

2-Pile Pilecap Design Example

Anchor Bolt Design ACI 318-11 Crane Beam Design www.civilbay.com	Project :	Anchor Bolt Design ACI 318-11 Crane Beam Design	Eng :	Test
	Jon No :	www.civilbay.com	Chk :	Test
	Doc No :	www.civilbay.com	Date :	2013-03-06
Calculation Sheet	Subject :	Pilecap Design Examples	Rev :	0

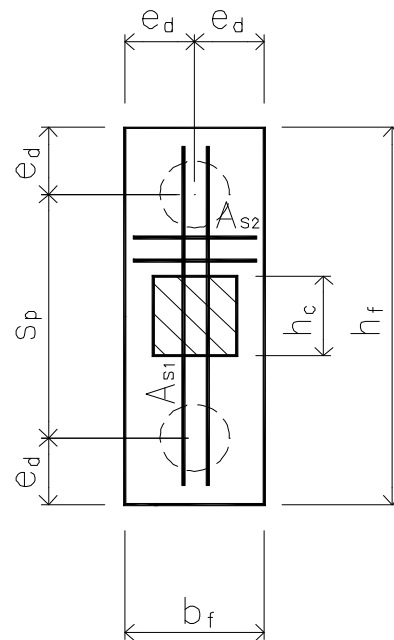
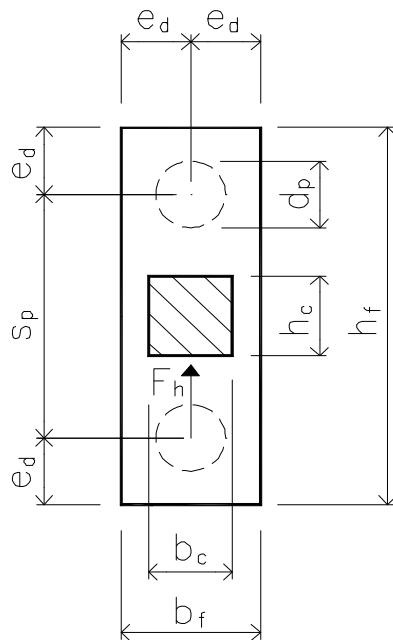
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DESCRIPTION

2 piles pilecap design based on
A23.3-04 Design of Concrete Structures

Code Abbreviation

A23.3-04



INPUT

Factored column load	$P_{cf} = 1500$	[kN]	Ver reinf.		
Column width	$b_c = 330$	[mm]	A_{s1} bar size =	25	500
Column length	$h_c = 500$	[mm]	A_{s1} bar No =	7	
Pilecap width	$b_f = 1000$	[mm]	A_{s1} prov =	3500	
Pilecap length	$h_f = 1750$	[mm]	Equivalent to	25	@ 133
Pilecap thickness	$t_f = 620$	[mm]			
			Hor reinf.		
Pile diameter	$d_p = 250$	[mm]	A_{s2} bar size =	20	300
Pile spacing	$s_p = 750$	[mm]	A_{s2} bar No =	7	
Pile edge distance	$e_d = 500$	[mm]	A_{s2} prov =	2100	
			Equivalent to	20	@ 258
Concrete strength	$f'_c = 30$	[MPa]			
Rebar yield strength	$f_y = 400$	[MPa]			
Concrete resistance factor	$\phi_c = 0.65$				
Rebar resistance factor	$\phi_s = 0.85$				
Low density conc factor	$\lambda = 1.0$				
Backfill soil weight above cap	$W_s = 0$	[kN]			
Pilecap self weight	$W_f = b_f \times h_f \times t_f \times 23.5$		= 25	[kN]	

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Factored total pilecap load	$P_f = P_{cf} + W_s + W_f$	= 1532	[kN]
Pilecap effective depth	$d = t_f - 1.5d_b - 150$	= 440	[mm]
Factored pile axial reaction	$Q_{pr} = P_f / 2$	= 766	[kN]
Vertical Direction			
Factored moment to column face	$M_f = Q_{pr} \times (0.5s_p - 0.5h_c)$	= 96	[kNm]
Factored shear to column face	$V_f = Q_{pr}$	= 766	[kN]

CONCLUSION

[Pilecap Reinf by S&T Model Is Adequate]

[Pilecap Reinf by Deep Beam Model Is Adequate]

[Column One Way Shear Is Adequate]

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Code Reference

S&T AND BEARING STRESS LIMIT MODEL by Adebar

Column Bearing Stress

	$A_c = 1.7E+05 \text{ [mm}^2\text{]}$	$A_2 = 1.8E+06 \text{ [mm}^2\text{]}$	
	$\alpha = 0.33 \left(\sqrt{\frac{A_2}{A_c}} - 1 \right) \leq 1.0$	= 0.75	
	$\beta = 0.33 \left(\frac{2d}{\sqrt{A_c}} - 1 \right) \leq 1.0$	= 0.39	
Allowable stress	$f_b = \phi_c (0.6 f'_c + 6\alpha\beta\sqrt{f'_c})$	= 17.9	[MPa]
Column stress	$f_{cb} = P_{cf} / (b_c \times h_c)$	= 9.1	[MPa]
		< f_b	OK

Pile Bearing Stress

	$A_p = 4.9E+04 \text{ [mm}^2\text{]}$	$A_2 = 7.9E+05 \text{ [mm}^2\text{]}$	
	$\alpha = 0.33 \left(\sqrt{\frac{A_2}{A_p}} - 1 \right) \leq 1.0$	= 1.00	
	$\beta = 0.33 \left(\frac{d}{d_p} - 1 \right) \leq 1.0$	= 0.25	
Allowable stress	$f_b = \phi_c (0.6 f'_c + 6\alpha\beta\sqrt{f'_c})$	= 17.1	[MPa]
Pile stress	$f_{cb} = Q_{pr} / (\pi * d_p^2 / 4)$	= 15.6	[MPa]
		< f_b	OK

Required Reinf

Vertical reinf.

$l = 0.5s_p - 0.25h_c$	= 250	[mm]
$F_h = l / d \times Q_{pr}$	= 435	[kN]
$A_{s1} = F_h / (\phi_s \times f_y)$	= 1280	[mm ²]
$A_{smin} = 0.2\% \times b_f \times t_f$	= 1240	[mm ²]
$A_{s1} = \max (A_{s1}, A_{smin})$	= 1280	[mm ²]
$A_{s1 \text{ prov}} =$	3500	[mm ²]
	> A_{s1}	OK

[Pilecap Reinf by S&T Model Is Adequate]

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REDUCED LEVER ARM MODEL by Park and Paulay

Vertical Direction

$$\begin{aligned}
 dV_f / M_f &= 3.52 > 1.0 \rightarrow \text{pilecap acts as deep beam} \\
 dV_f / M_f &> 2.0 & M_f / V_f &= 125 & [\text{mm}] \\
 z &= 0.4(d + M_f / V_f) \text{ for } dV_f / M_f \geq 1.0 & &= 150 & [\text{mm}] \\
 &1.2 M_f / V_f \text{ for } dV_f / M_f \geq 2.0 \\
 A_{s1} &= M_f / (\phi_s f_y z) & &= 1877 & [\text{mm}^2] \\
 A_{smin} &= 0.2\% \times b_f \times t_f & &= 1240 & [\text{mm}^2] \\
 A_{s1} &= \max(A_{s1}, A_{smin}) & &= 1877 & [\text{mm}^2] \\
 A_{s1 \text{ prov}} &= & &= 3500 & [\text{mm}^2] \\
 && &> A_{s1} & \text{OK}
 \end{aligned}$$

[Deep Beam Model Is Applicable]

[Pilecap Reinf by Deep Beam Model Is Adequate]

COLUMN ONE WAY SHEAR

Factored single pile load	$Q_{pr} = 766$	[kN]	$b_c = 330$	[mm]
Pile diameter	$d_p = 250$	[mm]	$h_c = 500$	[mm]
Pile edge distance	$e_d = 500$	[mm]	$b_f = 1000$	[mm]
Pilecap effective depth	$d = 440$	[mm]	$h_f = 1750$	[mm]

Hor Critical Shear Line

Dist from col face to pile edge	$d_c = 250$	[mm]		
Fraction of pile outside critical line	$r = 0.00$			
Factored shear force	$V_f = r \times Q_{pr}$		$= 0$	[kN]
	$b_w = b_f$		$= 1000$	[mm]
When no transverse reinf.	$\beta = 230 / (1000 + d)$		$= 0.160$	11.3.6.3 Eq (11-9)
	$V_c = \phi_c \lambda \beta \sqrt{f'_c} b_w d$		$= 250$	[kN] 11.3.4 Eq (11-6)
			$> V_f$	OK

[Column One Way Shear Is Adequate]

3-Pile Pilecap Design Example

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Factored total pilecap load	$P_f = P_{cf} + W_s + W_f$	= 4663	[kN]
Pilecap effective depth	$d = t_f - 1.5d_b - 150$	= 800	[mm]
Factored pile axial reaction	$Q_{pr} = P_f / 3$	= 1554	[kN]
Vertical Direction			
Factored moment to column face	$M_f = Q_{pr} \times (0.577s_p - 0.5h_c)$	= 631	[kNm]
Factored shear to column face	$V_f = Q_{pr}$	= 1554	[kN]

CONCLUSION

[Pilecap Reinf by S&T Model Is Adequate]

[Pilecap Reinf by Deep Beam Model Is NOT Adequate]

[Pile One and Two Way Shear Is Adequate]

[Column One Way Shear Is Adequate]

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Code Reference

S&T AND BEARING STRESS LIMIT MODEL by Adebar

Column Bearing Stress

	$A_c = 1.6E+05 \text{ [mm}^2\text{]}$	$A_2 = 5.2E+06 \text{ [mm}^2\text{]}$	
	$\alpha = 0.33 \left(\sqrt{\frac{A_2}{A_c}} - 1 \right) \leq 1.0$	$= 1.00$	
	$\beta = 0.33 \left(\frac{2d}{\sqrt{A_c}} - 1 \right) \leq 1.0$	$= 1.00$	
Allowable stress	$f_b = \phi_c (0.6 f'_c + 6\alpha\beta\sqrt{f'_c})$	$= 33.1$	[MPa]
Column stress	$f_{cb} = P_{cf} / (b_c \times h_c)$	$= 28.1$	[MPa]
		$< f_b$	OK

Pile Bearing Stress

	$A_p = 9.6E+04 \text{ [mm}^2\text{]}$	$A_2 = 1.5E+06 \text{ [mm}^2\text{]}$	
	$\alpha = 0.33 \left(\sqrt{\frac{A_2}{A_p}} - 1 \right) \leq 1.0$	$= 1.00$	
	$\beta = 0.33 \left(\frac{d}{d_p} - 1 \right) \leq 1.0$	$= 0.43$	
Allowable stress	$f_b = \phi_c (0.6 f'_c + 6\alpha\beta\sqrt{f'_c})$	$= 20.9$	[MPa]
Pile stress	$f_{cb} = Q_{pr} / (\pi * d_p^2 / 4)$	$= 16.2$	[MPa]
		$< f_b$	OK

Required Reinf

Vertical direction

	$l = 0.577s_p - 0.25h_c$	$= 506$	[mm]
	$F_h = l / d \times Q_{pr}$	$= 984$	[kN]
	$A_{sver} = F_h / (\phi_s \times f_y)$	$= 2893$	[mm ²]
	$A_{smin} = 0.2\% \times 2e_d \times t_f$	$= 2744$	[mm ²]
	$A_{sver} = \max (A_{sver}, A_{smin})$	$= 2893$	[mm ²]
	$A_{sver \text{ prov}} =$	3500	[mm ²]
		$> A_{sver}$	OK

Horizontal direction

	$b_1 = 425$	$h_1 = 203$	[mm]
	$l = \sqrt{b_1^2 + h_1^2}$	$= 471$	[mm]
	$F_h = l / d \times Q_{pr}$	$= 915$	[kN]
	$F_{T2} = b_1 / l \times F_h$	$= 826$	[kN]
	$A_{s1} = F_{T2} / (\phi_s \times f_y)$	$= 2429$	[mm ²]
	$A_{smin} = 0.2\% \times 2e_d \times t_f$	$= 2744$	[mm ²]
	$A_{s1} = \max (A_{s1}, A_{smin})$	$= 2744$	[mm ²]
	$A_{s1 \text{ prov}} =$	3500	[mm ²]
		$> A_{s1}$	OK

[Pilecap Reinf by S&T Model Is Adequate]

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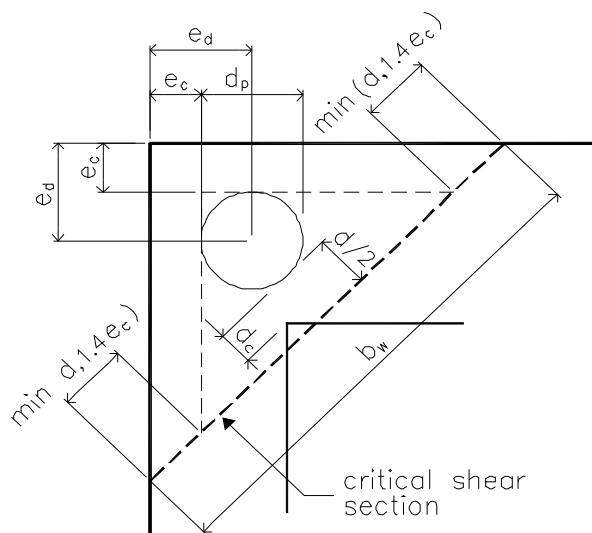
REDUCED LEVER ARM MODEL by Park and Paulay

Vertical Direction

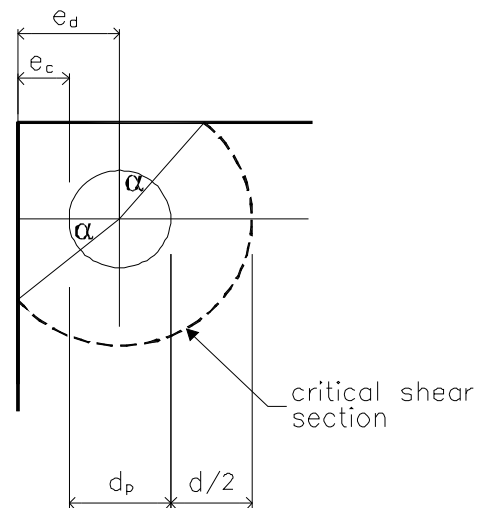
$$\begin{aligned}
 dV_f / M_f &= 1.97 > 1.0 \rightarrow \text{pilecap acts as deep beam} \\
 dV_f / M_f &< 2.0 & M_f / V_f &= 406 & [\text{mm}] \\
 z &= 0.4(d + M_f / V_f) \text{ for } dV_f / M_f \geq 1.0 & &= 482 & [\text{mm}] \\
 &1.2 M_f / V_f & \text{ for } dV_f / M_f \geq 2.0 & & \\
 A_{sver} &= M_f / (\phi_s f_y z) & &= 3849 & [\text{mm}^2] \\
 A_{smin} &= 0.2\% \times 2e_d \times t_f & &= 2744 & [\text{mm}^2] \\
 A_{sver} &= \max(A_{sver}, A_{smin}) & &= 3849 & [\text{mm}^2] \\
 A_{sver \text{ prov}} &= & &= 3500 & [\text{mm}^2] \\
 && &< A_{sver} & \text{NG}
 \end{aligned}$$

[Deep Beam Model Is Applicable]

[Pilecap Reinf by Deep Beam Model Is NOT Adequate]



Corner Pile One-Way Shear



Corner Pile Two-Way Shear

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CORNER PILE ONE WAY SHEAR

Code Reference

A23.3-04

Factored pile load	$V_f = 1554$	[kN]			
Pile diameter	$d_p = 350$	[mm]			
Pile edge distance	$e_d = 700$	[mm]	$e_c = 525$	[mm]	
Pilecap effective depth	$d = 800$	[mm]	$d/2 = 400$	[mm]	
Dist from pile edge to col corner	$d_c = 166$	[mm]	$d_c + 50 = 216$	[mm]	
			$< d/2$		
Critical shear line intersect column, one way shear needs NOT to be checked					
	$\text{sqrt}(f'_c) = \min(\text{sqrt}(f'_c), 8)$		$= 5.477$	[MPa]	11.3.4
	$\min(d, 1.414 e_c) = 742$	[mm]	$b_w = 2058$	[mm]	
When no transverse reinf.	$\beta = 230 / (1000 + d)$		$= 0.128$		11.3.6.3 Eq (11-9)
	$V_c = \phi_c \lambda \beta \sqrt{f'_c} b_w d$		$= 749$	[kN]	11.3.4 Eq (11-6)
			$< V_f$		OK

CORNER PILE TWO WAY SHEAR

Factored pile load	$V_f = 1554$	[kN]			
Pile diameter	$d_p = 350$	[mm]			
Pile edge distance	$e_d = 700$	[mm]	$e_c = 525$	[mm]	
Pilecap effective depth	$d = 800$	[mm]	$d/2 = 400$	[mm]	
Dist from pile edge to col corner	$d_c = 166$	[mm]	$d_c + 50 = 216$	[mm]	
			$< d/2$		
Critical shear line intersect column, one way shear needs NOT to be checked					
	$\alpha = 0.0$				
Critical perimeter length	$b_o = \pi (d_p + d) (270 - 2\alpha) / 360$		$= 2168$	[mm]	
	$v_{c1} = \left(1 + \frac{2}{\beta_c}\right) 0.19 \lambda \phi_c \sqrt{f'_c}$		$= 2.029$	[MPa]	13.3.4.1 (13-5)
	$\beta_c = \text{width} / \text{length} = 1$ for pile				
	$v_{c2} = \left(\frac{\alpha_s d}{b_o} + 0.19\right) \lambda \phi_c \sqrt{f'_c}$		$= 3.304$	[MPa]	13.3.4.1 (13-6)
	$\alpha_s = 2$ for corner pile				
	$v_{c3} = 0.38 \lambda \phi_c \sqrt{f'_c}$		$= 1.353$	[MPa]	13.3.4.1 (13-7)
	$v_c = \min(v_{c1}, v_{c2}, v_{c3})$		$= 1.353$	[MPa]	
	$V_c = v_c b_o d$		$= 2346$	[kN]	
			$> V_f$		OK

[Pile One and Two Way Shear Is Adequate]

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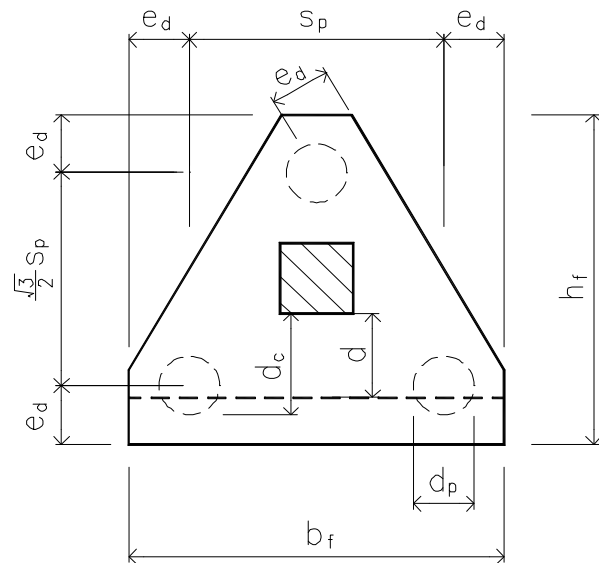
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COLUMN ONE WAY SHEAR

Factored single pile load	$Q_{pr} = 1554$	[kN]	$b_c = 400$	[mm]
Pile diameter	$d_p = 350$	[mm]	$h_c = 400$	[mm]
Pile edge distance	$e_d = 700$	[mm]	$b_f = 2450$	[mm]
Pilecap effective depth	$d = 800$	[mm]	$h_f = 2309$	[mm]

Hor Critical Shear Line

Dist from col face to pile edge	$d_c = 278$	[mm]		
Fraction of pile outside critical line	$r = 0.00$			
Factored shear force	$V_f = r \times 2 \times Q_{pr}$		$= 0$	[kN]
	$b_w = b_f$		$= 2450$	[mm]
When no transverse reinf.	$\beta = 230 / (1000 + d)$		$= 0.128$	11.3.6.3 Eq (11-9)
	$V_c = \phi_c \lambda \beta \sqrt{f'_c} b_w d$		$= 892$	[kN] 11.3.4 Eq (11-6)
			$> V_f$	OK



Column One-Way Shear

[Column One Way Shear Is Adequate]

4-Pile Pilecap Design Example

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Factored total pilecap load	$P_f = P_{cf} + W_s + W_f$	= 2031	[kN]
Pilecap effective depth	$d = t_f - 1.5d_b - 150$	= 360	[mm]
Factored pile axial reaction	$Q_{pr} = P_f / 4$	= 508	[kN]
Vertical Direction			
Factored moment to column face	$M_f = 2 \times Q_{pr} \times 0.5(S_p - h_c)$	= 102	[kNm]
Factored shear to column face	$V_f = 2 \times Q_{pr}$	= 1016	[kN]
Horizontal Direction			
Factored moment to column face	$M_f = 2 \times Q_{pr} \times 0.5(S_p - b_c)$	= -102	[kNm]
Factored shear to column face	$V_f = 2 \times Q_{pr}$	= 1016	[kN]

CONCLUSION

[Pilecap Reinf by S&T Model Is Adequate]

[Pilecap Reinf by Deep Beam Model Is Adequate]

[Pile One and Two Way Shear Is Adequate]

[Column One and Two Way Shear Is Adequate]

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S&T AND BEARING STRESS LIMIT MODEL by Adebar

Column Bearing Stress

	$A_c = 3.2E+05 \text{ [mm}^2\text{]}$	$A_2 = 2.0E+06 \text{ [mm}^2\text{]}$	
	$\alpha = 0.33 \left(\sqrt{\frac{A_2}{A_c}} - 1 \right) \leq 1.0$	= 0.49	
	$\beta = 0.33 \left(\frac{2d}{\sqrt{A_c}} - 1 \right) \leq 1.0$	= 0.09	
Allowable stress	$f_b = \phi_c (0.6 f'_c + 6\alpha\beta\sqrt{f'_c})$	= 12.7	[MPa]
Column stress	$f_{cb} = P_{cf} / (b_c \times h_c)$	= 6.3	[MPa]
		< f_b	OK

Pile Bearing Stress

	$A_p = 3.1E+04 \text{ [mm}^2\text{]}$	$A_2 = 5.0E+05 \text{ [mm}^2\text{]}$	
	$\alpha = 0.33 \left(\sqrt{\frac{A_2}{A_p}} - 1 \right) \leq 1.0$	= 1.00	
	$\beta = 0.33 \left(\frac{d}{d_p} - 1 \right) \leq 1.0$	= 0.27	
Allowable stress	$f_b = \phi_c (0.6 f'_c + 6\alpha\beta\sqrt{f'_c})$	= 17.4	[MPa]
Pile stress	$f_{cb} = Q_{pr} / (\pi * d_p^2 / 4)$	= 16.2	[MPa]
		< f_b	OK

Required Reinf

	$b_1 = 100 \text{ [mm]}$	$h_1 = 200 \text{ [mm]}$	
	$l = \text{sqrt}(b_1^2 + h_1^2)$	= 224	[mm]
	$F_h = l / d \times Q_{pr}$	= 315	[kN]
Vertical direction	$F_{T1} = h_1 / l \times F_h$	= 282	[kN]
	$A_{s1} = F_{T1} / (\phi_s \times f_y)$	= 830	[mm ²]
	$A_{smin} = 0.2\% \times b_f \times t_f / 2$	= 756	[mm ²]
	$A_{s1} = \max(A_{s1}, A_{smin})$	= 830	[mm ²]
	$A_{s1 \text{ prov}} =$	3500	[mm ²]
		> A_{s1}	OK
Horizontal direction	$F_{T2} = b_1 / l \times F_h$	= 141	[kN]
	$A_{s2} = F_{T2} / (\phi_s \times f_y)$	= 415	[mm ²]
	$A_{smin} = 0.2\% \times h_f \times t_f / 2$	= 756	[mm ²]
	$A_{s2} = \max(A_{s1}, A_{smin})$	= 756	[mm ²]
	$A_{s2 \text{ prov}} =$	3500	[mm ²]
		> A_{s2}	OK

[Pilecap Reinf by S&T Model Is Adequate]

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REDUCED LEVER ARM MODEL by Park and Paulay

Vertical Direction

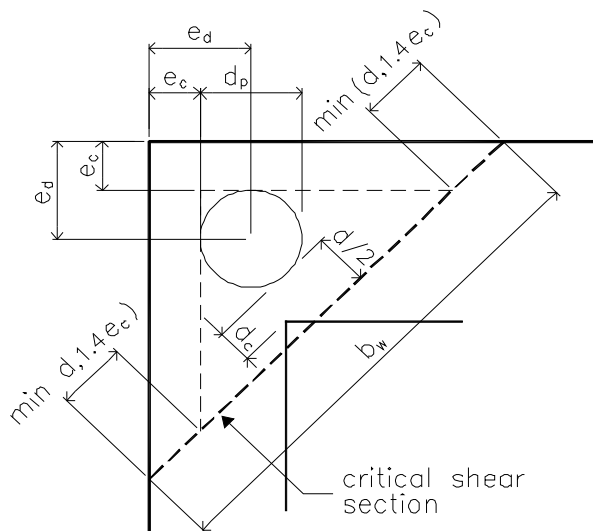
$$\begin{aligned}
 dV_f / M_f &= 3.60 > 1.0 \rightarrow \text{pilecap acts as deep beam} \\
 dV_f / M_f &> 2.0 & M_f / V_f &= 100 & [\text{mm}] \\
 z &= 0.4(d + M_f / V_f) \text{ for } dV_f / M_f \geq 1.0 & &= 120 & [\text{mm}] \\
 &1.2 M_f / V_f & \text{ for } dV_f / M_f \geq 2.0 \\
 A_{s\text{ver}} &= M_f / (\phi_s f_y z) & &= 2489 & [\text{mm}^2] \\
 A_{s\text{min}} &= 0.2\% \times b_f \times t_f & &= 1512 & [\text{mm}^2] \\
 A_{s\text{ver}} &= \max(A_{s\text{ver}}, A_{s\text{min}}) & &= 2489 & [\text{mm}^2] \\
 A_{s\text{prov}} &= 2 \times A_{s1\text{ prov}} & &= 7000 & [\text{mm}^2] \\
 &> A_{s\text{ver}} & & \text{OK}
 \end{aligned}$$

Horizontal Direction

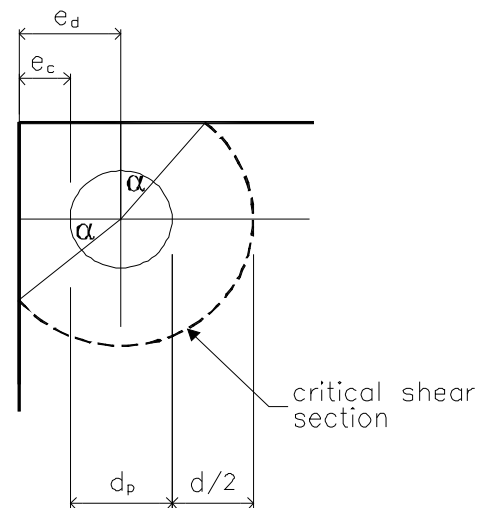
$$\begin{aligned}
 dV_f / M_f &= -3.60 < 1.0 \rightarrow \text{pilecap does NOT act as deep beam} \\
 dV_f / M_f &< 2.0 & M_f / V_f &= -100 & [\text{mm}] \\
 z &= 0.4(d + M_f / V_f) \text{ for } dV_f / M_f \geq 1.0 & &= 104 & [\text{mm}] \\
 &1.2 M_f / V_f & \text{ for } dV_f / M_f \geq 2.0 \\
 A_{s\text{hor}} &= M_f / (\phi_s f_y z) & &= -2872 & [\text{mm}^2] \\
 A_{s\text{min}} &= 0.2\% \times h_f \times t_f & &= 1512 & [\text{mm}^2] \\
 A_{s\text{hor}} &= \max(A_{s\text{hor}}, A_{s\text{min}}) & &= 1512 & [\text{mm}^2] \\
 A_{s\text{prov}} &= 2 \times A_{s2\text{ prov}} & &= 7000 & [\text{mm}^2] \\
 &> A_{s\text{hor}} & & \text{OK}
 \end{aligned}$$

[Deep Beam Model Is NOT Applicable. The Result Is Abandoned]

[Pilecap Reinf't by Deep Beam Model Is Adequate]



Corner Pile One-Way Shear



Corner Pile Two-Way Shear

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CORNER PILE ONE WAY SHEAR

Code Reference

A23.3-04

Factored pile load	$V_f = 508$	[kN]		
Pile diameter	$d_p = 200$	[mm]		
Pile edge distance	$e_d = 400$	[mm]	$e_c = 300$	[mm]
Pilecap effective depth	$d = 360$	[mm]	$d/2 = 180$	[mm]
Dist from pile edge to col corner	$d_c = 41$	[mm]	$d_c + 50 = 91$	[mm]
			$< d/2$	
Critical shear line intersect column, one way shear needs NOT to be checked				
	$\text{sqrt}(f'_c) = \min(\text{sqrt}(f'_c), 8)$		$= 5.477$	[MPa] 11.3.4
	$\min(d, 1.414 e_c) = 360$	[mm]	$b_w = 1563$	[mm]
When no transverse reinf.	$\beta = 230 / (1000 + d)$		$= 0.169$	11.3.6.3 Eq (11-9)
	$V_c = \phi_c \lambda \beta \sqrt{f'_c} b_w d$		$= 339$	[kN] 11.3.4 Eq (11-6)
			$< V_f$	OK

CORNER PILE TWO WAY SHEAR

Factored pile load	$V_f = 508$	[kN]		
Pile diameter	$d_p = 200$	[mm]		
Pile edge distance	$e_d = 400$	[mm]	$e_c = 300$	[mm]
Pilecap effective depth	$d = 360$	[mm]	$d/2 = 180$	[mm]
Dist from pile edge to col corner	$d_c = 41$	[mm]	$d_c + 50 = 91$	[mm]
			$< d/2$	
Critical shear line intersect column, one way shear needs NOT to be checked				
	$\alpha = 0.0$			
Critical perimeter length	$b_o = \pi (d_p + d) (270 - 2\alpha) / 360$		$= 1319$	[mm]
	$v_{c1} = \left(1 + \frac{2}{\beta_c}\right) 0.19 \lambda \phi_c \sqrt{f'_c}$		$= 2.029$	[MPa] 13.3.4.1 (13-5)
	$\beta_c = \text{width} / \text{length} = 1$ for pile			
	$v_{c2} = \left(\frac{\alpha_s d}{b_o} + 0.19\right) \lambda \phi_c \sqrt{f'_c}$		$= 2.619$	[MPa] 13.3.4.1 (13-6)
	$\alpha_s = 2$ for corner pile			
	$v_{c3} = 0.38 \lambda \phi_c \sqrt{f'_c}$		$= 1.353$	[MPa] 13.3.4.1 (13-7)
	$v_c = \min(v_{c1}, v_{c2}, v_{c3})$		$= 1.353$	[MPa]
	$V_c = v_c b_o d$		$= 643$	[kN]
			$> V_f$	OK

[Pile One and Two Way Shear Is Adequate]

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COLUMN ONE WAY SHEAR

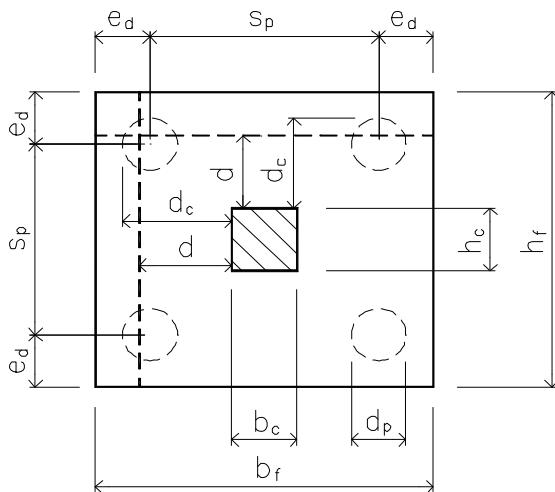
Factored single pile load	$Q_{pr} = 508$	[kN]	$b_c = 800$	[mm]
Pile diameter	$d_p = 200$	[mm]	$h_c = 400$	[mm]
Pile edge distance	$e_d = 400$	[mm]	$b_f = 1400$	[mm]
Pilecap effective depth	$d = 360$	[mm]	$h_f = 1400$	[mm]

Ver Critical Shear Line

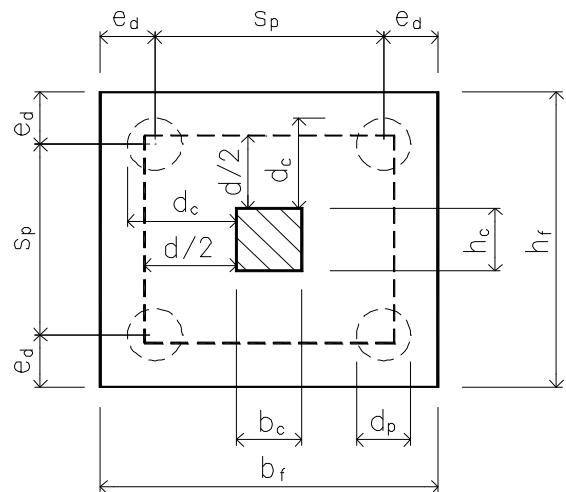
Dist from col face to pile edge	$d_c = 0$	[mm]		
Fraction of pile outside critical line	$r = 0.00$			
Factored shear force	$V_f = r \times 2 \times Q_{pr}$		$= 0$	[kN]
	$b_w = h_f$		$= 1400$	[mm]
When no transverse reinf.	$\beta = 230 / (1000 + d)$		$= 0.169$	11.3.6.3 Eq (11-9)
	$V_c = \phi_c \lambda \beta \sqrt{f'_c} b_w d$		$= 303$	[kN] 11.3.4 Eq (11-6)
			$> V_f$	OK

Hor Critical Shear Line

Dist from col face to pile edge	$d_c = 200$	[mm]		
Fraction of pile outside critical line	$r = 0.00$			
Factored shear force	$V_f = r \times 2 \times Q_{pr}$		$= 0$	[kN]
	$b_w = b_f$		$= 1400$	[mm]
When no transverse reinf.	$\beta = 230 / (1000 + d)$		$= 0.169$	11.3.6.3 Eq (11-9)
	$V_c = \phi_c \lambda \beta \sqrt{f'_c} b_w d$		$= 303$	[kN] 11.3.4 Eq (11-6)
			$> V_f$	OK



Column One-Way Shear



Column Two-Way Shear

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COLUMN TWO WAY SHEAR

A23.3-04

Factored single pile load	$Q_{pr} = 508$	[kN]	$b_c = 800$	[mm]
Pile diameter	$d_p = 200$	[mm]	$h_c = 400$	[mm]
Pile edge distance	$e_d = 400$	[mm]	$b_f = 1400$	[mm]
Pilecap effective depth	$d = 360$	[mm]	$h_f = 1400$	[mm]

Ver Critical Shear Line

Dist from col face to pile edge	$d_c = 0$	[mm]
Fraction of pile outside critical line	$r_1 = 0.00$	

Hor Critical Shear Line

Dist from col face to pile edge	$d_c = 200$	[mm]
Fraction of pile outside critical line	$r_2 = 0.10$	

Factored shear force	$V_f = 203$	[kN]		
Critical perimeter length	$b_o = 2x(b_c + d + h_c + d)$		$= 3840$	[mm]

$$v_{c1} = \left(1 + \frac{2}{\beta_c}\right) 0.19 \lambda \phi_c \sqrt{f'_c} = 1.353 \text{ [MPa]} \quad 13.3.4.1 (13-5)$$

$$\beta_c = \text{col length} / \text{col width} = 2.0$$

$$v_{c2} = \left(\frac{\alpha_s d}{b_o} + 0.19\right) \lambda \phi_c \sqrt{f'_c} = 2.012 \text{ [MPa]} \quad 13.3.4.1 (13-6)$$

$$\alpha_s = 4 \quad \text{for interior column}$$

$$v_{c3} = 0.38 \lambda \phi_c \sqrt{f'_c} = 1.353 \text{ [MPa]} \quad 13.3.4.1 (13-7)$$

$$v_c = \min(v_{c1}, v_{c2}, v_{c3}) = 1.353 \text{ [MPa]}$$

$$V_r = v_c b_o d = 1870 \text{ [kN]}$$

$$> V_f \quad \text{OK}$$

[Column One and Two Way Shear Is Adequate]

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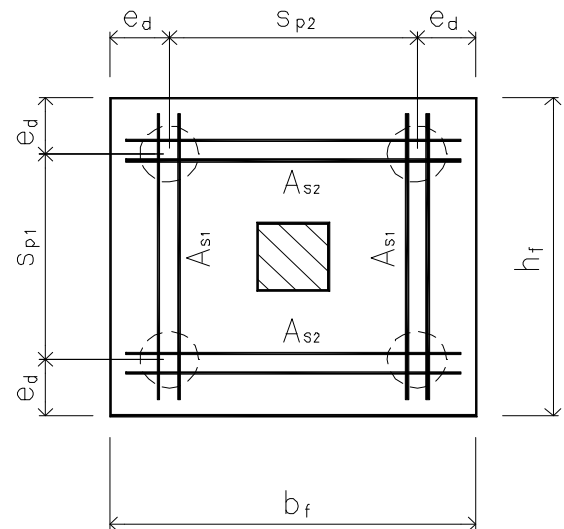
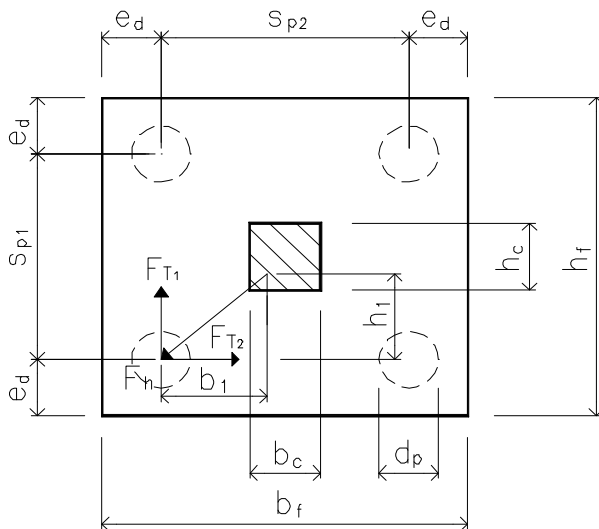
PILECAP DESIGN

4 piles pilecap design based on

A23.3-04 Design of Concrete Structures

Code Abbreviation

A23.3-04



INPUT

Factored column load	$P_{cf} = 700$ [kN]	Vertical reinf.	
Column width	$b_c = 900$ [mm]	A_{s1} bar size = 20	300
Column length	$h_c = 900$ [mm]	A_{s1} bar No = 6	
Pilecap width	$b_f = 2200$ [mm]	$A_{s1 \text{ prov}} = 1650$	
Pilecap length	$h_f = 3200$ [mm]	Equivalent to 20 @ 200	
Pilecap thickness	$t_f = 900$ [mm]		
		Horizontal reinf.	
Pile diameter	$d_p = 324$ [mm]	A_{s2} bar size = 20	300
Pile spacing	$S_{p1} = 2200$ [mm]	A_{s2} bar No = 8	
Pile spacing	$S_{p2} = 1200$ [mm]	$A_{s2 \text{ prov}} = 2400$	
Pile edge distance	$e_d = 500$ [mm]	Equivalent to 20 @ 200	
Concrete strength	$f'_c = 30$ [MPa]		
Rebar yield strength	$f_y = 400$ [MPa]		
Concrete resistance factor	$\phi_c = 0.65$		
Rebar resistance factor	$\phi_s = 0.85$		
Low density conc factor	$\lambda = 1.0$		
Backfill soil weight above cap	$W_s = 0$ [kN]		
Pilecap self weight	$W_f = b_f \times h_f \times t_f \times 23.5$	= 149 [kN]	

001

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Factored total pilecap load	$P_f = P_{cf} + W_s + W_f$	= 886	[kN]
Pilecap effective depth	$d = t_f - 1.5d_b - 150$	= 720	[mm]
Factored pile axial reaction	$Q_{pr} = P_f / 4$	= 222	[kN]
Vertical Direction			
Factored moment to column face	$M_f = 2 \times Q_{pr} \times 0.5(S_{p1} - h_c)$	= 288	[kNm]
Factored shear to column face	$V_f = 2 \times Q_{pr}$	= 443	[kN]
Horizontal Direction			
Factored moment to column face	$M_f = 2 \times Q_{pr} \times 0.5(S_{p2} - b_c)$	= 66	[kNm]
Factored shear to column face	$V_f = 2 \times Q_{pr}$	= 443	[kN]

CONCLUSION

[Pilecap Reinf by S&T Model Is NOT Adequate]

[Pilecap Reinf by Deep Beam Model Is NOT Adequate]

[Pile One and Two Way Shear Is Adequate]

[Column One and Two Way Shear Is Adequate]

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Code Reference

S&T AND BEARING STRESS LIMIT MODEL by Adebar

Column Bearing Stress

	$A_c = 8.1E+05 \text{ [mm}^2\text{]}$	$A_2 = 7.0E+06 \text{ [mm}^2\text{]}$	
	$\alpha = 0.33 \left(\sqrt{\frac{A_2}{A_c}} - 1 \right) \leq 1.0$	= 0.65	
	$\beta = 0.33 \left(\frac{2d}{\sqrt{A_c}} - 1 \right) \leq 1.0$	= 0.20	
Allowable stress	$f_b = \phi_c (0.6 f'_c + 6\alpha\beta\sqrt{f'_c})$	= 14.5	[MPa]
Column stress	$f_{cb} = P_{cf} / (b_c \times h_c)$	= 0.9	[MPa]
		< f_b	OK

Pile Bearing Stress

	$A_p = 8.2E+04 \text{ [mm}^2\text{]}$	$A_2 = 7.9E+05 \text{ [mm}^2\text{]}$	
	$\alpha = 0.33 \left(\sqrt{\frac{A_2}{A_p}} - 1 \right) \leq 1.0$	= 0.70	
	$\beta = 0.33 \left(\frac{d}{d_p} - 1 \right) \leq 1.0$	= 0.41	
Allowable stress	$f_b = \phi_c (0.6 f'_c + 6\alpha\beta\sqrt{f'_c})$	= 17.8	[MPa]
Pile stress	$f_{cb} = Q_{pr} / (\pi * d_p^2 / 4)$	= 2.7	[MPa]
		< f_b	OK

Required Reinf

	$b_1 = 375 \text{ [mm]}$	$h_1 = 875 \text{ [mm]}$	
	$l = \text{sqrt}(b_1^2 + h_1^2)$	= 952	[mm]
	$F_h = l / d \times Q_{pr}$	= 293	[kN]
Vertical direction	$F_{T1} = h_1 / l \times F_h$	= 269	[kN]
	$A_{s1} = F_{T1} / (\phi_s \times f_y)$	= 792	[mm ²]
	$A_{smin} = 0.2\% \times b_f \times t_f / 2$	= 1980	[mm ²]
	$A_{s1} = \max(A_{s1}, A_{smin})$	= 1980	[mm ²]
	$A_{s1 \text{ prov}} =$	1650	[mm ²]
		< A_{s1}	NG
Horizontal direction	$F_{T2} = b_1 / l \times F_h$	= 115	[kN]
	$A_{s2} = F_{T2} / (\phi_s \times f_y)$	= 339	[mm ²]
	$A_{smin} = 0.2\% \times h_f \times t_f / 2$	= 2880	[mm ²]
	$A_{s2} = \max(A_{s1}, A_{smin})$	= 2880	[mm ²]
	$A_{s2 \text{ prov}} =$	2400	[mm ²]
		< A_{s2}	NG

[Pilecap Reinf by S&T Model Is NOT Adequate]

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REDUCED LEVER ARM MODEL by Park and Paulay

Vertical Direction

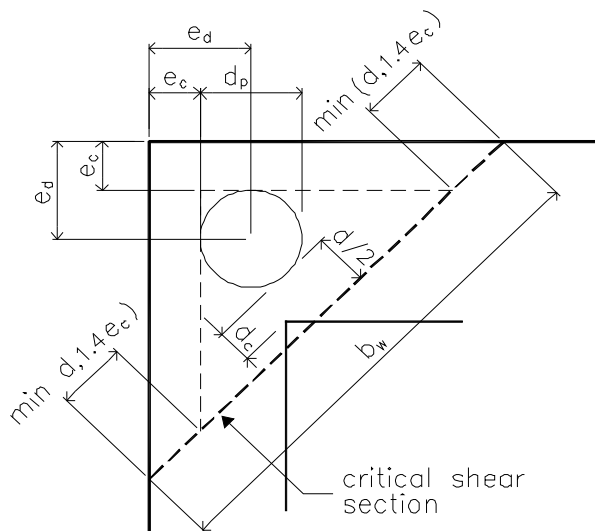
$$\begin{aligned}
 dV_f / M_f &= 1.11 > 1.0 \rightarrow \text{pilecap acts as deep beam} \\
 dV_f / M_f &< 2.0 & M_f / V_f &= 650 \quad [\text{mm}] \\
 z &= 0.4(d + M_f / V_f) \text{ for } dV_f / M_f \geq 1.0 & &= 548 \quad [\text{mm}] \\
 &1.2 M_f / V_f \quad \text{for } dV_f / M_f \geq 2.0 \\
 A_{s\text{ver}} &= M_f / (\phi_s f_y z) & &= 1546 \quad [\text{mm}^2] \\
 A_{s\text{min}} &= 0.2\% \times b_f \times t_f & &= 3960 \quad [\text{mm}^2] \\
 A_{s\text{ver}} &= \max(A_{s\text{ver}}, A_{s\text{min}}) & &= 3960 \quad [\text{mm}^2] \\
 A_{s\text{prov}} &= 2 \times A_{s1\text{ prov}} & &= 3300 \quad [\text{mm}^2] \\
 &< A_{s\text{ver}} & &\text{NG}
 \end{aligned}$$

Horizontal Direction

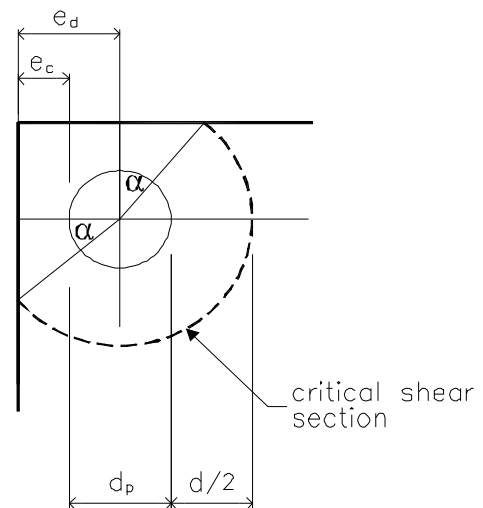
$$\begin{aligned}
 dV_f / M_f &= 4.80 > 1.0 \rightarrow \text{pilecap acts as deep beam} \\
 dV_f / M_f &> 2.0 & M_f / V_f &= 150 \quad [\text{mm}] \\
 z &= 0.4(d + M_f / V_f) \text{ for } dV_f / M_f \geq 1.0 & &= 180 \quad [\text{mm}] \\
 &1.2 M_f / V_f \quad \text{for } dV_f / M_f \geq 2.0 \\
 A_{s\text{hor}} &= M_f / (\phi_s f_y z) & &= 1086 \quad [\text{mm}^2] \\
 A_{s\text{min}} &= 0.2\% \times h_f \times t_f & &= 5760 \quad [\text{mm}^2] \\
 A_{s\text{hor}} &= \max(A_{s\text{hor}}, A_{s\text{min}}) & &= 5760 \quad [\text{mm}^2] \\
 A_{s\text{prov}} &= 2 \times A_{s2\text{ prov}} & &= 4800 \quad [\text{mm}^2] \\
 &< A_{s\text{hor}} & &\text{NG}
 \end{aligned}$$

[Deep Beam Model Is Applicable]

[Pilecap Reinf by Deep Beam Model is NOT Adequate]



Corner Pile One-Way Shear



Corner Pile Two-Way Shear

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CORNER PILE ONE WAY SHEAR

Code Reference

A23.3-04

Factored pile load	$V_f = 222$	[kN]			
Pile diameter	$d_p = 324$	[mm]			
Pile edge distance	$e_d = 500$	[mm]	$e_c = 338$	[mm]	
Pilecap effective depth	$d = 720$	[mm]	$d/2 = 360$	[mm]	
Dist from pile edge to col corner	$d_c = 505$	[mm]	$d_c + 50 = 555$	[mm]	
			$> d/2$		
Critical shear line doesn't intersect column, one way shear shall be checked					
	$\text{sqrt}(f'_c) = \min(\text{sqrt}(f'_c), 8)$		$= 5.477$	[MPa]	11.3.4
	$\min(d, 1.414 e_c) = 478$	[mm]	$b_w = 2458$	[mm]	
When no transverse reinf.	$\beta = 230 / (1000 + d)$		$= 0.134$		11.3.6.3 Eq (11-9)
	$V_c = \phi_c \lambda \beta \sqrt{f'_c} b_w d$		$= 843$	[kN]	11.3.4 Eq (11-6)
			$> V_f$		OK

CORNER PILE TWO WAY SHEAR

Factored pile load	$V_f = 222$	[kN]			
Pile diameter	$d_p = 324$	[mm]			
Pile edge distance	$e_d = 500$	[mm]	$e_c = 338$	[mm]	
Pilecap effective depth	$d = 720$	[mm]	$d/2 = 360$	[mm]	
Dist from pile edge to col corner	$d_c = 505$	[mm]	$d_c + 50 = 555$	[mm]	
			$> d/2$		
Critical shear line doesn't intersect column, one way shear shall be checked					
	$\alpha = 16.7$				
Critical perimeter length	$b_o = \pi (d_p + d) (270 - 2\alpha) / 360$		$= 2156$	[mm]	
	$v_{c1} = \left(1 + \frac{2}{\beta_c}\right) 0.19 \lambda \phi_c \sqrt{f'_c}$		$= 2.029$	[MPa]	13.3.4.1 (13-5)
	$\beta_c = \text{width} / \text{length} = 1$ for pile				
	$v_{c2} = \left(\frac{\alpha_s d}{b_o} + 0.19\right) \lambda \phi_c \sqrt{f'_c}$		$= 3.055$	[MPa]	13.3.4.1 (13-6)
	$\alpha_s = 2$ for corner pile				
	$v_{c3} = 0.38 \lambda \phi_c \sqrt{f'_c}$		$= 1.353$	[MPa]	13.3.4.1 (13-7)
	$v_c = \min(v_{c1}, v_{c2}, v_{c3})$		$= 1.353$	[MPa]	
	$V_c = v_c b_o d$		$= 2100$	[kN]	
			$> V_f$		OK

[Pile One and Two Way Shear Is Adequate]

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COLUMN ONE WAY SHEAR

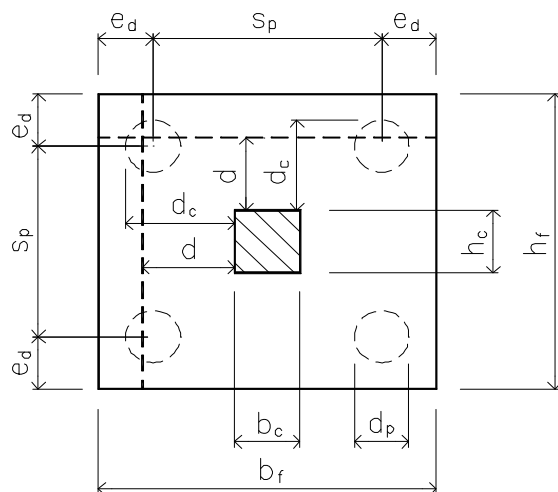
Factored single pile load	$Q_{pr} = 222$	[kN]	$b_c = 900$	[mm]
Pile diameter	$d_p = 324$	[mm]	$h_c = 900$	[mm]
Pile edge distance	$e_d = 500$	[mm]	$b_f = 2200$	[mm]
Pilecap effective depth	$d = 720$	[mm]	$h_f = 3200$	[mm]

Ver Critical Shear Line

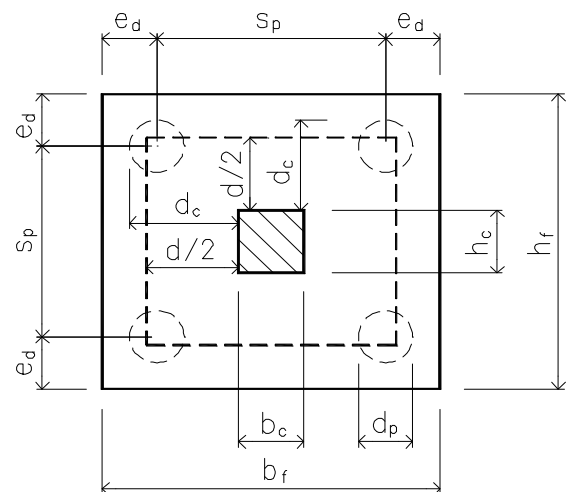
Dist from col face to pile edge	$d_c = 312$	[mm]		
Fraction of pile outside critical line	$r = 0.00$			
Factored shear force	$V_f = r \times 2 \times Q_{pr}$		$= 0$	[kN]
	$b_w = h_f$		$= 3200$	[mm]
When no transverse reinf.	$\beta = 230 / (1000 + d)$		$= 0.134$	11.3.6.3 Eq (11-9)
	$V_c = \phi_c \lambda \beta \sqrt{f'_c} b_w d$		$= 1097$	[kN] 11.3.4 Eq (11-6)
			$> V_f$	OK

Hor Critical Shear Line

Dist from col face to pile edge	$d_c = 812$	[mm]		
Fraction of pile outside critical line	$r = 0.28$			
Factored shear force	$V_f = r \times 2 \times Q_{pr}$		$= 126$	[kN]
	$b_w = b_f$		$= 2200$	[mm]
When no transverse reinf.	$\beta = 230 / (1000 + d)$		$= 0.134$	11.3.6.3 Eq (11-9)
	$V_c = \phi_c \lambda \beta \sqrt{f'_c} b_w d$		$= 754$	[kN] 11.3.4 Eq (11-6)
			$> V_f$	OK



Column One-Way Shear



Column Two-Way Shear

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COLUMN TWO WAY SHEAR

A23.3-04

Factored single pile load	$Q_{pr} = 222$	[kN]	$b_c = 900$	[mm]
Pile diameter	$d_p = 324$	[mm]	$h_c = 900$	[mm]
Pile edge distance	$e_d = 500$	[mm]	$b_f = 2200$	[mm]
Pilecap effective depth	$d = 720$	[mm]	$h_f = 3200$	[mm]

Ver Critical Shear Line

Dist from col face to pile edge	$d_c = 312$	[mm]
Fraction of pile outside critical line	$r_1 = 0.00$	

Hor Critical Shear Line

Dist from col face to pile edge	$d_c = 812$	[mm]
Fraction of pile outside critical line	$r_2 = 1.00$	

Factored shear force	$V_f = 886$	[kN]		
Critical perimeter length	$b_o = 2x(b_c + d + h_c + d)$		$= 6480$	[mm]

$$v_{c1} = \left(1 + \frac{2}{\beta_c}\right) 0.19 \lambda \phi_c \sqrt{f'_c} = 2.029 \text{ [MPa]} \quad 13.3.4.1 (13-5)$$

$$\beta_c = \text{col length} / \text{col width} = 1.0$$

$$v_{c2} = \left(\frac{\alpha_s d}{b_o} + 0.19\right) \lambda \phi_c \sqrt{f'_c} = 2.259 \text{ [MPa]} \quad 13.3.4.1 (13-6)$$

$$\alpha_s = 4 \quad \text{for interior column}$$

$$v_{c3} = 0.38 \lambda \phi_c \sqrt{f'_c} = 1.353 \text{ [MPa]} \quad 13.3.4.1 (13-7)$$

$$v_c = \min(v_{c1}, v_{c2}, v_{c3}) = 1.353 \text{ [MPa]}$$

$$V_r = v_c b_o d = 6312 \text{ [kN]}$$

$$> V_f \quad \text{OK}$$

[Column One and Two Way Shear Is Adequate]

5-Pile Pilecap Design Example

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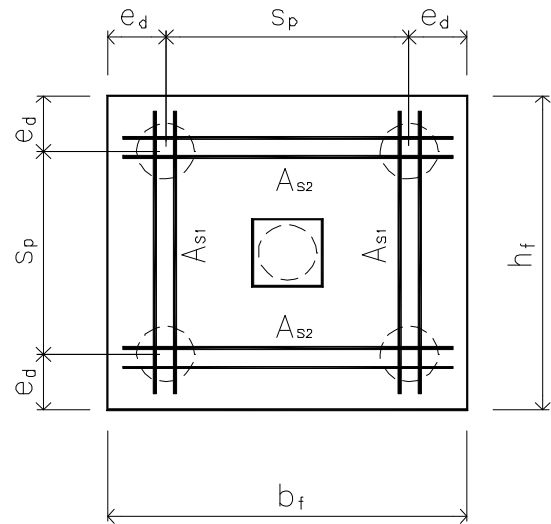
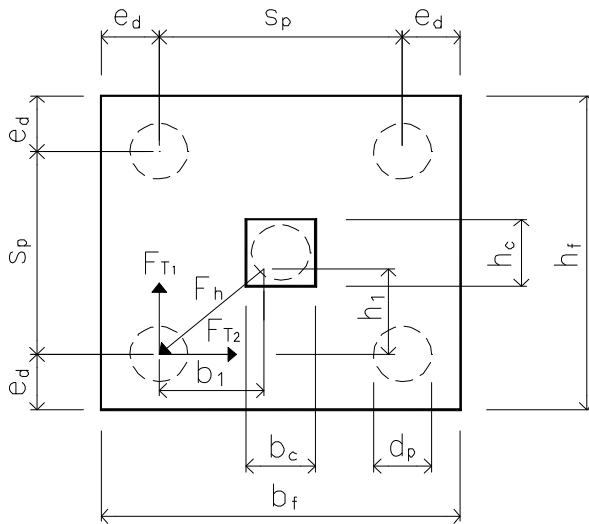
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DESCRIPTION

5 piles pilecap design based on
A23.3-04 Design of Concrete Structures

Code Abbreviation

A23.3-04



INPUT

Factored column load	$P_{cf} = 2500$ [kN]	Vertical reinf.	
Column width	$b_c = 880$ [mm]	A_{s1} bar size = 25	500
Column length	$h_c = 440$ [mm]	A_{s1} bar No = 7	
Pilecap width	$b_f = 2061$ [mm]	$A_{s1 \text{ prov}} = 3500$	
Pilecap length	$h_f = 2061$ [mm]	Equivalent to 25 @ 143	
Pilecap thickness	$t_f = 600$ [mm]		
		Horizontal reinf.	
Pile diameter	$d_p = 250$ [mm]	A_{s2} bar size = 25	500
Pile spacing	$s_p = 1061$ [mm]	A_{s2} bar No = 7	
Pile edge distance	$e_d = 500$ [mm]	$A_{s2 \text{ prov}} = 3500$	
		Equivalent to 25 @ 143	
Concrete strength	$f'_c = 30$ [MPa]		
Rebar yield strength	$f_y = 400$ [MPa]		
Concrete resistance factor	$\phi_c = 0.65$		
Rebar resistance factor	$\phi_s = 0.85$		
Low density conc factor	$\lambda = 1.0$		
Backfill soil weight above cap	$W_s = 0$ [kN]		
Pilecap self weight	$W_f = b_f \times h_f \times t_f \times 23.5$	= 60 [kN]	

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Factored total pilecap load	$P_f = P_{cf} + W_s + W_f$	= 2575	[kN]
Pilecap effective depth	$d = t_f - 1.5d_b - 150$	= 420	[mm]
Factored pile axial reaction	$Q_{pr} = P_f / 5$	= 515	[kN]
Vertical Direction			
Factored moment to column face	$M_f = 2 \times Q_{pr} \times 0.5(S_p - h_c)$	= 320	[kNm]
Factored shear to column face	$V_f = 2 \times Q_{pr}$	= 1030	[kN]
Horizontal Direction			
Factored moment to column face	$M_f = 2 \times Q_{pr} \times 0.5(S_p - b_c)$	= 93	[kNm]
Factored shear to column face	$V_f = 2 \times Q_{pr}$	= 1030	[kN]

CONCLUSION

[Pilecap Reinf by S&T Model Is Adequate]

[Pilecap Reinf by Deep Beam Model Is Adequate]

[Pile One and Two Way Shear Is NOT Adequate]

[Column One and Two Way Shear Is Adequate]

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Code Reference

S&T AND BEARING STRESS LIMIT MODEL by Adebar

Column Bearing Stress

	$A_c = 3.9E+05 \text{ [mm}^2\text{]}$	$A_2 = 4.2E+06 \text{ [mm}^2\text{]}$	
	$\alpha = 0.33 \left(\sqrt{\frac{A_2}{A_c}} - 1 \right) \leq 1.0$	$= 0.77$	
	$\beta = 0.33 \left(\frac{2d}{\sqrt{A_c}} - 1 \right) \leq 1.0$	$= 0.12$	
Allowable stress	$f_b = \phi_c (0.6 f'_c + 6\alpha\beta\sqrt{f'_c})$	$= 13.6$	[MPa]
Column stress	$f_{cb} = P_{cf} / (b_c \times h_c)$	$= 6.5$	[MPa]
		$< f_b$	OK

Pile Bearing Stress

	$A_p = 4.9E+04 \text{ [mm}^2\text{]}$	$A_2 = 7.9E+05 \text{ [mm}^2\text{]}$	
	$\alpha = 0.33 \left(\sqrt{\frac{A_2}{A_p}} - 1 \right) \leq 1.0$	$= 1.00$	
	$\beta = 0.33 \left(\frac{d}{d_p} - 1 \right) \leq 1.0$	$= 0.23$	
Allowable stress	$f_b = \phi_c (0.6 f'_c + 6\alpha\beta\sqrt{f'_c})$	$= 16.5$	[MPa]
Pile stress	$f_{cb} = Q_{pr} / (\pi * d_p^2 / 4)$	$= 10.5$	[MPa]
		$< f_b$	OK

Required Reinf

	$b_1 = 311 \text{ [mm]}$	$h_1 = 421 \text{ [mm]}$	
	$l = \text{sqrt}(b_1^2 + h_1^2)$	$= 523 \text{ [mm]}$	
	$F_h = l / d \times Q_{pr}$	$= 641 \text{ [kN]}$	
Vertical direction	$F_{T1} = h_1 / l \times F_h$	$= 516 \text{ [kN]}$	
	$A_{s1} = F_{T1} / (\phi_s \times f_y)$	$= 1516 \text{ [mm}^2\text{]}$	
	$A_{smin} = 0.2\% \times b_f \times t_f / 2$	$= 1237 \text{ [mm}^2\text{]}$	
	$A_{s1} = \max(A_{s1}, A_{smin})$	$= 1516 \text{ [mm}^2\text{]}$	
	$A_{s1 \text{ prov}} =$	$3500 \text{ [mm}^2\text{]}$	
		$> A_{s1}$	OK
Horizontal direction	$F_{T2} = b_1 / l \times F_h$	$= 381 \text{ [kN]}$	
	$A_{s2} = F_{T2} / (\phi_s \times f_y)$	$= 1120 \text{ [mm}^2\text{]}$	
	$A_{smin} = 0.2\% \times h_f \times t_f / 2$	$= 1237 \text{ [mm}^2\text{]}$	
	$A_{s2} = \max(A_{s1}, A_{smin})$	$= 1237 \text{ [mm}^2\text{]}$	
	$A_{s2 \text{ prov}} =$	$3500 \text{ [mm}^2\text{]}$	
		$> A_{s2}$	OK

[Pilecap Reinf by S&T Model Is Adequate]

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REDUCED LEVER ARM MODEL by Park and Paulay

Vertical Direction

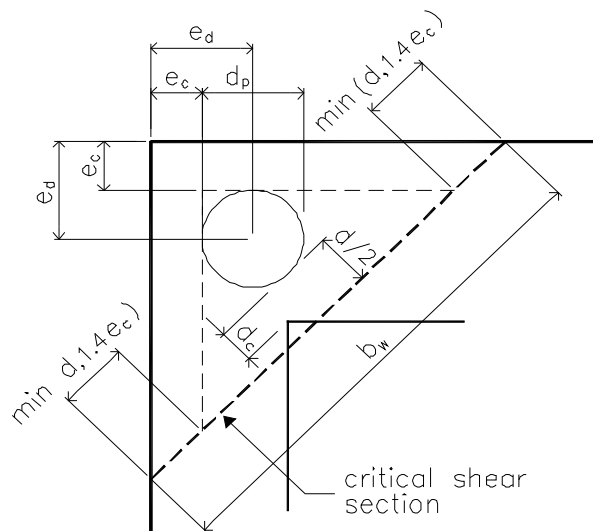
$$\begin{aligned}
 dV_f / M_f &= 1.35 > 1.0 \rightarrow \text{pilecap acts as deep beam} \\
 dV_f / M_f &< 2.0 & M_f / V_f &= 311 \quad [\text{mm}] \\
 z &= 0.4(d + M_f / V_f) \text{ for } dV_f / M_f \geq 1.0 & &= 292 \quad [\text{mm}] \\
 &1.2 M_f / V_f \quad \text{for } dV_f / M_f \geq 2.0 \\
 A_{s\text{ver}} &= M_f / (\phi_s f_y z) & &= 3219 \quad [\text{mm}^2] \\
 A_{s\text{min}} &= 0.2\% \times b_f \times t_f & &= 2473 \quad [\text{mm}^2] \\
 A_{s\text{ver}} &= \max(A_{s\text{ver}}, A_{s\text{min}}) & &= 3219 \quad [\text{mm}^2] \\
 A_{s\text{prov}} &= 2 \times A_{s1\text{ prov}} & &= 7000 \quad [\text{mm}^2] \\
 &> A_{s\text{ver}} & \text{OK}
 \end{aligned}$$

Horizontal Direction

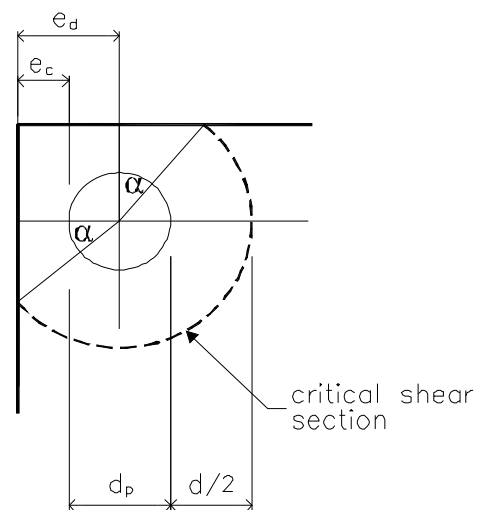
$$\begin{aligned}
 dV_f / M_f &= 4.64 > 1.0 \rightarrow \text{pilecap acts as deep beam} \\
 dV_f / M_f &> 2.0 & M_f / V_f &= 91 \quad [\text{mm}] \\
 z &= 0.4(d + M_f / V_f) \text{ for } dV_f / M_f \geq 1.0 & &= 109 \quad [\text{mm}] \\
 &1.2 M_f / V_f \quad \text{for } dV_f / M_f \geq 2.0 \\
 A_{s\text{hor}} &= M_f / (\phi_s f_y z) & &= 2524 \quad [\text{mm}^2] \\
 A_{s\text{min}} &= 0.2\% \times h_f \times t_f & &= 2473 \quad [\text{mm}^2] \\
 A_{s\text{hor}} &= \max(A_{s\text{hor}}, A_{s\text{min}}) & &= 2524 \quad [\text{mm}^2] \\
 A_{s\text{prov}} &= 2 \times A_{s2\text{ prov}} & &= 7000 \quad [\text{mm}^2] \\
 &> A_{s\text{hor}} & \text{OK}
 \end{aligned}$$

[Deep Beam Model Is Applicable]

[Pilecap Reinf't by Deep Beam Model Is Adequate]



Corner Pile One-Way Shear



Corner Pile Two-Way Shear

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CORNER PILE ONE WAY SHEAR

Code Reference

A23.3-04

Factored pile load	$V_f = 515$	[kN]		
Pile diameter	$d_p = 250$	[mm]		
Pile edge distance	$e_d = 500$	[mm]	$e_c = 375$	[mm]
Pilecap effective depth	$d = 420$	[mm]	$d/2 = 210$	[mm]
Dist from pile edge to col corner	$d_c = 198$	[mm]	$d_c + 50 = 248$	[mm]
			$> d/2$	
Critical shear line doesn't intersect column, one way shear shall be checked				
	$\text{sqrt}(f'_c) = \min(\text{sqrt}(f'_c), 8)$		$= 5.477$	[MPa] 11.3.4
	$\min(d, 1.414 e_c) = 420$	[mm]	$b_w = 1864$	[mm]
When no transverse reinf.	$\beta = 230 / (1000 + d)$		$= 0.162$	11.3.6.3 Eq (11-9)
	$V_c = \phi_c \lambda \beta \sqrt{f'_c} b_w d$		$= 451$	[kN] 11.3.4 Eq (11-6)
			$< V_f$	NG

CORNER PILE TWO WAY SHEAR

Factored pile load	$V_f = 515$	[kN]		
Pile diameter	$d_p = 250$	[mm]		
Pile edge distance	$e_d = 500$	[mm]	$e_c = 375$	[mm]
Pilecap effective depth	$d = 420$	[mm]	$d/2 = 210$	[mm]
Dist from pile edge to col corner	$d_c = 198$	[mm]	$d_c + 50 = 248$	[mm]
			$> d/2$	
Critical shear line doesn't intersect column, one way shear shall be checked				
	$\alpha = 0.0$			
Critical perimeter length	$b_o = \pi (d_p + d) (270 - 2\alpha) / 360$		$= 1579$	[mm]
	$v_{c1} = \left(1 + \frac{2}{\beta_c}\right) 0.19 \lambda \phi_c \sqrt{f'_c}$		$= 2.029$	[MPa] 13.3.4.1 (13-5)
	$\beta_c = \text{width} / \text{length} = 1$ for pile			
	$v_{c2} = \left(\frac{\alpha_s d}{b_o} + 0.19\right) \lambda \phi_c \sqrt{f'_c}$		$= 2.571$	[MPa] 13.3.4.1 (13-6)
	$\alpha_s = 2$ for corner pile			
	$v_{c3} = 0.38 \lambda \phi_c \sqrt{f'_c}$		$= 1.353$	[MPa] 13.3.4.1 (13-7)
	$v_c = \min(v_{c1}, v_{c2}, v_{c3})$		$= 1.353$	[MPa]
	$V_c = v_c b_o d$		$= 897$	[kN]
			$> V_f$	OK

[Pile One and Two Way Shear Is NOT Adequate]

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COLUMN ONE WAY SHEAR

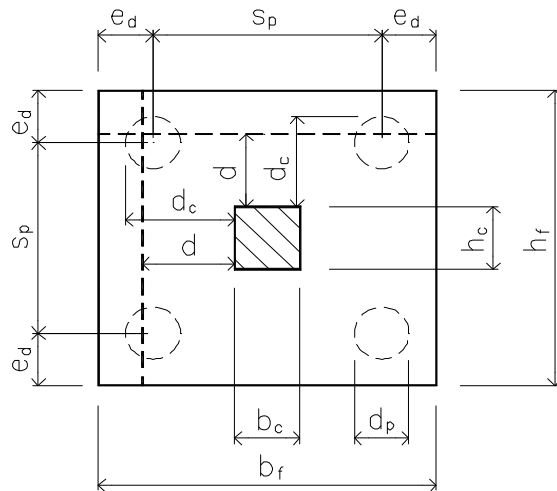
Factored single pile load	$Q_{pr} = 515$	[kN]	$b_c = 880$	[mm]
Pile diameter	$d_p = 250$	[mm]	$h_c = 440$	[mm]
Pile edge distance	$e_d = 500$	[mm]	$b_f = 2061$	[mm]
Pilecap effective depth	$d = 420$	[mm]	$h_f = 2061$	[mm]

Ver Critical Shear Line

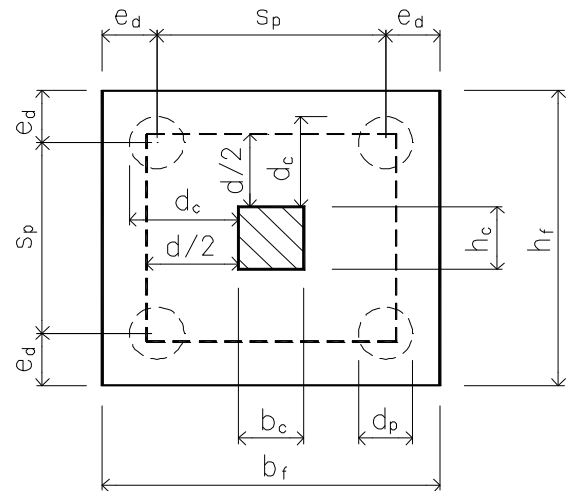
Dist from col face to pile edge	$d_c = 216$	[mm]		
Fraction of pile outside critical line	$r = 0.00$			
Factored shear force	$V_f = r \times 2 \times Q_{pr}$		$= 0$	[kN]
	$b_w = h_f$		$= 2061$	[mm]
When no transverse reinf.	$\beta = 230 / (1000 + d)$		$= 0.162$	11.3.6.3 Eq (11-9)
	$V_c = \phi_c \lambda \beta \sqrt{f'_c} b_w d$		$= 499$	[kN] 11.3.4 Eq (11-6)
			$> V_f$	OK

Hor Critical Shear Line

Dist from col face to pile edge	$d_c = 436$	[mm]		
Fraction of pile outside critical line	$r = 0.06$			
Factored shear force	$V_f = r \times 2 \times Q_{pr}$		$= 64$	[kN]
	$b_w = b_f$		$= 2061$	[mm]
When no transverse reinf.	$\beta = 230 / (1000 + d)$		$= 0.162$	11.3.6.3 Eq (11-9)
	$V_c = \phi_c \lambda \beta \sqrt{f'_c} b_w d$		$= 499$	[kN] 11.3.4 Eq (11-6)
			$> V_f$	OK



Column One-Way Shear



Column Two-Way Shear

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COLUMN TWO WAY SHEAR

A23.3-04

Factored single pile load	$Q_{pr} = 515$	[kN]	$b_c = 880$	[mm]
Pile diameter	$d_p = 250$	[mm]	$h_c = 440$	[mm]
Pile edge distance	$e_d = 500$	[mm]	$b_f = 2061$	[mm]
Pilecap effective depth	$d = 420$	[mm]	$h_f = 2061$	[mm]

Ver Critical Shear Line

Dist from col face to pile edge	$d_c = 216$	[mm]
Fraction of pile outside critical line	$r_1 = 0.02$	

Hor Critical Shear Line

Dist from col face to pile edge	$d_c = 436$	[mm]
Fraction of pile outside critical line	$r_2 = 0.90$	

Factored shear force	$V_f = 1862$	[kN]		
Critical perimeter length	$b_o = 2x(b_c + d + h_c + d)$		$= 4320$	[mm]

$$v_{c1} = \left(1 + \frac{2}{\beta_c}\right) 0.19 \lambda \phi_c \sqrt{f'_c} = 1.353 \text{ [MPa]} \quad 13.3.4.1 (13-5)$$

$$\beta_c = \text{col length} / \text{col width} = 2.0$$

$$v_{c2} = \left(\frac{\alpha_s d}{b_o} + 0.19\right) \lambda \phi_c \sqrt{f'_c} = 2.061 \text{ [MPa]} \quad 13.3.4.1 (13-6)$$

$$\alpha_s = 4 \quad \text{for interior column}$$

$$v_{c3} = 0.38 \lambda \phi_c \sqrt{f'_c} = 1.353 \text{ [MPa]} \quad 13.3.4.1 (13-7)$$

$$v_c = \min(v_{c1}, v_{c2}, v_{c3}) = 1.353 \text{ [MPa]}$$

$$V_r = v_c b_o d = 2455 \text{ [kN]}$$

$$> V_f \quad \text{OK}$$

[Column One and Two Way Shear Is Adequate]

6-Pile Pilecap Design Example

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Calculation Sheet	Subject :	Pilecap Design Examples	Rev :	0

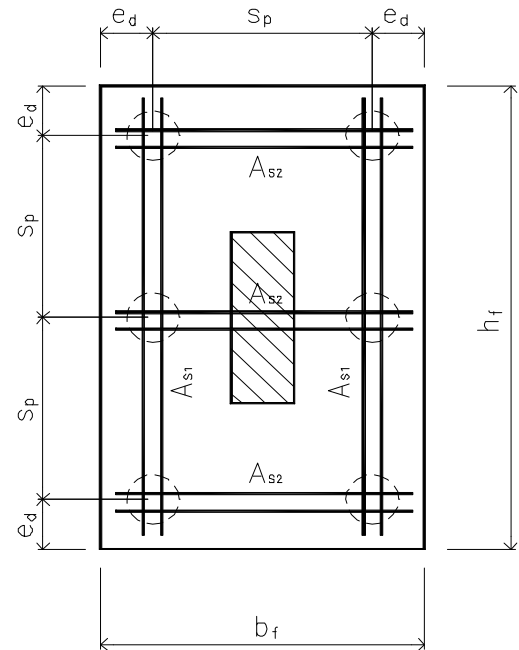
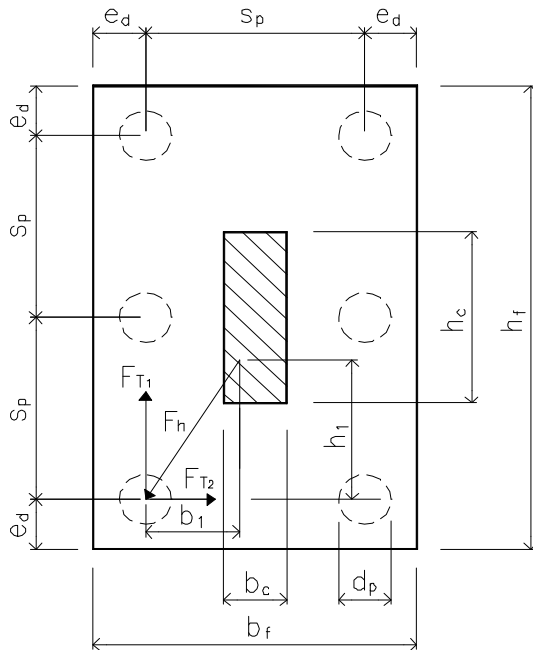
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DESCRIPTION

6 piles pilecap design based on
A23.3-04 Design of Concrete Structures

Code Abbreviation

A23.3-04



INPUT

Factored column load	$P_{cf} = 7500$ [kN]	Vertical reinf.	
Column width	$b_c = 610$ [mm]	A_{s1} bar size = 25	500
Column length	$h_c = 410$ [mm]	A_{s1} bar No = 6	
Pilecap width	$b_f = 2100$ [mm]	$A_{s1 \text{ prov}} = 3000$	
Pilecap length	$h_f = 3000$ [mm]	Equivalent to 25 @ 173	
Pilecap thickness	$t_f = 1180$ [mm]		
		Horizontal reinf.	
Pile diameter	$d_p = 300$ [mm]	A_{s2} bar size = 25	500
Pile spacing	$s_p = 900$ [mm]	A_{s2} bar No = 6	
Pile edge distance	$e_d = 600$ [mm]	$A_{s2 \text{ prov}} = 2750$	
		Equivalent to 25 @ 181	
Concrete strength	$f'_c = 30$ [MPa]		
Rebar yield strength	$f_y = 400$ [MPa]		
Concrete resistance factor	$\phi_c = 0.65$		
Rebar resistance factor	$\phi_s = 0.85$		
Low density conc factor	$\lambda = 1.0$		
Backfill soil weight above cap	$W_s = 10$ [kN]		
Pilecap self weight	$W_f = b_f \times h_f \times t_f \times 23.5$	= 175	[kN]

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Factored total pilecap load	$P_f = P_{cf} + W_s + W_f$	= 7731	[kN]
Pilecap effective depth	$d = t_f - 1.5d_b - 150$	= 1000	[mm]
Factored pile axial reaction	$Q_{pr} = P_f / 6$	= 1288	[kN]
Vertical Direction			
Factored moment to column face	$M_f = 2 \times Q_{pr} \times (S_p - 0.5h_c)$	= 1791	[kNm]
Factored shear to column face	$V_f = 2 \times Q_{pr}$	= 2577	[kN]
Horizontal Direction			
Factored moment to column face	$M_f = 3 \times Q_{pr} \times (S_p - 0.5b_c)$	= 560	[kNm]
Factored shear to column face	$V_f = 3 \times Q_{pr}$	= 3865	[kN]

CONCLUSION

[Pilecap Reinf by S&T Model Is NOT Adequate]

[Pilecap Reinf by Deep Beam Model Is NOT Adequate]

[Pile One and Two Way Shear Is NOT Adequate]

[Column One and Two Way Shear Is Adequate]

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Code Reference

S&T AND BEARING STRESS LIMIT MODEL by Adebar

Column Bearing Stress

	$A_c = 2.5E+05 \text{ [mm}^2\text{]}$	$A_2 = 6.3E+06 \text{ [mm}^2\text{]}$	
	$\alpha = 0.33 \left(\sqrt{\frac{A_2}{A_c}} - 1 \right) \leq 1.0$	$= 1.00$	
	$\beta = 0.33 \left(\frac{2d}{\sqrt{A_c}} - 1 \right) \leq 1.0$	$= 1.00$	
Allowable stress	$f_b = \phi_c (0.6 f'_c + 6\alpha\beta\sqrt{f'_c})$	$= 33.1$	[MPa]
Column stress	$f_{cb} = P_{cf} / (b_c \times h_c)$	$= 30.0$	[MPa]
		$< f_b$	OK

Pile Bearing Stress

	$A_p = 7.1E+04 \text{ [mm}^2\text{]}$	$A_2 = 1.1E+06 \text{ [mm}^2\text{]}$	
	$\alpha = 0.33 \left(\sqrt{\frac{A_2}{A_p}} - 1 \right) \leq 1.0$	$= 1.00$	
	$\beta = 0.33 \left(\frac{d}{d_p} - 1 \right) \leq 1.0$	$= 0.78$	
Allowable stress	$f_b = \phi_c (0.6 f'_c + 6\alpha\beta\sqrt{f'_c})$	$= 28.3$	[MPa]
Pile stress	$f_{cb} = Q_{pr} / (\pi * d_p^2 / 4)$	$= 18.2$	[MPa]
		$< f_b$	OK

Required Reinf

	$b_1 = 298 \text{ [mm]}$	$h_1 = 798 \text{ [mm]}$	
	$l = \text{sqrt}(b_1^2 + h_1^2)$	$= 851 \text{ [mm]}$	
	$F_h = l / d \times Q_{pr}$	$= 1097 \text{ [kN]}$	
Vertical direction	$F_{T1} = h_1 / l \times F_h$	$= 1028 \text{ [kN]}$	
	$A_{s1} = F_{T1} / (\phi_s \times f_y)$	$= 3022 \text{ [mm}^2\text{]}$	
	$A_{smin} = 0.2\% \times b_f \times t_f / 2$	$= 2478 \text{ [mm}^2\text{]}$	
	$A_{s1} = \max(A_{s1}, A_{smin})$	$= 3022 \text{ [mm}^2\text{]}$	
	$A_{s1 \text{ prov}} =$	$3000 \text{ [mm}^2\text{]}$	
		$< A_{s1}$	NG
Horizontal direction	$F_{T2} = b_1 / l \times F_h$	$= 383 \text{ [kN]}$	
	$A_{s2} = F_{T2} / (\phi_s \times f_y)$	$= 1127 \text{ [mm}^2\text{]}$	
	$A_{smin} = 0.2\% \times h_f \times t_f / 3$	$= 2360 \text{ [mm}^2\text{]}$	
	$A_{s2} = \max(A_{s1}, A_{smin})$	$= 2360 \text{ [mm}^2\text{]}$	
	$A_{s2 \text{ prov}} =$	$2750 \text{ [mm}^2\text{]}$	
		$> A_{s2}$	OK

[Pilecap Reinf by S&T Model Is NOT Adequate]

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REDUCED LEVER ARM MODEL by Park and Paulay

Vertical Direction

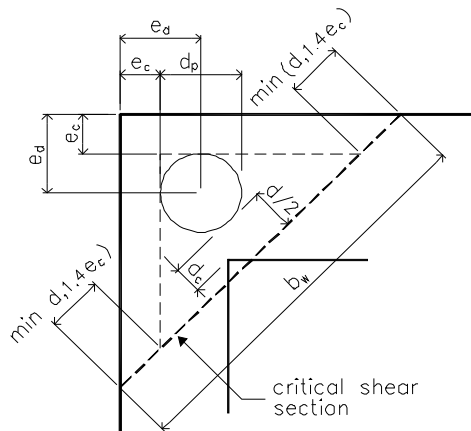
$$\begin{aligned}
 dV_f / M_f &= 1.44 > 1.0 \rightarrow \text{pilecap acts as deep beam} \\
 dV_f / M_f &< 2.0 & M_f / V_f &= 695 \quad [\text{mm}] \\
 z &= 0.4(d + M_f / V_f) \text{ for } dV_f / M_f \geq 1.0 & &= 678 \quad [\text{mm}] \\
 &1.2 M_f / V_f \quad \text{for } dV_f / M_f \geq 2.0 \\
 A_{s\text{ver}} &= M_f / (\phi_s f_y z) & &= 7769 \quad [\text{mm}^2] \\
 A_{s\text{min}} &= 0.2\% \times b_f \times t_f & &= 4956 \quad [\text{mm}^2] \\
 A_{s\text{ver}} &= \max(A_{s\text{ver}}, A_{s\text{min}}) & &= 7769 \quad [\text{mm}^2] \\
 A_{s\text{prov}} &= 2 \times A_{s1\text{ prov}} & &= 6000 \quad [\text{mm}^2] \\
 &< A_{s\text{ver}} & &\text{NG}
 \end{aligned}$$

Horizontal Direction

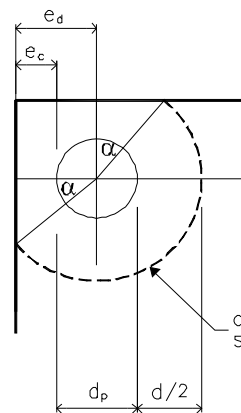
$$\begin{aligned}
 dV_f / M_f &= 6.90 > 1.0 \rightarrow \text{pilecap acts as deep beam} \\
 dV_f / M_f &> 2.0 & M_f / V_f &= 145 \quad [\text{mm}] \\
 z &= 0.4(d + M_f / V_f) \text{ for } dV_f / M_f \geq 1.0 & &= 174 \quad [\text{mm}] \\
 &1.2 M_f / V_f \quad \text{for } dV_f / M_f \geq 2.0 \\
 A_{s\text{hor}} &= M_f / (\phi_s f_y z) & &= 9474 \quad [\text{mm}^2] \\
 A_{s\text{min}} &= 0.2\% \times h_f \times t_f & &= 7080 \quad [\text{mm}^2] \\
 A_{s\text{hor}} &= \max(A_{s\text{hor}}, A_{s\text{min}}) & &= 9474 \quad [\text{mm}^2] \\
 A_{s\text{prov}} &= 3 \times A_{s2\text{ prov}} & &= 8250 \quad [\text{mm}^2] \\
 &< A_{s\text{hor}} & &\text{NG}
 \end{aligned}$$

[Deep Beam Model Is Applicable]

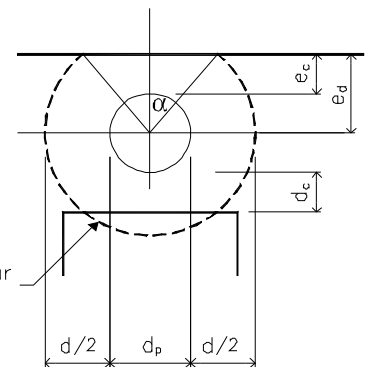
[Pilecap Reinf by Deep Beam Model Is NOT Adequate]



Corner Pile One-Way Shear



Corner Pile Two-Way Shear



Edge Pile Two-Way Shear

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CORNER PILE ONE WAY SHEAR

Code Reference

A23.3-04

Factored pile load	$V_f = 1288$	[kN]		
Pile diameter	$d_p = 300$	[mm]		
Pile edge distance	$e_d = 600$	[mm]	$e_c = 450$	[mm]
Pilecap effective depth	$d = 1000$	[mm]	$d/2 = 500$	[mm]
Dist from pile edge to col corner	$d_c = 560$	[mm]	$d_c + 50 = 610$	[mm]
			$> d/2$	
Critical shear line doesn't intersect column, one way shear shall be checked				
	$\sqrt{f'_c} = \min(\sqrt{f'_c}, 8)$		$= 5.477$	[MPa] 11.3.4
	$\min(d, 1.414 e_c) = 636$	[mm]	$b_w = 2997$	[mm]
When no transverse reinf.	$\beta = 230 / (1000 + d)$		$= 0.115$	11.3.6.3 Eq (11-9)
	$V_c = \phi_c \lambda \beta \sqrt{f'_c} b_w d$		$= 1227$	[kN] 11.3.4 Eq (11-6)
			$< V_f$	NG

CORNER PILE TWO WAY SHEAR

Factored pile load	$V_f = 1288$	[kN]		
Pile diameter	$d_p = 300$	[mm]		
Pile edge distance	$e_d = 600$	[mm]	$e_c = 450$	[mm]
Pilecap effective depth	$d = 1000$	[mm]	$d/2 = 500$	[mm]
Dist from pile edge to col corner	$d_c = 560$	[mm]	$d_c + 50 = 610$	[mm]
			$> d/2$	
Critical shear line doesn't intersect column, one way shear shall be checked				
	$\alpha = 22.6$			
Critical perimeter length	$b_o = \pi (d_p + d) (270 - 2\alpha) / 360$		$= 2550$	[mm]
	$v_{c1} = \left(1 + \frac{2}{\beta_c}\right) 0.19 \lambda \phi_c \sqrt{f'_c}$		$= 2.029$	[MPa] 13.3.4.1 (13-5)
	$\beta_c = \text{width} / \text{length} = 1$ for pile			
	$v_{c2} = \left(\frac{\alpha_s d}{b_o} + 0.19\right) \lambda \phi_c \sqrt{f'_c}$		$= 3.469$	[MPa] 13.3.4.1 (13-6)
	$\alpha_s = 2$ for corner pile			
	$v_{c3} = 0.38 \lambda \phi_c \sqrt{f'_c}$		$= 1.353$	[MPa] 13.3.4.1 (13-7)
	$v_c = \min(v_{c1}, v_{c2}, v_{c3})$		$= 1.353$	[MPa]
	$V_c = v_c b_o d$		$= 3450$	[kN]
			$> V_f$	OK

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EDGE PILE TWO WAY SHEAR

Factored pile load	$V_f = 1288$	[kN]		
Pile diameter	$d_p = 300$	[mm]		
Pile edge distance	$e_d = 600$	[mm]	$e_c = 450$	[mm]
Pilecap effective depth	$d = 1000$	[mm]	$d/2 = 500$	[mm]
Dist from pile edge to col corner	$d_c = -5$	[mm]	$d_c + 50 = 45$	[mm]
			$< d/2$	
Critical shear line intersect column, one way shear needs NOT to be checked				
	$\alpha = 22.6$			
Critical perimeter length	$b_o = \pi (d_p + d) (360 - 2\alpha)/360$		$= 3571$	[mm]
	$v_{c1} = \left(1 + \frac{2}{\beta_c}\right) 0.19 \lambda \phi_c \sqrt{f'_c}$		$= 2.029$	[MPa]
	$\beta_c = \text{width} / \text{length} = 1$ for pile			
	$v_{c2} = \left(\frac{\alpha_s d}{b_o} + 0.19\right) \lambda \phi_c \sqrt{f'_c}$		$= 3.667$	[MPa]
	$\alpha_s = 3$ for edge pile			
	$v_{c3} = 0.38 \lambda \phi_c \sqrt{f'_c}$		$= 1.353$	[MPa]
	$v_c = \min(v_{c1}, v_{c2}, v_{c3})$		$= 1.353$	[MPa]
	$V_r = v_c b_o d$		$= 4831$	[kN]
			$> V_f$	OK

[Pile One and Two Way Shear Is NOT Adequate]

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COLUMN ONE WAY SHEAR

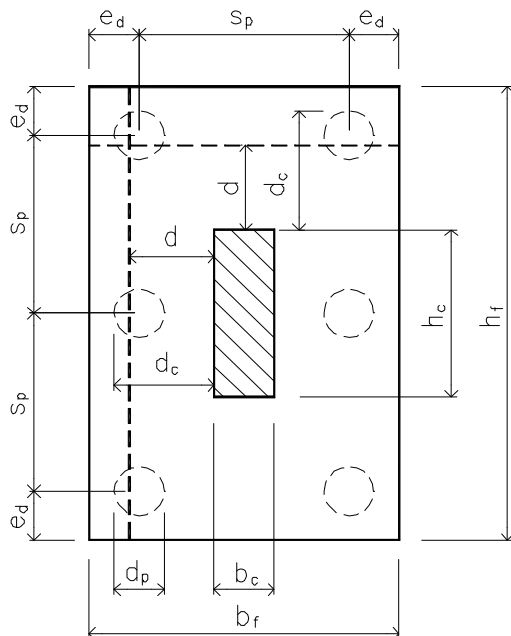
Factored single pile load	$Q_{pr} = 1288$	[kN]	$b_c = 610$	[mm]
Pile diameter	$d_p = 300$	[mm]	$h_c = 410$	[mm]
Pile edge distance	$e_d = 600$	[mm]	$b_f = 2100$	[mm]
Pilecap effective depth	$d = 1000$	[mm]	$h_f = 3000$	[mm]

Ver Critical Shear Line

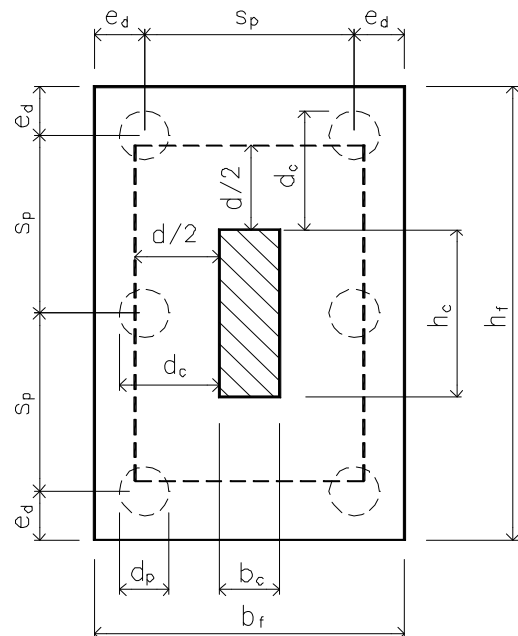
Dist from col face to pile edge	$d_c = 295$	[mm]		
Fraction of pile outside critical line	$r = 0.00$			
Factored shear force	$V_f = r \times 3 \times Q_{pr}$		$= 0$	[kN]
	$b_w = h_f$		$= 3000$	[mm]
When no transverse reinf.	$\beta = 230 / (1000 + d)$		$= 0.115$	11.3.6.3 Eq (11-9)
	$V_c = \phi_c \lambda \beta \sqrt{f'_c} b_w d$		$= 1228$	[kN] 11.3.4 Eq (11-6)
			$> V_f$	OK

Hor Critical Shear Line

Dist from col face to pile edge	$d_c = 845$	[mm]		
Fraction of pile outside critical line	$r = 0.00$			
Factored shear force	$V_f = r \times 2 \times Q_{pr}$		$= 0$	[kN]
	$b_w = b_f$		$= 2100$	[mm]
When no transverse reinf.	$\beta = 230 / (1000 + d)$		$= 0.115$	11.3.6.3 Eq (11-9)
	$V_c = \phi_c \lambda \beta \sqrt{f'_c} b_w d$		$= 860$	[kN] 11.3.4 Eq (11-6)
			$> V_f$	OK



Column One-Way Shear



Column Two-Way Shear

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COLUMN TWO WAY SHEAR

A23.3-04

Factored single pile load	$Q_{pr} = 1288$	[kN]	$b_c = 610$	[mm]
Pile diameter	$d_p = 300$	[mm]	$h_c = 410$	[mm]
Pile edge distance	$e_d = 600$	[mm]	$b_f = 2100$	[mm]
Pilecap effective depth	$d = 1000$	[mm]	$h_f = 3000$	[mm]

Ver Critical Shear Line

Dist from col face to pile edge	$d_c = 295$	[mm]
Fraction of pile outside critical line	$r_1 = 0.00$	

Hor Critical Shear Line

Dist from col face to pile edge	$d_c = 845$	[mm]
Fraction of pile outside critical line	$r_2 = 1.00$	

Factored shear force	$V_f = 5154$	[kN]		
Critical perimeter length	$b_o = 2x(b_c + d + h_c + d)$		$= 6040$	[mm]

$$v_{c1} = \left(1 + \frac{2}{\beta_c}\right) 0.19 \lambda \phi_c \sqrt{f'_c} = 1.586 \text{ [MPa]} \quad 13.3.4.1 (13-5)$$

$$\beta_c = \text{col length} / \text{col width} = 1.49$$

$$v_{c2} = \left(\frac{\alpha_s d}{b_o} + 0.19\right) \lambda \phi_c \sqrt{f'_c} = 3.034 \text{ [MPa]} \quad 13.3.4.1 (13-6)$$

$$\alpha_s = 4 \quad \text{for interior column}$$

$$v_{c3} = 0.38 \lambda \phi_c \sqrt{f'_c} = 1.353 \text{ [MPa]} \quad 13.3.4.1 (13-7)$$

$$v_c = \min(v_{c1}, v_{c2}, v_{c3}) = 1.353 \text{ [MPa]}$$

$$V_r = v_c b_o d = 8171 \text{ [kN]}$$

$$> V_f \quad \text{OK}$$

[Column One and Two Way Shear Is Adequate]

7-Pile Pilecap Design Example

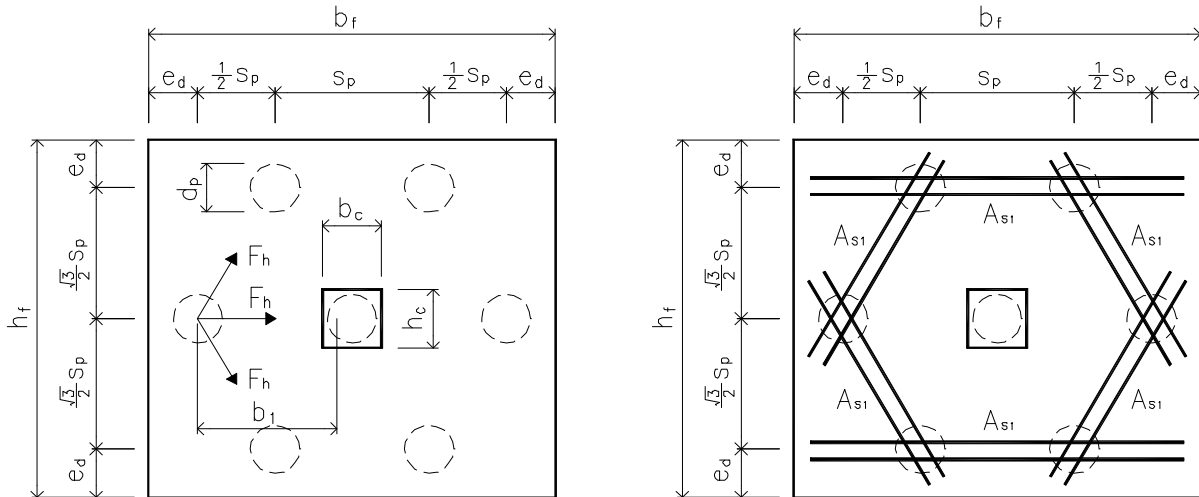
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DESCRIPTION

7 piles pilecap design based on
A23.3-04 Design of Concrete Structures

Code Abbreviation
A23.3-04



INPUT

Factored column load	$P_{cf} = 8750$ [kN]	Ver reinf. in $2x e_d$ width range	
Column width	$b_c = 740$ [mm]	A_{s1} bar size = 20	300
Column length	$h_c = 740$ [mm]	A_{s1} bar No = 12	
Pilecap width	$b_f = 3000$ [mm]	$A_{s1 \text{ prov}} = 3450$	
Pilecap length	$h_f = 2759$ [mm]	Equivalent to 20 @ 114	
Pilecap thickness	$t_f = 960$ [mm]		
		Hor reinf. in $2x e_d$ width range	
Pile diameter	$d_p = 300$ [mm]	A_{s2} bar size = 20	300
Pile spacing	$s_p = 900$ [mm]	A_{s2} bar No = 12	
Pile edge distance	$e_d = 600$ [mm]	$A_{s2 \text{ prov}} = 3450$	
		Equivalent to 20 @ 114	
Concrete strength	$f'_c = 30$ [MPa]		
Rebar yield strength	$f_y = 400$ [MPa]		
Concrete resistance factor	$\phi_c = 0.65$		
Rebar resistance factor	$\phi_s = 0.85$		
Low density conc factor	$\lambda = 1.0$		
Backfill soil weight above cap	$W_s = 0$ [kN]		
Pilecap self weight	$W_f = b_f \times h_f \times t_f \times 23.5$	= 187 [kN]	

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Factored total pilecap load	$P_f = P_{cf} + W_s + W_f$	= 8983	[kN]
Pilecap effective depth	$d = t_f - 1.5d_b - 150$	= 780	[mm]
Factored pile axial reaction	$Q_{pr} = P_f / 7$	= 1283	[kN]
Vertical Direction			
Factored moment to column face	$M_f = 2 \times Q_{pr} \times (0.866S_p - 0.5h_c)$	= 1051	[kNm]
Factored shear to column face	$V_f = 2 \times Q_{pr}$	= 2567	[kN]
Horizontal Direction			
Factored moment to column face	$M_f = 2Q_{pr} 0.5(S_p - b_c) + Q_{pr}(S_p - 0.5b_c)$	= 886	[kNm]
Factored shear to column face	$V_f = 3 \times Q_{pr}$	= 3850	[kN]

CONCLUSION

[Pilecap Reinf by S&T Model Is NOT Adequate]

[Pilecap Reinf by Deep Beam Model Is NOT Adequate]

[Edge Pile Two Way Shear Is Adequate]

[Column One and Two Way Shear Is Adequate]

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Code Reference

S&T AND BEARING STRESS LIMIT MODEL by Adebar

Column Bearing Stress

	$A_c = 5.5E+05 \text{ [mm}^2\text{]}$	$A_2 = 8.3E+06 \text{ [mm}^2\text{]}$	
	$\alpha = 0.33 \left(\sqrt{\frac{A_2}{A_c}} - 1 \right) \leq 1.0$	= 0.96	
	$\beta = 0.33 \left(\frac{2d}{\sqrt{A_c}} - 1 \right) \leq 1.0$	= 0.37	
Allowable stress	$f_b = \phi_c (0.6 f'_c + 6\alpha\beta\sqrt{f'_c})$	= 19.3	[MPa]
Column stress	$f_{cb} = P_{cf} / (b_c \times h_c)$	= 16.0	[MPa]
		< f_b	OK

Pile Bearing Stress

	$A_p = 7.1E+04 \text{ [mm}^2\text{]}$	$A_2 = 1.1E+06 \text{ [mm}^2\text{]}$	
	$\alpha = 0.33 \left(\sqrt{\frac{A_2}{A_p}} - 1 \right) \leq 1.0$	= 1.00	
	$\beta = 0.33 \left(\frac{d}{d_p} - 1 \right) \leq 1.0$	= 0.53	
Allowable stress	$f_b = \phi_c (0.6 f'_c + 6\alpha\beta\sqrt{f'_c})$	= 23.1	[MPa]
Pile stress	$f_{cb} = Q_{pr} / (\pi * d_p^2 / 4)$	= 18.2	[MPa]
		< f_b	OK

Required Reinf

$b_1 = 715$	[mm]		
$F_h = b_1 / d \times Q_{pr}$		= 1176	[kN]
$A_{s1} = F_h / (\phi_s \times f_y)$		= 3460	[mm ²]
$A_{smin} = 0.2\% \times b_t \times t_f / 2$		= 2880	[mm ²]
$A_{s1} = \max (A_{s1}, A_{smin})$		= 3460	[mm ²]
$A_{s1 \text{ prov}} =$		3450	[mm ²]
		< A_{s1}	NG

[Pilecap Reinf by S&T Model Is NOT Adequate]

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REDUCED LEVER ARM MODEL by Park and Paulay

Vertical Direction

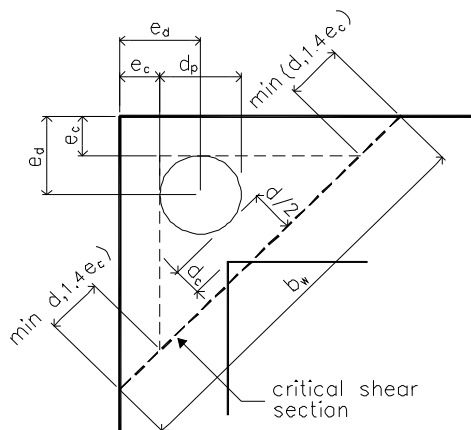
$$\begin{aligned}
 dV_f / M_f &= 1.91 > 1.0 \rightarrow \text{pilecap acts as deep beam} \\
 dV_f / M_f &< 2.0 & M_f / V_f &= 409 \quad [\text{mm}] \\
 z &= 0.4(d + M_f / V_f) \text{ for } dV_f / M_f \geq 1.0 & &= 476 \quad [\text{mm}] \\
 &1.2 M_f / V_f \quad \text{for } dV_f / M_f \geq 2.0 \\
 A_{s\text{ver}} &= M_f / (\phi_s f_y z) & &= 6496 \quad [\text{mm}^2] \\
 A_{s\text{min}} &= 0.2\% \times b_f \times t_f & &= 5760 \quad [\text{mm}^2] \\
 A_{s\text{ver}} &= \max(A_{s\text{ver}}, A_{s\text{min}}) & &= 6496 \quad [\text{mm}^2] \\
 A_{s\text{prov}} &= & &= 7350 \quad [\text{mm}^2] \\
 &> A_{s\text{ver}} & \text{OK}
 \end{aligned}$$

Horizontal Direction

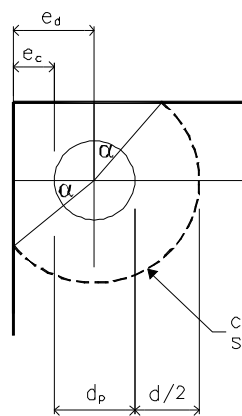
$$\begin{aligned}
 dV_f / M_f &= 3.39 > 1.0 \rightarrow \text{pilecap acts as deep beam} \\
 dV_f / M_f &> 2.0 & M_f / V_f &= 230 \quad [\text{mm}] \\
 z &= 0.4(d + M_f / V_f) \text{ for } dV_f / M_f \geq 1.0 & &= 276 \quad [\text{mm}] \\
 &1.2 M_f / V_f \quad \text{for } dV_f / M_f \geq 2.0 \\
 A_{s\text{hor}} &= M_f / (\phi_s f_y z) & &= 9436 \quad [\text{mm}^2] \\
 A_{s\text{min}} &= 0.2\% \times h_f \times t_f & &= 5297 \quad [\text{mm}^2] \\
 A_{s\text{hor}} &= \max(A_{s\text{hor}}, A_{s\text{min}}) & &= 9436 \quad [\text{mm}^2] \\
 A_{s\text{prov}} &= & &= 6717 \quad [\text{mm}^2] \\
 &< A_{s\text{hor}} & \text{NG}
 \end{aligned}$$

[Deep Beam Model Is Applicable]

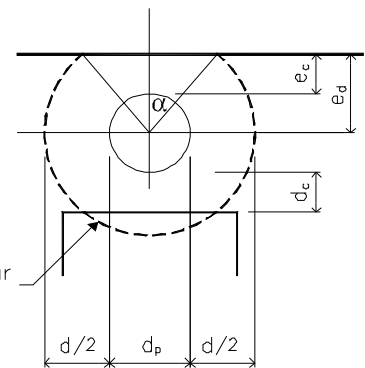
[Pilecap Reinf by Deep Beam Model Is NOT Adequate]



Corner Pile One-Way Shear



Corner Pile Two-Way Shear



Edge Pile Two-Way Shear

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EDGE PILE TWO WAY SHEAR

Code Reference

A23.3-04

Factored pile load	$V_f = 1283$	[kN]		
Pile diameter	$d_p = 300$	[mm]		
Pile edge distance	$e_d = 600$	[mm]	$e_c = 450$	[mm]
Pilecap effective depth	$d = 780$	[mm]	$d/2 = 390$	[mm]
Dist from pile edge to col corner	$d_c = 380$	[mm]	$d_c + 50 = 430$	[mm]
			$> d/2$	
Critical shear line doesn't intersect column, one way shear shall be checked				
	$\alpha = 0.0$			
Critical perimeter length	$b_o = \pi (d_p + d) (360 - 2\alpha)/360$		$= 3393$	[mm]
	$v_{c1} = \left(1 + \frac{2}{\beta_c}\right) 0.19 \lambda \phi_c \sqrt{f'_c}$		$= 2.029$	[MPa] 13.3.4.1 (13-5)
	$\beta_c = \text{width} / \text{length} = 1$ for pile			
	$v_{c2} = \left(\frac{\alpha_s d}{b_o} + 0.19\right) \lambda \phi_c \sqrt{f'_c}$		$= 3.132$	[MPa] 13.3.4.1 (13-6)
	$\alpha_s = 3$ for edge pile			
	$v_{c3} = 0.38 \lambda \phi_c \sqrt{f'_c}$		$= 1.353$	[MPa] 13.3.4.1 (13-7)
	$v_c = \min(v_{c1}, v_{c2}, v_{c3})$		$= 1.353$	[MPa]
	$V_r = v_c b_o d$		$= 3580$	[kN]
			$> V_f$	OK

[Edge Pile Two Way Shear Is Adequate]

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COLUMN ONE WAY SHEAR

Factored single pile load	$Q_{pr} = 1283$	[kN]	$b_c = 740$	[mm]
Pile diameter	$d_p = 300$	[mm]	$h_c = 740$	[mm]
Pile edge distance	$e_d = 600$	[mm]	$b_f = 3000$	[mm]
Pilecap effective depth	$d = 780$	[mm]	$h_f = 2759$	[mm]
Ver Critical Shear Line				
Dist from col face to pile edge	$d_{c1} = 230$	[mm]	$d_{c2} = 680$	[mm]
Fraction of pile outside critical line	$r_1 = 0.00$		$r_2 = 0.00$	
Factored shear force	$V_f = (2r_1 + r_2) Q_{pr}$		$= 0$	[kN]
	$b_w = h_f$		$= 2759$	[mm]
When no transverse reinf.	$\beta = 230 / (1000 + d)$		$= 0.129$	11.3.6.3 Eq (11-9)

$$V_c = \phi_c \lambda \beta \sqrt{f'_c} b_w d = 990 \text{ [kN]} \quad 11.3.4 \text{ Eq (11-6)}$$

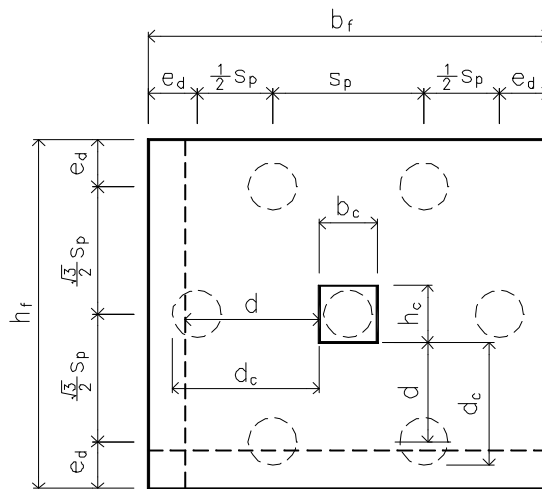
$> V_f$ **OK**

Hor Critical Shear Line

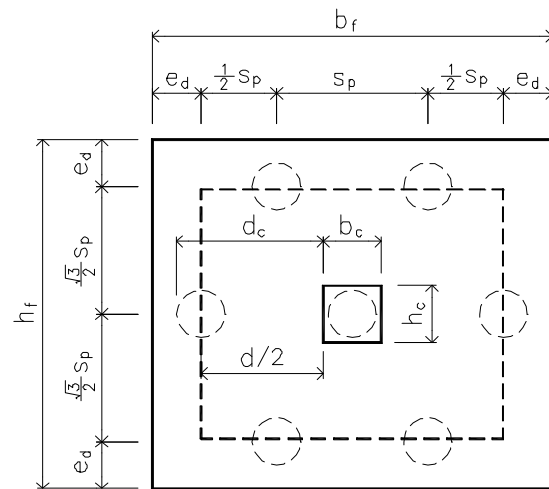
Dist from col face to pile edge	$d_c = 559$	[mm]		
Fraction of pile outside critical line	$r = 0.00$			
Factored shear force	$V_f = r \times 2 \times Q_{pr}$		$= 0$	[kN]
	$b_w = b_f$		$= 3000$	[mm]
When no transverse reinf.	$\beta = 230 / (1000 + d)$		$= 0.129$	11.3.6.3 Eq (11-9)

$$V_c = \phi_c \lambda \beta \sqrt{f'_c} b_w d = 1076 \text{ [kN]} \quad 11.3.4 \text{ Eq (11-6)}$$

$> V_f$ **OK**



Column One-Way Shear



Column Two-Way Shear

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COLUMN TWO WAY SHEAR

A23.3-04

Factored single pile load	$Q_{pr} = 1283$	[kN]	$b_c = 740$	[mm]
Pile diameter	$d_p = 300$	[mm]	$h_c = 740$	[mm]
Pile edge distance	$e_d = 600$	[mm]	$b_f = 3000$	[mm]
Pilecap effective depth	$d = 780$	[mm]	$h_f = 2759$	[mm]

Ver Critical Shear Line

Dist from col face to pile edge	$d_c = 230$	[mm]	$d_c = 680$	[mm]
Fraction of pile outside critical line	$r_1 = 0.00$		$r_2 = 0.97$	

Hor Critical Shear Line

Dist from col face to pile edge	$d_c = 559$	[mm]
Fraction of pile outside critical line	$r_3 = 0.56$	

Factored shear force	$V_f = 5380$	[kN]		
Critical perimeter length	$b_o = 2x(b_c + d + h_c + d)$		$= 6080$	[mm]

$$v_{c1} = \left(1 + \frac{2}{\beta_c}\right) 0.19 \lambda \phi_c \sqrt{f'_c} = 2.029 \text{ [MPa]} \quad 13.3.4.1 (13-5)$$

$$\beta_c = \text{col length} / \text{col width} = 1.0$$

$$v_{c2} = \left(\frac{\alpha_s d}{b_o} + 0.19\right) \lambda \phi_c \sqrt{f'_c} = 2.503 \text{ [MPa]} \quad 13.3.4.1 (13-6)$$

$$\alpha_s = 4 \quad \text{for interior column}$$

$$v_{c3} = 0.38 \lambda \phi_c \sqrt{f'_c} = 1.353 \text{ [MPa]} \quad 13.3.4.1 (13-7)$$

$$v_c = \min(v_{c1}, v_{c2}, v_{c3}) = 1.353 \text{ [MPa]}$$

$$V_r = v_c b_o d = 6416 \text{ [kN]}$$

$$> V_f \quad \text{OK}$$

[Column One and Two Way Shear Is Adequate]

8-Pile Pilecap Design Example

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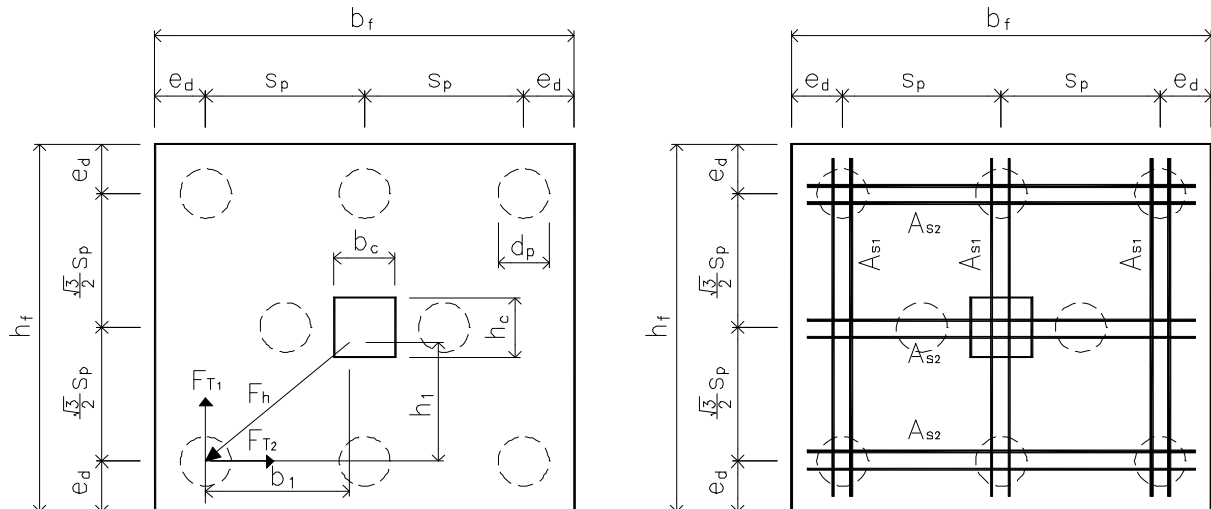
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DESCRIPTION

8 piles pilecap design based on
A23.3-04 Design of Concrete Structures

Code Abbreviation

A23.3-04



INPUT

Factored column load	$P_{cf} = 8000$ [kN]	Ver. reinf.	
Column width	$b_c = 930$ [mm]	A_{s1} bar size = 20	300
Column length	$h_c = 620$ [mm]	A_{s1} bar No = 7	
Pilecap width	$b_f = 2500$ [mm]	A_{s1} prov = 2100	
Pilecap length	$h_f = 2299$ [mm]	Equivalent to 20 @ 167	
Pilecap thickness	$t_f = 900$ [mm]		
		Hor. reinf.	
Pile diameter	$d_p = 250$ [mm]	A_{s2} bar size = 20	300
Pile spacing	$s_p = 750$ [mm]	A_{s2} bar No = 8	
Pile edge distance	$e_d = 500$ [mm]	A_{s2} prov = 2400	
		Equivalent to 20 @ 143	
Concrete strength	$f'_c = 30$ [MPa]		
Rebar yield strength	$f_y = 400$ [MPa]		
Concrete resistance factor	$\phi_c = 0.65$		
Rebar resistance factor	$\phi_s = 0.85$		
Low density conc factor	$\lambda = 1.0$		
Backfill soil weight above cap	$W_s = 0$ [kN]		
Pilecap self weight	$W_f = b_f \times h_f \times t_f \times 23.5$	= 122	[kN]

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Factored total pilecap load	$P_f = P_{cf} + W_s + W_f$	= 8152	[kN]
Pilecap effective depth	$d = t_f - 1.5d_b - 150$	= 720	[mm]
Factored pile axial reaction	$Q_{pr} = P_f / 8$	= 1019	[kN]
Vertical Direction			
Factored moment to column face	$M_f = 3 \times Q_{pr} \times (0.866S_p - 0.5h_c)$	= 1038	[kNm]
Factored shear to column face	$V_f = 3 \times Q_{pr}$	= 3057	[kN]
Horizontal Direction			
Factored moment to column face	$M_f = 2Q_{pr}(S_p - 0.5b_c) + Q_{pr}0.5(S_p - b_c)$	= 489	[kNm]
Factored shear to column face	$V_f = 3 \times Q_{pr}$	= 3057	[kN]

CONCLUSION

[Pilecap Reinf by S&T Model Is Adequate]

[Pilecap Reinf by Deep Beam Model Is NOT Adequate]

[Pile One and Two Way Shear Is NOT Adequate]

[Column One and Two Way Shear Is Adequate]

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Code Reference

S&T AND BEARING STRESS LIMIT MODEL by Adebar

Column Bearing Stress

	$A_c = 5.8E+05 \text{ [mm}^2\text{]}$	$A_2 = 5.7E+06 \text{ [mm}^2\text{]}$	
	$\alpha = 0.33 \left(\sqrt{\frac{A_2}{A_c}} - 1 \right) \leq 1.0$	= 0.72	
	$\beta = 0.33 \left(\frac{2d}{\sqrt{A_c}} - 1 \right) \leq 1.0$	= 0.30	
Allowable stress	$f_b = \phi_c (0.6 f'_c + 6\alpha\beta\sqrt{f'_c})$	= 16.3	[MPa]
Column stress	$f_{cb} = P_{cf} / (b_c \times h_c)$	= 13.9	[MPa]
		< f_b	OK

Pile Bearing Stress

	$A_p = 4.9E+04 \text{ [mm}^2\text{]}$	$A_2 = 7.9E+05 \text{ [mm}^2\text{]}$	
	$\alpha = 0.33 \left(\sqrt{\frac{A_2}{A_p}} - 1 \right) \leq 1.0$	= 1.00	
	$\beta = 0.33 \left(\frac{d}{d_p} - 1 \right) \leq 1.0$	= 0.63	
Allowable stress	$f_b = \phi_c (0.6 f'_c + 6\alpha\beta\sqrt{f'_c})$	= 25.1	[MPa]
Pile stress	$f_{cb} = Q_{pr} / (\pi * d_p^2 / 4)$	= 20.8	[MPa]
		< f_b	OK

Required Reinf

	$b_1 = 518 \text{ [mm]}$	$h_1 = 495 \text{ [mm]}$	
	$l = \text{sqrt}(b_1^2 + h_1^2)$	= 716	[mm]
	$F_h = l / d \times Q_{pr}$	= 1013	[kN]
Ver. Reinf.	$F_{T1} = h_1 / l \times F_h$	= 700	[kN]
	$A_{s1} = F_{T1} / (\phi_s \times f_y)$	= 2058	[mm ²]
	$A_{smin} = 0.2\% \times b_f \times t_f / 3$	= 1500	[mm ²]
	$A_{s1} = \max(A_{s1}, A_{smin})$	= 2058	[mm ²]
	$A_{s1 \text{ prov}} =$	2100	[mm ²]
		> A_{s1}	OK

Hor. Reinf.

	$F_{T2} = b_1 / l \times F_h$	= 732	[kN]
	$A_{s2} = F_{T2} / (\phi_s \times f_y)$	= 2154	[mm ²]
	$A_{smin} = 0.2\% \times h_f \times t_f / 2.4$	= 1724	[mm ²]
	$A_{s2} = \max(A_{s1}, A_{smin})$	= 2154	[mm ²]
	$A_{s2 \text{ prov}} =$	2400	[mm ²]
		> A_{s2}	OK

[Pilecap Reinf by S&T Model Is Adequate]

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REDUCED LEVER ARM MODEL by Park and Paulay

Vertical Direction

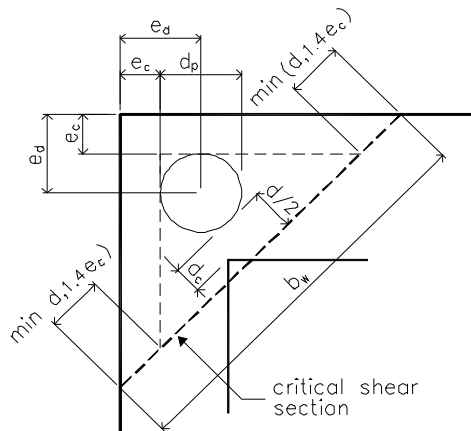
$$\begin{aligned}
 dV_f / M_f &= 2.12 > 1.0 \rightarrow \text{pilecap acts as deep beam} \\
 dV_f / M_f &> 2.0 & M_f / V_f &= 340 \quad [\text{mm}] \\
 z &= 0.4(d + M_f / V_f) \text{ for } dV_f / M_f \geq 1.0 & &= 407 \quad [\text{mm}] \\
 &1.2 M_f / V_f \quad \text{for } dV_f / M_f \geq 2.0 \\
 A_{s\text{ver}} &= M_f / (\phi_s f_y z) & &= 7493 \quad [\text{mm}^2] \\
 A_{s\text{min}} &= 0.2\% \times b_f \times t_f & &= 4500 \quad [\text{mm}^2] \\
 A_{s\text{ver}} &= \max(A_{s\text{ver}}, A_{s\text{min}}) & &= 7493 \quad [\text{mm}^2] \\
 A_{s\text{prov}} &= & &= 4140 \quad [\text{mm}^2] \\
 &< A_{s\text{ver}} & & \text{NG}
 \end{aligned}$$

Horizontal Direction

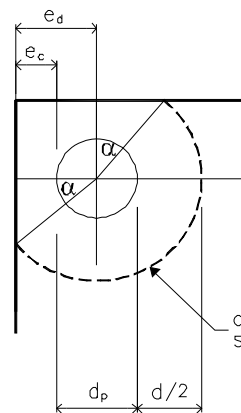
$$\begin{aligned}
 dV_f / M_f &= 4.50 > 1.0 \rightarrow \text{pilecap acts as deep beam} \\
 dV_f / M_f &> 2.0 & M_f / V_f &= 160 \quad [\text{mm}] \\
 z &= 0.4(d + M_f / V_f) \text{ for } dV_f / M_f \geq 1.0 & &= 192 \quad [\text{mm}] \\
 &1.2 M_f / V_f \quad \text{for } dV_f / M_f \geq 2.0 \\
 A_{s\text{hor}} &= M_f / (\phi_s f_y z) & &= 7493 \quad [\text{mm}^2] \\
 A_{s\text{min}} &= 0.2\% \times h_f \times t_f & &= 4138 \quad [\text{mm}^2] \\
 A_{s\text{hor}} &= \max(A_{s\text{hor}}, A_{s\text{min}}) & &= 7493 \quad [\text{mm}^2] \\
 A_{s\text{prov}} &= & &= 4408 \quad [\text{mm}^2] \\
 &< A_{s\text{hor}} & & \text{NG}
 \end{aligned}$$

[Deep Beam Model Is Applicable]

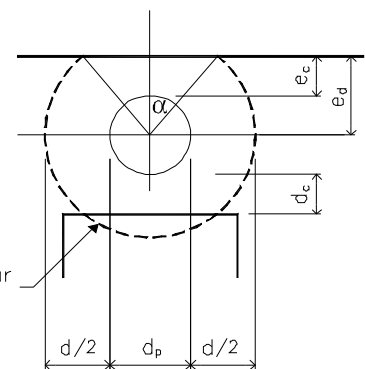
[Pilecap Reinf by Deep Beam Model Is NOT Adequate]



Corner Pile One-Way Shear



Corner Pile Two-Way Shear



Edge Pile Two-Way Shear

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CORNER PILE ONE WAY SHEAR

Code Reference

A23.3-04

Factored pile load	$V_f = 1019$	[kN]		
Pile diameter	$d_p = 250$	[mm]		
Pile edge distance	$e_d = 500$	[mm]	$e_c = 375$	[mm]
Pilecap effective depth	$d = 720$	[mm]	$d/2 = 360$	[mm]
Dist from pile edge to col corner	$d_c = 318$	[mm]	$d_c + 50 = 368$	[mm]
			$> d/2$	
Critical shear line doesn't intersect column, one way shear shall be checked				
	$\text{sqrt}(f'_c) = \min(\text{sqrt}(f'_c), 8)$		$= 5.477$	[MPa] 11.3.4
	$\min(d, 1.414 e_c) = 530$	[mm]	$b_w = 2384$	[mm]
When no transverse reinf.	$\beta = 230 / (1000 + d)$		$= 0.134$	11.3.6.3 Eq (11-9)
	$V_c = \phi_c \lambda \beta \sqrt{f'_c} b_w d$		$= 817$	[kN] 11.3.4 Eq (11-6)
			$< V_f$	NG

CORNER PILE TWO WAY SHEAR

Factored pile load	$V_f = 1019$	[kN]		
Pile diameter	$d_p = 250$	[mm]		
Pile edge distance	$e_d = 500$	[mm]	$e_c = 375$	[mm]
Pilecap effective depth	$d = 720$	[mm]	$d/2 = 360$	[mm]
Dist from pile edge to col corner	$d_c = 318$	[mm]	$d_c + 50 = 368$	[mm]
			$> d/2$	
Critical shear line doesn't intersect column, one way shear shall be checked				
	$\alpha = 0.0$			
Critical perimeter length	$b_o = \pi (d_p + d) (270 - 2\alpha) / 360$		$= 2286$	[mm]
	$v_{c1} = \left(1 + \frac{2}{\beta_c}\right) 0.19 \lambda \phi_c \sqrt{f'_c}$		$= 2.029$	[MPa] 13.3.4.1 (13-5)
	$\beta_c = \text{width} / \text{length} = 1$ for pile			
	$v_{c2} = \left(\frac{\alpha_s d}{b_o} + 0.19\right) \lambda \phi_c \sqrt{f'_c}$		$= 2.920$	[MPa] 13.3.4.1 (13-6)
	$\alpha_s = 2$ for corner pile			
	$v_{c3} = 0.38 \lambda \phi_c \sqrt{f'_c}$		$= 1.353$	[MPa] 13.3.4.1 (13-7)
	$v_c = \min(v_{c1}, v_{c2}, v_{c3})$		$= 1.353$	[MPa]
	$V_c = v_c b_o d$		$= 2226$	[kN]
			$> V_f$	OK

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EDGE PILE TWO WAY SHEAR

Factored pile load	$V_f = 1019$	[kN]		
Pile diameter	$d_p = 250$	[mm]		
Pile edge distance	$e_d = 500$	[mm]	$e_c = 375$	[mm]
Pilecap effective depth	$d = 720$	[mm]	$d/2 = 360$	[mm]
Dist from pile edge to col corner	$d_c = 215$	[mm]	$d_c + 50 = 265$	[mm]
			$< d/2$	
Critical shear line intersect column, one way shear needs NOT to be checked				
	$\alpha = 0.0$			
Critical perimeter length	$b_o = \pi (d_p + d) (360 - 2\alpha)/360$		$= 3047$	[mm]
	$v_{c1} = \left(1 + \frac{2}{\beta_c}\right) 0.19 \lambda \phi_c \sqrt{f'_c}$		$= 2.029$	[MPa]
	$\beta_c = \text{width} / \text{length} = 1$ for pile			
	$v_{c2} = \left(\frac{\alpha_s d}{b_o} + 0.19\right) \lambda \phi_c \sqrt{f'_c}$		$= 3.200$	[MPa]
	$\alpha_s = 3$ for edge pile			
	$v_{c3} = 0.38 \lambda \phi_c \sqrt{f'_c}$		$= 1.353$	[MPa]
	$v_c = \min(v_{c1}, v_{c2}, v_{c3})$		$= 1.353$	[MPa]
	$V_r = v_c b_o d$		$= 2968$	[kN]
			$> V_f$	OK

[Pile One and Two Way Shear Is NOT Adequate]

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COLUMN ONE WAY SHEAR

Factored single pile load	$Q_{pr} = 1019$	[kN]	$b_c = 930$	[mm]
Pile diameter	$d_p = 250$	[mm]	$h_c = 620$	[mm]
Pile edge distance	$e_d = 500$	[mm]	$b_f = 2500$	[mm]
Pilecap effective depth	$d = 720$	[mm]	$h_f = 2299$	[mm]
Ver Critical Shear Line				
Dist from col face to pile edge	$d_{c1} = 410$	[mm]	$d_{c2} = 35$	[mm]
Fraction of pile outside critical line	$r_1 = 0.00$		$r_2 = 0.00$	
Factored shear force	$V_f = (2r_1 + r_2) \times Q_{pr}$		$= 0$	[kN]
	$b_w = h_f$		$= 2299$	[mm]
When no transverse reinf.	$\beta = 230 / (1000 + d)$		$= 0.134$	11.3.6.3 Eq (11-9)

$$V_c = \phi_c \lambda \beta \sqrt{f'_c} b_w d = 788 \text{ [kN]} \quad 11.3.4 \text{ Eq (11-6)}$$

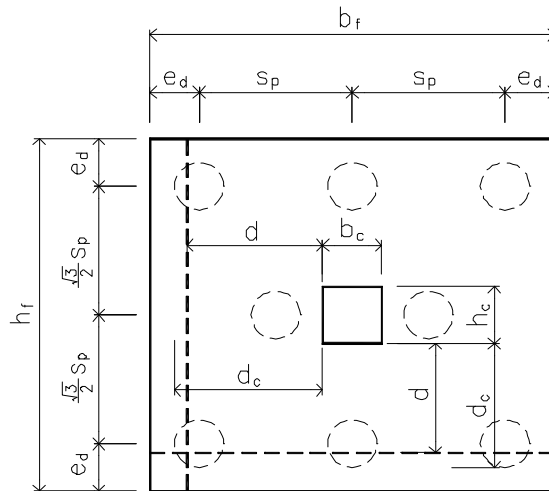
$> V_f$ **OK**

Hor Critical Shear Line

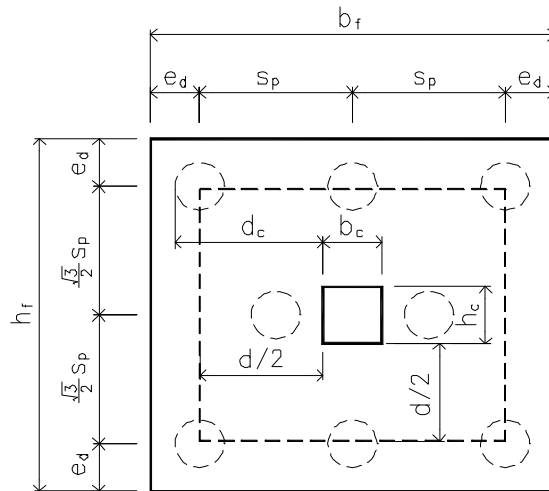
Dist from col face to pile edge	$d_c = 465$	[mm]		
Fraction of pile outside critical line	$r = 0.00$			
Factored shear force	$V_f = r \times 3Q_{pr}$		$= 0$	[kN]
	$b_w = b_f$		$= 2500$	[mm]
When no transverse reinf.	$\beta = 230 / (1000 + d)$		$= 0.134$	11.3.6.3 Eq (11-9)

$$V_c = \phi_c \lambda \beta \sqrt{f'_c} b_w d = 857 \text{ [kN]} \quad 11.3.4 \text{ Eq (11-6)}$$

$> V_f$ **OK**



Column One-Way Shear



Column Two-Way Shear

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COLUMN TWO WAY SHEAR

A23.3-04

Factored single pile load	$Q_{pr} = 1019$	[kN]	$b_c = 930$	[mm]
Pile diameter	$d_p = 250$	[mm]	$h_c = 620$	[mm]
Pile edge distance	$e_d = 500$	[mm]	$b_f = 2500$	[mm]
Pilecap effective depth	$d = 720$	[mm]	$h_f = 2299$	[mm]

Ver Critical Shear Line

Dist from col face to pile edge	$d_c = 410$	[mm]
Fraction of pile outside critical line	$r_1 = 0.20$	

Hor Critical Shear Line

Dist from col face to pile edge	$d_c = 465$	[mm]
Fraction of pile outside critical line	$r_2 = 0.42$	

Factored shear force	$V_f = 3030$	[kN]		
Critical perimeter length	$b_o = 2x(b_c + d + h_c + d)$		$= 5980$	[mm]

$$v_{c1} = \left(1 + \frac{2}{\beta_c}\right) 0.19 \lambda \phi_c \sqrt{f'_c} = 1.578 \text{ [MPa]} \quad 13.3.4.1 (13-5)$$

$$\beta_c = \text{col length} / \text{col width} = 1.50$$

$$v_{c2} = \left(\frac{\alpha_s d}{b_o} + 0.19\right) \lambda \phi_c \sqrt{f'_c} = 2.391 \text{ [MPa]} \quad 13.3.4.1 (13-6)$$

$$\alpha_s = 4 \quad \text{for interior column}$$

$$v_{c3} = 0.38 \lambda \phi_c \sqrt{f'_c} = 1.353 \text{ [MPa]} \quad 13.3.4.1 (13-7)$$

$$v_c = \min(v_{c1}, v_{c2}, v_{c3}) = 1.353 \text{ [MPa]}$$

$$V_r = v_c b_o d = 5825 \text{ [kN]}$$

$$> V_f \quad \text{OK}$$

[Column One and Two Way Shear Is Adequate]

9-Pile Pilecap Design Example

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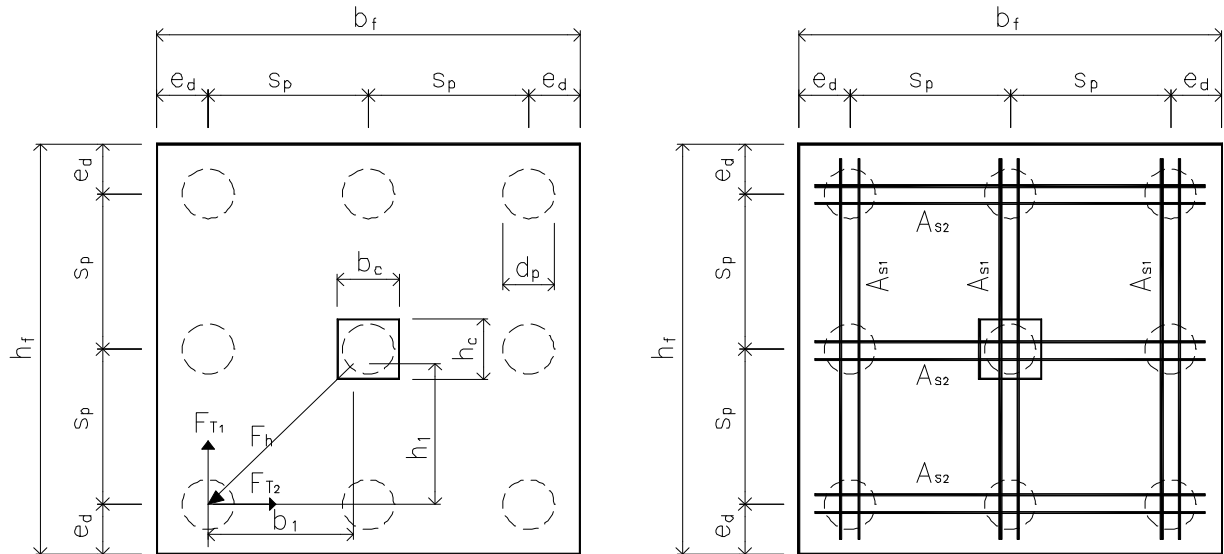
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DESCRIPTION

9 piles pilecap design based on
A23.3-04 Design of Concrete Structures

Code Abbreviation

A23.3-04



INPUT

Factored column load	$P_{cf} = 9000$ [kN]	Ver. reinf.	
Column width	$b_c = 750$ [mm]	A_{s1} bar size = 20	300
Column length	$h_c = 750$ [mm]	A_{s1} bar No = 8	
Pilecap width	$b_f = 2500$ [mm]	A_{s1} prov = 2400	
Pilecap length	$h_f = 2500$ [mm]	Equivalent to 20 @ 143	
Pilecap thickness	$t_f = 1060$ [mm]		
		Hor. reinf.	
Pile diameter	$d_p = 250$ [mm]	A_{s2} bar size = 20	300
Pile spacing	$S_p = 750$ [mm]	A_{s2} bar No = 8	
Pile edge distance	$e_d = 500$ [mm]	A_{s2} prov = 2400	
		Equivalent to 20 @ 143	
Concrete strength	$f'_c = 30$ [MPa]		
Rebar yield strength	$f_y = 400$ [MPa]		
Concrete resistance factor	$\phi_c = 0.65$		
Rebar resistance factor	$\phi_s = 0.85$		
Low density conc factor	$\lambda = 1.0$		
Backfill soil weight above cap	$W_s = 0$ [kN]		
Pilecap self weight	$W_f = b_f \times h_f \times t_f \times 23.5$	= 156	[kN]

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Factored total pilecap load	$P_f = P_{cf} + W_s + W_f$	= 9195	[kN]
Pilecap effective depth	$d = t_f - 1.5d_b - 150$	= 880	[mm]
Factored pile axial reaction	$Q_{pr} = P_f / 9$	= 1022	[kN]
Vertical Direction			
Factored moment to column face	$M_f = 3Q_{pr} \times (S_p - 0.5h_c)$	= 1149	[kNm]
Factored shear to column face	$V_f = 3 \times Q_{pr}$	= 3065	[kN]
Horizontal Direction			
Factored moment to column face	$M_f = 3Q_{pr} \times (S_p - 0.5b_c)$	= 1149	[kNm]
Factored shear to column face	$V_f = 3 \times Q_{pr}$	= 3065	[kN]

CONCLUSION

[Pilecap Reinf by S&T Model Is Adequate]

[Pilecap Reinf by Deep Beam Model Is NOT Adequate]

[Pile One and Two Way Shear Is NOT Adequate]

[Column One and Two Way Shear Is Adequate]

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Code Reference

S&T AND BEARING STRESS LIMIT MODEL by Adebar

Column Bearing Stress

	$A_c = 5.6E+05 \text{ [mm}^2\text{]}$	$A_2 = 6.3E+06 \text{ [mm}^2\text{]}$	
	$\alpha = 0.33 \left(\sqrt{\frac{A_2}{A_c}} - 1 \right) \leq 1.0$	= 0.78	
	$\beta = 0.33 \left(\frac{2d}{\sqrt{A_c}} - 1 \right) \leq 1.0$	= 0.45	
Allowable stress	$f_b = \phi_c (0.6 f'_c + 6\alpha\beta\sqrt{f'_c})$	= 19.2	[MPa]
Column stress	$f_{cb} = P_{cf} / (b_c \times h_c)$	= 16.0	[MPa]
		< f_b	OK

Pile Bearing Stress

	$A_p = 4.9E+04 \text{ [mm}^2\text{]}$	$A_2 = 7.9E+05 \text{ [mm}^2\text{]}$	
	$\alpha = 0.33 \left(\sqrt{\frac{A_2}{A_p}} - 1 \right) \leq 1.0$	= 1.00	
	$\beta = 0.33 \left(\frac{d}{d_p} - 1 \right) \leq 1.0$	= 0.84	
Allowable stress	$f_b = \phi_c (0.6 f'_c + 6\alpha\beta\sqrt{f'_c})$	= 29.6	[MPa]
Pile stress	$f_{cb} = Q_{pr} / (\pi * d_p^2 / 4)$	= 20.8	[MPa]
		< f_b	OK

Required Reinf

	$b_1 = 563 \text{ [mm]}$	$h_1 = 563 \text{ [mm]}$	
	$l = \text{sqrt}(b_1^2 + h_1^2)$	= 795	[mm]
	$F_h = l / d \times Q_{pr}$	= 924	[kN]
Ver. Reinf.	$F_{T1} = h_1 / l \times F_h$	= 653	[kN]
	$A_{s1} = F_{T1} / (\phi_s \times f_y)$	= 1921	[mm ²]
	$A_{smin} = 0.2\% \times b_f \times t_f / 3$	= 1767	[mm ²]
	$A_{s1} = \max(A_{s1}, A_{smin})$	= 1921	[mm ²]
	$A_{s1 \text{ prov}} =$	2400	[mm ²]
		> A_{s1}	OK
Hor. Reinf.	$F_{T2} = b_1 / l \times F_h$	= 653	[kN]
	$A_{s2} = F_{T2} / (\phi_s \times f_y)$	= 1921	[mm ²]
	$A_{smin} = 0.2\% \times h_f \times t_f / 3$	= 1767	[mm ²]
	$A_{s2} = \max(A_{s1}, A_{smin})$	= 1921	[mm ²]
	$A_{s2 \text{ prov}} =$	2400	[mm ²]
		> A_{s2}	OK

[Pilecap Reinf by S&T Model Is Adequate]

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REDUCED LEVER ARM MODEL by Park and Paulay

Vertical Direction

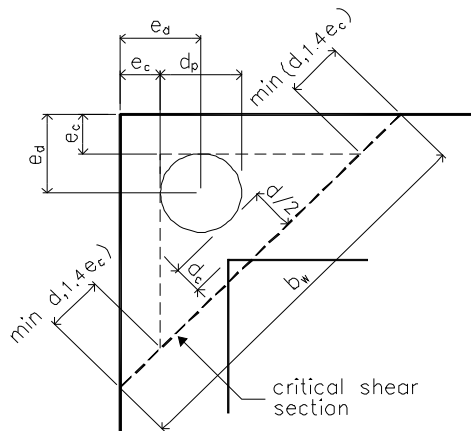
$$\begin{aligned}
 dV_f / M_f &= 2.35 > 1.0 \rightarrow \text{pilecap acts as deep beam} \\
 dV_f / M_f &> 2.0 & M_f / V_f &= 375 \quad [\text{mm}] \\
 z &= 0.4(d + M_f / V_f) \text{ for } dV_f / M_f \geq 1.0 & &= 450 \quad [\text{mm}] \\
 &1.2 M_f / V_f \quad \text{for } dV_f / M_f \geq 2.0 \\
 A_{s\text{ver}} &= M_f / (\phi_s f_y z) & &= 7512 \quad [\text{mm}^2] \\
 A_{s\text{min}} &= 0.2\% \times b_f \times t_f & &= 5300 \quad [\text{mm}^2] \\
 A_{s\text{ver}} &= \max(A_{s\text{ver}}, A_{s\text{min}}) & &= 7512 \quad [\text{mm}^2] \\
 A_{s\text{prov}} &= & &= 4830 \quad [\text{mm}^2] \\
 &< A_{s\text{ver}} & & \text{NG}
 \end{aligned}$$

Horizontal Direction

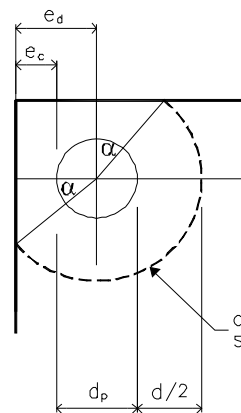
$$\begin{aligned}
 dV_f / M_f &= 2.35 > 1.0 \rightarrow \text{pilecap acts as deep beam} \\
 dV_f / M_f &> 2.0 & M_f / V_f &= 375 \quad [\text{mm}] \\
 z &= 0.4(d + M_f / V_f) \text{ for } dV_f / M_f \geq 1.0 & &= 450 \quad [\text{mm}] \\
 &1.2 M_f / V_f \quad \text{for } dV_f / M_f \geq 2.0 \\
 A_{s\text{hor}} &= M_f / (\phi_s f_y z) & &= 7512 \quad [\text{mm}^2] \\
 A_{s\text{min}} &= 0.2\% \times h_f \times t_f & &= 5300 \quad [\text{mm}^2] \\
 A_{s\text{hor}} &= \max(A_{s\text{hor}}, A_{s\text{min}}) & &= 7512 \quad [\text{mm}^2] \\
 A_{s\text{prov}} &= & &= 4830 \quad [\text{mm}^2] \\
 &< A_{s\text{hor}} & & \text{NG}
 \end{aligned}$$

[Deep Beam Model Is Applicable]

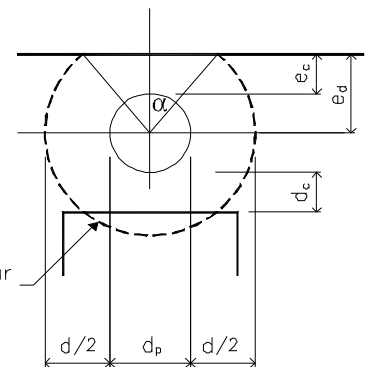
[Pilecap Reinf by Deep Beam Model Is NOT Adequate]



Corner Pile One-Way Shear



Corner Pile Two-Way Shear



Edge Pile Two-Way Shear

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CORNER PILE ONE WAY SHEAR

Code Reference

A23.3-04

Factored pile load	$V_f = 1022$	[kN]		
Pile diameter	$d_p = 250$	[mm]		
Pile edge distance	$e_d = 500$	[mm]	$e_c = 375$	[mm]
Pilecap effective depth	$d = 880$	[mm]	$d/2 = 440$	[mm]
Dist from pile edge to col corner	$d_c = 405$	[mm]	$d_c + 50 = 455$	[mm]
			$> d/2$	
Critical shear line doesn't intersect column, one way shear shall be checked				
	$\sqrt{f'_c} = \min(\sqrt{f'_c}, 8)$		$= 5.477$	[MPa] 11.3.4
	$\min(d, 1.414 e_c) = 530$	[mm]	$b_w = 2544$	[mm]
When no transverse reinf.	$\beta = 230 / (1000 + d)$		$= 0.122$	11.3.6.3 Eq (11-9)
	$V_c = \phi_c \lambda \beta \sqrt{f'_c} b_w d$		$= 975$	[kN] 11.3.4 Eq (11-6)
			$< V_f$	NG

CORNER PILE TWO WAY SHEAR

Factored pile load	$V_f = 1022$	[kN]		
Pile diameter	$d_p = 250$	[mm]		
Pile edge distance	$e_d = 500$	[mm]	$e_c = 375$	[mm]
Pilecap effective depth	$d = 880$	[mm]	$d/2 = 440$	[mm]
Dist from pile edge to col corner	$d_c = 405$	[mm]	$d_c + 50 = 455$	[mm]
			$> d/2$	
Critical shear line doesn't intersect column, one way shear shall be checked				
	$\alpha = 27.8$			
Critical perimeter length	$b_o = \pi (d_p + d) (270 - 2\alpha) / 360$		$= 2115$	[mm]
	$v_{c1} = \left(1 + \frac{2}{\beta_c}\right) 0.19 \lambda \phi_c \sqrt{f'_c}$		$= 2.029$	[MPa] 13.3.4.1 (13-5)
	$\beta_c = \text{width} / \text{length} = 1$ for pile			
	$v_{c2} = \left(\frac{\alpha_s d}{b_o} + 0.19\right) \lambda \phi_c \sqrt{f'_c}$		$= 3.639$	[MPa] 13.3.4.1 (13-6)
	$\alpha_s = 2$ for corner pile			
	$v_{c3} = 0.38 \lambda \phi_c \sqrt{f'_c}$		$= 1.353$	[MPa] 13.3.4.1 (13-7)
	$v_c = \min(v_{c1}, v_{c2}, v_{c3})$		$= 1.353$	[MPa]
	$V_c = v_c b_o d$		$= 2518$	[kN]
			$> V_f$	OK

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EDGE PILE TWO WAY SHEAR

Factored pile load	$V_f = 1022$	[kN]		
Pile diameter	$d_p = 250$	[mm]		
Pile edge distance	$e_d = 500$	[mm]	$e_c = 375$	[mm]
Pilecap effective depth	$d = 880$	[mm]	$d/2 = 440$	[mm]
Dist from pile edge to col corner	$d_c = 250$	[mm]	$d_c + 50 = 300$	[mm]
			$< d/2$	
Critical shear line intersect column, one way shear needs NOT to be checked				
	$\alpha = 27.8$			
Critical perimeter length	$b_o = \pi (d_p + d) (360 - 2\alpha)/360$		$= 3003$	[mm]
	$v_{c1} = \left(1 + \frac{2}{\beta_c}\right) 0.19 \lambda \phi_c \sqrt{f'_c}$		$= 2.029$	[MPa]
	$\beta_c = \text{width} / \text{length} = 1$ for pile			
	$v_{c2} = \left(\frac{\alpha_s d}{b_o} + 0.19\right) \lambda \phi_c \sqrt{f'_c}$		$= 3.807$	[MPa]
	$\alpha_s = 3$ for edge pile			
	$v_{c3} = 0.38 \lambda \phi_c \sqrt{f'_c}$		$= 1.353$	[MPa]
	$v_c = \min(v_{c1}, v_{c2}, v_{c3})$		$= 1.353$	[MPa]
	$V_r = v_c b_o d$		$= 3575$	[kN]
			$> V_f$	OK

[Pile One and Two Way Shear Is NOT Adequate]

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COLUMN ONE WAY SHEAR

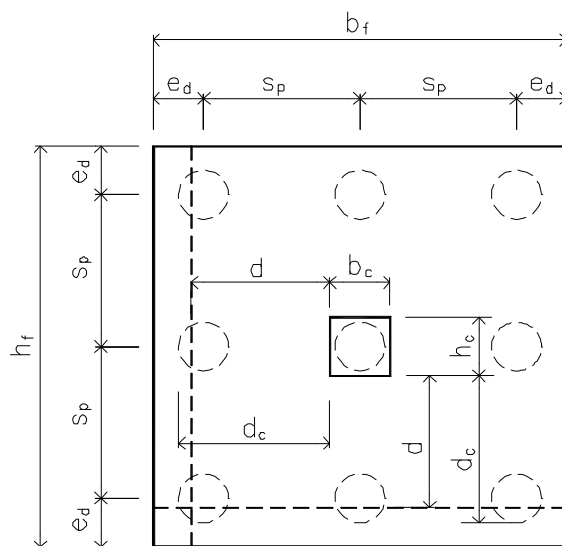
Factored single pile load	$Q_{pr} = 1022$	[kN]	$b_c = 750$	[mm]
Pile diameter	$d_p = 250$	[mm]	$h_c = 750$	[mm]
Pile edge distance	$e_d = 500$	[mm]	$b_f = 2500$	[mm]
Pilecap effective depth	$d = 880$	[mm]	$h_f = 2500$	[mm]

Ver Critical Shear Line

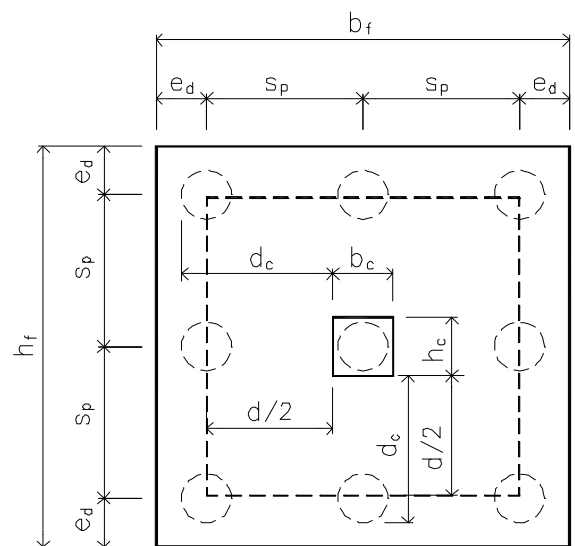
Dist from col face to pile edge	$d_{c1} = 500$	[mm]		
Fraction of pile outside critical line	$r_1 = 0.00$			
Factored shear force	$V_f = r_1 \times 3Q_{pr}$		$= 0$	[kN]
	$b_w = h_f$		$= 2500$	[mm]
When no transverse reinf.	$\beta = 230 / (1000 + d)$		$= 0.122$	11.3.6.3 Eq (11-9)
	$V_c = \phi_c \lambda \beta \sqrt{f'_c} b_w d$		$= 958$	[kN] 11.3.4 Eq (11-6)
			$> V_f$	OK

Hor Critical Shear Line

Dist from col face to pile edge	$d_c = 500$	[mm]		
Fraction of pile outside critical line	$r = 0.00$			
Factored shear force	$V_f = r \times 3Q_{pr}$		$= 0$	[kN]
	$b_w = b_f$		$= 2500$	[mm]
When no transverse reinf.	$\beta = 230 / (1000 + d)$		$= 0.122$	11.3.6.3 Eq (11-9)
	$V_c = \phi_c \lambda \beta \sqrt{f'_c} b_w d$		$= 958$	[kN] 11.3.4 Eq (11-6)
			$> V_f$	OK



Column One-Way Shear



Column Two-Way Shear

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COLUMN TWO WAY SHEAR

A23.3-04

Factored single pile load	$Q_{pr} = 1022$	[kN]	$b_c = 750$	[mm]
Pile diameter	$d_p = 250$	[mm]	$h_c = 750$	[mm]
Pile edge distance	$e_d = 500$	[mm]	$b_f = 2500$	[mm]
Pilecap effective depth	$d = 880$	[mm]	$h_f = 2500$	[mm]

Ver Critical Shear Line

Dist from col face to pile edge	$d_c = 500$	[mm]
Fraction of pile outside critical line	$r_1 = 0.24$	

Hor Critical Shear Line

Dist from col face to pile edge	$d_c = 500$	[mm]
Fraction of pile outside critical line	$r_2 = 0.24$	

Factored shear force	$V_f = 2707$	[kN]		
Critical perimeter length	$b_o = 2x(b_c + d + h_c + d)$		$= 6520$	[mm]
	$v_{c1} = \left(1 + \frac{2}{\beta_c}\right) 0.19 \lambda \phi_c \sqrt{f'_c}$		$= 2.029$	[MPa] 13.3.4.1 (13-5)
	$\beta_c = \text{col length} / \text{col width}$		$= 1.00$	
	$v_{c2} = \left(\frac{\alpha_s d}{b_o} + 0.19\right) \lambda \phi_c \sqrt{f'_c}$		$= 2.599$	[MPa] 13.3.4.1 (13-6)
	$\alpha_s = 4$	for interior column		
	$v_{c3} = 0.38 \lambda \phi_c \sqrt{f'_c}$		$= 1.353$	[MPa] 13.3.4.1 (13-7)
	$v_c = \min(v_{c1}, v_{c2}, v_{c3})$		$= 1.353$	[MPa]
	$V_r = v_c b_o d$		$= 7762$	[kN]
			$> V_f$	OK

[Column One and Two Way Shear Is Adequate]