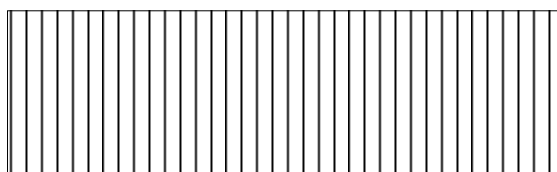
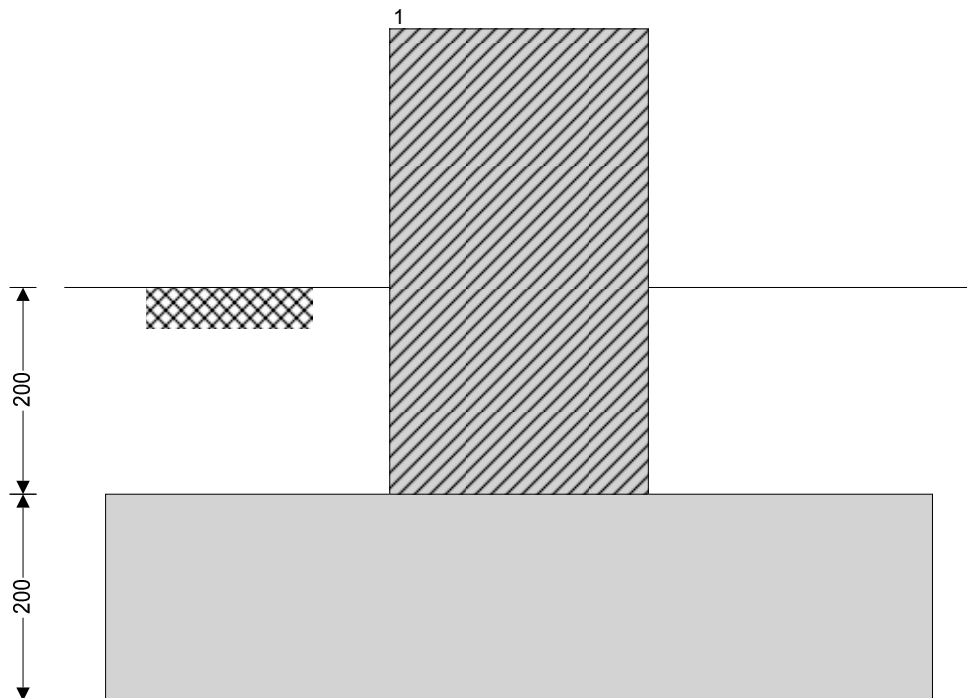
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FOUNDATION ANALYSIS (EN1997-1:2004)

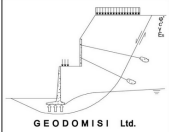
In accordance with EN1997-1:2004 incorporating Corrigendum dated February 2009 and the recommended values

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;	$\gamma_{water} = 9.8$ kN/m ³
Density of concrete;	$\gamma_{conc} = 24.5$ kN/m ³



243.5 kN/m²

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Wall no.1 details

Width of wall; $l_{y1} = \underline{250}$ mm
position in y-axis; $y_1 = \underline{400}$ mm

Soil properties

Density of soil; $\gamma_{soil} = \underline{20.0}$ kN/m³
Characteristic cohesion; $c'_k = \underline{17}$ kN/m²
Characteristic effective shear resistance angle; $\phi'_k = \underline{25}$ deg
Characteristic friction angle; $\delta_k = \underline{19.3}$ deg

Foundation loads

Self weight; $F_{swt} = h \times \gamma_{conc} = \underline{4.9}$ kN/m²
Soil weight; $F_{soil} = h_{soil} \times \gamma_{soil} = \underline{4.0}$ kN/m²

Wall no.1 loads per linear metre

Permanent load in y; $F_{Gy1} = \underline{10.0}$ kN
Permanent load in z; $F_{Gz1} = \underline{60.0}$ kN
Variable load in z; $F_{Qz1} = \underline{50.0}$ kN
Permanent moment in y; $M_{Gy1} = \underline{15.0}$ kNm

Partial factors on actions - Combination1

Permanent unfavourable action - Table A.3; $\gamma_G = \underline{1.35}$
Permanent favourable action - Table A.3; $\gamma_{Gf} = \underline{1.00}$
Variable unfavourable action - Table A.3; $\gamma_Q = \underline{1.50}$
Variable favourable action - Table A.3; $\gamma_{Qf} = \underline{0.00}$

Partial factors for soil parameters - Combination1

Angle of shearing resistance - Table A.4; $\gamma_{\phi'} = \underline{1.00}$
Effective cohesion - Table A.4; $\gamma_{c'} = \underline{1.00}$
Weight density - Table A.4; $\gamma_{\gamma} = \underline{1.00}$

Partial factors for spread foundations - Combination1

Bearing - Table A.5; $\gamma_{R,v} = \underline{1.00}$
Sliding - Table A.5; $\gamma_{R,h} = \underline{1.00}$

Bearing resistance (Section 6.5.2)

Forces on foundation per linear metre

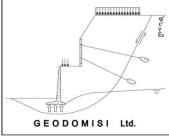
Force in y-axis; $F_{dy} = \gamma_G \times F_{Gy1} = \underline{13.5}$ kN
Force in z-axis; $F_{dz} = \gamma_G \times (A \times (F_{swt} + F_{soil}) + F_{Gz1}) + \gamma_Q \times F_{Qz1} = \underline{165.6}$ kN

Moments on foundation per linear metre

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

Eccentricity of base reaction

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

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Effective area of base per linear metre

Effective width; $L'_y = L_y - 2 \times e_y = \underline{523 \text{ mm}}$
Effective length; $L'_x = \underline{1000 \text{ mm}}$
Effective area; $A' = L'_x \times L'_y = \underline{0.523 \text{ m}^2}$

Pad base pressure

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

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

Design angle of shearing resistance; $\phi'_d = \text{atan}(\tan(\phi'_k) / \gamma_{\phi'}) = \underline{25.000 \text{ deg}}$
Design effective cohesion; $c'_d = c'_k / \gamma_{c'} = \underline{17.000 \text{ kN/m}^2}$
Effective overburden pressure; $q = (h + h_{\text{soil}}) \times \gamma_{\text{soil}} - h_{\text{water}} \times \gamma_{\text{water}} = \underline{8.000 \text{ kN/m}^2}$
Design effective overburden pressure; $q' = q / \gamma_{\gamma} = \underline{8.000 \text{ kN/m}^2}$
Bearing resistance factors;
 $N_q = \text{Exp}(\pi \times \tan(\phi'_d)) \times (\tan(45 \text{ deg} + \phi'_d / 2))^2 = \underline{10.662}$
 $N_c = (N_q - 1) \times \cot(\phi'_d) = \underline{20.721}$
 $N_{\gamma} = 2 \times (N_q - 1) \times \tan(\phi'_d) = \underline{9.011}$
Foundation shape factors;
 $s_q = \underline{1.000}$
 $s_{\gamma} = \underline{1.000}$
 $s_c = \underline{1.000}$
Load inclination factors;
 $H = \text{abs}(F_{dy}) = \underline{13.5 \text{ kN}}$
 $m_y = [2 + (L'_y / L'_x)] / [1 + (L'_y / L'_x)] = \underline{1.657}$
 $m_x = [2 + (L'_x / L'_y)] / [1 + (L'_x / L'_y)] = \underline{1.343}$
 $m = m_y = \underline{1.657}$
 $i_q = [1 - H / (F_{dz} + A' \times c'_d \times \cot(\phi'_d))]^m = \underline{0.882}$
 $i_{\gamma} = [1 - H / (F_{dz} + A' \times c'_d \times \cot(\phi'_d))]^{m+1} = \underline{0.817}$
 $i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_d)) = \underline{0.870}$
Net ultimate bearing capacity;
 $n_f = c'_d \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_{\text{soil}} \times L'_y \times N_{\gamma} \times s_{\gamma} \times i_{\gamma} = \underline{420.0 \text{ kN/m}^2}$

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; $F_{dy} = \gamma_G \times F_{Gy1} = \underline{13.5 \text{ kN}}$
Force in z-axis; $F_{dz} = \gamma_{Gf} \times (A \times (F_{\text{swt}} + F_{\text{soil}}) + F_{Gz1}) + \gamma_{Qf} \times F_{Qz1} = \underline{67.1 \text{ kN}}$

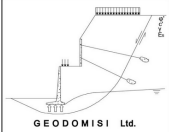
Sliding resistance verification per linear metre (Section 6.5.3)

Horizontal force on foundation; $H = \text{abs}(F_{dy}) = \underline{13.5 \text{ kN}}$
Sliding resistance (exp.6.3b); $R_{H,d} = F_{dz} \times \tan(\delta_k) / \gamma_{R,h} = \underline{23.5 \text{ kN}}$

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; $\gamma_{Gf} = \underline{1.00}$

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Variable unfavourable action - Table A.3;

$$\gamma_Q = \underline{1.30}$$

Variable favourable action - Table A.3;

$$\gamma_{Qf} = \underline{0.00}$$

Partial factors for soil parameters - Combination2

Angle of shearing resistance - Table A.4;

$$\gamma_{\phi'} = \underline{1.25}$$

Effective cohesion - Table A.4;

$$\gamma_{c'} = \underline{1.25}$$

Weight density - Table A.4;

$$\gamma_{\gamma} = \underline{1.00}$$

Partial factors for spread foundations - Combination2

Bearing - Table A.5;

$$\gamma_{R.v} = \underline{1.00}$$

Sliding - Table A.5;

$$\gamma_{R.h} = \underline{1.00}$$

Bearing resistance (Section 6.5.2)

Forces on foundation per linear metre

Force in y-axis;

$$F_{dy} = \gamma_G \times F_{Gy1} = \underline{10.0} \text{ kN}$$

Force in z-axis;

$$F_{dz} = \gamma_G \times (A \times (F_{swt} + F_{soil}) + F_{Gz1}) + \gamma_Q \times F_{Qz1} = \underline{132.1} \text{ kN}$$

Moments on foundation per linear metre

Moment in y-axis;

$$M_{dy} = \gamma_G \times (A \times (F_{swt} + F_{soil}) \times L_y / 2 + F_{Gz1} \times y_1) + \gamma_G \times M_{Gy1} + \gamma_Q \times F_{Qz1} \times y_1 + (\gamma_G \times F_{Gy1}) \times h = \underline{69.8} \text{ kNm}$$

Eccentricity of base reaction

Eccentricity of base reaction in y-axis;

$$e_y = M_{dy} / F_{dz} - L_y / 2 = \underline{129} \text{ mm}$$

Effective area of base per linear metre

Effective width;

$$L'_y = L_y - 2 \times e_y = \underline{543} \text{ mm}$$

Effective length;

$$L'_x = \underline{1000} \text{ mm}$$

Effective area;

$$A' = L'_x \times L'_y = \underline{0.543} \text{ m}^2$$

Pad base pressure

Design base pressure;

$$f_{dz} = F_{dz} / A' = \underline{243.5} \text{ kN/m}^2$$

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

Design angle of shearing resistance;

$$\phi'_d = \text{atan}(\tan(\phi'_k) / \gamma_{\phi'}) = \underline{20.458} \text{ deg}$$

Design effective cohesion;

$$c'_d = c'_k / \gamma_{c'} = \underline{13.600} \text{ kN/m}^2$$

Effective overburden pressure;

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

Design effective overburden pressure;

$$q' = q / \gamma_{\gamma} = \underline{8.000} \text{ kN/m}^2$$

Bearing resistance factors;

$$N_q = \text{Exp}(\pi \times \tan(\phi'_d)) \times (\tan(45 \text{ deg} + \phi'_d / 2))^2 = \underline{6.698}$$

$$N_c = (N_q - 1) \times \cot(\phi'_d) = \underline{15.273}$$

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

Foundation shape factors;

$$S_q = \underline{1.000}$$

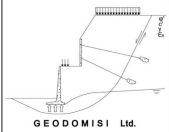
$$S_{\gamma} = \underline{1.000}$$

$$S_c = \underline{1.000}$$

Load inclination factors;

$$H = \text{abs}(F_{dy}) = \underline{10.0} \text{ kN}$$

$$m_y = [2 + (L'_y / L'_x)] / [1 + (L'_y / L'_x)] = \underline{1.648}$$

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

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

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

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

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

Net ultimate bearing capacity;

$$n_r = c'_d \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_{soil} \times$$

$$L'_y \times N_\gamma \times s_\gamma \times i_\gamma = \mathbf{248.9 \text{ kN/m}^2}$$

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;

$$F_{dy} = \gamma_G \times F_{Gy1} = \mathbf{10.0 \text{ kN}}$$

Force in z-axis;

$$F_{dz} = \gamma_{Gf} \times (A \times (F_{swt} + F_{soil}) + F_{Gz1}) + \gamma_{Qf} \times F_{Qz1} = \mathbf{67.1 \text{ kN}}$$

Sliding resistance verification per linear metre (Section 6.5.3)

Horizontal force on foundation;

$$H = \text{abs}(F_{dy}) = \mathbf{10.0 \text{ kN}}$$

Sliding resistance (exp.6.3b);

$$R_{H,d} = F_{dz} \times \tan(\delta_k) / \gamma_{R,h} = \mathbf{23.5 \text{ kN}}$$

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;

$$f_{ck} = \mathbf{40 \text{ N/mm}^2}$$

Characteristic compressive cube strength;

$$f_{ck,cube} = \mathbf{50 \text{ N/mm}^2}$$

Mean value of compressive cylinder strength;

$$f_{cm} = f_{ck} + 8 \text{ N/mm}^2 = \mathbf{48 \text{ N/mm}^2}$$

Mean value of axial tensile strength;

$$f_{ctm} = 0.3 \text{ N/mm}^2 \times (f_{ck} / 1 \text{ N/mm}^2)^{2/3} = \mathbf{3.5 \text{ N/mm}^2}$$

5% fractile of axial tensile strength;

$$f_{ctk,0.05} = 0.7 \times f_{ctm} = \mathbf{2.5 \text{ N/mm}^2}$$

Secant modulus of elasticity of concrete;

$$E_{cm} = 22 \text{ kN/mm}^2 \times [f_{cm} / 10 \text{ N/mm}^2]^{0.3} = \mathbf{35220 \text{ N/mm}^2}$$

Partial factor for concrete (Table 2.1N);

$$\gamma_C = \mathbf{1.50}$$

Compressive strength coefficient (cl.3.1.6(1));

$$\alpha_{cc} = \mathbf{1.00}$$

Design compressive concrete strength (exp.3.15);

$$f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C = \mathbf{26.7 \text{ N/mm}^2}$$

Tens.strength coeff.for plain concrete (cl.12.3.1(1));

$$\alpha_{ct,pl} = \mathbf{0.80}$$

Des.tens.strength for plain concrete (exp.12.1);

$$f_{ctd,pl} = \alpha_{ct,pl} \times f_{ctk,0.05} / \gamma_C = \mathbf{1.3 \text{ N/mm}^2}$$

Maximum aggregate size;

$$h_{agg} = \mathbf{20 \text{ mm}}$$

Reinforcement details

Characteristic yield strength of reinforcement;

$$f_{yk} = \mathbf{500 \text{ N/mm}^2}$$

Modulus of elasticity of reinforcement;

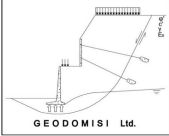
$$E_s = \mathbf{210000 \text{ N/mm}^2}$$

Partial factor for reinforcing steel (Table 2.1N);

$$\gamma_S = \mathbf{1.15}$$

Design yield strength of reinforcement;

$$f_{yd} = f_{yk} / \gamma_S = \mathbf{435 \text{ N/mm}^2}$$

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Nominal cover to reinforcement;

$$C_{nom} = \underline{30} \text{ mm}$$

Rectangular section in flexure (Section 6.1)

Design bending moment;

$$M_{Ed,y,max} = \underline{11.5} \text{ kNm}$$

Depth to tension reinforcement;

$$d = h - C_{nom} - \phi_{y,bot} / 2 = \underline{165} \text{ mm}$$

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

$$K' = \underline{0.207}$$

K' > K - No compression reinforcement is required

Lever arm;

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

$$\underline{157} \text{ mm}$$

Depth of neutral axis;

$$x = 2.5 \times (d - z) = \underline{21} \text{ mm}$$

Area of tension reinforcement required;

$$A_{s,y,bot,req} = M_{Ed,y,max} / (f_{yd} \times z) = \underline{169} \text{ mm}^2$$

Tension reinforcement provided;

10 dia.bars at 250 c/c bottom

Area of tension reinforcement provided;

$$A_{s,y,bot,prov} = \underline{314} \text{ mm}^2$$

Minimum area of reinforcement (exp.9.1N);
mm²

$$A_{s,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times L_x \times d = \underline{301}$$

Maximum area of reinforcement (cl.9.2.1.1(3));

$$A_{s,max} = 0.04 \times L_x \times d = \underline{6600} \text{ mm}^2$$

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

Crack control (Section 7.3)

Limiting crack width;

$$w_{max} = \underline{0.3} \text{ mm}$$

Variable load factor (EN1990 – Table A1.1);

$$\psi_2 = \underline{0.3}$$

Serviceability bending moment;

$$M_{sls,y,max} = \underline{7.7} \text{ kNm}$$

Tensile stress in reinforcement;

$$\sigma_s = M_{sls,y,max} / (A_{s,y,bot,prov} \times z) = \underline{156.5} \text{ N/mm}^2$$

Load duration factor;

$$k_t = \underline{0.4}$$

Effective depth of concrete in tension;

$$h_{c,eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2) = \underline{60} \text{ mm}$$

Effective area of concrete in tension;

$$A_{c,eff} = h_{c,eff} \times L_x = \underline{59792} \text{ mm}^2$$

Mean value of concrete tensile strength;

$$f_{ct,eff} = f_{ctm} = \underline{3.5} \text{ N/mm}^2$$

Reinforcement ratio;

$$\rho_{p,eff} = A_{s,y,bot,prov} / A_{c,eff} = \underline{0.005}$$

Modular ratio;

$$\alpha_e = E_s / E_{cm} = \underline{5.962}$$

Bond property coefficient;

$$k_1 = \underline{0.8}$$

Strain distribution coefficient;

$$k_2 = \underline{0.5}$$

$$k_3 = \underline{3.4}$$

$$k_4 = \underline{0.425}$$

Maximum crack spacing (exp.7.11);
mm

$$s_{r,max} = k_3 \times C_{nom} + k_1 \times k_2 \times k_4 \times \phi_{y,bot} / \rho_{p,eff} = \underline{426}$$

Maximum crack width (exp.7.8);

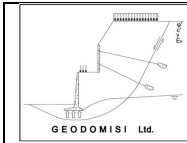
$$w_k = s_{r,max} \times \max([\sigma_s - k_t \times (f_{ct,eff} / \rho_{p,eff}) \times (1 + \alpha_e \times \rho_{p,eff})] / E_s, 0.6 \times \sigma_s / E_s) = \underline{0.19} \text{ mm}$$

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

Design shear force;

$$\text{abs}(V_{Ed,y,min}) = \underline{1.6} \text{ kN}$$

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



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Longitudinal reinforcement ratio;

Design shear resistance (exp.6.2a & 6.2b);

$v_{min} \times L_x \times d$

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

$$\rho_l = \min(A_{sy,bot,prov} / (L_x \times d), 0.02) = \mathbf{0.002}$$

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

$$V_{Rd,c} = \max(C_{Rd,c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3},$$

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

PASS - Design shear resistance exceeds design shear force

