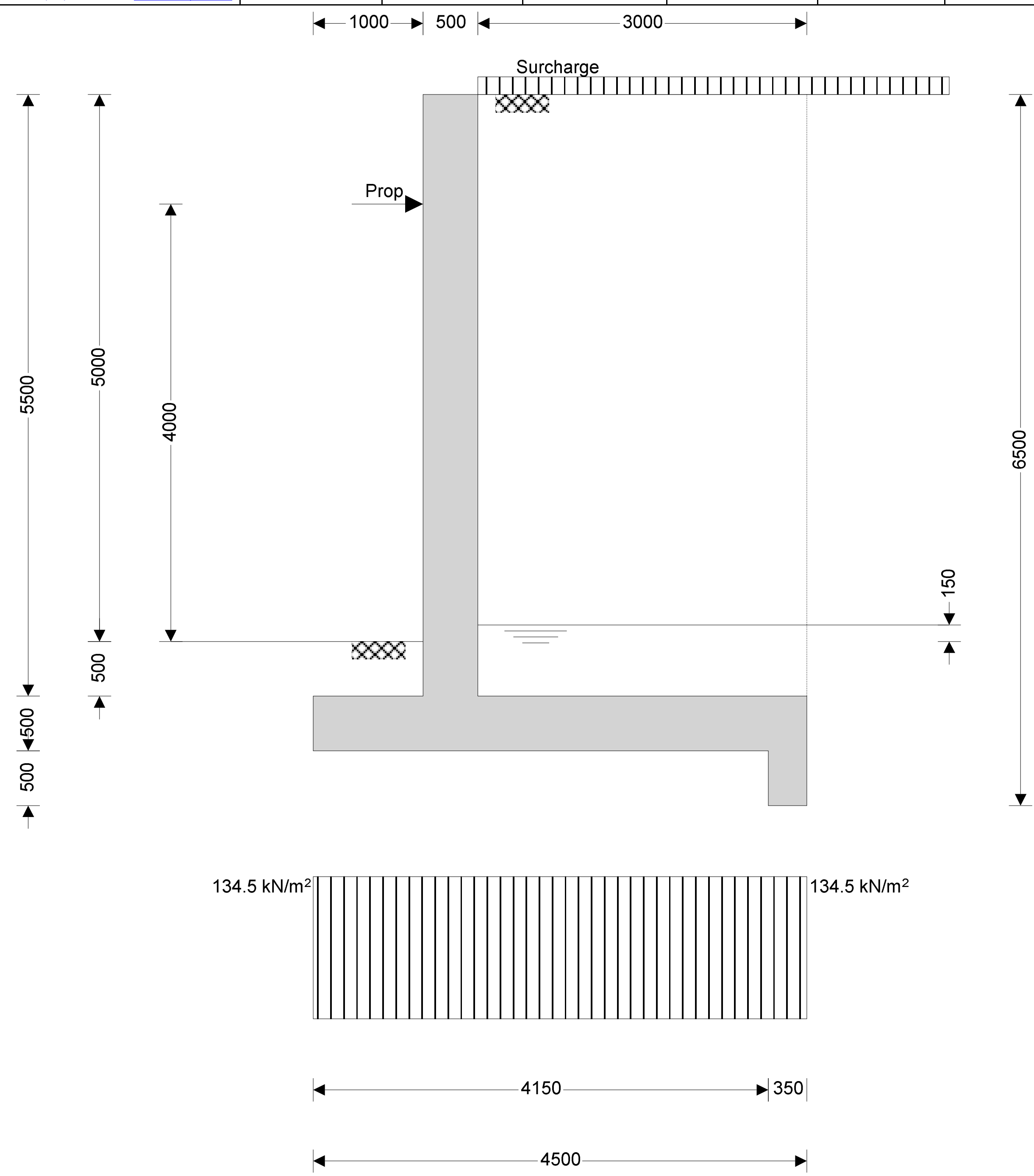
RETAINING WALL ANALYSIS

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

Retaining wall details

Stem type;	Propped cantilever
Stem height;	h_{stem} = **5500** mm
Prop height;	h_{prop} = **4500** mm
Stem thickness;	t_{stem} = **500** mm
Angle to rear face of stem;	α = **90** deg
Stem density;	γ_{stem} = **25** kN/m^3
Toe length;	l_{toe} = **1000** mm
Heel length;	l_{heel} = **3000** mm
Base thickness;	t_{base} = **500** mm
Key position;	p_{key} = **4150** mm
Key depth;	d_{key} = **500** mm
Key thickness;	t_{key} = **350** mm
Base density;	γ_{base} = **25** kN/m^3
Height of retained soil;	h_{ret} = **5000** mm
Angle of soil surface;	β = **0** deg
Depth of cover;	d_{cover} = **500** mm
Height of water;	h_{water} = **150** mm
Water density;	γ_w = **9.8** kN/m^3



Retained soil properties

Soil type;	Very loose gravel
Moist density;	γ_{mr} = **16** kN/m^3
Saturated density;	γ_{sr} = **20** kN/m^3

Characteristic effective shear resistance angle; $\phi'_{r.k}$ = **26** deg

Characteristic wall friction angle; $\delta_{r.k}$ = **13** deg

Base soil properties

Soil type; Firm clay

Moist density; γ_{mb} = **18** kN/m^3

Characteristic cohesion; $c'_{b.k}$ = **25** kN/m^2

Characteristic adhesion; $a_{b.k}$ = **20** kN/m^2

Characteristic effective shear resistance angle; $\phi'_{b.k}$ = **18** deg

Characteristic wall friction angle; $\delta_{b.k}$ = **9** deg

Characteristic base friction angle; $\delta_{bb.k}$ = **12** deg

Loading details

Variable surcharge load; $Surcharge_Q$ = **50** kN/m^2

Calculate retaining wall geometry

Base length; $l_{base} = l_{toe} + t_{stem} + l_{heel}$ = **4500** mm

Base height; $h_{base} = t_{base} + d_{key}$ = **1000** mm

Saturated soil height; $h_{sat} = h_{water} + d_{cover}$ = **650** mm

Moist soil height; $h_{moist} = h_{ret} - h_{water}$ = **4850** mm

Length of surcharge load; $l_{sur} = l_{heel}$ = **3000** mm

- Distance to vertical component; $x_{sur\_v} = l_{base} - l_{heel} / 2$ = **3000** mm

Effective height of wall; $h_{eff} = h_{base} + d_{cover} + h_{ret}$ = **6500** mm

- Distance to horizontal component; $x_{sur\_h} = h_{eff} / 2 - d_{key}$ = **2750** mm

Area of wall stem; $A_{stem} = h_{stem} \times t_{stem}$ = **2.75** m^2

- Distance to vertical component; $x_{stem} = l_{toe} + t_{stem} / 2$ = **1250** mm

Area of wall base; $A_{base} = l_{base} \times t_{base} + d_{key} \times t_{key}$ = **2.425** m^2

- Distance to vertical component; $x_{base} = (l_{base}^2 \times t_{base} / 2 + d_{key} \times t_{key} \times (p_{key} + t_{key} / 2)) / A_{base}$ = **2400** mm

Area of saturated soil; $A_{sat} = h_{sat} \times l_{heel}$ = **1.95** m^2

- Distance to vertical component; $x_{sat\_v} = l_{base} - (h_{sat} \times l_{heel}^2 / 2) / A_{sat}$ = **3000** mm

- Distance to horizontal component; $x_{sat\_h} = (h_{sat} + h_{base}) / 3 - d_{key}$ = **50** mm

Area of water; $A_{water} = h_{sat} \times l_{heel}$ = **1.95** m^2

- Distance to vertical component; $x_{water\_v} = l_{base} - (h_{sat} \times l_{heel}^2 / 2) / A_{sat}$ = **3000** mm

- Distance to horizontal component; $x_{water\_h} = (h_{sat} + h_{base}) / 3 - d_{key}$ = **50** mm

Area of moist soil; $A_{moist} = h_{moist} \times l_{heel}$ = **14.55** m^2

- Distance to vertical component; $x_{moist\_v} = l_{base} - (h_{moist} \times l_{heel}^2 / 2) / A_{moist}$ = **3000** mm

- Distance to horizontal component; $x_{moist\_h} = (h_{moist} \times (t_{base} + h_{sat} + h_{moist} / 3) / 2 + (h_{sat} + h_{base}) \times ((h_{sat} + h_{base})/2 - d_{key})) / (h_{sat} + h_{base} + h_{moist} / 2)$ = **1778** mm

Area of base soil; $A_{pass} = d_{cover} \times l_{toe}$ = **0.5** m^2

- Distance to vertical component; $x_{pass\_v} = l_{base} - (d_{cover} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{pass}$ = **500** mm

- Distance to horizontal component; $x_{pass\_h} = (d_{cover} + h_{base}) / 3 - d_{key}$ = **0** mm

Area of excavated base soil; $A_{exc} = h_{pass} \times l_{toe}$ = **0.5** m^2

- Distance to vertical component; $x_{exc\_v} = l_{base} - (h_{pass} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{exc}$ = **500** mm

- Distance to horizontal component; $x_{exc\_h} = (h_{pass} + h_{base}) / 3 - d_{key}$ = **0** mm

Partial factors on actions - Table A.3 - Combination 1

Permanent unfavourable action; γ_G = **1.35**

Permanent favourable action; γ_{Gf} = **1.00**

Variable unfavourable action; γ_Q = **1.50**

Variable favourable action; γ_{Qf} = **0.00**

Partial factors for soil parameters – Table A.4 - Combination 1

Angle of shearing resistance; $\gamma_{\phi'}$ = **1.00**

Effective cohesion; $\gamma_{c'}$ = **1.00**

Weight density; γ_γ = **1.00**

Retained soil properties

Design effective shear resistance angle; $\phi'_{r.d} = \text{atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'})$ = **26** deg

Design wall friction angle; $\delta_{r.d} = \text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'})$ = **13** deg

Base soil properties

Design effective shear resistance angle; $\phi'_{b.d} = \text{atan}(\tan(\phi'_{b.k}) / \gamma_{\phi'})$ = **18** deg

Design wall friction angle; $\delta_{b.d} = \text{atan}(\tan(\delta_{b.k}) / \gamma_{\phi'})$ = **9** deg

Design base friction angle; $\delta_{bb.d} = \text{atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'})$ = **12** deg

Design effective cohesion; $c'_{b.d} = c'_{b.k} / \gamma_{c'}$ = **25** kN/m^2

Design adhesion; $a_{b.d} = a_{b.k} / \gamma_{c'}$ = **20** kN/m^2

Using Coulomb theory

Active pressure coefficient; $K_A = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{[\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))]}]^2)$ = **0.353**

Passive pressure coefficient; $K_P = \sin(90 - \phi'_{b.d})^2 / (\sin(90 + \delta_{b.d}) \times [1 - \sqrt{[\sin(\phi'_{b.d} + \delta_{b.d}) \times \sin(\phi'_{b.d}) / (\sin(90 + \delta_{b.d}))]}]^2)$ = **2.359**

Bearing pressure check

Vertical forces on wall

Wall stem; $F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem}$ = **92.8** kN/m

Wall base; $F_{base} = \gamma_G \times A_{base} \times \gamma_{base}$ = **81.8** kN/m

Surcharge load; $F_{sur\_v} = \gamma_Q \times Surcharge_Q \times l_{heel}$ = **225** kN/m

Saturated retained soil; $F_{sat\_v} = \gamma_G \times A_{sat} \times (\gamma_{sr} - \gamma_w)$ = **26.8** kN/m

Water; $F_{water\_v} = \gamma_G \times A_{water} \times \gamma_w$ = **25.8** kN/m

Moist retained soil; $F_{moist\_v} = \gamma_G \times A_{moist} \times \gamma_{mr}$ = **314.3** kN/m

Base soil; $F_{pass\_v} = \gamma_G \times A_{pass} \times \gamma_{mb}$ = **12.2** kN/m

Total; $F_{total\_v} = F_{stem} + F_{base} + F_{sat\_v} + F_{moist\_v} + F_{pass\_v} + F_{water\_v} + F_{sur\_v}$ = **778.7** kN/m

Horizontal forces on wall

Surcharge load; $F_{sur\_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times Surcharge_Q \times h_{eff}$ = **167.8** kN/m

Saturated retained soil; $F_{sat\_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times (\gamma_{sr} - \gamma_w) \times (h_{sat} + h_{base})^2 / 2$ = **6.4** kN/m

Water; $F_{water\_h} = \gamma_G \times \gamma_w \times (h_{water} + d_{cover} + h_{base})^2 / 2$ = **18** kN/m

Moist retained soil; $F_{moist\_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr} \times ((h_{eff} - h_{sat} - h_{base})^2 / 2 + (h_{eff} - h_{sat} - h_{base}) \times (h_{sat} + h_{base}))$ = **146.9** kN/m

Total; $F_{total\_h} = F_{sat\_h} + F_{moist\_h} + F_{water\_h} + F_{sur\_h}$ = **339.2** kN/m

Moments on wall

Wall stem; $M_{stem} = F_{stem} \times x_{stem}$ = **116** kNm/m

Wall base; $M_{base} = F_{base} \times x_{base}$ = **196.4** kNm/m

Surcharge load; $M_{sur} = F_{sur\_v} \times x_{sur\_v} - F_{sur\_h} \times x_{sur\_h}$ = **213.6** kNm/m

Saturated retained soil; $M_{sat} = F_{sat\_v} \times x_{sat\_v} - F_{sat\_h} \times x_{sat\_h}$ = **80.2** kNm/m

Water; $M_{water} = F_{water\_v} \times x_{water\_v} - F_{water\_h} \times x_{water\_h}$ = **76.6** kNm/m

Moist retained soil; $M_{moist} = F_{moist\_v} \times x_{moist\_v} - F_{moist\_h} \times x_{moist\_h}$ = **681.6** kNm/m

Base soil; $M_{pass} = F_{pass\_v} \times x_{pass\_v}$ = **6.1** kNm/m

Total; $M_{total} = M_{stem} + M_{base} + M_{sat} + M_{moist} + M_{pass} + M_{water} + M_{sur}$ = **1370.5** kNm/m

Check bearing pressure

Maximum friction force; $F_{friction\_max} = F_{total\_v} \times \tan(\delta_{bb.d})$ = **165.5** kN/m

Maximum base soil resistance; $F_{pass\_h\_max} = \gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_{mb} \times (d_{cover} + h_{base})^2 / 2$ = **47.2** kN/m

Base soil resistance; $F_{pass\_h} = \min(\max((M_{total} + F_{total\_h} \times (h_{prop} + t_{base}) + F_{friction\_max} \times (h_{prop} + t_{base}) - F_{total\_v} \times l_{base} / 2) / (x_{pass\_h} - h_{prop} - t_{base}), 0\ kN/m), F_{pass\_h\_max})$ = **0** kN/m

Propping force; $F_{prop\_stem} = \min((F_{total\_v} \times l_{base} / 2 - M_{total}) / (h_{prop} + t_{base}), F_{total\_h})$ = **76.3** kN/m

Friction force; $F_{friction} = F_{total\_h} - F_{pass\_h} - F_{prop\_stem}$ = **262.8** kN/m

Moment from propping force; $M_{prop} = F_{prop\_stem} \times (h_{prop} + t_{base})$ = **381.7** kNm/m

Distance to reaction; $\bar{x} = (M_{total} + M_{prop}) / F_{total\_v}$ = **2250** mm

Eccentricity of reaction; $e = \bar{x} - l_{base} / 2$ = **0** mm

Loaded length of base; $l_{load} = l_{base}$ = **4500** mm

Bearing pressure at toe;	$q_{toe} = F_{total\_v} / l_{base} = \underline{\mathbf{173.1}}$ kN/m^2
Bearing pressure at heel;	$q_{heel} = F_{total\_v} / l_{base} = \underline{\mathbf{173.1}}$ kN/m^2
Effective overburden pressure;	$q = (t_{base} + d_{cover}) \times \gamma_{mb} - (t_{base} + d_{cover} + h_{water}) \times \gamma_w = \underline{\mathbf{6.7}}$ kN/m^2
Design effective overburden pressure;	$q' = q / \gamma_\gamma = \underline{\mathbf{6.7}}$ kN/m^2
Bearing resistance factors;	$N_q = Exp(\pi \times \tan(\phi'_{b.d})) \times (\tan(45 \text{ deg} + \phi'_{b.d} / 2))^2 = \underline{\mathbf{5.258}}$
	$N_c = (N_q - 1) \times \cot(\phi'_{b.d}) = \underline{\mathbf{13.104}}$
	$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b.d}) = \underline{\mathbf{2.767}}$
Foundation shape factors;	$s_q = 1$
	$s_\gamma = 1$
	$s_c = 1$
Load inclination factors;	$H = F_{total\_h} - F_{prop\_stem} - F_{friction} = \underline{\mathbf{0}}$ kN/m
	$V = F_{total\_v} = \underline{\mathbf{778.7}}$ kN/m
	$m = 2$
	$i_q = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^m = \underline{\mathbf{1}}$
	$i_\gamma = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^{(m + 1)} = \underline{\mathbf{1}}$
	$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b.d})) = \underline{\mathbf{1}}$
Net ultimate bearing capacity;	$n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times (\gamma_{mb} - \gamma_w) \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma = \underline{\mathbf{413.9}}$ kN/m^2
Factor of safety;	$FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) = \underline{\mathbf{2.392}}$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Partial factors on actions - Table A.3 - Combination 2

Permanent unfavourable action;	$\gamma_G = \underline{\mathbf{1.00}}$
Permanent favourable action;	$\gamma_{Gf} = \underline{\mathbf{1.00}}$
Variable unfavourable action;	$\gamma_Q = \underline{\mathbf{1.30}}$
Variable favourable action;	$\gamma_{Qf} = \underline{\mathbf{0.00}}$

Partial factors for soil parameters – Table A.4 - Combination 2

Angle of shearing resistance;	$\gamma_{\phi'} = \underline{\mathbf{1.25}}$
Effective cohesion;	$\gamma_{c'} = \underline{\mathbf{1.25}}$
Weight density;	$\gamma_\gamma = \underline{\mathbf{1.00}}$

Retained soil properties

Design effective shear resistance angle;	$\phi'_{r.d} = \text{atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'}) = \underline{\mathbf{21.3}}$ deg
Design wall friction angle;	$\delta_{r.d} = \text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'}) = \underline{\mathbf{10.5}}$ deg

Base soil properties

Design effective shear resistance angle;	$\phi'_{b.d} = \text{atan}(\tan(\phi'_{b.k}) / \gamma_{\phi'}) = \underline{\mathbf{14.6}}$ deg
Design wall friction angle;	$\delta_{b.d} = \text{atan}(\tan(\delta_{b.k}) / \gamma_{\phi'}) = \underline{\mathbf{7.2}}$ deg
Design base friction angle;	$\delta_{bb.d} = \text{atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'}) = \underline{\mathbf{9.7}}$ deg
Design effective cohesion;	$c'_{b.d} = c'_{b.k} / \gamma_{c'} = \underline{\mathbf{20}}$ kN/m^2
Design adhesion;	$a_{b.d} = a_{b.k} / \gamma_{c'} = \underline{\mathbf{16}}$ kN/m^2

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Using Coulomb theory

Active pressure coefficient; $K_A = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{[\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))]}]^2) = \underline{\mathbf{0.425}}$

Passive pressure coefficient; $K_P = \sin(90 - \phi'_{b.d})^2 / (\sin(90 + \delta_{b.d}) \times [1 - \sqrt{[\sin(\phi'_{b.d} + \delta_{b.d}) \times \sin(\phi'_{b.d}) / (\sin(90 + \delta_{b.d}))]}]^2) = \underline{\mathbf{1.965}}$

Bearing pressure check

Vertical forces on wall

Wall stem; $F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} = \underline{\mathbf{68.8}}$ kN/m

Wall base; $F_{base} = \gamma_G \times A_{base} \times \gamma_{base} = \underline{\mathbf{60.6}}$ kN/m

Surcharge load; $F_{sur\_v} = \gamma_Q \times Surcharge_Q \times l_{heel} = \underline{\mathbf{195}}$ kN/m

Saturated retained soil; $F_{sat\_v} = \gamma_G \times A_{sat} \times (\gamma_{sr} - \gamma_w) = \underline{\mathbf{19.9}}$ kN/m

Water; $F_{water\_v} = \gamma_G \times A_{water} \times \gamma_w = \underline{\mathbf{19.1}}$ kN/m

Moist retained soil; $F_{moist\_v} = \gamma_G \times A_{moist} \times \gamma_{mr} = \underline{\mathbf{232.8}}$ kN/m

Base soil; $F_{pass\_v} = \gamma_G \times A_{pass} \times \gamma_{mb} = \underline{\mathbf{9}}$ kN/m

Total; $F_{total\_v} = F_{stem} + F_{base} + F_{sat\_v} + F_{moist\_v} + F_{pass\_v} + F_{water\_v} + F_{sur\_v} = \underline{\mathbf{605.2}}$ kN/m

Horizontal forces on wall

Surcharge load; $F_{sur\_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times Surcharge_Q \times h_{eff} = \underline{\mathbf{176.5}}$ kN/m

Saturated retained soil; $F_{sat\_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times (\gamma_{sr} - \gamma_w) \times (h_{sat} + h_{base})^2 / 2 = \underline{\mathbf{5.8}}$ kN/m

Water; $F_{water\_h} = \gamma_G \times \gamma_w \times (h_{water} + d_{cover} + h_{base})^2 / 2 = \underline{\mathbf{13.4}}$ kN/m

Moist retained soil; $F_{moist\_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr} \times ((h_{eff} - h_{sat} - h_{base})^2 / 2 + (h_{eff} - h_{sat} - h_{base}) \times (h_{sat} + h_{base})) = \underline{\mathbf{132.1}}$ kN/m

Total; $F_{total\_h} = F_{sat\_h} + F_{moist\_h} + F_{water\_h} + F_{sur\_h} = \underline{\mathbf{327.8}}$ kN/m

Moments on wall

Wall stem; $M_{stem} = F_{stem} \times x_{stem} = \underline{\mathbf{85.9}}$ kNm/m

Wall base; $M_{base} = F_{base} \times x_{base} = \underline{\mathbf{145.5}}$ kNm/m

Surcharge load; $M_{sur} = F_{sur\_v} \times x_{sur\_v} - F_{sur\_h} \times x_{sur\_h} = \underline{\mathbf{99.5}}$ kNm/m

Saturated retained soil; $M_{sat} = F_{sat\_v} \times x_{sat\_v} - F_{sat\_h} \times x_{sat\_h} = \underline{\mathbf{59.3}}$ kNm/m

Water; $M_{water} = F_{water\_v} \times x_{water\_v} - F_{water\_h} \times x_{water\_h} = \underline{\mathbf{56.7}}$ kNm/m

Moist retained soil; $M_{moist} = F_{moist\_v} \times x_{moist\_v} - F_{moist\_h} \times x_{moist\_h} = \underline{\mathbf{463.5}}$ kNm/m

Base soil; $M_{pass} = F_{pass\_v} \times x_{pass\_v} = \underline{\mathbf{4.5}}$ kNm/m

Total; $M_{total} = M_{stem} + M_{base} + M_{sat} + M_{moist} + M_{pass} + M_{water} + M_{sur} = \underline{\mathbf{915}}$ kNm/m

Check bearing pressure

Maximum friction force; $F_{friction\_max} = F_{total\_v} \times \tan(\delta_{bb.d}) = \underline{\mathbf{102.9}}$ kN/m

Maximum base soil resistance; $F_{pass\_h\_max} = \gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_{mb} \times (d_{cover} + h_{base})^2 / 2 = \underline{\mathbf{39.5}}$ kN/m

Base soil resistance; $F_{pass\_h} = \min(\max((M_{total} + F_{total\_h} \times (h_{prop} + t_{base}) + F_{friction\_max} \times (h_{prop} + t_{base}) - F_{total\_v} \times l_{base} / 2) / (x_{pass\_h} - h_{prop} - t_{base}), 0 \text{ kN/m}), F_{pass\_h\_max}) = \underline{\mathbf{0}}$ kN/m

Propping force; $F_{prop\_stem} = \min((F_{total\_v} \times l_{base} / 2 - M_{total}) / (h_{prop} + t_{base}), F_{total\_h}) = \underline{\mathbf{89.3}}$ kN/m

Friction force; $F_{friction} = F_{total\_h} - F_{pass\_h} - F_{prop\_stem} = \underline{\mathbf{238.5}}$ kN/m

Moment from propping force; $M_{prop} = F_{prop\_stem} \times (h_{prop} + t_{base}) = \underline{\mathbf{446.7}}$ kNm/m

Distance to reaction; $\bar{x} = (M_{total} + M_{prop}) / F_{total\_v} = \underline{\mathbf{2250}}$ mm

Eccentricity of reaction; $e = \bar{x} - l_{base} / 2 = \underline{\mathbf{0}}$ mm

Loaded length of base; $l_{load} = l_{base} = \underline{\mathbf{4500}}$ mm

Bearing pressure at toe; $q_{toe} = F_{total\_v} / l_{base} = \underline{\mathbf{134.5}}$ kN/m^2

Bearing pressure at heel; $q_{heel} = F_{total\_v} / l_{base} = \underline{\mathbf{134.5}}$ kN/m^2

Effective overburden pressure; $q = (t_{base} + d_{cover}) \times \gamma_{mb} - (t_{base} + d_{cover} + h_{water}) \times \gamma_w = \underline{\mathbf{6.7}}$ kN/m^2

Design effective overburden pressure; $q' = q / \gamma_\gamma = \underline{\mathbf{6.7}}$ kN/m^2

Bearing resistance factors; $N_q = \text{Exp}(\pi \times \tan(\phi'_{b.d})) \times (\tan(45 \text{ deg} + \phi'_{b.d} / 2))^2 = \underline{\mathbf{3.784}}$

$N_c = (N_q - 1) \times \cot(\phi'_{b.d}) = \underline{\mathbf{10.711}}$

$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b.d}) = \underline{\mathbf{1.447}}$

Foundation shape factors; $s_q = 1$

$s_\gamma = 1$

$s_c = 1$

Load inclination factors; $H = F_{total\_h} - F_{prop\_stem} - F_{friction} = \underline{\mathbf{0}}$ kN/m

$V = F_{total\_v} = \underline{\mathbf{605.2}}$ kN/m

$m = 2$

$i_q = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^m = \underline{\mathbf{1}}$

$i_\gamma = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^{(m + 1)} = \underline{\mathbf{1}}$

$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b.d})) = \underline{\mathbf{1}}$

Net ultimate bearing capacity; $n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times (\gamma_{mb} - \gamma_w) \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma = \underline{\mathbf{266.3}}$ kN/m^2

Factor of safety; $FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) = \underline{\mathbf{1.98}}$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

RETAINING WALL DESIGN

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; C30/37

Characteristic compressive cylinder strength; f_{ck} = **30** N/mm^2

Characteristic compressive cube strength; $f_{ck,cube}$ = **37** N/mm^2

Mean value of compressive cylinder strength; $f_{cm} = f_{ck} + 8\ N/mm^2$ = **38** N/mm^2

Mean value of axial tensile strength; $f_{ctm} = 0.3\ N/mm^2 \times (f_{ck} / 1\ N/mm^2)^{2/3}$ = **2.9** N/mm^2

5% fractile of axial tensile strength; $f_{ctk,0.05} = 0.7 \times f_{ctm}$ = **2.0** N/mm^2

Secant modulus of elasticity of concrete; $E_{cm} = 22\ kN/mm^2 \times (f_{cm} / 10\ N/mm^2)^{0.3}$ = **32837** N/mm^2

Partial factor for concrete - Table 2.1N; γ_C = **1.50**

Compressive strength coefficient - cl.3.1.6(1); α_{cc} = **1.00**

Design compressive concrete strength - exp.3.15; $f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C$ = **20.0** N/mm^2

Maximum aggregate size; h_{agg} = **20** mm

Reinforcement details

Characteristic yield strength of reinforcement; f_{yk} = **500** N/mm^2

Modulus of elasticity of reinforcement; E_s = **210000** N/mm^2

Partial factor for reinforcing steel - Table 2.1N; γ_S = **1.15**

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

Cover to reinforcement

Front face of stem; c_{sf} = **40** mm

Rear face of stem; c_{sr} = **50** mm

Top face of base; c_{bt} = **50** mm

Bottom face of base; c_{bb} = **75** mm

Check stem design for maximum moment

Depth of section; h = **500** mm

Rectangular section in flexure - Section 6.1

Design bending moment; M = **94.6** kNm/m

Depth to tension reinforcement; $d = h - c_{sr} - \phi_{sr} / 2$ = **442** mm

$K = M / (d^2 \times f_{ck})$ = **0.016**

K' = **0.196**

K' > K - No compression reinforcement is required

Lever arm; $z = \min(0.5 + 0.5 \times (1 - 3.53 \times K)^{0.5}, 0.95) \times d$ = **420** mm

Depth of neutral axis; $x = 2.5 \times (d - z)$ = **55** mm

Area of tension reinforcement required; $A_{sr.req} = M / (f_{yd} \times z)$ = **518** mm^2/m

Tension reinforcement provided; 16 dia.bars @ 200 c/c

Area of tension reinforcement provided; $A_{sr.prov} = \pi \times \phi_{sr}^2 / (4 \times s_{sr})$ = **1005** mm^2/m

Minimum area of reinforcement - exp.9.1N; $A_{sr.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d$ = **666** mm^2/m

Maximum area of reinforcement - cl.9.2.1.1(3); $A_{sr.max} = 0.04 \times h$ = **20000** mm^2/m

$\max(A_{sr.req}, A_{sr.min}) / A_{sr.prov}$ = **0.662**

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} = **44.8** kNm/m

Tensile stress in reinforcement; $\sigma_s = M_{sls} / (A_{sr.prov} \times z)$ = **106.2** N/mm^2

Load duration; Long term

Load duration factor; k_t = **0.4**

Effective area of concrete in tension; $A_{c.eff} = \min(2.5 \times (h - d), (h – x) / 3, h / 2)$ = **145000** mm^2/m

Mean value of concrete tensile strength; $f_{ct.eff} = f_{ctm}$ = **2.9** N/mm^2

Reinforcement ratio; $\rho_{p.eff} = A_{sr.prov} / A_{c.eff}$ = **0.007**

Modular ratio; $\alpha_e = E_s / E_{cm}$ = **6.395**

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; $s_{r.max} = k_3 \times c_{sr} + k_1 \times k_2 \times k_4 \times \phi_{sr} / \rho_{p.eff}$ = **562** mm

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

w_k = **0.171** mm

w_k / w_{max} = **0.569**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force; V = **151.5** kN/m

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

$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2)$ = **1.673**

Longitudinal reinforcement ratio; $\rho_l = \min(A_{sr.prov} / d, 0.02)$ = **0.002**

$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5}$ = **0.415** N/mm^2

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

$V_{Rd.c}$ = **183.3** kN/m

$V / V_{Rd.c}$ = **0.827**

PASS - Design shear resistance exceeds design shear force

Rectangular section in flexure - Section 6.1

Design bending moment; M = **63.7** kNm/m

Depth to tension reinforcement; $d = h - c_{sf} - \phi_{sx} - \phi_{sf} / 2 =$ **440** mm

$K = M / (d^2 \times f_{ck}) =$ **0.011**

$K' =$ **0.196**

K' > K - No compression reinforcement is required

Lever arm; $z = \min(0.5 + 0.5 \times (1 - 3.53 \times K)^{0.5}, 0.95) \times d =$ **418** mm

Depth of neutral axis; $x = 2.5 \times (d - z) =$ **55** mm

Area of tension reinforcement required; $A_{sf.req} = M / (f_{yd} \times z) =$ **351** mm^2/m

Tension reinforcement provided; 16 dia.bars @ 200 c/c

Area of tension reinforcement provided; $A_{sf.prov} = \pi \times \phi_{sf}^2 / (4 \times s_{sf}) =$ **1005** mm^2/m

Minimum area of reinforcement - exp.9.1N; $A_{sf.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d =$ **663** mm^2/m

Maximum area of reinforcement - cl.9.2.1.1(3); $A_{sf.max} = 0.04 \times h =$ **20000** mm^2/m

$\max(A_{sf.req}, A_{sf.min}) / A_{sf.prov} =$ **0.659**

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; $\psi_2 =$ **0.3**

Serviceability bending moment; $M_{sls} =$ **29.6** kNm/m

Tensile stress in reinforcement; $\sigma_s = M_{sls} / (A_{sf.prov} \times z) =$ **70.4** N/mm^2

Load duration; Long term

Load duration factor; $k_t =$ **0.4**

Effective area of concrete in tension; $A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2) =$ **148333** mm^2/m

Mean value of concrete tensile strength; $f_{ct.eff} = f_{ctm} =$ **2.9** N/mm^2

Reinforcement ratio; $\rho_{p.eff} = A_{sf.prov} / A_{c.eff} =$ **0.007**

Modular ratio; $\alpha_e = E_s / E_{cm} =$ **6.395**

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; $s_{r.max} = k_3 \times c_{sf} + k_1 \times k_2 \times k_4 \times \phi_{sf} / \rho_{p.eff} =$ **537** mm

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

$w_k =$ **0.108** mm

$w_k / w_{max} =$ **0.36**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force; $V =$ **151.5** kN/m

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

$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) =$ **1.674**

Longitudinal reinforcement ratio; $\rho_l = \min(A_{sf.prov} / d, 0.02) =$ **0.002**

$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} =$ **0.415** N/mm^2

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

$V_{Rd.c} =$ **182.7** kN/m

$V / V_{Rd.c} =$ **0.829**

PASS - Design shear resistance exceeds design shear force

Horizontal reinforcement parallel to face of stem - Section 9.6

Minimum area of reinforcement – cl.9.6.3(1); $A_{sx.req} = \max(0.25 \times A_{sr.prov}, 0.001 \times t_{stem}) =$ **500** mm^2/m

Maximum spacing of reinforcement – cl.9.6.3(2); $s_{sx\_max} =$ **400** mm

Transverse reinforcement provided; 12 dia.bars @ 200 c/c

Area of transverse reinforcement provided; $A_{sx.prov} = \pi \times \phi_{sx}^2 / (4 \times s_{sx}) =$ **565** mm^2/m

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

Check base design

Depth of section; $h =$ **500** mm

Rectangular section in flexure - Section 6.1

Design bending moment at toe; $M =$ **72** kNm/m

Depth to tension reinforcement; $d = h - c_{bb} - \phi_{bb} / 2 =$ **417** mm

$K = M / (d^2 \times f_{ck}) =$ **0.014**

$K' =$ **0.196**

K' > K - No compression reinforcement is required

Lever arm; $z = \min(0.5 + 0.5 \times (1 - 3.53 \times K)^{0.5}, 0.95) \times d =$ **396** mm

Depth of neutral axis; $x = 2.5 \times (d - z) =$ **52** mm

Area of tension reinforcement required; $A_{bb.req} = M / (f_{yd} \times z) =$ **418** mm^2/m

Tension reinforcement provided; 16 dia.bars @ 200 c/c

Area of tension reinforcement provided; $A_{bb.prov} = \pi \times \phi_{bb}^2 / (4 \times s_{bb}) =$ **1005** mm^2/m

Minimum area of reinforcement - exp.9.1N; $A_{bb.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d =$ **628** mm^2/m

Maximum area of reinforcement - cl.9.2.1.1(3); $A_{bb.max} = 0.04 \times h =$ **20000** mm^2/m

$\max(A_{bb.req}, A_{bb.min}) / A_{bb.prov} =$ **0.625**

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; $\psi_2 =$ **0.3**

Serviceability bending moment; $M_{sls} =$ **39.8** kNm/m

Tensile stress in reinforcement; $\sigma_s = M_{sls} / (A_{bb.prov} \times z) =$ **100** N/mm^2

Load duration; Long term

Load duration factor; $k_t =$ **0.4**

Effective area of concrete in tension; $A_{c.eff}$ = min(2.5 × (h - d), (h – x) / 3, h / 2) = **149292** mm²/m

Mean value of concrete tensile strength; $f_{ct.eff} = f_{ctm}$ = **2.9** N/mm²

Reinforcement ratio; $\rho_{p.eff} = A_{bb.prov} / A_{c.eff}$ = **0.007**

Modular ratio; $\alpha_e = E_s / E_{cm}$ = **6.395**

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; $s_{r.max} = k_3 \times c_{bb} + k_1 \times k_2 \times k_4 \times \phi_{bb} / \rho_{p.eff}$ = **659** mm

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

w_k = **0.188** mm

w_k / w_{max} = **0.628**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force; V = **144** kN/m

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

k = min(1 + √(200 mm / d), 2) = **1.693**

Longitudinal reinforcement ratio; $\rho_l = \min(A_{bb.prov} / d, 0.02)$ = **0.002**

$v_{min} = 0.035 N^{1/2}/mm \times k^{3/2} \times f_{ck}^{0.5}$ = **0.422** N/mm²

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

$V_{Rd.c}$ = **176** kN/m

$V / V_{Rd.c}$ = **0.818**

PASS - Design shear resistance exceeds design shear force

Rectangular section in flexure - Section 6.1

Design bending moment at heel; M = **186.4** kNm/m

Depth to tension reinforcement; $d = h - c_{bt} - \phi_{bt} / 2$ = **442** mm

$K = M / (d^2 \times f_{ck})$ = **0.032**

K' = **0.196**

K' > K - No compression reinforcement is required

Lever arm; $z = \min(0.5 + 0.5 \times (1 - 3.53 \times K)^{0.5}, 0.95) \times d$ = **420** mm

Depth of neutral axis; x = 2.5 × (d – z) = **55** mm

Area of tension reinforcement required; $A_{bt.req} = M / (f_{yd} \times z)$ = **1021** mm²/m

Tension reinforcement provided; 16 dia.bars @ 175 c/c

Area of tension reinforcement provided; $A_{bt.prov} = \pi \times \phi_{bt}^2 / (4 \times s_{bt})$ = **1149** mm²/m

Minimum area of reinforcement - exp.9.1N; $A_{bt.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d$ = **666** mm²/m

Maximum area of reinforcement - cl.9.2.1.1(3); $A_{bt.max} = 0.04 \times h$ = **20000** mm²/m

$\max(A_{bt.req}, A_{bt.min}) / A_{bt.prov}$ = **0.888**

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} = **81.2** kNm/m

Tensile stress in reinforcement; $\sigma_s = M_{sls} / (A_{bt.prov} \times z)$ = **168.2** N/mm^2

Load duration; Long term

Load duration factor; k_t = **0.4**

Effective area of concrete in tension; $A_{c.eff} = \min(2.5 \times (h - d), (h – x) / 3, h / 2)$ = **145000** mm^2/m

Mean value of concrete tensile strength; $f_{ct.eff} = f_{ctm}$ = **2.9** N/mm^2

Reinforcement ratio; $\rho_{p.eff} = A_{bt.prov} / A_{c.eff}$ = **0.008**

Modular ratio; $\alpha_e = E_s / E_{cm}$ = **6.395**

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; $s_{r.max} = k_3 \times c_{bt} + k_1 \times k_2 \times k_4 \times \phi_{bt} / \rho_{p.eff}$ = **513** mm

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

w_k = **0.247** mm

w_k / w_{max} = **0.822**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force; V = **129.3** kN/m

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

$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2)$ = **1.673**

Longitudinal reinforcement ratio; $\rho_l = \min(A_{bt.prov} / d, 0.02)$ = **0.003**

$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5}$ = **0.415** N/mm^2

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

$V_{Rd.c}$ = **183.3** kN/m

$V / V_{Rd.c}$ = **0.705**

PASS - Design shear resistance exceeds design shear force

Secondary transverse reinforcement to base - Section 9.3

Minimum area of reinforcement – cl.9.3.1.1(2); $A_{bx.req} = 0.2 \times A_{bt.prov}$ = **230** mm^2/m

Maximum spacing of reinforcement – cl.9.3.1.1(3); s_{bx_max} = **450** mm

Transverse reinforcement provided; 8 dia.bars @ 200 c/c

Area of transverse reinforcement provided; $A_{bx.prov} = \pi \times \phi_{bx}^2 / (4 \times s_{bx})$ = **251** mm^2/m

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

Check key design

Depth of section; $h = \underline{\mathbf{350}}$ mm

Rectangular section in flexure - Section 6.1

Design bending moment at key; $M = \underline{\mathbf{1.3}}$ kNm/m

Depth to tension reinforcement; $d = h - c_{bb} - \phi_k / 2 = \underline{\mathbf{269}}$ mm

$K = M / (d^2 \times f_{ck}) = \underline{\mathbf{0.001}}$

$K' = \underline{\mathbf{0.196}}$

K' > K - No compression reinforcement is required

Lever arm; $z = \min(0.5 + 0.5 \times (1 - 3.53 \times K)^{0.5}, 0.95) \times d = \underline{\mathbf{256}}$ mm

Depth of neutral axis; $x = 2.5 \times (d - z) = \underline{\mathbf{34}}$ mm

Area of tension reinforcement required; $A_{k.req} = M / (f_{yd} \times z) = \underline{\mathbf{12}}$ mm^2/m

Tension reinforcement provided; 12 dia.bars @ 200 c/c

Area of tension reinforcement provided; $A_{k.prov} = \pi \times \phi_k^2 / (4 \times s_k) = \underline{\mathbf{565}}$ mm^2/m

Minimum area of reinforcement - exp.9.1N; $A_{k.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = \underline{\mathbf{405}}$ mm^2/m

Maximum area of reinforcement - cl.9.2.1.1(3); $A_{k.max} = 0.04 \times h = \underline{\mathbf{14000}}$ mm^2/m

$\max(A_{k.req}, A_{k.min}) / A_{k.prov} = \underline{\mathbf{0.716}}$

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

Crack control - Section 7.3

Limiting crack width; $w_{max} = \underline{\mathbf{0.3}}$ mm

Variable load factor - EN1990 – Table A1.1; $\psi_2 = \underline{\mathbf{0.3}}$

Serviceability bending moment; $M_{sls} = \underline{\mathbf{3.3}}$ kNm/m

Tensile stress in reinforcement; $\sigma_s = M_{sls} / (A_{k.prov} \times z) = \underline{\mathbf{23}}$ N/mm^2

Load duration; Long term

Load duration factor; $k_t = \underline{\mathbf{0.4}}$

Effective area of concrete in tension; $A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2) = \underline{\mathbf{105458}}$ mm^2/m

Mean value of concrete tensile strength; $f_{ct.eff} = f_{ctm} = \underline{\mathbf{2.9}}$ N/mm^2

Reinforcement ratio; $\rho_{p.eff} = A_{k.prov} / A_{c.eff} = \underline{\mathbf{0.005}}$

Modular ratio; $\alpha_e = E_s / E_{cm} = \underline{\mathbf{6.395}}$

Bond property coefficient; $k_1 = \underline{\mathbf{0.8}}$

Strain distribution coefficient; $k_2 = \underline{\mathbf{0.5}}$

$k_3 = \underline{\mathbf{3.4}}$

$k_4 = \underline{\mathbf{0.425}}$

Maximum crack spacing - exp.7.11; $s_{r.max} = k_3 \times c_{bb} + k_1 \times k_2 \times k_4 \times \phi_k / \rho_{p.eff} = \underline{\mathbf{635}}$ mm

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

$w_k = \underline{\mathbf{0.042}}$ mm

$w_k / w_{max} = \underline{\mathbf{0.139}}$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force; $V = \underline{\mathbf{4}}$ kN/m

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

$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = \underline{\mathbf{1.862}}$

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

$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = \underline{\mathbf{0.487}} \text{ N/mm}^2$

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

$V_{Rd.c} = \underline{\mathbf{131.1}}$ kN/m

$V / V_{Rd.c} = \underline{\mathbf{0.030}}$

PASS - Design shear resistance exceeds design shear force

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