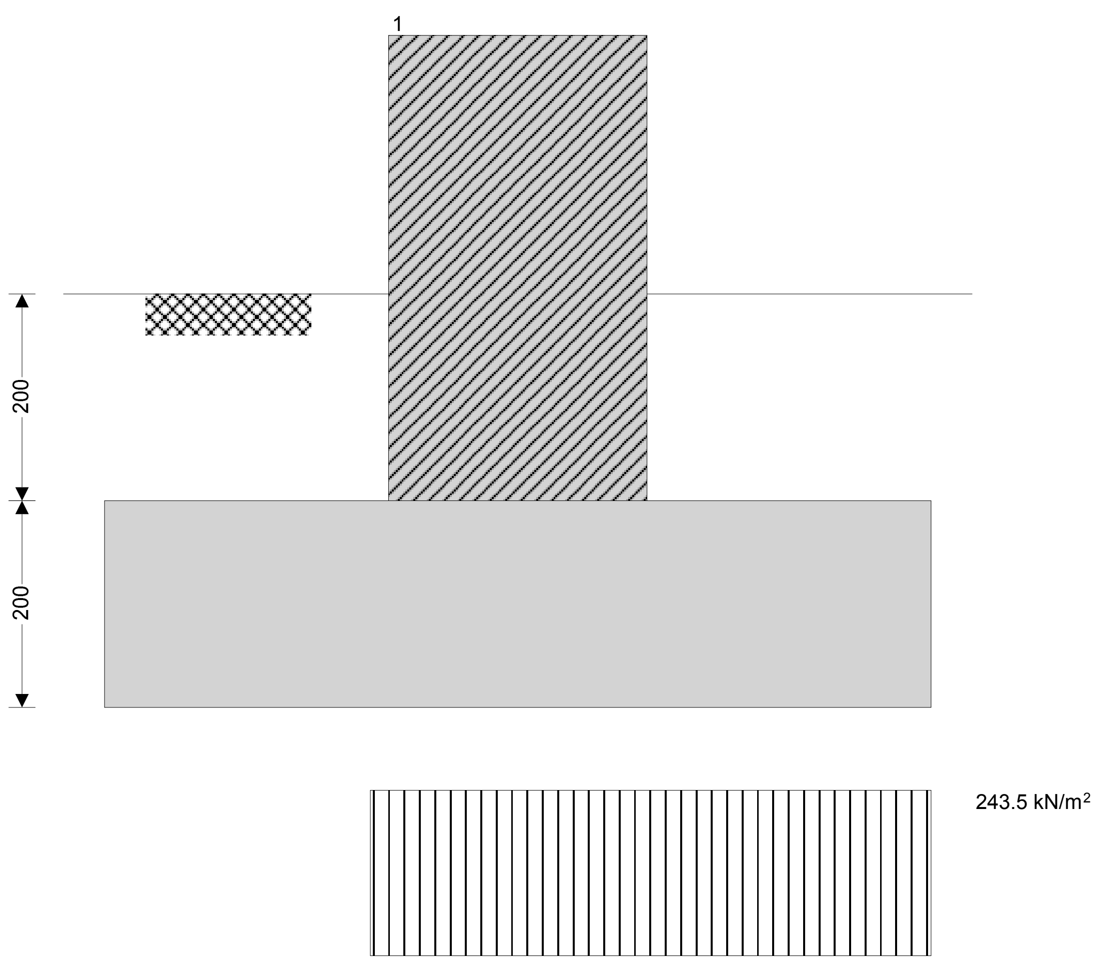
FOUNDATION ANALYSIS (EN1997-1:2004)

In accordance with EN1997-1:2004 incorporating Corrigendum dated February 2009 and the recommended values

Strip foundation details - considering a one metre strip

Length of foundation;	L_x = **1000** mm
Width of foundation;	L_y = **800** mm
Foundation area;	$A = L_x \times L_y$ = **0.800** m^2
Depth of foundation;	h = **200** mm
Depth of soil over foundation;	h_{soil} = **200** mm
Level of water;	h_{water} = **0** mm
Density of water;	γ_{water} = **9.8** kN/m^3
Density of concrete;	γ_{conc} = **24.5** kN/m^3



Wall no.1 details

Width of wall; l_{y1} = **250** mm

position in y-axis; y_1 = **400** mm

Soil properties

Density of soil; γ_{soil} = **20.0** kN/m^3

Characteristic cohesion; c'_k = **17** kN/m^2

Characteristic effective shear resistance angle; ϕ'_k = **25** deg

Characteristic friction angle; δ_k = **19.3** deg

Foundation loads

Self weight; $F_{swt} = h \times \gamma_{conc}$ = **4.9** kN/m^2

Soil weight; $F_{soil} = h_{soil} \times \gamma_{soil}$ = **4.0** kN/m^2

Wall no.1 loads per linear metre

Permanent load in y; F_{Gy1} = **10.0** kN

Permanent load in z; F_{Gz1} = **60.0** kN

Variable load in z; F_{Qz1} = **50.0** kN

Permanent moment in y; M_{Gy1} = **15.0** kNm

Partial factors on actions - Combination1

Permanent unfavourable action - Table A.3; γ_G = **1.35**

Permanent favourable action - Table A.3; γ_{Gf} = **1.00**

Variable unfavourable action - Table A.3; γ_Q = **1.50**

Variable favourable action - Table A.3; γ_{Qf} = **0.00**

Partial factors for soil parameters - Combination1

Angle of shearing resistance - Table A.4; $\gamma_{\phi'}$ = **1.00**

Effective cohesion - Table A.4; $\gamma_{c'}$ = **1.00**

Weight density - Table A.4; γ_γ = **1.00**

Partial factors for spread foundations - Combination1

Bearing - Table A.5; $\gamma_{R.v}$ = **1.00**

Sliding - Table A.5; $\gamma_{R.h}$ = **1.00**

Bearing resistance (Section 6.5.2)

Forces on foundation per linear metre

Force in y-axis; $F_{dy} = \gamma_G \times F_{Gy1}$ = **13.5** kN

Force in z-axis; $F_{dz} = \gamma_G \times (A \times (F_{swt} + F_{soil}) + F_{Gz1}) + \gamma_Q \times F_{Qz1}$ = **165.6** kN

Moments on foundation per linear metre

Moment in y-axis; $M_{dy} = \gamma_G \times (A \times (F_{swt} + F_{soil}) \times L_y / 2 + F_{Gz1} \times y_1) + \gamma_G \times M_{Gy1} + \gamma_Q \times F_{Qz1} \times y_1 + (\gamma_G \times F_{Gy1}) \times h$ = **89.2** kNm

Eccentricity of base reaction

Eccentricity of base reaction in y-axis; $e_y = M_{dy} / F_{dz} - L_y / 2$ = **139** mm

Effective area of base per linear metre

Effective width; $L'_y = L_y - 2 \times e_y = \underline{523}$ mm

Effective length; $L'_x = \underline{1000}$ mm

Effective area; $A' = L'_x \times L'_y = \underline{0.523}$ m^2

Pad base pressure

Design base pressure; $f_{dz} = F_{dz} / A' = \underline{316.8}$ kN/m^2

Net ultimate bearing capacity under drained conditions (Annex D.4)

Design angle of shearing resistance; $\phi'_d = atan(tan(\phi'_k) / \gamma_{\phi'}) = \underline{25.000}$ deg

Design effective cohesion; $c'_d = c'_k / \gamma_{c'} = \underline{17.000}$ kN/m^2

Effective overburden pressure; $q = (h + h_{soil}) \times \gamma_{soil} - h_{water} \times \gamma_{water} = \underline{8.000}$ kN/m^2

Design effective overburden pressure; $q' = q / \gamma_{\gamma} = \underline{8.000}$ kN/m^2

Bearing resistance factors; $N_q = Exp(\pi \times tan(\phi'_d)) \times (tan(45 \text{ deg} + \phi'_d / 2))^2 = \underline{10.662}$

$N_c = (N_q - 1) \times cot(\phi'_d) = \underline{20.721}$

$N_{\gamma} = 2 \times (N_q - 1) \times tan(\phi'_d) = \underline{9.011}$

Foundation shape factors; $s_q = \underline{1.000}$

$s_{\gamma} = \underline{1.000}$

$s_c = \underline{1.000}$

Load inclination factors; $H = abs(F_{dy}) = \underline{13.5}$ kN

$m_y = [2 + (L'_y / L'_x)] / [1 + (L'_y / L'_x)] = \underline{1.657}$

$m_x = [2 + (L'_x / L'_y)] / [1 + (L'_x / L'_y)] = \underline{1.343}$

$m = m_y = \underline{1.657}$

$i_q = [1 - H / (F_{dz} + A' \times c'_d \times cot(\phi'_d))]^m = \underline{0.882}$

$i_{\gamma} = [1 - H / (F_{dz} + A' \times c'_d \times cot(\phi'_d))]^{m + 1} = \underline{0.817}$

$i_c = i_q - (1 - i_q) / (N_c \times tan(\phi'_d)) = \underline{0.870}$

Net ultimate bearing capacity; $n_f = c'_d \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_{soil} \times L'_y \times N_{\gamma} \times s_{\gamma} \times i_{\gamma} = \underline{420.0}$ kN/m^2

PASS - Net ultimate bearing capacity exceeds design base pressure

Sliding resistance (Section 6.5.3)

Forces on foundation per linear metre

Force in y-axis; $F_{dy} = \gamma_G \times F_{Gy1} = \underline{13.5}$ kN

Force in z-axis; $F_{dz} = \gamma_{Gf} \times (A \times (F_{swt} + F_{soil}) + F_{Gz1}) + \gamma_{Qf} \times F_{Qz1} = \underline{67.1}$ kN

Sliding resistance verification per linear metre (Section 6.5.3)

Horizontal force on foundation; $H = abs(F_{dy}) = \underline{13.5}$ kN

Sliding resistance (exp.6.3b); $R_{H.d} = F_{dz} \times tan(\delta_k) / \gamma_{R.h} = \underline{23.5}$ kN

PASS - Foundation is not subject to failure by sliding

Partial factors on actions - Combination2

Permanent unfavourable action - Table A.3; $\gamma_G = \underline{1.00}$

Permanent favourable action - Table A.3; $\gamma_{Gf} = \underline{1.00}$

Variable unfavourable action - Table A.3; γ_Q = **1.30**

Variable favourable action - Table A.3; γ_{Qf} = **0.00**

Partial factors for soil parameters - Combination2

Angle of shearing resistance - Table A.4; $\gamma_{\phi'}$ = **1.25**

Effective cohesion - Table A.4; $\gamma_{c'}$ = **1.25**

Weight density - Table A.4; γ_γ = **1.00**

Partial factors for spread foundations - Combination2

Bearing - Table A.5; $\gamma_{R.v}$ = **1.00**

Sliding - Table A.5; $\gamma_{R.h}$ = **1.00**

Bearing resistance (Section 6.5.2)

Forces on foundation per linear metre

Force in y-axis; $F_{dy} = \gamma_G \times F_{Gy1}$ = **10.0** kN

Force in z-axis; $F_{dz} = \gamma_G \times (A \times (F_{swt} + F_{soil}) + F_{Gz1}) + \gamma_Q \times F_{Qz1}$ = **132.1** kN

Moments on foundation per linear metre

Moment in y-axis; $M_{dy} = \gamma_G \times (A \times (F_{swt} + F_{soil}) \times L_y / 2 + F_{Gz1} \times y_1) + \gamma_G \times M_{Gy1} + \gamma_Q \times F_{Qz1} \times y_1 + (\gamma_G \times F_{Gy1}) \times h$ = **69.8** kNm

Eccentricity of base reaction

Eccentricity of base reaction in y-axis; $e_y = M_{dy} / F_{dz} - L_y / 2$ = **129** mm

Effective area of base per linear metre

Effective width; $L'_y = L_y - 2 \times e_y$ = **543** mm

Effective length; L'_x = **1000** mm

Effective area; $A' = L'_x \times L'_y$ = **0.543** m^2

Pad base pressure

Design base pressure; $f_{dz} = F_{dz} / A'$ = **243.5** kN/m^2

Net ultimate bearing capacity under drained conditions (Annex D.4)

Design angle of shearing resistance; $\phi'_d = atan(tan(\phi'_k) / \gamma_{\phi'})$ = **20.458** deg

Design effective cohesion; $c'_d = c'_k / \gamma_{c'}$ = **13.600** kN/m^2

Effective overburden pressure; $q = (h + h_{soil}) \times \gamma_{soil} - h_{water} \times \gamma_{water}$ = **8.000** kN/m^2

Design effective overburden pressure; $q' = q / \gamma_\gamma$ = **8.000** kN/m^2

Bearing resistance factors; $N_q = Exp(\pi \times tan(\phi'_d)) \times (tan(45 deg + \phi'_d / 2))^2$ = **6.698**

$N_c = (N_q - 1) \times cot(\phi'_d)$ = **15.273**

$N_\gamma = 2 \times (N_q - 1) \times tan(\phi'_d)$ = **4.251**

Foundation shape factors; s_q = **1.000**

s_γ = **1.000**

s_c = **1.000**

Load inclination factors; $H = abs(F_{dy})$ = **10.0** kN

$m_y = [2 + (L'_y / L'_x)] / [1 + (L'_y / L'_x)]$ = **1.648**

$m_x = [2 + (L'_x / L'_y)] / [1 + (L'_x / L'_y)] = \underline{\mathbf{1.352}}$

$m = m_y = \underline{\mathbf{1.648}}$

$i_q = [1 - H / (F_{dz} + A' \times c'_d \times \cot(\phi'_d))]^m = \underline{\mathbf{0.894}}$

$i_\gamma = [1 - H / (F_{dz} + A' \times c'_d \times \cot(\phi'_d))]^{m+1} = \underline{\mathbf{0.835}}$

$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_d)) = \underline{\mathbf{0.875}}$

Net ultimate bearing capacity; $n_f = c'_d \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_{soil} \times L'_y \times N_\gamma \times s_\gamma \times i_\gamma = \underline{\mathbf{248.9}}$ kN/m^2

PASS - Net ultimate bearing capacity exceeds design base pressure

Sliding resistance (Section 6.5.3)

Forces on foundation per linear metre

Force in y-axis; $F_{dy} = \gamma_G \times F_{Gy1} = \underline{\mathbf{10.0}}$ kN

Force in z-axis; $F_{dz} = \gamma_{Gf} \times (A \times (F_{swt} + F_{soil}) + F_{Gz1}) + \gamma_{Qf} \times F_{Qz1} = \underline{\mathbf{67.1}}$ kN

Sliding resistance verification per linear metre (Section 6.5.3)

Horizontal force on foundation; $H = abs(F_{dy}) = \underline{\mathbf{10.0}}$ kN

Sliding resistance (exp.6.3b); $R_{H.d} = F_{dz} \times \tan(\delta_k) / \gamma_{R.h} = \underline{\mathbf{23.5}}$ kN

PASS - Foundation is not subject to failure by sliding

FOUNDATION DESIGN (EN1992-1-1:2004)

In accordance with EN1992-1-1:2004 incorporating Corrigendum dated January 2008 and the recommended values

Concrete details (Table 3.1 - Strength and deformation characteristics for concrete)

Concrete strength class; C40/50

Characteristic compressive cylinder strength; $f_{ck} = \underline{\mathbf{40}}$ N/mm^2

Characteristic compressive cube strength; $f_{ck,cube} = \underline{\mathbf{50}}$ N/mm^2

Mean value of compressive cylinder strength; $f_{cm} = f_{ck} + 8$ N/mm^2 $= \underline{\mathbf{48}}$ N/mm^2

Mean value of axial tensile strength; $f_{ctm} = 0.3$ N/mm^2 $\times (f_{ck}/ 1$ N/mm$^2)^{2/3} = \underline{\mathbf{3.5}}$ N/mm^2

5% fractile of axial tensile strength; $f_{ctk,0.05} = 0.7 \times f_{ctm} = \underline{\mathbf{2.5}}$ N/mm^2

Secant modulus of elasticity of concrete; $E_{cm} = 22$ kN/mm^2 $\times [f_{cm}/10$ N/mm$^2]^{0.3} = \underline{\mathbf{35220}}$ N/mm^2

Partial factor for concrete (Table 2.1N); $\gamma_C = \underline{\mathbf{1.50}}$

Compressive strength coefficient (cl.3.1.6(1)); $\alpha_{cc} = \underline{\mathbf{1.00}}$

Design compressive concrete strength (exp.3.15); $f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C = \underline{\mathbf{26.7}}$ N/mm^2

Tens.strength coeff.for plain concrete (cl.12.3.1(1)); $\alpha_{ct,pl} = \underline{\mathbf{0.80}}$

Des.tens.strength for plain concrete (exp.12.1); $f_{ctd,pl} = \alpha_{ct,pl} \times f_{ctk,0.05} / \gamma_C = \underline{\mathbf{1.3}}$ N/mm^2

Maximum aggregate size; $h_{agg} = \underline{\mathbf{20}}$ mm

Reinforcement details

Characteristic yield strength of reinforcement; $f_{yk} = \underline{\mathbf{500}}$ N/mm^2

Modulus of elasticity of reinforcement; $E_s = \underline{\mathbf{210000}}$ N/mm^2

Partial factor for reinforcing steel (Table 2.1N); $\gamma_S = \underline{\mathbf{1.15}}$

Design yield strength of reinforcement; $f_{yd} = f_{yk} / \gamma_S = \underline{\mathbf{435}}$ N/mm^2

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

Rectangular section in flexure (Section 6.1)

Design bending moment; $M_{Ed.y.max}$ = **11.5** kNm

Depth to tension reinforcement; $d = h - c_{nom} - \phi_{y.bot} / 2$ = **165** mm

$K = M_{Ed.y.max} / (L_x \times d^2 \times f_{ck})$ = **0.011**

K' = **0.207**

K' > K - No compression reinforcement is required

Lever arm; $z = \min((d / 2) \times [1 + (1 - 3.53 \times K)^{0.5}], 0.95 \times d)$ =
157 mm

Depth of neutral axis; $x = 2.5 \times (d - z)$ = **21** mm

Area of tension reinforcement required; $A_{sy.bot.req} = M_{Ed.y.max} / (f_{yd} \times z)$ = **169** mm^2

Tension reinforcement provided; 10 dia.bars at 250 c/c bottom

Area of tension reinforcement provided; $A_{sy.bot.prov}$ = **314** mm^2

Minimum area of reinforcement (exp.9.1N); $A_{s.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times L_x \times d$ = **301**
mm^2

Maximum area of reinforcement (cl.9.2.1.1(3)); $A_{s.max} = 0.04 \times L_x \times d$ = **6600** mm^2

PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control (Section 7.3)

Limiting crack width; w_{max} = **0.3** mm

Variable load factor (EN1990 – Table A1.1); ψ_2 = **0.3**

Serviceability bending moment; $M_{sls.y.max}$ = **7.7** kNm

Tensile stress in reinforcement; $\sigma_s = M_{sls.y.max} / (A_{sy.bot.prov} \times z)$ = **156.5** N/mm^2

Load duration factor; k_t = **0.4**

Effective depth of concrete in tension; $h_{c.ef} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$ = **60** mm

Effective area of concrete in tension; $A_{c.eff} = h_{c.ef} \times L_x$ = **59792** mm^2

Mean value of concrete tensile strength; $f_{ct.eff} = f_{ctm}$ = **3.5** N/mm^2

Reinforcement ratio; $\rho_{p.eff} = A_{sy.bot.prov} / A_{c.eff}$ = **0.005**

Modular ratio; $\alpha_e = E_s / E_{cm}$ = **5.962**

Bond property coefficient; k_1 = **0.8**

Strain distribution coefficient; k_2 = **0.5**

k_3 = **3.4**

k_4 = **0.425**

Maximum crack spacing (exp.7.11); $s_{r.max} = k_3 \times c_{nom} + k_1 \times k_2 \times k_4 \times \phi_{y.bot} / \rho_{p.eff}$ = **426**
mm

Maximum crack width (exp.7.8); $w_k = s_{r.max} \times \max([\sigma_s – k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff})] / E_s,$
$0.6 \times \sigma_s / E_s)$ = **0.19** mm

PASS - Maximum crack width is less than limiting crack width**Rectangular section in shear (Section 6.2)**

Design shear force; $\text{abs}(V_{Ed.y.min})$ = **1.6** kN

$C_{Rd,c} = 0.18 / \gamma_C$ = **0.120**

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$k = \min(1 + \sqrt{(200\text{ mm} / d)}, 2) = \underline{\mathbf{2.000}}$

Longitudinal reinforcement ratio; $\rho_l = \min(A_{sy.bot.prov} / (L_x \times d), 0.02) = \underline{\mathbf{0.002}}$

$v_{min} = 0.035\text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = \underline{\mathbf{0.626}}\text{ N/mm}^2$

Design shear resistance (exp.6.2a & 6.2b); $V_{Rd.c} = \max(C_{Rd.c} \times k \times (100\text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times L_x \times d$

$V_{Rd.c} = \underline{\mathbf{100.2}}\text{ kN}$

PASS - Design shear resistance exceeds design shear force