FOOTING ANALYSIS

In accordance with ACI318-19 (22)

Summary results

Overall design status PASS

Overall design utilisation 0.873

Description	Unit	Applied	Resisting	FoS	Result
Uplift verification	kN	373.6			Pass
Overturning stability, x	kNm	5	-280.2	58.65	Pass
Sliding stability, x	kN	6.8	219.2	32.113	Pass
Description	**Unit**	**Applied**	**Resisting**	**Utilization**	**Result**
Soil bearing	kN/m^2	174.5	200	0.873	Pass
Description	**Unit**	**Required**	**Provided**	**Utilization**	**Result**
Moment, positive, x-direction	kNm	32.2	72.5	0.444	Pass
Moment, positive, y-direction	kNm	32.2	100.7	0.319	Pass
Shear, one-way, x-direction	kips	77.2	104.5	0.739	Pass
Shear, one-way, y-direction	kips	77.2	115.2	0.671	Pass
Shear, two-way, Col 1	N/mm^2	0.477	1.134	0.420	Pass
Min.area of reinf.bot., x-direction	mm^2	810	905		Pass
Max.reinf. spacing, bot, x-direction	mm	457	191		Pass
Min.area of reinf.bot., y-direction	mm^2	810	1357		Pass
Max.reinf. spacing, bot, y-direction	mm	457	121		Pass

Pad footing details

Length of footing L_x = **1500** mm

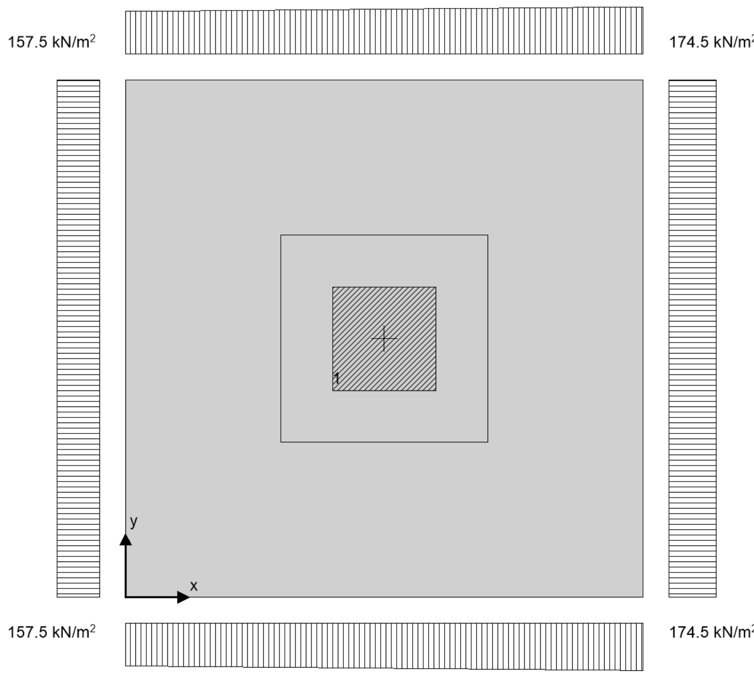
Width of footing L_y = **1500** mm

Footing area $A = L_x \times L_y$ = **2.250** m^2

Depth of footing h = **300** mm

Depth of soil over footing h_{soil} = **450** mm

Density of concrete γ_{conc} = **24.5** kN/m^3



Column no.1 details

Length of column	l_{x1} = **300** mm
Width of column	l_{y1} = **300** mm
position in x-axis	x_1 = **750** mm
position in y-axis	y_1 = **750** mm
Height of pedestal	h_{ped1} = **400** mm
Length of pedestal	$l_{x,ped1}$ = **600** mm
Width of pedestal	$l_{y,ped1}$ = **600** mm

Soil properties

Gross allowable bearing pressure	q_{allow_Gross} = **200** kN/m^2
Density of soil	γ_{soil} = **18.0** kN/m^3
Angle of internal friction	ϕ_b = **30.0** deg
Design base friction angle	δ_{bb} = **30.0** deg
Coefficient of base friction	$\tan(\delta_{bb})$ = **0.577**
Design wall friction angle	δ_b = **15.0** deg
Horizontal acceleration factor	K_h = **0.4**
Vertical acceleration factor	K_v = **0**
Acceleration coefficient	$\theta = \text{atan}(K_h / (1 - K_v))$ = **21.801**
Passive pressure coefficient (Coulomb)	$K_P = \sin(90 - \phi_b)^2 / (\sin(90 + \delta_b) \times [1 - \sqrt{[\sin(\phi_b + \delta_b) \times \sin(\phi_b) / (\sin(90 + \delta_b))]}]^2)$ = **4.977**
Passive dynamic pressure coefficient (M-O)	K_{PE} = 0 = **0**
Dead surcharge load	F_{Dsur} = **1.1** kN/m^2
Live surcharge load	F_{Lsur} = **4.5** kN/m^2
Self weight	$F_{swt} = h \times \gamma_{conc}$ = **7.4** kN/m^2

Soil weight $F_{soil} = h_{soil} \times \gamma_{soil} = \mathbf{8.1}$ kN/m^2

Column no.1 loads

Pedestal self weight $F_{SWz1} = \mathbf{3.5}$ kN

Dead load in z $F_{Dz1} = \mathbf{150.0}$ kN

Live load in z $F_{Lz1} = \mathbf{185.0}$ kN

Seismic load in z $F_{Ez1} = \mathbf{53.0}$ kN

Seismic load in x $F_{Ex1} = \mathbf{13.0}$ kN

Footing analysis for soil and stability

Load combinations per ASCE 7-22

1.0D (0.417)

1.0D + 1.0L (0.851)

1.0D + 1.0Lr (0.417)

1.0D + 0.75L + 0.75Lr (0.743)

(1.0 + 0.14 × S_{DS})D + 0.7E (0.591)

(1.0 + 0.105 × S_{DS})D + 0.75L + 0.1S + 0.525E (0.873)

(0.6 - 0.14 × S_{DS})D + 0.7E (0.355)

Combination 14 results: (1.0 + 0.105 × S_{DS})D + 0.75L + 0.1S + 0.525E

Forces on footing

Force in x-axis $F_{dx} = \gamma_E \times F_{Ex1} = \mathbf{6.8}$ kN

Force in z-axis $F_{dz} = \gamma_D \times A \times (F_{swt} + F_{soil} + F_{Dsur}) + \gamma_L \times A \times F_{Lsur} + \gamma_D \times (F_{Dz1} + F_{SWz1} - l_{x,ped1} \times l_{y,ped1} \times h_{soil} \times \gamma_{soil}) + \gamma_L \times F_{Lz1} + \gamma_E \times F_{Ez1} = \mathbf{373.6}$ kN

Moments on footing

Moment in x-axis, about x is 0 $M_{dx} = \gamma_D \times (A \times (F_{swt} + F_{soil} + F_{Dsur}) \times L_x / 2) + \gamma_L \times A \times F_{Lsur} \times L_x / 2 + \gamma_D \times (((F_{Dz1} + F_{SWz1} - l_{x,ped1} \times l_{y,ped1} \times h_{soil} \times \gamma_{soil})) \times x_1) + \gamma_L \times (F_{Lz1} \times x_1) + \gamma_E \times (F_{Ez1} \times x_1 + F_{Ex1} \times (h + h_{ped1})) = \mathbf{285.0}$ kNm

Moment in y-axis, about y is 0 $M_{dy} = \gamma_D \times (A \times (F_{swt} + F_{soil} + F_{Dsur}) \times L_y / 2) + \gamma_L \times A \times F_{Lsur} \times L_y / 2 + \gamma_D \times (((F_{Dz1} + F_{SWz1} - l_{x,ped1} \times l_{y,ped1} \times h_{soil} \times \gamma_{soil})) \times y_1) + \gamma_L \times (F_{Lz1} \times y_1) + \gamma_E \times (F_{Ez1} \times y_1) = \mathbf{280.2}$ kNm

Uplift verification

Vertical force $F_{dz} = \mathbf{373.6}$ kN

PASS - Footing is not subject to uplift

Stability against overturning in x direction, moment about x is L_x

Overturning moment $M_{OTxL} = \gamma_E \times (F_{Ex1} \times (h + h_{ped1})) = \mathbf{4.8}$ kNm

Resisting moment $M_{RxL} = -1 \times (\gamma_D \times (A \times (F_{swt} + F_{soil} + F_{Dsur}) \times L_x / 2) + \gamma_L \times A \times F_{Lsur} \times L_x / 2) + \gamma_D \times (((F_{Dz1} + F_{SWz1} - l_{x,ped1} \times l_{y,ped1} \times h_{soil} \times \gamma_{soil})) \times (x_1 - L_x)) + \gamma_L \times (F_{Lz1} \times (x_1 - L_x)) + \gamma_E \times (F_{Ez1} \times (x_1 - L_x)) = \mathbf{-280.2}$ kNm

Factor of safety $abs(M_{RxL} / M_{OTxL}) = \mathbf{58.646}$

PASS - Overturning moment safety factor exceeds the minimum of 1.00

Stability against sliding

Resistance due to base friction $F_{RFriction} = max(F_{dz}, 0 \text{ kN}) \times tan(\delta_{bb}) = \mathbf{215.7}$ kN

Stability against sliding in x direction

Resistance from passive soil pressure $F_{RxPass} = 0.5 \times K_{PE} \times (h^2 + 2 \times h \times h_{soil}) \times L_y \times \gamma_{soil} = \mathbf{3.5}$ kN

Total sliding resistance $F_{Rx} = F_{RFriction} + F_{RxPass} = \mathbf{219.2}$ kN

$abs(F_{Rx} / F_{dx})$

PASS - Sliding factor of safety exceeds the minimum of 1.00

Bearing resistance

Eccentricity of base reaction

Eccentricity of base reaction in x-axis $e_{dx} = M_{dx} / F_{dz} - L_x / 2 = \mathbf{13}$ mm

Eccentricity of base reaction in y-axis $e_{dy} = M_{dy} / F_{dz} - L_y / 2 = \mathbf{0}$ mm

Pad base pressures

$q_1 = F_{dz} \times (1 - 6 \times e_{dx} / L_x - 6 \times e_{dy} / L_y) / (L_x \times L_y) = \mathbf{157.5}$ kN/m^2

$q_2 = F_{dz} \times (1 - 6 \times e_{dx} / L_x + 6 \times e_{dy} / L_y) / (L_x \times L_y) = \mathbf{157.5}$ kN/m^2

$q_3 = F_{dz} \times (1 + 6 \times e_{dx} / L_x - 6 \times e_{dy} / L_y) / (L_x \times L_y) = \mathbf{174.5}$ kN/m^2

$q_4 = F_{dz} \times (1 + 6 \times e_{dx} / L_x + 6 \times e_{dy} / L_y) / (L_x \times L_y) = \mathbf{174.5}$ kN/m^2

Minimum base pressure $q_{min} = \min(q_1,q_2,q_3,q_4) = \mathbf{157.5}$ kN/m^2

Maximum base pressure $q_{max} = \max(q_1,q_2,q_3,q_4) = \mathbf{174.5}$ kN/m^2

Allowable bearing capacity

Allowable bearing capacity $q_{allow} = q_{allow\_Gross} = \mathbf{200.0}$ kN/m^2

$q_{max} / q_{allow} = \mathbf{0.873}$

PASS - Allowable bearing capacity exceeds design base pressure

<u>FOOTING DESIGN</u>

In accordance with ACI318-19 (22)

Tedds calculation version 3.3.08

Material details

Compressive strength of concrete $f'_c = \mathbf{21}$ MPa

Yield strength of reinforcement $f_y = \mathbf{420}$ MPa

Compression-controlled strain limit (21.2.2) $\varepsilon_{ty} = \mathbf{0.00200}$

Cover to top of footing $c_{nom\_t} = \mathbf{75}$ mm

Cover to side of footing $c_{nom\_s} = \mathbf{75}$ mm

Cover to bottom of footing $c_{nom\_b} = \mathbf{75}$ mm

Concrete type Normal weight

Concrete modification factor $\lambda = \mathbf{1.00}$

Column type Concrete

Analysis and design of concrete footing

Load combinations per ASCE 7-22

1.4D (0.327)

1.2D + 1.6L + 0.5Lr (0.739)

Combination 2 results: 1.2D + 1.6L + 0.5Lr

Forces on footing

Ultimate force in z-axis $F_{uz} = \gamma_D \times A \times (F_{swt} + F_{soil} + F_{Dsur}) + \gamma_L \times A \times F_{Lsur} + \gamma_D \times (F_{Dz1} + F_{SWz1} - l_{x,ped1} \times l_{y,ped1} \times h_{soil} \times \gamma_{soil}) + \gamma_L \times F_{Lz1} = \mathbf{537.6}$ kN

Moments on footing

Ultimate moment in x-axis, about x is 0 — $M_{ux} = \gamma_D \times (A \times (F_{swt} + F_{soil} + F_{Dsur}) \times L_x / 2) + \gamma_L \times A \times F_{Lsur} \times L_x / 2 + \gamma_D \times (((F_{Dz1} + F_{SWz1} - l_{x,ped1} \times l_{y,ped1} \times h_{soil} \times \gamma_{soil})) \times x_1) + \gamma_L \times (F_{Lz1} \times x_1)$ = **403.2** kNm

Ultimate moment in y-axis, about y is 0 — $M_{uy} = \gamma_D \times (A \times (F_{swt} + F_{soil} + F_{Dsur}) \times L_y / 2) + \gamma_L \times A \times F_{Lsur} \times L_y / 2 + \gamma_D \times (((F_{Dz1} + F_{SWz1} - l_{x,ped1} \times l_{y,ped1} \times h_{soil} \times \gamma_{soil})) \times y_1) + \gamma_L \times (F_{Lz1} \times y_1)$ = **403.2** kNm

Eccentricity of base reaction

Eccentricity of base reaction in x-axis — $e_{ux} = M_{ux} / F_{uz} - L_x / 2$ = **0** mm

Eccentricity of base reaction in y-axis — $e_{uy} = M_{uy} / F_{uz} - L_y / 2$ = **0** mm

Pad base pressures

$q_{u1} = F_{uz} \times (1 - 6 \times e_{ux} / L_x - 6 \times e_{uy} / L_y) / (L_x \times L_y)$ = **238.9** kN/m^2

$q_{u2} = F_{uz} \times (1 - 6 \times e_{ux} / L_x + 6 \times e_{uy} / L_y) / (L_x \times L_y)$ = **238.9** kN/m^2

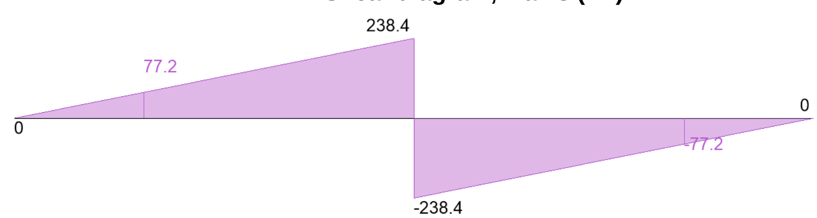
$q_{u3} = F_{uz} \times (1 + 6 \times e_{ux} / L_x - 6 \times e_{uy} / L_y) / (L_x \times L_y)$ = **238.9** kN/m^2

$q_{u4} = F_{uz} \times (1 + 6 \times e_{ux} / L_x + 6 \times e_{uy} / L_y) / (L_x \times L_y)$ = **238.9** kN/m^2

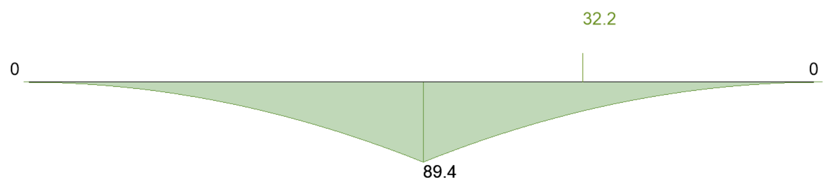
Minimum ultimate base pressure — $q_{umin} = \min(q_{u1},q_{u2},q_{u3},q_{u4})$ = **238.9** kN/m^2

Maximum ultimate base pressure — $q_{umax} = \max(q_{u1},q_{u2},q_{u3},q_{u4})$ = **238.9** kN/m^2

Shear diagram, x axis (kN)



Moment diagram, x axis (kNm)



Moment design, x direction, positive moment

Ultimate bending moment — $M_{u.x.max}$ = **32.2** kNm

Tension reinforcement provided — 8 x 12mm bottom bars (191 c/c)

Area of tension reinforcement provided — $A_{sx.bot.prov}$ = **905** mm^2

Minimum area of reinforcement (8.6.1.1) — $A_{s.min} = 0.0018 \times L_y \times h$ = **810** mm^2

PASS - Area of reinforcement provided exceeds minimum

Maximum spacing of reinforcement (8.7.2.2) — $s_{max} = \min(2 \times h, 457\text{ mm})$ = **457** mm

PASS - Maximum permissible reinforcement spacing exceeds actual spacing

Depth to tension reinforcement — $d = h - c_{nom\_b} - \phi_{x.bot} / 2$ = **219** mm

Depth of compression block — $a = A_{sx.bot.prov} \times f_y / (0.85 \times f'_c \times L_y)$ = **14** mm

Neutral axis factor — β_1 = **0.85**

Depth to neutral axis: $c = a / \beta_1 = \mathbf{17}$ mm

Strain in tensile reinforcement: $\varepsilon_t = 0.003 \times d / c - 0.003 = \mathbf{0.03635}$

Minimum tensile strain(8.3.3.1): $\varepsilon_{min} = \varepsilon_{ty} + 0.003 = \mathbf{0.00500}$

PASS - Tensile strain exceeds minimum required

Nominal moment capacity: $M_n = A_{sx.bot.prov} \times f_y \times (d - a / 2) = \mathbf{80.5}$ kNm

Flexural strength reduction factor: $\phi_f = \min(\max(0.65 + 0.25 \times (\varepsilon_t - \varepsilon_{ty}) / (0.003), 0.65), 0.9) = \mathbf{0.900}$

Design moment capacity: $\phi M_n = \phi_f \times M_n = \mathbf{72.5}$ kNm

$M_{u.x.max} / \phi M_n = \mathbf{0.444}$

PASS - Design moment capacity exceeds ultimate moment load

One-way shear design, x direction

Ultimate shear force: $V_{u.x} = \mathbf{77.2}$ kN

Depth to reinforcement: $d_v = h - c_{nom\_b} - \phi_{x.bot} / 2 = \mathbf{219}$ mm

Size effect factor (22.5.5.1.3): $\lambda_s = \mathbf{1}$

Ratio of longitudinal reinforcement: $\rho_w = A_{sx.bot.prov} / (L_y \times d_v) = \mathbf{0.00275}$

Shear strength reduction factor: $\phi_v = \mathbf{0.75}$

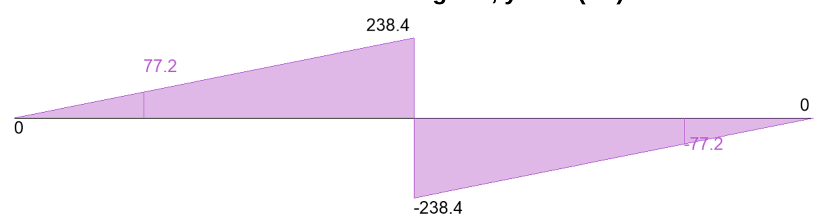
Nominal shear capacity (Eq. 22.5.5.1): $V_n = \min(0.66 \times \lambda_s \times \lambda \times (\rho_w)^{1/3} \times \sqrt{(f'_c \times 1 \text{ MPa})} \times L_y \times d_v, 0.42 \times \lambda \times \sqrt{(f'_c \times 1 \text{ MPa})} \times L_y \times d_v) = \mathbf{139.3}$ kN

Design shear capacity: $\phi V_n = \phi_v \times V_n = \mathbf{104.5}$ kN

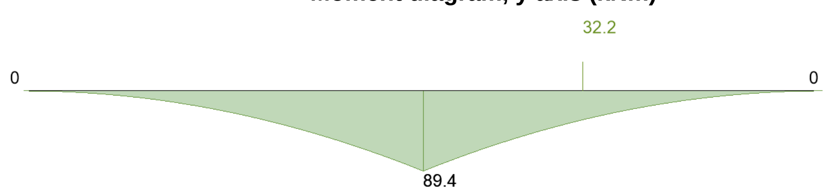
$V_{u.x} / \phi V_n = \mathbf{0.739}$

PASS - Design shear capacity exceeds ultimate shear load

Shear diagram, y axis (kN)



Moment diagram, y axis (kNm)



Moment design, y direction, positive moment

Ultimate bending moment: $M_{u.y.max} = \mathbf{32.2}$ kNm

Tension reinforcement provided: 12 x 12mm bottom bars (121 c/c)

Area of tension reinforcement provided: $A_{sy.bot.prov} = \mathbf{1357}$ mm^2

Minimum area of reinforcement (8.6.1.1): $A_{s.min} = 0.0018 \times L_x \times h = \mathbf{810}$ mm^2

PASS - Area of reinforcement provided exceeds minimum

Maximum spacing of reinforcement (8.7.2.2): $s_{max} = \min(2 \times h, 457 \text{ mm}) = \mathbf{457}$ mm

PASS - Maximum permissible reinforcement spacing exceeds actual spacing

Depth to tension reinforcement $d = h - c_{nom\_b} - \phi_{x.bot} - \phi_{y.bot} / 2 =$ **207** mm

Depth of compression block $a = A_{sy.bot.prov} \times f_y / (0.85 \times f'_c \times L_x) =$ **21** mm

Neutral axis factor $\beta_1 =$ **0.85**

Depth to neutral axis $c = a / \beta_1 =$ **25** mm

Strain in tensile reinforcement $\varepsilon_t = 0.003 \times d / c - 0.003 =$ **0.02179**

Minimum tensile strain(8.3.3.1) $\varepsilon_{min} = \varepsilon_{ty} + 0.003 =$ **0.00500**

PASS - Tensile strain exceeds minimum required

Nominal moment capacity $M_n = A_{sy.bot.prov} \times f_y \times (d - a / 2) =$ **111.9** kNm

Flexural strength reduction factor $\phi_f = \min(\max(0.65 + 0.25 \times (\varepsilon_t - \varepsilon_{ty}) / (0.003), 0.65), 0.9) =$ **0.900**

Design moment capacity $\phi M_n = \phi_f \times M_n =$ **100.7** kNm

$M_{u.y.max} / \phi M_n =$ **0.319**

PASS - Design moment capacity exceeds ultimate moment load

One-way shear design, y direction

Ultimate shear force $V_{u.y} =$ **77.2** kN

Depth to reinforcement $d_v = h - c_{nom\_b} - \phi_{x.bot} - \phi_{y.bot} / 2 =$ **207** mm

Size effect factor (22.5.5.1.3) $\lambda_s =$ **1**

Ratio of longitudinal reinforcement $\rho_w = A_{sy.bot.prov} / (L_x \times d_v) =$ **0.00437**

Shear strength reduction factor $\phi_v =$ **0.75**

Nominal shear capacity (Eq. 22.5.5.1) $V_n = \min(0.66 \times \lambda_s \times \lambda \times (\rho_w)^{1/3} \times \sqrt{(f'_c \times 1\text{ MPa})} \times L_x \times d_v, 0.42 \times \lambda \times \sqrt{(f'_c \times 1\text{ MPa})} \times L_x \times d_v) =$ **153.5** kN

Design shear capacity $\phi V_n = \phi_v \times V_n =$ **115.2** kN

$V_{u.y} / \phi V_n =$ **0.671**

PASS - Design shear capacity exceeds ultimate shear load

Two-way shear design at column 1

Depth to reinforcement $d_{v2} =$ **213** mm

Shear perimeter length (22.6.4) $l_{xp} =$ **813** mm

Shear perimeter width (22.6.4) $l_{yp} =$ **813** mm

Shear perimeter (22.6.4) $b_o = 2 \times (l_{x,ped1} + d_{v2}) + 2 \times (l_{y,ped1} + d_{v2}) =$ **3252** mm

Shear area $A_p = l_{x,perim} \times l_{y,perim} =$ **660969** mm²

Surcharge loaded area $A_{sur} = A_p - l_{x,ped1} \times l_{y,ped1} =$ **300969** mm²

Ultimate bearing pressure at center of shear area $q_{up.avg} =$ **238.9** kN/m²

Ultimate shear load $F_{up} = \gamma_D \times (F_{Dz1} + F_{SWz1} - l_{x,ped1} \times l_{y,ped1} \times h_{soil} \times \gamma_{soil}) + \gamma_L \times F_{Lz1} + \gamma_D \times A_p \times F_{swt} + \gamma_D \times A_{sur} \times F_{soil} + \gamma_D \times A_{sur} \times F_{Dsur} + \gamma_L \times A_{sur} \times F_{Lsur} - q_{up.avg} \times A_p =$ **330.1** kN

Ultimate shear stress from vertical load $v_{ug} = \max(F_{up} / (b_o \times d_{v2}), 0\text{ N/mm}^2) =$ **0.477** N/mm²

Column geometry factor (Table 22.6.5.2) $\beta = l_{y,ped1} / l_{x,ped1} =$ **1.00**

Column location factor (22.6.5.3) $\alpha_s =$ **40**

Size effect factor (22.5.5.1.3) $\lambda_s =$ **1**

Concrete shear strength (22.6.5.2) $v_{cpa} = 0.17 \times (1 + 2 / \beta) \times \lambda_s \times \lambda \times \sqrt{(f'_c \times 1\text{ MPa})} =$ **2.337** N/mm²

$v_{cpb} = 0.083 \times (\alpha_s \times d_{v2} / b_o + 2) \times \lambda_s \times \lambda \times \sqrt{(f'_c \times 1\text{ MPa})} =$ **1.757** N/mm²

$v_{cpc} = 0.33 \times \lambda_s \times \lambda \times \sqrt{(f'_c \times 1\text{ MPa})} =$ **1.512** N/mm²

$v_{cp} = \min(v_{cpa}, v_{cpb}, v_{cpc}) =$ **1.512** N/mm²

Shear strength reduction factor $\phi_v =$ **0.75**

Nominal shear stress capacity (Eq. 22.6.1.2) $v_n = v_{cp} = \mathbf{1.512}$ N/mm^2

Design shear stress capacity (8.5.1.1(d)) $\phi v_n = \phi_v \times v_n = \mathbf{1.134}$ N/mm^2

$v_{ug} / \phi v_n = \mathbf{0.420}$

PASS - Design shear stress capacity exceeds ultimate shear stress load