

Project Unreinforced Block on Flat Retaining Wall				Job no.	
Calcs for				Start page no./Revision 1	
Calcs by KJ	Calcs date 13/05/2021	Checked by KJ	Checked date 13/05/2021	Approved by KJ	Approved date 13/05/2021

RETAINING WALL ANALYSIS

In accordance with EN1997-1:2004 incorporating Corrigendum dated February 2009 and the UK National Annex incorporating Corrigendum No.1

Tedds calculation version 2.9.11

Analysis summary

Description	Unit	Capacity	Applied	F o S	Result
Sliding stability	kN/m	12.4	7.6	1.634	PASS
Overturning stability	kNm/m	20.6	3.9	5.226	PASS
Bearing pressure	kN/m ²	79.8	32.1	2.490	PASS

Design summary

Description	Unit	Provided	Required	Utilisation	Result
Stem p0 - Moment resistance	kNm/m	2.5	2.4	0.95	PASS
Stem p0 - Shear resistance	kN/m	42.5	6.4	0.15	PASS
Stem p1 - Moment resistance	kNm/m	1.2	0.1	0.06	PASS
Stem p1 - Shear resistance	kN/m	38.7	0.7	0.02	PASS
Base top face - Flexural reinforcement	mm ² /m	670.2	213.9	0.32	PASS
Base bottom face - Flexural reinforcement	mm ² /m	670.2	176.2	0.26	PASS
Base - Shear resistance	kN/m	72.5	9.6	0.13	PASS
Transverse base reinforcement	mm ² /m	261.8	134.0	0.51	PASS

Retaining wall details

Stem type	Cantilever with stepped rear face
Stem height	$h_{stem} = 1500$ mm
Number of steps	$N_{steps} = 2$
Height of step 1	$h_{s1} = 750$ mm
Thickness of step 1	$t_{s1} = 645$ mm
Height of step 2	$h_{s2} = 750$ mm
Thickness of step 2	$t_{s2} = 615$ mm
Angle to rear face of stem	$\alpha = 90$ deg
Stem density	$\gamma_{stem} = 25$ kN/m ³
Toe length	$l_{toe} = 250$ mm
Heel length	$l_{heel} = 250$ mm
Base thickness	$t_{base} = 200$ mm
Base density	$\gamma_{base} = 25$ kN/m ³
Height of retained soil	$h_{ret} = 1000$ mm
Angle of soil surface	$\beta = 0$ deg
Depth of cover	$d_{cover} = 0$ mm

Retained soil properties

Soil type	Organic clay
Moist density	$\gamma_{mr} = 15$ kN/m ³
Saturated density	$\gamma_{sr} = 15$ kN/m ³
Characteristic effective shear resistance angle	$\phi'_{r,k} = 18$ deg
Characteristic wall friction angle	$\delta_{r,k} = 9$ deg

Base soil properties

Soil type	Organic clay
Soil density	$\gamma_b = 15$ kN/m ³
Characteristic cohesion	$c'_{b,k} = 10$ kN/m ²
Characteristic adhesion	$a_{b,k} = 6.7$ kN/m ²
Characteristic effective shear resistance angle	$\phi'_{b,k} = 18$ deg

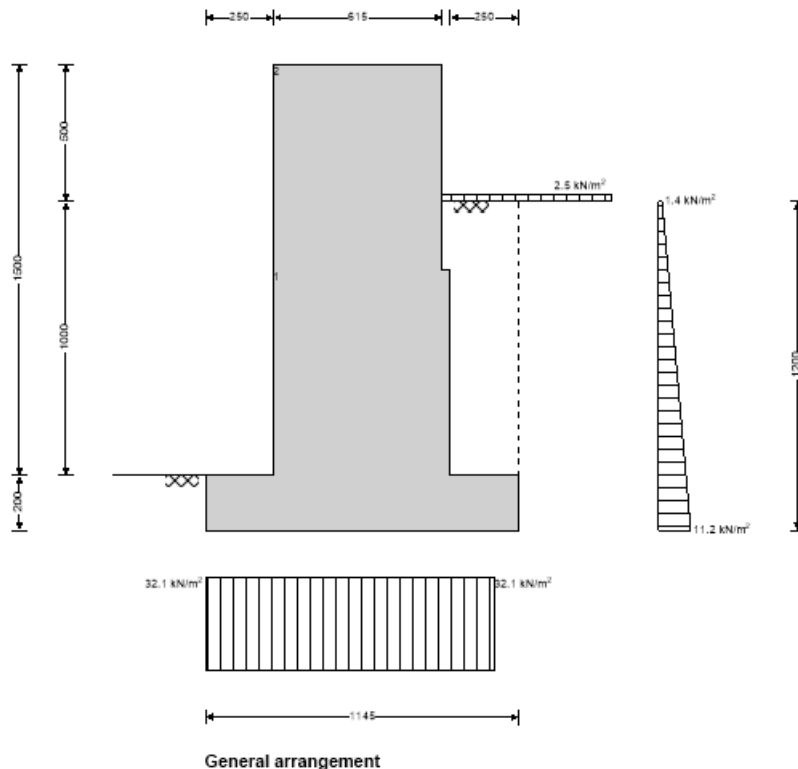
Project Unreinforced Block on Flat Retaining Wall				Job no.	
Calcs for				Start page no./Revision 2	
Calcs by KJ	Calcs date 13/05/2021	Checked by KJ	Checked date 13/05/2021	Approved by KJ	Approved date 13/05/2021

Characteristic wall friction angle
Characteristic base friction angle

$\delta_{b,k} = 9 \text{ deg}$
 $\delta_{bb,k} = 12 \text{ deg}$

Loading details

Permanent surcharge load Surcharge_G = **2.5 kN/m²**



Calculate retaining wall geometry

Base length
Moist soil height
Length of surcharge load
- Distance to vertical component
Effective height of wall
- Distance to horizontal component
Area of wall stem
- Distance to vertical component

Area of wall base
- Distance to vertical component
Area of moist soil
- Distance to vertical component
- Distance to horizontal component

$l_{base} = l_{toe} + t_{s1} + l_{heel} = \mathbf{1145 \text{ mm}}$
 $h_{moist} = h_{soil} = \mathbf{1000 \text{ mm}}$
 $l_{sur} = (l_{heel} + t_{s1} - t_{s2}) = \mathbf{280 \text{ mm}}$
 $x_{sur_v} = l_{base} - (l_{heel} + t_{s1} - t_{s2}) / 2 = \mathbf{1005 \text{ mm}}$
 $h_{eff} = h_{base} + d_{cover} + h_{ret} = \mathbf{1200 \text{ mm}}$
 $x_{sur_h} = h_{eff} / 2 = \mathbf{600 \text{ mm}}$
 $A_{stem} = h_{s1} \times t_{s1} + h_{s2} \times t_{s2} = \mathbf{0.945 \text{ m}^2}$
 $x_{stem} = l_{base} - (h_{s1} \times t_{s1} \times (l_{heel} + t_{s1} - t_{s1} / 2) + h_{s2} \times t_{s2} \times (l_{heel} + t_{s1} - t_{s2} / 2)) / A_{stem} = \mathbf{565 \text{ mm}}$
 $A_{base} = l_{base} \times t_{base} = \mathbf{0.229 \text{ m}^2}$
 $x_{base} = l_{base} / 2 = \mathbf{573 \text{ mm}}$
 $A_{moist} = l_{heel} \times h_{s1} + (l_{heel} + t_{s1} - t_{s2}) \times (h_{soil} - h_{s1}) = \mathbf{0.258 \text{ m}^2}$
 $x_{moist_v} = l_{base} - (l_{heel} \times h_{s1} \times l_{heel} / 2 + (l_{heel} + t_{s1} - t_{s2}) \times (h_{soil} - h_{s1}) \times (l_{heel} + t_{s1} - t_{s2}) / 2) / A_{moist} = \mathbf{1016 \text{ mm}}$
 $x_{moist_h} = h_{eff} / 3 = \mathbf{400 \text{ mm}}$

Project Unreinforced Block on Flat Retaining Wall				Job no.	
Calcs for				Start page no./Revision 3	
Calcs by KJ	Calcs date 13/05/2021	Checked by KJ	Checked date 13/05/2021	Approved by KJ	Approved date 13/05/2021

Design approach 1

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

Partial factor set	A1
Permanent unfavourable action	$\gamma_G = 1.35$
Permanent favourable action	$\gamma_{Gf} = 1.00$
Variable unfavourable action	$\gamma_Q = 1.50$
Variable favourable action	$\gamma_{Qf} = 0.00$

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

Soil parameter set	M1
Angle of shearing resistance	$\gamma_{\phi'} = 1.00$
Effective cohesion	$\gamma_{c'} = 1.00$
Weight density	$\gamma_r = 1.00$

Library item Partial factors output

Retained soil properties

Design moist density	$\gamma_{mr}' = \gamma_{mr} / \gamma_r = 15 \text{ kN/m}^3$
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_r = 15 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = 18 \text{ deg}$
Design wall friction angle	$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}) = 9 \text{ deg}$

Base soil properties

Design soil density	$\gamma_b' = \gamma_b / \gamma_r = 15 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi'}) = 18 \text{ deg}$
Design wall friction angle	$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi'}) = 9 \text{ deg}$
Design base friction angle	$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = 12 \text{ deg}$
Design effective cohesion	$c'_{b,d} = c'_{b,k} / \gamma_{c'} = 10 \text{ kN/m}^2$
Design adhesion	$a_{b,d} = a_{b,k} / \gamma_{c'} = 6.7 \text{ kN/m}^2$

Using Coulomb theory

Active pressure coefficient	$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}]^2) = 0.483$
Passive pressure coefficient	$K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) \times [1 - \sqrt{(\sin(\phi'_{b,d} + \delta_{b,d}) \times \sin(\phi'_{b,d} - \beta) / (\sin(90 + \delta_{b,d}))}]^2) = 2.359$

Sliding check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = 23.6 \text{ kN/m}$
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = 5.7 \text{ kN/m}$
Moist retained soil	$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = 3.9 \text{ kN/m}$
Total	$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} = 33.2 \text{ kN/m}$

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r,d}) \times \gamma_G \times \text{Surcharge}_G \times h_{eff} = 1.9 \text{ kN/m}$
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = 7 \text{ kN/m}$
Total	$F_{total_h} = F_{sur_h} + F_{moist_h} = 8.9 \text{ kN/m}$

Check stability against sliding

Base soil resistance	$F_{exc_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = 0.7 \text{ kN/m}$
----------------------	--

Project Unreinforced Block on Flat Retaining Wall				Job no.	
Calcs for				Start page no./Revision 4	
Calcs by KJ	Calcs date 13/05/2021	Checked by KJ	Checked date 13/05/2021	Approved by KJ	Approved date 13/05/2021

Base friction
Resistance to sliding
Factor of safety

$$F_{\text{friction}} = a_{b,d} \times l_{\text{base}} + F_{\text{total}_v} \times \tan(\delta_{bb,d}) = \mathbf{14.7 \text{ kN/m}}$$

$$F_{\text{rest}} = F_{\text{exc}_h} + F_{\text{friction}} = \mathbf{15.4 \text{ kN/m}}$$

$$F_{\text{oSsl}} = F_{\text{rest}} / F_{\text{total}_h} = \mathbf{1.736}$$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma_{\text{Gf}} \times A_{\text{stem}} \times \gamma_{\text{stem}} = \mathbf{23.6 \text{ kN/m}}$$

Wall base

$$F_{\text{base}} = \gamma_{\text{Gf}} \times A_{\text{base}} \times \gamma_{\text{base}} = \mathbf{5.7 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_v} = \gamma_{\text{Gf}} \times A_{\text{moist}} \times \gamma_{\text{mr}'} = \mathbf{3.9 \text{ kN/m}}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{moist}_v} = \mathbf{33.2 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A \times \cos(\delta_{r,d}) \times \gamma_{\text{G}} \times \text{Surcharge}_{\text{G}} \times h_{\text{eff}} = \mathbf{1.9 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma_{\text{G}} \times K_A \times \cos(\delta_{r,d}) \times \gamma_{\text{mr}'} \times h_{\text{eff}}^2 / 2 = \mathbf{7 \text{ kN/m}}$$

Base soil

$$F_{\text{exc}_h} = -\gamma_{\text{Gf}} \times K_P \times \cos(\delta_{b,d}) \times \gamma_{\text{b}'} \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = \mathbf{-0.7 \text{ kN/m}}$$

Total

$$F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{moist}_h} + F_{\text{exc}_h} = \mathbf{8.2 \text{ kN/m}}$$

Overturning moments on wall

Surcharge load

$$M_{\text{sur}_OT} = F_{\text{sur}_h} \times X_{\text{sur}_h} = \mathbf{1.2 \text{ kNm/m}}$$

Moist retained soil

$$M_{\text{moist}_OT} = F_{\text{moist}_h} \times X_{\text{moist}_h} = \mathbf{2.8 \text{ kNm/m}}$$

Total

$$M_{\text{total}_OT} = M_{\text{sur}_OT} + M_{\text{moist}_OT} = \mathbf{3.9 \text{ kNm/m}}$$

Restoring moments on wall

Wall stem

$$M_{\text{stem}_R} = F_{\text{stem}} \times X_{\text{stem}} = \mathbf{13.4 \text{ kNm/m}}$$

Wall base

$$M_{\text{base}_R} = F_{\text{base}} \times X_{\text{base}} = \mathbf{3.3 \text{ kNm/m}}$$

Moist retained soil

$$M_{\text{moist}_R} = F_{\text{moist}_v} \times X_{\text{moist}_v} = \mathbf{3.9 \text{ kNm/m}}$$

Base soil

$$M_{\text{exc}_R} = -F_{\text{exc}_h} \times X_{\text{exc}_h} = \mathbf{0 \text{ kNm/m}}$$

Total

$$M_{\text{total}_R} = M_{\text{stem}_R} + M_{\text{base}_R} + M_{\text{moist}_R} + M_{\text{exc}_R} = \mathbf{20.6 \text{ kNm/m}}$$

Check stability against overturning

Factor of safety

$$F_{\text{oSot}} = M_{\text{total}_R} / M_{\text{total}_OT} = \mathbf{5.226}$$

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma_{\text{G}} \times A_{\text{stem}} \times \gamma_{\text{stem}} = \mathbf{31.9 \text{ kN/m}}$$

Wall base

$$F_{\text{base}} = \gamma_{\text{G}} \times A_{\text{base}} \times \gamma_{\text{base}} = \mathbf{7.7 \text{ kN/m}}$$

Surcharge load

$$F_{\text{sur}_v} = \gamma_{\text{G}} \times \text{Surcharge}_{\text{G}} \times (l_{\text{heel}} + t_{s1} - t_{s2}) = \mathbf{0.9 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_v} = \gamma_{\text{G}} \times A_{\text{moist}} \times \gamma_{\text{mr}'} = \mathbf{5.2 \text{ kN/m}}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{sur}_v} + F_{\text{moist}_v} = \mathbf{45.8 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A \times \cos(\delta_{r,d}) \times \gamma_{\text{G}} \times \text{Surcharge}_{\text{G}} \times h_{\text{eff}} = \mathbf{1.9 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma_{\text{G}} \times K_A \times \cos(\delta_{r,d}) \times \gamma_{\text{mr}'} \times h_{\text{eff}}^2 / 2 = \mathbf{7 \text{ kN/m}}$$

Base soil

$$F_{\text{pass}_h} = -\gamma_{\text{Gf}} \times K_P \times \cos(\delta_{b,d}) \times \gamma_{\text{b}'} \times (d_{\text{cover}} + h_{\text{base}})^2 / 2 = \mathbf{-0.7 \text{ kN/m}}$$

Total

$$F_{\text{total}_h} = \max(F_{\text{sur}_h} + F_{\text{moist}_h} + F_{\text{pass}_h} - (a_{b,d} \times b + F_{\text{total}_v} \times \tan(\delta_{bb,d})), 0 \text{ kN/m}) = \mathbf{0 \text{ kN/m}}$$

Moments on wall

Wall stem

$$M_{\text{stem}} = F_{\text{stem}} \times X_{\text{stem}} = \mathbf{18 \text{ kNm/m}}$$

Project Unreinforced Block on Flat Retaining Wall				Job no.	
Calcs for				Start page no./Revision 5	
Calcs by KJ	Calcs date 13/05/2021	Checked by KJ	Checked date 13/05/2021	Approved by KJ	Approved date 13/05/2021

Wall base $M_{base} = F_{base} \times X_{base} = 4.4 \text{ kNm/m}$
 Surcharge load $M_{sur} = F_{sur_v} \times X_{sur_v} - F_{sur_h} \times X_{sur_h} = -0.2 \text{ kNm/m}$
 Moist retained soil $M_{moist} = F_{moist_v} \times X_{moist_v} - F_{moist_h} \times X_{moist_h} = 2.5 \text{ kNm/m}$
 Base soil $M_{pass} = -F_{pass_h} \times X_{pass_h} = 0 \text{ kNm/m}$
 Total $M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} + M_{pass} = 24.8 \text{ kNm/m}$

Check bearing pressure

Distance to reaction $\bar{X} = M_{total} / F_{total_v} = 542 \text{ mm}$
 Eccentricity of reaction $e = \bar{X} - l_{base} / 2 = -31 \text{ mm}$
 Loaded length of base $l_{load} = 2 \times \bar{X} = 1083 \text{ mm}$
 Bearing pressure at toe $q_{toe} = F_{total_v} / l_{load} = 42.3 \text{ kN/m}^2$
 Bearing pressure at heel $q_{heel} = 0 \text{ kN/m}^2$
 Effective overburden pressure $q = (t_{base} + d_{cover}) \times \gamma'_b = 3 \text{ kN/m}^2$
 Design effective overburden pressure $q' = q / \gamma_\gamma = 3 \text{ kN/m}^2$
 Bearing resistance factors $N_q = \text{Exp}(\pi \times \tan(\phi'_{b,d})) \times (\tan(45 \text{ deg} + \phi'_{b,d} / 2))^2 = 5.258$
 $N_c = (N_q - 1) \times \cot(\phi'_{b,d}) = 13.104$
 $N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b,d}) = 2.767$

Foundation shape factors

$S_q = 1$
 $S_\gamma = 1$
 $S_c = 1$

Load inclination factors

$H = F_{sur_h} + F_{moist_h} + F_{pass_h} = 8.2 \text{ kN/m}$
 $V = F_{total_v} = 45.8 \text{ kN/m}$
 $m = 2$
 $i_q = [1 - H / (V + l_{load} \times c'_{b,d} \times \cot(\phi'_{b,d}))]^m = 0.804$
 $i_\gamma = [1 - H / (V + l_{load} \times c'_{b,d} \times \cot(\phi'_{b,d}))]^{(m+1)} = 0.721$
 $i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b,d})) = 0.758$

Net ultimate bearing capacity

$$n_f = c'_{b,d} \times N_c \times S_c \times i_c + q' \times N_q \times S_q \times i_q + 0.5 \times \gamma'_b \times l_{load} \times N_\gamma \times S_\gamma \times i_\gamma = 128.2 \text{ kN/m}^2$$

Factor of safety

$$FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) = 3.033$$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Design approach 1

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

Partial factor set A2
 Permanent unfavourable action $\gamma_G = 1.00$
 Permanent favourable action $\gamma_{Gf} = 1.00$
 Variable unfavourable action $\gamma_Q = 1.30$
 Variable favourable action $\gamma_{Qf} = 0.00$

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

Soil parameter set M2
 Angle of shearing resistance $\gamma_\phi = 1.25$
 Effective cohesion $\gamma_{c'} = 1.25$
 Weight density $\gamma_\gamma = 1.00$

Library item Partial factors output

Retained soil properties

Design moist density $\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma = 15 \text{ kN/m}^3$

Project Unreinforced Block on Flat Retaining Wall				Job no.	
Calcs for				Start page no./Revision 6	
Calcs by KJ	Calcs date 13/05/2021	Checked by KJ	Checked date 13/05/2021	Approved by KJ	Approved date 13/05/2021

Design saturated density
Design effective shear resistance angle
Design wall friction angle

$$\gamma_{sr}' = \gamma_{sr} / \gamma_f = \mathbf{15 \text{ kN/m}^3}$$

$$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_\phi) = \mathbf{14.6 \text{ deg}}$$

$$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_\phi) = \mathbf{7.2 \text{ deg}}$$

Base soil properties

Design soil density
Design effective shear resistance angle
Design wall friction angle
Design base friction angle
Design effective cohesion
Design adhesion

$$\gamma_b' = \gamma_b / \gamma_f = \mathbf{15 \text{ kN/m}^3}$$

$$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_\phi) = \mathbf{14.6 \text{ deg}}$$

$$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_\phi) = \mathbf{7.2 \text{ deg}}$$

$$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_\phi) = \mathbf{9.7 \text{ deg}}$$

$$c'_{b,d} = c'_{b,k} / \gamma_c = \mathbf{8 \text{ kN/m}^2}$$

$$a_{b,d} = a_{b,k} / \gamma_c = \mathbf{5.4 \text{ kN/m}^2}$$

Using Coulomb theory

Active pressure coefficient

$$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{[\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))]}]) = \mathbf{0.553}$$

Passive pressure coefficient

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

Sliding check

Vertical forces on wall

Wall stem
Wall base
Moist retained soil
Total

$$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = \mathbf{23.6 \text{ kN/m}}$$

$$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = \mathbf{5.7 \text{ kN/m}}$$

$$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = \mathbf{3.9 \text{ kN/m}}$$

$$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} = \mathbf{33.2 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load
Moist retained soil
Total

$$F_{sur_h} = K_A \times \cos(\delta_{r,d}) \times \gamma_G \times \text{Surcharge}_G \times h_{eff} = \mathbf{1.6 \text{ kN/m}}$$

$$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = \mathbf{5.9 \text{ kN/m}}$$

$$F_{total_h} = F_{sur_h} + F_{moist_h} = \mathbf{7.6 \text{ kN/m}}$$

Check stability against sliding

Base soil resistance
Base friction
Resistance to sliding
Factor of safety

$$F_{exc_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = \mathbf{0.6 \text{ kN/m}}$$

$$F_{friction} = a_{b,d} \times l_{base} + F_{total_v} \times \tan(\delta_{bb,d}) = \mathbf{11.8 \text{ kN/m}}$$

$$F_{rest} = F_{exc_h} + F_{friction} = \mathbf{12.4 \text{ kN/m}}$$

$$FoS_{sl} = F_{rest} / F_{total_h} = \mathbf{1.634}$$

PASS - Resistance to sliding is greater than sliding force

Overtuning check

Vertical forces on wall

Wall stem
Wall base
Moist retained soil
Total

$$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = \mathbf{23.6 \text{ kN/m}}$$

$$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = \mathbf{5.7 \text{ kN/m}}$$

$$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = \mathbf{3.9 \text{ kN/m}}$$

$$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} = \mathbf{33.2 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load
Moist retained soil
Base soil
Total

$$F_{sur_h} = K_A \times \cos(\delta_{r,d}) \times \gamma_G \times \text{Surcharge}_G \times h_{eff} = \mathbf{1.6 \text{ kN/m}}$$

$$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = \mathbf{5.9 \text{ kN/m}}$$

$$F_{exc_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = \mathbf{-0.6 \text{ kN/m}}$$

$$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} = \mathbf{7 \text{ kN/m}}$$

Project Unreinforced Block on Flat Retaining Wall				Job no.	
Calcs for				Start page no./Revision 7	
Calcs by KJ	Calcs date 13/05/2021	Checked by KJ	Checked date 13/05/2021	Approved by KJ	Approved date 13/05/2021

Overturning moments on wall

Surcharge load	$M_{sur_OT} = F_{sur_h} \times X_{sur_h} = 1 \text{ kNm/m}$
Moist retained soil	$M_{moist_OT} = F_{moist_h} \times X_{moist_h} = 2.4 \text{ kNm/m}$
Total	$M_{total_OT} = M_{sur_OT} + M_{moist_OT} = 3.4 \text{ kNm/m}$

Restoring moments on wall

Wall stem	$M_{stem_R} = F_{stem} \times X_{stem} = 13.4 \text{ kNm/m}$
Wall base	$M_{base_R} = F_{base} \times X_{base} = 3.3 \text{ kNm/m}$
Moist retained soil	$M_{moist_R} = F_{moist_v} \times X_{moist_v} = 3.9 \text{ kNm/m}$
Base soil	$M_{exc_R} = -F_{exc_h} \times X_{exc_h} = 0 \text{ kNm/m}$
Total	$M_{total_R} = M_{stem_R} + M_{base_R} + M_{moist_R} + M_{exc_R} = 20.6 \text{ kNm/m}$

Check stability against overturning

Factor of safety	$FoS_{ot} = M_{total_R} / M_{total_OT} = 6.135$
------------------	---

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} = 23.6 \text{ kN/m}$
Wall base	$F_{base} = \gamma_G \times A_{base} \times \gamma_{base} = 5.7 \text{ kN/m}$
Surcharge load	$F_{sur_v} = \gamma_G \times \text{Surcharge}_G \times (l_{heel} + t_{s1} - t_{s2}) = 0.7 \text{ kN/m}$
Moist retained soil	$F_{moist_v} = \gamma_G \times A_{moist} \times \gamma_{mr}' = 3.9 \text{ kN/m}$
Total	$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{moist_v} = 33.9 \text{ kN/m}$

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r,d}) \times \gamma_G \times \text{Surcharge}_G \times h_{eff} = 1.6 \text{ kN/m}$
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = 5.9 \text{ kN/m}$
Base soil	$F_{pass_h} = -\gamma_{gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_{b'} \times (d_{cover} + h_{base})^2 / 2 = -0.6 \text{ kN/m}$
Total	$F_{total_h} = \max(F_{sur_h} + F_{moist_h} + F_{pass_h} - (a_{b,d} \times b + F_{total_v} \times \tan(\delta_{bb,d})), 0 \text{ kN/m}) = 0 \text{ kN/m}$

Moments on wall

Wall stem	$M_{stem} = F_{stem} \times X_{stem} = 13.4 \text{ kNm/m}$
Wall base	$M_{base} = F_{base} \times X_{base} = 3.3 \text{ kNm/m}$
Surcharge load	$M_{sur} = F_{sur_v} \times X_{sur_v} - F_{sur_h} \times X_{sur_h} = -0.3 \text{ kNm/m}$
Moist retained soil	$M_{moist} = F_{moist_v} \times X_{moist_v} - F_{moist_h} \times X_{moist_h} = 1.6 \text{ kNm/m}$
Base soil	$M_{pass} = -F_{pass_h} \times X_{pass_h} = 0 \text{ kNm/m}$
Total	$M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} + M_{pass} = 17.9 \text{ kNm/m}$

Check bearing pressure

Distance to reaction	$\bar{x} = M_{total} / F_{total_v} = 529 \text{ mm}$
Eccentricity of reaction	$e = \bar{x} - l_{base} / 2 = -44 \text{ mm}$
Loaded length of base	$l_{load} = 2 \times \bar{x} = 1058 \text{ mm}$
Bearing pressure at toe	$q_{toe} = F_{total_v} / l_{load} = 32.1 \text{ kN/m}^2$
Bearing pressure at heel	$q_{heel} = 0 \text{ kN/m}^2$
Effective overburden pressure	$q = (t_{base} + d_{cover}) \times \gamma_{b'} = 3 \text{ kN/m}^2$
Design effective overburden pressure	$q' = q / \gamma_{\gamma} = 3 \text{ kN/m}^2$
Bearing resistance factors	$N_q = \text{Exp}(\pi \times \tan(\phi'_{b,d})) \times (\tan(45 \text{ deg} + \phi'_{b,d} / 2))^2 = 3.784$
	$N_c = (N_q - 1) \times \cot(\phi'_{b,d}) = 10.711$

Project Unreinforced Block on Flat Retaining Wall				Job no.	
Calcs for				Start page no./Revision 8	
Calcs by KJ	Calcs date 13/05/2021	Checked by KJ	Checked date 13/05/2021	Approved by KJ	Approved date 13/05/2021

Foundation shape factors	$N_{\gamma} = 2 \times (N_q - 1) \times \tan(\phi'_{b,d}) = \mathbf{1.447}$ $S_q = 1$ $S_{\gamma} = 1$ $S_c = 1$
Load inclination factors	$H = F_{sur,h} + F_{moist,h} + F_{pass,h} = \mathbf{7 \text{ kN/m}}$ $V = F_{total,v} = \mathbf{33.9 \text{ kN/m}}$ $m = 2$ $i_q = [1 - H / (V + I_{load} \times c'_{b,d} \times \cot(\phi'_{b,d}))]^m = \mathbf{0.801}$ $i_{\gamma} = [1 - H / (V + I_{load} \times c'_{b,d} \times \cot(\phi'_{b,d}))]^{(m+1)} = \mathbf{0.717}$ $i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b,d})) = \mathbf{0.729}$
Net ultimate bearing capacity	
	$n_f = c'_{b,d} \times N_c \times S_c \times i_c + q' \times N_q \times S_q \times i_q + 0.5 \times \gamma'_b \times I_{load} \times N_{\gamma} \times S_{\gamma} \times i_{\gamma} = \mathbf{79.8 \text{ kN/m}^2}$
Factor of safety	$FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) = \mathbf{2.49}$ <i>PASS - Allowable bearing pressure exceeds maximum applied bearing pressure</i>

RETAINING WALL DESIGN

In accordance with EN1992-1-1:2004 incorporating Corrigendum dated January 2008 and the UK National Annex incorporating National Amendment No.1 and EN1996-1-1:2005 incorporating Corrigenda dated February 2006 and July 2009 and the UK National Annex

Tedds calculation version 2.9.11

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

Concrete strength class	C30/37
Characteristic compressive cylinder strength	$f_{ck} = \mathbf{30 \text{ N/mm}^2}$
Characteristic compressive cube strength	$f_{ck,cube} = \mathbf{37 \text{ N/mm}^2}$
Mean value of compressive cylinder strength	$f_{cm} = f_{ck} + 8 \text{ N/mm}^2 = \mathbf{38 \text{ N/mm}^2}$
Mean value of axial tensile strength	$f_{ctm} = 0.3 \text{ N/mm}^2 \times (f_{ck} / 1 \text{ N/mm}^2)^{2/3} = \mathbf{2.9 \text{ N/mm}^2}$
5% fractile of axial tensile strength	$f_{ctk,0.05} = 0.7 \times f_{ctm} = \mathbf{2.0 \text{ N/mm}^2}$
Secant modulus of elasticity of concrete	$E_{cm} = 22 \text{ kN/mm}^2 \times (f_{cm} / 10 \text{ N/mm}^2)^{0.3} = \mathbf{32837 \text{ N/mm}^2}$
Partial factor for concrete - Table 2.1N	$\gamma_c = \mathbf{1.50}$
Compressive strength coefficient - cl.3.1.6(1)	$\alpha_{cc} = \mathbf{0.85}$
Design compressive concrete strength - exp.3.15	$f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_c = \mathbf{17.0 \text{ N/mm}^2}$
Maximum aggregate size	$h_{agg} = \mathbf{20 \text{ mm}}$
Ultimate strain - Table 3.1	$\epsilon_{cu2} = \mathbf{0.0035}$
Shortening strain - Table 3.1	$\epsilon_{cu3} = \mathbf{0.0035}$
Effective compression zone height factor	$\lambda = \mathbf{0.80}$
Effective strength factor	$\eta = \mathbf{1.00}$
Bending coefficient k_1	$K_1 = \mathbf{0.40}$
Bending coefficient k_2	$K_2 = 1.00 \times (0.6 + 0.0014/\epsilon_{cu2}) = \mathbf{1.00}$
Bending coefficient k_3	$K_3 = \mathbf{0.40}$
Bending coefficient k_4	$K_4 = 1.00 \times (0.6 + 0.0014/\epsilon_{cu2}) = \mathbf{1.00}$

Reinforcement details

Characteristic yield strength of reinforcement	$f_{yk} = \mathbf{500 \text{ N/mm}^2}$
Modulus of elasticity of reinforcement	$E_s = \mathbf{200000 \text{ N/mm}^2}$
Partial factor for reinforcing steel - Table 2.1N	$\gamma_s = \mathbf{1.15}$
Design yield strength of reinforcement	$f_{yd} = f_{yk} / \gamma_s = \mathbf{435 \text{ N/mm}^2}$

Project Unreinforced Block on Flat Retaining Wall				Job no.	
Calcs for				Start page no./Revision 9	
Calcs by KJ	Calcs date 13/05/2021	Checked by KJ	Checked date 13/05/2021	Approved by KJ	Approved date 13/05/2021

Cover to reinforcement

Top face of base

$C_{bt} = 50 \text{ mm}$

Bottom face of base

$C_{bb} = 75 \text{ mm}$

Masonry details - Section 3.1

Masonry type

Aggregate concrete - Group 1

Normalised mean compressive strength

$f_b = 10.4 \text{ N/mm}^2$

Characteristic flexural strength - cl.6.3.4(1)

$f_{xk} = 0 \text{ N/mm}^2$

Initial shear strength - Table NA.5

$f_{vko} = 0.15 \text{ N/mm}^2$

Mortar details - Section 3.2

Mortar type

General purpose - M6, prescribed mix

Compressive strength of mortar

$f_m = 6 \text{ N/mm}^2$

Ultimate limit states - Table NA.1

Class of execution control

1

Category of manufacture control

1

Partial factor for direct or flexural compression

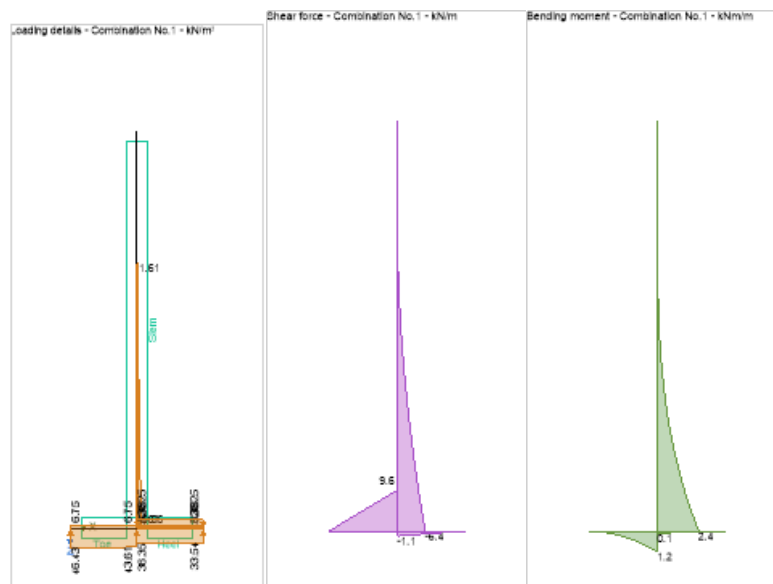
$\gamma_{Mc} = 2.3$

Partial factor for flexural tension

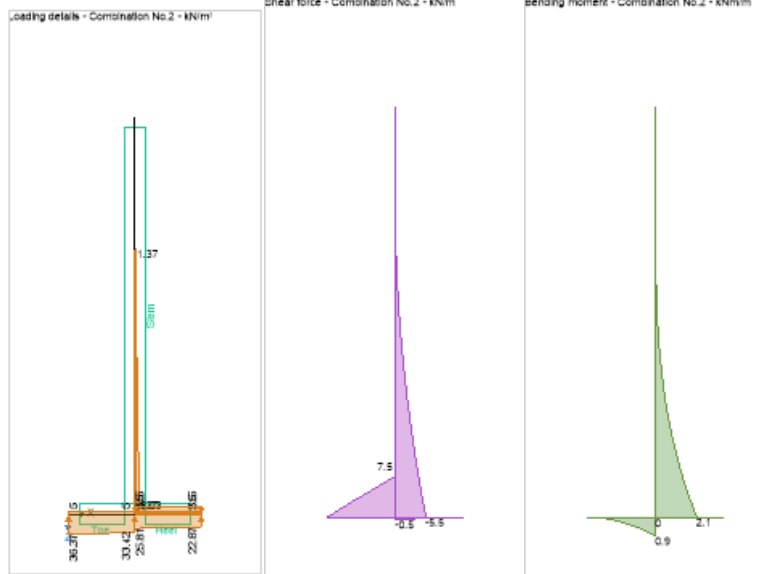
$\gamma_{Mt} = 2.3$

Partial factor for shear

$\gamma_{Mv} = 2.5$



Project Unreinforced Block on Flat Retaining Wall				Job no.	
Calcs for				Start page no./Revision 10	
Calcs by KJ	Calcs date 13/05/2021	Checked by KJ	Checked date 13/05/2021	Approved by KJ	Approved date 13/05/2021



Check stem design at base of stem

Depth of section

t = 645 mm

Masonry characteristics

Compressive strength constants - Table NA.4

K = 0.550

Characteristic compressive strength - cl.3.6.1.2(1)

$f_k = K \times f_b^{0.7} \times f_m^{0.3} = \mathbf{4.85 \text{ N/mm}^2}$

Design compressive strength

$f_d = f_k / \gamma_{Mc} = \mathbf{2.109 \text{ N/mm}^2}$

Design flexural strength

$f_{xd} = f_{xk} / \gamma_{Mt} = \mathbf{0 \text{ N/mm}^2}$

Height of masonry

$h_{wt} = h_{stem} = 1500 \text{ mm}$

Compressive axial force combination 1

$F_x = \gamma_{Gf} \times \gamma_{stem} \times (h_{s1} \times t_{s1} + h_{s2} \times t_{s2}) = \mathbf{23.6 \text{ kN/m}}$

Moment combination 1

$M_x = \gamma_{Gf} \times \gamma_{stem} \times (h_{s1} \times t_{s1} \times t_{s1} / 2 + h_{s2} \times t_{s2} \times t_{s2} / 2) = \mathbf{7.4 \text{ kNm/m}}$

Eccentricity of axial load

$e = \max(\text{abs}(t / 2 - M_x / F_x), 0.05 \times t) = \mathbf{32.3 \text{ mm}}$

Capacity reduction factor - exp.6.4

$\Phi = 1 - 2 \times e / t = \mathbf{0.9}$

Design vertical resistance - exp.6.2

$N_{Rd} = \Phi \times t \times f_d = \mathbf{1224.1 \text{ kN/m}}$

Design vertical compressive stress

$\sigma_d = \min(F_x / t, 0.15 \times N_{Rd} / t) = \mathbf{0.037 \text{ N/mm}^2}$

Apparent design flexural strength - exp.6.16

$f_{xd,app} = f_{xd} + \sigma_d = \mathbf{0.037 \text{ N/mm}^2}$

Limit of charact. shear strength - exp. 3.1

$f_{vk,lim} = 0.065 \times f_b = \mathbf{0.676 \text{ N/mm}^2}$

Characteristic shear strength - exp.3.5

$f_{vk} = \min(f_{vko} + 0.4 \times \sigma_d, f_{vk,lim}) = \mathbf{0.165 \text{ N/mm}^2}$

Design shear strength

$f_{vd} = f_{vk} / \gamma_{Mv} = \mathbf{0.066 \text{ N/mm}^2}$

Library item: Masonry characteristics output

Unreinforced masonry walls subjected to lateral loading - Section 6.3

Design bending moment combination 1

M = 2.415 kNm/m

Elastic section modulus of wall

Z = t² / 6 = 69337500 mm³/m

Moment of resistance of masonry - exp.6.15

M_{Rd} = f_{xd,app} × Z = 2.54 kNm/m

M / M_{Rd} = 0.951

PASS - Moment of resistance exceeds applied design moment

Unreinforced masonry walls subjected to shear loading - Section 6.2

Design shear force

V = 6.441 kN/m

Maximum compressive stress

$\sigma_{max} = F_x / t + M / Z = \mathbf{0.071 \text{ N/mm}^2}$

Minimum compressive stress

$\sigma_{min} = F_x / t - M / Z = \mathbf{0.002 \text{ N/mm}^2}$

Project Unreinforced Block on Flat Retaining Wall				Job no.	
Calcs for				Start page no./Revision 11	
Calcs by KJ	Calcs date 13/05/2021	Checked by KJ	Checked date 13/05/2021	Approved by KJ	Approved date 13/05/2021

Thickness of wall in compression
Design shear resistance - exp.6.13

$$t_c = t = \mathbf{645 \text{ mm}}$$

$$V_{Rd} = f_{vd} \times t_c = \mathbf{42.48 \text{ kN/m}}$$

$$V / V_{Rd} = \mathbf{0.152}$$

PASS - Design shear resistance exceeds applied design shear force

Check stem design at 750 mm

Depth of section

$$t = \mathbf{615 \text{ mm}}$$

Masonry characteristics

Compressive strength constants - Table NA.4

$$K = 0.550$$

Characteristic compressive strength - cl.3.6.1.2(1)

$$f_k = K \times f_b^{0.7} \times f_m^{0.3} = \mathbf{4.85 \text{ N/mm}^2}$$

Design compressive strength

$$f_d = f_k / \gamma_{Mc} = \mathbf{2.109 \text{ N/mm}^2}$$

Design flexural strength

$$f_{xd} = f_{xk} / \gamma_{Mt} = \mathbf{0 \text{ N/mm}^2}$$

Height of masonry

$$h_{wt} = h_{stem} - 750 \text{ mm} = \mathbf{750 \text{ mm}}$$

Compressive axial force combination 1

$$F_x = \gamma_{Gf} \times \gamma_{stem} \times h_{s2} \times t_{s2} = \mathbf{11.5 \text{ kN/m}}$$

Moment combination 1

$$M_x = \gamma_{Gf} \times \gamma_{stem} \times h_{s2} \times t_{s2} \times t_{s2} / 2 = \mathbf{3.5 \text{ kNm/m}}$$

Eccentricity of axial load

$$e = \max(\text{abs}(t / 2 - M_x / F_x), 0.05 \times t) = \mathbf{30.8 \text{ mm}}$$

Capacity reduction factor - exp.6.4

$$\Phi = 1 - 2 \times e / t = \mathbf{0.9}$$

Design vertical resistance - exp.6.2

$$N_{Rd} = \Phi \times t \times f_d = \mathbf{1167.1 \text{ kN/m}}$$

Design vertical compressive stress

$$\sigma_d = \min(F_x / t, 0.15 \times N_{Rd} / t) = \mathbf{0.019 \text{ N/mm}^2}$$

Apparent design flexural strength - exp.6.16

$$f_{xd,app} = f_{xd} + \sigma_d = \mathbf{0.019 \text{ N/mm}^2}$$

Limit of charact. shear strength - exp. 3.1

$$f_{vk,lim} = 0.065 \times f_b = \mathbf{0.676 \text{ N/mm}^2}$$

Characteristic shear strength - exp.3.5

$$f_{vk} = \min(f_{vko} + 0.4 \times \sigma_d, f_{vk,lim}) = \mathbf{0.158 \text{ N/mm}^2}$$

Design shear strength

$$f_{vd} = f_{vk} / \gamma_{Mv} = \mathbf{0.063 \text{ N/mm}^2}$$

Library item: Masonry characteristics output

Unreinforced masonry walls subjected to lateral loading - Section 6.3

Design bending moment combination 1

$$M = \mathbf{0.075 \text{ kNm/m}}$$

Elastic section modulus of wall

$$Z = t^2 / 6 = \mathbf{63037500 \text{ mm}^3/\text{m}}$$

Moment of resistance of masonry - exp.6.15

$$M_{Rd} = f_{xd,app} \times Z = \mathbf{1.182 \text{ kNm/m}}$$

$$M / M_{Rd} = \mathbf{0.064}$$

PASS - Moment of resistance exceeds applied design moment

Unreinforced masonry walls subjected to shear loading - Section 6.2

Design shear force

$$V = \mathbf{0.704 \text{ kN/m}}$$

Maximum compressive stress

$$\sigma_{max} = F_x / t + M / Z = \mathbf{0.020 \text{ N/mm}^2}$$

Minimum compressive stress

$$\sigma_{min} = F_x / t - M / Z = \mathbf{0.018 \text{ N/mm}^2}$$

Thickness of wall in compression

$$t_c = t = \mathbf{615 \text{ mm}}$$

Design shear resistance - exp.6.13

$$V_{Rd} = f_{vd} \times t_c = \mathbf{38.745 \text{ kN/m}}$$

$$V / V_{Rd} = \mathbf{0.018}$$

PASS - Design shear resistance exceeds applied design shear force

Check base design at toe

Depth of section

$$h = \mathbf{200 \text{ mm}}$$

Rectangular section in flexure - Section 6.1

Design bending moment combination 1

$$M = \mathbf{1.2 \text{ kNm/m}}$$

Depth to tension reinforcement

$$d = h - c_{bb} - \phi_{bb} / 2 = \mathbf{117 \text{ mm}}$$

$$K = M / (d^2 \times f_{ck}) = \mathbf{0.003}$$

$$K' = (2 \times \eta \times \alpha_{cc} / \gamma_c) \times (1 - \lambda \times (\delta - K_1) / (2 \times K_2)) \times (\lambda \times (\delta - K_1) / (2 \times K_2))$$

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

Project Unreinforced Block on Flat Retaining Wall				Job no.	
Calcs for				Start page no./Revision 12	
Calcs by KJ	Calcs date 13/05/2021	Checked by KJ	Checked date 13/05/2021	Approved by KJ	Approved date 13/05/2021

$K' > K$ - No compression reinforcement is required

Lever arm	$z = d \times \min(1 - 0.5 \times A_{sr1,prov} \times f_{yd} / (d \times f_d), 0.95) = 77 \text{ mm}$
Depth of neutral axis	$x = 2.5 \times (d - z) = 101 \text{ mm}$
Area of tension reinforcement required	$A_{bb,req} = M / (f_{yd} \times z) = 36 \text{ mm}^2/\text{m}$
Tension reinforcement provided	16 dia.bars @ 300 c/c
Area of tension reinforcement provided	$A_{bb,prov} = \pi \times \phi_{bb}^2 / (4 \times S_{bb}) = 670 \text{ mm}^2/\text{m}$
Minimum area of reinforcement - exp.9.1N	$A_{bb,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = 176 \text{ mm}^2/\text{m}$
Maximum area of reinforcement - cl.9.2.1.1(3)	$A_{bb,max} = 0.04 \times h = 8000 \text{ mm}^2/\text{m}$
	$\max(A_{bb,req}, A_{bb,min}) / A_{bb,prov} = 0.263$

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

Library item: Rectangular single output

Crack control - Section 7.3

Limiting crack width	$w_{max} = 0.3 \text{ mm}$
Variable load factor - EN1990 – Table A1.1	$\psi_2 = 0.6$
Serviceability bending moment	$M_{sls} = 0.9 \text{ kNm/m}$
Tensile stress in reinforcement	$\sigma_s = M_{sls} / (A_{bb,prov} \times z) = 17.5 \text{ N/mm}^2$
Load duration	Long term
Load duration factor	$k_t = 0.4$
Effective area of concrete in tension	$A_{c,eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$ $A_{c,eff} = 32929 \text{ mm}^2/\text{m}$
Mean value of concrete tensile strength	$f_{ct,eff} = f_{ctm} = 2.9 \text{ N/mm}^2$
Reinforcement ratio	$\rho_{p,eff} = A_{bb,prov} / A_{c,eff} = 0.020$
Modular ratio	$\alpha_e = E_s / E_{cm} = 6.091$
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	$s_{r,max} = k_3 \times C_{bb} + k_1 \times k_2 \times k_4 \times \phi_{bb} / \rho_{p,eff} = 389 \text{ mm}$
Maximum crack width - exp.7.8	$w_k = s_{r,max} \times \max(\sigma_s - k_t \times (f_{ct,eff} / \rho_{p,eff}) \times (1 + \alpha_e \times \rho_{p,eff}), 0.6 \times \sigma_s) / E_s$ $w_k = 0.02 \text{ mm}$ $w_k / w_{max} = 0.068$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force	$V = 9.6 \text{ kN/m}$ $C_{Rd,c} = 0.18 / \gamma_c = 0.120$ $k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = 2.000$
Longitudinal reinforcement ratio	$\rho_l = \min(A_{bb,prov} / d, 0.02) = 0.006$ $v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = 0.542 \text{ N/mm}^2$
Design shear resistance - exp.6.2a & 6.2b	$V_{Rd,c} = \max(C_{Rd,c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$ $V_{Rd,c} = 72.5 \text{ kN/m}$ $V / V_{Rd,c} = 0.132$

PASS - Design shear resistance exceeds design shear force

Check base design at toe

Depth of section	$h = 200 \text{ mm}$
------------------	----------------------

Rectangular section in shear - Section 6.2

Design shear force	$V = 1.1 \text{ kN/m}$
--------------------	------------------------

Project Unreinforced Block on Flat Retaining Wall				Job no.	
Calcs for				Start page no./Revision 13	
Calcs by KJ	Calcs date 13/05/2021	Checked by KJ	Checked date 13/05/2021	Approved by KJ	Approved date 13/05/2021

Longitudinal reinforcement ratio

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

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

$$\rho_l = \min(A_{bt,prov} / d, 0.02) = \mathbf{0.006}$$

$$V_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = \mathbf{0.542 \text{ N/mm}^2}$$

Design shear resistance - exp.6.2a & 6.2b

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

$$V_{Rd,c} = \mathbf{72.5 \text{ kN/m}}$$

$$V / V_{Rd,c} = \mathbf{0.016}$$

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)

$$A_{bx,req} = 0.2 \times A_{bb,prov} = \mathbf{134 \text{ mm}^2/\text{m}}$$

Maximum spacing of reinforcement – cl.9.3.1.1(3)

$$S_{bx,max} = \mathbf{450 \text{ mm}}$$

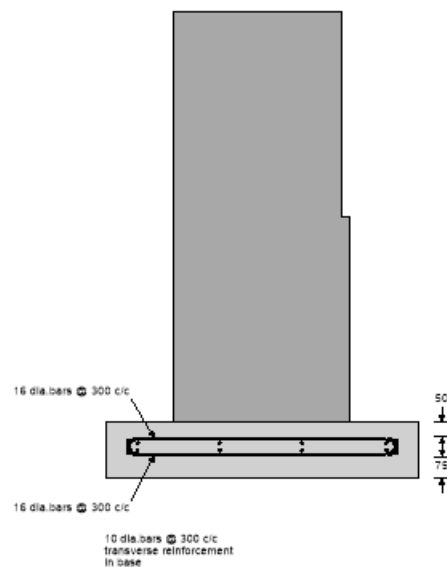
Transverse reinforcement provided

$$10 \text{ dia.bars @ } 300 \text{ c/c}$$

Area of transverse reinforcement provided

$$A_{bx,prov} = \pi \times \phi_{bx}^2 / (4 \times S_{bx}) = \mathbf{262 \text{ mm}^2/\text{m}}$$

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



Reinforcement details