



AXIOM
Structural Design Ltd

STRUCTURAL DESIGN CALCULATIONS

Project: **UNIT A, MAESGWYNNE IND EST, CEFN COED**
Job reference: **AX1501**
Date: **Sept 2026**

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*The Institution
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Engineering Statement – Gabion Retaining Wall

The proposed works comprise a gabion basket retaining wall approximately **3.0 m maximum retained height**. The wall is to be constructed using proprietary galvanised gabion baskets filled with durable, well-graded angular stone and installed in accordance with the basket manufacturer's recommendations.

The design is based upon **moderate ground conditions**, with an assumed allowable ground bearing pressure of **100 kN/m²**, and a nominal imposed surcharge of **2.5 kN/m²** applied to the retained ground.

The gabion wall shall be proportioned and stepped/battered as indicated on the structural drawings to provide adequate resistance against **overturning, sliding and excessive bearing pressures**. Overall stability is dependent upon the assumed ground conditions being achieved on site.

The founding formation shall comprise competent natural ground, suitably levelled and compacted as required. Any soft, loose, made or otherwise unsuitable material encountered at formation level shall be removed and replaced with suitable compacted granular material.

A suitable **free-draining granular backfill** shall be provided immediately behind the wall, together with a geotextile separator/filter membrane where required, to prevent migration of fines. The wall design assumes **no significant hydrostatic pressure** develops behind the gabions; positive drainage shall therefore be maintained at all times.

Construction shall be carried out in accordance with good practice and the gabion manufacturer's installation requirements. The engineer shall be notified if ground conditions encountered during excavation differ materially from those assumed within the design.

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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 2.0.05

Design summary

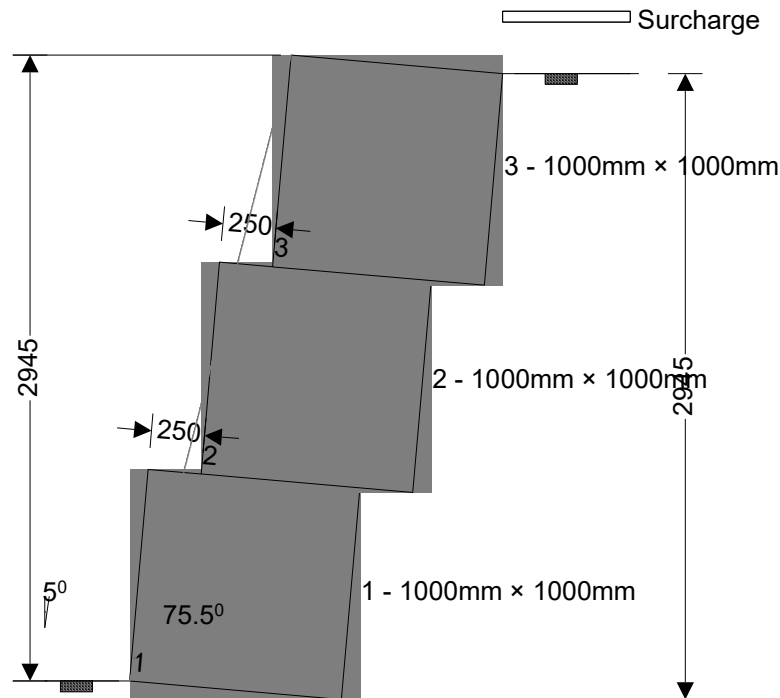
Combination 1

Action	Resistance	Force	FoS	Allowable FoS	Status
Overturning, sliding and bearing at base level					
Overturning (kNm/m)	54.7	35.1	1.559	1.000	PASS
Sliding (kN/m)	37.4	32.6	1.146	1.000	PASS
Bearing (kN/m ²)	100.0	81.2	1.232	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)	27.9	10.0	2.779	1.000	PASS
Sliding (kN/m)	27.0	13.6	1.995	1.000	PASS
Overturning and sliding between courses 2 and 3					
Overturning (kNm/m)	9.5	1.1	8.727	1.000	PASS
Sliding (kN/m)	12.0	2.6	4.630	1.000	PASS

Combination 2

Action	Resistance	Force	FoS	Allowable FoS	Status
Overturning, sliding and bearing at base level					
Overturning (kNm/m)	55.0	32.6	1.687	1.000	PASS
Sliding (kN/m)	29.9	29.7	1.006	1.000	PASS
Bearing (kN/m ²)	100.0	81.2	1.232	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)	27.9	9.4	2.963	1.000	PASS
Sliding (kN/m)	21.6	12.5	1.737	1.000	PASS
Overturning and sliding between courses 2 and 3					
Overturning (kNm/m)	9.5	1.1	8.880	1.000	PASS
Sliding (kN/m)	9.6	2.5	3.888	1.000	PASS

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Wall geometry

Width of gabion 1	$w_1 = 1000 \text{ mm}$
Height of gabion 1	$h_1 = 1000 \text{ mm}$
Width of gabion 2	$w_2 = 1000 \text{ mm}$
Height of gabion 2	$h_2 = 1000 \text{ mm}$
Step to front face between courses 1 and 2	$s_2 = 250 \text{ mm}$
Width of gabion 3	$w_3 = 1000 \text{ mm}$
Height of gabion 3	$h_3 = 1000 \text{ mm}$
Step to front face between courses 2 and 3	$s_3 = 250 \text{ mm}$
Wall inclination	$\varepsilon = 5 \text{ deg}$

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

Slope of retained soil	$\beta = 0.0 \text{ deg}$
Characteristic effective shearing resistance angle	$\phi'_{r,k} = 30.0 \text{ deg}$
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	$\delta'_{r,k} = 22.5 \text{ deg}$
Characteristic wall friction angle	$\delta_{r,k} = \min(\delta'_{r,k}, \phi'_{r,k} \times k_{\text{membrane}}) = 22.5 \text{ deg}$
Characteristic base friction angle	$\delta_{bb,k} = 30.0 \text{ deg}$
Bearing capacity of founding soil	$q = 100 \text{ kN/m}^2$

Wall geometry

Horizontal distance to centre of gravity gabion 1	$x_{g1} = w_1 / 2 = 500 \text{ mm}$
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Vertical distance to centre of gravity gabion 1	$y_{g1} = h_1 / 2 = \mathbf{500 \text{ mm}}$
Weight of gabion 1	$W_{g1} = \gamma_a \times w_1 \times h_1 = \mathbf{16.0 \text{ kN/m}}$
Horizontal distance to centre of gravity gabion 2	$x_{g2} = w_2 / 2 + s_2 = \mathbf{750 \text{ mm}}$
Vertical distance to centre of gravity gabion 2	$y_{g2} = h_2 / 2 + h_1 = \mathbf{1500 \text{ mm}}$
Weight of gabion 2	$W_{g2} = \gamma_a \times w_2 \times h_2 = \mathbf{16.0 \text{ kN/m}}$
Horizontal distance to centre of gravity gabion 3	$x_{g3} = w_3 / 2 + s_2 + s_3 = \mathbf{1000 \text{ mm}}$
Vertical distance to centre of gravity gabion 3	$y_{g3} = h_3 / 2 + h_1 + h_2 = \mathbf{2500 \text{ mm}}$
Weight of gabion 3	$W_{g3} = \gamma_a \times w_3 \times h_3 = \mathbf{16.0 \text{ kN/m}}$
Weight of entire gabion	$W_g = W_{g1} + W_{g2} + W_{g3} = \mathbf{48.0 \text{ kN/m}}$
Horiz distance to centre of gravity entire gabion	$x_g = ((W_{g1} \times x_{g1}) + (W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3})) / W_g = \mathbf{750 \text{ mm}}$
Vert distance to centre of gravity entire gabion	$y_g = ((W_{g1} \times y_{g1}) + (W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3})) / W_g = \mathbf{1500 \text{ mm}}$
Correcting for wall inclination horiz dist	$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{878 \text{ mm}}$
Vertical change in height due to wall inclination	$H_f = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) \times \cos(\epsilon) - (x_{g3} + w_3/2) \times \sin(\epsilon)) = \mathbf{142 \text{ mm}}$

Design dimensions

Effective angle of rear plane of wall	$\alpha = \text{Atan}((w_1 - (x_{g3} + (w_3 / 2))) / (y_{g3} + h_3 / 2)) + 90 \text{ deg} + \epsilon = \mathbf{85.5 \text{ deg}}$
Effective face angle	$\theta = \text{Atan}((y_{g3} + (h_3 / 2)) / ((x_{g3} - (w_3 / 2)))) - \epsilon = \mathbf{75.5 \text{ deg}}$
Effective height of wall	$H = (y_{g3} + h_3 / 2) + (w_1 \times \sin(\epsilon)) - H_f = \mathbf{2945 \text{ mm}}$
Height of wall from toe to front edge of top gabion	$H_{incl} = ((y_{g3} + h_3 / 2) \times \cos(\epsilon) - (x_{g3} - (w_3 / 2)) \times \sin(\epsilon)) = \mathbf{2945 \text{ mm}}$
Active pressure using Coulomb theory	$K_a = \sin(\alpha + \phi'_{r,k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,k}) \times (1 + \sqrt{(\sin(\phi'_{r,k} + \delta_{r,k}) \times \sin(\phi'_{r,k} - \beta) / (\sin(\alpha - \delta_{r,k}) \times \sin(\alpha + \beta))}))^2 = \mathbf{0.330}$
Active thrust due to soil	$P_{a,soil} = 0.5 \times K_a \times \gamma_{sr} \times H^2 = \mathbf{30.1 \text{ kN/m}}$

Pressure at base

Horizontal forces

Retained soil	$F_{soil_h,q} = P_{a,soil} \times \cos(90 - \alpha + \delta_{r,k}) = \mathbf{26.8 \text{ kN/m}}$
Height of soil thrust resolved vertically	$d_{h,soil} = H / 3 - w_1 \times \sin(\epsilon) = \mathbf{895 \text{ mm}}$
Surcharge	$F_{surch_h,q} = p_{o,Q} \times K_a \times H \times \cos(90 - \alpha + \delta_{r,k}) = \mathbf{1.3 \text{ kN/m}}$
Height of surcharge thrust resolved vertically	$d_{h,surch} = H / 2 - w_1 \times \sin(\epsilon) = \mathbf{1385 \text{ mm}}$

Vertical forces

Gabion weight	$F_{gabion_v,q} = W_g = \mathbf{48.0 \text{ kN/m}}$
Retained soil	$F_{soil_v,q} = P_{a,soil} \times \sin(90 - \alpha + \delta_{r,k}) = \mathbf{13.6 \text{ kN/m}}$
Horizontal dist to where soil thrust acts	$b_{v,soil} = w_1 \times \cos(\epsilon) - (H / 3) / \tan(\alpha) = \mathbf{920 \text{ mm}}$
Surcharge	$F_{surch_v,q} = p_{o,Q} \times K_a \times H \times \sin(90 - \alpha + \delta_{r,k}) = \mathbf{0.7 \text{ kN/m}}$
Horizontal dist to where surcharge thrust acts	$b_{v,surch} = w_1 \times \cos(\epsilon) - (H / 2) / \tan(\alpha) = \mathbf{881 \text{ mm}}$
Total horizontal unfactored force	$T_q = F_{soil_h,q} + F_{surch_h,q} = \mathbf{28.1 \text{ kN/m}}$
Total vertical unfactored force	$N_q = F_{gabion_v,q} + F_{soil_v,q} + F_{surch_v,q} = \mathbf{62.3 \text{ kN/m}}$
Force normal to base	$N_s = N_q \times \cos(\epsilon) + T_q \times \sin(\epsilon) = \mathbf{64.5 \text{ kN/m}}$
Total unfactored overturning force	$M_{o,q} = F_{soil_h,q} \times d_{h,soil} + F_{surch_h,q} \times d_{h,surch} = \mathbf{25.8 \text{ kNm/m}}$
Total unfactored restoring force	$M_{R,q} = F_{gabion_v,q} \times X_g + F_{soil_v,q} \times b_{v,soil} + F_{surch_v,q} \times b_{v,surch} = \mathbf{55.3 \text{ kNm/m}}$
Eccentricity	$e = w_1 / 2 - (M_{R,q} - M_{o,q}) / N_s = \mathbf{43 \text{ mm}}$

Reaction acts within middle third of base

Pressure at toe	$\sigma_{toe} = N_s / w_1 \times (1 + (6 \times e / w_1)) = \mathbf{81.2 \text{ kN/m}^2}$
Pressure at heel	$\sigma_{heel} = N_s / w_1 \times (1 - (6 \times e / w_1)) = \mathbf{47.9 \text{ kN/m}^2}$
Factor of safety	$FoS_Q = q / \max(\sigma_{toe}, \sigma_{heel}) = \mathbf{1.232}$
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	$\gamma_Y = 1.00$

Design soil properties

Design effective shearing resistance angle	$\phi'_{r,d} = \text{Atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = 30.0 \text{ deg}$
Design saturated density of retained soil	$\gamma_{s,d} = \gamma_{sr} / \gamma_Y = 21.0 \text{ kN/m}^3$
Design wall friction angle	$\delta_{r,d} = \min(\text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}), \phi'_{r,d} \times k_{\text{membrane}}) = 22.5 \text{ deg}$
Design base friction angle	$\delta_{bb,d} = \text{Atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = 30.0 \text{ deg}$
Design friction between gabions	$\delta_{bg,d} = \text{Atan}(\tan(\delta_{bg,k}) / \gamma_{\phi'}) = 35.0 \text{ deg}$
Active pressure using Coulomb theory	$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta)))})^2) = 0.330$
Active thrust due to soil	$P_{a,\text{soil}} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = 30.1 \text{ kN/m}$

Horizontal forces

Retained soil	$F_{\text{soil}_h} = \gamma_G \times P_{a,\text{soil}} \times \cos(90 - \alpha + \delta_{r,d}) = 36.2 \text{ kN/m}$
Surcharge	$F_{\text{surch}_h} = p_{o,Q} \times \gamma_Q \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = 2.0 \text{ kN/m}$

Vertical forces

Gabion weight	$F_{\text{gabion}_v,f} = \gamma_{G,f} \times W_g = 48.0 \text{ kN/m}$
Retained soil	$F_{\text{soil}_v,f} = \gamma_{G,f} \times P_{a,\text{soil}} \times \sin(90 - \alpha + \delta_{r,d}) = 13.6 \text{ kN/m}$
Surcharge	$F_{\text{surch}_v,f} = p_{o,Q} \times \gamma_{Q,f} \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = 0.0 \text{ kN/m}$

Overtuning stability - take moments about the toe

Overtuning moment	$M_o = F_{\text{soil}_h} \times d_{h,\text{soil}} + F_{\text{surch}_h} \times d_{h,\text{surch}} = 35.1 \text{ kNm/m}$
Restoring moment	$M_R = F_{\text{gabion}_v,f} \times X_g + F_{\text{soil}_v,f} \times b_{v,\text{soil}} + F_{\text{surch}_v,f} \times b_{v,\text{surch}} = 54.7 \text{ kNm/m}$
Factor of safety	$FoS_M = M_R / M_o = 1.559$
Allowable factor of safety	$FoS_{M,\text{allow}} = 1.000$

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	$T = F_{\text{soil}_h} + F_{\text{surch}_h} = 38.1 \text{ kN/m}$
Total vertical force	$N = F_{\text{gabion}_v,f} + F_{\text{soil}_v,f} + F_{\text{surch}_v,f} = 61.6 \text{ kN/m}$
Sliding force	$F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = 32.6 \text{ kN/m}$
Sliding resistance	$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bb,d}) = 37.4 \text{ kN/m}$
Factor of safety	$FoS_S = F_R / F_f = 1.146$
Allowable factor of safety	$FoS_{S,\text{allow}} = 1.000$

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	$x_{g2} = w_2 / 2 = 500 \text{ mm}$
Vertical distance to centre of gravity gabion 2	$y_{g2} = h_2 / 2 = 500 \text{ mm}$

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Weight of gabion 2	$W_{g2} = \gamma_d \times w_2 \times h_2 = \mathbf{16.0 \text{ kN/m}}$
Horizontal distance to centre of gravity gabion 3	$x_{g3} = w_3 / 2 + s_3 = \mathbf{750 \text{ mm}}$
Vertical distance to centre of gravity gabion 3	$y_{g3} = h_3 / 2 + h_2 = \mathbf{1500 \text{ mm}}$
Weight of gabion 3	$W_{g3} = \gamma_d \times w_3 \times h_3 = \mathbf{16.0 \text{ kN/m}}$
Weight of entire gabion	$W_g = W_{g2} + W_{g3} = \mathbf{32.0 \text{ kN/m}}$
Horiz distance to centre of gravity entire gabion	$x_g = ((W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3})) / W_g = \mathbf{625 \text{ mm}}$
Vert distance to centre of gravity entire gabion	$y_g = ((W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3})) / W_g = \mathbf{1000 \text{ mm}}$
Correcting for wall inclination horiz dist	$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{710 \text{ mm}}$
Vertical change in height due to wall inclination	$H_r = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) \times \cos(\epsilon) - (x_{g3} + w_3/2) \times \sin(\epsilon)) = \mathbf{117 \text{ mm}}$

Design dimensions

Effective angle of rear plane of wall	$\alpha = \text{Atan}((w_2 - (x_{g3} + (w_3 / 2))) / (y_{g3} + h_3 / 2)) + 90 \text{ deg} + \epsilon = \mathbf{87.9 \text{ deg}}$
Effective face angle	$\theta = \text{Atan}((y_{g3} + (h_3 / 2)) / ((x_{g3} - (w_3 / 2)))) - \epsilon = \mathbf{77.9 \text{ deg}}$
Effective height of wall	$H = (y_{g3} + h_3 / 2) + (w_2 \times \sin(\epsilon)) - H_r = \mathbf{1971 \text{ mm}}$
Height of wall from toe to front edge of top gabion	$H_{incl} = ((y_{g3} + h_3 / 2) \times \cos(\epsilon) - (x_{g3} - (w_3 / 2)) \times \sin(\epsilon)) = \mathbf{1971 \text{ mm}}$
Active pressure using Coulomb theory	$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}))^2 = \mathbf{0.312}$
Active thrust due to soil	$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = \mathbf{12.7 \text{ kN/m}}$

Horizontal forces

Retained soil	$F_{soil,h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{15.6 \text{ kN/m}}$
Surcharge	$F_{surch,h} = p_{o,Q} \times \gamma_Q \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{1.3 \text{ kN/m}}$

Vertical forces

Gabion weight	$F_{gabion,v,f} = \gamma_{G,f} \times W_g = \mathbf{32.0 \text{ kN/m}}$
Retained soil	$F_{soil,v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{5.3 \text{ kN/m}}$
Surcharge	$F_{surch,v,f} = p_{o,Q} \times \gamma_{Q,f} \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{0.0 \text{ kN/m}}$

Overturning stability - take moments about the toe

Overturning moment	$M_o = F_{soil,h} \times d_{h,soil} + F_{surch,h} \times d_{h,surch} = \mathbf{10.0 \text{ kNm/m}}$
Restoring moment	$M_R = F_{gabion,v,f} \times X_g + F_{soil,v,f} \times b_{v,soil} + F_{surch,v,f} \times b_{v,surch} = \mathbf{27.9 \text{ kNm/m}}$
Factor of safety	$FoSM = M_R / M_o = \mathbf{2.779}$
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	$T = F_{soil,h} + F_{surch,h} = \mathbf{16.9 \text{ kN/m}}$
Total vertical force	$N = F_{gabion,v,f} + F_{soil,v,f} + F_{surch,v,f} = \mathbf{37.3 \text{ kN/m}}$
Sliding force	$F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = \mathbf{13.6 \text{ kN/m}}$
Sliding resistance	$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = \mathbf{27.0 \text{ kN/m}}$
Factor of safety	$FoS_S = F_R / F_f = \mathbf{1.995}$
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 2 and 3

Wall geometry

Horizontal distance to centre of gravity gabion 3	$x_{g3} = w_3 / 2 = \mathbf{500 \text{ mm}}$
Vertical distance to centre of gravity gabion 3	$y_{g3} = h_3 / 2 = \mathbf{500 \text{ mm}}$
Weight of gabion 3	$W_{g3} = \gamma_d \times w_3 \times h_3 = \mathbf{16.0 \text{ kN/m}}$
Weight of entire gabion	$W_g = W_{g3} = \mathbf{16.0 \text{ kN/m}}$

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Horiz distance to centre of gravity entire gabion $x_g = ((W_{g3} \times x_{g3})) / W_g = \mathbf{500 \text{ mm}}$
 Vert distance to centre of gravity entire gabion $y_g = ((W_{g3} \times y_{g3})) / W_g = \mathbf{500 \text{ mm}}$
 Correcting for wall inclination horiz dist $X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{542 \text{ mm}}$
 Vertical change in height due to wall inclination $H_r = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) \times \cos(\epsilon) - (x_{g3} + w_3/2) \times \sin(\epsilon)) = \mathbf{91 \text{ mm}}$

Design dimensions

Effective angle of rear plane of wall $\alpha = 90 \text{ deg} + \epsilon = \mathbf{95.0 \text{ deg}}$
 Effective face angle $\theta = 90 \text{ deg} - \epsilon = \mathbf{85.0 \text{ deg}}$
 Effective height of wall $H = (y_{g3} + h_3 / 2) + (w_3 \times \sin(\epsilon)) - H_r = \mathbf{996 \text{ mm}}$
 Height of wall from toe to front edge of top gabion $H_{incl} = ((y_{g3} + h_3 / 2) \times \cos(\epsilon) - (x_{g3} - (w_3 / 2)) \times \sin(\epsilon)) = \mathbf{996 \text{ mm}}$
 Active pressure using Coulomb theory $K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}))^2 = \mathbf{0.262}$
 Active thrust due to soil $P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = \mathbf{2.7 \text{ kN/m}}$

Horizontal forces

Retained soil $F_{soil,h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{3.5 \text{ kN/m}}$
 Surcharge $F_{surch,h} = p_{o,Q} \times \gamma_Q \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{0.6 \text{ kN/m}}$

Vertical forces

Gabion weight $F_{gabion,v,f} = \gamma_{G,f} \times W_g = \mathbf{16.0 \text{ kN/m}}$
 Retained soil $F_{soil,v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{0.8 \text{ kN/m}}$
 Surcharge $F_{surch,v,f} = p_{o,Q} \times \gamma_{Q,f} \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{0.0 \text{ kN/m}}$

Overtuning stability - take moments about the toe

Overturning moment $M_o = F_{soil,h} \times d_{h,soil} + F_{surch,h} \times d_{h,surch} = \mathbf{1.1 \text{ kNm/m}}$
 Restoring moment $M_R = F_{gabion,v,f} \times X_g + F_{soil,v,f} \times b_{v,soil} + F_{surch,v,f} \times b_{v,surch} = \mathbf{9.5 \text{ kNm/m}}$
 Factor of safety $FoS_M = M_R / M_o = \mathbf{8.727}$
 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 $T = F_{soil,h} + F_{surch,h} = \mathbf{4.1 \text{ kN/m}}$
 Total vertical force $N = F_{gabion,v,f} + F_{soil,v,f} + F_{surch,v,f} = \mathbf{16.8 \text{ kN/m}}$
 Sliding force $F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = \mathbf{2.6 \text{ kN/m}}$
 Sliding resistance $F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = \mathbf{12.0 \text{ kN/m}}$
 Factor of safety $FoS_S = F_R / F_f = \mathbf{4.630}$
 Allowable factor of safety $FoS_{S,allow} = \mathbf{1.000}$

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

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

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

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Design soil properties

Design effective shearing resistance angle

$$\phi'_{r,d} = \text{Atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = \mathbf{24.8 \text{ deg}}$$

Design saturated density of retained soil

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

Design wall friction angle

$$\delta_{r,d} = \min(\text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}), \phi'_{r,d} \times k_{\text{membrane}}) = \mathbf{18.3 \text{ deg}}$$

Design base friction angle

$$\delta_{bb,d} = \text{Atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = \mathbf{24.8 \text{ deg}}$$

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

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

Vertical distance to centre of gravity gabion 1

$$y_{g1} = h_1 / 2 = \mathbf{500 \text{ mm}}$$

Weight of gabion 1

$$W_{g1} = \gamma_d \times w_1 \times h_1 = \mathbf{16.0 \text{ kN/m}}$$

Horizontal distance to centre of gravity gabion 2

$$x_{g2} = w_2 / 2 + s_2 = \mathbf{750 \text{ mm}}$$

Vertical distance to centre of gravity gabion 2

$$y_{g2} = h_2 / 2 + h_1 = \mathbf{1500 \text{ mm}}$$

Weight of gabion 2

$$W_{g2} = \gamma_d \times w_2 \times h_2 = \mathbf{16.0 \text{ kN/m}}$$

Horizontal distance to centre of gravity gabion 3

$$x_{g3} = w_3 / 2 + s_2 + s_3 = \mathbf{1000 \text{ mm}}$$

Vertical distance to centre of gravity gabion 3

$$y_{g3} = h_3 / 2 + h_1 + h_2 = \mathbf{2500 \text{ mm}}$$

Weight of gabion 3

$$W_{g3} = \gamma_d \times w_3 \times h_3 = \mathbf{16.0 \text{ kN/m}}$$

Weight of entire gabion

$$W_g = W_{g1} + W_{g2} + W_{g3} = \mathbf{48.0 \text{ kN/m}}$$

Horiz distance to centre of gravity entire gabion

$$x_g = ((W_{g1} \times x_{g1}) + (W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3})) / W_g = \mathbf{750 \text{ mm}}$$

Vert distance to centre of gravity entire gabion

$$y_g = ((W_{g1} \times y_{g1}) + (W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3})) / W_g = \mathbf{1500 \text{ mm}}$$

Correcting for wall inclination horiz dist

$$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{878 \text{ mm}}$$

Vertical change in height due to wall inclination

$$H_r = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) \times \cos(\epsilon) - (x_{g3} + w_3/2) \times \sin(\epsilon)) = \mathbf{142 \text{ mm}}$$

Design dimensions

Effective angle of rear plane of wall

$$\alpha = \text{Atan}((w_1 - (x_{g3} + (w_3 / 2))) / (y_{g3} + h_3 / 2)) + 90 \text{ deg} + \epsilon = \mathbf{85.5 \text{ deg}}$$

Effective face angle

$$\theta = \text{Atan}((y_{g3} + (h_3 / 2)) / ((x_{g3} - (w_3 / 2)))) - \epsilon = \mathbf{75.5 \text{ deg}}$$

Effective height of wall

$$H = (y_{g3} + h_3 / 2) + (w_1 \times \sin(\epsilon)) - H_r = \mathbf{2945 \text{ mm}}$$

Height of wall from toe to front edge of top gabion

$$H_{\text{incl}} = ((y_{g3} + h_3 / 2) \times \cos(\epsilon) - (x_{g3} - (w_3 / 2)) \times \sin(\epsilon)) = \mathbf{2945 \text{ mm}}$$

Active pressure using Coulomb theory

$$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))})^2) = \mathbf{0.395}$$

Active thrust due to soil

$$P_{a,\text{soil}} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = \mathbf{36.0 \text{ kN/m}}$$

Horizontal forces

Retained soil

$$F_{\text{soil}_h} = \gamma_G \times P_{a,\text{soil}} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{33.2 \text{ kN/m}}$$

Surcharge

$$F_{\text{surch}_h} = p_{o,Q} \times \gamma_Q \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{2.1 \text{ kN/m}}$$

Vertical forces

Gabion weight

$$F_{\text{gabion}_v,f} = \gamma_{G,f} \times W_g = \mathbf{48.0 \text{ kN/m}}$$

Retained soil

$$F_{\text{soil}_v,f} = \gamma_{G,f} \times P_{a,\text{soil}} \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{13.9 \text{ kN/m}}$$

Surcharge

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

Overturning stability - take moments about the toe

Overturning moment

$$M_o = F_{\text{soil}_h} \times d_{h,\text{soil}} + F_{\text{surch}_h} \times d_{h,\text{surch}} = \mathbf{32.6 \text{ kNm/m}}$$

Restoring moment

$$M_R = F_{\text{gabion}_v,f} \times X_g + F_{\text{soil}_v,f} \times b_{v,\text{soil}} + F_{\text{surch}_v,f} \times b_{v,\text{surch}} = \mathbf{55.0 \text{ kNm/m}}$$

Factor of safety

$$FoS_M = M_R / M_o = \mathbf{1.687}$$

Allowable factor of safety

$$FoS_{M,\text{allow}} = \mathbf{1.000}$$

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

$$T = F_{\text{soil}_h} + F_{\text{surch}_h} = \mathbf{35.3 \text{ kN/m}}$$

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Total vertical force $N = F_{\text{gabion_v,f}} + F_{\text{soil_v,f}} + F_{\text{surch_v,f}} = \mathbf{61.9 \text{ kN/m}}$
 Sliding force $F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = \mathbf{29.7 \text{ kN/m}}$
 Sliding resistance $F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{\text{bb,d}}) = \mathbf{29.9 \text{ kN/m}}$
 Factor of safety $FoS_S = F_R / F_f = \mathbf{1.006}$
 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 $x_{g2} = w_2 / 2 = \mathbf{500 \text{ mm}}$
 Vertical distance to centre of gravity gabion 2 $y_{g2} = h_2 / 2 = \mathbf{500 \text{ mm}}$
 Weight of gabion 2 $W_{g2} = \gamma_d \times w_2 \times h_2 = \mathbf{16.0 \text{ kN/m}}$
 Horizontal distance to centre of gravity gabion 3 $x_{g3} = w_3 / 2 + s_3 = \mathbf{750 \text{ mm}}$
 Vertical distance to centre of gravity gabion 3 $y_{g3} = h_3 / 2 + h_2 = \mathbf{1500 \text{ mm}}$
 Weight of gabion 3 $W_{g3} = \gamma_d \times w_3 \times h_3 = \mathbf{16.0 \text{ kN/m}}$
 Weight of entire gabion $W_g = W_{g2} + W_{g3} = \mathbf{32.0 \text{ kN/m}}$
 Horiz distance to centre of gravity entire gabion $x_g = ((W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3})) / W_g = \mathbf{625 \text{ mm}}$
 Vert distance to centre of gravity entire gabion $y_g = ((W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3})) / W_g = \mathbf{1000 \text{ mm}}$
 Correcting for wall inclination horiz dist $X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{710 \text{ mm}}$
 Vertical change in height due to wall inclination $H_f = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) \times \cos(\epsilon) - (x_{g3} + w_3/2) \times \sin(\epsilon)) = \mathbf{117 \text{ mm}}$

Design dimensions

Effective angle of rear plane of wall $\alpha = \text{Atan}((w_2 - (x_{g3} + (w_3 / 2))) / (y_{g3} + h_3 / 2)) + 90 \text{ deg} + \epsilon = \mathbf{87.9 \text{ deg}}$
 Effective face angle $\theta = \text{Atan}((y_{g3} + (h_3 / 2)) / ((x_{g3} - (w_3 / 2)))) - \epsilon = \mathbf{77.9 \text{ deg}}$
 Effective height of wall $H = (y_{g3} + h_3 / 2) + (w_2 \times \sin(\epsilon)) - H_f = \mathbf{1971 \text{ mm}}$
 Height of wall from toe to front edge of top gabion $H_{\text{incl}} = ((y_{g3} + h_3 / 2) \times \cos(\epsilon) - (x_{g3} - (w_3 / 2)) \times \sin(\epsilon)) = \mathbf{1971 \text{ mm}}$
 Active pressure using Coulomb theory $K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}))^2 = \mathbf{0.377}$
 Active thrust due to soil $P_{a,\text{soil}} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = \mathbf{15.4 \text{ kN/m}}$

Horizontal forces

Retained soil $F_{\text{soil_h}} = \gamma_G \times P_{a,\text{soil}} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{14.4 \text{ kN/m}}$
 Surcharge $F_{\text{surch_h}} = p_{o,Q} \times \gamma_Q \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{1.4 \text{ kN/m}}$

Vertical forces

Gabion weight $F_{\text{gabion_v,f}} = \gamma_G \times W_g = \mathbf{32.0 \text{ kN/m}}$
 Retained soil $F_{\text{soil_v,f}} = \gamma_G \times P_{a,\text{soil}} \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{5.4 \text{ kN/m}}$
 Surcharge $F_{\text{surch_v,f}} = p_{o,Q} \times \gamma_{Q,f} \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{0.0 \text{ kN/m}}$

Overturning stability - take moments about the toe

Overturning moment $M_o = F_{\text{soil_h}} \times d_{h,\text{soil}} + F_{\text{surch_h}} \times d_{h,\text{surch}} = \mathbf{9.4 \text{ kNm/m}}$
 Restoring moment $M_R = F_{\text{gabion_v,f}} \times X_g + F_{\text{soil_v,f}} \times b_{v,\text{soil}} + F_{\text{surch_v,f}} \times b_{v,\text{surch}} = \mathbf{27.9 \text{ kNm/m}}$
 Factor of safety $FoSM = M_R / M_o = \mathbf{2.963}$
 Allowable factor of safety $FoSM_{\text{allow}} = \mathbf{1.000}$

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 $T = F_{\text{soil_h}} + F_{\text{surch_h}} = \mathbf{15.8 \text{ kN/m}}$
 Total vertical force $N = F_{\text{gabion_v,f}} + F_{\text{soil_v,f}} + F_{\text{surch_v,f}} = \mathbf{37.4 \text{ kN/m}}$
 Sliding force $F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = \mathbf{12.5 \text{ kN/m}}$

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Sliding resistance $F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = 21.6 \text{ kN/m}$

Factor of safety $FoS_S = F_R / F_f = 1.737$

Allowable factor of safety $FoS_{S_allow} = 1.000$

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

Check overturning and sliding between courses 2 and 3

Wall geometry

Horizontal distance to centre of gravity gabion 3 $x_{g3} = w_3 / 2 = 500 \text{ mm}$

Vertical distance to centre of gravity gabion 3 $y_{g3} = h_3 / 2 = 500 \text{ mm}$

Weight of gabion 3 $W_{g3} = \gamma_d \times w_3 \times h_3 = 16.0 \text{ kN/m}$

Weight of entire gabion $W_g = W_{g3} = 16.0 \text{ kN/m}$

Horiz distance to centre of gravity entire gabion $x_g = ((W_{g3} \times x_{g3})) / W_g = 500 \text{ mm}$

Vert distance to centre of gravity entire gabion $y_g = ((W_{g3} \times y_{g3})) / W_g = 500 \text{ mm}$

Correcting for wall inclination horiz dist $X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = 542 \text{ mm}$

Vertical change in height due to wall inclination $H_f = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) \times \cos(\epsilon) - (x_{g3} + w_3/2) \times \sin(\epsilon)) = 91 \text{ mm}$

Design dimensions

Effective angle of rear plane of wall $\alpha = 90 \text{ deg} + \epsilon = 95.0 \text{ deg}$

Effective face angle $\theta = 90 \text{ deg} - \epsilon = 85.0 \text{ deg}$

Effective height of wall $H = (y_{g3} + h_3 / 2) + (w_3 \times \sin(\epsilon)) - H_f = 996 \text{ mm}$

Height of wall from toe to front edge of top gabion $H_{incl} = ((y_{g3} + h_3 / 2) \times \cos(\epsilon) - (x_{g3} - (w_3 / 2)) \times \sin(\epsilon)) = 996 \text{ mm}$

Active pressure using Coulomb theory $K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}))^2 = 0.327$

Active thrust due to soil $P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = 3.4 \text{ kN/m}$

Horizontal forces

Retained soil $F_{soil_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = 3.3 \text{ kN/m}$

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

Vertical forces

Gabion weight $F_{gabion_v,f} = \gamma_G \times W_g = 16.0 \text{ kN/m}$

Retained soil $F_{soil_v,f} = \gamma_G \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = 0.8 \text{ kN/m}$

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 $M_o = F_{soil_h} \times d_{h,soil} + F_{surch_h} \times d_{h,surch} = 1.1 \text{ kNm/m}$

Restoring moment $M_R = F_{gabion_v,f} \times X_g + F_{soil_v,f} \times b_{v,soil} + F_{surch_v,f} \times b_{v,surch} = 9.5 \text{ kNm/m}$

Factor of safety $FoS_M = M_R / M_o = 8.880$

Allowable factor of safety $FoS_{M_allow} = 1.000$

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 $T = F_{soil_h} + F_{surch_h} = 3.9 \text{ kN/m}$

Total vertical force $N = F_{gabion_v,f} + F_{soil_v,f} + F_{surch_v,f} = 16.8 \text{ kN/m}$

Sliding force $F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = 2.5 \text{ kN/m}$

Sliding resistance $F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = 9.6 \text{ kN/m}$

Factor of safety $FoS_S = F_R / F_f = 3.888$

Allowable factor of safety $FoS_{S_allow} = 1.000$

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

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