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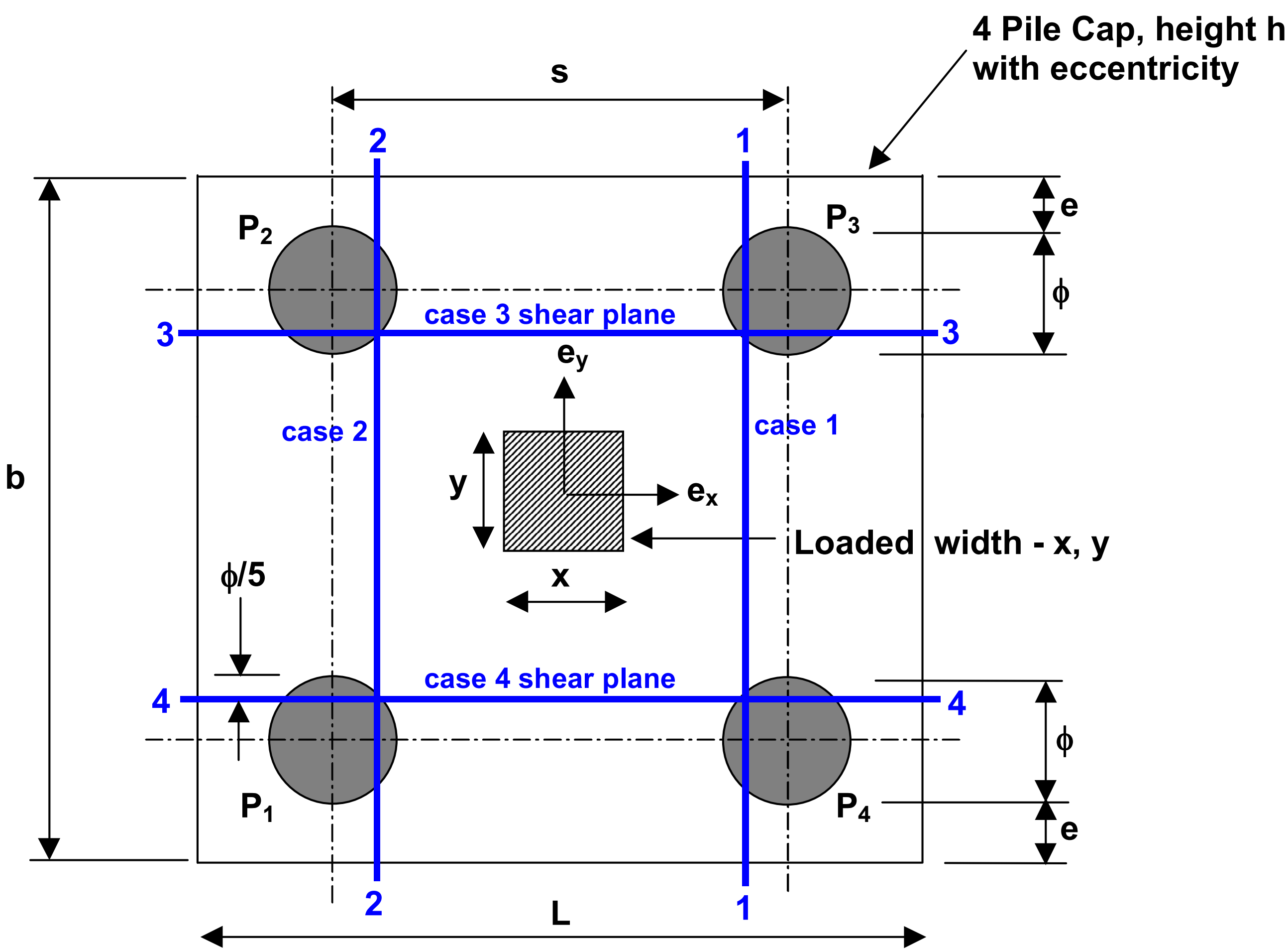
Project: Reinforced Pile Cap Design, in accordance with (BS8110:Part1:1997)				Job Ref.		
Section: Civil & Geotechnical Engineering				Sheet no./rev. 1		
Calc. by Dr.C.Sachpazis	Date 10/08/2013	Chk'd by -	Date	App'd by	Date	

RC PILE CAP DESIGN (BS8110:PART1:1997)



Pile Cap Design – Truss Method

Design Input - 4 Piles - With Eccentricity

Number of piles;	N = 4
ULS axial load;	F_{uls} = **1850.0** kN
Pile diameter;	ϕ = **350** mm
Pile spacing, both directions;	s = **900** mm
Eccentricity from centroid of pile cap;	e_x = **75** mm
Eccentricity from centroid of pile cap;	e_y = **50** mm

Characteristic load in pile, ϕ1; $F_{char\_pile\_1} = F_{char} \times (0.5 \times s - e_x)/s \times (0.5 \times s - e_y)/s$ = **291.7** kN

Characteristic load in pile, ϕ2; $F_{char\_pile\_2} = F_{char} \times (0.5 \times s - e_x)/s \times (0.5 \times s + e_y)/s$ = **364.6** kN

Characteristic load in pile, ϕ3; $F_{char\_pile\_3} = F_{char} \times (0.5 \times s + e_x)/s \times (0.5 \times s + e_y)/s$ = **510.4** kN

Characteristic load in pile, ϕ4; $F_{char\_pile\_4} = F_{char} \times (0.5 \times s + e_x)/s \times (0.5 \times s - e_y)/s$ = **408.3** kN

Pile cap overhang; e = **200** mm

Overall length of pile cap; $L = s + \phi + 2 \times e$ = **1650** mm

Overall width of pile cap; $b = s + \phi + 2 \times e$ = **1650** mm

Overall height of pile cap; h = **450** mm

Dimension x of loaded area; x = **300** mm

Dimension y of loaded area; y = **300** mm

Cover

Concrete grade; f_{cu} = **40.0** N/mm^2

Nominal cover; c_{nom} = **40** mm

Tension bar diameter; D_t = **16** mm

Link bar diameter; L_{dia} = **12** mm

Depth to tension steel; $d = h – c_{nom} - L_{dia} - D_t/2$ = **390** mm

Pile Cap Forces

Maximum compression within pile cap; $F_c = \max(F_{c1}, F_{c2}, F_{c3}, F_{c4})$ = **1034.4** kN

Maximum tension within pile cap; $F_t = \max(F_{t1}, F_{t2}, F_{t3}, F_{t4})$ = **614.9** kN

Compression In Pile Cap - Suggested Additional Check

Check compression diagonal as an unreinforced column, using a core equivalent to pile diameter

Compressive force in pile cap; $P_c = 0.4 \times f_{cu} \times \pi \times \phi^2/4$ = **1539.4** kN

PASS Compression

Cl. 3.8.4.3

Tension In One Truss Member

Characteristic strength of reinforcement; f_y = **500** N/mm^2

Partial safety factor for strength of steel; γ_{ms} = **1.15**

Required area of reinforcement; $A_{s\_req} = F_t /(1/\gamma_{ms} \times f_y)$ =**1414** mm^2

Provided area of reinforcement; $A_{s\_prov} = A_{st}$ = **1608** mm^2

Tension in truss member; $P_t = (1/\gamma_{ms} \times f_y) \times A_{s\_prov}$ = **699.3** kN

PASS Tension

Cl. 3.11.4.2

Max / Min Areas of Reinforcement - Considering A Strip Of Cap

Minimum required area of steel; $A_{st\_min} = k_t \times A_c$ = **439** mm^2

Maximum allowable area of steel; $A_{st\_max} = 4\ \% \times A_c$ = **13500** mm^2

Area of tension steel provided OK

Cl. 3.12.6 & Table 3.25

Beam Shear

Check shear stress on the sections at distance ϕ / 5 inside face of piles.

Cl. 3.11.4.3 & fig. 3.23

Applied shear stress to be checked across each pile pair

Effective width of pile cap in shear allowing for Clause 3.11.4.4 (b)

b_v = if (s ≤ 3 × ϕ, s + ϕ + 2 × e, 3 × ϕ + 2 × min(1.5 × ϕ, ϕ / 2 + e)) = **1650** mm

$v_1 = V_1/(b_v \times d)$ = **1.68** N/mm^2

$v_2 = V_2/(b_v \times d)$ = **1.20** N/mm^2

$v_3 = V_3/(b_v \times d)$ = **1.60** N/mm^2

$v_4 = V_4/(b_v \times d)$ = **1.28** N/mm^2

$v_{allowable}$ = min ((0.8 N$^{1/2}$/mm) × √(f_{cu}), 5 N/mm^2) = **5.00** N/mm^2

Shear stress - OK

Cl. 3.4.5.2

Design concrete shear strength

Percentage of reinforcement; r = 100 × 2 × A_{s_prov} /(b_v × d) = **0.50**

From BS8110-1:1997 Table 3.8;

v_{c_25} = 0.79 × r$^{1/3}$ × max(0.67, (400 mm/d)$^{1/4}$) × 1.0 N/mm^2 / 1.25 = **0.50** N/mm^2

Shear enhancement - Cl. 3.4.5.8 and fig. 3.5; $v_c = v_{c\_25}$ × (min(f_{cu}, 40 N/mm^2)/25 N/mm^2)$^{1/3}$ = **0.59** N/mm^2

Case 1; a_{v_1} = min(2 × d, max((s/2 - ϕ/2 + ϕ/5 - e_x - x/2), 0.1 mm)) = **120** mm

$v_{c\_enh\_1} = 2 \times d \times v_c/a_{v\_1}$ = **3.84** N/mm^2

Concrete shear strength - OK, no links reqd. for Case 1

Case 2; a_{v_2} = min(2 × d, max((s/2 - ϕ/2 + ϕ/5 + e_x - x/2), 0.1 mm)) = **270** mm

$v_{c\_enh\_2} = 2 \times d \times v_c/a_{v\_2}$ = **1.71** N/mm^2

Concrete shear strength - OK, no links reqd. for Case 2

Case 3; a_{v_3} = min(2 × d, max((s/2 - ϕ/2 + ϕ/5 - e_y - y/2), 0.1 mm)) = **145** mm

$v_{c\_enh\_3} = 2 \times d \times v_c/a_{v\_3}$ = **3.18** N/mm^2

Concrete shear strength - OK, no links reqd. for Case 3

Case 4; a_{v_4} = min(2 × d, max((s/2 - ϕ/2 + ϕ/5 + e_y - y/2), 0.1 mm)) = **245** mm

$v_{c\_enh\_4} = 2 \times d \times v_c/a_{v\_4}$ = **1.88** N/mm^2

Concrete shear strength - OK, no links reqd. for Case 4

Table 3.16

Note: If no links are provided, the bond strengths for **PLAIN** bars must be used in calculations for anchorage and lap lengths.

Cl. 3.12.8.3

Local Shear At Concentrated Loads (Cl 3.7.7)

Total length of inner perim. at edge of loaded area; $u_0 = 2 \times (x + y)$ =**1200** mm

Assumed average depth to tension steel; $d_{av} = d - D_t$ = **374** mm

Max shear effective across perimeter; $V_p = F_{uls}$ = **1850.0** kN

Stress around loaded area; $v_{max} = V_p / (u_0 \times d_{av})$ = **4.12** N/mm^2

Allowable shear stress; $v_{allowable} = \min((0.8\ N^{1/2}/mm) \times \sqrt{(f_{cu})}, 5\ N/mm^2)$ = **5.00** N/mm^2

Shear stress - OK

Cl. 3.4.5.2

Clear Distance Between Bars In Tension (Cl 3.12.11.2.4)

Maximum / Minimum allowable clear distances between tension bars considering a strip of cap

Actual bar spacing;

$spacing_{bars} = \max(0mm, (b_{ccs} - n_{surfaces} \times (c_{adopt} + L_{dia}) - D_t)/(L_{nt} - 1) - D_t)$ =**75** mm

Maximum allowable spacing of bars; $spacing_{max} = \min((47000\ N/mm)/f_s, 300\ mm)$ = **160** mm

Minimum required spacing of bars; $spacing_{min} = h_{agg} + 5\ mm$ = **25** mm

Bar spacing OK

Clear Distance Between Face Of Beam And Tension Bars (Cl 3.12.11.2.5)

Distance to face of beam; $Dist_{edge} = c_{adopt} + L_{dia} + D_t/2$ = **60** mm

Design service stress in reinforcement; $f_s = 2 \times f_y \times A_{s\_req} /(3 \times A_{s\_prov} \times \beta_b)$ = **293.1** N/mm^2

Max allowable clear spacing; $Spacing_{max} = \min((47000\ N/mm)/f_s, 300\ mm)$ = **160** mm

Max distance to face of beam; $Dist_{max} = Spacing_{max} /2$ = **80** mm

Max distance to beam edge check - OK

Anchorage Of Tension Steel

Anchorage factor; ϕ_{factor} =**35**

Type of lap length; lap_type =**"tens_lap"**

Type of reinforcement; reft_type = **"def2_fy500"**

Minimum radius; r_{bar} = **32** mm

Minimum end projection; P_{bar} = **130** mm

Minimum anchorage length or lap length req'd; $L_{table\ 3.27} = \phi_{factor} \times D_t$ = **560** mm

Check anchorage length to cl. 3.12.9.4 (b); $L_{cl.\ 3.12.9.4} = 12 \times D_t + d/2$ = **387** mm

Required minimum effective anchorage length; $L_a = \max(L_{table\ 3.27}, L_{cl.\ 3.12.9.4})$ = **560** mm

Check bearing stress on minimum radius bend

Note that the bars must extend at least 4D past the bend

Force per bar at bend; $F_{bt} = F_t / L_{nt}$ = **76.9** kN

Bearing stress; $f_{bt} = F_{bt} / (r_{bar} \times D_t)$ = **150.12** N/mm^2

Edge bar centres; $s_{ext} = c_{adopt} + D_t$ = **56** mm

Edge maximum allowable bearing stress; $f_{bt\_max\_ext} = 2 \times f_{cu} / (1 + 2\times(D_t / s_{ext}))$ = **50.91** N/mm^2

Internal bar centres; $s_{int} = spacing_{bars} + D_t$ = **91** mm

Internal maximum allowable bearing stress; $f_{bt\_max\_int} = 2 \times f_{cu} / (1 + 2\times(D_t / s_{int}))$ = **59.19** N/mm^2

FAIL - Bearing stress on minimum radius bend exceeds maximum allowable

Deflection Check (Cl 3.4.6)

Redistribution ratio; $\beta_b = 1.0$

Design service stress in tension reinforcement; $f_s = 2 \times f_y \times A_{s\_req} /(3 \times A_{s\_prov} \times \beta_b)$ = **293.1** N/mm^2

Modification for tension reinforcement;

$factor_{tens} = \min(2, 0.55 + (477 \text{ N/mm}^2 - f_s)/(120 \times (0.9 \text{ N/mm}^2 + F_t /(b\times d))))$ = **1.376**

Modified span to depth ratio; $modf_{span\_depth} = factor_{tens} \times basic_{span\_depth}$ = **27.5**

Span of pile cap for deflection check; L_s = **900** mm

Actual span to depth ratio; $actual_{span\_depth} = L_s /d$ = **2.31**

PASS - Deflection