Tekla Tedds	Project			Job Ref.	
	Section			Sheet no./rev. 1	
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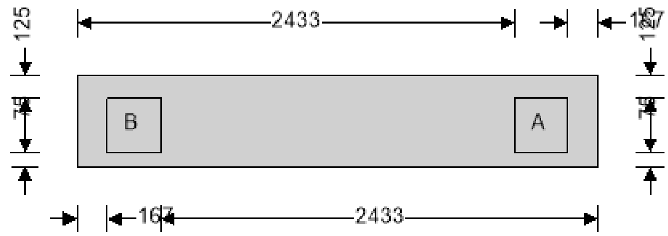
PAD FOOTING ANALYSIS AND DESIGN (BS8110-1:1997)

Tedds calculation version 2.0.07



Pad footing details

Length of pad footing	L = **2900** mm
Width of pad footing	B = **500** mm
Area of pad footing	A = L × B = **1.450** m^2
Depth of pad footing	h = **500** mm
Depth of soil over pad footing	h_{soil} = **0** mm
Density of concrete	ρ_{conc} = **25.0** kN/m^3

Column details	**Column A**	**Column B**
Column base length	l_A = **300** mm	l_B = **300** mm
Column base width	b_A = **300** mm	b_B = **300** mm
Column eccentricity in x	e_{PxA} = **1133** mm	e_{PxB} = **-1133** mm
Column eccentricity in y	e_{PyA} = **-25** mm	e_{PyB} = **-25** mm

Soil details

Density of soil	ρ_{soil} = **17.0** kN/m^3
Design shear strength	ϕ' = **33.0** deg
Design base friction	δ = **25.0** deg
Allowable bearing pressure	$P_{bearing}$ = **100** kN/m^2

Axial loading on columns	**Column A**	**Column B**
Dead axial load on column	P_{GA} = **55.0** kN	P_{GB} = **55.0** kN
Imposed axial load on column	P_{QA} = **0.0** kN	P_{QB} = **0.0** kN
Wind axial load on column	P_{WA} = **0.0** kN	P_{WB} = **0.0** kN
Total axial load on column	P_A = **55.0** kN	P_B = **55.0** kN

Foundation loads

Dead surcharge load	F_{Gsur} = **0.000** kN/m^2
Imposed surcharge load	F_{Qsur} = **0.000** kN/m^2
Pad footing self weight	$F_{swt} = h \times \rho_{conc}$ = **12.500** kN/m^2
Soil self weight	$F_{soil} = h_{soil} \times \rho_{soil}$ = **0.000** kN/m^2
Total foundation load	$F = A \times (F_{Gsur} + F_{Qsur} + F_{swt} + F_{soil})$ = **18.1** kN

Horizontal loading on column bases	**Column A**	**Column B**
Dead horizontal load in x direction	H_{GxA} = **0.0** kN	H_{GxB} = **0.0** kN
Imposed horizontal load in x direction	H_{QxA} = **0.0** kN	H_{QxB} = **0.0** kN
Wind horizontal load in x direction	H_{WxA} = **-4.5** kN	H_{WxB} = **4.5** kN
Total horizontal load in x direction	H_{xA} = **-4.5** kN	H_{xB} = **4.5** kN

Dead horizontal load in y direction H_{GyA} = **0.0** kN H_{GyB} = **0.0** kN

Imposed horizontal load in y direction H_{QyA} = **0.0** kN H_{QyB} = **0.0** kN

Wind horizontal load in y direction H_{WyA} = **2.5** kN H_{WyB} = **2.5** kN

Total horizontal load in y direction H_{yA} = **2.5** kN H_{yB} = **2.5** kN

Check stability against sliding

Resistance to sliding due to base friction

$H_{friction} = \max([P_{GA} + P_{GB} + (F_{Gsur} + F_{swt} + F_{soil}) \times A], 0\text{ kN}) \times \tan(\delta)$ = **59.7** kN

Passive pressure coefficient $K_p = (1 + \sin(\phi')) / (1 - \sin(\phi'))$ = **3.392**

Stability against sliding in y direction

Passive resistance of soil in y direction $H_{ypas} = 0.5 \times K_p \times (h^2 + 2 \times h \times h_{soil}) \times L \times \rho_{soil}$ = **20.9** kN

Total resistance to sliding in y direction $H_{yres} = H_{friction} + H_{ypas}$ = **80.6** kN

PASS - Resistance to sliding is greater than horizontal load in y direction

Check stability against overturning in y direction

Total overturning moment $M_{yOT} = M_{yA} + M_{yB} + (H_{yA} + H_{yB}) \times h$ = **2.500** kNm

Restoring moment in y direction

Foundation loading $M_{ysur} = A \times (F_{Gsur} + F_{swt} + F_{soil}) \times B / 2$ = **4.531** kNm

Axial loading on column $M_{yaxial} = (P_{GA}) \times (B / 2 - e_{PyA}) + (P_{GB}) \times (B / 2 - e_{PyB})$ = **30.250** kNm

Total restoring moment $M_{yres} = M_{ysur} + M_{yaxial}$ = **34.781** kNm

PASS - Overturning safety factor exceeds the minimum of 1.5 in the y direction

Calculate pad base reaction

Total base reaction $T = F + P_A + P_B$ = **128.1** kN

Eccentricity of base reaction in x $e_{Tx} = (P_A \times e_{PxA} + P_B \times e_{PxB} + M_{xA} + M_{xB} + (H_{xA} + H_{xB}) \times h) / T$ = **0** mm

Eccentricity of base reaction in y $e_{Ty} = (P_A \times e_{PyA} + P_B \times e_{PyB} + M_{yA} + M_{yB} + (H_{yA} + H_{yB}) \times h) / T$ = **-2** mm

Check pad base reaction eccentricity

$\text{abs}(e_{Tx}) / L + \text{abs}(e_{Ty}) / B$ = **0.004**

Base reaction acts within middle third of base

Calculate pad base pressures

$q_1 = T / A - 6 \times T \times e_{Tx} / (L \times A) - 6 \times T \times e_{Ty} / (B \times A)$ = **90.431** kN/m^2

$q_2 = T / A - 6 \times T \times e_{Tx} / (L \times A) + 6 \times T \times e_{Ty} / (B \times A)$ = **86.293** kN/m^2

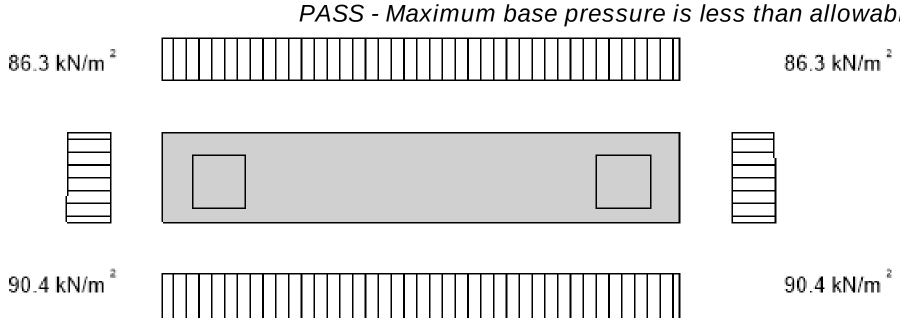
$q_3 = T / A + 6 \times T \times e_{Tx} / (L \times A) - 6 \times T \times e_{Ty} / (B \times A)$ = **90.431** kN/m^2

$q_4 = T / A + 6 \times T \times e_{Tx} / (L \times A) + 6 \times T \times e_{Ty} / (B \times A)$ = **86.293** kN/m^2

Minimum base pressure $q_{min} = \min(q_1, q_2, q_3, q_4)$ = **86.293** kN/m^2

Maximum base pressure $q_{max} = \max(q_1, q_2, q_3, q_4)$ = **90.431** kN/m^2

PASS - Maximum base pressure is less than allowable bearing pressure



Partial safety factors for loads

Partial safety factor for dead loads γ_{fG} = **1.40**

Partial safety factor for imposed loads γ_{fQ} = **1.60**

Partial safety factor for wind loads γ_{fW} = **0.00**

Ultimate axial loading on columns

Ultimate axial load on column A $P_{uA} = P_{GA} \times \gamma_{fG} + P_{QA} \times \gamma_{fQ} + P_{WA} \times \gamma_{fW}$ = **77.0** kN

Ultimate axial load on column B $P_{uB} = P_{GB} \times \gamma_{fG} + P_{QB} \times \gamma_{fQ} + P_{WB} \times \gamma_{fW}$ = **77.0** kN

Ultimate foundation loads

Ultimate foundation load $F_u = A \times [(F_{Gsur} + F_{swt} + F_{soil}) \times \gamma_{fG} + F_{Qsur} \times \gamma_{fQ}]$ = **25.4** kN

Ultimate horizontal loading on column A

Ultimate horizontal load in x direction $H_{xuA} = H_{GxA} \times \gamma_{fG} + H_{QxA} \times \gamma_{fQ} + H_{WxA} \times \gamma_{fW}$ = **0.0** kN

Ultimate horizontal load in y direction $H_{yuA} = H_{GyA} \times \gamma_{fG} + H_{QyA} \times \gamma_{fQ} + H_{WyA} \times \gamma_{fW}$ = **0.0** kN

Ultimate horizontal loading on column B

Ultimate horizontal load in x direction $H_{xuB} = H_{GxB} \times \gamma_{fG} + H_{QxB} \times \gamma_{fQ} + H_{WxB} \times \gamma_{fW}$ = **0.0** kN

Ultimate horizontal load in y direction $H_{yuB} = H_{GyB} \times \gamma_{fG} + H_{QyB} \times \gamma_{fQ} + H_{WyB} \times \gamma_{fW}$ = **0.0** kN

Ultimate moment on column A

Ultimate moment on column in x direction $M_{xuA} = M_{GxA} \times \gamma_{fG} + M_{QxA} \times \gamma_{fQ} + M_{WxA} \times \gamma_{fW}$ = **0.000** kNm

Ultimate moment on column in y direction $M_{yuA} = M_{GyA} \times \gamma_{fG} + M_{QyA} \times \gamma_{fQ} + M_{WyA} \times \gamma_{fW}$ = **0.000** kNm

Ultimate moment on column B

Ultimate moment on column in x direction $M_{xuB} = M_{GxB} \times \gamma_{fG} + M_{QxB} \times \gamma_{fQ} + M_{WxB} \times \gamma_{fW}$ = **0.000** kNm

Ultimate moment on column in y direction $M_{yuB} = M_{GyB} \times \gamma_{fG} + M_{QyB} \times \gamma_{fQ} + M_{WyB} \times \gamma_{fW}$ = **0.000** kNm

Calculate ultimate pad base reaction

Ultimate base reaction $T_u = F_u + P_{uA} + P_{uB}$ = **179.4** kN

Eccentricity of ultimate base reaction in x $e_{Txu} = (P_{uA} \times e_{PxA} + P_{uB} \times e_{PxB} + M_{xuA} + M_{xuB} + (H_{xuA} + H_{xuB}) \times h) / T_u$ = **0** mm

Eccentricity of ultimate base reaction in y $e_{Tyu} = (P_{uA} \times e_{PyA} + P_{uB} \times e_{PyB} + M_{yuA} + M_{yuB} + (H_{yuA} + H_{yuB}) \times h) / T_u$ = **-21** mm

Calculate ultimate pad base pressures

$q_{1u} = T_u/A - 6 \times T_u \times e_{Txu}/(L \times A) - 6 \times T_u \times e_{Tyu}/(B \times A)$ = **155.569** kN/m^2

$q_{2u} = T_u/A - 6 \times T_u \times e_{Txu}/(L \times A) + 6 \times T_u \times e_{Tyu}/(B \times A)$ = **91.845** kN/m^2

$q_{3u} = T_u/A + 6 \times T_u \times e_{Txu}/(L \times A) - 6 \times T_u \times e_{Tyu}/(B \times A)$ = **155.569** kN/m^2

$q_{4u} = T_u/A + 6 \times T_u \times e_{Txu}/(L \times A) + 6 \times T_u \times e_{Tyu}/(B \times A)$ = **91.845** kN/m^2

Minimum ultimate base pressure $q_{minu} = \min(q_{1u}, q_{2u}, q_{3u}, q_{4u})$ = **91.845** kN/m^2

Maximum ultimate base pressure $q_{maxu} = \max(q_{1u}, q_{2u}, q_{3u}, q_{4u})$ = **155.569** kN/m^2

Calculate rate of change of base pressure in x direction

Left hand base reaction $f_{uL} = (q_{1u} + q_{2u}) \times B / 2$ = **61.853** kN/m

Right hand base reaction $f_{uR} = (q_{3u} + q_{4u}) \times B / 2$ = **61.853** kN/m

Length of base reaction $L_x = L$ = **2900** mm

Rate of change of base pressure $C_x = (f_{uR} - f_{uL}) / L_x$ = **0.000** kN/m/m

Calculate pad lengths in x direction

Left hand length $L_L = L / 2 + \min(e_{PxA}, e_{PxB})$ = **317** mm

Middle length $L_M = max(e_{PxA}, e_{PxB}) - min(e_{PxA}, e_{PxB})$ = **2266** mm

Right hand length $L_R = L / 2 - max(e_{PxA}, e_{PxB})$ = **317** mm

Calculate shear forces in x direction

Shear at left hand column $S_L = f_{uL} \times L_L + C_x \times L_L^2 / 2 - F_u \times L_L / L$ = **16.834** kN

Shear at right hand column $S_R = f_{uL} \times (L_L + L_M) + C_x \times (L_L + L_M)^2 / 2 - P_{uB} - F_u \times (L_L + L_M) / L$ = **60.166** kN

Calculate ultimate moments in x direction

Ultimate positive moment in x direction $M_x = f_{uL} \times L_L^2 / 2 + C_x \times L_L^3 / 6 - F_u \times L_L^2 / (2 \times L)$ = **2.668** kNm

Position of maximum negative moment L_z = **1450** mm

Ultimate negative moment in x direction $M_{xneg} = f_{uL} \times L_z^2 / 2 + C_x \times L_z^3 / 6 - P_{uB} \times (L_z - L_L) - F_u \times L_z^2 / (2 \times L) + H_{xuB} \times h + M_{xuB}$

M_{xneg} = **-31.416** kNm

Calculate rate of change of base pressure in y direction

Top edge base reaction $f_{uT} = (q_{2u} + q_{4u}) \times L / 2$ = **266.350** kN/m

Bottom edge base reaction $f_{uB} = (q_{1u} + q_{3u}) \times L / 2$ = **451.150** kN/m

Length of base reaction $L_y = B$ = **500** mm

Rate of change of base pressure $C_y = (f_{uB} - f_{uT}) / L_y$ = **369.600** kN/m/m

Calculate pad lengths in y direction

Top length $L_T = B / 2 - e_{PyA}$ = **275** mm

Bottom length $L_B = B / 2 + e_{PyA}$ = **225** mm

Calculate ultimate moments in y direction

Ultimate moment in y direction $M_y = f_{uT} \times L_T^2 / 2 + C_y \times L_T^3 / 6 - F_u \times L_T^2 / (2 \times B)$ = **9.433** kNm

Material details

Characteristic strength of concrete f_{cu} = **30** N/mm²

Characteristic strength of reinforcement f_y = **500** N/mm²

Characteristic strength of shear reinforcement f_{yv} = **500** N/mm²

Nominal cover to reinforcement c_{nom} = **30** mm

Moment design in x direction

Diameter of tension reinforcement ϕ_{xB} = **16** mm

Depth of tension reinforcement $d_x = h - c_{nom} - \phi_{xB} / 2$ = **462** mm

Design formula for rectangular beams (cl 3.4.4.4)

$K_x = M_x / (B \times d_x^2 \times f_{cu})$ = **0.001**

$K_x' = 0.156$

$K_x < K_x'$ compression reinforcement is not required

Lever arm $z_x = d_x \times min([0.5 + \sqrt{(0.25 - K_x / 0.9)}], 0.95)$ = **439** mm

Area of tension reinforcement required $A_{s\_x\_req} = M_x / (0.87 \times f_y \times z_x)$ = **14** mm²

Minimum area of tension reinforcement $A_{s\_x\_min} = 0.0013 \times B \times h$ = **325** mm²

Tension reinforcement provided **5 No. 16 dia. bars bottom (100 centres)**

Area of tension reinforcement provided $A_{s\_xB\_prov} = N_{xB} \times \pi \times \phi_{xB}^2 / 4$ = **1005** mm²

PASS - Tension reinforcement provided exceeds tension reinforcement required

Negative moment design in x direction

Diameter of tension reinforcement ϕ_{xT} = **16** mm

Depth of tension reinforcement $d_x = h - c_{nom} - \phi_{xT} / 2 =$ **462** mm

Design formula for rectangular beams (cl 3.4.4.4)

$K_x = -M_{xneg} / (B \times d_x^2 \times f_{cu}) =$ **0.010**

$K_x' = 0.156$

$K_x < K_x'$ compression reinforcement is not required

Lever arm $z_x = d_x \times \min([0.5 + \sqrt{(0.25 - K_x / 0.9)}], 0.95) =$ **439** mm

Area of tension reinforcement required $A_{s\_x\_req} = -M_{xneg} / (0.87 \times f_y \times z_x) =$ **165** mm²

Minimum area of tension reinforcement $A_{s\_x\_min} = 0.0013 \times B \times h =$ **325** mm²

Tension reinforcement provided **5 No. 16 dia. bars top (100 centres)**

Area of tension reinforcement provided $A_{s\_xT\_prov} = N_{xT} \times \pi \times \phi_{xT}^2 / 4 =$ **1005** mm²

PASS - Tension reinforcement provided exceeds tension reinforcement required

Moment design in y direction

Diameter of tension reinforcement $\phi_{yB} =$ **16** mm

Depth of tension reinforcement $d_y = h - c_{nom} - \phi_{xB} - \phi_{yB} / 2 =$ **446** mm

Design formula for rectangular beams (cl 3.4.4.4)

$K_y = M_y / (L \times d_y^2 \times f_{cu}) =$ **0.001**

$K_y' = 0.156$

$K_y < K_y'$ compression reinforcement is not required

Lever arm $z_y = d_y \times \min([0.5 + \sqrt{(0.25 - K_y / 0.9)}], 0.95) =$ **424** mm

Area of tension reinforcement required $A_{s\_y\_req} = M_y / (0.87 \times f_y \times z_y) =$ **51** mm²

Minimum area of tension reinforcement $A_{s\_y\_min} = 0.0013 \times L \times h =$ **1885** mm²

Tension reinforcement provided **23 No. 16 dia. bars bottom (125 centres)**

Area of tension reinforcement provided $A_{s\_yB\_prov} = N_{yB} \times \pi \times \phi_{yB}^2 / 4 =$ **4624** mm²

PASS - Tension reinforcement provided exceeds tension reinforcement required

Calculate ultimate shear force at d from left face of column A

Ultimate pressure for shear $q_{su} = (q_{2u} + C_x \times (L / 2 + e_{PxA} - l_A / 2 - d_x) / B + q_{1u}) / 2$

$q_{su} =$ **123.707** kN/m²

Area loaded for shear $A_s = B \times \min((L / 2 + e_{PxA} - l_A / 2 - d_x), 3 \times (L / 2 + e_{Tx})) =$ **0.986** m²

Ultimate shear force $V_{su} = A_s \times (q_{su} - F_u / A) - P_{uB} =$ **27.667** kN

Shear stresses at d from left face of column A (cl 3.5.5.2)

Design shear stress $v_{su} = V_{su} / (B \times d_x) =$ **0.120** N/mm²

From BS 8110:Part 1:1997 - Table 3.8

Design concrete shear stress $v_c = 0.79\ \text{N/mm}^2 \times \min(3, [100 \times A_{s\_xB\_prov} / (B \times d_x)]^{1/3}) \times \max((400\ \text{mm} / d_x)^{1/4}, 0.67) \times (\min(f_{cu} / 1\ \text{N/mm}^2, 40) / 25)^{1/3} / 1.25 =$ **0.491** N/mm²

Allowable design shear stress $v_{max} = \min(0.8\ \text{N/mm}^2 \times \sqrt{(f_{cu} / 1\ \text{N/mm}^2)}, 5\ \text{N/mm}^2) =$ **4.382** N/mm²

PASS - $v_{su} < v_c$ - No shear reinforcement required

Calculate ultimate punching shear force at face of column A

Ultimate pressure for punching shear $q_{puA} = q_{1u}+[(L/2+e_{PxA}-l_A/2)+(l_A)/2]\times C_x/B-[(B/2+e_{PyA}-b_A/2)+(b_A)/2]\times C_y/L =$ **126.893** kN/m²

Average effective depth of reinforcement $d = (d_x + d_y) / 2 =$ **454** mm

Area loaded for punching shear at column $A_{pA} = (l_A)\times(b_A) =$ **0.090** m²

Length of punching shear perimeter $u_{pA} = 2\times(l_A)+2\times(b_A) =$ **1200** mm

Ultimate shear force at shear perimeter $V_{puA} = P_{uA} + (F_u / A - q_{puA}) \times A_{pA}$ = **67.155** kN

Effective shear force at shear perimeter $V_{puAeff} = V_{puA}$ = **67.155** kN

Punching shear stresses at face of column A (cl 3.7.7.2)

Design shear stress $v_{puA} = V_{puAeff} / (u_{pA} \times d)$ = **0.123** N/mm^2

Allowable design shear stress $v_{max} = \min(0.8\text{N/mm}^2 \times \sqrt{(f_{cu} / 1\text{ N/mm}^2)}, 5\text{ N/mm}^2)$ = **4.382** N/mm^2

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

Calculate ultimate punching shear force at face of column B

Ultimate pressure for punching shear $q_{puB} = q_{1u}+[(L/2+e_{PxB}-l_B/2)+(l_B)/2]\times C_x/B-[(B/2+e_{PyB}-b_B/2)+(b_B)/2]\times C_y/L$ = **126.893** kN/m^2

Average effective depth of reinforcement $d = (d_x + d_y) / 2$ = **454** mm

Area loaded for punching shear at column $A_{pB} = (l_B)\times(b_B)$ = **0.090** m^2

Length of punching shear perimeter $u_{pB} = 2\times(l_B)+2\times(b_B)$ = **1200** mm

Ultimate shear force at shear perimeter $V_{puB} = P_{uB} + (F_u / A - q_{puB}) \times A_{pB}$ = **67.155** kN

Effective shear force at shear perimeter $V_{puBeff} = V_{puB}$ = **67.155** kN

Punching shear stresses at face of column B (cl 3.7.7.2)

Design shear stress $v_{puB} = V_{puBeff} / (u_{pB} \times d)$ = **0.123** N/mm^2

Allowable design shear stress $v_{max} = \min(0.8\text{N/mm}^2 \times \sqrt{(f_{cu} / 1\text{ N/mm}^2)}, 5\text{ N/mm}^2)$ = **4.382** N/mm^2

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