| A A A A A A A A A A A A A A A A A A A | Project Pad footing analysis and design (BS8110-1:1997) | | | | Job Ref. | |
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PAD FOOTING ANALYSIS AND DESIGN (BS8110-1:1997)



Pad footing details

| Length of pad footing; | L = <u>2500</u> mm |
|---|---|
| Width of pad footing; | B = <u>1500</u> mm |
| Area of pad footing; | A = L × B = <u>3.750</u> m ² |
| Depth of pad footing; | h = <u>400</u> mm |
| Depth of soil over pad footing; | h _{soil} = <u>200</u> mm |
| Density of concrete; | ρ _{conc} = <u>23.6</u> kN/m ³ |
| Column details | |
| Column base length; | l _A = <u>300</u> mm |
| Column base width; | b _A = <u>300</u> mm |
| Column eccentricity in x; | e _{PxA} = <u>0</u> mm |
| Column eccentricity in y; | e _{PyA} = <u>0</u> mm |
| Soil details | |
| Dense, moderately graded, sub-angular, gravel | |
| Mobilisation factor; | m= ; <u>1.5</u> ; |
| Density of soil; | ρ _{soil} = <u>20.0</u> kN/m ³ |
| Design shear strength; | ∲' = <u>25.0</u> deg |
| Design base friction; | δ = <u>19.3</u> deg |
| Allowable bearing pressure; | P _{bearing} = <u>200</u> kN/m ² |
| Axial loading on column | |
| Dead axial load on column; | P _{GA} = 200.0 kN |

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| Imposed axial load o | n column; | P _{QA} = <u>165.0</u> kN | i |
| Wind axial load on co | olumn; | P _{WA} = <u>0.0</u> kN | |
| Total axial load on co | olumn; | P _A = <u>365.0</u> kN | |
| Foundation loads | | | |
| Dead surcharge load | l; | F _{Gsur} = <u>0.000</u> kN/m ² | |
| Imposed surcharge I | oad; | F _{Qsur} = <u>0.000</u> kN/m ² | |
| Pad footing self weig | ht; | F _{swt} = h × ρ _{conc} = <u>9.440</u> | kN/m ² |
| Soil self weight; | | F _{soil} = h _{soil} × ρ _{soil} = <u>4.00</u> | <u>0</u> kN/m ² |
| Total foundation load | l; | $F = A \times (F_{Gsur} + F_{Qsur} +$ | F _{swt} + F _{soil}) = <u>50.4</u> kN |
| Horizontal loading | on column base | | |
| Dead horizontal load | in x direction; | H _{GxA} = <u>20.0</u> kN | |
| Imposed horizontal lo | bad in x direction; | H _{QxA} = <u>15.0</u> kN | |
| Wind horizontal load | in x direction; | H _{WxA} = <u>0.0</u> kN | |
| Total horizontal load | in x direction; | H _{xA} = <u>35.0</u> kN | |
| Dead horizontal load | in y direction; | H _{GyA} = <u>5.0</u> kN | |
| Imposed horizontal le | oad in y direction; | H _{QyA} = <u>5.0</u> kN | |
| Wind horizontal load | in y direction; | H _{WyA} = <u>0.0</u> kN | |
| Total horizontal load | in y direction; | H _{yA} = <u>10.0</u> kN | |
| Moment on column | base | | |
| Dead moment on col | umn in x direction; | M _{GxA} = <u>15.000</u> kNm | |
| Imposed moment on | column in x direction; | M _{QxA} = <u>10.000</u> kNm | |
| Wind moment on col | umn in x direction; | M _{WxA} = <u>0.000</u> kNm | |
| Total moment on col | umn in x direction; | M _{xA} = <u>25.000</u> kNm | |
| Dead moment on col | umn in y direction; | M _{GyA} = <u>25.000</u> kNm | |
| Imposed moment on | column in y direction; | M _{QyA} = <u>30.000</u> kNm | |
| Wind moment on col | umn in y direction; | M _{WyA} = <u>0.000</u> kNm | |
| Total moment on col | umn in y direction; | M _{yA} = <u>55.000</u> kNm | |
| Check stability aga | inst sliding | | |
| Resistance to sliding | due to base friction | | |
| | H _{friction} = max(| $P_{GA} + (F_{Gsur} + F_{swt} + F_{soil}) >$ | < Α], 0 kN) × tan(δ) = <u>87.7</u> kN |
| Passive pressure co | efficient; | $K_p = (1 + sin(\phi')) / (1 - s)$ | sin(φ')) = <u>2.464</u> |
| Stability against sli | ding in x direction | | |
| Passive resistance o <u>11.8</u> kN | f soil in x direction; | H_{xpas} = 0.5 \times K _p \times (h ² + | $2 \times h \times h_{soil}) \times B \times \rho_{soil} =$ |
| Total resistance to sl | iding in x direction; | H _{xres} = H _{friction} + H _{xpas} = | <u>99.5</u> kN |
| | PASS - Resistance to | sliding is greater than ho | prizontal load in x direction |
| Stability against sli | ding in v direction | | |
| Passive resistance o | f soil in y direction; | H_{ypas} = 0.5 × K _p × (h ² + | $2 \times h \times h_{soil}) \times L \times \rho_{soil} =$ |
| Total resistance to sl | iding in y direction; | H _{yres} = H _{friction} + H _{ypas} = | <u>107.4</u> kN |

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| | PASS - Resistance to sl | iding is greater t | han horizontal | load in y direction | า |
| Check stability agair | nst overturning in x direction | n | | | |
| Total overturning mon | nent; | $M_{xOT} = M_{xA} + H_{xA}$ | ₄ × h = <u>39.000</u> ki | Nm | |
| Restoring moment in | n x direction | | | | |
| Foundation loading; kNm | | $M_{xsur} = A \times (F_{Gsur}$ | $r + F_{swt} + F_{soil}) \times$ | L/2= <u>63.000</u> | |
| Axial loading on colur | nn: | $M_{xaxial} = (P_{GA}) \times ($ | (L / 2 - e _{PxA}) = 2 | 50.000 kNm | |
| Total restoring mome | nt; | $M_{xres} = M_{xsur} + M$ | _{xaxial} = <u>313.000</u> k | ٨m | |
| Ũ | PASS - Restoring moment | is greater than o | verturning mon | nent in x directior | า |
| Check stability agair | nst overturning in y direction | n | | | |
| Total overturning mon | nent; | $M_{yOT} = M_{yA} + H_{yA}$ | ₄ × h = <u>59.000</u> ki | Nm | |
| Restoring moment in | n v direction | | | | |
| Foundation loading; kNm | | $M_{ysur} = A \times (F_{Gsur}$ | r + F _{swt} + F _{soil}) × | B / 2 = <u>37.800</u> | |
| Axial loading on colun | าท; | $M_{vaxial} = (P_{GA}) \times ($ | (B / 2 - e _{PvA}) = 1 | 50.000 kNm | |
| Total restoring mome | nt; | M _{yres} = M _{ysur} + M | _{yaxial} = <u>187.800</u> k | ٨m | |
| | PASS - Restoring moment | is greater than o | verturning mon | nent in y directior | ו |
| Calculate pad base r | reaction | | | | |
| Total base reaction; | | T = F + P _A = <u>415</u> | 5.4 kN | | |
| Eccentricity of base re | eaction in x; | $e_{Tx} = (P_A \times e_{PxA} +$ | + M_{xA} + $H_{xA} \times h$) | / T = <u>94</u> mm | |
| Eccentricity of base re | eaction in y; | $e_{Ty} = (P_A \times e_{PyA} +$ | + M_{yA} + $H_{yA} \times h$) | / T = <u>142</u> mm | |
| Check pad base read | ction eccentricity | | | | |
| | | abs(e _{Tx}) / L + ab | s(e _{Ty}) / B = <u>0.13</u> | <u>2</u> | |
| | Base re | action acts with | in combined m | iddle third of base | 9 |
| Calculate pad base p | pressures | | | | |
| | | $q_1 = T / A - 6 \times T$ | $ \times e_{Tx} / (L \times A) - $ | $6 \times T \times e_{Ty}$ / (B \times | |
| A) = <u>22.880</u> kN/m ² | | | | | |
| <u>^</u> | | $q_2 = T / A - 6 \times T$ | $ \times e_{Tx} / (L \times A) + $ | $6 \times T \times e_{Ty}$ / (B \times | |
| A) = <u>148.747</u> kN/m ² | | | | | |
| A) 70 000 101/ ² | | $q_3 = T / A + 6 \times 7$ | $\Gamma \times e_{Tx} / (L \times A) -$ | \cdot 6 × T × e _{Ty} / (B × | |
| A) = <u>72.800</u> kN/m² | | | | | |
| $(A) = 400 \ \text{cc}^2 \ \text{km}^2$ | | q ₄ = 1 / A + 6 × 1 | $I \times e_{Tx} / (L \times A)$ | + б × I × е _{ту} / (В × | |
| $A_{i} = \frac{190.007}{190.007} \text{ KIN/M}^{-1}$ | Iro. | $a_{\rm min} = \min(a_{\rm min})$ | (10, 10) = 33.800 | kN/m^2 | |
| Maximum base pressu | ווכ, וורף | $q_{min} = \min(q_1, q_2, q_2, q_3)$ | (43, 44) = 22.000 | $\frac{2}{67}$ kN/m ² | |
| Maximum base press | | | $_{2}, y_{3}, y_{4} = \frac{130.0}{130.0}$ | boaring process | • |



| Partial safety factor for imposed loads; |
|---|
| Partial safety factor for wind loads; |
| Ultimate axial loading on column |
| Ultimate axial load on column; |
| Ultimate foundation loads |
| Ultimate foundation load; |
| <u>70.6</u> kN |
| Ultimate horizontal loading on column |
| Ultimate horizontal load in x direction; |
| kN |
| Ultimate horizontal load in y direction; |
| kN |
| Ultimate moment on column |
| Ultimate moment on column in x direction; |
| <u>37.000</u> kNm |

Ultimate moment on column in y direction; **83.000** kNm

 $\gamma_{fQ} = <u>1.40</u>$ $\gamma_{fQ} = <u>1.60</u>$ $\gamma_{fW} = <u>0.00</u>$

 $P_{uA} = P_{GA} \times \gamma_{fG} + P_{QA} \times \gamma_{fQ} + P_{WA} \times \gamma_{fW} = \underline{544.0} \text{ kN}$

 $F_{u} = A \times [(F_{Gsur} + F_{swt} + F_{soil}) \times \gamma_{fG} + F_{Qsur} \times \gamma_{fQ}] =$

 $\mathbf{H}_{xuA} = \mathbf{H}_{GxA} \times \gamma_{fG} + \mathbf{H}_{QxA} \times \gamma_{fQ} + \mathbf{H}_{WxA} \times \gamma_{fW} = \underline{\textbf{52.0}}$

 $H_{yuA} = H_{GyA} \times \gamma_{fG} + H_{QyA} \times \gamma_{fQ} + H_{WyA} \times \gamma_{fW} = \underline{\textbf{15.0}}$

 $M_{xuA} = M_{GxA} \times \gamma_{fG} + M_{QxA} \times \gamma_{fQ} + M_{WxA} \times \gamma_{fW} =$

 $M_{yuA} = M_{GyA} \times \gamma_{fG} + M_{QyA} \times \gamma_{fQ} + M_{WyA} \times \gamma_{fW} =$

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| Calculate ultimate pa | d base reaction | | | | |
| Ultimate base reaction | ; | T _u = F _u + P _{uA} = <u>61</u> | 4.6 kN | | |
| Eccentricity of ultimate | base reaction in x; | $e_{Txu} = (P_{uA} \times e_{PxA})$ | + M_{xuA} + $H_{xuA} \times h$ | n) / T _u = <u>94</u> mm | |
| Eccentricity of ultimate | e base reaction in y; | $e_{Tyu} = (P_{uA} \times e_{PyA})$ | + M _{vuA} + H _{vuA} × ł | n) / T _u = <u>145</u> mm | l |
| Calculate ultimate pa | id base pressures | | | | |
| 31 957 kN/m ² | | $q_{1u} = T_u/A - 6 \times T_u \times$ | e _{Txu} /(L×A) - 6×T _u | u×e _{Tyu} /(B×A) = | |
| 221.824 kN/m ² | | $q_{2u} = T_u/A - 6 \times T_u \times$ | e _{⊺xu} /(L×A) + 6×T | $u \times e_{Tyu}/(B \times A) =$ | |
| <u>105.941</u> kN/m ² | | $q_{3u} = T_u/A + 6 \times T_u$ | ≺e⊤ _{xu} /(L×A) - 6×T | u×e⊤yu/(B×A) = | |
| 295.808 kN/m ² | | $q_{4u} = T_u/A + 6 \times T_u$ | $(L \times A) + 6$ | $\Gamma_u \times e_{Tyu}/(B \times A) =$ | |
| Minimum ultimate bas Maximum ultimate bas | e pressure; se pressure; | $q_{minu} = min(q_{1u}, q_2)$ $q_{maxu} = max(q_{1u}, q_2)$ | _u , q _{3u} , q _{4u}) = <u>31.</u> _{2u} , q _{3u} , q _{4u}) = <u>29</u> | 957 kN/m ² 5.808 kN/m ² | |
| Calculate rate of cha | nge of base pressure in x di | irection | | | |
| Left hand base reaction | n; | $f_{uL} = (q_{1u} + q_{2u}) \times I$ | B / 2 = 190.336 | kN/m | |
| Right hand base react | ion: | $f_{\rm uR} = (q_{3\rm u} + q_{4\rm u}) \times$ | B / 2 = 301.312 | kN/m | |
| I ength of base reaction | n: | $ _{v} = _{z} = 2500 \text{ mm}$ | | | |
| Rate of change of bas | e pressure; | $C_x = (f_{UR} - f_{UI}) / L_x$ | = 44.390 kN/m/r | n | |
| Calculate nad length | s in x direction | | | | |
| Left hand length: | | $ _{1} = /2 + e_{\text{DM}} =$ | 1250 mm | | |
| Right hand length: | | $L_{\rm L} = L/2 \cdot c_{\rm PXA} =$ | 1250 mm | | |
| | amanta in v dinastian | | 1200 | | |
| Ultimate moment in x of a 198.900 kNm | direction; | $M_x = f_{uL} \times L_L^2 / 2 + C_x^2$ | ×L ³ /6-F _u ×L ² /(2> | ⟨L)+H _{xuA} ×h+M _{xuA} | A. |
| Calculate rate of cha | nge of base pressure in v di | irection | | | |
| Top edge base reaction | n: | $f_{\rm uT} = (q_{2\rm u} + q_{4\rm u}) \times$ | L/2 = 647.040 k | N/m | |
| Bottom edge base rea | ction. | $f_{uP} = (q_{1u} + q_{2u}) \times (q_{2u} + q_{2u$ | / 2 = 172.373 | «N/m | |
| Length of base reaction | n: | $I_{v} = B = 1500 \text{ mm}$ | 1 <u>11 - 10 - 0</u> - | | |
| Rate of change of bas | e pressure: | $C_v = (f_{UB} - f_{UT}) / L_v$ | = -316.444 kN/n | n/m | |
| Calculate and length | s in v direction | -y (ab ar) y | | | |
| Ton length: | ວ ແມ່ງ ແມ່ອບແບບໃ | $I_{T} = B/2 = 0 = -$ | 750 mm | | |
| Bottom length: | | $L_1 = D/2 = e_{PyA} =$ | 750 mm | | |
| | , . | | <u>7 30</u> mm | | |
| Calculate ultimate m Ultimate moment in y | oments in y direction direction; | $M_y = f_{uT} \times L_T^2 / 2 + C_y$ | ×L _T ³ /6-F _u ×L _T ² /(2) | ×B) = <u>146.500</u> | |
| kNm | | | | | |
| | | | | | |
| Material details | | | | | |

| No. | Project Pad footing analysis an | nd design (BS8110-1:1997) | Job Ref. | | |
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| Characteristic streng | th of reinforcement; | f _y = <u>500</u> N/mm ² | | | |
| Characteristic streng | th of shear reinforcement; | f _{yv} = <u>500</u> N/mm ² | | | |
| Nominal cover to reir | iforcement; | c _{nom} = <u>30</u> mm | | | |
| Moment design in x | direction | | | | |
| Diameter of tension r | einforcement; | φ _{xB} = 12 mm | | | |
| Depth of tension rein | forcement: | $d_x = h - c_{nom} - \phi_{xB} / 2 = 364 \text{ mm}$ | | | |
| Design formula for | rectangular beams (cl 3.4.4 | 4) | | | |
| Doorgin formatia for | lootangulai soumo (oi o | $K_{\rm x} = M_{\rm x} / (B \times d_{\rm x}^2 \times f_{\rm au}) = 0.033$ | | | |
| | | $K_{v}' = 0.156$ | | | |
| | I | K _v < K _v ' compression reinforceme | ent is not required | | |
| l ever arm: | - | $z_{x} = d_{x} \times \min([0.5 + \sqrt{(0.25 - K_{x})/(0.5 + ($ | 0.9)]. 0.95) = 346 | | |
| mm | | | <u></u> | | |
| Area of tension reinfo | prcement required: | $A_{s,v}$ reg = $M_{v} / (0.87 \times f_{v} \times z_{v}) = 13$ | 322 mm ² | | |
| Minimum area of ten | sion reinforcement | $A_{s,x,min} = 0.0013 \times B \times h = 780 \text{ mm}^2$ | | | |
| Tension reinforceme | nt provided: | 12 No. 12 dia. bars bottom (12) | 5 centres) | | |
| Area of tension reinfr | provided. | A_{0} vp prov = Nvp × $\pi \times \phi v p^{2} / 4 = 13$ | 57 mm ² | | |
| PA | SS - Tension reinforcement | t provided exceeds tension reinfo | orcement required | | |
| Moment design in y | direction | | | | |
| Diameter of tension r | einforcement; | φ _{yB} = <u>12</u> mm | | | |
| Depth of tension rein | forcement; | $d_y = h - c_{nom} - \phi_{xB} - \phi_{yB} / 2 = 352$ r | nm | | |
| Design formula for | rectangular beams (cl 3.4.4 | .4) | | | |
| C C | - | $K_v = M_v / (L \times d_v^2 \times f_{cu}) = 0.016$ | | | |
| | | K _v ' = 0.156 | | | |
| | <u> </u> | K _v < K _v ' compression reinforceme | ent is not required | | |
| Lever arm; mm | | $z_y = d_y \times min([0.5 + \sqrt{0.25 - K_y}))$ | 0.9)], 0.95) = <u>334</u> | | |
| Δrea of tension reinfr | prcement required; | $A_{s v reg} = M_v / (0.87 \times f_v \times z_v) = 10$ |)07 mm ² | | |
| | • • | | | | |
| Minimum area of ten | sion reinforcement: | $A_{s v min} = 0.0013 \times L \times h = 1300$ | mm ² | | |
| Minimum area of tension reinforcemen | sion reinforcement; nt provided; | A_{s_y} = 0.0013 × L × h = 1300 13 No. 12 dia. bars bottom (200 | mm ²) centres) | | |
| Minimum area of tension reinforcement Area of tension reinforcement | sion reinforcement; nt provided; yrcement provided; | $A_{s_y_min} = 0.0013 \times L \times h = 1300$ 13 No. 12 dia. bars bottom (200 $A_{s_yB_prov} = N_{vB} \times \pi \times \phi_{vB}^{-2} / 4 = 14$ | mm ² <u>) centres)</u> 70 mm ² | | |
| Minimum area of tension reinforcement Tension reinforcement Area of tension reinforcement PA | sion reinforcement; nt provided; prcement provided; <u>SS - Tension reinforcement</u> | $A_{s_y_min} = 0.0013 \times L \times h = \underline{1300}$ $\underline{13 \text{ No. 12 dia. bars bottom (200)}}$ $A_{s_yB_prov} = N_{yB} \times \pi \times \phi_{yB}^{2} / 4 = \underline{14}$ <i>t provided exceeds tension reinfo</i> | mm ² <u>) centres)</u> 70 mm ² prcement required | | |
| Minimum area of tension reinforcement Tension reinforcement Area of tension reinforcement <u>PA</u> Calculate ultimate s | sion reinforcement; nt provided; prcement provided; <u>SS - Tension reinforcement</u> hear force at d from right fa | $A_{s_y_min} = 0.0013 \times L \times h = \underline{1300}$ $\underline{13 \text{ No. 12 dia. bars bottom (200)}}$ $A_{s_yB_prov} = N_{yB} \times \pi \times \phi_{yB}^{2} / 4 = \underline{14}$ $\underline{14 \text{ provided exceeds tension reinfo}}$ ace of column | mm ² <u>) centres)</u> 7 <u>0</u> mm ² prcement required | | |
| Minimum area of tension reinforcement Tension reinforcement Area of tension reinforcement PA Calculate ultimate s Ultimate pressure for | sion reinforcement; nt provided; orcement provided; <u>SS - Tension reinforcement</u> hear force at d from right fa shear; | $A_{s_y_min} = 0.0013 \times L \times h = \underline{1300}$ $\underline{13 \text{ No. 12 dia. bars bottom (200)}$ $A_{s_yB_prov} = N_{yB} \times \pi \times \phi_{yB}^2 / 4 = \underline{14}$ $\underline{t \text{ provided exceeds tension reinfo}}$ $ace \text{ of column}$ $q_{su} = (q_{1u} + C_x \times (L / 2 + e_{PxA} + I_A))$ | mm ² <u>) centres)</u> <u>70</u> mm ² <u>prcement required</u> / 2 + d _x) / B + q _{4u}) | | |
| Minimum area of tension reinforcement Tension reinforcement Area of tension reinforcement PA Calculate ultimate s Ultimate pressure for / 2 | sion reinforcement; nt provided; prcement provided; <u>SS - Tension reinforcement</u> hear force at d from right fa shear; | $A_{s_y_min} = 0.0013 \times L \times h = \underline{1300}$ $\underline{13 \text{ No. 12 dia. bars bottom (200)}$ $A_{s_yB_prov} = N_{yB} \times \pi \times \phi_{yB}^2 / 4 = \underline{14}$ $\underline{t \ provided \ exceeds \ tension \ reinfo}$ ace of column $q_{su} = (q_{1u} + C_x \times (L / 2 + e_{PxA} + I_A))$ $q_{su} = 189.984 \text{ kN/m}^2$ | mm ² <u>) centres)</u> <u>70</u> mm ² <u>prcement required</u> / 2 + d _x) / B + q _{4u}) | | |
| Minimum area of ten Tension reinforcement Area of tension reinforcement PA Calculate ultimate s Ultimate pressure for / 2 Area loaded for shea | sion reinforcement; nt provided; orcement provided; <u>SS - Tension reinforcement</u> ; hear force at d from right fa shear; r; | $A_{s_y_min} = 0.0013 \times L \times h = \underline{1300}$ $\underline{13 \text{ No. 12 dia. bars bottom (200)}$ $A_{s_yB_prov} = N_{yB} \times \pi \times \phi_{yB}^2 / 4 = \underline{14}$ $\underline{t \text{ provided exceeds tension reinfo}}$ $ace \text{ of column}$ $q_{su} = (q_{1u} + C_x \times (L / 2 + e_{PxA} + I_A))$ $q_{su} = \underline{189.984} \text{ kN/m}^2$ $A_s = B \times \min(3 \times (L / 2 - e_{Tx}), L / 2)$ | mm ² <u>70</u> centres) <u>70</u> mm ² <u>prcement required</u> / 2 + d _x) / B + q _{4u}) 2 - e _{PxA} - I _A / 2 - d _x) | | |
| Area loaded for shea = 1.104 m ² | sion reinforcement; nt provided; orcement provided; <u>SS - Tension reinforcement</u> shear force at d from right fa shear; r; | $A_{s_y_min} = 0.0013 \times L \times h = \underline{1300}$ $\underline{13 \text{ No. 12 dia. bars bottom (200)}$ $A_{s_yB_prov} = N_{yB} \times \pi \times \phi_{yB}^2 / 4 = \underline{14}$ $\underline{t \text{ provided exceeds tension reinfo}}$ ace of column $q_{su} = (q_{1u} + C_x \times (L / 2 + e_{PxA} + I_A))$ $q_{su} = \underline{189.984} \text{ kN/m}^2$ $A_s = B \times \min(3 \times (L / 2 - e_{Tx}), L / 2)$ $M_s = 40 \times (q_s - E_s / A_s) = 428.276$ | mm ² <u>) centres)</u> <u>70</u> mm ² <u>prcement required</u> / 2 + d _x) / B + q _{4u}) 2 - e _{PxA} - I _A / 2 - d _x) | | |
| Minimum area of tension reinforcement Area of tension reinforcement Area of tension reinforcement PA Calculate ultimate s Ultimate pressure for / 2 Area loaded for sheat = 1.104 m ² Ultimate shear force; | sion reinforcement; nt provided; orcement provided; SS - Tension reinforcement shear force at d from right f shear; r; | $A_{s_y_min} = 0.0013 \times L \times h = \underline{1300}$ $\underline{13 \text{ No. 12 dia. bars bottom (200)}$ $A_{s_yB_prov} = N_{yB} \times \pi \times \phi_{yB}^2 / 4 = \underline{14}$ $\underline{t \text{ provided exceeds tension reinfo}}$ $ace \text{ of column}$ $q_{su} = (q_{1u} + C_x \times (L / 2 + e_{PxA} + I_A)$ $q_{su} = \underline{189.984} \text{ kN/m}^2$ $A_s = B \times \min(3 \times (L / 2 - e_{Tx}), L / 2)$ $V_{su} = A_s \times (q_{su} - F_u / A) = \underline{188.970}$ | mm ² <u>70</u> mm ² <u>prcement required</u> / 2 + d _x) / B + q _{4u}) 2 - e _{PxA} - I _A / 2 - d _x) <u>0</u> kN | | |
| Area loaded for shea = 1.104 m ² Ultimate shear force; Shear stresses at d | sion reinforcement; nt provided; orcement provided; SS - Tension reinforcement; shear force at d from right fa shear; r; from right face of column (| $A_{s_y_min} = 0.0013 \times L \times h = 1300$ $\frac{13 \text{ No. 12 dia. bars bottom (200)}{A_{s_yB_prov} = N_{yB} \times \pi \times \phi_{yB}^2 / 4 = \underline{14}$ $\frac{t \text{ provided exceeds tension reinfo}{ace of column}$ $q_{su} = (q_{1u} + C_x \times (L / 2 + e_{PxA} + I_A))$ $q_{su} = \underline{189.984} \text{ kN/m}^2$ $A_s = B \times \min(3 \times (L / 2 - e_{Tx}), L / 2)$ $V_{su} = A_s \times (q_{su} - F_u / A) = \underline{188.970}$ $(cl 3.5.5.2)$ | mm ² <u>2 centres)</u> <u>70</u> mm ² <u>5 ccement required</u> / 2 + d _x) / B + q _{4u}) 2 - e _{PxA} - I _A / 2 - d _x) <u>0</u> kN | | |

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| Structural Engineering, Soil Mechanics, Rock Mechanics, Foundation Engineering & Retaining Structures. Tel.: (+30) 210 5238127, 210 5711263 - Fax: +30 210 5711461 - Mobile: (+30) 6936425722 & (+44) 7585939944, <u>costa@eachparis.info</u> | Dr.C.Sach pazis | 23/05/2013 | - | | | |

From BS 8110:Part 1:1997 - Table 3.8

Design concrete shear stress;

Allowable design shear stress;

= <u>4.382</u> N/mm²

v_c = <u>0.432</u> N/mm²

 $v_{max} = min(0.8N/mm^2 \times \sqrt{(f_{cu} / 1 N/mm^2)}, 5 N/mm^2)$

<u>PASS - v_{su} < v_c - No shear reinforcement required</u>

Calculate ultimate punching shear force at face of column

| Ultimate pressure for punching shear; | $q_{puA} = q_{1u} + [(L/2 + e_{PxA} - I_A/2) + (I_A)/2] \times C_x/B - [(B/2 + e_{PyA} - I_A/2) + (I_A)/2] \times C_x/B - [$ |
|--|--|
| $b_{A}/2)+(b_{A})/2]\times C_{y}/L$ | |
| | q _{puA} = <u>163.883</u> kN/m ² |
| Average effective depth of reinforcement; | $d = (d_x + d_y) / 2 = 358 \text{ mm}$ |
| Area loaded for punching shear at column; | $A_{pA} = (I_A) \times (b_A) = $ <u>0.090</u> m ² |
| Length of punching shear perimeter; | u _{pA} = 2×(I _A)+2×(b _A) = <u>1200</u> mm |
| Ultimate shear force at shear perimeter; | $V_{puA} = P_{uA} + (F_u / A - q_{puA}) \times A_{pA} = $ <u>530.944</u> kN |
| Effective shear force at shear perimeter; | V _{puAeff} = |
| $V_{puA} \times [1+1.5 \times abs(M_{xuA})/(V_{puA} \times (b_A)) + 1.5 \times abs(M_{yuA})/(V_{puA} \times (b_A)) + 1.5 \times abs(M_{yuA} \times (b_A)) + 1.5 \times abs(M_{y$ | / _{puA} ×(I _A))] = <u>1130.944</u> kN |
| | |

Punching shear stresses at face of column (cl 3.7.7.2)

| Design shear stress; | $v_{puA} = V_{puAeff} / (u_{pA} \times d) = 2.633 \text{ N/mm}^2$ |
|----------------------------------|--|
| Allowable design shear stress; | $v_{max} = min(0.8N/mm^2 \times \sqrt{(f_{cu} \ / \ 1 \ N/mm^2)}, \ 5 \ N/mm^2)$ |
| = <u>4.382</u> N/mm ² | |

PASS - Design shear stress is less than allowable design shear stress

Calculate ultimate punching shear force at perimeter of 1.5 d from face of column Ultimate pressure for punching shear: $q_{\text{max}} = q_{\text{max}} [(1/2+e_{\text{max}})/2+e_{\text{max}}]/2$

| olimate pressure for punching shear, | YpuA1.5d − Y1u+[(L/Z+CPxA+IA/Z+ |
|--|--|
| $1.5 \times d$ +(I _A +2×1.5×d)/2]×C _x /B-[B/2]×C _y /L | |
| | q _{puA1.5d} = <u>163.883</u> kN/m ² |
| Average effective depth of reinforcement; | d = (d _x + d _y) / 2 = <u>358</u> mm |
| Area loaded for punching shear at column; | $A_{pA1.5d} = (I_A + 2 \times 1.5 \times d) \times B = 2.061 m^2$ |
| Length of punching shear perimeter; | u _{pA1.5d} = 2×B = <u>3000</u> mm |
| Ultimate shear force at shear perimeter; | $V_{puA1.5d} = P_{uA} + (F_u / A - q_{puA1.5d}) \times A_{pA1.5d} = 245.018$ kN |
| Effective shear force at shear perimeter; | V _{puA1.5deff} = V _{puA1.5d} × 1.25 = <u>306.272</u> kN |
| Punching shear stresses at perimeter of 1.5 d f | rom face of column (cl 3.7.7.2) |
| Design shear stress; | $v_{puA1.5d} = V_{puA1.5deff} / (u_{pA1.5d} \times d) = 0.285 \text{ N/mm}^2$ |
| | |

From BS 8110:Part 1:1997 - Table 3.8 Design concrete shear stress; Allowable design shear stress; = <u>4.382</u> N/mm²

 $v_c = 0.409$ N/mm² $v_{max} = min(0.8N/mm^2 \times \sqrt{(f_{cu} / 1 N/mm^2)}, 5 N/mm^2)$

PASS - v_{puA1.5d} < v_c - No shear reinforcement required

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| Structural Engineering, Soil Mechanics, Rock Mechanics, Foundation Engineering & Retaining Structures. Tel.: (+30) 210 5238127, 210 5711263 - Fax:+30 210 5711461 - Mobile: (+30) 6936425722 (+(44) 7585939944, <u>costae2eschapais</u> , info | Dr.C.Sach pazis | 23/05/2013 | - | | | |



- - Punching shear perimeter at 1.5 × d from column face