_{ozS0,k} + (z_{Kq1} - D_{strata1}) \times \gamma'_{1,k}$ = **16** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); K_{q1} = **1.11**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); K_{c1} = **6.85**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z1} = p_{oz1} \times K_{q1} + c'_{1,k} \times K_{c1}$ = **360.182** kN/m^2

Unit passive resistance at mid-height; $p_{z1,m} = (p_{z1} + p_{z0}) / 2$ = **180.091** kN/m^2

Segment lateral point load; $P_{LatS1} = L / 10 \times p_{z1,m} \times h$ = **446.6** kN

Segment moment about applied load; $M_{trS1} = P_{LatS1} \times (e + (1 - 0.5) \times L / 10)$ = **357.3** kNm

Segment moment about X; $M_{XS1} = P_{LatS1} \times (X - (1 - 0.5) \times L / 10)$ = **4980.6** kNm

Segment 2 properties:

Depth to base of segment from ground; $z_{Kq2} = 2 \times L / 10$ = **3200** mm

Depth to base of segment from top of stratum; $z_{Kc2} = z_{Kq2} - D_{strata1}$ = **3200** mm

Depth to pile width ratio for K_q; z_{Kq2} / h = **2.1**

Depth to pile width ratio for K_c; z_{Kc2} / h = **2.1**

Effective overburden pressure; $p_{oz2} = p_{ozS0,k} + (z_{Kq2} - D_{strata1}) \times \gamma'_{1,k}$ = **32** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); K_{q2} = **1.22**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); K_{c2} = **8.51**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z2} = p_{oz2} \times K_{q2} + c'_{1,k} \times K_{c2}$ = **464.435** kN/m^2

Unit passive resistance at mid-height; $p_{z2,m} = (p_{z2} + p_{z1}) / 2$ = **412.308** kN/m^2

Segment lateral point load; $P_{LatS2} = L / 10 \times p_{z2,m} \times h =$ **1022.5** kN

Segment moment about applied load; $M_{trS2} = P_{LatS2} \times (e + (2 - 0.5) \times L / 10) =$ **2454.1** kNm

Segment moment about X; $M_{XS2} = P_{LatS2} \times (X - (2 - 0.5)\times L / 10) =$ **9766.9** kNm

Segment 3 properties:

Depth to base of segment from ground; $z_{Kq3}= 3 \times L / 10 =$ **4800** mm

Depth to base of segment from top of stratum; $z_{Kc3} = z_{Kq3} - D_{strata1} =$ **4800** mm

Depth to pile width ratio for K_q; $z_{Kq3} / h =$ **3.1**

Depth to pile width ratio for K_c; $z_{Kc3} / h =$ **3.1**

Effective overburden pressure; $p_{oz3} = p_{ozS0,k} + (z_{Kq3} - D_{strata1}) \times \gamma'_{1,k} =$ **48** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); $K_{q3} =$ **1.3**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); $K_{c3} =$ **9.48**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z3} = p_{oz3} \times K_{q3} + c'_{1,k} \times K_{c3} =$ **536.679** kN/m^2

Unit passive resistance at mid-height; $p_{z3,m} = (p_{z3} + p_{z2}) / 2 =$ **500.557** kN/m^2

Segment lateral point load; $P_{LatS3} = L / 10 \times p_{z3,m} \times h =$ **1241.4** kN

Segment moment about applied load; $M_{trS3} = P_{LatS3} \times (e + (3 - 0.5) \times L / 10) =$ **4965.5** kNm

Segment moment about X; $M_{XS3} = P_{LatS3} \times (X - (3 - 0.5)\times L / 10) =$ **9871.1** kNm

Segment 4 properties:

Depth to base of segment from ground; $z_{Kq4}= 4 \times L / 10 =$ **6400** mm

Depth to base of segment from top of stratum; $z_{Kc4} = z_{Kq4} - D_{strata2} =$ **1400** mm

Depth to pile width ratio for K_q; $z_{Kq4} / h =$ **4.1**

Depth to pile width ratio for K_c; $z_{Kc4} / h =$ **0.9**

Effective overburden pressure; $p_{oz4} = p_{ozS1,k} + (z_{Kq4} - D_{strata2}) \times \gamma'_{2,k} =$ **66.8** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); $K_{q4} =$ **13.27**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); $K_{c4} =$ **21.57**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z4} = p_{oz4} \times K_{q4} + c'_{2,k} \times K_{c4} =$ **886.587** kN/m^2

Unit passive resistance at mid-height; $p_{z4,m} = (p_{z4} + p_{z3}) / 2 =$ **711.633** kN/m^2

Segment lateral point load; $P_{LatS4} = L / 10 \times p_{z4,m} \times h =$ **1764.8** kN

Segment moment about applied load; $M_{trS4} = P_{LatS4} \times (e + (4 - 0.5) \times L / 10) =$ **9883.2** kNm

Segment moment about X; $M_{XS4} = P_{LatS4} \times (X - (4 - 0.5)\times L / 10) =$ **11209.9** kNm

Segment 5 properties:

Depth to base of segment from ground; $z_{Kq5}= 5 \times L / 10 =$ **8000** mm

Depth to base of segment from top of stratum; $z_{Kc5} = z_{Kq5} - D_{strata2} =$ **3000** mm

Depth to pile width ratio for K_q; $z_{Kq5} / h =$ **5.2**

Depth to pile width ratio for K_c; $z_{Kc5} / h =$ **1.9**

Effective overburden pressure; $p_{oz5} = p_{ozS1,k} + (z_{Kq5} - D_{strata2}) \times \gamma'_{2,k} =$ **86** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); $K_{q5} =$ **14.42**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); $K_{c5} =$ **32.86**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z5} = p_{oz5} \times K_{q5} + c'_{2,k} \times K_{c5} =$ **1240.486** kN/m^2

Unit passive resistance at mid-height; $p_{z5,m} = (p_{z5} + p_{z4}) / 2 =$ **1063.537** kN/m^2

Segment lateral point load; $P_{LatS5} = L / 10 \times p_{z5,m} \times h =$ **2637.6** kN

Segment moment about applied load; $M_{trS5} = P_{LatS5} \times (e + (5 - 0.5) \times L / 10)$ = **18990.5** kNm

Segment moment about X; $M_{XS5} = P_{LatS5} \times (X - (5 - 0.5) \times L / 10)$ = **12533** kNm

Segment 6 properties:

Depth to base of segment from ground; $z_{Kq6} = 6 \times L / 10$ = **9600** mm

Depth to base of segment from top of stratum; $z_{Kc6} = z_{Kq6} - D_{strata2}$ = **4600** mm

Depth to pile width ratio for K_q; z_{Kq6} / h = **6.2**

Depth to pile width ratio for K_c; z_{Kc6} / h = **3**

Effective overburden pressure; $p_{oz6} = p_{ozS1,k} + (z_{Kq6} - D_{strata2}) \times \gamma'_{2,k}$ = **105.2** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); K_{q6} = **15.46**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); K_{c6} = **41.79**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z6} = p_{oz6} \times K_{q6} + c'_{2,k} \times K_{c6}$ = **1626.576** kN/m^2

Unit passive resistance at mid-height; $p_{z6,m} = (p_{z6} + p_{z5}) / 2$ = **1433.531** kN/m^2

Segment lateral point load; $P_{LatS6} = L / 10 \times p_{z6,m} \times h$ = **3555.2** kN

Segment moment about applied load; $M_{trS6} = P_{LatS6} \times (e + (6 - 0.5) \times L / 10)$ = **31285.4** kNm

Segment moment about X; $M_{XS6} = P_{LatS6} \times (X - (6 - 0.5) \times L / 10)$ = **11204.9** kNm

Segment 7 properties:

Depth to base of segment from ground; $z_{Kq7} = 7 \times L / 10$ = **11200** mm

Depth to base of segment from top of stratum; $z_{Kc7} = z_{Kq7} - D_{strata2}$ = **6200** mm

Depth to pile width ratio for K_q; z_{Kq7} / h = **7.2**

Depth to pile width ratio for K_c; z_{Kc7} / h = **4**

Effective overburden pressure; $p_{oz7} = p_{ozS1,k} + (z_{Kq7} - D_{strata2}) \times \gamma'_{2,k}$ = **124.4** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); K_{q7} = **16.4**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); K_{c7} = **49.03**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z7} = p_{oz7} \times K_{q7} + c'_{2,k} \times K_{c7}$ = **2040.284** kN/m^2

Unit passive resistance at mid-height; $p_{z7,m} = (p_{z7} + p_{z6}) / 2$ = **1833.430** kN/m^2

Segment lateral point load; $P_{LatS7} = L / 10 \times p_{z7,m} \times h$ = **4546.9** kN

Segment moment about applied load; $M_{trS7} = P_{LatS7} \times (e + (7 - 0.5) \times L / 10)$ = **47287.8** kNm

Segment moment about X; $M_{XS7} = P_{LatS7} \times (X - (7 - 0.5) \times L / 10)$ = **7055.6** kNm

Segment 8 properties:

Depth to base of segment from ground; $z_{Kq8} = 8 \times L / 10$ = **12800** mm

Depth to base of segment from top of stratum; $z_{Kc8} = z_{Kq8} - D_{strata2}$ = **7800** mm

Depth to pile width ratio for K_q; z_{Kq8} / h = **8.3**

Depth to pile width ratio for K_c; z_{Kc8} / h = **5**

Effective overburden pressure; $p_{oz8} = p_{ozS1,k} + (z_{Kq8} - D_{strata2}) \times \gamma'_{2,k}$ = **143.6** kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); K_{q8} = **17.26**

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); K_{c8} = **55.01**

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z8} = p_{oz8} \times K_{q8} + c'_{2,k} \times K_{c8}$ = **2477.864** kN/m^2

Unit passive resistance at mid-height; $p_{z8,m} = (p_{z8} + p_{z7}) / 2 = \mathbf{2259.074}$ kN/m^2

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

Segment (above X) lateral point load; $P_{LatS8t} = (X - 7 \times L / 10) \times h \times p_{z8,m} = \mathbf{2632.2}$ kN

Segment (above X) moment about applied load; $M_{trS8t} = P_{LatS8t} \times (e + X - (X - (7 \times L / 10)) / 2) =$ **30470.5** kNm

Segment (above X) moment about X; $M_{XS8t} = P_{LatS8t} \times ((X - (7 \times L / 10)) / 2) = \mathbf{989.4}$ kNm

Segment (below X) lateral point load; $P_{LatS8b} = -(8 \times L / 10 - X) \times h \times p_{z8,m} = \mathbf{-2970.3}$ kN

Segment (below X) moment about applied load; $M_{trS8b} = P_{LatS8b} \times (e + X + (8 \times L / 10 - X) / 2) =$ **-36759.5** kNm

Segment (below X) moment about X; $M_{XS8b} = P_{LatS8b} \times ((X - (8 \times L / 10)) / 2) = \mathbf{1259.8}$ kNm

Segment 9 properties:

Depth to base of segment from ground; $z_{Kq9} = 9 \times L / 10 = \mathbf{14400}$ mm

Depth to base of segment from top of stratum; $z_{Kc9} = z_{Kq9} - D_{strata3} = \mathbf{400}$ mm

Depth to pile width ratio for K_q; $z_{Kq9} / h = \mathbf{9.3}$

Depth to pile width ratio for K_c; $z_{Kc9} / h = \mathbf{0.3}$

Effective overburden pressure; $p_{oz9} = p_{ozS2,k} + (z_{Kq9} - D_{strata3}) \times \gamma'_{3,k} = \mathbf{162.4}$ kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); $K_{q9} = \mathbf{2.01}$

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); $K_{c9} = \mathbf{4.87}$

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z9} = p_{oz9} \times K_{q9} + c'_{3,k} \times K_{c9} = \mathbf{1055.889}$ kN/m^2

Unit passive resistance at mid-height; $p_{z9,m} = (p_{z9} + p_{z8}) / 2 = \mathbf{1766.876}$ kN/m^2

Segment lateral point load; $P_{LatS9} = -L / 10 \times p_{z9,m} \times h = \mathbf{-4381.9}$ kN

Segment moment about applied load; $M_{trS9} = P_{LatS9} \times (e + (9 - 0.5) \times L / 10) = \mathbf{-59593.2}$ kNm

Segment moment about X; $M_{XS9} = P_{LatS9} \times (X - (9 - 0.5) \times L / 10) = \mathbf{7222.5}$ kNm

Segment 10 properties:

Depth to base of segment from ground; $z_{Kq10} = 10 \times L / 10 = \mathbf{16000}$ mm

Depth to base of segment from top of stratum; $z_{Kc10} = z_{Kq10} - D_{strata3} = \mathbf{2000}$ mm

Depth to pile width ratio for K_q; $z_{Kq10} / h = \mathbf{10.3}$

Depth to pile width ratio for K_c; $z_{Kc10} / h = \mathbf{1.3}$

Effective overburden pressure; $p_{oz10} = p_{ozS2,k} + (z_{Kq10} - D_{strata3}) \times \gamma'_{3,k} = \mathbf{180}$ kN/m^2

Brinch Hansen coefficient, K_q (Tomlison Fig 7.37); $K_{q10} = \mathbf{2.04}$

Brinch Hansen coefficient, K_c (Tomlison Fig 7.37); $K_{c10} = \mathbf{7.97}$

Unit passive resist. at base (Tomlinson Eqn 7.49); $p_{z10} = p_{oz10} \times K_{q10} + c'_{3,k} \times K_{c10} = \mathbf{1562.015}$ kN/m^2

Unit passive resistance at mid-height; $p_{z10,m} = (p_{z10} + p_{z9}) / 2 = \mathbf{1308.952}$ kN/m^2

Segment lateral point load; $P_{LatS10} = -L / 10 \times p_{z10,m} \times h = \mathbf{-3246.2}$ kN

Segment moment about applied load; $M_{trS10} = P_{LatS10} \times (e + (10 - 0.5) \times L / 10) = \mathbf{-49342.3}$ kNm

Segment moment about X; $M_{XS10} = P_{LatS10} \times (X - (10 - 0.5) \times L / 10) = \mathbf{10544.5}$ kNm

Sum of moments about point of load application near zero;

$\Sigma M_{tr} = M_{trS1} + M_{trS2} + M_{trS3} + M_{trS4} + M_{trS5} + M_{trS6} + M_{trS7} + M_{trS8t} + M_{trS8b} + M_{trS9} + M_{trS10}$ = **-1** kNm

Sum of moments about point of rotation;

$\Sigma M_X = M_{XS1} + M_{XS2} + M_{XS3} + M_{XS4} + M_{XS5} + M_{XS6} + M_{XS7} + M_{XS8t} + M_{XS8b} + M_{XS9} + M_{XS10}$ = **86638.2** kNm

Calculated soil lateral resist. (Tomlinson Eqn 7.52); $R_{tr,calc} = \Sigma M_X / (e + X)$ = **7249** kN

Lateral deflection

Characteristic lateral action; $F_{tr,k} = G_{tr,k,unfav} - G_{tr,k,fav} + Q_{tr,k}$ = **1200** kN

Virtual point of fixity, from iteration; $V_{zf} = R_{tr,calc} - P_{LatS1} - P_{LatS2} - P_{LatS3} - P_{LatS4} - P_{LatS5} - R \times P_{LatS6}$ = **0** kN

$z_f = (5 + R) \times L / 10$ = **8061** mm

Actual lateral deflection at top of pile; $\delta_{Lat} = (F_{tr,k} \times (e + z_f)^3) / (3 \times E \times I)$ = **23.5** mm

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

$\delta_{Lat} / \delta_{LatAllow}$ = **0.94**

PASS - Allowable lateral deflection exceeds actual lateral deflection

GEODOMISI Ltd

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