

ING Design Limited, Railway House,
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131-133 Holcombe Rd

Retaining Wall Structural Calculations

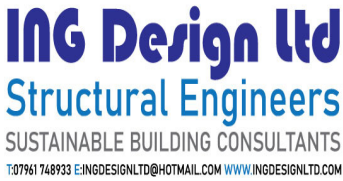
 ING Design Ltd Structural Engineers SUSTAINABLE BUILDING CONSULTANTS T:07961 748933 E:INGDESIGNLTD@HOTMAIL.COM WWW.INGDESIGNLTD.COM		Project		Job Ref.	
		131-133 Holcombe rd retaining wall calcs		J-21179	
		Section		Sheet no./rev.	
		Structural Calculations		1	
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SW	7/22	IG	7/22		

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INTRODUCTION:

The following calcs are for the structural elements of the proposed construction works at the above site.

In order to fully prepare these calculations it has been necessary to make some assumptions regarding the existing construction details and the prevailing ground conditions. These assumptions are indicated on the drawings and must be checked and confirmed by the Building Contractor prior to any major construction works being started.

The Building Contractor & Building Inspector are responsible for confirming that the assumed safe bearing pressure is a fair reflection of the prevailing ground conditions.

The following calculations should be read in conjunction with the drawings and the designers risk assessments.

REFERENCES

Element	Description	Code
Loadings	Dead Loads	BS648:1964
	Live Loads	BS6399:Part 1:1996
	Wind Loads	BS6399:Part 2:1997
	Drifting Snow Loads	BS6399:Part 3:1988
Materials	Structural Steel	BS EN 10 025:2004
	Cement	BS EN 197-1:2000
	Concrete	BS 8500:Part 1 2002
	Reinforcement	BS8666:2005
	Bricks	BS3921:1985
Steelwork	Simple frame construction	
	Composite beams	BS5950:Sect 3.1:1990
	Non-composite members	BS5950:Part 1:2000
Floors	Composite flooring	BS5950:Part 4:1994
Masonry	Wall panels	BS5628:Part 1:2005
	Loadbearing masonry	BS5628:Part 1:2005
	Cavity fill retaining walls	BS5628:Part 2:2005
Foundations	General	BS8004:1986
	Concrete pile caps	BS8110:Part 1:1997
Basements	Water retaining walls	BS8007:1987
Timber	Structural Framing	BS5268:Part 2

OTHER REFERENCES

Steel Designer's Manual
 Reinforced Concrete Designer's Manual
 Foundation Design and Construction
 Timber Designers' Manual
 Structural Masonry Designers' Manual
 Structural Engineers Pocket Book 1st Edition

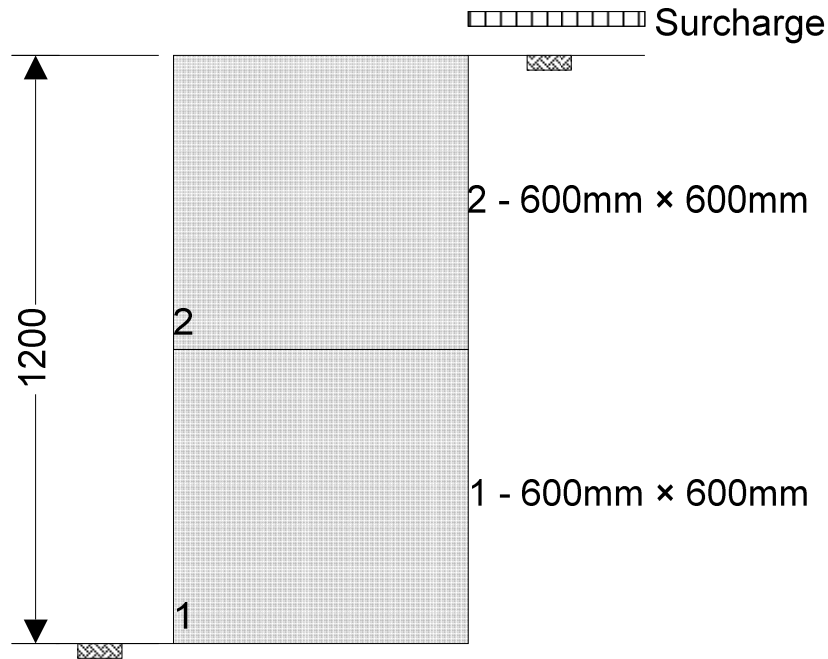
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GABION BASKET WALL DESIGN

GABION RETAINING WALL ANALYSIS & DESIGN

In accordance with EN 1997-1:2004 - Code of Practice for Geotechnical design and the UK National Annex

Tedds calculation version 2.0.02



Wall geometry

Width of gabion 1	$w_1 = 600 \text{ mm}$
Height of gabion 1	$h_1 = 600 \text{ mm}$
Width of gabion 2	$w_2 = 600 \text{ mm}$
Height of gabion 2	$h_2 = 600 \text{ mm}$
Step to front face between courses 1 and 2	$s_2 = 0 \text{ mm}$
Wall inclination	$\epsilon = 0 \text{ deg}$

Gabion properties

Unit weight of fill	$\gamma_d = 16.0 \text{ kN/m}^3$
Friction between gabions	$\delta_{bg,k} = 35.0 \text{ deg}$

Loading

Variable surcharge	$p_{o,Q} = 3 \text{ kN/m}^2$
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Soil properties

Slope of retained soil	$\beta = 0.0 \text{ deg}$
Characteristic effective shearing resistance angle	$\phi'_{r,k} = 35.0 \text{ deg}$
Characteristic saturated density of retained soil	$\gamma_{sr} = 21.0 \text{ kN/m}^3$
Coefficient for wall friction	$k_{\text{membrane}} = 0.75$
Wall friction angle	$\delta_{r,k} = 26.3 \text{ deg}$
Characteristic base friction angle	$\delta_{bb,k} = 35.0 \text{ deg}$
Bearing capacity of founding soil	$q = 100 \text{ kN/m}^2$

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Wall geometry

Horizontal distance to centre of gravity gabion 1	$x_{g1} = w_1 / 2 = \mathbf{300 \text{ mm}}$
Vertical distance to centre of gravity gabion 1	$y_{g1} = h_1 / 2 = \mathbf{300 \text{ mm}}$
Weight of gabion 1	$W_{g1} = \gamma_d \times w_1 \times h_1 = \mathbf{5.8 \text{ kN/m}}$
Horizontal distance to centre of gravity gabion 2	$x_{g2} = w_2 / 2 + s_2 = \mathbf{300 \text{ mm}}$
Vertical distance to centre of gravity gabion 2	$y_{g2} = h_2 / 2 + h_1 = \mathbf{900 \text{ mm}}$
Weight of gabion 2	$W_{g2} = \gamma_d \times w_2 \times h_2 = \mathbf{5.8 \text{ kN/m}}$
Weight of entire gabion	$W_g = W_{g1} + W_{g2} = \mathbf{11.5 \text{ kN/m}}$
Horiz distance to centre of gravity entire gabion	$x_g = ((W_{g1} \times x_{g1}) + (W_{g2} \times x_{g2})) / W_g = \mathbf{300 \text{ mm}}$
Vert distance to centre of gravity entire gabion	$y_g = ((W_{g1} \times y_{g1}) + (W_{g2} \times y_{g2})) / W_g = \mathbf{600 \text{ mm}}$
Correcting for wall inclination horiz dist	$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{300 \text{ mm}}$
Vertical change in height due to wall inclination	$H_f = y_{g2} + h_2/2 - ((y_{g2} + h_2/2) \times \cos(\epsilon) - (x_{g2} + w_2/2) \times \sin(\epsilon)) = \mathbf{0 \text{ mm}}$

Design dimensions

Effective angle of rear plane of wall	$\alpha = 90 \text{ deg} + \epsilon = \mathbf{90.0 \text{ deg}}$
Effective face angle	$\theta = 90 \text{ deg} - \epsilon = \mathbf{90.0 \text{ deg}}$
Effective height of wall	$H = (y_{g2} + h_2 / 2) + (w_1 \times \sin(\epsilon)) - H_f = \mathbf{1200 \text{ mm}}$
Height of wall from toe to front edge of top gabion	$H_{incl} = ((y_{g2} + h_2 / 2) \times \cos(\epsilon) - (x_{g2} - (w_2 / 2)) \times \sin(\epsilon)) = \mathbf{1200 \text{ mm}}$
Active pressure using Coulomb theory	$K_a = \sin(\alpha + \phi'_{r,k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,k}) \times (1 + \sqrt{(\sin(\phi'_{r,k} + \delta_{r,k}) \times \sin(\phi'_{r,k} - \beta) / (\sin(\alpha - \delta_{r,k}) \times \sin(\alpha + \beta))})^2) = \mathbf{0.245}$
Active thrust due to soil	$P_{a,soil} = 0.5 \times K_a \times \gamma_{sr} \times H^2 = \mathbf{3.7 \text{ kN/m}}$

Pressure at base

Horizontal forces

Retained soil	$F_{soil,h,q} = P_{a,soil} \times \cos(90 - \alpha + \delta_{r,k}) = \mathbf{3.3 \text{ kN/m}}$
Height of soil thrust resolved vertically	$d_{h,soil} = H / 3 - w_1 \times \sin(\epsilon) = \mathbf{400 \text{ mm}}$
Surcharge	$F_{surch,h,q} = p_{o,Q} \times K_a \times H \times \cos(90 - \alpha + \delta_{r,k}) = \mathbf{0.7 \text{ kN/m}}$
Height of surcharge thrust resolved vertically	$d_{h,surch} = H / 2 - w_1 \times \sin(\epsilon) = \mathbf{600 \text{ mm}}$

Vertical forces

Gabion weight	$F_{gabion,v,q} = W_g = \mathbf{11.5 \text{ kN/m}}$
Retained soil	$F_{soil,v,q} = P_{a,soil} \times \sin(90 - \alpha + \delta_{r,k}) = \mathbf{1.6 \text{ kN/m}}$
Horizontal dist to where soil thrust acts	$b_{v,soil} = w_1 \times \cos(\epsilon) - (H / 3) / \tan(\alpha) = \mathbf{600 \text{ mm}}$
Surcharge	$F_{surch,v,q} = p_{o,Q} \times K_a \times H \times \sin(90 - \alpha + \delta_{r,k}) = \mathbf{0.3 \text{ kN/m}}$
Horizontal dist to where surcharge thrust acts	$b_{v,surch} = w_1 \times \cos(\epsilon) - (H / 2) / \tan(\alpha) = \mathbf{600 \text{ mm}}$
Total horizontal unfactored force	$T_q = F_{soil,h,q} + F_{surch,h,q} = \mathbf{4.0 \text{ kN/m}}$
Total vertical unfactored force	$N_q = F_{gabion,v,q} + F_{soil,v,q} + F_{surch,v,q} = \mathbf{13.5 \text{ kN/m}}$
Force normal to base	$N_s = N_q \times \cos(\epsilon) + T_q \times \sin(\epsilon) = \mathbf{13.5 \text{ kN/m}}$
Total unfactored overturning force	$M_{o,q} = F_{soil,h,q} \times d_{h,soil} + F_{surch,h,q} \times d_{h,surch} = \mathbf{1.7 \text{ kNm/m}}$
Total unfactored restoring force	$M_{R,q} = F_{gabion,v,q} \times X_g + F_{soil,v,q} \times b_{v,soil} + F_{surch,v,q} \times b_{v,surch} = \mathbf{4.6 \text{ kNm/m}}$
Eccentricity	$e = w_1 / 2 - (M_{R,q} - M_{o,q}) / N_s = \mathbf{84 \text{ mm}}$

Reaction acts within middle third of base

Pressure at toe	$\sigma_{toe} = N_s / w_1 \times (1 + (6 \times e / w_1)) = \mathbf{41.4 \text{ kN/m}^2}$
Pressure at heel	$\sigma_{heel} = N_s / w_1 \times (1 - (6 \times e / w_1)) = \mathbf{3.6 \text{ kN/m}^2}$
Factor of safety	$FoS_Q = q / \max(\sigma_{toe}, \sigma_{heel}) = \mathbf{2.418}$
Allowable factor of safety	$FoS_{Q,allow} = \mathbf{1.000}$

PASS - Design FoS for allowable bearing pressure exceeds min allowable pressure to base

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Design approach 1

Partial factors on actions - Section A.3.1 - Combination 1

Permanent unfavourable action	$\gamma_G = 1.35$
Permanent favourable action	$\gamma_{G,f} = 1.00$
Variable unfavourable action	$\gamma_Q = 1.50$
Variable favourable action	$\gamma_{Q,f} = 0.00$

Partial factors for soil parameters - Section A.3.2 - Combination 1

Angle of shearing resistance	$\gamma_{\phi'} = 1.00$
Weight density	$\gamma_f = 1.00$

Design soil properties

Design effective shearing resistance angle	$\phi'_{r,d} = \text{Atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = 35.0 \text{ deg}$
Design saturated density of retained soil	$\gamma_{s,d} = \gamma_{sr} / \gamma_f = 21.0 \text{ kN/m}^3$
Design wall friction angle	$\delta_{r,d} = \min(\text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}), \phi'_{r,d} \times k_{\text{membrane}}) = 26.3 \text{ deg}$
Design base friction angle	$\delta_{bb,d} = \text{Atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = 35.0 \text{ deg}$
Design friction between gabions	$\delta_{bg,d} = \text{Atan}(\tan(\delta_{bg,k}) / \gamma_{\phi'}) = 35.0 \text{ deg}$
Active pressure using Coulomb theory	$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta)))^2}) = 0.245$
Active thrust due to soil	$P_{a,\text{soil}} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = 3.7 \text{ kN/m}$

Horizontal forces

Retained soil	$F_{\text{soil}_h} = \gamma_G \times P_{a,\text{soil}} \times \cos(90 - \alpha + \delta_{r,d}) = 4.5 \text{ kN/m}$
Surcharge	$F_{\text{surch}_h} = p_{o,Q} \times \gamma_Q \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = 1.0 \text{ kN/m}$

Vertical forces

Gabion weight	$F_{\text{gabion}_v,f} = \gamma_{G,f} \times W_g = 11.5 \text{ kN/m}$
Retained soil	$F_{\text{soil}_v,f} = \gamma_{G,f} \times P_{a,\text{soil}} \times \sin(90 - \alpha + \delta_{r,d}) = 1.6 \text{ kN/m}$
Surcharge	$F_{\text{surch}_v,f} = p_{o,Q} \times \gamma_{Q,f} \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = 0.0 \text{ kN/m}$

Overturning stability - take moments about the toe

Overturning moment	$M_o = F_{\text{soil}_h} \times d_{h,\text{soil}} + F_{\text{surch}_h} \times d_{h,\text{surch}} = 2.4 \text{ kNm/m}$
Restoring moment	$M_R = F_{\text{gabion}_v,f} \times X_g + F_{\text{soil}_v,f} \times b_{v,\text{soil}} + F_{\text{surch}_v,f} \times b_{v,\text{surch}} = 4.4 \text{ kNm/m}$
Factor of safety	$\text{FoSM} = M_R / M_o = 1.862$
Allowable factor of safety	$\text{FoSM}_{\text{allow}} = 1.000$

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force	$T = F_{\text{soil}_h} + F_{\text{surch}_h} = 5.5 \text{ kN/m}$
Total vertical force	$N = F_{\text{gabion}_v,f} + F_{\text{soil}_v,f} + F_{\text{surch}_v,f} = 13.2 \text{ kN/m}$
Sliding force	$F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = 5.5 \text{ kN/m}$
Sliding resistance	$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bb,d}) = 9.2 \text{ kN/m}$
Factor of safety	$\text{FoSS} = F_R / F_f = 1.685$
Allowable factor of safety	$\text{FoSS}_{\text{allow}} = 1.000$

PASS - Design FOS for sliding exceeds min allowable FOS for sliding

Check overturning and sliding between courses 1 and 2

Wall geometry

Horizontal distance to centre of gravity gabion 2	$x_{g2} = w_2 / 2 = 300 \text{ mm}$
Vertical distance to centre of gravity gabion 2	$y_{g2} = h_2 / 2 = 300 \text{ mm}$
Weight of gabion 2	$W_{g2} = \gamma_d \times w_2 \times h_2 = 5.8 \text{ kN/m}$

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Weight of entire gabion $W_g = W_{g2} = 5.8 \text{ kN/m}$
 Horiz distance to centre of gravity entire gabion $X_g = ((W_{g2} \times x_{g2})) / W_g = 300 \text{ mm}$
 Vert distance to centre of gravity entire gabion $y_g = ((W_{g2} \times y_{g2})) / W_g = 300 \text{ mm}$
 Correcting for wall inclination horiz dist $X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = 300 \text{ mm}$
 Vertical change in height due to wall inclination $H_f = y_{g2} + h_2/2 - ((y_{g2} + h_2/2) \times \cos(\epsilon) - (x_{g2} + w_2/2) \times \sin(\epsilon)) = 0 \text{ mm}$

Design dimensions

Effective angle of rear plane of wall $\alpha = 90 \text{ deg} + \epsilon = 90.0 \text{ deg}$
 Effective face angle $\theta = 90 \text{ deg} - \epsilon = 90.0 \text{ deg}$
 Effective height of wall $H = (y_{g2} + h_2 / 2) + (w_2 \times \sin(\epsilon)) - H_f = 600 \text{ mm}$
 Height of wall from toe to front edge of top gabion $H_{incl} = ((y_{g2} + h_2 / 2) \times \cos(\epsilon) - (x_{g2} - (w_2 / 2)) \times \sin(\epsilon)) = 600 \text{ mm}$
 Active pressure using Coulomb theory $K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta)))^2}) = 0.245$
 Active thrust due to soil $P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = 0.9 \text{ kN/m}$

Horizontal forces

Retained soil $F_{soil_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = 1.1 \text{ kN/m}$
 Surcharge $F_{surch_h} = p_{o,Q} \times \gamma_Q \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = 0.5 \text{ kN/m}$

Vertical forces

Gabion weight $F_{gabion_v,f} = \gamma_{G,f} \times W_g = 5.8 \text{ kN/m}$
 Retained soil $F_{soil_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = 0.4 \text{ kN/m}$
 Surcharge $F_{surch_v,f} = p_{o,Q} \times \gamma_{Q,f} \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = 0.0 \text{ kN/m}$

Overturning stability - take moments about the toe

Overturning moment $M_o = F_{soil_h} \times d_{h,soil} + F_{surch_h} \times d_{h,surch} = 0.4 \text{ kNm/m}$
 Restoring moment $M_R = F_{gabion_v,f} \times X_g + F_{soil_v,f} \times b_{v,soil} + F_{surch_v,f} \times b_{v,surch} = 2.0 \text{ kNm/m}$
 Factor of safety $FoSM = M_R / M_o = 5.304$
 Allowable factor of safety $FoSM_{allow} = 1.000$

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force $T = F_{soil_h} + F_{surch_h} = 1.6 \text{ kN/m}$
 Total vertical force $N = F_{gabion_v,f} + F_{soil_v,f} + F_{surch_v,f} = 6.2 \text{ kN/m}$
 Sliding force $F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = 1.6 \text{ kN/m}$
 Sliding resistance $F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = 4.3 \text{ kN/m}$
 Factor of safety $FoSS = F_R / F_f = 2.677$
 Allowable factor of safety $FoSS_{allow} = 1.000$

PASS - Design FOS for sliding exceeds min allowable FOS for sliding

Design approach 1

Partial factors on actions - Section A.3.1 - Combination 2

Permanent unfavourable action $\gamma_G = 1.00$
 Permanent favourable action $\gamma_{G,f} = 1.00$
 Variable unfavourable action $\gamma_Q = 1.30$
 Variable favourable action $\gamma_{Q,f} = 0.00$

Partial factors for soil parameters - Section A.3.2 - Combination 2

Angle of shearing resistance $\gamma_\phi = 1.25$
 Weight density $\gamma_\gamma = 1.00$

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Design soil properties

Design effective shearing resistance angle

$$\phi'_{r,d} = \text{Atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = \mathbf{29.3 \text{ deg}}$$

Design saturated density of retained soil

$$\gamma_{s,d} = \gamma_{sr} / \gamma_f = \mathbf{21.0 \text{ kN/m}^3}$$

Design wall friction angle

$$\delta_{r,d} = \min(\text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}), \phi'_{r,d} \times k_{\text{membrane}}) = \mathbf{21.5 \text{ deg}}$$

Design base friction angle

$$\delta_{bb,d} = \text{Atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = \mathbf{29.3 \text{ deg}}$$

Design friction between gabions

$$\delta_{bg,d} = \text{Atan}(\tan(\delta_{bg,k}) / \gamma_{\phi'}) = \mathbf{29.3 \text{ deg}}$$

Wall geometry

Horizontal distance to centre of gravity gabion 1

$$x_{g1} = w_1 / 2 = \mathbf{300 \text{ mm}}$$

Vertical distance to centre of gravity gabion 1

$$y_{g1} = h_1 / 2 = \mathbf{300 \text{ mm}}$$

Weight of gabion 1

$$W_{g1} = \gamma_d \times w_1 \times h_1 = \mathbf{5.8 \text{ kN/m}}$$

Horizontal distance to centre of gravity gabion 2

$$x_{g2} = w_2 / 2 + s_2 = \mathbf{300 \text{ mm}}$$

Vertical distance to centre of gravity gabion 2

$$y_{g2} = h_2 / 2 + h_1 = \mathbf{900 \text{ mm}}$$

Weight of gabion 2

$$W_{g2} = \gamma_d \times w_2 \times h_2 = \mathbf{5.8 \text{ kN/m}}$$

Weight of entire gabion

$$W_g = W_{g1} + W_{g2} = \mathbf{11.5 \text{ kN/m}}$$

Horiz distance to centre of gravity entire gabion

$$x_g = ((W_{g1} \times x_{g1}) + (W_{g2} \times x_{g2})) / W_g = \mathbf{300 \text{ mm}}$$

Vert distance to centre of gravity entire gabion

$$y_g = ((W_{g1} \times y_{g1}) + (W_{g2} \times y_{g2})) / W_g = \mathbf{600 \text{ mm}}$$

Correcting for wall inclination horiz dist

$$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{300 \text{ mm}}$$

Vertical change in height due to wall inclination

$$H_f = y_{g2} + h_2/2 - ((y_{g2} + h_2/2) \times \cos(\epsilon) - (x_{g2} + w_2/2) \times \sin(\epsilon)) = \mathbf{0 \text{ mm}}$$

Design dimensions

Effective angle of rear plane of wall

$$\alpha = 90 \text{ deg} + \epsilon = \mathbf{90.0 \text{ deg}}$$

Effective face angle

$$\theta = 90 \text{ deg} - \epsilon = \mathbf{90.0 \text{ deg}}$$

Effective height of wall

$$H = (y_{g2} + h_2 / 2) + (w_1 \times \sin(\epsilon)) - H_f = \mathbf{1200 \text{ mm}}$$

Height of wall from toe to front edge of top gabion

$$H_{incl} = ((y_{g2} + h_2 / 2) \times \cos(\epsilon) - (x_{g2} - (w_2 / 2)) \times \sin(\epsilon)) = \mathbf{1200 \text{ mm}}$$

Active pressure using Coulomb theory

$$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta)))^2}) = \mathbf{0.305}$$

Active thrust due to soil

$$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = \mathbf{4.6 \text{ kN/m}}$$

Horizontal forces

Retained soil

$$F_{soil,h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{4.3 \text{ kN/m}}$$

Surcharge

$$F_{surch,h} = p_{o,Q} \times \gamma_Q \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{1.1 \text{ kN/m}}$$

Vertical forces

Gabion weight

$$F_{gabion,v,f} = \gamma_{G,f} \times W_g = \mathbf{11.5 \text{ kN/m}}$$

Retained soil

$$F_{soil,v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{1.7 \text{ kN/m}}$$

Surcharge

$$F_{surch,v,f} = p_{o,Q} \times \gamma_{Q,f} \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{0.0 \text{ kN/m}}$$

Overturning stability - take moments about the toe

Overturning moment

$$M_o = F_{soil,h} \times d_{h,soil} + F_{surch,h} \times d_{h,surch} = \mathbf{2.4 \text{ kNm/m}}$$

Restoring moment

$$M_R = F_{gabion,v,f} \times x_g + F_{soil,v,f} \times b_{v,soil} + F_{surch,v,f} \times b_{v,surch} = \mathbf{4.5 \text{ kNm/m}}$$

Factor of safety

$$FoSM = M_R / M_o = \mathbf{1.879}$$

Allowable factor of safety

$$FoSM_{allow} = \mathbf{1.000}$$

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force

$$T = F_{soil,h} + F_{surch,h} = \mathbf{5.4 \text{ kN/m}}$$

Total vertical force

$$N = F_{gabion,v,f} + F_{soil,v,f} + F_{surch,v,f} = \mathbf{13.2 \text{ kN/m}}$$

Sliding force

$$F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = \mathbf{5.4 \text{ kN/m}}$$

Sliding resistance

$$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bb,d}) = \mathbf{7.4 \text{ kN/m}}$$

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Factor of safety

$$FoS_S = F_R / F_t = \mathbf{1.372}$$

Allowable factor of safety

$$FoS_{S_allow} = \mathbf{1.000}$$

PASS - Design FOS for sliding exceeds min allowable FOS for sliding

Check overturning and sliding between courses 1 and 2

Wall geometry

Horizontal distance to centre of gravity gabion 2

$$x_{g2} = w_2 / 2 = \mathbf{300 \text{ mm}}$$

Vertical distance to centre of gravity gabion 2

$$y_{g2} = h_2 / 2 = \mathbf{300 \text{ mm}}$$

Weight of gabion 2

$$W_{g2} = \gamma_d \times w_2 \times h_2 = \mathbf{5.8 \text{ kN/m}}$$

Weight of entire gabion

$$W_g = W_{g2} = \mathbf{5.8 \text{ kN/m}}$$

Horiz distance to centre of gravity entire gabion

$$x_g = ((W_{g2} \times x_{g2})) / W_g = \mathbf{300 \text{ mm}}$$

Vert distance to centre of gravity entire gabion

$$y_g = ((W_{g2} \times y_{g2})) / W_g = \mathbf{300 \text{ mm}}$$

Correcting for wall inclination horiz dist

$$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{300 \text{ mm}}$$

Vertical change in height due to wall inclination

$$H_f = y_{g2} + h_2/2 - ((y_{g2} + h_2/2) \times \cos(\epsilon) - (x_{g2} + w_2/2) \times \sin(\epsilon)) = \mathbf{0 \text{ mm}}$$

Design dimensions

Effective angle of rear plane of wall

$$\alpha = 90 \text{ deg} + \epsilon = \mathbf{90.0 \text{ deg}}$$

Effective face angle

$$\theta = 90 \text{ deg} - \epsilon = \mathbf{90.0 \text{ deg}}$$

Effective height of wall

$$H = (y_{g2} + h_2 / 2) + (w_2 \times \sin(\epsilon)) - H_f = \mathbf{600 \text{ mm}}$$

Height of wall from toe to front edge of top gabion

$$H_{incl} = ((y_{g2} + h_2 / 2) \times \cos(\epsilon) - (x_{g2} - (w_2 / 2)) \times \sin(\epsilon)) = \mathbf{600 \text{ mm}}$$

Active pressure using Coulomb theory

$$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}))^2) = \mathbf{0.305}$$

Active thrust due to soil

$$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = \mathbf{1.2 \text{ kN/m}}$$

Horizontal forces

Retained soil

$$F_{soil_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{1.1 \text{ kN/m}}$$

Surcharge

$$F_{surch_h} = p_{o,Q} \times \gamma_Q \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{0.6 \text{ kN/m}}$$

Vertical forces

Gabion weight

$$F_{gabion_v,f} = \gamma_G \times W_g = \mathbf{5.8 \text{ kN/m}}$$

Retained soil

$$F_{soil_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{0.4 \text{ kN/m}}$$

Surcharge

$$F_{surch_v,f} = p_{o,Q} \times \gamma_{Q,f} \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{0.0 \text{ kN/m}}$$

Overturning stability - take moments about the toe

Overturning moment

$$M_o = F_{soil_h} \times d_{h,soil} + F_{surch_h} \times d_{h,surch} = \mathbf{0.4 \text{ kNm/m}}$$

Restoring moment

$$M_R = F_{gabion_v,f} \times X_g + F_{soil_v,f} \times b_{v,soil} + F_{surch_v,f} \times b_{v,surch} = \mathbf{2.0 \text{ kNm/m}}$$

Factor of safety

$$FoS_M = M_R / M_o = \mathbf{5.209}$$

Allowable factor of safety

$$FoS_{M_allow} = \mathbf{1.000}$$

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force

$$T = F_{soil_h} + F_{surch_h} = \mathbf{1.6 \text{ kN/m}}$$

Total vertical force

$$N = F_{gabion_v,f} + F_{soil_v,f} + F_{surch_v,f} = \mathbf{6.2 \text{ kN/m}}$$

Sliding force

$$F_t = T \times \cos(\epsilon) - N \times \sin(\epsilon) = \mathbf{1.6 \text{ kN/m}}$$

Sliding resistance

$$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = \mathbf{3.5 \text{ kN/m}}$$

Factor of safety

$$FoS_S = F_R / F_t = \mathbf{2.131}$$

Allowable factor of safety

$$FoS_{S_allow} = \mathbf{1.000}$$

PASS - Design FOS for sliding exceeds min allowable FOS for sliding

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NEW GABION BASKET WALL DESIGN

GABION RETAINING WALL ANALYSIS & DESIGN

In accordance with EN 1997-1:2004 - Code of Practice for Geotechnical design and the UK National Annex

Tedds calculation version 2.0.02

Design summary

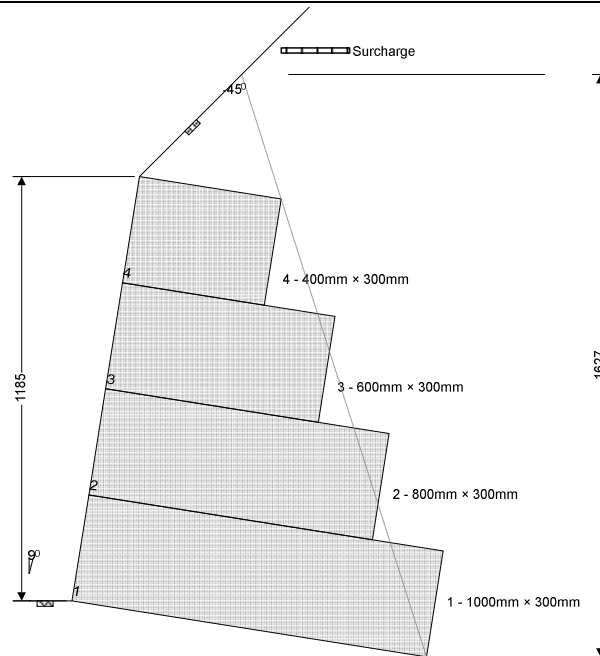
Combination 1

Action	Resistance	Force	FoS	Allowable FoS	Status
Overturning, sliding and bearing at base level					
Overturning (kNm/m)	30.5	16.0	1.905	1.000	PASS
Sliding (kN/m)	33.9	30.6	1.110	1.000	PASS
Bearing (kN/m ²)	100.0	72.2	1.384	1.000	PASS
Eccentricity (mm)	Reaction acts within the middle third of base				PASS
Overturning and sliding between courses 1 and 2					
Overturning (kNm/m)	14.3	8.2	1.739	1.000	PASS
Sliding (kN/m)	19.8	19.4	1.022	1.000	PASS
Overturning and sliding between courses 2 and 3					
Overturning (kNm/m)	5.1	3.5	1.453	1.000	PASS
Sliding (kN/m)	9.4	10.6	0.886	1.000	FAIL
Overturning and sliding between courses 3 and 4					
Overturning (kNm/m)	0.9	1.2	0.806	1.000	FAIL
Sliding (kN/m)	2.6	4.1	0.639	1.000	FAIL

Combination 2

Action	Resistance	Force	FoS	Allowable FoS	Status
Overturning, sliding and bearing at base level					
Overturning (kNm/m)	28.2	13.6	2.075	1.000	PASS
Sliding (kN/m)	25.1	25.0	1.003	1.000	PASS
Bearing (kN/m ²)	100.0	72.2	1.384	1.000	PASS
Eccentricity (mm)	Reaction acts within the middle third of base				PASS
Overturning and sliding between courses 1 and 2					
Overturning (kNm/m)	13.4	7.1	1.884	1.000	PASS
Sliding (kN/m)	14.8	16.2	0.917	1.000	FAIL
Overturning and sliding between courses 2 and 3					
Overturning (kNm/m)	4.9	3.2	1.553	1.000	PASS
Sliding (kN/m)	7.2	9.2	0.779	1.000	FAIL
Overturning and sliding between courses 3 and 4					
Overturning (kNm/m)	0.9	1.2	0.778	1.000	FAIL
Sliding (kN/m)	2.1	4.2	0.503	1.000	FAIL

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Wall geometry

Width of gabion 1	$w_1 = 1000$ mm
Height of gabion 1	$h_1 = 300$ mm
Width of gabion 2	$w_2 = 800$ mm
Height of gabion 2	$h_2 = 300$ mm
Step to front face between courses 1 and 2	$s_2 = 0$ mm
Width of gabion 3	$w_3 = 600$ mm
Height of gabion 3	$h_3 = 300$ mm
Step to front face between courses 2 and 3	$s_3 = 0$ mm
Width of gabion 4	$w_4 = 400$ mm
Height of gabion 4	$h_4 = 300$ mm
Step to front face between courses 3 and 4	$s_4 = 0$ mm
Wall inclination	$\epsilon = 9$ deg

Gabion properties

Unit weight of fill	$\gamma_d = 15.5$ kN/m ³
Friction between gabions	$\delta_{bg,k} = 35.0$ deg

Loading

Variable surcharge	$p_{o,Q} = 3$ kN/m ²
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Soil properties

Slope of retained soil	$\beta = 45.0$ deg
Characteristic effective shearing resistance angle	$\phi'_{r,k} = 45.0$ deg
Characteristic saturated density of retained soil	$\gamma_{sr} = 21.0$ kN/m ³
Coefficient for wall friction	$k_{membrane} = 0.75$
Wall friction angle	$\delta_{r,k} = 33.8$ deg
Characteristic base friction angle	$\delta_{bb,k} = 35.0$ deg
Bearing capacity of founding soil	$q = 100$ kN/m ²

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Wall geometry

Horizontal distance to centre of gravity gabion 1

$$x_{g1} = w_1 / 2 = \mathbf{500 \text{ mm}}$$

Vertical distance to centre of gravity gabion 1

$$y_{g1} = h_1 / 2 = \mathbf{150 \text{ mm}}$$

Weight of gabion 1

$$W_{g1} = \gamma_d \times w_1 \times h_1 = \mathbf{4.7 \text{ kN/m}}$$

Horizontal distance to centre of gravity gabion 2

$$x_{g2} = w_2 / 2 + s_2 = \mathbf{400 \text{ mm}}$$

Vertical distance to centre of gravity gabion 2

$$y_{g2} = h_2 / 2 + h_1 = \mathbf{450 \text{ mm}}$$

Weight of gabion 2

$$W_{g2} = \gamma_d \times w_2 \times h_2 = \mathbf{3.7 \text{ kN/m}}$$

Horizontal distance to centre of gravity gabion 3

$$x_{g3} = w_3 / 2 + s_2 + s_3 = \mathbf{300 \text{ mm}}$$

Vertical distance to centre of gravity gabion 3

$$y_{g3} = h_3 / 2 + h_1 + h_2 = \mathbf{750 \text{ mm}}$$

Weight of gabion 3

$$W_{g3} = \gamma_d \times w_3 \times h_3 = \mathbf{2.8 \text{ kN/m}}$$

Horizontal distance to centre of gravity gabion 4

$$x_{g4} = w_4 / 2 + s_2 + s_3 + s_4 = \mathbf{200 \text{ mm}}$$

Vertical distance to centre of gravity gabion 4

$$y_{g4} = h_4 / 2 + h_1 + h_2 + h_3 = \mathbf{1050 \text{ mm}}$$

Weight of gabion 4

$$W_{g4} = \gamma_d \times w_4 \times h_4 = \mathbf{1.9 \text{ kN/m}}$$

Weight of entire gabion

$$W_g = W_{g1} + W_{g2} + W_{g3} + W_{g4} = \mathbf{13.0 \text{ kN/m}}$$

Horiz distance to centre of gravity entire gabion

$$x_g = ((W_{g1} \times x_{g1}) + (W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4})) / W_g = \mathbf{386 \text{ mm}}$$

Vert distance to centre of gravity entire gabion

$$y_g = ((W_{g1} \times y_{g1}) + (W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4})) / W_g = \mathbf{493 \text{ mm}}$$

Correcting for wall inclination horiz dist

$$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{458 \text{ mm}}$$

Vertical change in height due to wall inclination

$$H_f = y_{g4} + h_4/2 - ((y_{g4} + h_4/2) \times \cos(\epsilon) - (x_{g4} + w_4/2) \times \sin(\epsilon)) = \mathbf{77 \text{ mm}}$$

Design dimensions

Effective angle of rear plane of wall

$$\alpha = 90\text{deg} - \text{Atan}((w_1 - (x_{g4} + (w_4 / 2))) / (y_{g4} + h_4 / 2)) + \epsilon = \mathbf{72.4 \text{ deg}}$$

Effective face angle

$$\theta = 90\text{deg} - \epsilon = \mathbf{81.0 \text{ deg}}$$

Effective height of wall

$$H = (y_{g4} + h_4 / 2) + (w_1 \times \sin(\epsilon)) - H_f + (\cos(90 - \alpha) \times \sin(\beta + \epsilon) \times w_4) / \sin(180 - (\alpha + \beta)) = \mathbf{1627 \text{ mm}}$$

Height of wall from toe to front edge of top gabion

$$H_{incl} = ((y_{g4} + h_4 / 2) \times \cos(\epsilon) - (x_{g4} - (w_4 / 2)) \times \sin(\epsilon)) = \mathbf{1185 \text{ mm}}$$

Active pressure using Coulomb theory

$$K_a = \sin(\alpha + \phi'_{r,k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,k}) \times (1 + \sqrt{(\sin(\phi'_{r,k} + \delta_{r,k}) \times \sin(\phi'_{r,k} - \beta) / (\sin(\alpha - \delta_{r,k}) \times \sin(\alpha + \beta)))^2}) = \mathbf{1.387}$$

Active thrust due to soil

$$P_{a,soil} = 0.5 \times K_a \times \gamma_{sr} \times H^2 = \mathbf{38.5 \text{ kN/m}}$$

Pressure at base

Horizontal forces

Retained soil

$$F_{soil,h,q} = P_{a,soil} \times \cos(90 - \alpha + \delta_{r,k}) = \mathbf{24.1 \text{ kN/m}}$$

Height of soil thrust resolved vertically

$$d_{h,soil} = H / 3 - w_1 \times \sin(\epsilon) = \mathbf{386 \text{ mm}}$$

Surcharge

$$F_{surch,h,q} = p_{o,Q} \times K_a \times H \times \cos(90 - \alpha + \delta_{r,k}) = \mathbf{3.5 \text{ kN/m}}$$

Height of surcharge thrust resolved vertically

$$d_{h,surch} = H / 2 - w_1 \times \sin(\epsilon) = \mathbf{657 \text{ mm}}$$

Vertical forces

Gabion weight

$$F_{gabion,v,q} = W_g = \mathbf{13.0 \text{ kN/m}}$$

Retained soil

$$F_{soil,v,q} = P_{a,soil} \times \sin(90 - \alpha + \delta_{r,k}) = \mathbf{30.1 \text{ kN/m}}$$

Horizontal dist to where soil thrust acts

$$b_{v,soil} = w_1 \times \cos(\epsilon) - (H / 3) / \tan(\alpha) = \mathbf{816 \text{ mm}}$$

Surcharge

$$F_{surch,v,q} = p_{o,Q} \times K_a \times H \times \sin(90 - \alpha + \delta_{r,k}) = \mathbf{4.4 \text{ kN/m}}$$

Horizontal dist to where surcharge thrust acts

$$b_{v,surch} = w_1 \times \cos(\epsilon) - (H / 2) / \tan(\alpha) = \mathbf{730 \text{ mm}}$$

Total horizontal unfactored force

$$T_q = F_{soil,h,q} + F_{surch,h,q} = \mathbf{27.6 \text{ kN/m}}$$

Total vertical unfactored force

$$N_q = F_{gabion,v,q} + F_{soil,v,q} + F_{surch,v,q} = \mathbf{47.5 \text{ kN/m}}$$

Force normal to base

$$N_s = N_q \times \cos(\epsilon) + T_q \times \sin(\epsilon) = \mathbf{51.2 \text{ kN/m}}$$

Total unfactored overturning force

$$M_{o,q} = F_{soil,h,q} \times d_{h,soil} + F_{surch,h,q} \times d_{h,surch} = \mathbf{11.6 \text{ kNm/m}}$$

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Total unfactored restoring force
 Eccentricity

$$M_{R,q} = F_{gabion_v,q} \times X_g + F_{soil_v,q} \times b_{v,soil} + F_{surch_v,q} \times b_{v,surch} = \mathbf{33.7 \text{ kNm/m}}$$

$$e = w_1 / 2 - (M_{R,q} - M_{o,q}) / N_s = \mathbf{68 \text{ mm}}$$

Reaction acts within middle third of base

Pressure at toe

$$\sigma_{toe} = N_s / w_1 \times (1 + (6 \times e / w_1)) = \mathbf{72.2 \text{ kN/m}^2}$$

Pressure at heel

$$\sigma_{heel} = N_s / w_1 \times (1 - (6 \times e / w_1)) = \mathbf{30.2 \text{ kN/m}^2}$$

Factor of safety

$$FoS_Q = q / \max(\sigma_{toe}, \sigma_{heel}) = \mathbf{1.384}$$

Allowable factor of safety

$$FoS_{Q_allow} = \mathbf{1.000}$$

PASS - Design FoS for allowable bearing pressure exceeds min allowable pressure to base

Design approach 1

Partial factors on actions - Section A.3.1 - Combination 1

Permanent unfavourable action

$$\gamma_G = \mathbf{1.35}$$

Permanent favourable action

$$\gamma_{G,f} = \mathbf{1.00}$$

Variable unfavourable action

$$\gamma_Q = \mathbf{1.50}$$

Variable favourable action

$$\gamma_{Q,f} = \mathbf{0.00}$$

Partial factors for soil parameters - Section A.3.2 - Combination 1

Angle of shearing resistance

$$\gamma_{\phi'} = \mathbf{1.00}$$

Weight density

$$\gamma_Y = \mathbf{1.00}$$

Design soil properties

Design effective shearing resistance angle

$$\phi'_{r,d} = \text{Atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = \mathbf{45.0 \text{ deg}}$$

Design saturated density of retained soil

$$\gamma_{s,d} = \gamma_{sr} / \gamma_Y = \mathbf{21.0 \text{ kN/m}^3}$$

Design wall friction angle

$$\delta_{r,d} = \min(\text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}), \phi'_{r,d} \times k_{\text{membrane}}) = \mathbf{33.8 \text{ deg}}$$

Design base friction angle

$$\delta_{bb,d} = \text{Atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = \mathbf{35.0 \text{ deg}}$$

Design friction between gabions

$$\delta_{bg,d} = \text{Atan}(\tan(\delta_{bg,k}) / \gamma_{\phi'}) = \mathbf{35.0 \text{ deg}}$$

Active pressure using Coulomb theory

$$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta)))^2}) = \mathbf{1.387}$$

Active thrust due to soil

$$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = \mathbf{38.5 \text{ kN/m}}$$

Horizontal forces

Retained soil

$$F_{soil_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{32.5 \text{ kN/m}}$$

Surcharge

$$F_{surch_h} = p_{o,Q} \times \gamma_Q \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{5.3 \text{ kN/m}}$$

Vertical forces

Gabion weight

$$F_{gabion_v,f} = \gamma_{G,f} \times W_g = \mathbf{13.0 \text{ kN/m}}$$

Retained soil

$$F_{soil_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{30.1 \text{ kN/m}}$$

Surcharge

$$F_{surch_v,f} = p_{o,Q} \times \gamma_{Q,f} \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{0.0 \text{ kN/m}}$$

Overturning stability - take moments about the toe

Overturning moment

$$M_o = F_{soil_h} \times d_{h,soil} + F_{surch_h} \times d_{h,surch} = \mathbf{16.0 \text{ kNm/m}}$$

Restoring moment

$$M_R = F_{gabion_v,f} \times X_g + F_{soil_v,f} \times b_{v,soil} + F_{surch_v,f} \times b_{v,surch} = \mathbf{30.5 \text{ kNm/m}}$$

Factor of safety

$$FoS_M = M_R / M_o = \mathbf{1.905}$$

Allowable factor of safety

$$FoS_{M_allow} = \mathbf{1.000}$$

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force

$$T = F_{soil_h} + F_{surch_h} = \mathbf{37.8 \text{ kN/m}}$$

Total vertical force

$$N = F_{gabion_v,f} + F_{soil_v,f} + F_{surch_v,f} = \mathbf{43.1 \text{ kN/m}}$$

Sliding force

$$F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = \mathbf{30.6 \text{ kN/m}}$$

Sliding resistance

$$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bb,d}) = \mathbf{33.9 \text{ kN/m}}$$

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Factor of safety

$$FoS_S = F_R / F_t = \mathbf{1.110}$$

Allowable factor of safety

$$FoS_{S_allow} = \mathbf{1.000}$$

PASS - Design FOS for sliding exceeds min allowable FOS for sliding

Check overturning and sliding between courses 1 and 2

Wall geometry

Horizontal distance to centre of gravity gabion 2

$$x_{g2} = w_2 / 2 = \mathbf{400 \text{ mm}}$$

Vertical distance to centre of gravity gabion 2

$$y_{g2} = h_2 / 2 = \mathbf{150 \text{ mm}}$$

Weight of gabion 2

$$W_{g2} = \gamma_d \times w_2 \times h_2 = \mathbf{3.7 \text{ kN/m}}$$

Horizontal distance to centre of gravity gabion 3

$$x_{g3} = w_3 / 2 + s_3 = \mathbf{300 \text{ mm}}$$

Vertical distance to centre of gravity gabion 3

$$y_{g3} = h_3 / 2 + h_2 = \mathbf{450 \text{ mm}}$$

Weight of gabion 3

$$W_{g3} = \gamma_d \times w_3 \times h_3 = \mathbf{2.8 \text{ kN/m}}$$

Horizontal distance to centre of gravity gabion 4

$$x_{g4} = w_4 / 2 + s_3 + s_4 = \mathbf{200 \text{ mm}}$$

Vertical distance to centre of gravity gabion 4

$$y_{g4} = h_4 / 2 + h_2 + h_3 = \mathbf{750 \text{ mm}}$$

Weight of gabion 4

$$W_{g4} = \gamma_d \times w_4 \times h_4 = \mathbf{1.9 \text{ kN/m}}$$

Weight of entire gabion

$$W_g = W_{g2} + W_{g3} + W_{g4} = \mathbf{8.4 \text{ kN/m}}$$

Horiz distance to centre of gravity entire gabion

$$x_g = ((W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4})) / W_g = \mathbf{322 \text{ mm}}$$

Vert distance to centre of gravity entire gabion

$$y_g = ((W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4})) / W_g = \mathbf{383 \text{ mm}}$$

Correcting for wall inclination horiz dist

$$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{378 \text{ mm}}$$

Vertical change in height due to wall inclination

$$H_t = y_{g4} + h_4/2 - ((y_{g4} + h_4/2) \times \cos(\epsilon) - (x_{g4} + w_4/2) \times \sin(\epsilon)) = \mathbf{74 \text{ mm}}$$

Design dimensions

Effective angle of rear plane of wall

$$\alpha = 90\text{deg} - \text{Atan}((w_2 - (x_{g4} + (w_4 / 2))) / (y_{g4} + h_4 / 2)) + \epsilon = \mathbf{75.0 \text{ deg}}$$

Effective face angle

$$\theta = 90\text{deg} - \epsilon = \mathbf{81.0 \text{ deg}}$$

Effective height of wall

$$H = (y_{g4} + h_4 / 2) + (w_2 \times \sin(\epsilon)) - H_t + (\cos(90 - \alpha) \times \sin(\beta + \epsilon) \times w_4) / \sin(180 - (\alpha + \beta)) = \mathbf{1313 \text{ mm}}$$

Height of wall from toe to front edge of top gabion

$$H_{incl} = ((y_{g4} + h_4 / 2) \times \cos(\epsilon) - (x_{g4} - (w_4 / 2)) \times \sin(\epsilon)) = \mathbf{889 \text{ mm}}$$

Active pressure using Coulomb theory

$$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta)))^2}) = \mathbf{1.217}$$

Active thrust due to soil

$$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = \mathbf{22.0 \text{ kN/m}}$$

Horizontal forces

Retained soil

$$F_{soil_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{19.6 \text{ kN/m}}$$

Surcharge

$$F_{surch_h} = p_{o,Q} \times \gamma_Q \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{4.0 \text{ kN/m}}$$

Vertical forces

Gabion weight

$$F_{gabion_v,f} = \gamma_{G,f} \times W_g = \mathbf{8.4 \text{ kN/m}}$$

Retained soil

$$F_{soil_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{16.5 \text{ kN/m}}$$

Surcharge

$$F_{surch_v,f} = p_{o,Q} \times \gamma_{Q,f} \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{0.0 \text{ kN/m}}$$

Overturning stability - take moments about the toe

Overturning moment

$$M_o = F_{soil_h} \times d_{h,soil} + F_{surch_h} \times d_{h,surch} = \mathbf{8.2 \text{ kNm/m}}$$

Restoring moment

$$M_R = F_{gabion_v,f} \times X_g + F_{soil_v,f} \times b_{v,soil} + F_{surch_v,f} \times b_{v,surch} = \mathbf{14.3 \text{ kNm/m}}$$

Factor of safety

$$FoS_M = M_R / M_o = \mathbf{1.739}$$

Allowable factor of safety

$$FoS_{M_allow} = \mathbf{1.000}$$

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force

$$T = F_{soil_h} + F_{surch_h} = \mathbf{23.6 \text{ kN/m}}$$

Total vertical force

$$N = F_{gabion_v,f} + F_{soil_v,f} + F_{surch_v,f} = \mathbf{24.9 \text{ kN/m}}$$

Sliding force

$$F_t = T \times \cos(\epsilon) - N \times \sin(\epsilon) = \mathbf{19.4 \text{ kN/m}}$$

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Sliding resistance

$$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = \mathbf{19.8 \text{ kN/m}}$$

Factor of safety

$$FoS_S = F_R / F_i = \mathbf{1.022}$$

Allowable factor of safety

$$FoS_{S_allow} = \mathbf{1.000}$$

FAIL - Min allowable FOS for sliding exceeds design FOS for sliding

Check overturning and sliding between courses 2 and 3

Wall geometry

Horizontal distance to centre of gravity gabion 3

$$x_{g3} = w_3 / 2 = \mathbf{300 \text{ mm}}$$

Vertical distance to centre of gravity gabion 3

$$y_{g3} = h_3 / 2 = \mathbf{150 \text{ mm}}$$

Weight of gabion 3

$$W_{g3} = \gamma_d \times w_3 \times h_3 = \mathbf{2.8 \text{ kN/m}}$$

Horizontal distance to centre of gravity gabion 4

$$x_{g4} = w_4 / 2 + s_4 = \mathbf{200 \text{ mm}}$$

Vertical distance to centre of gravity gabion 4

$$y_{g4} = h_4 / 2 + h_3 = \mathbf{450 \text{ mm}}$$

Weight of gabion 4

$$W_{g4} = \gamma_d \times w_4 \times h_4 = \mathbf{1.9 \text{ kN/m}}$$

Weight of entire gabion

$$W_g = W_{g3} + W_{g4} = \mathbf{4.7 \text{ kN/m}}$$

Horiz distance to centre of gravity entire gabion

$$x_g = ((W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4})) / W_g = \mathbf{260 \text{ mm}}$$

Vert distance to centre of gravity entire gabion

$$y_g = ((W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4})) / W_g = \mathbf{270 \text{ mm}}$$

Correcting for wall inclination horiz dist

$$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{299 \text{ mm}}$$

Vertical change in height due to wall inclination

$$H_i = y_{g4} + h_4/2 - ((y_{g4} + h_4/2) \times \cos(\epsilon) - (x_{g4} + w_4/2) \times \sin(\epsilon)) = \mathbf{70 \text{ mm}}$$

Design dimensions

Effective angle of rear plane of wall

$$\alpha = 90\text{deg} - \text{Atan}((w_3 - (x_{g4} + (w_4 / 2))) / (y_{g4} + h_4 / 2)) + \epsilon = \mathbf{80.6 \text{ deg}}$$

Effective face angle

$$\theta = 90\text{deg} - \epsilon = \mathbf{81.0 \text{ deg}}$$

Effective height of wall

$$H = (y_{g4} + h_4 / 2) + (w_3 \times \sin(\epsilon)) - H_i + (\cos(90 - \alpha) \times \sin(\beta + \epsilon) \times w_4) / \sin(180 - (\alpha + \beta)) = \mathbf{1016 \text{ mm}}$$

Height of wall from toe to front edge of top gabion

$$H_{incl} = ((y_{g4} + h_4 / 2) \times \cos(\epsilon) - (x_{g4} - (w_4 / 2)) \times \sin(\epsilon)) = \mathbf{593 \text{ mm}}$$

Active pressure using Coulomb theory

$$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta)))^2}) = \mathbf{0.933}$$

Active thrust due to soil

$$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = \mathbf{10.1 \text{ kN/m}}$$

Horizontal forces

Retained soil

$$F_{soil_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{10.0 \text{ kN/m}}$$

Surcharge

$$F_{surch_h} = p_{o,Q} \times \gamma_Q \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{2.6 \text{ kN/m}}$$

Vertical forces

Gabion weight

$$F_{gabion_v,f} = \gamma_{G,f} \times W_g = \mathbf{4.7 \text{ kN/m}}$$

Retained soil

$$F_{soil_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{6.9 \text{ kN/m}}$$

Surcharge

$$F_{surch_v,f} = p_{o,Q} \times \gamma_{Q,f} \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{0.0 \text{ kN/m}}$$

Overturning stability - take moments about the toe

Overturning moment

$$M_o = F_{soil_h} \times d_{h,soil} + F_{surch_h} \times d_{h,surch} = \mathbf{3.5 \text{ kNm/m}}$$

Restoring moment

$$M_R = F_{gabion_v,f} \times X_g + F_{soil_v,f} \times b_{v,soil} + F_{surch_v,f} \times b_{v,surch} = \mathbf{5.1 \text{ kNm/m}}$$

Factor of safety

$$FoS_M = M_R / M_o = \mathbf{1.453}$$

Allowable factor of safety

$$FoS_{M_allow} = \mathbf{1.000}$$

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force

$$T = F_{soil_h} + F_{surch_h} = \mathbf{12.5 \text{ kN/m}}$$

Total vertical force

$$N = F_{gabion_v,f} + F_{soil_v,f} + F_{surch_v,f} = \mathbf{11.6 \text{ kN/m}}$$

Sliding force

$$F_i = T \times \cos(\epsilon) - N \times \sin(\epsilon) = \mathbf{10.6 \text{ kN/m}}$$

Sliding resistance

$$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = \mathbf{9.4 \text{ kN/m}}$$

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Factor of safety

$$FoSS = F_R / F_t = \mathbf{0.886}$$

Allowable factor of safety

$$FoSS_{allow} = \mathbf{1.000}$$

FAIL - Min allowable FOS for sliding exceeds design FOS for sliding

Check overturning and sliding between courses 3 and 4

Wall geometry

Horizontal distance to centre of gravity gabion 4

$$x_{g4} = w_4 / 2 = \mathbf{200 \text{ mm}}$$

Vertical distance to centre of gravity gabion 4

$$y_{g4} = h_4 / 2 = \mathbf{150 \text{ mm}}$$

Weight of gabion 4

$$W_{g4} = \gamma_d \times w_4 \times h_4 = \mathbf{1.9 \text{ kN/m}}$$

Weight of entire gabion

$$W_g = W_{g4} = \mathbf{1.9 \text{ kN/m}}$$

Horiz distance to centre of gravity entire gabion

$$x_g = ((W_{g4} \times x_{g4})) / W_g = \mathbf{200 \text{ mm}}$$

Vert distance to centre of gravity entire gabion

$$y_g = ((W_{g4} \times y_{g4})) / W_g = \mathbf{150 \text{ mm}}$$

Correcting for wall inclination horiz dist

$$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{221 \text{ mm}}$$

Vertical change in height due to wall inclination

$$H_t = y_{g4} + h_4/2 - ((y_{g4} + h_4/2) \times \cos(\epsilon) - (x_{g4} + w_4/2) \times \sin(\epsilon)) = \mathbf{66 \text{ mm}}$$

Design dimensions

Effective angle of rear plane of wall

$$\alpha = 90 \text{ deg} + \epsilon = \mathbf{99.0 \text{ deg}}$$

Effective face angle

$$\theta = 90 \text{ deg} - \epsilon = \mathbf{81.0 \text{ deg}}$$

Effective height of wall

$$H = (y_{g4} + h_4 / 2) + (w_4 \times \sin(\epsilon)) - H_t + (\cos(90 - \alpha) \times \sin(\beta + \epsilon) \times w_4) / \sin(180 - (\alpha + \beta)) = \mathbf{840 \text{ mm}}$$

Height of wall from toe to front edge of top gabion

$$H_{incl} = ((y_{g4} + h_4 / 2) \times \cos(\epsilon) - (x_{g4} - (w_4 / 2)) \times \sin(\epsilon)) = \mathbf{296 \text{ mm}}$$

Active pressure using Coulomb theory

$$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta)))^2}) = \mathbf{0.390}$$

Active thrust due to soil

$$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = \mathbf{2.9 \text{ kN/m}}$$

Horizontal forces

Retained soil

$$F_{soil,h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{3.5 \text{ kN/m}}$$

Surcharge

$$F_{surch,h} = p_{o,Q} \times \gamma_Q \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{1.1 \text{ kN/m}}$$

Vertical forces

Gabion weight

$$F_{gabion,v,f} = \gamma_{G,f} \times W_g = \mathbf{1.9 \text{ kN/m}}$$

Retained soil

$$F_{soil,v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{1.2 \text{ kN/m}}$$

Surcharge

$$F_{surch,v,f} = p_{o,Q} \times \gamma_{Q,f} \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{0.0 \text{ kN/m}}$$

Overturning stability - take moments about the toe

Overturning moment

$$M_o = F_{soil,h} \times d_{h,soil} + F_{surch,h} \times d_{h,surch} = \mathbf{1.2 \text{ kNm/m}}$$

Restoring moment

$$M_R = F_{gabion,v,f} \times X_g + F_{soil,v,f} \times b_{v,soil} + F_{surch,v,f} \times b_{v,surch} = \mathbf{0.9 \text{ kNm/m}}$$

Factor of safety

$$FoSM = M_R / M_o = \mathbf{0.806}$$

Allowable factor of safety

$$FoSM_{allow} = \mathbf{1.000}$$

FAIL - Min allowable FOS for overturning exceeds design FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force

$$T = F_{soil,h} + F_{surch,h} = \mathbf{4.7 \text{ kN/m}}$$

Total vertical force

$$N = F_{gabion,v,f} + F_{soil,v,f} + F_{surch,v,f} = \mathbf{3.1 \text{ kN/m}}$$

Sliding force

$$F_t = T \times \cos(\epsilon) - N \times \sin(\epsilon) = \mathbf{4.1 \text{ kN/m}}$$

Sliding resistance

$$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = \mathbf{2.6 \text{ kN/m}}$$

Factor of safety

$$FoSS = F_R / F_t = \mathbf{0.639}$$

Allowable factor of safety

$$FoSS_{allow} = \mathbf{1.000}$$

FAIL - Min allowable FOS for sliding exceeds design FOS for sliding

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Design approach 1

Partial factors on actions - Section A.3.1 - Combination 2

Permanent unfavourable action	$\gamma_G = 1.00$
Permanent favourable action	$\gamma_{G,f} = 1.00$
Variable unfavourable action	$\gamma_Q = 1.30$
Variable favourable action	$\gamma_{Q,f} = 0.00$

Partial factors for soil parameters - Section A.3.2 - Combination 2

Angle of shearing resistance	$\gamma_{\phi'} = 1.25$
Weight density	$\gamma_f = 1.00$

Design soil properties

Design effective shearing resistance angle	$\phi'_{r,d} = \text{Atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = 38.7 \text{ deg}$
Design saturated density of retained soil	$\gamma_{s,d} = \gamma_{sr} / \gamma_f = 21.0 \text{ kN/m}^3$
Design wall friction angle	$\delta_{r,d} = \min(\text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}), \phi'_{r,d} \times k_{\text{membrane}}) = 28.1 \text{ deg}$
Design base friction angle	$\delta_{bb,d} = \text{Atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = 29.3 \text{ deg}$
Design friction between gabions	$\delta_{bg,d} = \text{Atan}(\tan(\delta_{bg,k}) / \gamma_{\phi'}) = 29.3 \text{ deg}$

Wall geometry

Horizontal distance to centre of gravity gabion 1	$x_{g1} = w_1 / 2 = 500 \text{ mm}$
Vertical distance to centre of gravity gabion 1	$y_{g1} = h_1 / 2 = 150 \text{ mm}$
Weight of gabion 1	$W_{g1} = \gamma_d \times w_1 \times h_1 = 4.7 \text{ kN/m}$
Horizontal distance to centre of gravity gabion 2	$x_{g2} = w_2 / 2 + s_2 = 400 \text{ mm}$
Vertical distance to centre of gravity gabion 2	$y_{g2} = h_2 / 2 + h_1 = 450 \text{ mm}$
Weight of gabion 2	$W_{g2} = \gamma_d \times w_2 \times h_2 = 3.7 \text{ kN/m}$
Horizontal distance to centre of gravity gabion 3	$x_{g3} = w_3 / 2 + s_2 + s_3 = 300 \text{ mm}$
Vertical distance to centre of gravity gabion 3	$y_{g3} = h_3 / 2 + h_1 + h_2 = 750 \text{ mm}$
Weight of gabion 3	$W_{g3} = \gamma_d \times w_3 \times h_3 = 2.8 \text{ kN/m}$
Horizontal distance to centre of gravity gabion 4	$x_{g4} = w_4 / 2 + s_2 + s_3 + s_4 = 200 \text{ mm}$
Vertical distance to centre of gravity gabion 4	$y_{g4} = h_4 / 2 + h_1 + h_2 + h_3 = 1050 \text{ mm}$
Weight of gabion 4	$W_{g4} = \gamma_d \times w_4 \times h_4 = 1.9 \text{ kN/m}$
Weight of entire gabion	$W_g = W_{g1} + W_{g2} + W_{g3} + W_{g4} = 13.0 \text{ kN/m}$
Horiz distance to centre of gravity entire gabion	$x_g = ((W_{g1} \times x_{g1}) + (W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4})) / W_g = 386 \text{ mm}$
Vert distance to centre of gravity entire gabion	$y_g = ((W_{g1} \times y_{g1}) + (W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4})) / W_g = 493 \text{ mm}$
Correcting for wall inclination horiz dist	$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = 458 \text{ mm}$
Vertical change in height due to wall inclination	$H_f = y_{g4} + h_4/2 - ((y_{g4} + h_4/2) \times \cos(\epsilon) - (x_{g4} + w_4/2) \times \sin(\epsilon)) = 77 \text{ mm}$

Design dimensions

Effective angle of rear plane of wall	$\alpha = 90\text{deg} - \text{Atan}((w_1 - (x_{g4} + (w_4 / 2))) / (y_{g4} + h_4 / 2)) + \epsilon = 72.4 \text{ deg}$
Effective face angle	$\theta = 90\text{deg} - \epsilon = 81.0 \text{ deg}$
Effective height of wall	$H = (y_{g4} + h_4 / 2) + (w_1 \times \sin(\epsilon)) - H_f + (\cos(90 - \alpha) \times \sin(\beta + \epsilon) \times w_4) / \sin(180 - (\alpha + \beta)) = 1627 \text{ mm}$
Height of wall from toe to front edge of top gabion	$H_{\text{incl}} = ((y_{g4} + h_4 / 2) \times \cos(\epsilon) - (x_{g4} - (w_4 / 2)) \times \sin(\epsilon)) = 1185 \text{ mm}$
Active pressure using Coulomb theory	$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d})) = 1.371$
Active thrust due to soil	$P_{a,\text{soil}} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = 38.1 \text{ kN/m}$

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Horizontal forces

Retained soil $F_{soil_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = 26.6 \text{ kN/m}$
 Surcharge $F_{surch_h} = p_{o,Q} \times \gamma_Q \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = 5.1 \text{ kN/m}$

Vertical forces

Gabion weight $F_{gabion_v,f} = \gamma_{G,f} \times W_g = 13.0 \text{ kN/m}$
 Retained soil $F_{soil_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = 27.3 \text{ kN/m}$
 Surcharge $F_{surch_v,f} = p_{o,Q} \times \gamma_{Q,f} \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = 0.0 \text{ kN/m}$

Overturning stability - take moments about the toe

Overturning moment $M_o = F_{soil_h} \times d_{h,soil} + F_{surch_h} \times d_{h,surch} = 13.6 \text{ kNm/m}$
 Restoring moment $M_R = F_{gabion_v,f} \times X_g + F_{soil_v,f} \times b_{v,soil} + F_{surch_v,f} \times b_{v,surch} = 28.2 \text{ kNm/m}$
 Factor of safety $FoSM = M_R / M_o = 2.075$
 Allowable factor of safety $FoSM_{allow} = 1.000$

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force $T = F_{soil_h} + F_{surch_h} = 31.7 \text{ kN/m}$
 Total vertical force $N = F_{gabion_v,f} + F_{soil_v,f} + F_{surch_v,f} = 40.3 \text{ kN/m}$
 Sliding force $F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = 25.0 \text{ kN/m}$
 Sliding resistance $F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bb,d}) = 25.1 \text{ kN/m}$
 Factor of safety $FoSS = F_R / F_f = 1.003$
 Allowable factor of safety $FoSS_{allow} = 1.000$

PASS - Design FOS for sliding exceeds min allowable FOS for sliding

Check overturning and sliding between courses 1 and 2

Wall geometry

Horizontal distance to centre of gravity gabion 2 $x_{g2} = w_2 / 2 = 400 \text{ mm}$
 Vertical distance to centre of gravity gabion 2 $y_{g2} = h_2 / 2 = 150 \text{ mm}$
 Weight of gabion 2 $W_{g2} = \gamma_d \times w_2 \times h_2 = 3.7 \text{ kN/m}$
 Horizontal distance to centre of gravity gabion 3 $x_{g3} = w_3 / 2 + s_3 = 300 \text{ mm}$
 Vertical distance to centre of gravity gabion 3 $y_{g3} = h_3 / 2 + h_2 = 450 \text{ mm}$
 Weight of gabion 3 $W_{g3} = \gamma_d \times w_3 \times h_3 = 2.8 \text{ kN/m}$
 Horizontal distance to centre of gravity gabion 4 $x_{g4} = w_4 / 2 + s_3 + s_4 = 200 \text{ mm}$
 Vertical distance to centre of gravity gabion 4 $y_{g4} = h_4 / 2 + h_2 + h_3 = 750 \text{ mm}$
 Weight of gabion 4 $W_{g4} = \gamma_d \times w_4 \times h_4 = 1.9 \text{ kN/m}$
 Weight of entire gabion $W_g = W_{g2} + W_{g3} + W_{g4} = 8.4 \text{ kN/m}$
 Horiz distance to centre of gravity entire gabion $X_g = ((W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4})) / W_g = 322 \text{ mm}$
 Vert distance to centre of gravity entire gabion $y_g = ((W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4})) / W_g = 383 \text{ mm}$
 Correcting for wall inclination horiz dist $X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = 378 \text{ mm}$
 Vertical change in height due to wall inclination $H_f = y_{g4} + h_4/2 - ((y_{g4} + h_4/2) \times \cos(\epsilon) - (x_{g4} + w_4/2) \times \sin(\epsilon)) = 74 \text{ mm}$

Design dimensions

Effective angle of rear plane of wall $\alpha = 90\text{deg} - \text{Atan}((w_2 - (x_{g4} + (w_4 / 2))) / (y_{g4} + h_4 / 2)) + \epsilon = 75.0 \text{ deg}$
 Effective face angle $\theta = 90\text{deg} - \epsilon = 81.0 \text{ deg}$
 Effective height of wall $H = (y_{g4} + h_4 / 2) + (w_2 \times \sin(\epsilon)) - H_f + (\cos(90 - \alpha) \times \sin(\beta + \epsilon) \times w_4) / \sin(180 - (\alpha + \beta)) = 1313 \text{ mm}$
 Height of wall from toe to front edge of top gabion $H_{incl} = ((y_{g4} + h_4 / 2) \times \cos(\epsilon) - (x_{g4} - (w_4 / 2)) \times \sin(\epsilon)) = 889 \text{ mm}$
 Active pressure using Coulomb theory $K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d})) = 1.230$
 Active thrust due to soil $P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = 22.3 \text{ kN/m}$

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Horizontal forces

Retained soil $F_{soil_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{16.3 \text{ kN/m}}$
 Surcharge $F_{surch_h} = p_{o,Q} \times \gamma_Q \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{3.8 \text{ kN/m}}$

Vertical forces

Gabion weight $F_{gabion_v,f} = \gamma_{G,f} \times W_g = \mathbf{8.4 \text{ kN/m}}$
 Retained soil $F_{soil_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{15.2 \text{ kN/m}}$
 Surcharge $F_{surch_v,f} = p_{o,Q} \times \gamma_{Q,f} \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{0.0 \text{ kN/m}}$

Overturning stability - take moments about the toe

Overturning moment $M_o = F_{soil_h} \times d_{h,soil} + F_{surch_h} \times d_{h,surch} = \mathbf{7.1 \text{ kNm/m}}$
 Restoring moment $M_R = F_{gabion_v,f} \times X_g + F_{soil_v,f} \times b_{v,soil} + F_{surch_v,f} \times b_{v,surch} = \mathbf{13.4 \text{ kNm/m}}$
 Factor of safety $FoSM = M_R / M_o = \mathbf{1.884}$
 Allowable factor of safety $FoSM_{allow} = \mathbf{1.000}$

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force $T = F_{soil_h} + F_{surch_h} = \mathbf{20.1 \text{ kN/m}}$
 Total vertical force $N = F_{gabion_v,f} + F_{soil_v,f} + F_{surch_v,f} = \mathbf{23.6 \text{ kN/m}}$
 Sliding force $F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = \mathbf{16.2 \text{ kN/m}}$
 Sliding resistance $F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = \mathbf{14.8 \text{ kN/m}}$
 Factor of safety $FoSS = F_R / F_f = \mathbf{0.917}$
 Allowable factor of safety $FoSS_{allow} = \mathbf{1.000}$

FAIL - Min allowable FOS for sliding exceeds design FOS for sliding

Check overturning and sliding between courses 2 and 3

Wall geometry

Horizontal distance to centre of gravity gabion 3 $x_{g3} = w_3 / 2 = \mathbf{300 \text{ mm}}$
 Vertical distance to centre of gravity gabion 3 $y_{g3} = h_3 / 2 = \mathbf{150 \text{ mm}}$
 Weight of gabion 3 $W_{g3} = \gamma_d \times w_3 \times h_3 = \mathbf{2.8 \text{ kN/m}}$
 Horizontal distance to centre of gravity gabion 4 $x_{g4} = w_4 / 2 + s_4 = \mathbf{200 \text{ mm}}$
 Vertical distance to centre of gravity gabion 4 $y_{g4} = h_4 / 2 + h_3 = \mathbf{450 \text{ mm}}$
 Weight of gabion 4 $W_{g4} = \gamma_d \times w_4 \times h_4 = \mathbf{1.9 \text{ kN/m}}$
 Weight of entire gabion $W_g = W_{g3} + W_{g4} = \mathbf{4.7 \text{ kN/m}}$
 Horiz distance to centre of gravity entire gabion $X_g = ((W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4})) / W_g = \mathbf{260 \text{ mm}}$
 Vert distance to centre of gravity entire gabion $y_g = ((W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4})) / W_g = \mathbf{270 \text{ mm}}$
 Correcting for wall inclination horiz dist $X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{299 \text{ mm}}$
 Vertical change in height due to wall inclination $H_f = y_{g4} + h_4/2 - ((y_{g4} + h_4/2) \times \cos(\epsilon) - (x_{g4} + w_4/2) \times \sin(\epsilon)) = \mathbf{70 \text{ mm}}$

Design dimensions

Effective angle of rear plane of wall $\alpha = 90\text{deg} - \text{Atan}((w_3 - (x_{g4} + (w_4 / 2))) / (y_{g4} + h_4 / 2)) + \epsilon = \mathbf{80.6 \text{ deg}}$
 Effective face angle $\theta = 90\text{deg} - \epsilon = \mathbf{81.0 \text{ deg}}$
 Effective height of wall $H = (y_{g4} + h_4 / 2) + (w_3 \times \sin(\epsilon)) - H_f + (\cos(90 - \alpha) \times \sin(\beta + \epsilon) \times w_4) / \sin(180 - (\alpha + \beta)) = \mathbf{1016 \text{ mm}}$
 Height of wall from toe to front edge of top gabion $H_{incl} = ((y_{g4} + h_4 / 2) \times \cos(\epsilon) - (x_{g4} - (w_4 / 2)) \times \sin(\epsilon)) = \mathbf{593 \text{ mm}}$
 Active pressure using Coulomb theory $K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d})) = \mathbf{0.987}$
 Active thrust due to soil $P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = \mathbf{10.7 \text{ kN/m}}$

Horizontal forces

Retained soil $F_{soil_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{8.5 \text{ kN/m}}$

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Surcharge

$$F_{surch_h} = p_{o,Q} \times \gamma_Q \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = 2.6 \text{ kN/m}$$

Vertical forces

Gabion weight

$$F_{gabion_v,f} = \gamma_{G,f} \times W_g = 4.7 \text{ kN/m}$$

Retained soil

$$F_{soil_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = 6.5 \text{ kN/m}$$

Surcharge

$$F_{surch_v,f} = p_{o,Q} \times \gamma_Q \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = 0.0 \text{ kN/m}$$

Overturning stability - take moments about the toe

Overturning moment

$$M_o = F_{soil_h} \times d_{h,soil} + F_{surch_h} \times d_{h,surch} = 3.2 \text{ kNm/m}$$

Restoring moment

$$M_R = F_{gabion_v,f} \times X_g + F_{soil_v,f} \times b_{v,soil} + F_{surch_v,f} \times b_{v,surch} = 4.9 \text{ kNm/m}$$

Factor of safety

$$FoSM = M_R / M_o = 1.553$$

Allowable factor of safety

$$FoSM_{allow} = 1.000$$

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force

$$T = F_{soil_h} + F_{surch_h} = 11.1 \text{ kN/m}$$

Total vertical force

$$N = F_{gabion_v,f} + F_{soil_v,f} + F_{surch_v,f} = 11.2 \text{ kN/m}$$

Sliding force

$$F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = 9.2 \text{ kN/m}$$

Sliding resistance

$$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = 7.2 \text{ kN/m}$$

Factor of safety

$$FoSS = F_R / F_f = 0.779$$

Allowable factor of safety

$$FoSS_{allow} = 1.000$$

FAIL - Min allowable FOS for sliding exceeds design FOS for sliding

Check overturning and sliding between courses 3 and 4

Wall geometry

Horizontal distance to centre of gravity gabion 4

$$x_{g4} = w_4 / 2 = 200 \text{ mm}$$

Vertical distance to centre of gravity gabion 4

$$y_{g4} = h_4 / 2 = 150 \text{ mm}$$

Weight of gabion 4

$$W_{g4} = \gamma_d \times w_4 \times h_4 = 1.9 \text{ kN/m}$$

Weight of entire gabion

$$W_g = W_{g4} = 1.9 \text{ kN/m}$$

Horiz distance to centre of gravity entire gabion

$$x_g = ((W_{g4} \times x_{g4})) / W_g = 200 \text{ mm}$$

Vert distance to centre of gravity entire gabion

$$y_g = ((W_{g4} \times y_{g4})) / W_g = 150 \text{ mm}$$

Correcting for wall inclination horiz dist

$$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = 221 \text{ mm}$$

Vertical change in height due to wall inclination

$$H_f = y_{g4} + h_4/2 - ((y_{g4} + h_4/2) \times \cos(\epsilon) - (x_{g4} + w_4/2) \times \sin(\epsilon)) = 66 \text{ mm}$$

Design dimensions

Effective angle of rear plane of wall

$$\alpha = 90 \text{ deg} + \epsilon = 99.0 \text{ deg}$$

Effective face angle

$$\theta = 90 \text{ deg} - \epsilon = 81.0 \text{ deg}$$

Effective height of wall

$$H = (y_{g4} + h_4 / 2) + (w_4 \times \sin(\epsilon)) - H_f + (\cos(90 - \alpha) \times \sin(\beta + \epsilon) \times w_4) / \sin(180 - (\alpha + \beta)) = 840 \text{ mm}$$

Height of wall from toe to front edge of top gabion

$$H_{incl} = ((y_{g4} + h_4 / 2) \times \cos(\epsilon) - (x_{g4} - (w_4 / 2)) \times \sin(\epsilon)) = 296 \text{ mm}$$

Active pressure using Coulomb theory

$$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d})) = 0.492$$

Active thrust due to soil

$$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = 3.6 \text{ kN/m}$$

Horizontal forces

Retained soil

$$F_{soil_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = 3.4 \text{ kN/m}$$

Surcharge

$$F_{surch_h} = p_{o,Q} \times \gamma_Q \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = 1.3 \text{ kN/m}$$

Vertical forces

Gabion weight

$$F_{gabion_v,f} = \gamma_{G,f} \times W_g = 1.9 \text{ kN/m}$$

Retained soil

$$F_{soil_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = 1.2 \text{ kN/m}$$

Surcharge

$$F_{surch_v,f} = p_{o,Q} \times \gamma_Q \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = 0.0 \text{ kN/m}$$

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Overturning stability - take moments about the toe

Overturning moment $M_o = F_{soil_h} \times d_{h,soil} + F_{surch_h} \times d_{h,surch} = 1.2 \text{ kNm/m}$
 Restoring moment $M_R = F_{gabion_v,f} \times X_g + F_{soil_v,f} \times b_{v,soil} + F_{surch_v,f} \times b_{v,surch} = 0.9 \text{ kNm/m}$
 Factor of safety $FoS_M = M_R / M_o = 0.778$
 Allowable factor of safety $FoS_{M_allow} = 1.000$

FAIL - Min allowable FOS for overturning exceeds design FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force $T = F_{soil_h} + F_{surch_h} = 4.7 \text{ kN/m}$
 Total vertical force $N = F_{gabion_v,f} + F_{soil_v,f} + F_{surch_v,f} = 3.1 \text{ kN/m}$
 Sliding force $F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = 4.2 \text{ kN/m}$
 Sliding resistance $F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = 2.1 \text{ kN/m}$
 Factor of safety $FoS_S = F_R / F_f = 0.503$
 Allowable factor of safety $FoS_{S_allow} = 1.000$

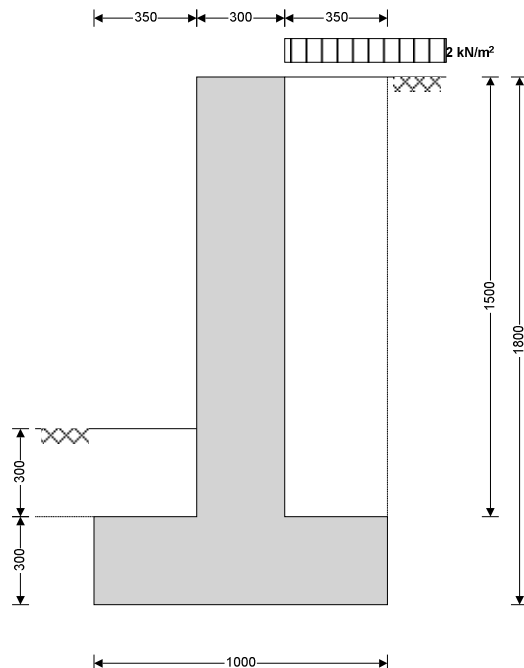
FAIL - Min allowable FOS for sliding exceeds design FOS for sliding

Gabion baskets to be reinforced with H12 bars tied from top to bottom to resist the overturning and sliding forces. H12 bars to be spaced at 600ctrs.

CAVITY REINFORCED RETAINING WALL DESIGN

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.08



Wall details

Retaining wall type
 Height of retaining wall stem

Unpropped cantilever
 $h_{stem} = 1500 \text{ mm}$

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Thickness of wall stem	$t_{wall} = 300 \text{ mm}$
Length of toe	$l_{toe} = 350 \text{ mm}$
Length of heel	$l_{heel} = 350 \text{ mm}$
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall} = 1000 \text{ mm}$
Thickness of base	$t_{base} = 300 \text{ mm}$
Depth of downstand	$d_{ds} = 0 \text{ mm}$
Position of downstand	$l_{ds} = 250 \text{ mm}$
Thickness of downstand	$t_{ds} = 300 \text{ mm}$
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds} = 1800 \text{ mm}$
Depth of cover in front of wall	$d_{cover} = 300 \text{ mm}$
Depth of unplanned excavation	$d_{exc} = 300 \text{ mm}$
Height of ground water behind wall	$h_{water} = 0 \text{ mm}$
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0 \text{ mm}) = 0 \text{ mm}$
Density of wall construction	$\gamma_{wall} = 23.6 \text{ kN/m}^3$
Density of base construction	$\gamma_{base} = 23.6 \text{ kN/m}^3$
Angle of rear face of wall	$\alpha = 90.0 \text{ deg}$
Angle of soil surface behind wall	$\beta = 0.0 \text{ deg}$
Effective height at virtual back of wall	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta) = 1800 \text{ mm}$

Retained material details

Mobilisation factor	$M = 1.5$
Moist density of retained material	$\gamma_m = 19.0 \text{ kN/m}^3$
Saturated density of retained material	$\gamma_s = 21.5 \text{ kN/m}^3$
Design shear strength	$\phi' = 24.2 \text{ deg}$
Angle of wall friction	$\delta = 18.6 \text{ deg}$

Base material details

Firm clay	
Moist density	$\gamma_{mb} = 18.0 \text{ kN/m}^3$
Design shear strength	$\phi'_b = 24.2 \text{ deg}$
Design base friction	$\delta_b = 18.6 \text{ deg}$
Allowable bearing pressure	$P_{bearing} = 100 \text{ kN/m}^2$

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))}]^2) = 0.369$$

Passive pressure coefficient for base material

$$K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b)))}]^2) = 4.187$$

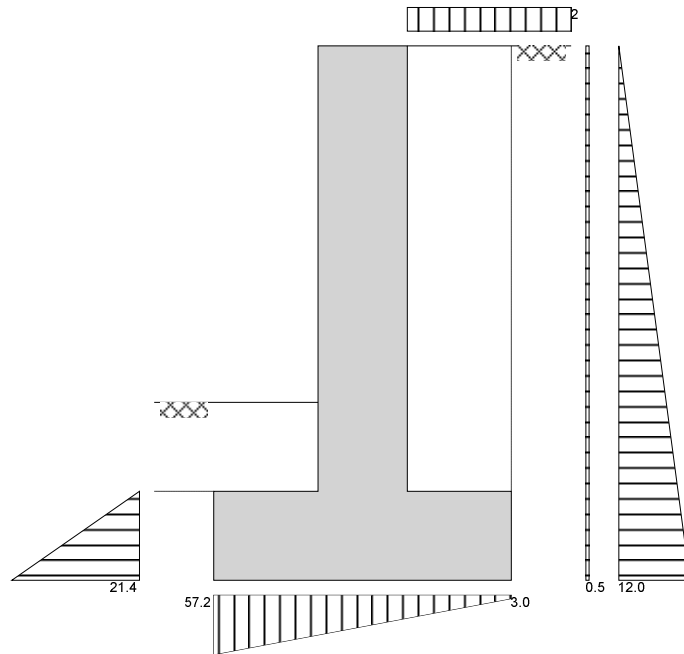
At-rest pressure

At-rest pressure for retained material	$K_0 = 1 - \sin(\phi') = 0.590$
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Loading details

Surcharge load on plan	Surcharge = 1.5 kN/m^2
Applied vertical dead load on wall	$W_{dead} = 0.0 \text{ kN/m}$
Applied vertical live load on wall	$W_{live} = 0.0 \text{ kN/m}$
Position of applied vertical load on wall	$l_{load} = 0 \text{ mm}$
Applied horizontal dead load on wall	$F_{dead} = 0.0 \text{ kN/m}$
Applied horizontal live load on wall	$F_{live} = 0.0 \text{ kN/m}$
Height of applied horizontal load on wall	$h_{load} = 0 \text{ mm}$

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Loads shown in kN/m, pressures shown in kN/m²

Vertical forces on wall

Wall stem

$$W_{\text{wall}} = h_{\text{stem}} \times t_{\text{wall}} \times \gamma_{\text{wall}} = 10.6 \text{ kN/m}$$

Wall base

$$W_{\text{base}} = l_{\text{base}} \times t_{\text{base}} \times \gamma_{\text{base}} = 7.1 \text{ kN/m}$$

Surcharge

$$W_{\text{sur}} = \text{Surcharge} \times l_{\text{heel}} = 0.5 \text{ kN/m}$$

Moist backfill to top of wall

$$W_{\text{m}_w} = l_{\text{heel}} \times (h_{\text{stem}} - h_{\text{sat}}) \times \gamma_m = 10 \text{ kN/m}$$

Soil in front of wall

$$W_p = l_{\text{toe}} \times d_{\text{cover}} \times \gamma_{\text{mb}} = 1.9 \text{ kN/m}$$

Total vertical load

$$W_{\text{total}} = W_{\text{wall}} + W_{\text{base}} + W_{\text{sur}} + W_{\text{m}_w} + W_p = 30.1 \text{ kN/m}$$

Horizontal forces on wall

Surcharge

$$F_{\text{sur}} = K_a \times \cos(90 - \alpha + \delta) \times \text{Surcharge} \times h_{\text{eff}} = 0.9 \text{ kN/m}$$

Moist backfill above water table

$$F_{\text{m}_a} = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{\text{eff}} - h_{\text{water}})^2 = 10.8 \text{ kN/m}$$

Total horizontal load

$$F_{\text{total}} = F_{\text{sur}} + F_{\text{m}_a} = 11.7 \text{ kN/m}$$

Calculate stability against sliding

Passive resistance of soil in front of wall

$$F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{\text{cover}} + t_{\text{base}} + d_{\text{ds}} - d_{\text{exc}})^2 \times \gamma_{\text{mb}} = 3.2 \text{ kN/m}$$

Resistance to sliding

$$F_{\text{res}} = F_p + (W_{\text{total}} - W_{\text{sur}} - W_p) \times \tan(\delta_b) = 12.5 \text{ kN/m}$$

PASS - Resistance force is greater than sliding force

Overturning moments

Surcharge

$$M_{\text{sur}} = F_{\text{sur}} \times (h_{\text{eff}} - 2 \times d_{\text{ds}}) / 2 = 0.9 \text{ kNm/m}$$

Moist backfill above water table

$$M_{\text{m}_a} = F_{\text{m}_a} \times (h_{\text{eff}} + 2 \times h_{\text{water}} - 3 \times d_{\text{ds}}) / 3 = 6.5 \text{ kNm/m}$$

Total overturning moment

$$M_{\text{ot}} = M_{\text{sur}} + M_{\text{m}_a} = 7.3 \text{ kNm/m}$$

Restoring moments

Wall stem

$$M_{\text{wall}} = W_{\text{wall}} \times (l_{\text{toe}} + t_{\text{wall}} / 2) = 5.3 \text{ kNm/m}$$

Wall base

$$M_{\text{base}} = W_{\text{base}} \times l_{\text{base}} / 2 = 3.5 \text{ kNm/m}$$

Moist backfill

$$M_{\text{m}_r} = (W_{\text{m}_w} \times (l_{\text{base}} - l_{\text{heel}} / 2) + W_{\text{m}_s} \times (l_{\text{base}} - l_{\text{heel}} / 3)) = 8.2 \text{ kNm/m}$$

Total restoring moment

$$M_{\text{rest}} = M_{\text{wall}} + M_{\text{base}} + M_{\text{m}_r} = 17.1 \text{ kNm/m}$$

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Check stability against overturning

Total overturning moment

$$M_{ot} = 7.3 \text{ kNm/m}$$

Total restoring moment

$$M_{rest} = 17.1 \text{ kNm/m}$$

PASS - Restoring moment is greater than overturning moment

Check bearing pressure

Surcharge

$$M_{sur_r} = w_{sur} \times (l_{base} - l_{heel} / 2) = 0.4 \text{ kNm/m}$$

Soil in front of wall

$$M_{p_r} = w_p \times l_{toe} / 2 = 0.3 \text{ kNm/m}$$

Total moment for bearing

$$M_{total} = M_{rest} - M_{ot} + M_{sur_r} + M_{p_r} = 10.5 \text{ kNm/m}$$

Total vertical reaction

$$R = W_{total} = 30.1 \text{ kN/m}$$

Distance to reaction

$$x_{bar} = M_{total} / R = 350 \text{ mm}$$

Eccentricity of reaction

$$e = \text{abs}((l_{base} / 2) - x_{bar}) = 150 \text{ mm}$$

Reaction acts within middle third of base

Bearing pressure at toe

$$p_{toe} = (R / l_{base}) + (6 \times R \times e / l_{base}^2) = 57.2 \text{ kN/m}^2$$

Bearing pressure at heel

$$p_{heel} = (R / l_{base}) - (6 \times R \times e / l_{base}^2) = 3 \text{ kN/m}^2$$

PASS - Maximum bearing pressure is less than allowable bearing pressure

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RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.08

Ultimate limit state load factors

Dead load factor	$\gamma_{f_d} = 1.4$
Live load factor	$\gamma_{f_l} = 1.6$
Earth and water pressure factor	$\gamma_{f_e} = 1.4$

Factored vertical forces on wall

Wall stem	$W_{wall_f} = \gamma_{f_d} \times h_{stem} \times t_{wall} \times \gamma_{wall} = 14.9 \text{ kN/m}$
Wall base	$W_{base_f} = \gamma_{f_d} \times l_{base} \times t_{base} \times \gamma_{base} = 9.9 \text{ kN/m}$
Surcharge	$W_{sur_f} = \gamma_{f_l} \times \text{Surcharge} \times l_{heel} = 0.8 \text{ kN/m}$
Moist backfill to top of wall	$W_{m_w_f} = \gamma_{f_d} \times l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m = 14 \text{ kN/m}$
Soil in front of wall	$W_{p_f} = \gamma_{f_d} \times l_{toe} \times d_{cover} \times \gamma_{mb} = 2.6 \text{ kN/m}$
Total vertical load	$W_{total_f} = W_{wall_f} + W_{base_f} + W_{sur_f} + W_{m_w_f} + W_{p_f} = 42.2 \text{ kN/m}$

Factored horizontal active forces on wall

Surcharge	$F_{sur_f} = \gamma_{f_l} \times K_a \times \cos(90 - \alpha + \delta) \times \text{Surcharge} \times h_{eff} = 1.5 \text{ kN/m}$
Moist backfill above water table	$F_{m_a_f} = \gamma_{f_e} \times 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water})^2 = 15.1 \text{ kN/m}$
Total horizontal load	$F_{total_f} = F_{sur_f} + F_{m_a_f} = 16.6 \text{ kN/m}$
Passive resistance of soil in front of wall	$F_{p_f} = \gamma_{f_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = 4.5 \text{ kN/m}$

Factored overturning moments

Surcharge	$M_{sur_f} = F_{sur_f} \times (h_{eff} - 2 \times d_{ds}) / 2 = 1.4 \text{ kNm/m}$
Moist backfill above water table	$M_{m_a_f} = F_{m_a_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = 9 \text{ kNm/m}$
Total overturning moment	$M_{ot_f} = M_{sur_f} + M_{m_a_f} = 10.4 \text{ kNm/m}$

Restoring moments

Wall stem	$M_{wall_f} = W_{wall_f} \times (l_{toe} + t_{wall} / 2) = 7.4 \text{ kNm/m}$
Wall base	$M_{base_f} = W_{base_f} \times l_{base} / 2 = 5 \text{ kNm/m}$
Surcharge	$M_{sur_r_f} = W_{sur_f} \times (l_{base} - l_{heel} / 2) = 0.7 \text{ kNm/m}$
Moist backfill	$M_{m_r_f} = (W_{m_w_f} \times (l_{base} - l_{heel} / 2) + W_{m_s_f} \times (l_{base} - l_{heel} / 3)) = 11.5 \text{ kNm/m}$
Soil in front of wall	$M_{p_r_f} = W_{p_f} \times l_{toe} / 2 = 0.5 \text{ kNm/m}$
Total restoring moment	$M_{rest_f} = M_{wall_f} + M_{base_f} + M_{sur_r_f} + M_{m_r_f} + M_{p_r_f} = 25.1 \text{ kNm/m}$

Factored bearing pressure

Total moment for bearing	$M_{total_f} = M_{rest_f} - M_{ot_f} = 14.7 \text{ kNm/m}$
Total vertical reaction	$R_f = W_{total_f} = 42.2 \text{ kN/m}$
Distance to reaction	$X_{bar_f} = M_{total_f} / R_f = 347 \text{ mm}$
Eccentricity of reaction	$e_f = \text{abs}((l_{base} / 2) - X_{bar_f}) = 153 \text{ mm}$

Reaction acts within middle third of base

Bearing pressure at toe	$p_{toe_f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2) = 81 \text{ kN/m}^2$
Bearing pressure at heel	$p_{heel_f} = (R_f / l_{base}) - (6 \times R_f \times e_f / l_{base}^2) = 3.5 \text{ kN/m}^2$
Rate of change of base reaction	$\text{rate} = (p_{toe_f} - p_{heel_f}) / l_{base} = 77.45 \text{ kN/m}^2/\text{m}$
Bearing pressure at stem / toe	$p_{stem_toe_f} = \text{max}(p_{toe_f} - (\text{rate} \times l_{toe}), 0 \text{ kN/m}^2) = 53.8 \text{ kN/m}^2$
Bearing pressure at mid stem	$p_{stem_mid_f} = \text{max}(p_{toe_f} - (\text{rate} \times (l_{toe} + t_{wall} / 2)), 0 \text{ kN/m}^2) = 42.2 \text{ kN/m}^2$
Bearing pressure at stem / heel	$p_{stem_heel_f} = \text{max}(p_{toe_f} - (\text{rate} \times (l_{toe} + t_{wall})), 0 \text{ kN/m}^2) = 30.6 \text{ kN/m}^2$

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Design of reinforced concrete retaining wall toe (BS 8002:1994)

Material properties

Characteristic strength of concrete $f_{cu} = 30 \text{ N/mm}^2$
 Characteristic strength of reinforcement $f_y = 250 \text{ N/mm}^2$

Base details

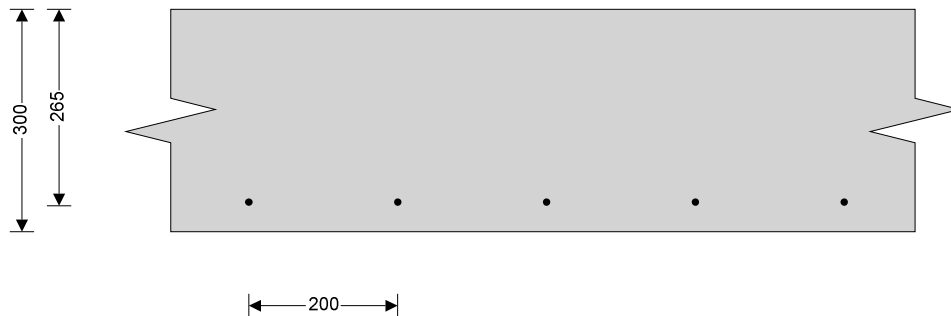
Minimum area of reinforcement $k = 0.13 \%$
 Cover to reinforcement in toe $c_{toe} = 30 \text{ mm}$

Calculate shear for toe design

Shear from bearing pressure $V_{toe_bear} = (p_{toe_f} + p_{stem_toe_f}) \times l_{toe} / 2 = 23.6 \text{ kN/m}$
 Shear from weight of base $V_{toe_wt_base} = \gamma_{fd} \times \gamma_{base} \times l_{toe} \times t_{base} = 3.5 \text{ kN/m}$
 Total shear for toe design $V_{toe} = V_{toe_bear} - V_{toe_wt_base} = 20.1 \text{ kN/m}$

Calculate moment for toe design

Moment from bearing pressure $M_{toe_bear} = (2 \times p_{toe_f} + p_{stem_mid_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 = 8.5 \text{ kNm/m}$
 Moment from weight of base $M_{toe_wt_base} = (\gamma_{fd} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) = 1.2 \text{ kNm/m}$
 Total moment for toe design $M_{toe} = M_{toe_bear} - M_{toe_wt_base} = 7.3 \text{ kNm/m}$



Check toe in bending

Width of toe $b = 1000 \text{ mm/m}$
 Depth of reinforcement $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) = 265.0 \text{ mm}$
 Constant $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) = 0.003$

Compression reinforcement is not required

Lever arm $z_{toe} = \min(0.5 + \sqrt{(0.25 - (\min(K_{toe}, 0.225) / 0.9))}, 0.95) \times d_{toe}$
 $z_{toe} = 252 \text{ mm}$

Area of tension reinforcement required $A_{s_toe_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) = 133 \text{ mm}^2/\text{m}$
 Minimum area of tension reinforcement $A_{s_toe_min} = k \times b \times t_{base} = 390 \text{ mm}^2/\text{m}$
 Area of tension reinforcement required $A_{s_toe_req} = \text{Max}(A_{s_toe_des}, A_{s_toe_min}) = 390 \text{ mm}^2/\text{m}$
 Reinforcement provided **A393 mesh**
 Area of reinforcement provided $A_{s_toe_prov} = 393 \text{ mm}^2/\text{m}$

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress $v_{toe} = V_{toe} / (b \times d_{toe}) = 0.076 \text{ N/mm}^2$
 Allowable shear stress $v_{adm} = \min(0.8 \times \sqrt{f_{cu}} / 1 \text{ N/mm}^2, 5) \times 1 \text{ N/mm}^2 = 4.382 \text{ N/mm}^2$

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress $v_{c_toe} = 0.394 \text{ N/mm}^2$

$v_{toe} < v_{c_toe}$ - No shear reinforcement required

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Design of reinforced concrete retaining wall heel (BS 8002:1994)

Material properties

Characteristic strength of concrete $f_{cu} = 30 \text{ N/mm}^2$
 Characteristic strength of reinforcement $f_y = 250 \text{ N/mm}^2$

Base details

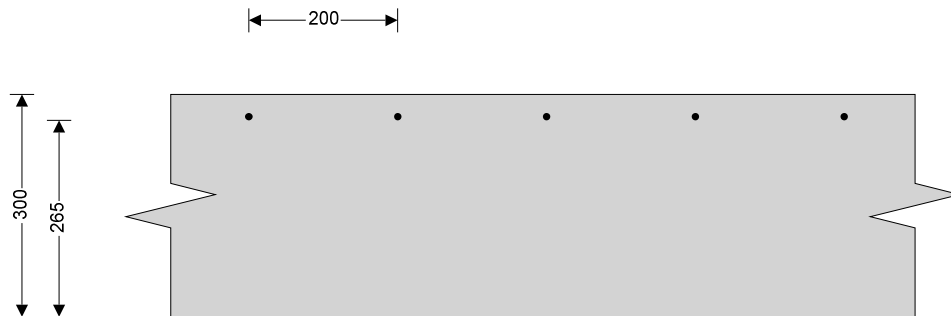
Minimum area of reinforcement $k = 0.13 \%$
 Cover to reinforcement in heel $C_{heel} = 30 \text{ mm}$

Calculate shear for heel design

Shear from bearing pressure $V_{heel_bear} = (p_{heel_f} + p_{stem_heel_f}) \times l_{heel} / 2 = 6 \text{ kN/m}$
 Shear from weight of base $V_{heel_wt_base} = \gamma_{f_d} \times \gamma_{base} \times l_{heel} \times t_{base} = 3.5 \text{ kN/m}$
 Shear from weight of moist backfill $V_{heel_wt_m} = w_{m_w_f} = 14 \text{ kN/m}$
 Shear from surcharge $V_{heel_sur} = w_{sur_f} = 0.8 \text{ kN/m}$
 Total shear for heel design $V_{heel} = -V_{heel_bear} + V_{heel_wt_base} + V_{heel_wt_m} + V_{heel_sur} = 12.3 \text{ kN/m}$

Calculate moment for heel design

Moment from bearing pressure $M_{heel_bear} = (2 \times p_{heel_f} + p_{stem_mid_f}) \times (l_{heel} + t_{wall} / 2)^2 / 6 = 2.1 \text{ kNm/m}$
 Moment from weight of base $M_{heel_wt_base} = (\gamma_{f_d} \times \gamma_{base} \times t_{base} \times (l_{heel} + t_{wall} / 2)^2 / 2) = 1.2 \text{ kNm/m}$
 Moment from weight of moist backfill $M_{heel_wt_m} = w_{m_w_f} \times (l_{heel} + t_{wall}) / 2 = 4.5 \text{ kNm/m}$
 Moment from surcharge $M_{heel_sur} = w_{sur_f} \times (l_{heel} + t_{wall}) / 2 = 0.3 \text{ kNm/m}$
 Total moment for heel design $M_{heel} = -M_{heel_bear} + M_{heel_wt_base} + M_{heel_wt_m} + M_{heel_sur} = 4 \text{ kNm/m}$



Check heel in bending

Width of heel $b = 1000 \text{ mm/m}$
 Depth of reinforcement $d_{heel} = t_{base} - C_{heel} - (\phi_{heel} / 2) = 265.0 \text{ mm}$
 Constant $K_{heel} = M_{heel} / (b \times d_{heel}^2 \times f_{cu}) = 0.002$

Compression reinforcement is not required

Lever arm $Z_{heel} = \min(0.5 + \sqrt{(0.25 - (\min(K_{heel}, 0.225) / 0.9))}, 0.95) \times d_{heel}$
 $Z_{heel} = 252 \text{ mm}$

Area of tension reinforcement required $A_{s_heel_des} = M_{heel} / (0.87 \times f_y \times Z_{heel}) = 73 \text{ mm}^2/\text{m}$
 Minimum area of tension reinforcement $A_{s_heel_min} = k \times b \times t_{base} = 390 \text{ mm}^2/\text{m}$
 Area of tension reinforcement required $A_{s_heel_req} = \text{Max}(A_{s_heel_des}, A_{s_heel_min}) = 390 \text{ mm}^2/\text{m}$
 Reinforcement provided **A393 mesh**
 Area of reinforcement provided $A_{s_heel_prov} = 393 \text{ mm}^2/\text{m}$

PASS - Reinforcement provided at the retaining wall heel is adequate

Check shear resistance at heel

Design shear stress $v_{heel} = V_{heel} / (b \times d_{heel}) = 0.046 \text{ N/mm}^2$
 Allowable shear stress $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5) \times 1 \text{ N/mm}^2 = 4.382 \text{ N/mm}^2$

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PASS - Design shear stress is less than maximum shear stress

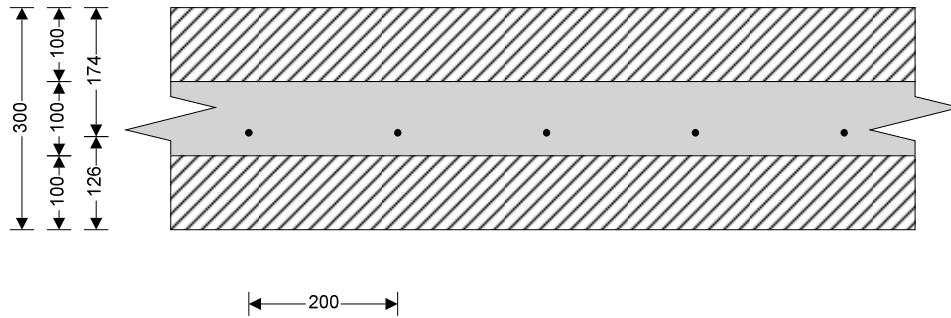
From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$$V_{c_heel} = 0.394 \text{ N/mm}^2$$

$V_{heel} < V_{c_heel}$ - No shear reinforcement required

Design of cavity reinforced masonry retaining wall stem - BS5628-2:2000



Wall details

Thickness of outer leaf of wall

$$t_{outer} = 100 \text{ mm}$$

Thickness of inner leaf of wall

$$t_{inner} = 100 \text{ mm}$$

Thickness of reinforced cavity

$$t_{cavity} = t_{wall} - t_{outer} - t_{inner} = 100 \text{ mm}$$

Depth of stem reinforcement

$$d_{stem} = 174 \text{ mm}$$

Masonry details

Masonry type

Aggregate concrete blocks no voids

Compressive strength of units

$$p_{unit} = 7.3 \text{ N/mm}^2$$

Mortar designation

(ii)

Category of manufacturing control of units

Category II

Partial safety factor for material strength

$$\gamma_{mm} = 2.3$$

Characteristic compressive strength of masonry

Least horizontal dimension of masonry units

$$b_{unit} = 100.0 \text{ mm}$$

Height of masonry units

$$h_{unit} = 215.0 \text{ mm}$$

Ratio of height to least horizontal dimension

$$\text{ratio} = h_{unit} / b_{unit} = 2.2$$

From BS5628:2 Table 3d, mortar ii

Characteristic compressive strength

$$f_k = 6.4 \text{ N/mm}^2$$

Factored horizontal active forces on stem

Surcharge

$$F_{s_sur_f} = \gamma_{t_l} \times K_a \times \cos(90 - \alpha + \delta) \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds}) = 1.3$$

kN/m

Moist backfill above water table

$$F_{s_m_a_f} = 0.5 \times \gamma_{t_e} \times K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2 =$$

10.5 kN/m

Calculate shear for stem design

Shear at base of stem

$$V_{stem} = F_{s_sur_f} + F_{s_m_a_f} = 11.7 \text{ kN/m}$$

Calculate moment for stem design

Surcharge

$$M_{s_sur} = F_{s_sur_f} \times (h_{stem} + t_{base}) / 2 = 1.1 \text{ kNm/m}$$

Moist backfill above water table

$$M_{s_m_a} = F_{s_m_a_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base}) / 3 = 6.8 \text{ kNm/m}$$

Total moment for stem design

$$M_{stem} = M_{s_sur} + M_{s_m_a} = 7.9 \text{ kNm/m}$$

Check maximum design moment for wall stem

Width of wall

$$b = 1000 \text{ mm/m}$$

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Maximum design moment

$$M_{d_stem} = 0.4 \times f_k \times b \times d_{stem}^2 / \gamma_{mm} = \mathbf{33.7 \text{ kNm/m}}$$

PASS - Applied moment is less than maximum design moment

Check wall stem in bending

Moment of resistance factor

$$Q = M_{stem} / d_{stem}^2 = \mathbf{0.262 \text{ N/mm}^2}$$

$$Q = 2 \times c \times (1 - c) \times f_k / \gamma_{mm}$$

Lever arm factor

$$c = \mathbf{0.950}$$

Lever arm

$$Z_{stem} = \min(0.95, c) \times d_{stem} = \mathbf{165.3 \text{ mm}}$$

Area of tension reinforcement required

$$A_{s_stem_des} = M_{stem} \times \gamma_{ms} / (f_y \times Z_{stem}) = \mathbf{221 \text{ mm}^2/\text{m}}$$

Minimum area of tension reinforcement

$$A_{s_stem_min} = k \times b \times t_{wall} = \mathbf{390 \text{ mm}^2/\text{m}}$$

Area of tension reinforcement required

$$A_{s_stem_req} = \text{Max}(A_{s_stem_des}, A_{s_stem_min}) = \mathbf{390 \text{ mm}^2/\text{m}}$$

Reinforcement provided

A393 mesh

Area of reinforcement provided

$$A_{s_stem_prov} = \pi \times \phi_{stem}^2 / (4 \times s_{stem}) = \mathbf{393 \text{ mm}^2/\text{m}}$$

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress

$$v_{stem} = V_{stem} / (b \times d_{stem}) = \mathbf{0.067 \text{ N/mm}^2}$$

Basic characteristic shear strength of masonry

$$f_{vbas} = \min[0.35 + (17.5 \times A_{s_stem_prov} / (b \times d_{stem})), 0.7] \times 1 \text{ N/mm}^2$$

$$f_{vbas} = \mathbf{0.389 \text{ N/mm}^2}$$

Shear span

$$a = M_{stem} / V_{stem} = \mathbf{676.8 \text{ mm}}$$

Characteristic shear strength of masonry

$$f_v = \text{Min}(f_{vbas} \times \max(2.5 - 0.25 \times (a / d_{stem}), 1), 1.75 \text{ N/mm}^2)$$

$$f_v = \mathbf{0.595 \text{ N/mm}^2}$$

Allowable shear stress

$$V_{adm} = f_v / \gamma_{mv} = \mathbf{0.297 \text{ N/mm}^2}$$

PASS - Design shear stress is less than maximum shear stress

Check limiting dimensions

Limiting span/effective depth ratio

$$\text{ratio}_{max} = \mathbf{18.00}$$

Actual span/effective depth ratio

$$\text{ratio}_{act} = (h_{stem} + d_{stem} / 2) / d_{stem} = \mathbf{9.12}$$

PASS - Span to depth ratio is acceptable

Axial load check

Factored axial load on wall

$$N_{wall} = ([t_{wall} \times h_{stem} \times \gamma_{wall} + W_{dead}] \times \gamma_{f_d}) + (W_{live} \times \gamma_{f_l}) = \mathbf{14.9 \text{ kN/m}}$$

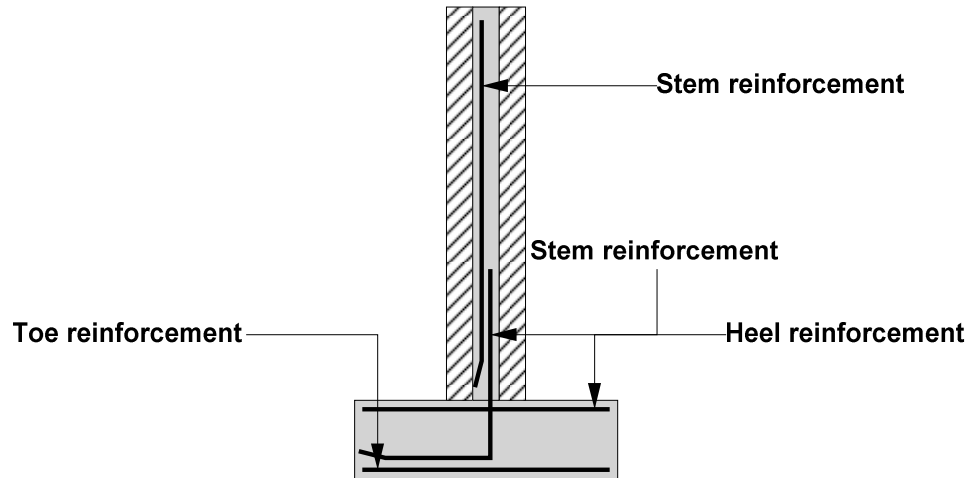
Limiting axial load

$$N_{limit} = 0.1 \times f_k \times t_{wall} = \mathbf{192.0 \text{ kN/m}}$$

Applied axial load may be ignored - calculations valid

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Indicative retaining wall reinforcement diagram



Toe mesh - A393 - (393 mm²/m)
 Heel mesh - A393 - (393 mm²/m)
 Stem mesh - A393 - (393 mm²/m)