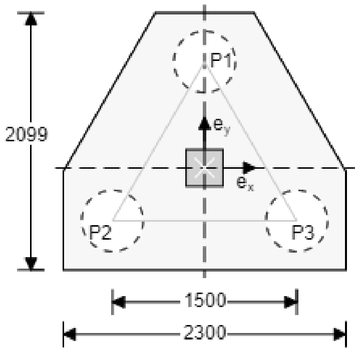
1.0 INPUT

1.1 Pile cap

Pile Shape		**Circle**
Pile Diameter	D	= **500** mm
Spacing of Piles	s	= **1500** mm
Pile cap Overhang	e	= **150** mm
Thickness of Pile cap	h	= **1200** mm



1.2 Column

Column Shape		**Rectangle**
Column Dimension - X Direction	x	= **300** mm
Column Dimension - Y Direction	y	= **300** mm
Eccentricity - X Direction	e_x	= **0** mm
Eccentricity - Y Direction	e_y	= **0** mm

1.3 Reinforcement

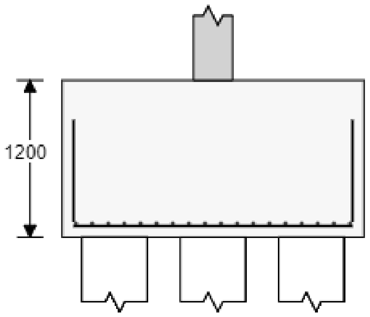
Reinforcement Provided		**20** @ **125** mm C/C
	A_{st}	= **2513.3** mm^2/m
Clear Cover	C_{ot}	= **75** mm

1.4 Design Loads

Factored Axial Load	F_{ult}	= **3000** kN
Un-factored Axial Load	F_{work}	= **2000** kN

1.5 Materials

Concrete Grade	f_{cu}	= **35** N/mm^2
Main Reinforcement Grade	f_y	= **460** N/mm^2
Density of Concrete	γ_{con}	= **24** kN/m^3



Main Reinforcement 20ϕ - 125 c/c bothways

1.6 Material Safety Factors

Concrete in Compression	γ_{mc}	= **1.5**
Concrete in Shear	γ_{mcs}	= **1.25**
Reinforcement	γ_{ms}	= **1.15**

2.0 OUTPUT

Ref: BS 8110 - Part 1

2.1 Dimensions

Pile cap Length	L	= √3 / 2 * s + D + 2 * e = **2099** mm
Pile cap Width	b	= s + D + 2 * e = **2300** mm
Pile cap Width Parallel to L	w_1	= D + 2 * e = **800** mm
Pile cap Width Parallel to b	w_2	= D + 2 * e = **800** mm

Diagonal Length of Sides L_{side} = $((L - w_1)^2 + ((b - w_2) / 2)^2)^{1/2}$ = **1500** mm

Effective Depth d = **1115** mm

2.2 Pile Loads (Factored)

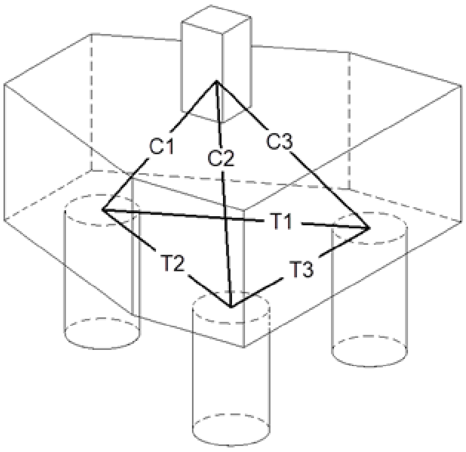
Load on Pile 1 F_{pile1} = $F_{ult} * (s * \cos(30) / 3 + e_y) / (s * \cos(30))$= **1000** kN

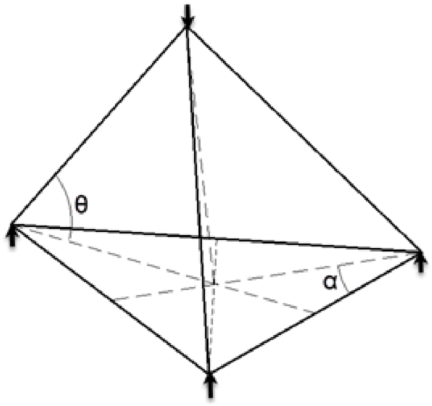
Load on Pile 3 F_{pile3} = $(F_{ult} - F_{pile1}) * (s / 2 + e_x) / s$ = **1000** kN

Load on Pile 2 F_{pile2} = $F_{ult} - F_{pile1} - F_{pile3}$ = **1000** kN

2.3 Strut and Tie Analogy

The pile cap forces are computed on the basis of strut and tie analogy wherby the force from the column is assumed to be transmitted by a triangular truss action with concrete providing the compressive members of the truss and steel reinforcement providing the tensile member.





2.3.1 Angle Computations

Vertical Angle θ_1 = $\tan^{-1}(d / \sqrt{((((\cos(30) - \cos(30) / 3) * s) - e_y)^2 + (e_x)^2})$ = **52.2** deg

θ_2 = $\tan^{-1}(d / \sqrt{(((s * \cos(30) / 3) + e_y)^2 + (s / 2 + e_x)^2})$ = **52.2** deg

θ_3 = $\tan^{-1}(d / \sqrt{(((s * \cos(30) / 3) + e_y)^2 + (s / 2 - e_x)^2})$ = **52.2** deg

Horizontal Angle α_1 = $\tan^{-1}(((s * \cos(30) / 3) + e_y) / (s / 2 + e_x))$
= **30** deg

α_2 = $60 - \alpha_1$ = **30** deg

2.3.2 Truss Member Forces

<u>Compressive Forces within Pile cap</u>

C_1 = $F_{pile1} / \sin \theta_1$ = **1266.2** kN

C_2 = $F_{pile2} / \sin \theta_2$ = **1266.2** kN

C_3 = $F_{pile3} / \sin \theta_3$ = **1266.2** kN

<u>Tensile Forces within Pile cap</u>

T_1 = $C_1 * \cos \theta_1 / (2 * \cos(30))$ = **448.4** kN

T_2 = $C_1 * \cos \theta_1 / (2 * \cos(30))$ = **448.4** kN

T_3 = $T_1 * \sin \alpha_2 / \sin \alpha_1$ = **448.4** kN

Maximum Compressive Force within Pile cap C = $\max(C_1, C_2, C_3)$ = **1266.2** kN

Design Tensile Force T = $\max(T_3, (T_1 + T_2) * \cos(30))$ = **776.7** kN

2.4 Pile cap Compression Check

Compression Capacity for Pile c/s P_c = $(0.67 / \gamma_{mc}) * f_{cu} * \pi * (D^2 / 4)$ = **3069.6** kN *Cl. 3.8.4.3*

2.5 Pile Loads (Un-factored Loads)

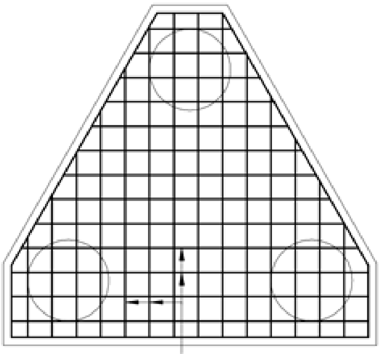
Selfweight of Pile cap S_{wt} = $(2 * D + 4 * e + s) / 2) * s * \cos(30)$
$+ ((D + 2 * e) * (D + 2 * e + s))) * h * \gamma_{con}$ = **111** kN

Reaction at Pile 1 $F_{workpile1}$ = $F_{work} * (s * \cos(30) / 3 + e_y) / (s * \cos(30))$
$+ S_{wt} / 3$ = **703.7** kN

Reaction at Pile 3 $F_{workpile3}$ = $(F_{work} - F_{workpile1}) * (s / 2 + e_x) / s + S_{wt} / 3$
= **703.7** kN

Reaction at Pile 2 $F_{workpile2}$ = $F_{work} - F_{workpile1} - F_{workpile3} + S_{wt}$ = **703.7** kN

2.6 Reinforcement Design



MAIN REINFORCEMENT

Minimum Area of Reinforcement /m A_{stmin} = $0.0013 * 1000 * h$ = **1560** mm^2 *Table 3.25*

Maximum Area of Reinforcement /m A_{stmax} = $0.04 * 1000 * h$ = **48000** mm^2 *Cl 3.12.6*

Reinforcement Required for Tension /m A_{sreq1} = $T / (f_y / \gamma_{ms})) * 1000 / \min(3 * D , D + 2 * e)$
= **2427.2** mm^2

Area of Reinforcement Required /m A_{sreq} = $\max(A_{stmin}, A_{sreq1})$ = **2427.2** mm^2

2.7 Shear - One Way

Shear Plane Width at Pile 1 b_{v1} = $\max(3 * D, 9 * D / 5 + 3 * e)$ = **1500** mm

Shear Plane Width at Pile 2 & 3 b_{v2} = $\min(2 * e + D) / \sqrt{3} + (0.4 * D / \cos(\alpha_1)$
$+ (e + D / 2)) * (1 + \tan(\alpha_1))) * \cos(\alpha_1)$
$* (\tan(\alpha_1) + \tan(\alpha_2))), 3 * D)$ = **1323.8** mm

Shear Stress at Pile 1 v_1 = $F_{pile1} / (b_{v1} * d)$ = **0.598** N/mm^2 *Cl. 3.5.5.2*

Shear Stress at Pile 2 v_2 = $F_{pile2} / (b_{v2} * d)$ = **0.678** N/mm^2

Shear Stress at Pile 3 v_3 = $F_{pile3} / (b_{v2} * d)$ = **0.678** N/mm^2

Design Shear Stress v = $\max(v_1, v_2, v_3)$ = **0.678** N/mm^2

Max. Allowable Shear Stress v_{max} = $\min(0.8 * \sqrt{f_{cu}}, 5)$ = **4.733** N/mm^2 *Cl. 3.4.5.12*

Percentage of Provided Reinforcement P_{t1} = $100 * A_{st} / (b_{v1} * d)$ = **0.2** %

Design Concrete Shear Stress at Pile 1 v_{c1} = **0.376** N/mm^2 *Table 3.8*

Percentage of Provided Reinforcement P_{t2} = $100 * A_{st} / (b_{v2} * d)$ = **0.2** %

Design Concrete Shear Stress at Pile 2 v_{c2} = **0.392** N/mm^2

Design Concrete Shear Stress at Pile 3 v_{c3} = **0.392** N/mm^2

Maximum Concrete Shear Stress v_c = $\max(v_{c1} ,v_{c2} , v_{c3})$ = **0.392** N/mm^2

a_1 = $(s / \sqrt{3}) - e_y - D / 2 + D / 5 - y / 2$
= **566** mm

Critical Section Distance for Pile 1 a_{v1} = $\min(2 * d, a_1)$ = **566** mm *Cl. 3.11.4.3*

Enhanced Shear Strength at Pile 1 v_{cenh1} = $\min(v_{max}, (2 * d * v_c) / a_{v1})$ = **1.481** N/mm^2 *Cl. 3.11.4.4*

a_2 = $s / 2 + e_x / \cos(\alpha_1) - D / 2 + D / 5$
$- x / 2$ = **566** mm

Critical Section Distance for Pile 2 a_{v2} = $\min(2 * d, a_2)$ = **566** mm

Enhanced Shear Strength at Pile 2 v_{cenh2} = min(v_{max}, 2 * d * v_c / a_{v2}) = **1.544** N/mm^2

a_3 = s / 2 - e_x / cos α_1 - D / 2 + D / 5
- x / 2 = **566** mm

Critical Section Distance for Pile 3 a_{v3} = min(2 * d, a_3) = **566** mm

Enhanced Shear Strength at Pile 3 v_{cenh3} = min(v_{max}, 2 * d * v_c / a_{v3}) = **1.544** N/mm^2

2.8 Punching Shear Check

Punching Shear Stress at Column Face v_{punch} = F_{ult} / (2 * (x + y) * d) = **2.242** N/mm^2 *Cl. 3.11.4.5*

Punching Shear Stress at 1.5d $v_{1.5d}$ = F_{ult} / (2 * (x + y) + 12 * d) * d) = **0.185** N/mm^2

3.0 SUMMARY

Description	Required	Actual	Status
Compressive Force (kN)	P_c <= **3069.6**	C = **1266.2**	**PASS**
Area of Tension Steel (mm^2/m)	A_{sreq} >= **2427.2**	A_{st} = **2513.3**	**PASS**
Maximum Area of Reinforcement (mm^2/m)	A_{stmax} <= **48000**	A_{st} = **2513.3**	**PASS**
Punching Shear at Column Face (N/mm^2)	v_{max} <= **4.733**	v_{punch} = **2.242**	**PASS**
Punching Shear Stress at 1.5d (N/mm^2)	v_c <= **0.392**	$v_{1.5d}$ = **0.185**	**PASS**
Shear Stress at Pile 1 (N/mm^2)	v_{cenh1} <= **1.481**	v = **0.678**	**PASS**
Shear Stress at Pile 2 (N/mm^2)	v_{cenh2} <= **1.544**	v = **0.678**	**PASS**
Shear Stress at Pile 3 (N/mm^2)	v_{cenh3} <= **1.544**	v = **0.678**	**PASS**