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STRUCTURAL CALCULATIONS

For

GABION BASKET RETAINING STRUCTURE

at

**27 GLANNANT PLACE
CWMGWRACH
GLYNNEATH
SA11 5TE**

Date: July 2022

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	Calcs for Gabion Retaining Structure				Start page no./Revision 2	
	Calcs by AR	Calcs date 25/07/2022	Checked by AR	Checked date 25/07/2022	Approved by	Approved date

GABION RETAINING WALL ANALYSIS & DESIGN

In accordance with BS8002:2015 - Code of Practice for Earth Retaining Structures and the UK National Annex

Tedds calculation version 2.0.02

Design summary

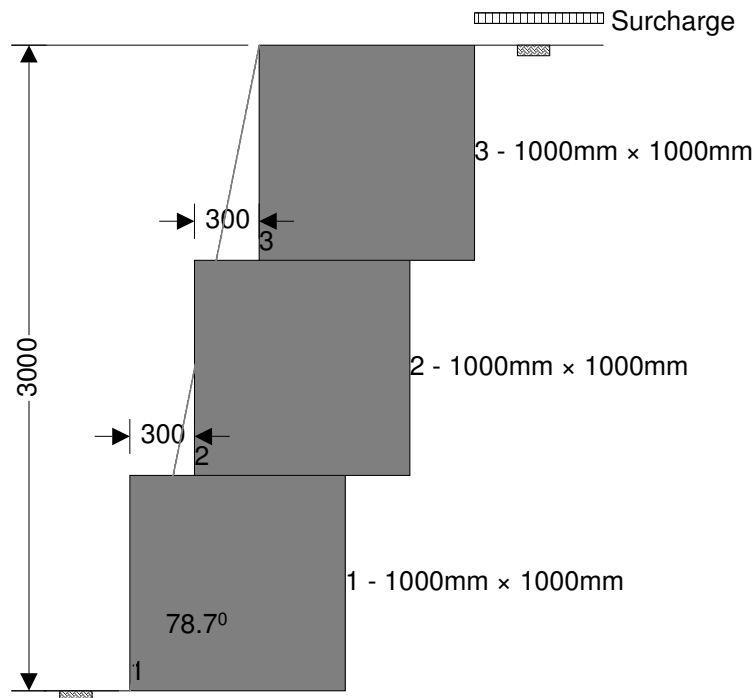
Combination 1

Action	Resistance	Force	FoS	Allowable FoS	Status
Overturning, sliding and bearing at base level					
Overturning (kNm/m)	48.6	28.3	1.720	1.000	PASS
Sliding (kN/m)	35.1	26.2	1.342	1.000	PASS
Bearing (kN/m ²)	125.0	73.8	1.694	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)	25.6	9.7	2.646	1.000	PASS
Sliding (kN/m)	26.1	13.0	2.005	1.000	PASS
Overturning and sliding between courses 2 and 3					
Overturning (kNm/m)	9.0	1.7	5.233	1.000	PASS
Sliding (kN/m)	11.9	4.4	2.727	1.000	PASS

Combination 2

Action	Resistance	Force	FoS	Allowable FoS	Status
Overturning, sliding and bearing at base level					
Overturning (kNm/m)	47.5	23.1	2.055	1.000	PASS
Sliding (kN/m)	27.4	21.2	1.296	1.000	PASS
Bearing (kN/m ²)	125.0	73.8	1.694	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)	25.0	8.0	3.141	1.000	PASS
Sliding (kN/m)	20.6	10.6	1.940	1.000	PASS
Overturning and sliding between courses 2 and 3					
Overturning (kNm/m)	8.9	1.4	6.175	1.000	PASS
Sliding (kN/m)	9.4	3.6	2.639	1.000	PASS

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	Calcs for Gabion Retaining Structure			Start page no./Revision 3	
	Calcs by AR	Calcs date 25/07/2022	Checked by AR	Checked date 25/07/2022	Approved by Approved date



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	$s_2 = 300 \text{ mm}$
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	$s_3 = 300 \text{ mm}$
Wall inclination	$\varepsilon = 0 \text{ deg}$

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	$p_{o,Q} = 5 \text{ kN/m}^2$
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Soil properties

Slope of retained soil	$\beta = 0.0 \text{ deg}$
Characteristic peak shearing resistance angle	$\phi'_{pk,k} = 36.0 \text{ deg}$
Characteristic saturated density of retained soil	$\gamma_{sr} = 19.0 \text{ kN/m}^3$
Coefficient for wall friction	$k_{membrane} = 0.75$
Wall friction angle	$\delta_{r,k} = 27.0 \text{ deg}$
Characteristic base friction angle	$\delta_{bb,k} = 30.0 \text{ deg}$
Bearing capacity of founding soil	$q = 125 \text{ kN/m}^2$

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

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	Calcs for Gabion Retaining Structure			Start page no./Revision 4	
	Calcs by AR	Calcs date 25/07/2022	Checked by AR	Checked date 25/07/2022	Approved by Approved date

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

$$x_{g2} = w_2 / 2 + s_2 = \mathbf{800 \text{ mm}}$$

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

$$x_{g3} = w_3 / 2 + s_2 + s_3 = \mathbf{1100 \text{ mm}}$$

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

$$x_g = ((W_{g1} \times x_{g1}) + (W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3})) / W_g = \mathbf{800 \text{ mm}}$$

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

$$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{800 \text{ mm}}$$

Vertical change in height due to wall inclination

$$H_f = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) \times \cos(\epsilon) - (x_{g3} + w_3/2) \times \sin(\epsilon)) = \mathbf{0 \text{ mm}}$$

Design dimensions

Effective angle of rear plane of wall

$$\alpha = \text{Atan}((w_1 - (x_{g3} + (w_3 / 2))) / (y_{g3} + h_3 / 2)) + 90 \text{ deg} + \epsilon = \mathbf{78.7 \text{ deg}}$$

Effective face angle

$$\theta = \text{Atan}((y_{g3} + (h_3 / 2)) / ((x_{g3} - (w_3 / 2)))) - \epsilon = \mathbf{78.7 \text{ deg}}$$

Effective height of wall

$$H = (y_{g3} + h_3 / 2) + (w_1 \times \sin(\epsilon)) - H_f = \mathbf{3000 \text{ mm}}$$

Height of wall from toe to front edge of top gabion

$$H_{incl} = ((y_{g3} + h_3 / 2) \times \cos(\epsilon) - (x_{g3} - (w_3 / 2)) \times \sin(\epsilon)) = \mathbf{3000 \text{ mm}}$$

Active pressure using Kerisel and Absi theory

$$K_a = \mathbf{0.242}$$

Active thrust due to soil

$$P_{a,soil} = 0.5 \times K_a \times \gamma_{sr} \times H^2 = \mathbf{20.7 \text{ kN/m}}$$

Pressure at base

Horizontal forces

Retained soil

$$F_{soil_h,q} = P_{a,soil} \times \cos(90 - \alpha + \delta_{r,k}) = \mathbf{16.2 \text{ kN/m}}$$

Height of soil thrust resolved vertically

$$d_{h,soil} = H / 3 - w_1 \times \sin(\epsilon) = \mathbf{1000 \text{ mm}}$$

Surcharge

$$F_{surch_h,q} = p_{o,Q} \times K_a \times H \times \cos(90 - \alpha + \delta_{r,k}) = \mathbf{2.8 \text{ kN/m}}$$

Height of surcharge thrust resolved vertically

$$d_{h,surch} = H / 2 - w_1 \times \sin(\epsilon) = \mathbf{1500 \text{ mm}}$$

Vertical forces

Gabion weight

$$F_{gabion_v,q} = W_g = \mathbf{48.0 \text{ kN/m}}$$

Retained soil

$$F_{soil_v,q} = P_{a,soil} \times \sin(90 - \alpha + \delta_{r,k}) = \mathbf{12.8 \text{ kN/m}}$$

Horizontal dist to where soil thrust acts

$$b_{v,soil} = w_1 \times \cos(\epsilon) - (H / 3) / \tan(\alpha) = \mathbf{800 \text{ mm}}$$

Surcharge

$$F_{surch_v,q} = p_{o,Q} \times K_a \times H \times \sin(90 - \alpha + \delta_{r,k}) = \mathbf{2.2 \text{ kN/m}}$$

Horizontal dist to where surcharge thrust acts

$$b_{v,surch} = w_1 \times \cos(\epsilon) - (H / 2) / \tan(\alpha) = \mathbf{700 \text{ mm}}$$

Total horizontal unfactored force

$$T_q = F_{soil_h,q} + F_{surch_h,q} = \mathbf{19.1 \text{ kN/m}}$$

Total vertical unfactored force

$$N_q = F_{gabion_v,q} + F_{soil_v,q} + F_{surch_v,q} = \mathbf{63.1 \text{ kN/m}}$$

Force normal to base

$$N_s = N_q \times \cos(\epsilon) + T_q \times \sin(\epsilon) = \mathbf{63.1 \text{ kN/m}}$$

Total unfactored overturning force

$$M_{o,q} = F_{soil_h,q} \times d_{h,soil} + F_{surch_h,q} \times d_{h,surch} = \mathbf{20.5 \text{ kNm/m}}$$

Total unfactored restoring force

$$M_{R,q} = F_{gabion_v,q} \times X_g + F_{soil_v,q} \times b_{v,soil} + F_{surch_v,q} \times b_{v,surch} = \mathbf{50.2 \text{ kNm/m}}$$

Eccentricity

$$e = w_1 / 2 - (M_{R,q} - M_{o,q}) / N_s = \mathbf{28 \text{ mm}}$$

Reaction acts within middle third of base

Pressure at toe

$$\sigma_{toe} = N_s / w_1 \times (1 + (6 \times e / w_1)) = \mathbf{73.8 \text{ kN/m}^2}$$

Pressure at heel

$$\sigma_{heel} = N_s / w_1 \times (1 - (6 \times e / w_1)) = \mathbf{52.3 \text{ kN/m}^2}$$

Factor of safety

$$FoS_Q = q / \max(\sigma_{toe}, \sigma_{heel}) = \mathbf{1.694}$$

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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	Calcs for Gabion Retaining Structure		Start page no./Revision 5	
	Calcs by AR	Calcs date 25/07/2022	Checked by AR	Checked date 25/07/2022
		Approved by	Approved date	

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	$\phi'_{r,d} = \text{Atan}(\tan(\phi'_{pk,k}) / \gamma_{\phi'}) = 36.0 \text{ deg}$
Design saturated density of retained soil	$\gamma_{s,d} = \gamma_{sr} / \gamma_Y = 19.0 \text{ kN/m}^3$
Design wall friction angle (cl.5.4.2.1)	$\delta_{r,d} = \min(\text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}), \phi'_{r,d} \times k_{\text{membrane}}) = 27.0 \text{ deg}$
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 Kerisel and Absi theory	$K_a = 0.242$
Active thrust due to soil	$P_{a,\text{soil}} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = 20.7 \text{ kN/m}$

Horizontal forces

Retained soil	$F_{\text{soil}_h} = \gamma_G \times P_{a,\text{soil}} \times \cos(90 - \alpha + \delta_{r,d}) = 21.9 \text{ kN/m}$
Surcharge	$F_{\text{surch}_h} = p_{o,Q} \times \gamma_Q \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = 4.3 \text{ kN/m}$

Vertical forces

Gabion weight	$F_{\text{gabion}_v,f} = \gamma_{G,f} \times W_g = 48.0 \text{ kN/m}$
Retained soil	$F_{\text{soil}_v,f} = \gamma_{G,f} \times P_{a,\text{soil}} \times \sin(90 - \alpha + \delta_{r,d}) = 12.8 \text{ kN/m}$
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	$M_o = F_{\text{soil}_h} \times d_{h,\text{soil}} + F_{\text{surch}_h} \times d_{h,\text{surch}} = 28.3 \text{ kNm/m}$
Restoring moment	$M_R = F_{\text{gabion}_v,f} \times X_g + F_{\text{soil}_v,f} \times b_{v,\text{soil}} + F_{\text{surch}_v,f} \times b_{v,\text{surch}} = 48.6 \text{ kNm/m}$
Factor of safety	$\text{FoSM} = M_R / M_o = 1.720$
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	$T = F_{\text{soil}_h} + F_{\text{surch}_h} = 26.2 \text{ kN/m}$
Total vertical force	$N = F_{\text{gabion}_v,f} + F_{\text{soil}_v,f} + F_{\text{surch}_v,f} = 60.8 \text{ kN/m}$
Sliding force	$F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = 26.2 \text{ kN/m}$
Sliding resistance	$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bb,d}) = 35.1 \text{ kN/m}$
Factor of safety	$\text{FoSS} = F_R / F_f = 1.342$
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	$x_{g2} = w_2 / 2 = 500 \text{ mm}$
Vertical distance to centre of gravity gabion 2	$y_{g2} = h_2 / 2 = 500 \text{ mm}$
Weight of gabion 2	$W_{g2} = \gamma_d \times w_2 \times h_2 = 16.0 \text{ kN/m}$

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	Calcs for Gabion Retaining Structure		Start page no./Revision 6	
	Calcs by AR	Calcs date 25/07/2022	Checked by AR	Checked date 25/07/2022
		Approved by	Approved date	

Horizontal distance to centre of gravity gabion 3

$$x_{g3} = w_3 / 2 + s_3 = \mathbf{800 \text{ mm}}$$

Vertical distance to centre of gravity gabion 3

$$y_{g3} = h_3 / 2 + h_2 = \mathbf{1500 \text{ mm}}$$

Weight of gabion 3

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

Weight of entire gabion

$$W_g = W_{g2} + W_{g3} = \mathbf{32.0 \text{ kN/m}}$$

Horiz distance to centre of gravity entire gabion

$$x_g = ((W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3})) / W_g = \mathbf{650 \text{ mm}}$$

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

$$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{650 \text{ mm}}$$

Vertical change in height due to wall inclination

$$H_f = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) \times \cos(\epsilon) - (x_{g3} + w_3/2) \times \sin(\epsilon)) = \mathbf{0 \text{ mm}}$$

Design dimensions

Effective angle of rear plane of wall

$$\alpha = \text{Atan}((w_2 - (x_{g3} + (w_3 / 2))) / (y_{g3} + h_3 / 2)) + 90 \text{ deg} + \epsilon = \mathbf{81.5 \text{ deg}}$$

Effective face angle

$$\theta = \text{Atan}((y_{g3} + (h_3 / 2)) / ((x_{g3} - (w_3 / 2)))) - \epsilon = \mathbf{81.5 \text{ deg}}$$

Effective height of wall

$$H = (y_{g3} + h_3 / 2) + (w_2 \times \sin(\epsilon)) - H_f = \mathbf{2000 \text{ mm}}$$

Height of wall from toe to front edge of top gabion

$$H_{incl} = ((y_{g3} + h_3 / 2) \times \cos(\epsilon) - (x_{g3} - (w_3 / 2)) \times \sin(\epsilon)) = \mathbf{2000 \text{ mm}}$$

Active pressure using Kerisel and Absi theory

$$K_a = \mathbf{0.242}$$

Active thrust due to soil

$$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = \mathbf{9.2 \text{ kN/m}}$$

Horizontal forces

Retained soil

$$F_{soil,h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{10.1 \text{ kN/m}}$$

Surcharge

$$F_{surch,h} = p_{o,Q} \times \gamma_Q \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{2.9 \text{ kN/m}}$$

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

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

Overtuning stability - take moments about the toe

Overtuning moment

$$M_o = F_{soil,h} \times d_{h,soil} + F_{surch,h} \times d_{h,surch} = \mathbf{9.7 \text{ kNm/m}}$$

Restoring moment

$$M_R = F_{gabion,v,f} \times X_g + F_{soil,v,f} \times b_{v,soil} + F_{surch,v,f} \times b_{v,surch} = \mathbf{25.6 \text{ kNm/m}}$$

Factor of safety

$$FoS_M = M_R / M_o = \mathbf{2.646}$$

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

$$T = F_{soil,h} + F_{surch,h} = \mathbf{13.0 \text{ kN/m}}$$

Total vertical force

$$N = F_{gabion,v,f} + F_{soil,v,f} + F_{surch,v,f} = \mathbf{37.3 \text{ kN/m}}$$

Sliding force

$$F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = \mathbf{13.0 \text{ kN/m}}$$

Sliding resistance

$$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = \mathbf{26.1 \text{ kN/m}}$$

Factor of safety

$$FoS_S = F_R / F_f = \mathbf{2.005}$$

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

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

Weight of entire gabion

$$W_g = W_{g3} = \mathbf{16.0 \text{ kN/m}}$$

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

$$y_g = ((W_{g3} \times y_{g3})) / W_g = \mathbf{500 \text{ mm}}$$

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	Calcs for Gabion Retaining Structure		Start page no./Revision 7	
	Calcs by AR	Calcs date 25/07/2022	Checked by AR	Checked date 25/07/2022
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Correcting for wall inclination horiz dist

$$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{500 \text{ mm}}$$

Vertical change in height due to wall inclination

$$H_f = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) \times \cos(\epsilon) - (x_{g3} + w_3/2) \times \sin(\epsilon)) = \mathbf{0 \text{ mm}}$$

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

$$H = (y_{g3} + h_3 / 2) + (w_3 \times \sin(\epsilon)) - H_f = \mathbf{1000 \text{ mm}}$$

Height of wall from toe to front edge of top gabion

$$H_{incl} = ((y_{g3} + h_3 / 2) \times \cos(\epsilon) - (x_{g3} - (w_3 / 2)) \times \sin(\epsilon)) = \mathbf{1000 \text{ mm}}$$

Active pressure using Kerisel and Absi theory

$$K_a = \mathbf{0.242}$$

Active thrust due to soil

$$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = \mathbf{2.3 \text{ kN/m}}$$

Horizontal forces

Retained soil

$$F_{soil,h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{2.8 \text{ kN/m}}$$

Surcharge

$$F_{surch,h} = p_{o,Q} \times \gamma_Q \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{1.6 \text{ kN/m}}$$

Vertical forces

Gabion weight

$$F_{gabion,v,f} = \gamma_{G,f} \times W_g = \mathbf{16.0 \text{ kN/m}}$$

Retained soil

$$F_{soil,v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{1.0 \text{ kN/m}}$$

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

Overtuning moment

$$M_o = F_{soil,h} \times d_{h,soil} + F_{surch,h} \times d_{h,surch} = \mathbf{1.7 \text{ kNm/m}}$$

Restoring moment

$$M_R = F_{gabion,v,f} \times X_g + F_{soil,v,f} \times b_{v,soil} + F_{surch,v,f} \times b_{v,surch} = \mathbf{9.0 \text{ kNm/m}}$$

Factor of safety

$$FoSM = M_R / M_o = \mathbf{5.233}$$

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

$$T = F_{soil,h} + F_{surch,h} = \mathbf{4.4 \text{ kN/m}}$$

Total vertical force

$$N = F_{gabion,v,f} + F_{soil,v,f} + F_{surch,v,f} = \mathbf{17.0 \text{ kN/m}}$$

Sliding force

$$F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = \mathbf{4.4 \text{ kN/m}}$$

Sliding resistance

$$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = \mathbf{11.9 \text{ kN/m}}$$

Factor of safety

$$FoSS = F_R / F_f = \mathbf{2.727}$$

Allowable factor of safety

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

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

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

Design soil properties

Design effective shearing resistance angle

$$\phi'_{r,d} = \text{Atan}(\tan(\phi'_{pk,k}) / \gamma_{\phi'}) = \mathbf{30.2 \text{ deg}}$$

Design saturated density of retained soil

$$\gamma_{s,d} = \gamma_{sr} / \gamma_{\gamma} = \mathbf{19.0 \text{ kN/m}^3}$$

Design wall friction angle (cl.5.4.2.1)

$$\delta_{r,d} = \min(\text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}), \phi'_{r,d} \times k_{\text{membrane}}) = \mathbf{22.2 \text{ deg}}$$

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	Calcs for Gabion Retaining Structure		Start page no./Revision 8	
	Calcs by AR	Calcs date 25/07/2022	Checked by AR	Checked date 25/07/2022
		Approved by	Approved date	

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

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

Horizontal distance to centre of gravity gabion 2

$$x_{g2} = w_2 / 2 + s_2 = \mathbf{800 \text{ mm}}$$

Vertical distance to centre of gravity gabion 2

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

Weight of gabion 2

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

Horizontal distance to centre of gravity gabion 3

$$x_{g3} = w_3 / 2 + s_2 + s_3 = \mathbf{1100 \text{ mm}}$$

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

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

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

$$x_g = ((W_{g1} \times x_{g1}) + (W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3})) / W_g = \mathbf{800 \text{ mm}}$$

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

$$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{800 \text{ mm}}$$

Vertical change in height due to wall inclination

$$H_f = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) \times \cos(\epsilon) - (x_{g3} + w_3/2) \times \sin(\epsilon)) = \mathbf{0 \text{ mm}}$$

Design dimensions

Effective angle of rear plane of wall

$$\alpha = \text{Atan}((w_1 - (x_{g3} + (w_3 / 2))) / (y_{g3} + h_3 / 2)) + 90 \text{ deg} + \epsilon = \mathbf{78.7 \text{ deg}}$$

Effective face angle

$$\theta = \text{Atan}((y_{g3} + (h_3 / 2)) / ((x_{g3} - (w_3 / 2)))) - \epsilon = \mathbf{78.7 \text{ deg}}$$

Effective height of wall

$$H = (y_{g3} + h_3 / 2) + (w_1 \times \sin(\epsilon)) - H_f = \mathbf{3000 \text{ mm}}$$

Height of wall from toe to front edge of top gabion

$$H_{incl} = ((y_{g3} + h_3 / 2) \times \cos(\epsilon) - (x_{g3} - (w_3 / 2)) \times \sin(\epsilon)) = \mathbf{3000 \text{ mm}}$$

Active pressure using Kerisel and Absi theory

$$K_a = \mathbf{0.242}$$

Active thrust due to soil

$$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = \mathbf{20.7 \text{ kN/m}}$$

Horizontal forces

Retained soil

$$F_{soil,h} = \gamma_g \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{17.2 \text{ kN/m}}$$

Surcharge

$$F_{surch,h} = p_{o,Q} \times \gamma_Q \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{3.9 \text{ kN/m}}$$

Vertical forces

Gabion weight

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

Retained soil

$$F_{soil,v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{11.4 \text{ kN/m}}$$

Surcharge

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

Overtuning stability - take moments about the toe

Overtuning moment

$$M_o = F_{soil,h} \times d_{h,soil} + F_{surch,h} \times d_{h,surch} = \mathbf{23.1 \text{ kNm/m}}$$

Restoring moment

$$M_R = F_{gabion,v,f} \times X_g + F_{soil,v,f} \times b_{v,soil} + F_{surch,v,f} \times b_{v,surch} = \mathbf{47.5 \text{ kNm/m}}$$

Factor of safety

$$FoS_M = M_R / M_o = \mathbf{2.055}$$

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

$$T = F_{soil,h} + F_{surch,h} = \mathbf{21.2 \text{ kN/m}}$$

Total vertical force

$$N = F_{gabion,v,f} + F_{soil,v,f} + F_{surch,v,f} = \mathbf{59.4 \text{ kN/m}}$$

Sliding force

$$F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = \mathbf{21.2 \text{ kN/m}}$$

Sliding resistance

$$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bb,d}) = \mathbf{27.4 \text{ kN/m}}$$

Factor of safety

$$FoS_S = F_R / F_f = \mathbf{1.296}$$

Allowable factor of safety

$$FoS_{S,allow} = \mathbf{1.000}$$

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	Calcs for Gabion Retaining Structure				Start page no./Revision 9	
	Calcs by AR	Calcs date 25/07/2022	Checked by AR	Checked date 25/07/2022	Approved by	Approved date

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	$y_{g2} = h_2 / 2 = 500 \text{ mm}$
Weight of gabion 2	$W_{g2} = \gamma_d \times w_2 \times h_2 = 16.0 \text{ kN/m}$
Horizontal distance to centre of gravity gabion 3	$x_{g3} = w_3 / 2 + s_3 = 800 \text{ mm}$
Vertical distance to centre of gravity gabion 3	$y_{g3} = h_3 / 2 + h_2 = 1500 \text{ mm}$
Weight of gabion 3	$W_{g3} = \gamma_d \times w_3 \times h_3 = 16.0 \text{ kN/m}$
Weight of entire gabion	$W_g = W_{g2} + W_{g3} = 32.0 \text{ kN/m}$
Horiz distance to centre of gravity entire gabion	$x_g = ((W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3})) / W_g = 650 \text{ mm}$
Vert distance to centre of gravity entire gabion	$y_g = ((W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3})) / W_g = 1000 \text{ mm}$
Correcting for wall inclination horiz dist	$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = 650 \text{ mm}$
Vertical change in height due to wall inclination	$H_f = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) \times \cos(\epsilon) - (x_{g3} + w_3/2) \times \sin(\epsilon)) = 0 \text{ mm}$

Design dimensions

Effective angle of rear plane of wall	$\alpha = \text{Atan}((w_2 - (x_{g3} + (w_3 / 2))) / (y_{g3} + h_3 / 2)) + 90 \text{ deg} + \epsilon = 81.5 \text{ deg}$
Effective face angle	$\theta = \text{Atan}((y_{g3} + (h_3 / 2)) / ((x_{g3} - (w_3 / 2)))) - \epsilon = 81.5 \text{ deg}$
Effective height of wall	$H = (y_{g3} + h_3 / 2) + (w_2 \times \sin(\epsilon)) - H_f = 2000 \text{ mm}$
Height of wall from toe to front edge of top gabion	$H_{incl} = ((y_{g3} + h_3 / 2) \times \cos(\epsilon) - (x_{g3} - (w_3 / 2)) \times \sin(\epsilon)) = 2000 \text{ mm}$
Active pressure using Kerisel and Absi theory	$K_a = 0.242$
Active thrust due to soil	$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = 9.2 \text{ kN/m}$

Horizontal forces

Retained soil	$F_{soil_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = 7.9 \text{ kN/m}$
Surcharge	$F_{surch_h} = p_{o,Q} \times \gamma_Q \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = 2.7 \text{ kN/m}$

Vertical forces

Gabion weight	$F_{gabion_v,f} = \gamma_{G,f} \times W_g = 32.0 \text{ kN/m}$
Retained soil	$F_{soil_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = 4.7 \text{ kN/m}$
Surcharge	$F_{surch_v,f} = p_{o,Q} \times \gamma_{Q,f} \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = 0.0 \text{ kN/m}$

Overturning stability - take moments about the toe

Overturning moment	$M_o = F_{soil_h} \times d_{h,soil} + F_{surch_h} \times d_{h,surch} = 8.0 \text{ kNm/m}$
Restoring moment	$M_R = F_{gabion_v,f} \times X_g + F_{soil_v,f} \times b_{v,soil} + F_{surch_v,f} \times b_{v,surch} = 25.0 \text{ kNm/m}$
Factor of safety	$FoS_M = M_R / M_o = 3.141$
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	$T = F_{soil_h} + F_{surch_h} = 10.6 \text{ kN/m}$
Total vertical force	$N = F_{gabion_v,f} + F_{soil_v,f} + F_{surch_v,f} = 36.7 \text{ kN/m}$
Sliding force	$F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = 10.6 \text{ kN/m}$
Sliding resistance	$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = 20.6 \text{ kN/m}$
Factor of safety	$FoS_S = F_R / F_f = 1.940$
Allowable factor of safety	$FoS_{S_allow} = 1.000$

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

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	Calcs for Gabion Retaining Structure		Start page no./Revision 10	
	Calcs by AR	Calcs date 25/07/2022	Checked by AR	Checked date 25/07/2022
		Approved by	Approved date	

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	$W_g = W_{g3} = \mathbf{16.0 \text{ kN/m}}$
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	$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{500 \text{ mm}}$
Vertical change in height due to wall inclination	$H_f = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) \times \cos(\epsilon) - (x_{g3} + w_3/2) \times \sin(\epsilon)) = \mathbf{0 \text{ mm}}$

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	$H = (y_{g3} + h_3 / 2) + (w_3 \times \sin(\epsilon)) - H_f = \mathbf{1000 \text{ mm}}$
Height of wall from toe to front edge of top gabion	$H_{incl} = ((y_{g3} + h_3 / 2) \times \cos(\epsilon) - (x_{g3} - (w_3 / 2)) \times \sin(\epsilon)) = \mathbf{1000 \text{ mm}}$
Active pressure using Kerisel and Absi theory	$K_a = \mathbf{0.242}$
Active thrust due to soil	$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = \mathbf{2.3 \text{ kN/m}}$

Horizontal forces

Retained soil	$F_{soil_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{2.1 \text{ kN/m}}$
Surcharge	$F_{surch_h} = p_{o,Q} \times \gamma_Q \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{1.5 \text{ kN/m}}$

Vertical forces

Gabion weight	$F_{gabion_v,f} = \gamma_G \times W_g = \mathbf{16.0 \text{ kN/m}}$
Retained soil	$F_{soil_v,f} = \gamma_G \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{0.9 \text{ kN/m}}$
Surcharge	$F_{surch_v,f} = p_{o,Q} \times \gamma_Q \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{0.0 \text{ kN/m}}$

Overturning stability - take moments about the toe

Overturning moment	$M_o = F_{soil_h} \times d_{h,soil} + F_{surch_h} \times d_{h,surch} = \mathbf{1.4 \text{ kNm/m}}$
Restoring moment	$M_R = F_{gabion_v,f} \times X_g + F_{soil_v,f} \times b_{v,soil} + F_{surch_v,f} \times b_{v,surch} = \mathbf{8.9 \text{ kNm/m}}$
Factor of safety	$FoSM = M_R / M_o = \mathbf{6.175}$
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	$T = F_{soil_h} + F_{surch_h} = \mathbf{3.6 \text{ kN/m}}$
Total vertical force	$N = F_{gabion_v,f} + F_{soil_v,f} + F_{surch_v,f} = \mathbf{16.9 \text{ kN/m}}$
Sliding force	$F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = \mathbf{3.6 \text{ kN/m}}$
Sliding resistance	$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = \mathbf{9.4 \text{ kN/m}}$
Factor of safety	$FoS_S = F_R / F_f = \mathbf{2.639}$
Allowable factor of safety	$FoS_S_{allow} = \mathbf{1.000}$

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