| CONSULTING ENGINEERS | Engineering Calculation Sheet<br>Consulting Engineers | Job No. | Sheet No. | Rev. |
|---|---|---|---|---|
| | | jXXX | 1 | |
| | | Member/Location | | |
| Job Title | Structure, Member Design - Geotechnics Pile Cap v2021 | Drg. | | |
| Structure, Member Design - Geotechnics Pile Cap | | Made by **XX** | Date **21/11/2021** | Chd. |

**Material Properties**

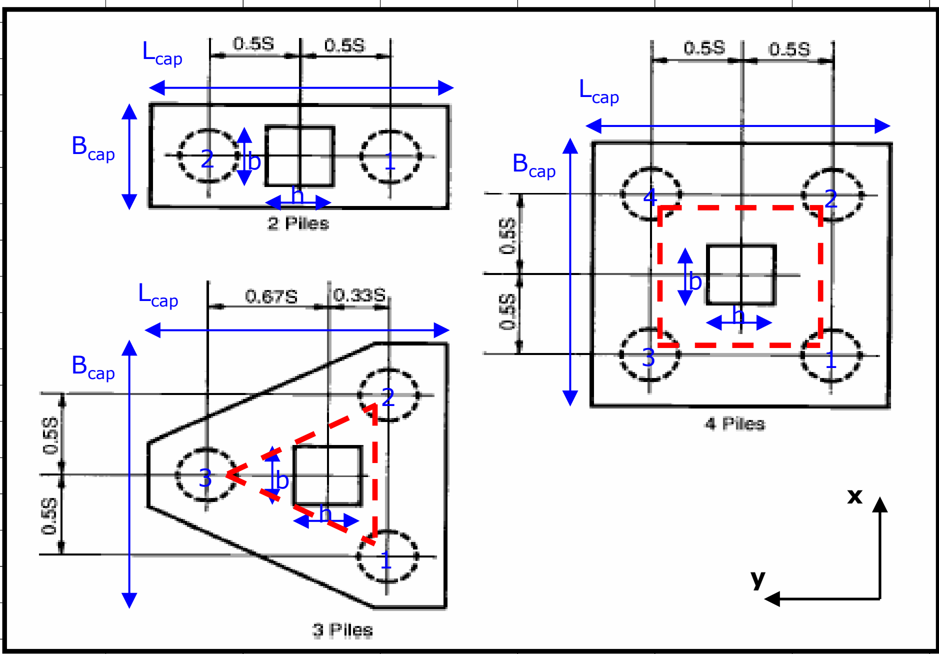
| | | | |
|---|---|---|---|
| Characteristic strength of concrete, $f_{cu}$ (≤ 60N/mm$^2$; HSC N/A) | 45 | N/mm$^2$ | **OK** |
| Yield strength of longitudinal steel, $f_y$ | 460 | N/mm$^2$ | |
| Yield strength of shear link steel, $f_{yv}$ | 460 | N/mm$^2$ | |
| Type of concrete and density, $\rho_c$ | Normal Weight 24 | kN/m$^3$ | **OK** |

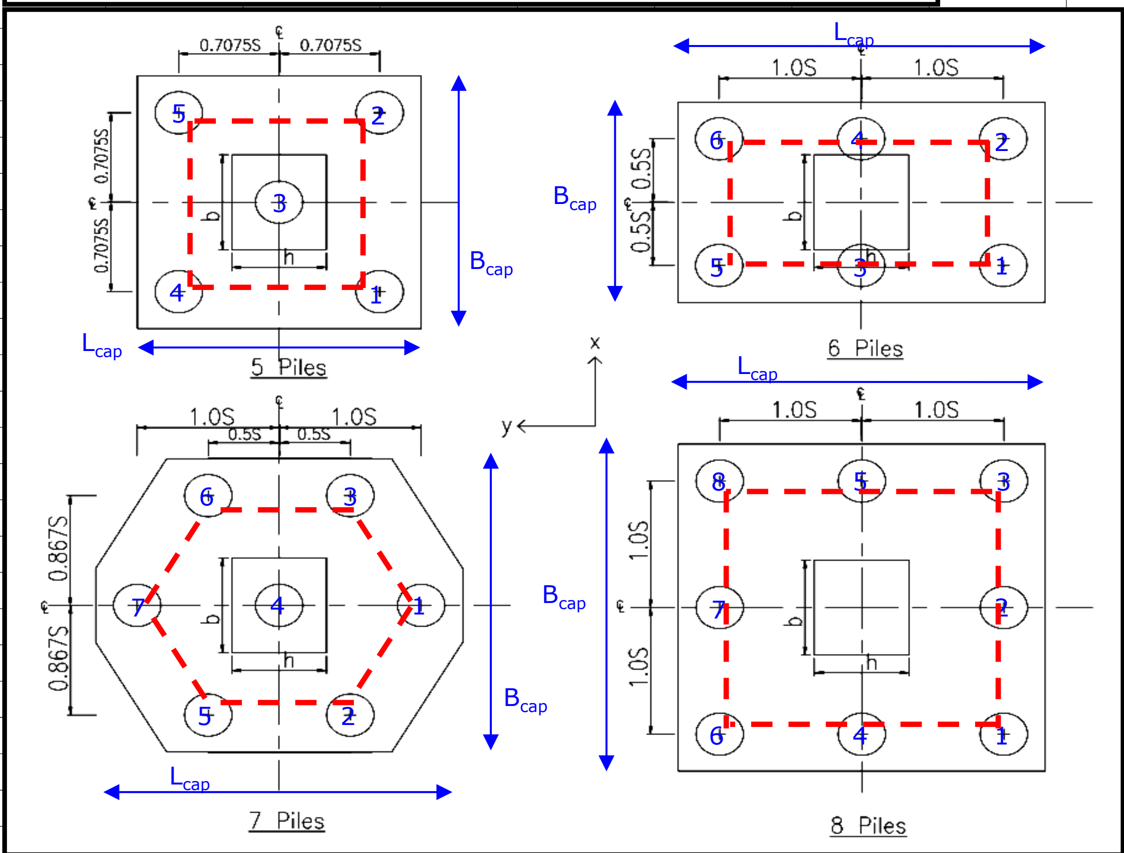
**Factor of Safety**

| | | |
|---|---|---|
| Loading factor, K (between 1.40 and 1.60 depending on DL to LL ratio) | 1.45 | *BS8110* |

*Note loading factor K multiplies SLS loads for ULS loads for section (reinforcement) design;* *cl. 2.4.3.1.1*

**Pile Cap Dimension Definitions**



| CONSULTING ENGINEERS | Engineering Calculation Sheet<br>Consulting Engineers | Job No. | Sheet No. | Rev. |
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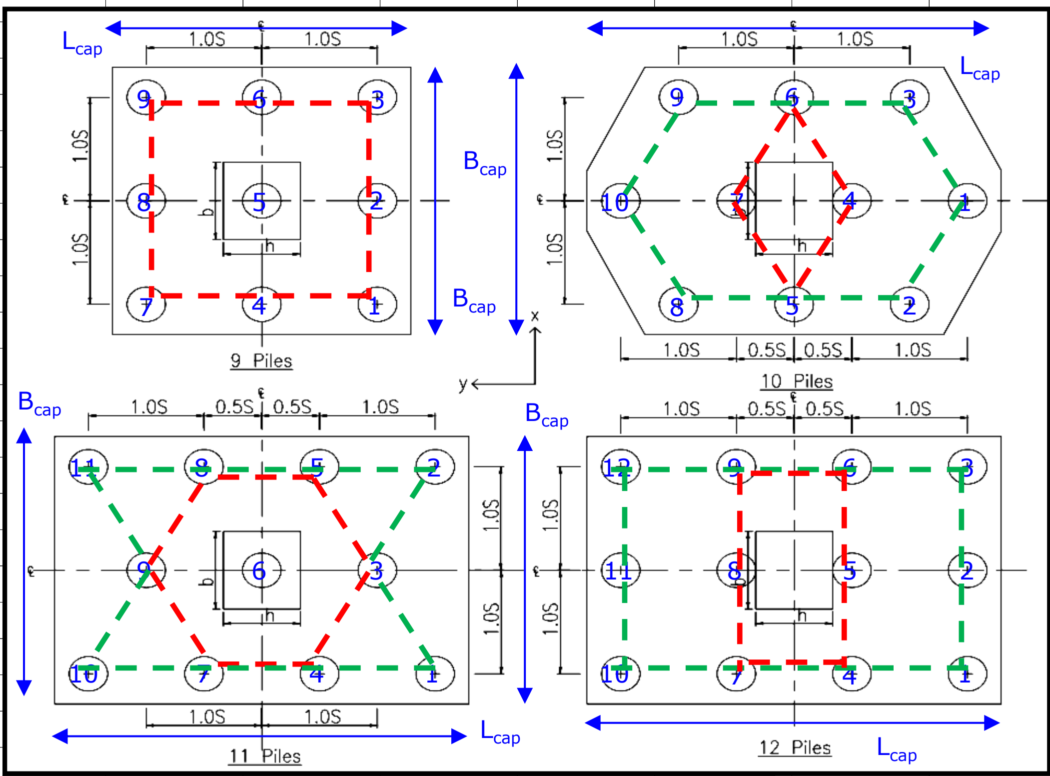
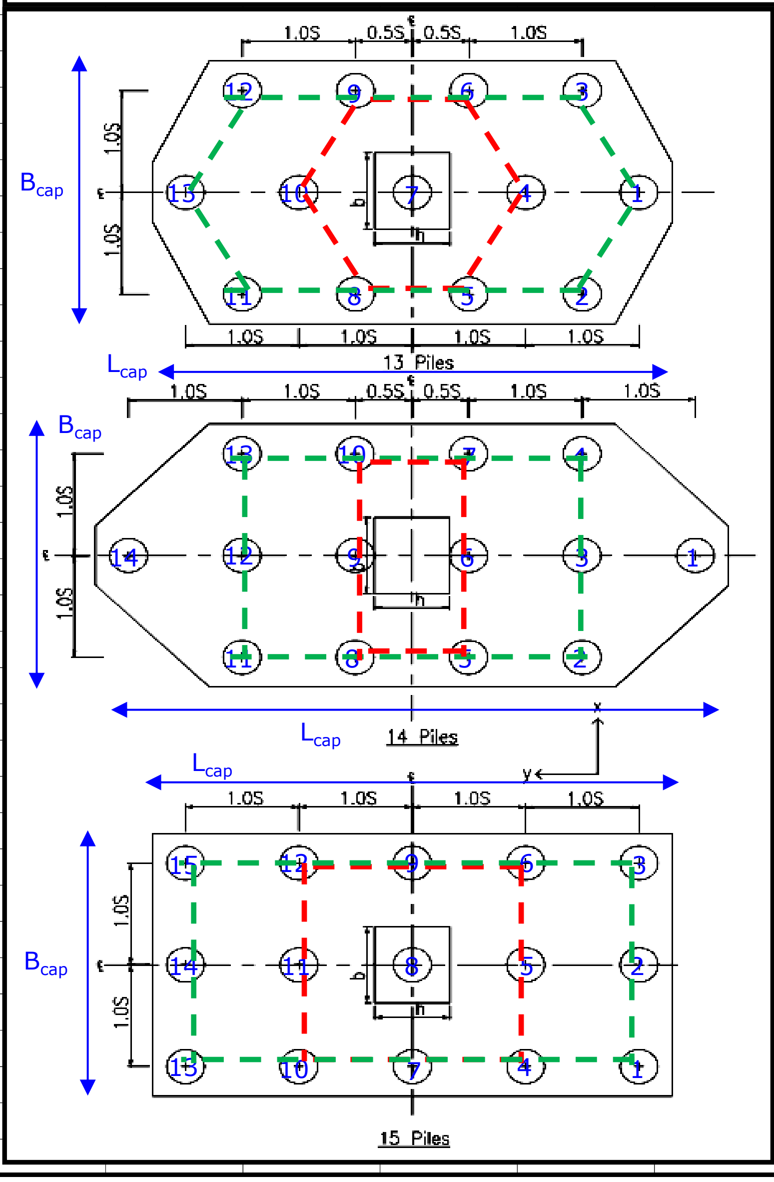
| | | jXXX | 2 | |
| | | Member/Location | | |
| Job Title | Structure, Member Design - Geotechnics Pile Cap v2021 | Drg. | | |
| Structure, Member Design - Geotechnics Pile Cap | | Made by XX | Date 21/11/2021 | Chd. |




First Shear Perimeter

Second Shear Perimeter

Shear Links Zone 1

Shear Links Zone 2

**Pile Cap Dimensions**

| | | | | |
|---|---|---|---|---|
| Pile group arrangement | | Nine Pile Arrangement | | |
| Number of piles in pile group, Σn | | | 9 | |
| Number of piles in pile group, Σn (generic only) | | | N/A | N/A |
| Pile shaft diameter (circular) or width (square), D | | 1200mm | 1200 | mm |
| | | in x | in y | |
| Pile group pile spacing, S | 2.5D / 2.5D | 3000 | 3000 | mm |

*Note that spacing, S refers to distance from c/l to c/l between piles;*

*$S >= $ perimeter $\pi.D$ (or simply 3.0D) for circular friction piles and 4.0D for square friction piles;*

*$S >= 2.0D_b$ for end bearing piles;*

| | | | | |
|---|---|---|---|---|
| | | in x | in y | |
| Projection of pile cap beyond face of pile, $c_{proj}$ (usually 150) | | 150 | 150 | mm |
| Width of pile cap in x, $B_{cap}$ | | | 7.500 | m |
| *1P:* | $B_{cap} = D + 2.c_{proj}$ | | N/A | m |
| *2P:* | $B_{cap} = D + 2.c_{proj}$ | | N/A | m |
| *3P:* | $B_{cap} = 1.0S + D + 2.c_{proj}$ | | N/A | m |
| *4P:* | $B_{cap} = 1.0S + D + 2.c_{proj}$ | | N/A | m |
| *5P:* | $B_{cap} = 1.415S + D + 2.c_{proj}$ | | N/A | m |
| *6P:* | $B_{cap} = 1.0S + D + 2.c_{proj}$ | | N/A | m |
| *7P:* | $B_{cap} = 1.734S + D + 2.c_{proj}$ | | N/A | m |
| *8P:* | $B_{cap} = 2.0S + D + 2.c_{proj}$ | | N/A | m |
| *9P:* | $B_{cap} = 2.0S + D + 2.c_{proj}$ | | 7.500 | m |
| *10P:* | $B_{cap} = 2.0S + D + 2.c_{proj}$ | | N/A | m |
| *11P:* | $B_{cap} = 2.0S + D + 2.c_{proj}$ | | N/A | m |
| *12P:* | $B_{cap} = 2.0S + D + 2.c_{proj}$ | | N/A | m |
| *13P:* | $B_{cap} = 2.0S + D + 2.c_{proj}$ | | N/A | m |
| *14P:* | $B_{cap} = 2.0S + D + 2.c_{proj}$ | | N/A | m |
| *15P:* | $B_{cap} = 2.0S + D + 2.c_{proj}$ | | N/A | m |
| *Generic:* | $B_{cap}$ = *user-defined* | | N/A | m |
| Length of pile cap in y, $L_{cap}$ | | | 7.500 | m |
| *1P:* | $L_{cap} = D + 2.c_{proj}$ | | N/A | m |
| *2P:* | $L_{cap} = 1.0S + D + 2.c_{proj}$ | | N/A | m |
| *3P:* | $L_{cap} = 1.0S + D + 2.c_{proj}$ | | N/A | m |
| *4P:* | $L_{cap} = 1.0S + D + 2.c_{proj}$ | | N/A | m |
| *5P:* | $L_{cap} = 1.415S + D + 2.c_{proj}$ | | N/A | m |
| *6P:* | $L_{cap} = 2.0S + D + 2.c_{proj}$ | | N/A | m |
| *7P:* | $L_{cap} = 2.0S + D + 2.c_{proj}$ | | N/A | m |
| *8P:* | $L_{cap} = 2.0S + D + 2.c_{proj}$ | | N/A | m |
| *9P:* | $L_{cap} = 2.0S + D + 2.c_{proj}$ | | 7.500 | m |
| *10P:* | $L_{cap} = 3.0S + D + 2.c_{proj}$ | | N/A | m |
| *11P:* | $L_{cap} = 3.0S + D + 2.c_{proj}$ | | N/A | m |
| *12P:* | $L_{cap} = 3.0S + D + 2.c_{proj}$ | | N/A | m |
| *13P:* | $L_{cap} = 4.0S + D + 2.c_{proj}$ | | N/A | m |
| *14P:* | $L_{cap} = 5.0S + D + 2.c_{proj}$ | | N/A | m |
| *15P:* | $L_{cap} = 4.0S + D + 2.c_{proj}$ | | N/A | m |
| *Generic:* | $L_{cap}$ = *user-defined* | | N/A | m |

| | | | |
|---|---|---|---|
| Banding ratio (affects truss base force and enhanced shear capacity) | Included | | |
| Banding ratio in plane of width, $b_{r,x} = L_{cap} / L_{cap(3.0D)} \geq 1.0$ | 1.000 | | *cl.3.11.4.2* |
| Banding ratio in plane of width, $b_{r,x}$ (generic only) | N/A | | *BS8110* |
| Banding ratio in plane of length, $b_{r,y} = B_{cap} / B_{cap(3.0D)} \geq 1.0$ | 1.000 | | *cl.3.11.4.2* |
| Banding ratio in plane of length, $b_{r,y}$ (generic only) | N/A | | *BS8110* |

*Note only steel reinforcement within 1.5D from pile centre considered effective;*

| | | | | | |
|---|---|---|---|---|---|
| Stress concentration (affects bending moment a | Included (BS8110 cl.3.11.3.2) (3D Effect) | | | | |
| Stress concentration in plane of width, $s_{c,x}$ ≥ | 1.0 | 1.0 | 1.000 | 1.000 | |
| Stress concentration in plane of length, $s_{c,y}$ ≥ | 1.0 | 1.0 | 1.000 | 1.000 | |
| ***Basis: BS8110 cl.3.11.3.2 (3D Effect)*** | | | | | |
| Factor, $s_{c,x}$ = 2/3 $L_{cap}$ / (h or D + 3$d_x$) | | | 0.300 | | *cl.3.11.3.2* |
| *applicable if $L_{cap}$/2 > 3/4(h or D)+9/4$d_x$* | 3.750 | <= | 12.479 | m | *BS8110* |
| Factor, $s_{c,y}$ = 2/3 $B_{cap}$ / (b or D + 3$d_y$) | | | 0.365 | | *cl.3.11.3.2* |
| *applicable if $B_{cap}$/2 > 3/4(b or D)+9/4$d_y$* | 3.750 | <= | 10.267 | m | *BS8110* |
| ***Basis: BS8110 cl.3.4.1.5 (2D Effect)*** | | | | | |
| Factor, $s_{c,x}$ = $L_{cap}$ / (h or D + $B_{cap}$/5) | | | 0.968 | | *cl.3.4.1.5* |
| Factor, $s_{c,y}$ = $B_{cap}$ / (b or D + $L_{cap}$/5) | | | 1.563 | | *BS8110* |

| | | | |
|---|---|---|---|
| Thickness of pile cap, $T_{cap}$ | 3.800 | m | |
| *Note usually $T_{cap}$ ≈ (MIN($L_{db,x}$,$L_{db,y}$)/2) / tan45° + $cover_1$ + $\phi_{link,2/3}$ + (0.5 t* | 3.140 | m | OK |
| *to $T_{cap}$ ≈ (MIN($L_{db,x}$,$L_{db,y}$)/2) / tan30° + $cover_1$ + $\phi_{link,2/3}$ + (0.5* | 5.340 | m | |
| *for single layer base steel and angle 45° to 30° from vertical to line of compression;* | | | |
| *Note sufficient pile cap rebar anchorage, $T_{cap}$ ≥ $t_{anchor,pilecap}$-D/2-$c_{proj}$+$cover_1$+$cover_2$* | | | |
| *+$cover_3$+$\phi_{link,2/3}$+(0.5 to 1.5). $\phi_b$ ≈* | 0.590 | m | OK |
| *for single layer base steel; Note also that the minimum (large) bending radius needs to be evaluated;* | | | |
| *Note sufficient pile rebar anchorage, $T_{cap}$ ≥ $t_{anchor,pile}$+$cover_1$+$cover_3$ ≈* | 0.810 | m | OK |
| *Pile longitudinal steel reinforcement diameter, $\phi_p$* | 20 | mm | |
| *Note tension anchorage, $t_{anchor}$ = (1/1.05).$f_y$. $\phi$/4/$f_{bu}$.$A_s$/$A_{s,prov,b}$, $f_{bu}$=(0.50 G460, 0.28 G250). √$f_{cu}$, $A_s$/$A_{s,pr}$* | | | |

| | | | |
|---|---|---|---|
| Column base section type *(for punching shear only)* | Rectangular | | |
| Column base depth, h (rectangular) (≥ b) or diameter, D (circular) | 6250 | mm | 4.7 |
| Column base width, b (≤ h) (rectangular) or N/A (circular) | 3300 | mm | |
| *Note where applicable, it is assumed that h is in same plane as $L_{cap}$ and that the column base* | | | *N/mm²* |
| *is always interior and located in the centre of the pile cap $B_{cap}$ and $L_{cap}$; Generally h ≥ b (not mandatory);* | | | |

| | | |
|---|---|---|
| Centroid of pile group in x, $x_c$ = Σ$x_n$/Σn | 3.000 | m |
| Centroid of pile group in y, $y_c$ = Σ$y_n$/Σn | 3.000 | m |
| Second moment of distance of pile group in x, $I_1$ = Σ$x_{n-c}^2$ | 54 | $m^2$ |
| Second moment of distance of pile group in y, $I_2$ = Σ$y_{n-c}^2$ | 54 | $m^2$ |
| Second moment of distance of pile group in xy, $I_{12}$ = Σ$x_{n-c}$.$y_{n-c}$ | 0 | $m^2$ |

| CONSULTING ENGINEERS | Engineering Calculation Sheet<br>Consulting Engineers | Job No. | Sheet No. | Rev. |
|---|---|---|---|---|
| | | jXXX | 5 | |
| | | Member/Location | | |
| Job Title | Structure, Member Design - Geotechnics Pile Cap v2021 | Drg. | | |
| Structure, Member Design - Geotechnics Pile Cap | | Made by XX | Date 21/11/2021 | Chd. |

**Coordinates and Geometrical Properties**

| Pile n | Coordinates (m) | | eneric Coordinates (ı | | Offset (m) | | Geometrical Properties ($m^2$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | $x_n$ | $y_n$ | $x_n$ | $y_n$ | $x_{n-c}$ | $y_{n-c}$ | $x_{n-c}^2$ | $y_{n-c}^2$ | $x_{n-c}.y_{n-c}$ |
| 1 | 0.000 | 0.000 | N/A | N/A | -3.00 | -3.00 | 9.00 | 9.00 | 9.00 |
| 2 | 3.000 | 0.000 | N/A | N/A | 0.00 | -3.00 | 0.00 | 9.00 | 0.00 |
| 3 | 6.000 | 0.000 | N/A | N/A | 3.00 | -3.00 | 9.00 | 9.00 | -9.00 |
| 4 | 0.000 | 3.000 | N/A | N/A | -3.00 | 0.00 | 9.00 | 0.00 | 0.00 |
| 5 | 3.000 | 3.000 | N/A | N/A | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 6 | 6.000 | 3.000 | N/A | N/A | 3.00 | 0.00 | 9.00 | 0.00 | 0.00 |
| 7 | 0.000 | 6.000 | N/A | N/A | -3.00 | 3.00 | 9.00 | 9.00 | -9.00 |
| 8 | 3.000 | 6.000 | N/A | N/A | 0.00 | 3.00 | 0.00 | 9.00 | 0.00 |
| 9 | 6.000 | 6.000 | N/A | N/A | 3.00 | 3.00 | 9.00 | 9.00 | 9.00 |
| 10 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 11 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 12 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 13 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 14 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 15 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 16 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 17 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 18 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 19 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 20 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 21 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 22 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 23 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 24 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 25 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 26 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 27 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 28 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 29 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 30 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 31 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 32 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 33 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 34 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 35 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 36 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 37 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 38 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 39 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 40 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 41 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 42 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 43 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 44 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 45 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 46 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 47 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 48 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 49 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 50 | 0.000 | 0.000 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Σ | **27** | **27** | | | **0** | **0** | **54** | **54** | **0** |

**Pile Cap Reinforcement**

| | | | | |
|---|---|---|---|---|
| Cover to all (bottom) reinforcement, $cover_1$ (usually 100) | | 75 | mm | |
| Cover to all (side) reinforcement, $cover_2$ (usually 75) | | 75 | mm | |
| Cover to all (top) reinforcement, $cover_3$ (usually 45 integrated base slab and 7 | | 75 | mm | |
| Base steel reinforcement diameter in direction of width x, $\phi_{b,x}$ | | 32 | mm | |
| Base steel reinforcement pitch for resistance in direction of width x, $p_{b,x}$ | | 250 | mm | Goal Seek |
| *Note for accuracy, goal seek pitch, $p_{b,x}$ to achieve a whole no. for the actual no. of rebars below;* | | | | |
| Number of layers of base steel for resistance in direction of width x, $n_{layers,base,x}$ | | 4 | layer(s) | |
| Base steel area provided per metre in direction of width x, $A_{s,prov,b,x} = (\pi.\phi_{b,x}{}^2/4$ | | 12863 | $mm^2/m$ | |
| Spacer for base steel, $s_{r,base,x}$ (≥ MAX ($\phi_{b,x}$, 25mm)) | | 100 | mm | OK |
| Base steel area provided in direction of width x, $A_{s,prov,b,x} = A_{s,prov,b,x} . L_{cap}$ | | 96471 | $mm^2$ | |
| No. of rebars, $n_x = A_{s,prov,b,x} / (\pi.\phi_{b,x}{}^2/4)$ | 120.0 ~ | 120.0 | numbers | |
| Actual bar pitch, $p_{b,x} = (n_x.p_{b,x} - 2.cover_2 - 3.\phi_{b,x}) / n_x$ | | 248 | mm | |
| Base steel reinforcement diameter in direction of length y, $\phi_{b,y}$ | | 32 | mm | |
| Base steel reinforcement pitch for resistance in direction of length y, $p_{b,y}$ | | 221 | mm | Goal Seek |
| *Note for accuracy, goal seek pitch, $p_{b,y}$ to achieve a whole no. for the actual no. of rebars below;* | | | | |
| Number of layers of base steel for resistance in direction of length y, $n_{layers,base}$ | | 4 | layer(s) | |
| Base steel area provided per metre in direction of length y, $A_{s,prov,b,y} = (\pi.\phi_{b,y}{}^2/$ | | 14577 | $mm^2/m$ | |
| Spacer for base steel, $s_{r,base,y}$ = (≥ MAX ($\phi_{b,y}$, 25mm)) | | 100 | mm | OK |
| Base steel area provided in direction of length y, $A_{s,prov,b,y} = A_{s,prov,b,y} . B_{cap}$ | | 109328 | $mm^2$ | |
| No. of rebars, $n_y = A_{s,prov,b,y} / (\pi.\phi_{b,y}{}^2/4)$ | 135.9 ~ | 136.0 | numbers | |
| Actual bar pitch, $p_{b,y} = (n_y.p_{b,y} - 2.cover_2 - 3.\phi_{b,y}) / n_y$ | | 219 | mm | |
| Shear link diameter for first and second shear perimeter, $\phi_{link,2/3}$ | | 16 | mm | |
| Number of links for first shear perimeter, $n_{l,2}$ | First Shear Perimeter | 42 | | |
| Number of perimeters within first shear perimeter, $n_{p,2}$ (>= 2) | | 1 | | NOT OK |
| Area provided by all links for first shear perimeter, $A_{sv,prov,2} = n_{l,2}.\pi.$ | | 8445 | $mm^2$ | |
| Distance between perimeters within first shear perimeter, $S_2 = S_{l,1}$ | | 500 | mm | |
| Number of links for second shear perimeter, $n_{l,3}$ | Second Shear Perimeter | N/A | | |
| Number of perimeters within second shear perimeter, $n_{p,3}$ (>= 2) | | N/A | | N/A |
| Area provided by all links for second shear perimeter, $A_{sv,prov,3} = n_{l,}$ | | N/A | $mm^2$ | |
| Distance between perimeters within second shear perimeter, $S_3$ = | | N/A | mm | |
| Shear link diameter, $\phi_{link} = \phi_{link,2/3}$ | | 16 | mm | |
| Number of link legs per metre, $n_{link} = 1/S_{l,1/2}$ | | 2.0 | /m | |
| Area provided by all links per metre, $A_{sv,prov} = n_{link}.\pi.\phi_{link}{}^2/4$ | | 402 | $mm^2/m$ | |
| Pitch of links in zone 1 and zone 2, $S_{l,1/2}$ | Zone 1 500 N/A | 500 | mm | N/A |
| Side steel reinforcement diameter, $\phi_s$ | | 16 | mm | |
| Side steel reinforcement pitch, $p_s$ | | 225 | mm | |
| Detailing code of practice | BS 8666:2000 | | | |
| Internal radius of bend for resistance in x and y, $r_{x/y}$ | 150 | 150 | mm | |
| Effective depth to base steel in direction of width x, $d_x$ | | 3463 | mm | |
| *1P to 2P:* | $d_x = T_{cap} - cover_1 - \phi_{link,2/3} - [\phi_{b,x} + (n_{layers,base,x} - 1)(\phi_b$ | N/A | mm | |
| *3P to 15P:* | $d_x = T_{cap} - cover_1 - \phi_{link,2/3} - [\phi_{b,x} + (n_{layers,base,x} - 1)(\phi_b$ | 3463 | mm | |
| Effective depth to base steel in direction of length y, $d_y$ | | 3463 | mm | |
| *1P to 2P:* | $d_y = T_{cap} - cover_1 - \phi_{link,2/3} - [\phi_{b,y} + (n_{layers,base,y} - 1)(\phi_b$ | N/A | mm | |
| *3P to 15P:* | $d_y = T_{cap} - cover_1 - \phi_{link,2/3} - [\phi_{b,y} + (n_{layers,base,y} - 1)(\phi_b$ | 3463 | mm | |
| Estimated steel reinforcement quantity | With Top Steel ((0.5-1.0)T20EW@Sl,1) | 123 | $kg/m^3$ | 468 |
| *Base steel with full anchorage, shear links with 8 x $\phi_{link,2/3}$ anchorage, binders* | | 113 | $kg/m^3$ | 430 |
| *{T20EW@$p_b$, T20@$S_{l,1}$ in x and T20@$S_{l,1}$/2 in y, none} with 700mm anchora* | | 10 | $kg/m^3$ | 39 |

**Pile Cap SLS Loading**

| | | | | |
|---|---|---|---|---|
| SLS vertical (downward) load from column and base slab, $F_{col,v}$ | | 96570 | kN | Goal Seek |
| *Note that $F_{col,v}$ is positive (downward) and includes SLS loads from suspended or integrated base slab;* | | | | |
| Coordinate of $F_{col,v}$ loading in x, $x_{Fcol,v}$, centroid at | *3.000 m* | 3.000 | m | |
| Coordinate of $F_{col,v}$ loading in y, $y_{Fcol,v}$, centroid at | *3.000 m* | 3.000 | m | |
| Eccentricity of $F_{col,v}$ from centroid in x, $e_1 = x_{Fcol,v} - x_c$ | | 0.000 | m | |
| Eccentricity of $F_{col,v}$ from centroid in y, $e_2 = y_{Fcol,v} - y_c$ | | 0.000 | m | |
| SLS horizontal load from column in x, $F_{col,h1}$ | | 0 | kN | |
| SLS horizontal load from column in y, $F_{col,h2}$ | | 0 | kN | |
| SLS moment from column in plane of x, $M_1$ (defined to add to positive $e_1$ ecce | | 0 | kNm | |
| SLS moment from column in plane of y, $M_2$ (defined to add to positive $e_2$ ecce | | 0 | kNm | |
| *Note M is defined to add to the corresponding positive eccentricity, hence enter a positive or negative value to match the sign of the corresponding eccentricity;* | | | | |
| Pile cap weight, $F_{cap} \approx B_{cap}.L_{cap}.T_{cap}.\rho_c$ | | 5130 | kN | |
| Total pile cap SLS vertical (downward) load, $F_{pilecap,v} = F_{col,v} + F_{cap}$ | | 101700 | kN | |
| *Note that water uplift force at pile and pile cap base have been ignored in the calculation of $F_{pilecap,v}$;* | | | | |

*Note compression is positive, tension negative;*

*Equation set to employ, symmetrical or unsymmetrical ?* Symmetrical

*For pile groups symmetrical about at least one (of the two) axis:-*

| | |
|---|---|
| *Note A = $(F_{col,v}.e_1)/(\Sigma x_{n-c}^2)$;* | *Note D = $(M_2)/(\Sigma y_{n-c}^2)$;* |
| *Note B = $(F_{col,v}.e_2)/(\Sigma y_{n-c}^2)$;* | *Note E = $(F_{col,h1}.T_{cap})/(\Sigma x_{n-c}^2)$;* |
| *Note C = $(M_1)/(\Sigma x_{n-c}^2)$;* | *Note F = $(F_{col,h2}.T_{cap})/(\Sigma y_{n-c}^2)$;* |

*For pile groups unsymmetrical about both axes:-*

*Note A = $(F_{col,v}.e_1.\Sigma y_{n-c}^2 - F_{col,v}.e_2.\Sigma x_{n-c}.y_{n-c})/(\Sigma x_{n-c}^2.\Sigma y_{n-c}^2 - (\Sigma x_{n-c}.y_{n-c})^2)$;*

*Note B = $(F_{col,v}.e_2.\Sigma x_{n-c}^2 - F_{col,v}.e_1.\Sigma x_{n-c}.y_{n-c})/(\Sigma x_{n-c}^2.\Sigma y_{n-c}^2 - (\Sigma x_{n-c}.y_{n-c})^2)$;*

*Note C = $(M_1.\Sigma y_{n-c}^2 - M_2.\Sigma x_{n-c}.y_{n-c})/(\Sigma x_{n-c}^2.\Sigma y_{n-c}^2 - (\Sigma x_{n-c}.y_{n-c})^2)$;*

*Note D = $(M_2.\Sigma x_{n-c}^2 - M_1.\Sigma x_{n-c}.y_{n-c})/(\Sigma x_{n-c}^2.\Sigma y_{n-c}^2 - (\Sigma x_{n-c}.y_{n-c})^2)$;*

*Note E = $(F_{col,h1}.T_{cap}.\Sigma y_{n-c}^2 - F_{col,h2}.T_{cap}.\Sigma x_{n-c}.y_{n-c})/(\Sigma x_{n-c}^2.\Sigma y_{n-c}^2 - (\Sigma x_{n-c}.y_{n-c})^2)$;*

*Note F = $(F_{col,h2}.T_{cap}.\Sigma x_{n-c}^2 - F_{col,h1}.T_{cap}.\Sigma x_{n-c}.y_{n-c})/(\Sigma x_{n-c}^2.\Sigma y_{n-c}^2 - (\Sigma x_{n-c}.y_{n-c})^2)$;*

*Note $F_{pile,v,n} = F_{pilecap,v}/\Sigma n + A.x_{n-c} + B.y_{n-c} + C.x_{n-c} + D.y_{n-c} + E.x_{n-c} + F.y_{n-c}$;*

**Pile Cap ULS Loading**

| | | |
|---|---|---|
| ULS vertical (downward) load from column and base slab, $F_{col,v,uls} = K.F_{col,v}$ | 140027 | kN |
| *Note that $F_{col,v,uls}$ is positive (downward);* | | |

$kg/m^2$

$kg/m^2$ *[Base steel + top steel]*

$kg/m^2$ *[Binders + shear links]*

| CONSULTING ENGINEERS | Engineering Calculation Sheet<br>Consulting Engineers | Job No. | Sheet No. | Rev. |
|---|---|---|---|---|
| | | jXXX | 8 | |
| | | Member/Location | | |
| Job Title | Structure, Member Design - Geotechnics Pile Cap v2021 | Drg. | | |
| Structure, Member Design - Geotechnics Pile Cap | | Made by XX | Date 21/11/2021 | Chd. |

| Pile n | $\Sigma n$ | Axial Force (kN) Due To $F_{col,v}.e_1$ and $F_{col,v}.e_2$ | | $M_1$ and $M_2$ | | $F_{col,h1}.T_{cap}$ and $F_{col,h2}.T_{cap}$ | | $F_{pile,v,n}$ |
|---|---|---|---|---|---|---|---|---|
| | $F_{pilecap,v}/\Sigma n$ | $A.x_{n-c}$ | $B.y_{n-c}$ | $C.x_{n-c}$ | $D.y_{n-c}$ | $E.x_{n-c}$ | $F.y_{n-c}$ | |
| 1 | 11300 | 0 | 0 | 0 | 0 | 0 | 0 | 11300 |
| 2 | 11300 | 0 | 0 | 0 | 0 | 0 | 0 | 11300 |
| 3 | 11300 | 0 | 0 | 0 | 0 | 0 | 0 | 11300 |
| 4 | 11300 | 0 | 0 | 0 | 0 | 0 | 0 | 11300 |
| 5 | 11300 | 0 | 0 | 0 | 0 | 0 | 0 | 11300 |
| 6 | 11300 | 0 | 0 | 0 | 0 | 0 | 0 | 11300 |
| 7 | 11300 | 0 | 0 | 0 | 0 | 0 | 0 | 11300 |
| 8 | 11300 | 0 | 0 | 0 | 0 | 0 | 0 | 11300 |
| 9 | 11300 | 0 | 0 | 0 | 0 | 0 | 0 | 11300 |
| 10 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 11 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 12 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 13 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 14 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 15 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 16 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 17 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 18 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 19 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 20 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 21 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 22 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 23 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 24 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 25 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 26 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 27 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 28 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 29 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 30 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 31 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 32 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 33 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 34 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 35 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 36 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 37 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 38 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 39 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 40 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 41 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 42 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 43 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 44 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 45 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 46 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 47 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 48 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 49 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 50 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

**Pile Cap Spanning Theory**

**Continuous Spans (Rigid Piles, Flexible Pile Cap) Theory**

| | | |
|---|---|---|
| Span / depth ratio in width x (continuous spans), $S / d_x$ | 0.87 | |
| Span / depth ratio in length y (continuous spans), $S / d_y$ | 0.87 | |

*Note based on continuous spans, S / d usually 1.0 to 2.0;*

| | | |
|---|---|---|
| Pile cap spanning theory in width x | Truss / Deep Beam Theory | Too Deep |
| Pile cap spanning theory in length y | Truss / Deep Beam Theory | Too Deep |

*Note shallow beam theory is applicable for continuous span / depth > 2.0 (Mosley 5th 10.7);*

*Note truss / deep beam theories are applicable for 1.0 ≤ continuous span / depth ≤ 2.0 (CIRIA Guide 2 cl.1.3);*

**Inverted Cantilever Spans (Rigid Pile Cap, Flexible Piles) Theory**

| | | |
|---|---|---|
| Span / depth ratio in width x (inverted cantilever spans), MAX $(x_{n-c}) / d_x$ | 0.87 | Adopted |
| Span / depth ratio in width x (inverted cantilever spans), MIN $(x_{n-c}) / d_x$ | 0.87 | Not Adopted |
| Span / depth ratio in length y (inverted cantilever spans), MAX $(y_{n-c}) / d_y$ | 0.87 | Adopted |
| Span / depth ratio in length y (inverted cantilever spans), MIN $(y_{n-c}) / d_y$ | 0.87 | Not Adopted |

*Note based on inverted cantilever spans, MAX or MIN $(x_{n-c} / y_{n-c}) / d$ usually 0.5 to 1.0;*

*Note MAX would be critical for longitudinal shear, MIN would be critical for deep beam bending and shear;*

| | | |
|---|---|---|
| Pile cap spanning theory in width x | Truss / Deep Beam Theory | OK |
| Pile cap spanning theory in length y | Truss / Deep Beam Theory | OK |

*Note shallow beam theory is applicable for cantilever span / depth > 1.0;*

*Note truss / deep beam theories are applicable for 0.5 ≤ cantilever span / depth ≤ 1.0;*

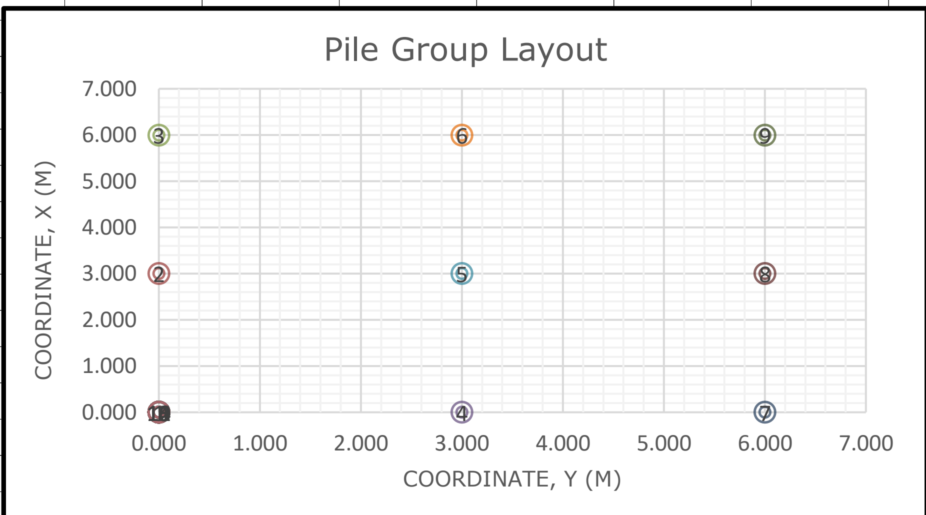
**Adopted Pile Cap Spanning Theory**

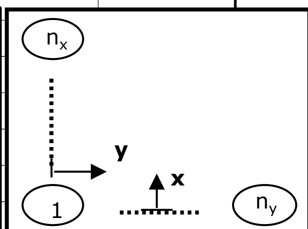
| | | |
|---|---|---|
| Span / depth ratio definition adopted | Inverted Cantilever Spans (Rigid Pile Cap, Flexible Piles) | OK |

*Note that for pile caps with 5 or more piles, only the Inverted Cantilever Span theory is valid for bending theory to be applicable, i.e. for there to be only sagging steel (base steel) and such that the distribution of loads into the multiple piles is fairly uniform, say to 95% uniformity. For the verification of the validity of the Inverted Cantilever Span theory, a soil-structure interaction needs to be carried out to ensure that the pile cap thickness is sufficiently stiff with respect to the vertical pile stiffness;*

| | | |
|---|---|---|
| Pile cap spanning theory in width x | Truss / Deep Beam Theory | OK |
| Pile cap spanning theory in length y | Truss / Deep Beam Theory | OK |

**Pile Group Layout**

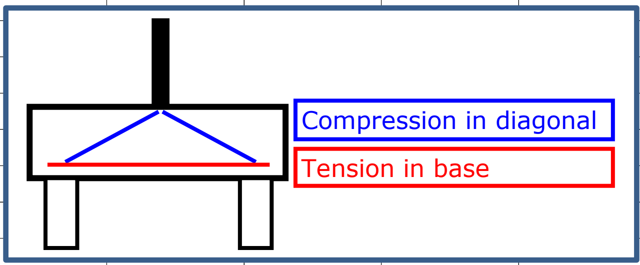



*Note that the coordinate datum is chosen as centre of pile 1; Note enter piles from 1 up to Σn; Note $x_{n-c} = x_n - x_c$*

NTS

**Pile Cap Design Theory**




| | |
|---|---|
| **Pile cap design theory (truss theory)** | Included Always |
| **Pile cap design theory (shallow beam bending theory)** | Included Always |
| **Pile cap design theory (shallow beam shear theory)** | Included Only If Applicable |
| **Pile cap design theory (deep beam bending and shear t** | Included Always |

*Note although truss / deep beam theory may not apply for the extreme piles in certain pile caps due to their large width and / or length, it may be prudent to include them in circumstances where there exist a significant number of piles which are also very close to the column;*

| | |
|---|---|
| **Inclusion of effect of b, h dimensions on truss base force** | Not Included |
| **Base bending moment cal** | Method 1 - Cantilever Span Moment (Modified) |

*Note herewith that both shallow beam and deep beam bending moments are affected;*

| | | | |
|---|---|---|---|
| ***Method 1*** | ***Cantilever Span Moment (Modified)*** | | *Average* |
| | Inclusion of effect of b, h dimensions on base bending momer | Included | |
| | User-defined factor for $M_x$ to correlate with F.E. analysis, $f_{mx}$ | | 1.00 |
| | User-defined factor for $M_y$ to correlate with F.E. analysis, $f_{my}$ | | 1.00 |

*Note in Method 1, it may be unconservative to calculate bending moments to the face of the column (as opposed to the centroid of the column) unless the dimension of the column in the direction orthogonal to the plane under consideration is significant with respect to the pile cap dimension also in the direction orthogonal to the plane under consideration;*

| | | | |
|---|---|---|---|
| ***Method 2*** | ***Timoshenko Simply-Supported Coefficients (Modified)*** | | *Peak* |
| | Aspect ratio, actual and adopted | **1.0** | Ldb,y = 1.0Ldb,x |

*Note Method 2 only applicable for centrally loaded pile caps without column moments as shown in Timoshenko Theory of Plates and Shells pp.139. The theory which assumes a continuous simply-supported rectangular plate is then factored by the ratio of moment coefficients between a corner-supported and simply-supported (but uniformly loaded) rectangular plate;*

| | | | | |
|---|---|---|---|---|
| ***Method 3*** | ***GPSS GSA Corner-Supported Coefficients*** | | Average | *Average* |
| | Aspect ratio, actual and adopted | **1.0** | Ldb,y = 1.0Ldb,x | |

| | |
|---|---|
| **Inclusion of effect of b, h dimensions on shear span** | Included |

*Note that it may be unconservative to calculate the shear span, $a_v$ to the face of the column (as opposed to the centroid of the column) unless the dimension of the column in the direction orthogonal to the plane under consideration is significant with respect to the pile cap dimension also in the direction orthogonal to the plane under consideration. This option affects the shallow beam enhanced shear capacity in x and y but not the enhanced punching shear capacity, whereby the b and h dimensions are always included in the calculation of the shear enhancement. This option also affects the shear span in the deep beam shear capacity in x and y calculations;*

| | | |
|---|---|---|
| **Inclusion of cl.6.2.3(8) EC2 on shear span minimum limit** | Not Included | **Note** |
| **Inclusion of punching shear at first shear perimeter check** | Included | |

*Note that the punching shear at the first shear perimeter check may not be appropriate in the case where the column dimensions extend significantly beyond the perimeter in question;*

| | |
|---|---|
| **Inclusion of punching shear at first and second shear p** | Included Only If Applicable |

*Note that the punching shear at the first and second shear perimeter check may be excluded if it is deemed that the distance between the extreme piles is less than 3D (cl.3.11.4.5 BS8110) and that deep beam theory is applicable for the MAX $(x_{n-c}) / d_x$ and MAX $(y_{n-c}) / d_y$ cases;*

**Criteria Not Met**

| | |
|---|---|
| **Ultimate shear force theory (deep beam theory)** | CIRIA Guide 2 cl.2.4.2 |
| **Check longitudinal shear wi** | Checked Only If Shallow Beam Theory Included and Applicable |

| CONSULTING ENGINEERS | Engineering Calculation Sheet<br>Consulting Engineers | Job No.<br>jXXX | Sheet No.<br>11 | Rev. |
|---|---|---|---|---|
| | | Member/Location | | |
| Job Title | Structure, Member Design - Geotechnics Pile Cap v2021 | Drg. | | |
| Structure, Member Design - Geotechnics Pile Cap | | Made by XX | Date 21/11/2021 | Chd. |

**Executive Summary**

| Pile Cap Shape | Pile Cap Reference | Pile Diameter (mm) | Pile Safe Capacity (kN) | Concrete Grade | Size $S_x$ (mm) | Size $S_y$ (mm) | Depth D (mm) | $R_x$ (B) | $R_y$ (B) |
|---|---|---|---|---|---|---|---|---|---|
| PC9P | PC9P1200 | 1200 | 11300 | C45 | 7500 | 7500 | 3800 | 4x30T32 | 4x34T32 |

| $T_x$ (T) | $T_y$ (T) | Min Col Size, $C_x$ (mm) | Min Col Size, $C_y$ (mm) | Binder | Binder Number | Shear Hooks (Zone 1) | Shear Hooks (Zone 2) | Overall Tonnage kg/m$^3$ | Overall Tonnage kg/m$^2$ |
|---|---|---|---|---|---|---|---|---|---|
| 15T20 | 8T20 | 3300 | 6250 | T16-225 | 17 | T16-500EW | T16-500EW | 123 | 468 |

Perform optimisation — Optimise! — Tidy Up!

| | | | | |
|---|---|---|---|---|
| Optimisation algorithm | | GRG Nonlinear | | |
| Thickness of pile cap, $T_{cap}$ | 1.200 | to | 7.200 | m |
| Base steel pitch x, $p_{b,x}$ | 150 | to | 300 | mm |
| Base steel pitch y, $p_{b,y}$ | 150 | to | 300 | mm |
| Pitch of links in zone 1, $S_{l,1}$ | 300 | to | 450 | mm |
| Pitch of links in zone 2, $S_{l,2}$ | 300 | to | 600 | mm |

| | |
|---|---|
| Pile cap spanning theory in width x | Truss / Deep Beam Theory |
| Pile cap spanning theory in length y | Truss / Deep Beam Theory |

| | | | | |
|---|---|---|---|---|
| Base tension capacity (truss theory) | Applicable | | 96% | OK |
| Diagonal compression capacity (truss theory) | | | 51% | OK |
| Sagging bending moment (shallow beam theory) | | | 48% | OK |
| Sagging bending moment (deep beam theory) | | | 69% | OK |
| % Min base reinforcement | | | 38% | OK |
| Punching shear at column base face | | | 42% | OK |
| Punching shear at first shear perimeter | | Nom.Links | 57% | OK |
| Punching shear at second shear perimeter | | N/A | N/A | N/A |
| Ultimate shear stress | | | N/A | N/A |
| Design shear resistance (shallow beam theor | N/A | N/A | N/A | N/A |
| Ultimate shear force (deep beam theory) | | | 48% | OK |
| Design shear resistance (deep beam theory) | Nom.Links | Nom.Links | 52% | OK |
| Longitudinal shear within section (EC2) | | | N/A | N/A |
| Longitudinal shear within section (BS8110) | | | N/A | N/A |
| Longitudinal shear within section (BS5400-4) | | | N/A | N/A |
| Adequacy of shear links when design links not required | | | NOT OK | |
| Detailing requirements | | | OK | |
| Input parameters checks | | | NOT OK | |
| Minimum recommended depth of pile cap | | | OK | |
| Spanning and design theory checks | | | OK | |
| Deep beam depth zone | | | OK | |
| Min breadth for deep beam bending | | | OK | |

| | | | |
|---|---|---|---|
| Overall utilisation summary | | 96% | |
| % Base reinforcement | 0.34 | 0.38 | % |
| Estimated pile cap steel reinforcement quantity (110 – 150kg/m$^3$) | | 123 | kg/m$^3$ |

*[Note that steel quantity in kg/m$^3$ can be obtained from 78.5 x % rebar];*

| | | | | | |
|---|---|---|---|---|---|
| Material cost: | concrete, c | 305 | units/m$^3$ | steel, s | 4600 units/tonne |
| Reinforced concrete material cost = c+(est. rebar quant).s | | | | 872 | units/m$^3$ |

| CONSULTING ENGINEERS | Engineering Calculation Sheet<br>Consulting Engineers | Job No. | Sheet No. | Rev. |
|---|---|---|---|---|
| | | jXXX | 12 | |
| | | Member/Location | | |
| Job Title | Structure, Member Design - Geotechnics Pile Cap v2021 | Drg. | | |
| Structure, Member Design - Geotechnics Pile Cap | | Made by XX | Date 21/11/2021 | Chd. |

## Pile Cap Base Reinforcement Design (Truss Theory)

| | | |
|---|---|---|
| ULS vertical (downward) load from column and base slab, $F_{col,v,uls}$ | **140027** | kN |
| *Note that $F_{col,v,uls}$ is positive (downward);* | | |
| ULS base force in plane of width, $F_{base,uls,x}$ | **40435** | kN |
| ULS base force in plane of length, $F_{base,uls,y}$ | **40435** | kN |

| | $F_{base,uls,x}$ | | $F_{base,uls,y}$ | | | |
|---|---|---|---|---|---|---|
| *1P:* | *N/A* | *N/A* | *N/A* | *N/A* | kN | |
| *2P:* | *N/A* | *N/A* | $F_{col,v,uls}.S/(4d_y)$ | *N/A* | kN | *Mosley* |
| *3P:* | $F_{col,v,uls}.S/(4.5d_x)$ | *N/A* | $F_{col,v,uls}.S/(4.5d_y)$ | *N/A* | kN | *Mosley* |
| *4P:* | $F_{col,v,uls}.S/(4d_x)$ | *N/A* | $F_{col,v,uls}.S/(4d_y)$ | *N/A* | kN | *Mosley* |
| *5P:* | $F_{col,v,uls}.S/(5d_x)$ | *N/A* | $F_{col,v,uls}.S/(5d_y)$ | *N/A* | kN | *Masterseries* |
| *6P:* | $F_{col,v,uls}.S/(4d_x)$ | *N/A* | $F_{col,v,uls}.S/(3d_y)$ | *N/A* | kN | *Masterseries* |
| *7P:* | $F_{col,v,uls}.S/(4d_x)$ | *N/A* | $F_{col,v,uls}.S/(3.5d_y)$ | *N/A* | kN | *Masterseries* |
| *8P:* | $F_{col,v,uls}.S/(3d_x)$ | *N/A* | $F_{col,v,uls}.S/(3d_y)$ | *N/A* | kN | *Masterseries* |
| *9P:* | $F_{col,v,uls}.S/(3d_x)$ | *40435* | $F_{col,v,uls}.S/(3d_y)$ | *40435* | kN | *Masterseries* |
| *10P:* | $\Sigma F_{col,v,uls}.L_{x,i}/(4d_x)$ | *N/A* | $\Sigma F_{col,v,uls}.L_{y,i}/(4d_y)$ | *N/A* | kN | *Extrapolation* |
| *11P:* | $\Sigma F_{col,v,uls}.L_{x,i}/(4d_x)$ | *N/A* | $\Sigma F_{col,v,uls}.L_{y,i}/(4d_y)$ | *N/A* | kN | *Extrapolation* |
| *12P:* | $\Sigma F_{col,v,uls}.L_{x,i}/(4d_x)$ | *N/A* | $\Sigma F_{col,v,uls}.L_{y,i}/(4d_y)$ | *N/A* | kN | *Extrapolation* |
| *13P:* | $\Sigma F_{col,v,uls}.L_{x,i}/(4d_x)$ | *N/A* | $\Sigma F_{col,v,uls}.L_{y,i}/(4d_y)$ | *N/A* | kN | *Extrapolation* |
| *14P:* | $\Sigma F_{col,v,uls}.L_{x,i}/(4d_x)$ | *N/A* | $\Sigma F_{col,v,uls}.L_{y,i}/(4d_y)$ | *N/A* | kN | *Extrapolation* |
| *15P:* | $\Sigma F_{col,v,uls}.L_{x,i}/(4d_x)$ | *N/A* | $\Sigma F_{col,v,uls}.L_{y,i}/(4d_y)$ | *N/A* | kN | *Extrapolation* |
| *Generic:* | *user-defined* | *N/A* | *user-defined* | *N/A* | kN | |

*Note that $F_{base,uls}$ is positive (tensile);*

| | | | |
|---|---|---|---|
| ULS base force in plane of width per metre, $F_{base,uls,x}/L_{cap}$ | **5391** | kN/m | |
| ULS base force in plane of length per metre, $F_{base,uls,y}/B_{cap}$ | **5391** | kN/m | |
| ULS base force in plane of width per metre, $b_{r,x}.F_{base,uls,x}/L_{cap}$ | **5391** | kN/m | *cl.3.11.4.2* |
| ULS base force in plane of length per metre, $b_{r,y}.F_{base,uls,y}/B_{cap}$ | **5391** | kN/m | *BS8110* |
| Area of steel required in x per metre, $A_{s,t,x} = (b_{r,x}.F_{base,uls,x}/L_{cap}) / (0.95f_y)$ | **12337** | $mm^2/m$ | |
| Area of steel required in y per metre, $A_{s,t,y} = (b_{r,y}.F_{base,uls,y}/B_{cap}) / (0.95f_y)$ | **12337** | $mm^2/m$ | |

*Note that $F_{col,v,uls}$ does not account for primary moments nor secondary moments due to eccentricity of vertical loading and horizontal loading, thus not accounted for within the base area steel;*

| | | | |
|---|---|---|---|
| Area of tensile steel reinforcement provided in x per metre, $A_{s,prov,b,x}$ | 12863 | $mm^2/m$ | |
| Base tension capacity in x utilisation = $A_{s,t,x}$ / $A_{s,prov,b,x}$ | **96%** | | **OK** |
| Area of tensile steel reinforcement provided in y per metre, $A_{s,prov,b,y}$ | 14577 | $mm^2/m$ | |
| Base tension capacity in y utilisation = $A_{s,t,y}$ / $A_{s,prov,b,y}$ | **85%** | | **OK** |

## Pile Cap Diagonal Compression Capacity Design (Truss Theory)

ULS diagonal force, $F_{diagonal,uls} = K . MAX (F_{pile,v,i}) . (d^2+L_d^2)^{0.5} / d$ — **25910** kN

| | $L_d$ | | $L_d$ | | $L_d$ | | |
|---|---|---|---|---|---|---|---|
| *1P/6P/11P:* | *N/A* | *N/A* | *1.118S* | *N/A* | *1.803S* | *N/A* | mm |
| *2P/7P/12P:* | *0.5S* | *N/A* | *1.0S* | *N/A* | *1.803S* | *N/A* | mm |
| *3P/8P/13P:* | *0.6S* | *N/A* | *1.414S* | *N/A* | *2.0S* | *N/A* | mm |
| *4P/9P/14P:* | *0.7071S* | *N/A* | *1.414S* | *4242* | *2.5S* | *N/A* | mm |
| *5P/10P/15P:* | *1.0S* | *N/A* | *1.5S* | *N/A* | *2.236S* | *N/A* | mm |
| *Generic:* | | | | | *user-defined* | *N/A* | mm |

*Note that $L_d$ is the distance of the furthest pile from the centroid of the column load;*

| | | | |
|---|---|---|---|
| Diagonal compression capacity, $N_{cap} = 1.00f_{cu}.(\pi.D^2/4)$ | 50894 | kN | |
| Diagonal compression capacity utilisation = $F_{diagonal,uls}$ / $N_{cap}$ | **51%** | | **OK** |

| CONSULTING ENGINEERS | Engineering Calculation Sheet<br>Consulting Engineers | Job No. | Sheet No. | Rev. |
|---|---|---|---|---|
| | | jXXX | 13 | |
| | | Member/Location | | |
| Job Title | Structure, Member Design - Geotechnics Pile Cap v2021 | Drg. | | |
| Structure, Member Design - Geotechnics Pile Cap | | Made by XX | Date 21/11/2021 | Chd. |

**Pile Cap Base Reinforcement Design (Shallow and Deep Beam Theory)**

| | | |
|---|---|---|
| ULS moment at column base in plane of width, $M_x$ | 66359 | kNm |
| ULS moment at column base in plane of length, $M_y$ | 0 | kNm |

| | $M_x$ | | $M_y$ | | |
|---|---|---|---|---|---|
| *1P:* | *N/A* | *N/A* | *N/A* | *N/A* | kNm |
| *2P:* | *N/A* | *N/A* | *$M_y$={M1 only}* | *N/A* | kNm |
| *3P:* | *$M_x$={M1, M2, M3}* | *N/A* | *$M_y$={M1, M2, M3}* | *N/A* | kNm |
| *4P:* | *$M_x$={M1, M2, M3}* | *N/A* | *$M_y$={M1, M2, M3}* | *N/A* | kNm |
| *5P:* | *$M_x$={M1, M2, M3}* | *N/A* | *$M_y$={M1, M2, M3}* | *N/A* | kNm |
| *6P:* | *$M_x$={M1, M2, M3}* | *N/A* | *$M_y$={M1, M2, M3}* | *N/A* | kNm |
| *7P:* | *$M_x$={M1, M2, M3}* | *N/A* | *$M_y$={M1, M2, M3}* | *N/A* | kNm |
| *8P:* | *$M_x$={M1, M2, M3}* | *N/A* | *$M_y$={M1, M2, M3}* | *N/A* | kNm |
| *9P:* | *$M_x$={M1, M2, M3}* | *66359* | *$M_y$={M1, M2, M3}* | *0* | kNm |
| *10P:* | *$M_x$={M1, M2, M3}* | *N/A* | *$M_y$={M1, M2, M3}* | *N/A* | kNm |
| *11P:* | *$M_x$={M1, M2, M3}* | *N/A* | *$M_y$={M1, M2, M3}* | *N/A* | kNm |
| *12P:* | *$M_x$={M1, M2, M3}* | *N/A* | *$M_y$={M1, M2, M3}* | *N/A* | kNm |
| *13P:* | *$M_x$={M1, M2, M3}* | *N/A* | *$M_y$={M1, M2, M3}* | *N/A* | kNm |
| *14P:* | *$M_x$={M1, M2, M3}* | *N/A* | *$M_y$={M1, M2, M3}* | *N/A* | kNm |
| *15P:* | *$M_x$={M1, M2, M3}* | *N/A* | *$M_y$={M1, M2, M3}* | *N/A* | kNm |
| *Generic:* | *user-defined* | *N/A* | *user-defined* | *N/A* | kNm |

*Note moment calculations based on either: -*

| | | |
|---|---|---|
| *Method 1* | *Cantilever Span Moment (Modified)* | $M_x = f_{mx}.K.\Sigma F_{pile,v,i}.(x_{i-c}-b/2)$ |
| | | $M_y = f_{my}.K.\Sigma F_{pile,v,i}.(y_{i-c}-h/2)$ |
| *Method 2* | *Timoshenko S/S Coefficients (Modified)* | $M_x = K.F_{pilecap,v}.\beta.L_{cap}$ |
| | | $M_y = K.F_{pilecap,v}.\beta_1.B_{cap}$ |
| *Method 3* | *GPSS GSA C/S Coefficients* | $M_x = K.F_{pilecap,v}.\beta.L_{cap}$ |
| | | $M_y = K.F_{pilecap,v}.\beta_1.B_{cap}$ |

| | | | |
|---|---|---|---|
| ULS moment at column base in plane of width per metre, $M_x/L_{cap}$ | 8848 | kNm/m | |
| ULS moment at column base in plane of length per metre, $M_y/B_{cap}$ | 0 | kNm/m | |
| ULS moment at column base in plane of width per metre, $s_{c,x}.M_x/L_{cap}$ | 8848 | kNm/m | |
| ULS moment at column base in plane of length per metre, $s_{c,y}.M_y/B_{cap}$ | 0 | kNm/m | |
| Concrete moment capacity in x per metre, $M_{u,x} = 0.156f_{cu}.1000.d_x^2$ | 84186 | kNm/m | |
| Concrete moment capacity in y per metre, $M_{u,y} = 0.156f_{cu}.1000.d_y^2$ | 84186 | kNm/m | |
| Bending stress in x, $[M/bd^2]_x = (s_{c,x}.M_x/L_{cap}) / [(1000).d_x^2]$ | 0.74 | $N/mm^2$ | |
| Bending stress in y, $[M/bd^2]_y = (s_{c,y}.M_y/B_{cap}) / [(1000).d_y^2]$ | 0.00 | $N/mm^2$ | |
| Bending stress ratio in x, $K_x = [M/bd^2]_x / f_{cu} <= 0.156$ | 0.016 | | OK |
| Bending stress ratio in y, $K_y = [M/bd^2]_y / f_{cu} <= 0.156$ | 0.000 | | OK |
| Lever arm in x, $z_x = d_x . [0.5 + (0.25-K_x/0.9)^{0.5}] <= 0.95d_x$ | 3290 | mm | |
| Lever arm in y, $z_y = d_y . [0.5 + (0.25-K_y/0.9)^{0.5}] <= 0.95d_y$ | 3290 | mm | |
| Area of steel required in x per metre, $A_{s,m,x} = (s_{c,x}.M_x/L_{cap}) / [(0.95f_y).z_x]$ | 6154 | $mm^2/m$ | |
| Area of steel required in y per metre, $A_{s,m,y} = (s_{c,y}.M_y/B_{cap}) / [(0.95f_y).z_y]$ | 0 | $mm^2/m$ | |

| | | | | |
|---|---|---|---|---|
| Area of steel required in x per metre (deep beam), $A_{s,m,x,db}$ = 1.75($s_{c,x}$.$M_x$/$L_{cap}$) | | **8858** | $mm^2/m$ | *Reynolds* |
| Area of steel required in y per metre (deep beam), $A_{s,m,y,db}$ = 1.75($s_{c,y}$.$M_y$/$B_{cap}$) | | **0** | $mm^2/m$ | *T.148* |
| *Note $A_{s,m,x,db}$ to be distributed over depth of $(5T_{cap} - L_{db,x})/20$ from soffit* | | ***650*** | *mm* | *cl.21.4.1* |
| *Depth of zone used by $A_{s,m,x,db}$ ($\geq 0.75(5T_{cap} - L_{db,x})/20$)* | ***93%*** | ***603*** | *mm* | ***OK*** |
| *Note $A_{s,m,y,db}$ to be distributed over depth of $(5T_{cap} - L_{db,y})/20$ from soffit* | | ***650*** | *mm* | *cl.21.4.1* |
| *Depth of zone used by $A_{s,m,y,db}$ ($\geq 0.75(5T_{cap} - L_{db,y})/20$)* | ***93%*** | ***603*** | *mm* | ***OK*** |

| | $L_{db,x}$ | | $L_{db,y}$ | | |
|---|---|---|---|---|---|
| *1P:* | *N/A* | *N/A* | *N/A* | *N/A* | mm |
| *2P:* | *N/A* | *N/A* | *1.0S* | *N/A* | mm |
| *3P:* | *1.0S* | *N/A* | *1.0S* | *N/A* | mm |
| *4P:* | *1.0S* | *N/A* | *1.0S* | *N/A* | mm |
| *5P:* | *1.415S* | *N/A* | *1.415S* | *N/A* | mm |
| *6P:* | *1.0S* | *N/A* | *2.0S* | *N/A* | mm |
| *7P:* | *1.734S* | *N/A* | *2.0S* | *N/A* | mm |
| *8P:* | *2.0S* | *N/A* | *2.0S* | *N/A* | mm |
| *9P:* | *2.0S* | *6000* | *2.0S* | *6000* | mm |
| *10P:* | *2.0S* | *N/A* | *3.0S* | *N/A* | mm |
| *11P:* | *2.0S* | *N/A* | *3.0S* | *N/A* | mm |
| *12P:* | *2.0S* | *N/A* | *3.0S* | *N/A* | mm |
| *13P:* | *2.0S* | *N/A* | *4.0S* | *N/A* | mm |
| *14P:* | *2.0S* | *N/A* | *5.0S* | *N/A* | mm |
| *15P:* | *2.0S* | *N/A* | *4.0S* | *N/A* | mm |
| *Generic:* | *user-defined* | *N/A* | *user-defined* | *N/A* | mm |

| | | | |
|---|---|---|---|
| Area of tensile steel reinforcement provided in x per metre, $A_{s,prov,b,x}$ | 12863 | $mm^2/m$ | |
| Sagging bending moment (shallow beam theory) in x utilisation = $A_{s,m,x}$ / $A_{s,pro}$ | **48%** | | **OK** |
| Sagging bending moment (deep beam theory) in x utilisation = $A_{s,m,x,db}$ / $A_{s,prov}$ | **69%** | | **OK** |
| Area of tensile steel reinforcement provided in y per metre, $A_{s,prov,b,y}$ | 14577 | $mm^2/m$ | |
| Sagging bending moment (shallow beam theory) in y utilisation = $A_{s,m,y}$ / $A_{s,pro}$ | **0%** | | **OK** |
| Sagging bending moment (deep beam theory) in y utilisation = $A_{s,m,y,db}$ / $A_{s,prov}$ | **0%** | | **OK** |

**Base Reinforcement Percentage**

| | | | |
|---|---|---|---|
| % Min base reinforcement in x (>= 0.0024.1000.$T_{cap}$ G250; >= 0.0013.1000.) | 0.34 | % | |
| % Min base reinforcement in x utilisation | **38%** | | **OK** |
| % Min base reinforcement in y (>= 0.0024.1000.$T_{cap}$ G250; >= 0.0013.1000.) | 0.38 | % | |
| % Min base reinforcement in y utilisation | **34%** | | **OK** |

| | | | | |
|---|---|---|---|---|
| **CONSULTING ENGINEERS** | Engineering Calculation Sheet<br>Consulting Engineers | Job No.<br>jXXX | Sheet No.<br>15 | Rev. |
| | | Member/Location | | |
| Job Title | Structure, Member Design - Geotechnics Pile Cap v2021 | Drg. | | |
| Structure, Member Design - Geotechnics Pile Cap | | Made by **XX** | Date **21/11/2021** | Chd. |

## Pile Cap Punching Shear Reinforcement Design

*cl.3.11.4.5 BS8110*

| | | | |
|---|---|---|---|
| ULS vertical (downward) load from column and base slab, $F_{col,v,uls}$ | **140027** | kN | |
| *Note that $F_{col,v,uls}$ is positive (downward);* | | | |
| Area of column base section, $A_{c1}$ = b.h (rectangular) or $\pi D^2/4$ (circular) | 20625000 | $mm^2$ | |
| Effective depth to base steel, $d = (d_x + d_y) / 2$ | 3463 | mm | |
| Area of tensile steel reinforcement provided per metre, $(A_{s,prov,b,x}.L_{cap} + A_{s,prov,b}$ | 13720 | $mm^2/m$ | |
| $\rho_w = 100A_{s,prov,b}/(1000.d)$ | 0.40 | % | |
| First shear perimeter, $\nu_c = (0.79/1.25)(\rho_w f_{cu}/25)^{1/3}(400/d)^{1/4}$; $\rho_w$<3 *0.67* | **0.36** | $N/mm^2$ | *T.3.8* |
| Second shear perimeter, $\nu_c = (0.79/1.25)(\rho_w f_{cu}/25)^{1/3}(400/d)^{1/4}$; $\rho_w$ *N/A* | **N/A** | $N/mm^2$ | *BS8110* |

### Column Base Face Perimeter

| | | | | | |
|---|---|---|---|---|---|
| Shear force at column base face, $V_1 = ABS(F_{col,v,uls})$ | | | | 140027 | kN |
| Effective shear force, $V_{eff,1}$ = 1.00 . $V_1$ *(moment effects ignored)* | | | | 140027 | kN |
| Column base face perimeter, $u_1$ | | | | 19100 | mm |
| | *Rectangular* | | *Circular* | | |
| *Internal column:* | *2.(b+h)* | *19100* | *π.D* | *N/A* | mm |
| Shear stress at column base face perimeter, $\nu_1 = V_{eff,1} / u_1 d$ (< $0.8f_{cu}^{0.5}$ & 5N/ | | | | **2.12** | $N/mm^2$ |
| Ultimate shear stress utilisation | | | | **42%** | **OK** |

### First Shear Perimeter

Shear force 20% D inside face of pile from column base face, $V_2 = F_{col,v,uls} - F_{N/}$ 123642 kN

| | $F_{N/A}$ | | $F_{N/A}$ | | $F_{N/A}$ | | |
|---|---|---|---|---|---|---|---|
| *1P/6P/11P:* | *N/A* | *N/A* | *0.M(F<sub></sub>P)* | *N/A* | *1.M(FP)* | *N/A* | kN |
| *2P/7P/12P:* | *N/A* | *N/A* | *1.M(FP)* | *N/A* | *0.M(FP)* | *N/A* | kN |
| *3P/8P/13P:* | *0.M(FP)* | *N/A* | *0.M(FP)* | *N/A* | *1.M(FP)* | *N/A* | kN |
| *4P/9P/14P:* | *0.M(FP)* | *N/A* | *1.M(FP)* | *16385* | *0.M(FP)* | *N/A* | kN |
| *5P/10P/15P:* | *1.M(FP)* | *N/A* | *0.M(FP)* | *N/A* | *1.M(FP)* | *N/A* | kN |
| *Generic:* | | | | | *user-defined* | *N/A* | kN |

*Note $M(F_P)$ above refers to K . MIN ($F_{pile,v,i}$);*

| | | | |
|---|---|---|---|
| Effective shear force, $V_{eff,2}$ = 1.00 . $V_2$ *(moment effects ignored)* | | 123642 | kN |
| Column base first shear perimeter, $u_2$ | | 21120 | mm |
| *Internal column:* | *Rectangular or Circular* | | |
| *1P:* | *N/A* | *N/A* | mm |
| *2P:* | *N/A* | *N/A* | mm |
| *3P:* | *[1.0S-D+2.(0.2D)] + 2.[(0.5²+1.0²)^0.5 S-D+2.(0.2D)]* | *N/A* | mm |
| *4P:* | *4.[1.0S-D+2.(0.2D)]* | *N/A* | mm |
| *5P:* | *4.[1.415S-D+2.(0.2D)]* | *N/A* | mm |
| *6P:* | *2.[1.0S-D+2.(0.2D)] + 2.[2.0S-D+2.(0.2D)]* | *N/A* | mm |
| *7P:* | *6.[1.0S-D+2.(0.2D)]* | *N/A* | mm |
| *8P:* | *4.[2.0S-D+2.(0.2D)]* | *N/A* | mm |
| *9P:* | *4.[2.0S-D+2.(0.2D)]* | *21120* | mm |
| *10P:* | *4.[(1.0²+0.5²)^0.5 S-D+2.(0.2D)]* | *N/A* | mm |
| *11P:* | *[(1.0²+0.5²)^0.5 S-D+2.(0.2D)] + 2.[1.0S-D+2.(0.2D)]* | *N/A* | mm |
| *12P:* | *2.[2.0S-D+2.(0.2D)] + 2.[1.0S-D+2.(0.2D)]* | *N/A* | mm |
| *13P:* | *[(1.0²+0.5²)^0.5 S-D+2.(0.2D)] + 2.[1.0S-D+2.(0.2D)]* | *N/A* | mm |
| *14P:* | *2.[2.0S-D+2.(0.2D)] + 2.[1.0S-D+2.(0.2D)]* | *N/A* | mm |
| *15P:* | *4.[2.0S-D+2.(0.2D)]* | *N/A* | mm |
| *Generic:* | *user-defined* | *N/A* | mm |

*Note first shear perimeter refers to first perimeter 20% D inside face of pile;*

Shear stress at column base first shear perimeter, $\nu_2 = V_{eff,2} / u_2 d$ **1.69** $N/mm^2$

*(Shear capacity enhancement by calculating $v_d$ at "support" and comparing against enhanced $v_c$ within 1.5d of the "support" as clause 3.7.7.4 BS8110 employed, that of clause 3.7.7.6 BS8110 not applicable;)*

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSULTING ENGINEERS** | | Engineering Calculation Sheet<br>Consulting Engineers | | | | Job No.<br>jXXX | Sheet No.<br>16 | | Rev. |
| | | | | | | Member/Location | | | |
| Job Title | Structure, Member Design - Geotechnics Pile Cap v2021 | | | | | Drg. | | | |
| Structure, Member Design - Geotechnics Pile Cap | | | | | | Made by **XX** | Date **21/11/2021** | | Chd. |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| Distance 20% D inside face of pile from column base face, $a_v$ (≥ 0.375d) | | | | | | | **253** | mm | *6.2.3(8) EC* |
| | *1P:* | | | | | *N/A* | *N/A* | mm | ***Not Incl.*** |
| | *2P:* | | | | | *N/A* | *N/A* | mm | |
| | *3P:* | *AVE [(1.0S-D-b)/2+0.2D, (4/3S-D-h)/2+0.2D]* | | | | | *N/A* | mm | |
| | *4P:* | *AVE [(1.0S-D-b)/2+0.2D, (1.0S-D-h)/2+0.2D]* | | | | | *N/A* | mm | |
| | *5P:* | *AVE [(1.415S-D-b)/2+0.2D, (1.415S-D-h)/2+0.2D]* | | | | | *N/A* | mm | |
| | *6P:* | *AVE [(1.0S-D-b)/2+0.2D, (2.0S-D-h)/2+0.2D]* | | | | | *N/A* | mm | |
| | *7P:* | *AVE [(1.734S-D-b)/2+0.2D, (2.0S-D-h)/2+0.2D]* | | | | | *N/A* | mm | |
| | *8P:* | *AVE [(2.0S-D-b)/2+0.2D, (2.0S-D-h)/2+0.2D]* | | | | | *N/A* | mm | |
| | *9P:* | *AVE [(2.0S-D-b)/2+0.2D, (2.0S-D-h)/2+0.2D]* | | | | | *253* | mm | |
| | *10P:* | *AVE [(2.0S-D-b)/2+0.2D, (1.0S-D-h)/2+0.2D]* | | | | | *N/A* | mm | |
| | *11P:* | *AVE [(2.0S-D-b)/2+0.2D, (2.0S-D-h)/2+0.2D]* | | | | | *N/A* | mm | |
| | *12P:* | *AVE [(2.0S-D-b)/2+0.2D, (1.0S-D-h)/2+0.2D]* | | | | | *N/A* | mm | |
| | *13P:* | *AVE [(2.0S-D-b)/2+0.2D, (2.0S-D-h)/2+0.2D]* | | | | | *N/A* | mm | |
| | *14P:* | *AVE [(2.0S-D-b)/2+0.2D, (1.0S-D-h)/2+0.2D]* | | | | | *N/A* | mm | |
| | *15P:* | *AVE [(2.0S-D-b)/2+0.2D, (2.0S-D-h)/2+0.2D]* | | | | | *N/A* | mm | |
| | *Generic:* | | | | | *user-defined* | *N/A* | mm | |
| *Note b and h above are replaced by D for circular columns, here D referring to the column dimension;* | | | | | | | | | |
| *Note conservatively, the furthest pile in the relevant perimeter is taken for the calculation of $a_v$;* | | | | | | | | | |
| *(Note that $a_v$ is limited to 1.5d, beyond which no shear capacity enhancement is exhibited, i.e. $1.5d/a_v = 1$;)* | | | | | | | | | |
| Shear enhancement, $a_v$ = | | | 253 | mm | <= | 1.5d = | 5195 | mm | **Adopted** |
| Enhanced shear capacity, $1.5dv_c/a_v$ | | | | | | *x 20.57* | **7.48** | $N/mm^2$ | |
| Enhanced shear capacity, $1.5dv_c/a_v$ (< $0.8f_{cu}^{0.5}$ & $5N/mm^2$) | | | | | | *x 8.11* | **2.95** | $N/mm^2$ | **Note** |
| *Note that the enhanced shear capacity is limited to $0.8f_{cu}^{0.5}$ & $5N/mm^2$ & $k_1 0.5f_{cu}^{0.5}$ \| $2\lambda_1 0.5f_{cu}^{0.5}$;* | | | | | | | | | |
| | | | | | | | | | |
| | **Case $v_2 < 1.5dv_c/a_v$** | | | | | | **VALID** | | |
| | | No nominal / design links required | | | 6333 | < | 66946 | $mm^2$ | **NOT OK** |
| | **Case $1.5dv_c/a_v < v_2 < 1.6(1.5dv_c/a_v)$** | | | | | | **N/A** | | |
| | | $\Sigma A_{sv}\sin\alpha \geq \frac{(v-v_c)ud}{0.95f_{yv}}$ | | | N/A | >= | N/A | $mm^2$ | |
| | | Note | $\Sigma A_{sv}\sin\alpha$ | > | $0.4ud/0.95f_{yv}$ | *Note that $v_c$ above refers to $1.5dv_c/a_v$;* | | | |
| | **Case $1.6(1.5dv_c/a_v) < v_2 < 2.0(1.5dv_c/a_v)$** | | | | | | **N/A** | | |
| | | $\Sigma A_{sv}\sin\alpha \geq \frac{5(0.7v-v_c)ud}{0.95f_{yv}}$ | | | N/A | >= | N/A | $mm^2$ | |
| | | Note | $\Sigma A_{sv}\sin\alpha$ | > | $0.4ud/0.95f_{yv}$ | *Note that $v_c$ above refers to $1.5dv_c/a_v$;* | | | |
| | **Case $v_2 > 2.0(1.5dv_c/a_v)$** | | | | | | **N/A** | | |
| | | | | | | | | | |
| Shear link diameter for first shear perimeter, $\phi_{link,2/3}$ | | | | | | | 16 | mm | |
| No. of links for first shear perimeter, $n_{l,2}$ | | | | | | | 42 | | |
| No. of perimeters within first shear perimeter, $n_{p,2}$ (>= 2) | | | | | | | 1 | | |
| No. of links, $n_{l,2,0/-5/-10/-15/-20}$ = ($u_2$ | | | 42 | 0 | 0 | 0 | 0 | | |
| No. of links, $n_{l,2,-1/-6/-11/-16/-21}$ = (u | | | 0 | 0 | 0 | 0 | 0 | | |
| No. of links, $n_{l,2,-2/-7/-12/-17/-22}$ = (u | | | 0 | 0 | 0 | 0 | 0 | | |
| No. of links, $n_{l,2,-3/-8/-13/-18/-23}$ = (u | | | 0 | 0 | 0 | 0 | 0 | | |
| No. of links, $n_{l,2,-4/-9/-14/-19/-24}$ = (u | | | 0 | 0 | 0 | 0 | 0 | | |
| *Note links are to be distributed over ≥ 2 perimeters (spaced at ≤ 0.75d) within the first shear perimeter* | | | | | | | | | |
| *(of zone 1.5d) with a pitch of links of ≤ 1.5d. Links should be anchored round at least 1 layer of tension* | | | | | | | | | |
| *rebars, i.e. bottom rebars;* | | | | | | | | | |
| Effective area provided by all links for first shear perimeter, $0.75A_{sv,prov,2}$ | | | | | | | 6333 | $mm^2$ | |
| *Note only links within the central $0.75a_v$ effectively cross the inclined shear cracks (EC2 cl.6.2.3(8), BS8110 cl.* | | | | | | | | | |
| First shear perimeter shear utilisation | | | | | | | **57%** | | **OK** |
| | | | | | | | | | |

**Second Shear Perimeter**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Shear force 20% D inside face of pile from column base face, $V_3 = F_{col,v,uls} - F_{N/}$ | | | | | | N/A | kN |
| | ***F*** $_{N/A}$ | | ***F*** $_{N/A}$ | | ***F*** $_{N/A}$ | | |
| *1P/6P/11P:* | *N/A* | *N/A* | *N/A* | *N/A* | *1.M($F_P$)* | *N/A* | kN |
| *2P/7P/12P:* | *N/A* | *N/A* | *N/A* | *N/A* | *2.M($F_P$)* | *N/A* | kN |
| *3P/8P/13P:* | *N/A* | *N/A* | *N/A* | *N/A* | *3.M($F_P$)* | *N/A* | kN |
| *4P/9P/14P:* | *N/A* | *N/A* | *N/A* | *N/A* | *2.M($F_P$)* | *N/A* | kN |
| *5P/10P/15P:* | *N/A* | *N/A* | *2.M($F_P$)* | *N/A* | *3.M($F_P$)* | *N/A* | kN |
| *Generic:* | | | | | *user-defined* | *N/A* | kN |
| *Note M($F_P$) above refers to K . MIN ($F_{pile,v,i}$);* | | | | | | | |
| Effective shear force, $V_{eff,3}$ = 1.00 . $V_3$ *(moment effects ignored)* | | | | | | N/A | kN |
| Column base second shear perimeter, $u_3$ | | | | | | N/A | mm |
| *Internal column:* | | | | | *Rectangular or Circular* | | |
| *1P:* | | | | | *N/A* | *N/A* | mm |
| *2P:* | | | | | *N/A* | *N/A* | mm |
| *3P:* | | | | | *N/A* | *N/A* | mm |
| *4P:* | | | | | *N/A* | *N/A* | mm |
| *5P:* | | | | | *N/A* | *N/A* | mm |
| *6P:* | | | | | *N/A* | *N/A* | mm |
| *7P:* | | | | | *N/A* | *N/A* | mm |
| *8P:* | | | | | *N/A* | *N/A* | mm |
| *9P:* | | | | | *N/A* | *N/A* | mm |
| *10P:* | *[$(1.0^2+0.5^2)^{0.5}$ S-D+2.(0.2D)] + 2.[2.0S-D+2.(0.2D)]* | | | | | *N/A* | mm |
| *11P:* | *[$(1.0^2+0.5^2)^{0.5}$ S-D+2.(0.2D)] + 2.[3.0S-D+2.(0.2D)]* | | | | | *N/A* | mm |
| *12P:* | *2.[2.0S-D+2.(0.2D)] + 2.[3.0S-D+2.(0.2D)]* | | | | | *N/A* | mm |
| *13P:* | *[$(1.0^2+0.5^2)^{0.5}$ S-D+2.(0.2D)] + 2.[3.0S-D+2.(0.2D)]* | | | | | *N/A* | mm |
| *14P:* | *2.[2.0S-D+2.(0.2D)] + 2.[3.0S-D+2.(0.2D)]* | | | | | *N/A* | mm |
| *15P:* | *2.[2.0S-D+2.(0.2D)] + 2.[4.0S-D+2.(0.2D)]* | | | | | *N/A* | mm |
| *Generic:* | | | | | *user-defined* | *N/A* | mm |
| *Note second shear perimeter refers to second perimeter 20% D inside face of pile;* | | | | | | | |
| Shear stress at column base second shear perimeter, $v_3 = V_{eff,3} / u_3 d$ | | | | | | **N/A** | $N/mm^2$ |

*(Shear capacity enhancement by calculating $v_d$ at "support" and comparing against enhanced $v_c$ within 1.5d of the "support" as clause 3.7.7.4 BS8110 employed, that of clause 3.7.7.6 BS8110 not applicable;)*

*3.4.5.9);*

| | | | | |
|---|---|---|---|---|
| Distance 20% D inside face of pile from column base face, $a_v$ (≥ 0.375d) | | **N/A** | mm | *6.2.3(8) EC* |
| *1P:* | *N/A* | *N/A* | mm | ***Not Incl.*** |
| *2P:* | *N/A* | *N/A* | mm | |
| *3P:* | *N/A* | *N/A* | mm | |
| *4P:* | *N/A* | *N/A* | mm | |
| *5P:* | *N/A* | *N/A* | mm | |
| *6P:* | *N/A* | *N/A* | mm | |
| *7P:* | *N/A* | *N/A* | mm | |
| *8P:* | *N/A* | *N/A* | mm | |
| *9P:* | *N/A* | *N/A* | mm | |
| *10P:* | *AVE [(2.0S-D-b)/2+0.2D, (3.0S-D-h)/2+0.2D]* | *N/A* | mm | |
| *11P:* | *AVE [(2.0S-D-b)/2+0.2D, (3.0S-D-h)/2+0.2D]* | *N/A* | mm | |
| *12P:* | *AVE [(2.0S-D-b)/2+0.2D, (3.0S-D-h)/2+0.2D]* | *N/A* | mm | |
| *13P:* | *AVE [(2.0S-D-b)/2+0.2D, (4.0S-D-h)/2+0.2D]* | *N/A* | mm | |
| *14P:* | *AVE [(2.0S-D-b)/2+0.2D, (3.0S-D-h)/2+0.2D]* | *N/A* | mm | |
| *15P:* | *AVE [(2.0S-D-b)/2+0.2D, (4.0S-D-h)/2+0.2D]* | *N/A* | mm | |
| *Generic:* | *user-defined* | *N/A* | mm | |

*Note b and h above are replaced by D for circular columns, here D referring to the column dimension;*

*Note conservatively, the furthest pile in the relevant perimeter is taken for the calculation of $a_v$;*

*(Note that $a_v$ is limited to 1.5d, beyond which no shear capacity enhancement is exhibited, i.e. $1.5d/a_v = 1$;)*

| | | | | | | |
|---|---|---|---|---|---|---|
| Shear enhancement, $a_v$ = | N/A | mm | <= | 1.5d = | N/A mm | **N/A** |
| Enhanced shear capacity, $1.5dv_c/a_v$ | | | | *x N/A* | **N/A** $N/mm^2$ | |
| Enhanced shear capacity, $1.5dv_c/a_v$ (< $0.8f_{cu}^{0.5}$ & $5N/mm^2$) | | | | *x N/A* | **N/A** $N/mm^2$ | **Note** |

*Note that the enhanced shear capacity is limited to $0.8f_{cu}^{0.5}$ & $5N/mm^2$ & $k_1 0.5f_{cu}^{0.5}$ | $2\lambda_1 0.5f_{cu}^{0.5}$;*

**Case $v_3 < 1.5dv_c/a_v$** **N/A**

No nominal / design links require N/A >= N/A $mm^2$ **N/A**

**Case $1.5dv_c/a_v < v_3 < 1.6(1.5dv_c/a_v)$** **N/A**

$$\Sigma A_{sv}\sin\alpha \geq \frac{(v-v_c)ud}{0.95f_{yv}}$$ N/A >= N/A $mm^2$

Note $\Sigma A_{sv}\sin\alpha$ > $0.4ud/0.95f_{yv}$ *Note that $v_c$ above refers to $1.5dv_c/a_v$;*

**Case $1.6(1.5dv_c/a_v) < v_3 < 2.0(1.5dv_c/a_v)$** **N/A**

$$\Sigma A_{sv}\sin\alpha \geq \frac{5(0.7v-v_c)ud}{0.95f_{yv}}$$ N/A >= N/A $mm^2$

Note $\Sigma A_{sv}\sin\alpha$ > $0.4ud/0.95f_{yv}$ *Note that $v_c$ above refers to $1.5dv_c/a_v$;*

**Case $v_3 > 2.0(1.5dv_c/a_v)$** **N/A**

| | | | | | | |
|---|---|---|---|---|---|---|
| Shear link diameter for second shear perimeter, $\phi_{link,2/3}$ | | | | | N/A | mm |
| No. of links for second shear perimeter, $n_{l,3}$ | | | | | N/A | |
| No. of perimeters within second shear perimeter, $n_{p,3}$ (>= 2) | | | | | N/A | |
| No. of links, $n_{l,3,0/-5/-10/-15/-20}$ = (u3 | N/A | N/A | N/A | N/A | N/A | |
| No. of links, $n_{l,3,-1/-6/-11/-16/-21}$ = (u | N/A | N/A | N/A | N/A | N/A | |
| No. of links, $n_{l,3,-2/-7/-12/-17/-22}$ = (u | N/A | N/A | N/A | N/A | N/A | |
| No. of links, $n_{l,3,-3/-8/-13/-18/-23}$ = (u | N/A | N/A | N/A | N/A | N/A | |
| No. of links, $n_{l,3,-4/-9/-14/-19/-24}$ = (u | N/A | N/A | N/A | N/A | N/A | |

*Note links are to be distributed over ≥ 2 perimeters (spaced at ≤ 0.75d) within the second shear perimeter (of zone 1.5d) with a pitch of links of ≤ 1.5d. Links should be anchored round at least 1 layer of tension rebars, i.e. bottom rebars;*

Effective area provided by all links for second shear perimeter, $0.75A_{sv,prov,3}$ N/A $mm^2$

*Note only links within the central $0.75a_v$ effectively cross the inclined shear cracks (EC2 cl.6.2.3(8), BS8110 cl.*

Second shear perimeter shear utilisation **N/A** **N/A**

| | | | | | |
|---|---|---|---|---|---|
| **CONSULTING ENGINEERS** | Engineering Calculation Sheet<br>Consulting Engineers | Job No. | Sheet No. | | Rev. |
| | | jXXX | 19 | | |
| | | Member/Location | | | |
| Job Title | Structure, Member Design - Geotechnics Pile Cap v2021 | Drg. | | | |
| Structure, Member Design - Geotechnics Pile Cap | | Made by **XX** | Date **21/11/2021** | Chd. | |

**Pile Cap Shear Reinforcement Design (Shallow Beam Theory)** *cl.3.11.4.4 BS8110*

| | | | |
|---|---|---|---|
| ULS shear force for bending in plane of width, $V_x$ | **N/A** | kN | |
| ULS shear force for bending in plane of length, $V_y$ | **N/A** | kN | |

| | | ***$V_x$*** | | ***$V_y$*** | |
|---|---|---|---|---|---|
| *1P:* | *N/A* | *N/A* | *N/A* | *N/A* | kN |
| *2P:* | *N/A* | *N/A* | *$K.\Sigma F_{pile,v,i}$* | *N/A* | kN |
| *3P:* | *$K.\Sigma F_{pile,v,i}$* | *N/A* | *$K.\Sigma F_{pile,v,i}$* | *N/A* | kN |
| *4P:* | *$K.\Sigma F_{pile,v,i}$* | *N/A* | *$K.\Sigma F_{pile,v,i}$* | *N/A* | kN |
| *5P:* | *$K.\Sigma F_{pile,v,i}$* | *N/A* | *$K.\Sigma F_{pile,v,i}$* | *N/A* | kN |
| *6P:* | *$K.\Sigma F_{pile,v,i}$* | *N/A* | *$K.\Sigma F_{pile,v,i}$* | *N/A* | kN |
| *7P:* | *$K.\Sigma F_{pile,v,i}$* | *N/A* | *$K.\Sigma F_{pile,v,i}$* | *N/A* | kN |
| *8P:* | *$K.\Sigma F_{pile,v,i}$* | *N/A* | *$K.\Sigma F_{pile,v,i}$* | *N/A* | kN |
| *9P:* | *$K.\Sigma F_{pile,v,i}$* | *49155* | *$K.\Sigma F_{pile,v,i}$* | *49155* | kN |
| *10P:* | *$K.\Sigma F_{pile,v,i}$* | *N/A* | *$K.\Sigma F_{pile,v,i}$* | *N/A* | kN |
| *11P:* | *$K.\Sigma F_{pile,v,i}$* | *N/A* | *$K.\Sigma F_{pile,v,i}$* | *N/A* | kN |
| *12P:* | *$K.\Sigma F_{pile,v,i}$* | *N/A* | *$K.\Sigma F_{pile,v,i}$* | *N/A* | kN |
| *13P:* | *$K.\Sigma F_{pile,v,i}$* | *N/A* | *$K.\Sigma F_{pile,v,i}$* | *N/A* | kN |
| *14P:* | *$K.\Sigma F_{pile,v,i}$* | *N/A* | *$K.\Sigma F_{pile,v,i}$* | *N/A* | kN |
| *15P:* | *$K.\Sigma F_{pile,v,i}$* | *N/A* | *$K.\Sigma F_{pile,v,i}$* | *N/A* | kN |
| *Generic:* | *user-defined* | *N/A* | *user-defined* | *N/A* | kN |

| | | | |
|---|---|---|---|
| ULS shear force in plane of width per metre, $V_x/L_{cap}$ | **N/A** | kN/m | |
| ULS shear force in plane of length per metre, $V_y/B_{cap}$ | **N/A** | kN/m | |
| ULS shear force in plane of width per metre, $s_{c,x}.V_x/L_{cap}$ | **N/A** | kN/m | |
| ULS shear force in plane of length per metre, $s_{c,y}.V_y/B_{cap}$ | **N/A** | kN/m | |
| Ultimate shear stress in x, $v_{ult,x}=(s_{c,x}.V_x/L_{cap})/(1000.d_x)$ (< $0.8f_{cu}^{0.5}$ & 5N/mm$^2$) | **N/A** | N/mm$^2$ | |
| Ultimate shear stress in x utilisation | **N/A** | | **N/A** |
| Ultimate shear stress in y, $v_{ult,y}=(s_{c,y}.V_y/B_{cap})/(1000.d_y)$ (< $0.8f_{cu}^{0.5}$ & 5N/mm$^2$ | **N/A** | N/mm$^2$ | |
| Ultimate shear stress in y utilisation | **N/A** | | **N/A** |
| Design shear stress in x, $v_{d,x}=(s_{c,x}.V_x/L_{cap})/(1000.d_x)$ | **N/A** | N/mm$^2$ | |
| Design shear stress in y, $v_{d,y}=(s_{c,y}.V_y/B_{cap})/(1000.d_y)$ | **N/A** | N/mm$^2$ | |

*(Shear capacity enhancement by calculating $v_d$ at "support" and comparing against enhanced $v_c$ within 2d of the "support" as clause 3.4.5.8 BS8110 employed, that of clause 3.4.5.10 BS8110 not applicable;)*

| | | | |
|---|---|---|---|
| Area of tensile steel reinforcement provided in x per metre, $A_{s,prov,b,x}$ | 12863 | mm$^2$/m | |
| $\rho_{w,x} = 100A_{s,prov,b,x}/(1000.d_x)$ | 0.37 | % | |
| *Coefficient, $(400/d_x)^{1/4}$ >0.67 no links, $(400/d_x)^{1/4}$ >1.00 with links* | *0.67* | | *T.3.8* |
| $v_{c,x} = (0.79/1.25)(\rho_{w,x}f_{cu}/25)^{1/3}(400/d_x)^{1/4}$; $\rho_{w,x}<3$; $f_{cu}<40$; $(400/d_x)^{1/4}>(0.67$ c | **0.36** | N/mm$^2$ | *BS8110* |
| Area of tensile steel reinforcement provided in y per metre, $A_{s,prov,b,y}$ | 14577 | mm$^2$/m | |
| $\rho_{w,y} = 100A_{s,prov,b,y}/(1000.d_y)$ | 0.42 | % | |
| *Coefficient, $(400/d_y)^{1/4}$ >0.67 no links, $(400/d_y)^{1/4}$ >1.00 with links* | *0.67* | | *T.3.8* |
| $v_{c,y} = (0.79/1.25)(\rho_{w,y}f_{cu}/25)^{1/3}(400/d_y)^{1/4}$; $\rho_{w,y}<3$; $f_{cu}<40$; $(400/d_y)^{1/4}>(0.67$ c | **0.37** | N/mm$^2$ | *BS8110* |

*3.4.5.9);*

| | | | | |
|---|---|---|---|---|
| **CONSULTING ENGINEERS** | Engineering Calculation Sheet<br>Consulting Engineers | Job No.<br>jXXX | Sheet No.<br>20 | Rev. |
| | | Member/Location | | |
| Job Title | Structure, Member Design - Geotechnics Pile Cap v2021 | Drg. | | |
| Structure, Member Design - Geotechnics Pile Cap | | Made by **XX** | Date **21/11/2021** | Chd. |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Distance 20% D inside face of pile from column base face, $a_{v,x}$ (≥ $0.5d_x$) | | | | | | | **N/A** | mm | *6.2.3(8) EC* |
| Distance 20% D inside face of pile from column base face, $a_{v,y}$ (≥ $0.5d_y$) | | | | | | | **N/A** | mm | *6.2.3(8) EC* |
| | | | ***a v,x*** | | | ***a v,y*** | | | ***Not Incl.*** |
| | *1P:* | | *N/A* | *N/A* | | *N/A* | *N/A* | mm | |
| | *2P:* | | *N/A* | *N/A* | | *(1.0S-D-h)/2+0.2D* | *N/A* | mm | |
| | *3P:* | | *(1.0S-D-b)/2+0.2D* | *N/A* | | *(4/3S-D-h)/2+0.2D* | *N/A* | mm | |
| | *4P:* | | *(1.0S-D-b)/2+0.2D* | *N/A* | | *(1.0S-D-h)/2+0.2D* | *N/A* | mm | |
| | *5P:* | | *(1.415S-D-b)/2+0.2D* | *N/A* | | *(1.415S-D-h)/2+0.2D* | *N/A* | mm | |
| | *6P:* | | *(1.0S-D-b)/2+0.2D* | *N/A* | | *(2.0S-D-h)/2+0.2D* | *N/A* | mm | |
| | *7P:* | | *(1.734S-D-b)/2+0.2D* | *N/A* | | *(2.0S-D-h)/2+0.2D* | *N/A* | mm | |
| | *8P:* | | *(2.0S-D-b)/2+0.2D* | *N/A* | | *(2.0S-D-h)/2+0.2D* | *N/A* | mm | |
| | *9P:* | | *(2.0S-D-b)/2+0.2D* | *990* | | *(2.0S-D-h)/2+0.2D* | *-485* | mm | |
| | *10P:* | | *(2.0S-D-b)/2+0.2D* | *N/A* | | *(1.0S-D-h)/2+0.2D* | *N/A* | mm | |
| | *11P:* | | *(2.0S-D-b)/2+0.2D* | *N/A* | | *(2.0S-D-h)/2+0.2D* | *N/A* | mm | |
| | *12P:* | | *(2.0S-D-b)/2+0.2D* | *N/A* | | *(1.0S-D-h)/2+0.2D* | *N/A* | mm | |
| | *13P:* | | *(2.0S-D-b)/2+0.2D* | *N/A* | | *(2.0S-D-h)/2+0.2D* | *N/A* | mm | |
| | *14P:* | | *(2.0S-D-b)/2+0.2D* | *N/A* | | *(1.0S-D-h)/2+0.2D* | *N/A* | mm | |
| | *15P:* | | *(2.0S-D-b)/2+0.2D* | *N/A* | | *(2.0S-D-h)/2+0.2D* | *N/A* | mm | |
| | *Generic:* | | *user-defined* | *N/A* | | *user-defined* | *N/A* | mm | |
| *Note b and h above are replaced by D for circular columns, here D referring to the column dimension;* | | | | | | | | | |
| *Note conservatively, the furthest pile in the relevant direction is taken for the calculation of $a_v$;* | | | | | | | | | |
| *(Note that $a_v$ is limited to 2d, beyond which no shear capacity enhancement is exhibited, i.e. $2d/a_v = 1$;)* | | | | | | | | | |
| Shear enhancement, $a_{v,x}$ = | | | N/A | mm | <= | $2d_x$ = | N/A | mm | **N/A** |
| Shear enhancement, $a_{v,y}$ = | | | N/A | mm | <= | $2d_y$ = | N/A | mm | **N/A** |
| Enhanced shear capacity in x, $2d_xv_{c,x}/a_{v,x}$ | | | | | | *x N/A* | **N/A** | N/mm$^2$ | |
| Enhanced shear capacity in y, $2d_yv_{c,y}/a_{v,y}$ | | | | | | *x N/A* | **N/A** | N/mm$^2$ | |
| Enhanced shear capacity in x, $[(2d_xv_{c,x}/a_{v,x}).L_{cap(3.0D)}+v_{c,x}.(L_{cap}-L_{cap(}$ | | | | | | *x N/A* | **N/A** | N/mm$^2$ | **Note** |
| Enhanced shear capacity in y, $[(2d_yv_{c,y}/a_{v,y}).B_{cap(3.0D)}+v_{c,y}.(B_{cap}-B_{cap}$ | | | | | | *x N/A* | **N/A** | N/mm$^2$ | **Note** |
| *Note that enhanced shear capacity is reduced to account for effective breadth (to cl.3.11.4.2 BS8110) and limit* | | | | | | | | | |
| | | | | | | | | | |
| **Shear Resistance for Bending in Plane of Width** | | | | | | | | | |
| | | | | | | | | | |
| | **Check $v_{d,x}$ < $2d_xv_{c,x}/a_{v,x}$ for no nominal / design links** | | | | | | **N/A** | | |
| | | Concrete shear capacity $2d_xv_{c,x}/a_{v,x}.(1000.d_x)$ | | | | | **N/A** | kN/m | |
| | | | | | | | | | |
| | **Check $v_{d,x}$ >= $2d_xv_{c,x}/a_{v,x}$ for design links** | | | | | | **N/A** | | |
| | | Provide shear links $A_{sv}$ / $S_l$ > $1000.(v_{d,x}-2d_xv_{c,x}/a_{v,x})/(0.9$ | | | | | **N/A** | mm$^2$/mm/m | |
| | | Concrete and design links shear capacity $(0.75A_{sv,prov}/S_l$ | | | | | **N/A** | kN/m | |
| | | | | | | | | | |
| **Shear Resistance for Bending in Plane of Length** | | | | | | | | | |
| | | | | | | | | | |
| | **Check $v_{d,y}$ < $2d_yv_{c,y}/a_{v,y}$ for no nominal / design links** | | | | | | **N/A** | | |
| | | Concrete shear capacity $2d_yv_{c,y}/a_{v,y}.(1000.d_y)$ | | | | | **N/A** | kN/m | |
| | | | | | | | | | |
| | **Check $v_{d,y}$ >= $2d_yv_{c,y}/a_{v,y}$ for design links** | | | | | | **N/A** | | |
| | | Provide shear links $A_{sv}$ / $S_l$ > $1000.(v_{d,y}-2d_yv_{c,y}/a_{v,y})/(0.9$ | | | | | **N/A** | mm$^2$/mm/m | |
| | | Concrete and design links shear capacity $(0.75A_{sv,prov}/S_l$ | | | | | **N/A** | kN/m | |
| | | | | | | | | | |
| Effective area provided by all links per metre, $0.75A_{sv,prov}$ | | | | | | | N/A | mm$^2$/m | |
| Tried effective $0.75A_{sv,prov}$ / $S_{l,1/2}$ value | | | | | | | N/A | mm$^2$/mm/ | **N/A** |
| Design shear resistance (shallow beam theory) in x utilisation | | | | | | | **N/A** | | **N/A** |
| Design shear resistance (shallow beam theory) in y utilisation | | | | | | | **N/A** | | **N/A** |
| Design shear resistance (shallow beam theory) in x and y combined utilisation | | | | | | | **N/A** | | **N/A** |

| | | | | | |
|---|---|---|---|---|---|
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| | | | |
|---|---|---|---|
| **Pile Cap Shear Reinforcement Design (Deep Beam Theory)** | | | *Reynolds T.1* |
| | | | *CIRIA Guide* |
| ULS shear force for bending in plane of width, $V_x$ | **49155** | kN | |
| ULS shear force for bending in plane of length, $V_y$ | **49155** | kN | |
| | | | |
| ULS shear force in plane of width per metre, $s_{c,x}.V_x/L_{cap}$ | **6554** | kN/m | |
| Ultimate shear force limit, $1000.T_{cap}.f_c'/10\gamma_m$ | **8867** | kN/m | *cl.21.4.1* |
| *Note $f_c$' is the cylinder compressive strength and $\gamma_m$ = 1.5;* | | | *Reynolds* |
| Ultimate shear force limit, $\min\{1000.T_{cap}.v_u, 2.1000.T_{cap}^2 v_{c,x} k_{s,x}/a_x\}$ | **13709** | kN/m | *cl.2.4.2* |
| *Note $v_u$ ultimate concrete shear strength from CP 110 T.6 and T.26 replaced by $\min\{0.8f_{cu}^{0.5}$, 5.0}N/mm$^2$}, $v_{c,x}$ design concrete shear strength from CP 110 T.5 and T.25 replaced by $v_{c,x}$ and factor, $k_{s,x}$ = 1.0 for $T_{cap}/L_{cap}$ < 4, else 0.6;* | | | *CIRIA Guide 2* |
| Ultimate shear force (deep beam theory) in x utilisation | **48%** | | **OK** |
| ULS shear force in plane of length per metre, $s_{c,y}.V_y/B_{cap}$ | **6554** | kN/m | |
| Ultimate shear force limit, $1000.T_{cap}.f_c'/10\gamma_m$ | **8867** | kN/m | *cl.21.4.1* |
| *Note $f_c$' is the cylinder compressive strength and $\gamma_m$ = 1.5;* | | | *Reynolds* |
| Ultimate shear force limit, $\min\{1000.T_{cap}.v_u, 2.1000.T_{cap}^2 v_{c,y} k_{s,y}/a_y\}$ | **19000** | kN/m | *cl.2.4.2* |
| *Note $v_u$ ultimate concrete shear strength from CP 110 T.6 and T.26 replaced by $\min\{0.8f_{cu}^{0.5}$, 5.0}N/mm$^2$}, $v_{c,y}$ design concrete shear strength from CP 110 T.5 and T.25 replaced by $v_{c,y}$ and factor, $k_{s,y}$ = 1.0 for $T_{cap}/B_{cap}$ < 4, else 0.6;* | | | *CIRIA Guide 2* |
| Ultimate shear force (deep beam theory) in y utilisation | **34%** | | **OK** |
| | | | |
| Area of tensile steel reinforcement provided in x per metre, $A_{s,prov,b,x}$ | 12863 | mm$^2$/m | |
| Area of tensile steel reinforcement provided in y per metre, $A_{s,prov,b,y}$ | 14577 | mm$^2$/m | |
| | | | |
| Distance to face of pile from column base face, $a_x$ = MAX (0, $a_{v,x}$ - 0.2D) | **750** | mm | |
| Distance to face of pile from column base face, $a_y$ = MAX (0, $a_{v,y}$ - 0.2D) | **0** | mm | |
| Angle between horizontal bar and critical diagonal crack, $\theta_x = \tan^{-1}(T_{cap}/a_x)$ | 78.8 | degrees | |
| Angle between horizontal bar and critical diagonal crack, $\theta_y = \tan^{-1}(T_{cap}/a_y)$ | 90.0 | degrees | |
| Empirical coeff., $k_1$ = {0.70 NWC, 0.50 LWC} \| $2\lambda_1$ = {0.88 NWC, 0.64 LWC} | 0.88 | | *CIRIA Guide* |
| Empirical coeff., $k_2$ = {100 PRB, 225 DFB} \| $100\lambda_2$ = {85 PRB, 195 DFB} | 195 | N/mm$^2$ | *IRIA Guide* |
| Cylinder splitting tensile strength, $f_t = 0.5(f_{cu})^{0.5}$ | 3.35 | N/mm$^2$ | |
| Min breadth for deep beam bending in x, $b_L \approx$ MAX {0, $0.65V_x/[(k_1\|2\lambda_1).(T_{cap}$-0 | 3060 | mm | **OK** |
| Min breadth for deep beam bending in y, $b_B \approx$ MAX {0, $0.65V_y/[k_1\|2\lambda_1).(T_{cap}$-0. | 2849 | mm | **OK** |
| | | | |
| **Shear Resistance for Bending in Plane of Width** | | | |
| **No design links** | | | |
| Concrete shear capacity, $V_{1,x}$ | **12641** | kN/m | |
| *Note $V_{1,x}$ = $MAX[0,k_1.(T_{cap}-0.35a_x).f_t.1000]+k_2.A_{s,prov,b,x}.d_x.\sin^2\theta/T_{cap}$;* | | | *Reynolds* |
| *Note $V_{1,x}$ = $MAX[0,2\lambda_1.(T_{cap}-0.35a_x).f_t.1000]+100\lambda_2.A_{s,prov,b,x}.d_x.\sin^2\theta/$* | | | *CIRIA Guide* |
| **Design links** | | | |
| *Note design links are not calculated as they require horizontal links;* | | | |
| | | | |
| **Shear Resistance for Bending in Plane of Length** | | | |
| **No design links** | | | |
| Concrete shear capacity, $V_{1,y}$ | **13807** | kN/m | |
| *Note $V_{1,y}$ = $MAX[0,k_1.(T_{cap}-0.35a_y).f_t.1000]+k_2.A_{s,prov,b,y}.d_y.\sin^2\theta/T_{cap}$;* | | | *Reynolds* |
| *Note $V_{1,y}$ = $MAX[0,2\lambda_1.(T_{cap}-0.35a_y).f_t.1000]+100\lambda_2.A_{s,prov,b,y}.d_y.\sin^2\theta/$* | | | *CIRIA Guide* |
| **Design links** | | | |
| *Note design links are not calculated as they require horizontal links;* | | | |
| | | | |
| Design shear resistance (deep beam theory) in x utilisation | **52%** | | **OK** |
| Design shear resistance (deep beam theory) in y utilisation | **47%** | | **OK** |

| | | | | |
|---|---|---|---|---|
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**Pile Cap Longitudinal Shear Within Section (EC2)** — ***EC2***

*2*

| | | $V_x$ | $V_y$ | Unit | Ref. |
|---|---|---|---|---|---|
| Longitudinal shear stress, $v_{Edi} = \beta\, V_{Ed} / (z\, b_i)$ | | **N/A** | **N/A** | $N/mm^2$ | *cl.6.2.5* |
| | Ratio, $\beta$ = 1.0 | N/A | N/A | | *cl.6.2.5* |
| | Transverse shear force, $V_{Ed}$ = {$s_{c,x}.V_x*/L_{cap}$, $s_{c,y}.V_y*/B_{cap}$ | N/A | N/A | kN/m | *cl.6.2.5* |
| | Lever arm, z = {$z_x$, $z_y$} | N/A | N/A | m | *cl.6.2.5* |
| | Width of the interface, $b_i$ = 1000mm | N/A | N/A | mm | *cl.6.2.5* |
| Longitudinal shear stress limit, $v_{Rdi}$ | | **N/A** | **N/A** | $N/mm^2$ | |
| | $v_{Rdi} = c\, f_{ctd} + \mu\, \sigma_n + \rho\, f_{yd}\, (\mu \sin\alpha + \cos\alpha) \le 0,5\, \nu\, f_{cd}$ | | | | *cl.6.2.5* |
| | *Note $c.f_{ctd}$ = 0.00 if $\sigma_n$ is negative (tension);* | | | | *cl.6.2.5* |
| | Roughness coefficient, c — Indented | | N/A | | *cl.6.2.5* |
| | Roughness coefficient, $\mu$ — Indented | | N/A | | *cl.6.2.5* |
| | Very smooth: a surface cast against steel, plastic or specially prepared wooden moulds: $c$ = 0,025 to 0,10 and $\mu$ = 0,5<br>Smooth: a slipformed or extruded surface, or a free surface left without further treatment after vibration: $c$ = 0,20 and $\mu$ = 0,6<br>Rough: a surface with at least 3 mm roughness at about 40 mm spacing, achieved by raking, exposing of aggregate or other methods giving an equivalent behaviour: $c$ = 0,40 and $\mu$ = 0,7 AC1<br>Indented: a surface with indentations complying with Figure 6.9: $c$ = 0,50 and $\mu$ = 0,9 | | | | |
| | Design tensile strength, $f_{ctd}$ | | **N/A** | $N/mm^2$ | |
| | $f_{ctd} = \alpha_{ct}\, f_{ctk,0,05} / \gamma_C$ with $\alpha_{ct}$=1.0, $\gamma_C$=1.5 | | | | *cl.3.1.6* |
| | $f_{ctk;0,05} = 0,7 \times f_{ctm}$ | | N/A | $N/mm^2$ | *T.3.1* |
| | $f_{ctm} = 0,30 \times f_{ck}^{(2/3)} \le C50/60$ ; $f_{ctm} = 2,12 \cdot \ln(1+(f_{cm}/10))$ > C50/60 | | N/A | $N/mm^2$ | *T.3.1* |
| | $f_{cm} = f_{ck} + 8(MPa)$ | | N/A | $N/mm^2$ | *T.3.1* |
| | Characteristic cylinder strength of concrete, $f_{ck}$ | | N/A | $N/mm^2$ | *T.3.1* |
| | Characteristic cube strength of concrete, $f_{cu}$ | | N/A | $N/mm^2$ | *T.3.1* |
| | Normal stress across longitudinal shear interface, $\sigma_n$ | **N/A** | **N/A** | $N/mm^2$ | |
| | *Note $\sigma_n$ = $\Sigma$[factor . 0.75$F_{pile,v,n}$/($B_{cap}$.$L_{cap}$)];* | | | | |
| *2* | Reinforcement ratio, $\rho = A_s / A_i$ | **N/A** | **N/A** | | *cl.6.2.5* |
| *2* | Area of reinforcement, $A_s = A_{sv,prov} / S_{l,1/2}$ | N/A | N/A | $mm^2/m/m$ | |
| | *Note that the area of reinforcement crossing the shear interface may include ordinary shear reinforcement with adequate anchorage at both sides of the interface;* | | | | *cl.6.2.5* |
| | Area of the joint, $A_i$ = 1000.$b_i$ | N/A | N/A | $mm^2/m/m$ | |
| | Design yield strength of reinforcement, $f_{yd} = f_{yv} / \gamma_S$ , $\gamma_S$=1.15 | | N/A | $N/mm^2$ | *cl.2.4.2.4* |
| | Angle of reinforcement, $\alpha$ = 90.0° | | N/A | degrees | *cl.6.2.5* |
| | Design compressive strength, $f_{cd}$ | | N/A | $N/mm^2$ | |
| | $f_{cd} = \alpha_{cc}\, f_{ck} / \gamma_C$ with $\alpha_{cc}$=1.0, $\gamma_C$=1.5 | | | | *cl.3.1.6* |
| | Strength reduction factor for concrete cracked in shear, $\nu$ | | N/A | | |
| *2* | $\nu = 0,6\left[1 - \frac{f_{ck}}{250}\right]$ | | | | *cl.6.2.2* |
| Longitudinal shear stress limit utilisation, $v_{Edi}/v_{Rdi}$ | | **N/A** | **N/A** | | **N/A** |

*2*

| CONSULTING ENGINEERS | Engineering Calculation Sheet<br>Consulting Engineers | Job No. | Sheet No. | | Rev. |
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**Pile Cap Longitudinal Shear Within Section (BS8110)** ***BS8110***

| | $M_x$ | $M_y$ | Unit | Ref. |
|---|---|---|---|---|
| Longitudinal shear stress, $v_h = K_S \cdot \Delta F_c / (b_w \cdot \Delta x)$ | **N/A** | **N/A** | N/mm$^2$ | *cl.5.4.7.2* |
| Change of total compression force over $\Delta x$, $\Delta F_c$ | N/A | N/A | kN/m | *cl.5.4.7.1* |
| *Note $\Delta F_c = \{(s_{c,x}.M_x/L_{cap}-0)/z_x,\ (s_{c,y}.M_y/B_{cap}-0)/z_y\}$;* | | | | |
| Lever arm, $z = \{z_x, z_y\}$ | N/A | N/A | m | |
| Length under consideration, $\Delta x = \{L_{db,x}/2, L_{db,y}/2\}$ | N/A | N/A | mm | |
| *Note $\Delta x$ is the beam length between the point of maximum design moment and the point of zero moment;* | | | | *cl.5.4.7.2* |
| Shear stress distribution factor, $K_S$ = 2.00 | N/A | N/A | | |
| *The average design shear stress should then be distributed in proportion to the vertical design shear force diagram to give the horizontal shear stress at any point along the length of the member. For UDLs, $K_S$ maybe taken as 2.00 for simply supported beams, 1.33 for continuous beams and 2.00 for cantilever beams;* | | | | *cl.5.4.7.2* |
| Width, $b_w$ = 1000mm | N/A | N/A | mm | |

| | | | |
|---|---|---|---|
| Longitudinal shear stress limit for no nominal / design vertical reinforcement, v | **N/A** | N/mm$^2$ | |
| Surface type | Washed to Remove Laitance etc | | *T.5.5* |

**Table 5.5 — Design ultimate horizontal shear stresses at interface**

| Precast unit | Surface type | Grade of in-situ concrete 25 N/mm$^2$ | 30 N/mm$^2$ | 40 and over N/mm$^2$ |
|---|---|---|---|---|
| Without links | As-cast or as-extruded | 0.4 | 0.55 | 0.65 |
| | Brushed, screeded or rough-tamped | 0.6 | 0.65 | 0.75 |
| | Washed to remove laitance or treated with retarder and cleaned | 0.7 | 0.75 | 0.80 |
| With nominal links projecting into in-situ concrete | As-cast or as-extruded | 1.2 | 1.8 | 2.0 |
| | Brushed, screeded or rough-tamped | 1.8 | 2.0 | 2.2 |
| | Washed to remove laitance or treated with retarder and cleaned | 2.1 | 2.2 | 2.5 |

NOTE 1 The description "as-cast" covers those cases where the concrete is placed and vibrated leaving a rough finish. The surface is rougher than would be required for finishes to be applied directly without a further finishing screed but not as rough as would be obtained if tamping, brushing or other artificial roughening had taken place.

NOTE 2 The description "as-extruded" covers those cases in which an open-textured surface is produced direct from an extruding machine.

NOTE 3 The description "brushed, screeded or rough-tamped" covers those cases where some form of deliberate surface roughening has taken place but not to the extent of exposing the aggregate.

NOTE 4 For structural assessment purposes, it may be assumed that the appropriate value of $\gamma_m$ included in the table is 1.5.

| | $M_x$ | $M_y$ | Unit | Ref. |
|---|---|---|---|---|
| Longitudinal shear stress limit for no nominal / design vertical reinf | **N/A** | **N/A** | | **N/A** |
| Required nominal vertical reinforcement per unit length, 0.15%$b_w$ | **N/A** | **N/A** | mm$^2$/m/m | *cl.5.4.7.3* |
| Provided vertical reinforcement per unit length, $A_e$ | N/A | N/A | mm$^2$/m/m | |
| *Note $A_e = A_{sv,prov} / S_{l,1/2}$;* | | | | |
| Required nominal vertical reinforcement per unit length utilisation, | **N/A** | **N/A** | | **N/A** |

*Note UT set to 0% if longitudinal shear stress limit for no nominal vertical reinforcement UT <= 100%;*

| | $M_x$ | $M_y$ | Unit | Ref. |
|---|---|---|---|---|
| Required design vertical reinforcement per unit length, $A_h$ | **N/A** | **N/A** | mm$^2$/m/m | |
| $A_h = \dfrac{1\,000 b v_h}{0.95 f_y}$ | | | | *cl.5.4.7.4* |
| Required design vertical reinforcement per unit length utilisation, A | **N/A** | **N/A** | | **N/A** |

*Note UT set to 0% if longitudinal shear stress limit for no design vertical reinforcement UT <= 100%;*

**Pile Cap Longitudinal Shear Within Section (BS5400-4)** **BS5400-4**

| | $M_x$ | $M_y$ | | |
|---|---|---|---|---|
| Longitudinal shear force per unit length, $V_1 = K_S \cdot \Delta F_c / \Delta x$ | **N/A** | **N/A** | kN/m | |
| Change of total compression force over $\Delta x$, $\Delta F_c$ | N/A | N/A | kN/m | |
| *Note $\Delta F_c = \{(s_{c,x} . M_x */L_{cap} - 0)/z_x, (s_{c,y} . M_y */B_{cap} - 0)/z_y\}$;* | | | | |
| Lever arm, $z = \{z_x, z_y\}$ | N/A | N/A | m | |
| Length under consideration, $\Delta x = \{L_{db,x}/2, L_{db,y}/2\}$ | N/A | N/A | mm | |
| *Note $\Delta x$ is the beam length between the point of maximum design moment and the point of zero moment;* | | | | |
| Shear stress distribution factor, $K_S$ = 2.00 | N/A | N/A | | |
| *The longitudinal shear should be calculated per unit length. For UDLs, $K_S$ may be taken as 2.00 for simply supported beams, 1.33 for continuous beams and 2.00 for cantilever beams;* | | | | *cl.7.4.2.3* |
| Width, $b_w$ = 1000mm | N/A | N/A | mm | |
| Longitudinal shear force limit per unit length, $V_{1,limit}$ | **N/A** | **N/A** | kN/m | |

$V_1$ should not exceed the lesser of the following:
a) $k_1 f_{cu} L_s$
b) $v_1 L_s + 0.7 A_e f_y$

| | $M_x$ | $M_y$ | | |
|---|---|---|---|---|
| (a) | N/A | N/A | kN/m | *cl.7.4.2.3* |
| (b) | N/A | N/A | kN/m | *cl.7.4.2.3* |

**Table 31 — Ultimate longitudinal shear stress, $v_1$, and values of $k_1$ for composite members**

| Type of shear plane | Longitudinal shear stress for concrete grade | | | | $k_1$ |
|---|---|---|---|---|---|
| | 20 | 25 | 30 | 40 or more | |
| | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ | |
| Monolithic construction | 0.90 | 0.90 | 1.25 | 1.25 | 0.15 |
| Surface type 1 | 0.50 | 0.63 | 0.75 | 0.80 | 0.15 |
| Surface type 2 | 0.30 | 0.38 | 0.45 | 0.50 | 0.09 |

NOTE For construction with lightweight aggregate concrete, the values given in this table should be reduced by 25 %.

| | $M_x$ | $M_y$ | | |
|---|---|---|---|---|
| Concrete bond constant, $k_1$ | | N/A | | *T.31* |
| Ultimate longitudinal shear stress limit, $v_1$ | | N/A | N/mm$^2$ | *T.31* |
| Surface type: Monolithic Construction | | | | *T.31* |
| Length of shear plane, $L_s = b_w$ | N/A | N/A | mm | |
| Provided vertical reinforcement per unit length, $A_e$ | N/A | N/A | mm$^2$/m/m | |
| *Note $A_e = A_{sv,prov} / S_{l,1/2}$;* | | | | |
| *Note reinforcement provided for coexistent bending effects and shear reinforcement crossing the shear plane, provided to resist vertical shear, may be included provided they are fully anchored;* | | | | *cl.7.4.2.3* |
| Characteristic strength of reinforcement, $f_{yv}$ | | N/A | N/mm$^2$ | |
| Longitudinal shear force limit per unit length utilisation, $V_1/V_{1,limit}$ | **N/A** | **N/A** | | **N/A** |
| Required nominal vertical reinforcement per unit length, $0.15\%L_s$ | **N/A** | **N/A** | mm$^2$/m/m | *cl.7.4.2.3* |
| Required nominal vertical reinforcement per unit length utilisation, | **N/A** | **N/A** | | **N/A** |

*Note UT set to 0% if longitudinal shear force limit per unit length for no nominal vertical reinforcement UT <= 100%;*

| CONSULTING ENGINEERS | Engineering Calculation Sheet<br>Consulting Engineers | Job No. | Sheet No. | Rev. |
|---|---|---|---|---|
| | | jXXX | 25 | |
| | | Member/Location | | |
| Job Title | Structure, Member Design - Geotechnics Pile Cap v2021 | Drg. | | |
| Structure, Member Design - Geotechnics Pile Cap | | Made by **XX** | Date **21/11/2021** | Chd. |

**Pile Cap Detailing Requirements**

| | | | | | |
|---|---|---|---|---|---|
| All detailing requirements met ? | | | **OK** | | |
| Max base steel reinforcement pitch in x ($<3d_x$, <750mm) | | | 248 | mm | **OK** |
| Max base steel reinforcement pitch in y ($<3d_y$, <750mm) | | | 219 | mm | **OK** |

Maximum spacing: 0.5% Ast or less - 300mm
Between 0.5% and 1.0% - 225mm
1.0% Ast or greater - 175mm

| | | | | | |
|---|---|---|---|---|---|
| Max base steel reinforcement pitch in x | | | 248 | mm | **OK** |
| Max base steel reinforcement pitch in y | | | 219 | mm | **OK** |
| Min base steel reinforcement pitch (>100mm) | | | 219 | mm | **OK** |
| Base steel reinforcement diameter, $\phi_b$ (>=16mm) | | | 32 | mm | **OK** |
| Max side steel reinforcement pitch (<=250mm) | | | 225 | mm | **OK** |
| Max side steel reinforcement pitch ($<=\phi_s^2.f_y/MIN(500mm,B_{cap},L_{cap})$) | | | 225 | mm | **OK** |
| Side steel reinforcement diameter, $\phi_s$ (>=12mm) | | | 16 | mm | **OK** |
| Max base steel bearing stress (in direction of width x) $\frac{F_{bt}}{r\varphi} \leq \frac{2f_{cu}}{1+2(\varphi/a_b)}$ | 70.2 | <= | 71.7 | $N/mm^2$ | **OK** |
| Tensile force per bar, $F_{bt}$ = MAX $(b_{r,x}.F_{base,uls,x}/L_{cap}, (s_{c,x}.M_x/L_{cap})/d_x)$ | | | 337 | kN | |
| Internal radius of bend, $r_x$ | | | 150 | mm | |
| Size of bar, $\varphi = \phi_{b,x}$ | | | 32 | mm | |
| Characteristic strength of concrete, $f_{cu}$ | | | 45.0 | $N/mm^2$ | |
| Pitch of bar, $a_b = p_{b,x}$ | | | 250 | mm | |
| Max base steel bearing stress (in direction of length y) $\frac{F_{bt}}{r\varphi} \leq \frac{2f_{cu}}{1+2(\varphi/a_b)}$ | 62.0 | <= | 69.8 | $N/mm^2$ | **OK** |
| Tensile force per bar, $F_{bt}$ = MAX $(b_{r,y}.F_{base,uls,y}/B_{cap}, (s_{c,y}.M_y/B_{cap})/d_y)$ | | | 297 | kN | |
| Internal radius of bend, $r_y$ | | | 150 | mm | |
| Size of bar, $\varphi = \phi_{b,y}$ | | | 32 | mm | |
| Characteristic strength of concrete, $f_{cu}$ | | | 45.0 | $N/mm^2$ | |
| Pitch of bar, $a_b = p_{b,y}$ | | | 221 | mm | |
| Min internal radius of bend in x, $r_x$ ($>=r_{min}$) | | | 150 | mm | **OK** |
| Min internal radius of bend, $r_{min}$ | | | 112 | mm | |
| Min internal radius of bend in y, $r_y$ ($>=r_{min}$) | | | 150 | mm | **OK** |
| Min internal radius of bend, $r_{min}$ | | | 112 | mm | |
| Min zone for bend in x, $D/2+c_{proj} >= r_x+\phi_{b,x}+\phi_s+cover_2$ | 750 | >= | 273 | mm | **OK** |
| Min zone for bend in y, $D/2+c_{proj} >= r_y+\phi_{b,y}+\phi_s+cover_2$ | 750 | >= | 273 | mm | **OK** |