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31 WREXHAM ROAD GABION RETAINING WALL

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

Tedds calculation version 2.0.01

Design summary

Combination 1

Action	Resistance	Force	FoS	Allowable FoS	Status
Overturning, sliding and bearing at base level					
Overturning (kNm/m)	61.9	32.5	1.905	1.000	PASS
Sliding (kN/m)	51.2	32.0	1.603	1.000	PASS
Bearing (kN/m ²)	100.0	97.4	1.027	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)	17.2	8.4	2.036	1.000	PASS
Sliding (kN/m)	21.5	13.3	1.615	1.000	PASS
Overturning and sliding between courses 2 and 3					
Overturning (kNm/m)	1.3	0.4	3.039	1.000	PASS
Sliding (kN/m)	3.4	1.9	1.762	1.000	PASS

Combination 2

Action	Resistance	Force	FoS	Allowable FoS	Status
Overturning, sliding and bearing at base level					
Overturning (kNm/m)	63.1	31.7	1.992	1.000	PASS
Sliding (kN/m)	41.5	30.4	1.363	1.000	PASS
Bearing (kN/m ²)	100.0	97.4	1.027	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)	17.5	8.5	2.068	1.000	PASS
Sliding (kN/m)	17.4	13.1	1.332	1.000	PASS
Overturning and sliding between courses 2 and 3					
Overturning (kNm/m)	1.3	0.5	2.770	1.000	PASS
Sliding (kN/m)	2.7	2.1	1.290	1.000	PASS

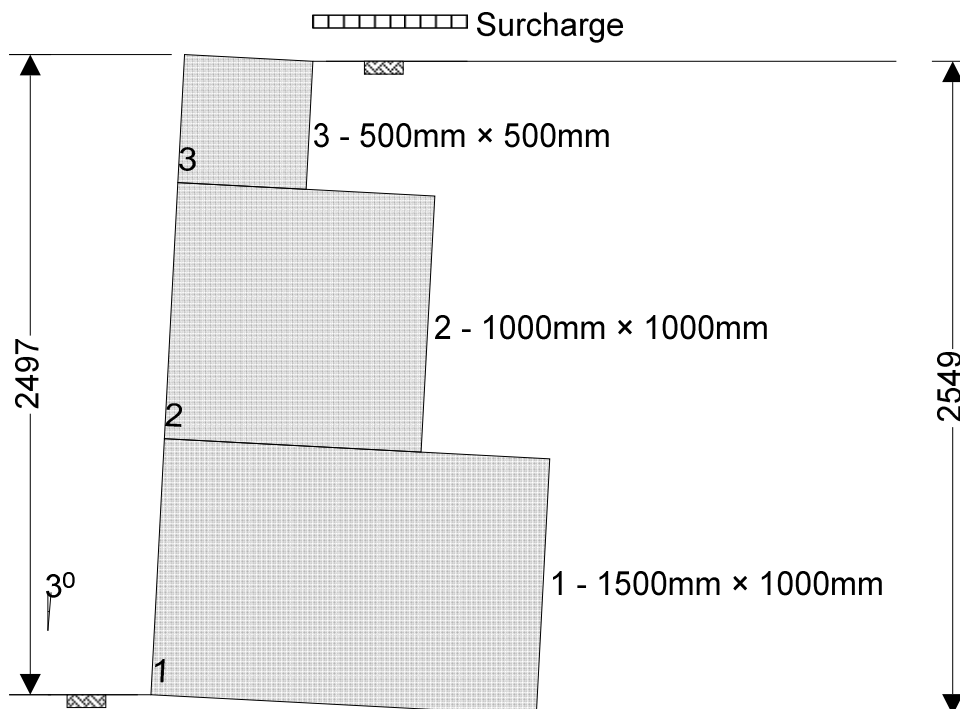


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Wall geometry

Width of gabion 1;	$w_1 = 1500$ mm
Height of gabion 1;	$h_1 = 1000$ mm
Width of gabion 2;	$w_2 = 1000$ mm
Height of gabion 2;	$h_2 = 1000$ mm
Step to front face between courses 1 and 2;	$s_2 = 0$ mm
Width of gabion 3;	$w_3 = 500$ mm
Height of gabion 3;	$h_3 = 500$ mm
Step to front face between courses 2 and 3;	$s_3 = 0$ mm
Wall inclination;	$\varepsilon = 3$ deg

Gabion properties

Unit weight of fill;	$\gamma_d = 18.0$ kN/m ³
Friction between gabions;	$\delta_{bg,k} = 35.0$ deg

Loading

Variable surcharge;	$p_{o,Q} = 10$ kN/m ²
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Soil properties

Slope of retained soil;	$\beta = 0.0$ deg
Characteristic peak shearing resistance angle;	$\phi'_{pk,k} = 35.0$ deg
Characteristic saturated density of retained soil;	$\gamma_{sr} = 19.0$ kN/m ³
Coefficient for wall friction;	$k_{membrane} = 0.75$
Wall friction angle;	$\delta_{r,k} = 26.3$ deg



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Characteristic base friction angle;

$$\delta_{bb,k} = \mathbf{34.0 \text{ deg}}$$

Bearing capacity of founding soil;

$$q = \mathbf{100 \text{ kN/m}^2}$$

Wall geometry

Horizontal distance to centre of gravity gabion 1;

$$x_{g1} = w_1 / 2 = \mathbf{750 \text{ mm}}$$

Vertical distance to centre of gravity gabion 1;

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

Weight of gabion 1;

$$W_{g1} = \gamma_d * w_1 * h_1 = \mathbf{27.0 \text{ kN/m}}$$

Horizontal distance to centre of gravity gabion 2;

$$x_{g2} = w_2 / 2 + s_2 = \mathbf{500 \text{ mm}}$$

Vertical distance to centre of gravity gabion 2;

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

Weight of gabion 2;

$$W_{g2} = \gamma_d * w_2 * h_2 = \mathbf{18.0 \text{ kN/m}}$$

Horizontal distance to centre of gravity gabion 3;

$$x_{g3} = w_3 / 2 + s_2 + s_3 = \mathbf{250 \text{ mm}}$$

Vertical distance to centre of gravity gabion 3;

$$y_{g3} = h_3 / 2 + h_1 + h_2 = \mathbf{2250 \text{ mm}}$$

Weight of gabion 3;

$$W_{g3} = \gamma_d * w_3 * h_3 = \mathbf{4.5 \text{ kN/m}}$$

Weight of entire gabion;

$$W_g = W_{g1} + W_{g2} + W_{g3} = \mathbf{49.5 \text{ kN/m}}$$

Horiz distance to centre of gravity entire gabion;

$$x_g = ((W_{g1} * x_{g1}) + (W_{g2} * x_{g2}) + (W_{g3} * x_{g3})) / W_g = \mathbf{614 \text{ mm}}$$

Vert distance to centre of gravity entire gabion;

$$y_g = ((W_{g1} * y_{g1}) + (W_{g2} * y_{g2}) + (W_{g3} * y_{g3})) / W_g = \mathbf{1023 \text{ mm}}$$

Correcting for wall inclination horiz dist;

$$X_g = x_g * \cos(\epsilon) + y_g * \sin(\epsilon) = \mathbf{666 \text{ mm}}$$

Vertical change in height due to wall inclination;

$$H_f = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) * \cos(\epsilon) - (x_{g3} + w_3/2) * \sin(\epsilon)) = \mathbf{30 \text{ mm}}$$

Design dimensions

Effective angle of rear plane of wall;

$$\alpha = 90\text{deg} - \text{Atan}((w_1 - (x_{g3} + (w_3 / 2))) / (y_{g3} + h_3 / 2)) + \epsilon = \mathbf{71.2 \text{ deg}}$$

Effective face angle;

$$\theta = 90\text{deg} - \epsilon = \mathbf{87.0 \text{ deg}}$$

Effective height of wall;

$$H = (y_{g3} + h_3 / 2) + (w_1 * \sin(\epsilon)) - H_f = \mathbf{2549 \text{ mm}}$$

Height of wall from toe to front edge of top gabion;

$$H_{incl} = ((y_{g3} + h_3 / 2) * \cos(\epsilon) - (x_{g3} - (w_3 / 2)) * \sin(\epsilon)) = \mathbf{2497 \text{ mm}}$$

Active pressure using Coulomb theory;

$$K_a = \sin(\alpha + \phi'_{r,k})^2 / (\sin(\alpha)^2 * \sin(\alpha - \delta_{r,k}) * (1 + \sqrt{(\sin(\phi'_{r,k} + \delta_{r,k}) * \sin(\phi'_{r,k} - \beta) / (\sin(\alpha - \delta_{r,k}) * \sin(\alpha + \beta)))})^2) = \mathbf{0.418}$$

Active thrust due to soil;

$$P_{a,soil} = 0.5 * K_a * \gamma_{sr} * H^2 = \mathbf{25.8 \text{ kN/m}}$$

Minimum surcharge (cl.4.6.3.2);

$$p_{o,min} = \min(H / H_{ref}, 1) * q_{d,min} = \mathbf{8.5 \text{ kN/m}^2}$$

Pressure at base

Horizontal forces

Retained soil;

$$F_{soil_h,q} = P_{a,soil} * \cos(90 - \alpha + \delta_{r,k}) = \mathbf{18.2 \text{ kN/m}}$$

Height of soil thrust resolved vertically;

$$d_{h,soil} = H / 3 - w_1 * \sin(\epsilon) = \mathbf{771 \text{ mm}}$$

Surcharge;

$$F_{surch_h,q} = \max(p_{o,Q}, p_{o,min}) * K_a * H * \cos(90 - \alpha + \delta_{r,k}) = \mathbf{7.5 \text{ kN/m}}$$

Height of surcharge thrust resolved vertically;

$$d_{h,surch} = H / 2 - w_1 * \sin(\epsilon) = \mathbf{1196 \text{ mm}}$$

Vertical forces

Gabion weight;

$$F_{gabion_v,q} = W_g = \mathbf{49.5 \text{ kN/m}}$$

Retained soil;

$$F_{soil_v,q} = P_{a,soil} * \sin(90 - \alpha + \delta_{r,k}) = \mathbf{18.3 \text{ kN/m}}$$

Horizontal dist to where soil thrust acts;

$$b_{v,soil} = w_1 * \cos(\epsilon) - (H / 3) / \tan(\alpha) = \mathbf{1209 \text{ mm}}$$

Surcharge;

$$F_{surch_v,q} = \max(p_{o,Q}, p_{o,min}) * K_a * H * \sin(90 - \alpha + \delta_{r,k}) = \mathbf{7.5 \text{ kN/m}}$$

Horizontal dist to where surcharge thrust acts;

$$b_{v,surch} = w_1 * \cos(\epsilon) - (H / 2) / \tan(\alpha) = \mathbf{1064 \text{ mm}}$$

Total horizontal unfactored force;

$$T_q = F_{soil_h,q} + F_{surch_h,q} = \mathbf{25.7 \text{ kN/m}}$$

Total vertical unfactored force;

$$N_q = F_{gabion_v,q} + F_{soil_v,q} + F_{surch_v,q} = \mathbf{75.3 \text{ kN/m}}$$

Force normal to base;

$$N_s = N_q * \cos(\epsilon) + T_q * \sin(\epsilon) = \mathbf{76.5 \text{ kN/m}}$$

Total unfactored overturning force;

$$M_{o,q} = F_{soil_h,q} * d_{h,soil} + F_{surch_h,q} * d_{h,surch} = \mathbf{23.0 \text{ kNm/m}}$$



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Total unfactored restoring force;

$$M_{R,q} = F_{gabion_v,q} * X_g + F_{soil_v,q} * b_{v,soil} + F_{surch_v,q} * b_{v,surch} = \mathbf{63.1 \text{ kNm/m}}$$

Eccentricity;

$$e = w_1 / 2 - (M_{R,q} - M_{o,q}) / N_s = \mathbf{227 \text{ mm}}$$

Reaction acts within middle third of base

Pressure at toe;

$$\sigma_{toe} = N_s / w_1 * (1 + (6 * e / w_1)) = \mathbf{97.4 \text{ kN/m}^2}$$

Pressure at heel;

$$\sigma_{heel} = N_s / w_1 * (1 - (6 * e / w_1)) = \mathbf{4.7 \text{ kN/m}^2}$$

Factor of safety;

$$FoS_Q = q / \max(\sigma_{toe}, \sigma_{heel}) = \mathbf{1.027}$$

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;

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

Design soil properties

Design effective shearing resistance angle;

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

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);

$$\delta_{r,d} = \min(\text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}), \phi'_{r,d} * k_{\text{membrane}}) = \mathbf{26.3 \text{ deg}}$$

Design base friction angle;

$$\delta_{bb,d} = \text{Atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = \mathbf{34.0 \text{ deg}}$$

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;

$$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 * \sin(\alpha - \delta_{r,d}) * (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) * \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) * \sin(\alpha + \beta)))^2}) = \mathbf{0.418}$$

Active thrust due to soil;

$$P_{a,soil} = 0.5 * K_a * \gamma_{s,d} * H^2 = \mathbf{25.8 \text{ kN/m}}$$

Minimum surcharge (cl.4.6.3.2);

$$p_{o,min} = \min(H / H_{ref}, 1) * q_{d,min} = \mathbf{8.5 \text{ kN/m}^2}$$

Horizontal forces

Retained soil;

$$F_{soil_h} = \gamma_G * P_{a,soil} * \cos(90 - \alpha + \delta_{r,d}) = \mathbf{24.6 \text{ kN/m}}$$

Surcharge;

$$F_{surch_h} = \max(p_{o,Q} * \gamma_Q, p_{o,min}) * K_a * H * \cos(90 - \alpha + \delta_{r,d}) = \mathbf{11.3 \text{ kN/m}}$$

Vertical forces

Gabion weight;

$$F_{gabion_v,f} = \gamma_{G,f} * W_g = \mathbf{49.5 \text{ kN/m}}$$

Retained soil;

$$F_{soil_v,f} = \gamma_{G,f} * P_{a,soil} * \sin(90 - \alpha + \delta_{r,d}) = \mathbf{18.3 \text{ kN/m}}$$

Surcharge;

$$F_{surch_v,f} = \max(p_{o,Q} * \gamma_{Q,f}, p_{o,min}) * K_a * H * \sin(90 - \alpha + \delta_{r,d}) = \mathbf{6.4 \text{ kN/m}}$$

Overturning stability - take moments about the toe

Overturning moment;

$$M_o = F_{soil_h} * d_{h,soil} + F_{surch_h} * d_{h,surch} = \mathbf{32.5 \text{ kNm/m}}$$

Restoring moment;

$$M_R = F_{gabion_v,f} * X_g + F_{soil_v,f} * b_{v,soil} + F_{surch_v,f} * b_{v,surch} = \mathbf{61.9 \text{ kNm/m}}$$

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;

$$T = F_{soil_h} + F_{surch_h} = \mathbf{35.9 \text{ kN/m}}$$



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Total vertical force;

$$N = F_{\text{gabion}_v,f} + F_{\text{soil}_v,f} + F_{\text{surch}_v,f} = \mathbf{74.2 \text{ kN/m}}$$

Sliding force;

$$F_t = T * \cos(\epsilon) - N * \sin(\epsilon) = \mathbf{32.0 \text{ kN/m}}$$

Sliding resistance;

$$F_R = (T * \sin(\epsilon) + N * \cos(\epsilon)) * \tan(\delta_{bb,d}) = \mathbf{51.2 \text{ kN/m}}$$

Factor of safety;

$$FoS_S = F_R / F_t = \mathbf{1.603}$$

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;

$$W_{g2} = \gamma_d * w_2 * h_2 = \mathbf{18.0 \text{ kN/m}}$$

Horizontal distance to centre of gravity gabion 3;

$$x_{g3} = w_3 / 2 + s_3 = \mathbf{250 \text{ mm}}$$

Vertical distance to centre of gravity gabion 3;

$$y_{g3} = h_3 / 2 + h_2 = \mathbf{1250 \text{ mm}}$$

Weight of gabion 3;

$$W_{g3} = \gamma_d * w_3 * h_3 = \mathbf{4.5 \text{ kN/m}}$$

Weight of entire gabion;

$$W_g = W_{g2} + W_{g3} = \mathbf{22.5 \text{ kN/m}}$$

Horiz distance to centre of gravity entire gabion;

$$x_g = ((W_{g2} * x_{g2}) + (W_{g3} * x_{g3})) / W_g = \mathbf{450 \text{ mm}}$$

Vert distance to centre of gravity entire gabion;

$$y_g = ((W_{g2} * y_{g2}) + (W_{g3} * y_{g3})) / W_g = \mathbf{650 \text{ mm}}$$

Correcting for wall inclination horiz dist;

$$X_g = x_g * \cos(\epsilon) + y_g * \sin(\epsilon) = \mathbf{483 \text{ mm}}$$

Vertical change in height due to wall inclination;

$$H_t = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) * \cos(\epsilon) - (x_{g3} + w_3/2) * \sin(\epsilon)) = \mathbf{28 \text{ mm}}$$

Design dimensions

Effective angle of rear plane of wall;

$$\alpha = 90\text{deg} - \text{Atan}((w_2 - (x_{g3} + (w_3 / 2))) / (y_{g3} + h_3 / 2)) + \epsilon = \mathbf{74.6 \text{ deg}}$$

Effective face angle;

$$\theta = 90\text{deg} - \epsilon = \mathbf{87.0 \text{ deg}}$$

Effective height of wall;

$$H = (y_{g3} + h_3 / 2) + (w_2 * \sin(\epsilon)) - H_t = \mathbf{1524 \text{ mm}}$$

Height of wall from toe to front edge of top gabion;

$$H_{\text{incl}} = ((y_{g3} + h_3 / 2) * \cos(\epsilon) - (x_{g3} - (w_3 / 2)) * \sin(\epsilon)) = \mathbf{1498 \text{ mm}}$$

Active pressure using Coulomb theory;

$$K_a = \sin(\alpha + \phi'_{r,d})^2 / ((\sin(\alpha)^2 * \sin(\alpha - \delta_{r,d}) * (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) * \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) * \sin(\alpha + \beta))))^2) = \mathbf{0.380}$$

Active thrust due to soil;

$$P_{a,\text{soil}} = 0.5 * K_a * \gamma_{s,d} * H^2 = \mathbf{8.4 \text{ kN/m}}$$

Minimum surcharge (cl.4.6.3.2);

$$p_{o,\text{min}} = \min(H / H_{\text{ref}}, 1) * q_{d,\text{min}} = \mathbf{5.1 \text{ kN/m}^2}$$

Horizontal forces

Retained soil;

$$F_{\text{soil}_h} = \gamma_G * P_{a,\text{soil}} * \cos(90 - \alpha + \delta_{r,d}) = \mathbf{8.4 \text{ kN/m}}$$

Surcharge;

$$F_{\text{surch}_h} = \max(p_{o,Q} * \gamma_Q, p_{o,\text{min}}) * K_a * H * \cos(90 - \alpha + \delta_{r,d}) = \mathbf{6.5 \text{ kN/m}}$$

Vertical forces

Gabion weight;

$$F_{\text{gabion}_v,f} = \gamma_{G,f} * W_g = \mathbf{22.5 \text{ kN/m}}$$

Retained soil;

$$F_{\text{soil}_v,f} = \gamma_{G,f} * P_{a,\text{soil}} * \sin(90 - \alpha + \delta_{r,d}) = \mathbf{5.6 \text{ kN/m}}$$

Surcharge;

$$F_{\text{surch}_v,f} = \max(p_{o,Q} * \gamma_{Q,f}, p_{o,\text{min}}) * K_a * H * \sin(90 - \alpha + \delta_{r,d}) = \mathbf{2.0 \text{ kN/m}}$$

Overturning stability - take moments about the toe

Overturning moment;

$$M_o = F_{\text{soil}_h} * d_{h,\text{soil}} + F_{\text{surch}_h} * d_{h,\text{surch}} = \mathbf{8.4 \text{ kNm/m}}$$

Restoring moment;

$$M_R = F_{\text{gabion}_v,f} * X_g + F_{\text{soil}_v,f} * b_{v,\text{soil}} + F_{\text{surch}_v,f} * b_{v,\text{surch}} = \mathbf{17.2 \text{ kNm/m}}$$

Factor of safety;

$$FoS_M = M_R / M_o = \mathbf{2.036}$$

Allowable factor of safety;

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

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



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

Total horizontal force;	$T = F_{\text{soil}_h} + F_{\text{surch}_h} = 14.9 \text{ kN/m}$
Total vertical force;	$N = F_{\text{gabion}_v,f} + F_{\text{soil}_v,f} + F_{\text{surch}_v,f} = 30.0 \text{ kN/m}$
Sliding force;	$F_t = T * \cos(\epsilon) - N * \sin(\epsilon) = 13.3 \text{ kN/m}$
Sliding resistance;	$F_R = (T * \sin(\epsilon) + N * \cos(\epsilon)) * \tan(\delta_{bg,d}) = 21.5 \text{ kN/m}$
Factor of safety;	$FoS_S = F_R / F_t = 1.615$
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;	$x_{g3} = w_3 / 2 = 250 \text{ mm}$
Vertical distance to centre of gravity gabion 3;	$y_{g3} = h_3 / 2 = 250 \text{ mm}$
Weight of gabion 3;	$W_{g3} = \gamma_d * w_3 * h_3 = 4.5 \text{ kN/m}$
Weight of entire gabion;	$W_g = W_{g3} = 4.5 \text{ kN/m}$
Horiz distance to centre of gravity entire gabion;	$x_g = ((W_{g3} * x_{g3})) / W_g = 250 \text{ mm}$
Vert distance to centre of gravity entire gabion;	$y_g = ((W_{g3} * y_{g3})) / W_g = 250 \text{ mm}$
Correcting for wall inclination horiz dist;	$X_g = x_g * \cos(\epsilon) + y_g * \sin(\epsilon) = 263 \text{ mm}$
Vertical change in height due to wall inclination;	$H_t = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) * \cos(\epsilon) - (x_{g3} + w_3/2) * \sin(\epsilon)) = 27 \text{ mm}$

Design dimensions

Effective angle of rear plane of wall;	$\alpha = 90 \text{ deg} + \epsilon = 93.0 \text{ deg}$
Effective face angle;	$\theta = 90 \text{ deg} - \epsilon = 87.0 \text{ deg}$
Effective height of wall;	$H = (y_{g3} + h_3 / 2) + (w_3 * \sin(\epsilon)) - H_t = 499 \text{ mm}$
Height of wall from toe to front edge of top gabion;	$H_{incl} = ((y_{g3} + h_3 / 2) * \cos(\epsilon) - (x_{g3} - (w_3 / 2)) * \sin(\epsilon)) = 499 \text{ mm}$
Active pressure using Coulomb theory;	$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 * \sin(\alpha - \delta_{r,d}) * (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) * \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) * \sin(\alpha + \beta))))^2) = 0.224$
Active thrust due to soil;	$P_{a,soil} = 0.5 * K_a * \gamma_{s,d} * H^2 = 0.5 \text{ kN/m}$
Minimum surcharge (cl.4.6.3.2);	$p_{o,min} = \min(H / H_{ref}, 1) * q_{d,min} = 1.7 \text{ kN/m}^2$

Horizontal forces

Retained soil;	$F_{\text{soil}_h} = \gamma_G * P_{a,soil} * \cos(90 - \alpha + \delta_{r,d}) = 0.7 \text{ kN/m}$
Surcharge;	$F_{\text{surch}_h} = \max(p_{o,Q} * \gamma_{Q,f}, p_{o,min}) * K_a * H * \cos(90 - \alpha + \delta_{r,d}) = 1.5 \text{ kN/m}$

Vertical forces

Gabion weight;	$F_{\text{gabion}_v,f} = \gamma_{G,f} * W_g = 4.5 \text{ kN/m}$
Retained soil;	$F_{\text{soil}_v,f} = \gamma_{G,f} * P_{a,soil} * \sin(90 - \alpha + \delta_{r,d}) = 0.2 \text{ kN/m}$
Surcharge;	$F_{\text{surch}_v,f} = \max(p_{o,Q} * \gamma_{Q,f}, p_{o,min}) * K_a * H * \sin(90 - \alpha + \delta_{r,d}) = 0.1 \text{ kN/m}$

Overturning stability - take moments about the toe

Overturning moment;	$M_o = F_{\text{soil}_h} * d_{h,soil} + F_{\text{surch}_h} * d_{h,surch} = 0.4 \text{ kNm/m}$
Restoring moment;	$M_R = F_{\text{gabion}_v,f} * X_g + F_{\text{soil}_v,f} * b_{v,soil} + F_{\text{surch}_v,f} * b_{v,surch} = 1.3 \text{ kNm/m}$
Factor of safety;	$FoS_M = M_R / M_o = 3.039$
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;	$T = F_{\text{soil}_h} + F_{\text{surch}_h} = 2.2 \text{ kN/m}$
Total vertical force;	$N = F_{\text{gabion}_v,f} + F_{\text{soil}_v,f} + F_{\text{surch}_v,f} = 4.8 \text{ kN/m}$



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Sliding force;

$$F_t = T * \cos(\epsilon) - N * \sin(\epsilon) = \mathbf{1.9 \text{ kN/m}}$$

Sliding resistance;

$$F_R = (T * \sin(\epsilon) + N * \cos(\epsilon)) * \tan(\delta_{bg,d}) = \mathbf{3.4 \text{ kN/m}}$$

Factor of safety;

$$FoS_S = F_R / F_t = \mathbf{1.762}$$

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;

$$\gamma_f = \mathbf{1.00}$$

Design soil properties

Design effective shearing resistance angle;

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

Design saturated density of retained soil;

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

Design wall friction angle (cl.5.4.2.1);

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

Design base friction angle;

$$\delta_{bb,d} = \text{Atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = \mathbf{28.4 \text{ deg}}$$

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;

$$x_{g1} = w_1 / 2 = \mathbf{750 \text{ mm}}$$

Vertical distance to centre of gravity gabion 1;

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

Weight of gabion 1;

$$W_{g1} = \gamma_d * w_1 * h_1 = \mathbf{27.0 \text{ kN/m}}$$

Horizontal distance to centre of gravity gabion 2;

$$x_{g2} = w_2 / 2 + s_2 = \mathbf{500 \text{ mm}}$$

Vertical distance to centre of gravity gabion 2;

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

Weight of gabion 2;

$$W_{g2} = \gamma_d * w_2 * h_2 = \mathbf{18.0 \text{ kN/m}}$$

Horizontal distance to centre of gravity gabion 3;

$$x_{g3} = w_3 / 2 + s_2 + s_3 = \mathbf{250 \text{ mm}}$$

Vertical distance to centre of gravity gabion 3;

$$y_{g3} = h_3 / 2 + h_1 + h_2 = \mathbf{2250 \text{ mm}}$$

Weight of gabion 3;

$$W_{g3} = \gamma_d * w_3 * h_3 = \mathbf{4.5 \text{ kN/m}}$$

Weight of entire gabion;

$$W_g = W_{g1} + W_{g2} + W_{g3} = \mathbf{49.5 \text{ kN/m}}$$

Horiz distance to centre of gravity entire gabion;

$$x_g = ((W_{g1} * x_{g1}) + (W_{g2} * x_{g2}) + (W_{g3} * x_{g3})) / W_g = \mathbf{614 \text{ mm}}$$

Vert distance to centre of gravity entire gabion;

$$y_g = ((W_{g1} * y_{g1}) + (W_{g2} * y_{g2}) + (W_{g3} * y_{g3})) / W_g = \mathbf{1023 \text{ mm}}$$

Correcting for wall inclination horiz dist;

$$X_g = x_g * \cos(\epsilon) + y_g * \sin(\epsilon) = \mathbf{666 \text{ mm}}$$

Vertical change in height due to wall inclination;

$$H_f = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) * \cos(\epsilon) - (x_{g3} + w_3/2) * \sin(\epsilon)) = \mathbf{30 \text{ mm}}$$

Design dimensions

Effective angle of rear plane of wall;

$$\alpha = 90\text{deg} - \text{Atan}((w_1 - (x_{g3} + (w_3 / 2))) / (y_{g3} + h_3 / 2)) + \epsilon = \mathbf{71.2 \text{ deg}}$$

Effective face angle;

$$\theta = 90\text{deg} - \epsilon = \mathbf{87.0 \text{ deg}}$$

Effective height of wall;

$$H = (y_{g3} + h_3 / 2) + (w_1 * \sin(\epsilon)) - H_f = \mathbf{2549 \text{ mm}}$$

Height of wall from toe to front edge of top gabion;

$$H_{incl} = ((y_{g3} + h_3 / 2) * \cos(\epsilon) - (x_{g3} - (w_3 / 2)) * \sin(\epsilon)) = \mathbf{2497 \text{ mm}}$$

Active pressure using Coulomb theory;

$$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 * \sin(\alpha - \delta_{r,d}) * (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) * \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) * \sin(\alpha + \beta))))^2) = \mathbf{0.476}$$

Active thrust due to soil;

$$P_{a,soil} = 0.5 * K_a * \gamma_{s,d} * H^2 = \mathbf{29.4 \text{ kN/m}}$$

Minimum surcharge (cl.4.6.3.2);

$$p_{o,min} = \min(H / H_{ref}, 1) * q_{d,min} = \mathbf{8.5 \text{ kN/m}^2}$$



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Horizontal forces

Retained soil;

$$F_{\text{soil}_h} = \gamma_G * P_{a,\text{soil}} * \cos(90 - \alpha + \delta_{r,d}) = \mathbf{22.4 \text{ kN/m}}$$

Surcharge;

$$F_{\text{surch}_h} = \max(p_{o,Q} * \gamma_Q, p_{o,\min}) * K_a * H * \cos(90 - \alpha + \delta_{r,d}) = \mathbf{12.0 \text{ kN/m}}$$

Vertical forces

Gabion weight;

$$F_{\text{gabion}_{v,f}} = \gamma_{G,f} * W_g = \mathbf{49.5 \text{ kN/m}}$$

Retained soil;

$$F_{\text{soil}_{v,f}} = \gamma_{G,f} * P_{a,\text{soil}} * \sin(90 - \alpha + \delta_{r,d}) = \mathbf{19.0 \text{ kN/m}}$$

Surcharge;

$$F_{\text{surch}_{v,f}} = \max(p_{o,Q} * \gamma_{Q,f}, p_{o,\min}) * K_a * H * \sin(90 - \alpha + \delta_{r,d}) = \mathbf{6.7 \text{ kN/m}}$$

Overtuning stability - take moments about the toe

Overtuning moment;

$$M_o = F_{\text{soil}_h} * d_{h,\text{soil}} + F_{\text{surch}_h} * d_{h,\text{surch}} = \mathbf{31.7 \text{ kNm/m}}$$

Restoring moment;

$$M_R = F_{\text{gabion}_{v,f}} * X_g + F_{\text{soil}_{v,f}} * b_{v,\text{soil}} + F_{\text{surch}_{v,f}} * b_{v,\text{surch}} = \mathbf{63.1 \text{ kNm/m}}$$

Factor of safety;

$$F_oSM = M_R / M_o = \mathbf{1.992}$$

Allowable factor of safety;

$$F_oSM_{\text{allow}} = \mathbf{1.000}$$

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;

$$T = F_{\text{soil}_h} + F_{\text{surch}_h} = \mathbf{34.4 \text{ kN/m}}$$

Total vertical force;

$$N = F_{\text{gabion}_{v,f}} + F_{\text{soil}_{v,f}} + F_{\text{surch}_{v,f}} = \mathbf{75.2 \text{ kN/m}}$$

Sliding force;

$$F_t = T * \cos(\epsilon) - N * \sin(\epsilon) = \mathbf{30.4 \text{ kN/m}}$$

Sliding resistance;

$$F_R = (T * \sin(\epsilon) + N * \cos(\epsilon)) * \tan(\delta_{bb,d}) = \mathbf{41.5 \text{ kN/m}}$$

Factor of safety;

$$F_oSS = F_R / F_t = \mathbf{1.363}$$

Allowable factor of safety;

$$F_oSS_{\text{allow}} = \mathbf{1.000}$$

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;

$$W_{g2} = \gamma_d * w_2 * h_2 = \mathbf{18.0 \text{ kN/m}}$$

Horizontal distance to centre of gravity gabion 3;

$$x_{g3} = w_3 / 2 + s_3 = \mathbf{250 \text{ mm}}$$

Vertical distance to centre of gravity gabion 3;

$$y_{g3} = h_3 / 2 + h_2 = \mathbf{1250 \text{ mm}}$$

Weight of gabion 3;

$$W_{g3} = \gamma_d * w_3 * h_3 = \mathbf{4.5 \text{ kN/m}}$$

Weight of entire gabion;

$$W_g = W_{g2} + W_{g3} = \mathbf{22.5 \text{ kN/m}}$$

Horiz distance to centre of gravity entire gabion;

$$x_g = ((W_{g2} * x_{g2}) + (W_{g3} * x_{g3})) / W_g = \mathbf{450 \text{ mm}}$$

Vert distance to centre of gravity entire gabion;

$$y_g = ((W_{g2} * y_{g2}) + (W_{g3} * y_{g3})) / W_g = \mathbf{650 \text{ mm}}$$

Correcting for wall inclination horiz dist;

$$X_g = x_g * \cos(\epsilon) + y_g * \sin(\epsilon) = \mathbf{483 \text{ mm}}$$

Vertical change in height due to wall inclination;

$$H_t = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) * \cos(\epsilon) - (x_{g3} + w_3/2) * \sin(\epsilon)) = \mathbf{28 \text{ mm}}$$

Design dimensions

Effective angle of rear plane of wall;

$$\alpha = 90\text{deg} - \text{Atan}((w_2 - (x_{g3} + (w_3 / 2))) / (y_{g3} + h_3 / 2)) + \epsilon = \mathbf{74.6 \text{ deg}}$$

Effective face angle;

$$\theta = 90\text{deg} - \epsilon = \mathbf{87.0 \text{ deg}}$$

Effective height of wall;

$$H = (y_{g3} + h_3 / 2) + (w_2 * \sin(\epsilon)) - H_t = \mathbf{1524 \text{ mm}}$$

Height of wall from toe to front edge of top gabion;

$$H_{\text{incl}} = ((y_{g3} + h_3 / 2) * \cos(\epsilon) - (x_{g3} - (w_3 / 2)) * \sin(\epsilon)) = \mathbf{1498 \text{ mm}}$$

Active pressure using Coulomb theory;

$$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 * \sin(\alpha - \delta_{r,d}) * (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) * \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) * \sin(\alpha + \beta))))^2) = \mathbf{0.439}$$



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Active thrust due to soil;

$$P_{a,soil} = 0.5 * K_a * \gamma_{s,d} * H^2 = \mathbf{9.7 \text{ kN/m}}$$

Minimum surcharge (cl.4.6.3.2);

$$p_{o,min} = \min(H / H_{ref}, 1) * q_{d,min} = \mathbf{5.1 \text{ kN/m}^2}$$

Horizontal forces

Retained soil;

$$F_{soil_h} = \gamma_G * P_{a,soil} * \cos(90 - \alpha + \delta_{r,d}) = \mathbf{7.7 \text{ kN/m}}$$

Surcharge;

$$F_{surch_h} = \max(p_{o,Q} * \gamma_Q, p_{o,min}) * K_a * H * \cos(90 - \alpha + \delta_{r,d}) = \mathbf{6.9 \text{ kN/m}}$$

Vertical forces

Gabion weight;

$$F_{gabion_v,f} = \gamma_{G,f} * W_g = \mathbf{22.5 \text{ kN/m}}$$

Retained soil;

$$F_{soil_v,f} = \gamma_{G,f} * P_{a,soil} * \sin(90 - \alpha + \delta_{r,d}) = \mathbf{5.8 \text{ kN/m}}$$

Surcharge;

$$F_{surch_v,f} = \max(p_{o,Q} * \gamma_{Q,f}, p_{o,min}) * K_a * H * \sin(90 - \alpha + \delta_{r,d}) = \mathbf{2.0 \text{ kN/m}}$$

Overturning stability - take moments about the toe

Overturning moment;

$$M_o = F_{soil_h} * d_{h,soil} + F_{surch_h} * d_{h,surch} = \mathbf{8.5 \text{ kNm/m}}$$

Restoring moment;

$$M_R = F_{gabion_v,f} * X_g + F_{soil_v,f} * b_{v,soil} + F_{surch_v,f} * b_{v,surch} = \mathbf{17.5 \text{ kNm/m}}$$

Factor of safety;

$$FoS_M = M_R / M_o = \mathbf{2.068}$$

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;

$$T = F_{soil_h} + F_{surch_h} = \mathbf{14.7 \text{ kN/m}}$$

Total vertical force;

$$N = F_{gabion_v,f} + F_{soil_v,f} + F_{surch_v,f} = \mathbf{30.4 \text{ kN/m}}$$

Sliding force;

$$F_f = T * \cos(\epsilon) - N * \sin(\epsilon) = \mathbf{13.1 \text{ kN/m}}$$

Sliding resistance;

$$F_R = (T * \sin(\epsilon) + N * \cos(\epsilon)) * \tan(\delta_{bg,d}) = \mathbf{17.4 \text{ kN/m}}$$

Factor of safety;

$$FoS_S = F_R / F_f = \mathbf{1.332}$$

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;

$$x_{g3} = w_3 / 2 = \mathbf{250 \text{ mm}}$$

Vertical distance to centre of gravity gabion 3;

$$y_{g3} = h_3 / 2 = \mathbf{250 \text{ mm}}$$

Weight of gabion 3;

$$W_{g3} = \gamma_d * w_3 * h_3 = \mathbf{4.5 \text{ kN/m}}$$

Weight of entire gabion;

$$W_g = W_{g3} = \mathbf{4.5 \text{ kN/m}}$$

Horiz distance to centre of gravity entire gabion;

$$x_g = ((W_{g3} * x_{g3})) / W_g = \mathbf{250 \text{ mm}}$$

Vert distance to centre of gravity entire gabion;

$$y_g = ((W_{g3} * y_{g3})) / W_g = \mathbf{250 \text{ mm}}$$

Correcting for wall inclination horiz dist;

$$X_g = x_g * \cos(\epsilon) + y_g * \sin(\epsilon) = \mathbf{263 \text{ mm}}$$

Vertical change in height due to wall inclination;

$$H_f = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) * \cos(\epsilon) - (x_{g3} + w_3/2) * \sin(\epsilon)) = \mathbf{27 \text{ mm}}$$

Design dimensions

Effective angle of rear plane of wall;

$$\alpha = 90 \text{ deg} + \epsilon = \mathbf{93.0 \text{ deg}}$$

Effective face angle;

$$\theta = 90 \text{ deg} - \epsilon = \mathbf{87.0 \text{ deg}}$$

Effective height of wall;

$$H = (y_{g3} + h_3 / 2) + (w_3 * \sin(\epsilon)) - H_f = \mathbf{499 \text{ mm}}$$

Height of wall from toe to front edge of top gabion;

$$H_{incl} = ((y_{g3} + h_3 / 2) * \cos(\epsilon) - (x_{g3} - (w_3 / 2)) * \sin(\epsilon)) = \mathbf{499 \text{ mm}}$$

Active pressure using Coulomb theory;

$$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 * \sin(\alpha - \delta_{r,d}) * (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) * \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) * \sin(\alpha + \beta)))^2}) = \mathbf{0.284}$$

Active thrust due to soil;

$$P_{a,soil} = 0.5 * K_a * \gamma_{s,d} * H^2 = \mathbf{0.7 \text{ kN/m}}$$

Minimum surcharge (cl.4.6.3.2);

$$p_{o,min} = \min(H / H_{ref}, 1) * q_{d,min} = \mathbf{1.7 \text{ kN/m}^2}$$



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Horizontal forces

Retained soil;

$$F_{\text{soil}_h} = \gamma_G * P_{a,\text{soil}} * \cos(90 - \alpha + \delta_{r,d}) = \mathbf{0.6 \text{ kN/m}}$$

Surcharge;

$$F_{\text{surch}_h} = \max(p_{o,Q} * \gamma_Q, p_{o,\min}) * K_a * H * \cos(90 - \alpha + \delta_{r,d}) = \mathbf{1.7 \text{ kN/m}}$$

Vertical forces

Gabion weight;

$$F_{\text{gabion}_{v,f}} = \gamma_{G,f} * W_g = \mathbf{4.5 \text{ kN/m}}$$

Retained soil;

$$F_{\text{soil}_{v,f}} = \gamma_{G,f} * P_{a,\text{soil}} * \sin(90 - \alpha + \delta_{r,d}) = \mathbf{0.2 \text{ kN/m}}$$

Surcharge;

$$F_{\text{surch}_{v,f}} = \max(p_{o,Q} * \gamma_{Q,f}, p_{o,\min}) * K_a * H * \sin(90 - \alpha + \delta_{r,d}) = \mathbf{0.1 \text{ kN/m}}$$

Overtuning stability - take moments about the toe

Overtuning moment;

$$M_o = F_{\text{soil}_h} * d_{h,\text{soil}} + F_{\text{surch}_h} * d_{h,\text{surch}} = \mathbf{0.5 \text{ kNm/m}}$$

Restoring moment;

$$M_R = F_{\text{gabion}_{v,f}} * X_g + F_{\text{soil}_{v,f}} * b_{v,\text{soil}} + F_{\text{surch}_{v,f}} * b_{v,\text{surch}} = \mathbf{1.3 \text{ kNm/m}}$$

Factor of safety;

$$FoS_M = M_R / M_o = \mathbf{2.770}$$

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;

$$T = F_{\text{soil}_h} + F_{\text{surch}_h} = \mathbf{2.4 \text{ kN/m}}$$

Total vertical force;

$$N = F_{\text{gabion}_{v,f}} + F_{\text{soil}_{v,f}} + F_{\text{surch}_{v,f}} = \mathbf{4.8 \text{ kN/m}}$$

Sliding force;

$$F_f = T * \cos(\epsilon) - N * \sin(\epsilon) = \mathbf{2.1 \text{ kN/m}}$$

Sliding resistance;

$$F_R = (T * \sin(\epsilon) + N * \cos(\epsilon)) * \tan(\delta_{bg,d}) = \mathbf{2.7 \text{ kN/m}}$$

Factor of safety;

$$FoS_S = F_R / F_f = \mathbf{1.290}$$

Allowable factor of safety;

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

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