



Dson Industries

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Project Gabion Retaining Wall - erf 962 Kingsburgh				Job Ref. Dson -Design Build	
Section Section 8				Sheet no./rev. 1	
Calc. by Hudson	Date 4/30/2020	Chk'd by Mr.M	Date 4/15/2020	App'd by Dson	Date 7/30/2018

## 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 2.0.01

Geosynthetic Applications of the Retained Material

See Notes in Project Construction Details

### Design summary

#### Combination 1

Action	Resistance	Force	FoS	Allowable FoS	Status
<b>Overturning, sliding and bearing at base level</b>					
Overturning (kNm/m)	813.1	267.3	3.042	1.000	PASS
Sliding (kN/m)	224.9	107.7	2.089	1.000	PASS
Bearing (kN/m <sup>2</sup> )	100.0	88.8	1.126	1.000	PASS
Eccentricity (mm)	Reaction acts within the middle third of base				PASS
<b>Overturning and sliding between courses 1 and 2</b>					
Overturning (kNm/m)	429.0	162.3	2.644	1.000	PASS
Sliding (kN/m)	161.6	73.6	2.194	1.000	PASS
<b>Overturning and sliding between courses 2 and 3</b>					
Overturning (kNm/m)	245.0	89.1	2.751	1.000	PASS
Sliding (kN/m)	111.4	49.5	2.247	1.000	PASS
<b>Overturning and sliding between courses 3 and 4</b>					
Overturning (kNm/m)	122.1	41.3	2.955	1.000	PASS
Sliding (kN/m)	70.0	29.9	2.339	1.000	PASS
<b>Overturning and sliding between courses 4 and 5</b>					
Overturning (kNm/m)	48.2	14.0	3.452	1.000	PASS
Sliding (kN/m)	37.5	14.8	2.541	1.000	PASS
<b>Overturning and sliding between courses 5 and 6</b>					
Overturning (kNm/m)	11.4	2.0	5.810	1.000	PASS
Sliding (kN/m)	14.0	4.1	3.425	1.000	PASS

#### Combination 2

Action	Resistance	Force	FoS	Allowable FoS	Status
<b>Overturning, sliding and bearing at base level</b>					
Overturning (kNm/m)	818.8	257.9	3.175	1.000	PASS
Sliding (kN/m)	179.9	99.7	1.804	1.000	PASS
Bearing (kN/m <sup>2</sup> )	100.0	88.8	1.126	1.000	PASS
Eccentricity (mm)	Reaction acts within the middle third of base				PASS
<b>Overturning and sliding between courses 1 and 2</b>					
Overturning (kNm/m)	430.7	158.6	2.716	1.000	PASS
Sliding (kN/m)	129.2	69.7	1.854	1.000	PASS
<b>Overturning and sliding between courses 2 and 3</b>					
Overturning (kNm/m)	245.7	87.7	2.803	1.000	PASS
Sliding (kN/m)	89.0	47.4	1.879	1.000	PASS
<b>Overturning and sliding between courses 3 and 4</b>					
Overturning (kNm/m)	122.2	41.1	2.974	1.000	PASS

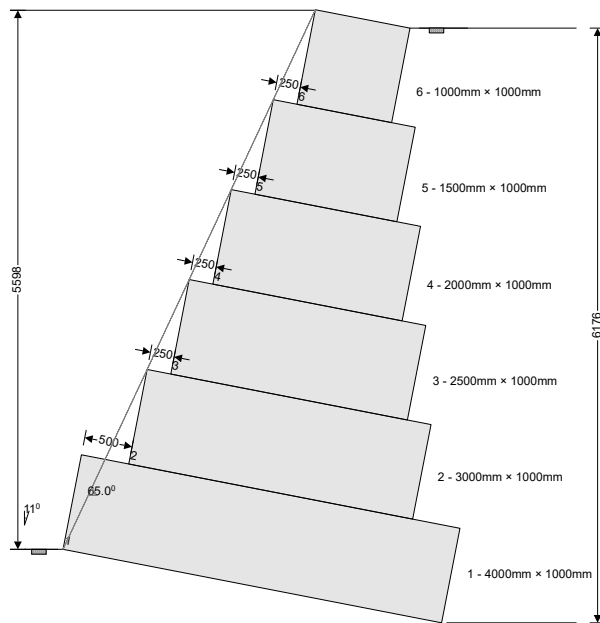


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Action	Resistance	Force	FoS	Allowable FoS	Status
Sliding (kN/m)	56.0	29.1	1.924	1.000	PASS
<b>Overturing and sliding between courses 4 and 5</b>					
Overturing (kNm/m)	48.1	14.1	3.403	1.000	PASS
Sliding (kN/m)	30.0	14.8	2.029	1.000	PASS
<b>Overturing and sliding between courses 5 and 6</b>					
Overturing (kNm/m)	11.3	2.1	5.428	1.000	PASS
Sliding (kN/m)	11.2	4.5	2.498	1.000	PASS

Surcharge



**Wall geometry**

Width of gabion 1	$w_1 = 4000$ mm
Height of gabion 1	$h_1 = 1000$ mm
Width of gabion 2	$w_2 = 3000$ mm
Height of gabion 2	$h_2 = 1000$ mm
Step to front face between courses 1 and 2	$s_2 = 500$ mm
Width of gabion 3	$w_3 = 2500$ mm
Height of gabion 3	$h_3 = 1000$ mm
Step to front face between courses 2 and 3	$s_3 = 250$ mm
Width of gabion 4	$w_4 = 2000$ mm
Height of gabion 4	$h_4 = 1000$ mm
Step to front face between courses 3 and 4	$s_4 = 250$ mm
Width of gabion 5	$w_5 = 1500$ mm
Height of gabion 5	$h_5 = 1000$ mm
Step to front face between courses 4 and 5	$s_5 = 250$ mm
Width of gabion 6	$w_6 = 1000$ mm
Height of gabion 6	$h_6 = 1000$ mm
Step to front face between courses 5 and 6	$s_6 = 250$ mm



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Wall inclination

$$\varepsilon = 11 \text{ deg}$$

### Gabion properties

Unit weight of fill

$$\gamma_d = 18.0 \text{ kN/m}^3$$

Friction between gabions

$$\delta_{bg,k} = 35.0 \text{ deg}$$

### Loading

Permanent surcharge

$$p_{o,G} = 10 \text{ kN/m}^2$$

Variable surcharge

$$p_{o,Q} = 10 \text{ kN/m}^2$$

### Soil properties

Slope of retained soil

$$\beta = 0.0 \text{ deg}$$

Characteristic peak shearing resistance angle

$$\phi'_{pk,k} = 32.0 \text{ deg}$$

Characteristic saturated density of retained soil

$$\gamma_{sr} = 18.0 \text{ kN/m}^3$$

Coefficient for wall friction

$$k_{membrane} = 0.75$$

Wall friction angle

$$\delta_{r,k} = 24.0 \text{ deg}$$

Characteristic base friction angle

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

Bearing capacity of founding soil

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

### Wall geometry

Horizontal distance to centre of gravity gabion 1

$$x_{g1} = w_1 / 2 = 2000 \text{ mm}$$

Vertical distance to centre of gravity gabion 1

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

Weight of gabion 1

$$W_{g1} = \gamma_d \times w_1 \times h_1 = 72.0 \text{ kN/m}$$

Horizontal distance to centre of gravity gabion 2

$$x_{g2} = w_2 / 2 + s_2 = 2000 \text{ mm}$$

Vertical distance to centre of gravity gabion 2

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

Weight of gabion 2

$$W_{g2} = \gamma_d \times w_2 \times h_2 = 54.0 \text{ kN/m}$$

Horizontal distance to centre of gravity gabion 3

$$x_{g3} = w_3 / 2 + s_2 + s_3 = 2000 \text{ mm}$$

Vertical distance to centre of gravity gabion 3

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

Weight of gabion 3

$$W_{g3} = \gamma_d \times w_3 \times h_3 = 45.0 \text{ kN/m}$$

Horizontal distance to centre of gravity gabion 4

$$x_{g4} = w_4 / 2 + s_2 + s_3 + s_4 = 2000 \text{ mm}$$

Vertical distance to centre of gravity gabion 4

$$y_{g4} = h_4 / 2 + h_1 + h_2 + h_3 = 3500 \text{ mm}$$

Weight of gabion 4

$$W_{g4} = \gamma_d \times w_4 \times h_4 = 36.0 \text{ kN/m}$$

Horizontal distance to centre of gravity gabion 5

$$x_{g5} = w_5 / 2 + s_2 + s_3 + s_4 + s_5 = 2000 \text{ mm}$$

Vertical distance to centre of gravity gabion 5

$$y_{g5} = h_5 / 2 + h_1 + h_2 + h_3 + h_4 = 4500 \text{ mm}$$

Weight of gabion 5

$$W_{g5} = \gamma_d \times w_5 \times h_5 = 27.0 \text{ kN/m}$$

Horizontal distance to centre of gravity gabion 6

$$x_{g6} = w_6 / 2 + s_2 + s_3 + s_4 + s_5 + s_6 = 2000 \text{ mm}$$

Vertical distance to centre of gravity gabion 6

$$y_{g6} = h_6 / 2 + h_1 + h_2 + h_3 + h_4 + h_5 = 5500 \text{ mm}$$

Weight of gabion 6

$$W_{g6} = \gamma_d \times w_6 \times h_6 = 18.0 \text{ kN/m}$$

Weight of entire gabion

$$W_g = W_{g1} + W_{g2} + W_{g3} + W_{g4} + W_{g5} + W_{g6} = 252.0 \text{ kN/m}$$

Horiz distance to centre of gravity entire gabion

$$x_g = ((W_{g1} \times x_{g1}) + (W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4}) + (W_{g5} \times x_{g5}) + (W_{g6} \times x_{g6})) / W_g = 2000 \text{ mm}$$

Vert distance to centre of gravity entire gabion

$$y_g = ((W_{g1} \times y_{g1}) + (W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4}) + (W_{g5} \times y_{g5}) + (W_{g6} \times y_{g6})) / W_g = 2286 \text{ mm}$$

Correcting for wall inclination horiz dist

$$x_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon) = 2399 \text{ mm}$$

Vertical change in height due to wall inclination

$$H_r = y_{g6} + h_6/2 - ((y_{g6} + h_6/2) \times \cos(\varepsilon) - (x_{g6} + w_6/2) \times \sin(\varepsilon)) = 587 \text{ mm}$$



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### Design dimensions

Effective angle of rear plane of wall	$\alpha = 90\text{deg} - \text{Atan}((w_1 - (x_{g6} + (w_6 / 2))) / (y_{g6} + h_6 / 2)) + \epsilon = 87.0 \text{ deg}$
Effective face angle	$\theta = \text{Atan}((y_{g6} + (h_6 / 2)) / ((x_{g6} - (w_6 / 2)))) - \epsilon = 65.0 \text{ deg}$
Effective height of wall	$H = (y_{g6} + h_6 / 2) + (w_1 \times \sin(\epsilon)) - H_f = 6176 \text{ mm}$
Height of wall from toe to front edge of top gabion	$H_{\text{incl}} = ((y_{g6} + h_6 / 2) \times \cos(\epsilon) - (x_{g6} - (w_6 / 2)) \times \sin(\epsilon)) = 5604 \text{ mm}$
Active pressure using Coulomb theory	$K_a = \sin(\alpha + \phi'_{r,k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,k}) \times (1 + \sqrt{(\sin(\phi'_{r,k} + \delta_{r,k}) \times \sin(\phi'_{r,k} - \beta)) / (\sin(\alpha - \delta_{r,k}) \times \sin(\alpha + \beta))})^2 = 0.297$
Active thrust due to soil	$P_{a,\text{soil}} = 0.5 \times K_a \times \gamma_{sr} \times H^2 = 102.0 \text{ kN/m}$
Minimum surcharge (cl.4.6.3.2)	$p_{o,\text{min}} = \min(H / H_{\text{ref}}, 1) \times q_{d,\text{min}} = 10.0 \text{ kN/m}^2$

### Pressure at base

#### Horizontal forces

Retained soil	$F_{\text{soil},h,q} = P_{a,\text{soil}} \times \cos(90 - \alpha + \delta_{r,k}) = 90.9 \text{ kN/m}$
Height of soil thrust resolved vertically	$d_{h,\text{soil}} = H / 3 - w_1 \times \sin(\epsilon) = 1295 \text{ mm}$
Surcharge	$F_{\text{surch},h,q} = \max((p_{o,G} + p_{o,Q}), p_{o,\text{min}}) \times K_a \times H \times \cos(90 - \alpha + \delta_{r,k}) = 32.7 \text{ kN/m}$
Height of surcharge thrust resolved vertically	$d_{h,\text{surch}} = H / 2 - w_1 \times \sin(\epsilon) = 2325 \text{ mm}$

#### Vertical forces

Gabion weight	$F_{\text{gabion},v,q} = W_g = 252.0 \text{ kN/m}$
Retained soil	$F_{\text{soil},v,q} = P_{a,\text{soil}} \times \sin(90 - \alpha + \delta_{r,k}) = 46.4 \text{ kN/m}$
Horizontal dist to where soil thrust acts	$b_{v,\text{soil}} = w_1 \times \cos(\epsilon) - (H / 3) / \tan(\alpha) = 3817 \text{ mm}$
Surcharge	$F_{\text{surch},v,q} = \max((p_{o,G} + p_{o,Q}), p_{o,\text{min}}) \times K_a \times H \times \sin(90 - \alpha + \delta_{r,k}) = 16.7 \text{ kN/m}$
Horizontal dist to where surcharge thrust acts	$b_{v,\text{surch}} = w_1 \times \cos(\epsilon) - (H / 2) / \tan(\alpha) = 3763 \text{ mm}$
Total horizontal unfactored force	$T_q = F_{\text{soil},h,q} + F_{\text{surch},h,q} = 123.6 \text{ kN/m}$
Total vertical unfactored force	$N_q = F_{\text{gabion},v,q} + F_{\text{soil},v,q} + F_{\text{surch},v,q} = 315.1 \text{ kN/m}$
Force normal to base	$N_s = N_q \times \cos(\epsilon) + T_q \times \sin(\epsilon) = 332.9 \text{ kN/m}$
Total unfactored overturning force	$M_{o,q} = F_{\text{soil},h,q} \times d_{h,\text{soil}} + F_{\text{surch},h,q} \times d_{h,\text{surch}} = 193.8 \text{ kNm/m}$
Total unfactored restoring force	$M_{R,q} = F_{\text{gabion},v,q} \times X_g + F_{\text{soil},v,q} \times b_{v,\text{soil}} + F_{\text{surch},v,q} \times b_{v,\text{surch}} = 844.5 \text{ kNm/m}$
Eccentricity	$e = w_1 / 2 - (M_{R,q} - M_{o,q}) / N_s = 45 \text{ mm}$

**Reaction acts within middle third of base**

Pressure at toe	$\sigma_{\text{toe}} = N_s / w_1 \times (1 + (6 \times e / w_1)) = 88.8 \text{ kN/m}^2$
Pressure at heel	$\sigma_{\text{heel}} = N_s / w_1 \times (1 - (6 \times e / w_1)) = 77.6 \text{ kN/m}^2$
Factor of safety	$FoS_Q = q / \max(\sigma_{\text{toe}}, \sigma_{\text{heel}}) = 1.126$
Allowable factor of safety	$FoS_{Q,\text{allow}} = 1.000$

**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	$\gamma_G = 1.35$
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	$\gamma_{\psi} = 1.00$
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Weight density

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

### Design soil properties

Design effective shearing resistance angle

$$\phi'_{r,d} = \text{Atan}(\tan(\phi'_{pk,k}) / \gamma_{\phi}) = 32.0 \text{ deg}$$

Design saturated density of retained soil

$$\gamma_{s,d} = \gamma_{sr} / \gamma_{\gamma} = 18.0 \text{ kN/m}^3$$

Design wall friction angle (cl.5.4.2.1)

$$\delta_{r,d} = \min(\text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi}), \phi'_{r,d} \times K_{\text{membrane}}) = 24.0 \text{ deg}$$

Design base friction angle

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

Design friction between gabions

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

Active pressure using Coulomb theory

$$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta)))^2}) = 0.297$$

Active thrust due to soil

$$P_{a,\text{soil}} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = 102.0 \text{ kN/m}$$

Minimum surcharge (cl.4.6.3.2)

$$p_{o,\text{min}} = \min(H / H_{\text{ref}}, 1) \times q_{d,\text{min}} = 10.0 \text{ kN/m}^2$$

### Horizontal forces

Retained soil

$$F_{\text{soil}_h} = \gamma_G \times P_{a,\text{soil}} \times \cos(90 - \alpha + \delta_{r,d}) = 122.7 \text{ kN/m}$$

Surcharge

$$F_{\text{surch}_h} = \max((p_{o,G} \times \gamma_G + p_{o,Q} \times \gamma_Q), p_{o,\text{min}}) \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = 46.6 \text{ kN/m}$$

### Vertical forces

Gabion weight

$$F_{\text{gabion}_v,f} = \gamma_{G,f} \times W_g = 252.0 \text{ kN/m}$$

Retained soil

$$F_{\text{soil}_v,f} = \gamma_{G,f} \times P_{a,\text{soil}} \times \sin(90 - \alpha + \delta_{r,d}) = 46.4 \text{ kN/m}$$

Surcharge

$$F_{\text{surch}_v,f} = \max((p_{o,G} \times \gamma_{G,f} + p_{o,Q} \times \gamma_{Q,f}), p_{o,\text{min}}) \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = 8.3 \text{ kN/m}$$

### Overtuning stability - take moments about the toe

Overtuning moment

$$M_o = F_{\text{soil}_h} \times d_{h,\text{soil}} + F_{\text{surch}_h} \times d_{h,\text{surch}} = 267.3 \text{ kNm/m}$$

Restoring moment

$$M_R = F_{\text{gabion}_v,f} \times X_g + F_{\text{soil}_v,f} \times b_{v,\text{soil}} + F_{\text{surch}_v,f} \times b_{v,\text{surch}} = 813.1 \text{ kNm/m}$$

Factor of safety

$$FoS_M = M_R / M_o = 3.042$$

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

$$T = F_{\text{soil}_h} + F_{\text{surch}_h} = 169.3 \text{ kN/m}$$

Total vertical force

$$N = F_{\text{gabion}_v,f} + F_{\text{soil}_v,f} + F_{\text{surch}_v,f} = 306.7 \text{ kN/m}$$

Sliding force

$$F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = 107.7 \text{ kN/m}$$

Sliding resistance

$$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bb,d}) = 224.9 \text{ kN/m}$$

Factor of safety

$$FoS_S = F_R / F_f = 2.089$$

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

$$x_{g2} = w_2 / 2 = 1500 \text{ mm}$$

Vertical distance to centre of gravity gabion 2

$$y_{g2} = h_2 / 2 = 500 \text{ mm}$$

Weight of gabion 2

$$W_{g2} = \gamma_d \times w_2 \times h_2 = 54.0 \text{ kN/m}$$

Horizontal distance to centre of gravity gabion 3

$$x_{g3} = w_3 / 2 + s_3 = 1500 \text{ mm}$$

Vertical distance to centre of gravity gabion 3

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

Weight of gabion 3

$$W_{g3} = \gamma_d \times w_3 \times h_3 = 45.0 \text{ kN/m}$$



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Horizontal distance to centre of gravity gabion 4	$x_{g4} = w_4 / 2 + s_3 + s_4 = \mathbf{1500 \text{ mm}}$
Vertical distance to centre of gravity gabion 4	$y_{g4} = h_4 / 2 + h_2 + h_3 = \mathbf{2500 \text{ mm}}$
Weight of gabion 4	$W_{g4} = \gamma_d \times w_4 \times h_4 = \mathbf{36.0 \text{ kN/m}}$
Horizontal distance to centre of gravity gabion 5	$x_{g5} = w_5 / 2 + s_3 + s_4 + s_5 = \mathbf{1500 \text{ mm}}$
Vertical distance to centre of gravity gabion 5	$y_{g5} = h_5 / 2 + h_2 + h_3 + h_4 = \mathbf{3500 \text{ mm}}$
Weight of gabion 5	$W_{g5} = \gamma_d \times w_5 \times h_5 = \mathbf{27.0 \text{ kN/m}}$
Horizontal distance to centre of gravity gabion 6	$x_{g6} = w_6 / 2 + s_3 + s_4 + s_5 + s_6 = \mathbf{1500 \text{ mm}}$
Vertical distance to centre of gravity gabion 6	$y_{g6} = h_6 / 2 + h_2 + h_3 + h_4 + h_5 = \mathbf{4500 \text{ mm}}$
Weight of gabion 6	$W_{g6} = \gamma_d \times w_6 \times h_6 = \mathbf{18.0 \text{ kN/m}}$
Weight of entire gabion	$W_g = W_{g2} + W_{g3} + W_{g4} + W_{g5} + W_{g6} = \mathbf{180.0 \text{ kN/m}}$
Horiz distance to centre of gravity entire gabion	$x_g = ((W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4}) + (W_{g5} \times x_{g5}) + (W_{g6} \times x_{g6})) / W_g = \mathbf{1500 \text{ mm}}$
Vert distance to centre of gravity entire gabion	$y_g = ((W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4}) + (W_{g5} \times y_{g5}) + (W_{g6} \times y_{g6})) / W_g = \mathbf{2000 \text{ mm}}$
Correcting for wall inclination horiz dist	$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{1854 \text{ mm}}$
Vertical change in height due to wall inclination	$H_f = y_{g6} + h_6/2 - ((y_{g6} + h_6/2) \times \cos(\epsilon) - (x_{g6} + w_6/2) \times \sin(\epsilon)) = \mathbf{473 \text{ mm}}$
<b>Design dimensions</b>	
Effective angle of rear plane of wall	$\alpha = 90\text{deg} - \text{Atan}((w_2 - (x_{g6} + (w_6 / 2))) / (y_{g6} + h_6 / 2)) + \epsilon = \mathbf{89.7 \text{ deg}}$
Effective face angle	$\theta = \text{Atan}((y_{g6} + (h_6 / 2)) / ((x_{g6} - (w_6 / 2)))) - \epsilon = \mathbf{67.7 \text{ deg}}$
Effective height of wall	$H = (y_{g6} + h_6 / 2) + (w_2 \times \sin(\epsilon)) - H_f = \mathbf{5099 \text{ mm}}$
Height of wall from toe to front edge of top gabion	$H_{\text{incl}} = ((y_{g6} + h_6 / 2) \times \cos(\epsilon) - (x_{g6} - (w_6 / 2)) \times \sin(\epsilon)) = \mathbf{4717\text{mm}}$
Active pressure using Coulomb theory	$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))})^2) = \mathbf{0.277}$
Active thrust due to soil	$P_{a,\text{soil}} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = \mathbf{64.8 \text{ kN/m}}$
Minimum surcharge (cl.4.6.3.2)	$p_{o,\text{min}} = \min(H / H_{\text{ref}}, 1) \times q_{d,\text{min}} = \mathbf{10.0 \text{ kN/m}^2}$
<b>Horizontal forces</b>	
Retained soil	$F_{\text{soil}_h} = \gamma_G \times P_{a,\text{soil}} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{79.7 \text{ kN/m}}$
Surcharge	$F_{\text{surch}_h} = \max((p_{o,G} \times \gamma_G + p_{o,Q} \times \gamma_Q), p_{o,\text{min}}) \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{36.7 \text{ kN/m}}$
<b>Vertical forces</b>	
Gabion weight	$F_{\text{gabion}_v,f} = \gamma_{G,f} \times W_g = \mathbf{180.0 \text{ kN/m}}$
Retained soil	$F_{\text{soil}_v,f} = \gamma_{G,f} \times P_{a,\text{soil}} \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{26.7 \text{ kN/m}}$
Surcharge	$F_{\text{surch}_v,f} = \max((p_{o,G} \times \gamma_{G,f} + p_{o,Q} \times \gamma_{Q,f}), p_{o,\text{min}}) \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{5.8 \text{ kN/m}}$
<b>Overtuning stability - take moments about the toe</b>	
Overtuning moment	$M_o = F_{\text{soil}_h} \times d_{h,\text{soil}} + F_{\text{surch}_h} \times d_{h,\text{surch}} = \mathbf{162.3 \text{ kNm/m}}$
Restoring moment	$M_R = F_{\text{gabion}_v,f} \times X_g + F_{\text{soil}_v,f} \times b_{v,\text{soil}} + F_{\text{surch}_v,f} \times b_{v,\text{surch}} = \mathbf{429.0 \text{ kNm/m}}$
Factor of safety	$F_{\text{OSM}} = M_R / M_o = \mathbf{2.644}$
Allowable factor of safety	$F_{\text{OSM}_{\text{allow}}} = \mathbf{1.000}$
<b>PASS - Design FOS for overturning exceeds min allowable FOS for overturning</b>	
<b>Sliding stability - ignore any passive pressure in front of the structure</b>	
Total horizontal force	$T = F_{\text{soil}_h} + F_{\text{surch}_h} = \mathbf{116.3 \text{ kN/m}}$



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Total vertical force

$$N = F_{\text{gabion}_v,f} + F_{\text{soil}_v,f} + F_{\text{surch}_v,f} = \mathbf{212.5 \text{ kN/m}}$$

Sliding force

$$F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon) = \mathbf{73.6 \text{ kN/m}}$$

Sliding resistance

$$F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{b,g,d}) = \mathbf{161.6 \text{ kN/m}}$$

Factor of safety

$$FoS_S = F_R / F_f = \mathbf{2.194}$$

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

$$x_{g3} = w_3 / 2 = \mathbf{1250 \text{ mm}}$$

Vertical distance to centre of gravity gabion 3

$$y_{g3} = h_3 / 2 = \mathbf{500 \text{ mm}}$$

Weight of gabion 3

$$W_{g3} = \gamma_d \times w_3 \times h_3 = \mathbf{45.0 \text{ kN/m}}$$

Horizontal distance to centre of gravity gabion 4

$$x_{g4} = w_4 / 2 + s_4 = \mathbf{1250 \text{ mm}}$$

Vertical distance to centre of gravity gabion 4

$$y_{g4} = h_4 / 2 + h_3 = \mathbf{1500 \text{ mm}}$$

Weight of gabion 4

$$W_{g4} = \gamma_d \times w_4 \times h_4 = \mathbf{36.0 \text{ kN/m}}$$

Horizontal distance to centre of gravity gabion 5

$$x_{g5} = w_5 / 2 + s_4 + s_5 = \mathbf{1250 \text{ mm}}$$

Vertical distance to centre of gravity gabion 5

$$y_{g5} = h_5 / 2 + h_3 + h_4 = \mathbf{2500 \text{ mm}}$$

Weight of gabion 5

$$W_{g5} = \gamma_d \times w_5 \times h_5 = \mathbf{27.0 \text{ kN/m}}$$

Horizontal distance to centre of gravity gabion 6

$$x_{g6} = w_6 / 2 + s_4 + s_5 + s_6 = \mathbf{1250 \text{ mm}}$$

Vertical distance to centre of gravity gabion 6

$$y_{g6} = h_6 / 2 + h_3 + h_4 + h_5 = \mathbf{3500 \text{ mm}}$$

Weight of gabion 6

$$W_{g6} = \gamma_d \times w_6 \times h_6 = \mathbf{18.0 \text{ kN/m}}$$

Weight of entire gabion

$$W_g = W_{g3} + W_{g4} + W_{g5} + W_{g6} = \mathbf{126.0 \text{ kN/m}}$$

Horiz distance to centre of gravity entire gabion

$$x_g = ((W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4}) + (W_{g5} \times x_{g5}) + (W_{g6} \times x_{g6})) / W_g = \mathbf{1250 \text{ mm}}$$

Vert distance to centre of gravity entire gabion

$$y_g = ((W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4}) + (W_{g5} \times y_{g5}) + (W_{g6} \times y_{g6})) / W_g = \mathbf{1643 \text{ mm}}$$

Correcting for wall inclination horiz dist

$$X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon) = \mathbf{1541 \text{ mm}}$$

Vertical change in height due to wall inclination

$$H_f = y_{g6} + h_6/2 - ((y_{g6} + h_6/2) \times \cos(\varepsilon) - (x_{g6} + w_6/2) \times \sin(\varepsilon)) = \mathbf{407 \text{ mm}}$$

#### Design dimensions

Effective angle of rear plane of wall

$$\alpha = 90\text{deg} - \text{Atan}((w_3 - (x_{g6} + (w_6 / 2))) / (y_{g6} + h_6 / 2)) + \varepsilon = \mathbf{90.4 \text{ deg}}$$

Effective face angle

$$\theta = \text{Atan}((y_{g6} + (h_6 / 2)) / ((x_{g6} - (w_6 / 2)))) - \varepsilon = \mathbf{68.4 \text{ deg}}$$

Effective height of wall

$$H = (y_{g6} + h_6 / 2) + (w_3 \times \sin(\varepsilon)) - H_f = \mathbf{4070 \text{ mm}}$$

Height of wall from toe to front edge of top gabion

$$H_{incl} = ((y_{g6} + h_6 / 2) \times \cos(\varepsilon) - (x_{g6} - (w_6 / 2)) \times \sin(\varepsilon)) = \mathbf{3783 \text{ mm}}$$

Active pressure using Coulomb theory

$$K_a = \frac{\sin(\alpha + \phi'_{r,d})^2}{(\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))))^2} = \mathbf{0.272}$$

Active thrust due to soil

$$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = \mathbf{40.5 \text{ kN/m}}$$

Minimum surcharge (cl.4.6.3.2)

$$p_{o,min} = \min(H / H_{ref}, 1) \times q_{d,min} = \mathbf{10.0 \text{ kN/m}^2}$$

#### Horizontal forces

Retained soil

$$F_{soil,h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{50.1 \text{ kN/m}}$$

Surcharge

$$F_{surch,h} = \max((p_{o,G} \times \gamma_G + p_{o,Q} \times \gamma_Q), p_{o,min}) \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{28.9 \text{ kN/m}}$$

#### Vertical forces

Gabion weight

$$F_{gabion_v,f} = \gamma_{G,f} \times W_g = \mathbf{126.0 \text{ kN/m}}$$

Retained soil

$$F_{soil_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{16.2 \text{ kN/m}}$$



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Surcharge

$$F_{surch\_v,f} = \max((p_{o,G} \times \gamma_{G,f} + p_{o,Q} \times \gamma_{Q,f}), p_{o,min}) \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = 4.4 \text{ kN/m}$$

**Overturing stability - take moments about the toe**

Overturing moment

$$M_o = F_{soil\_h} \times d_{h,soil} + F_{surch\_h} \times d_{h,surch} = 89.1 \text{ kNm/m}$$

Restoring moment

$$M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{surch\_v,f} \times b_{v,surch} = 245.0 \text{ kNm/m}$$

Factor of safety

$$FoS_M = M_R / M_o = 2.751$$

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

$$T = F_{soil\_h} + F_{surch\_h} = 79.0 \text{ kN/m}$$

Total vertical force

$$N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{surch\_v,f} = 146.7 \text{ kN/m}$$

Sliding force

$$F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = 49.5 \text{ kN/m}$$

Sliding resistance

$$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = 111.4 \text{ kN/m}$$

Factor of safety

$$FoS_S = F_R / F_f = 2.247$$

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 3 and 4**

**Wall geometry**

Horizontal distance to centre of gravity gabion 4

$$x_{g4} = w_4 / 2 = 1000 \text{ mm}$$

Vertical distance to centre of gravity gabion 4

$$y_{g4} = h_4 / 2 = 500 \text{ mm}$$

Weight of gabion 4

$$W_{g4} = \gamma_d \times w_4 \times h_4 = 36.0 \text{ kN/m}$$

Horizontal distance to centre of gravity gabion 5

$$x_{g5} = w_5 / 2 + s_5 = 1000 \text{ mm}$$

Vertical distance to centre of gravity gabion 5

$$y_{g5} = h_5 / 2 + h_4 = 1500 \text{ mm}$$

Weight of gabion 5

$$W_{g5} = \gamma_d \times w_5 \times h_5 = 27.0 \text{ kN/m}$$

Horizontal distance to centre of gravity gabion 6

$$x_{g6} = w_6 / 2 + s_5 + s_6 = 1000 \text{ mm}$$

Vertical distance to centre of gravity gabion 6

$$y_{g6} = h_6 / 2 + h_4 + h_5 = 2500 \text{ mm}$$

Weight of gabion 6

$$W_{g6} = \gamma_d \times w_6 \times h_6 = 18.0 \text{ kN/m}$$

Weight of entire gabion

$$W_g = W_{g4} + W_{g5} + W_{g6} = 81.0 \text{ kN/m}$$

Horiz distance to centre of gravity entire gabion

$$X_g = ((W_{g4} \times x_{g4}) + (W_{g5} \times x_{g5}) + (W_{g6} \times x_{g6})) / W_g = 1000 \text{ mm}$$

Vert distance to centre of gravity entire gabion

$$y_g = ((W_{g4} \times y_{g4}) + (W_{g5} \times y_{g5}) + (W_{g6} \times y_{g6})) / W_g = 1278 \text{ mm}$$

Correcting for wall inclination horiz dist

$$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = 1225 \text{ mm}$$

Vertical change in height due to wall inclination

$$H_f = y_{g6} + h_6/2 - ((y_{g6} + h_6/2) \times \cos(\epsilon) - (x_{g6} + w_6/2) \times \sin(\epsilon)) = 341 \text{ mm}$$

**Design dimensions**

Effective angle of rear plane of wall

$$\alpha = 90\text{deg} - \text{Atan}((w_4 - (x_{g6} + (w_6 / 2))) / (y_{g6} + h_6 / 2)) + \epsilon = 91.5 \text{ deg}$$

Effective face angle

$$\theta = \text{Atan}((y_{g6} + (h_6 / 2)) / ((x_{g6} - (w_6 / 2)))) - \epsilon = 69.5 \text{ deg}$$

Effective height of wall

$$H = (y_{g6} + h_6 / 2) + (w_4 \times \sin(\epsilon)) - H_f = 3040 \text{ mm}$$

Height of wall from toe to front edge of top gabion

$$H_{incl} = ((y_{g6} + h_6 / 2) \times \cos(\epsilon) - (x_{g6} - (w_6 / 2)) \times \sin(\epsilon)) = 2849 \text{ mm}$$

Active pressure using Coulomb theory

$$K_a = \frac{\sin(\alpha + \phi'_{r,d})^2}{(\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))))^2} = 0.264$$

Active thrust due to soil

$$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = 21.9 \text{ kN/m}$$

Minimum surcharge (cl.4.6.3.2)

$$p_{o,min} = \min(H / H_{ref}, 1) \times q_{d,min} = 10.0 \text{ kN/m}^2$$



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### Horizontal forces

Retained soil  $F_{soil,h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = 27.4 \text{ kN/m}$   
 Surcharge  $F_{surch,h} = \max((p_{o,G} \times \gamma_G + p_{o,Q} \times \gamma_Q), p_{o,min}) \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = 21.1 \text{ kN/m}$

### Vertical forces

Gabion weight  $F_{gabion,v,f} = \gamma_{G,f} \times W_g = 81.0 \text{ kN/m}$   
 Retained soil  $F_{soil,v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = 8.4 \text{ kN/m}$   
 Surcharge  $F_{surch,v,f} = \max((p_{o,G} \times \gamma_{G,f} + p_{o,Q} \times \gamma_{Q,f}), p_{o,min}) \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = 3.1 \text{ kN/m}$

### Overtuning stability - take moments about the toe

Overtuning moment  $M_o = F_{soil,h} \times d_{h,soil} + F_{surch,h} \times d_{h,surch} = 41.3 \text{ kNm/m}$   
 Restoring moment  $M_R = F_{gabion,v,f} \times X_g + F_{soil,v,f} \times b_{v,soil} + F_{surch,v,f} \times b_{v,surch} = 122.1 \text{ kNm/m}$   
 Factor of safety  $FoS_M = M_R / M_o = 2.955$   
 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  $T = F_{soil,h} + F_{surch,h} = 48.5 \text{ kN/m}$   
 Total vertical force  $N = F_{gabion,v,f} + F_{soil,v,f} + F_{surch,v,f} = 92.4 \text{ kN/m}$   
 Sliding force  $F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = 29.9 \text{ kN/m}$   
 Sliding resistance  $F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = 70.0 \text{ kN/m}$   
 Factor of safety  $FoS_S = F_R / F_f = 2.339$   
 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 4 and 5

#### Wall geometry

Horizontal distance to centre of gravity gabion 5  $x_{g5} = w_5 / 2 = 750 \text{ mm}$   
 Vertical distance to centre of gravity gabion 5  $y_{g5} = h_5 / 2 = 500 \text{ mm}$   
 Weight of gabion 5  $W_{g5} = \gamma_d \times w_5 \times h_5 = 27.0 \text{ kN/m}$   
 Horizontal distance to centre of gravity gabion 6  $x_{g6} = w_6 / 2 + s_6 = 750 \text{ mm}$   
 Vertical distance to centre of gravity gabion 6  $y_{g6} = h_6 / 2 + h_5 = 1500 \text{ mm}$   
 Weight of gabion 6  $W_{g6} = \gamma_d \times w_6 \times h_6 = 18.0 \text{ kN/m}$   
 Weight of entire gabion  $W_g = W_{g5} + W_{g6} = 45.0 \text{ kN/m}$   
 Horiz distance to centre of gravity entire gabion  $X_g = ((W_{g5} \times x_{g5}) + (W_{g6} \times x_{g6})) / W_g = 750 \text{ mm}$   
 Vert distance to centre of gravity entire gabion  $y_g = ((W_{g5} \times y_{g5}) + (W_{g6} \times y_{g6})) / W_g = 900 \text{ mm}$   
 Correcting for wall inclination horiz dist  $X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = 908 \text{ mm}$   
 Vertical change in height due to wall inclination  $H_f = y_{g6} + h_6/2 - ((y_{g6} + h_6/2) \times \cos(\epsilon) - (x_{g6} + w_6/2) \times \sin(\epsilon)) = 275 \text{ mm}$

#### Design dimensions

Effective angle of rear plane of wall  $\alpha = 90\text{deg} - \text{Atan}((w_5 - (x_{g6} + (w_6 / 2))) / (y_{g6} + h_6 / 2)) + \epsilon = 93.9 \text{ deg}$   
 Effective face angle  $\theta = \text{Atan}((y_{g6} + (h_6 / 2)) / ((x_{g6} - (w_6 / 2)))) - \epsilon = 71.9 \text{ deg}$   
 Effective height of wall  $H = (y_{g6} + h_6 / 2) + (w_5 \times \sin(\epsilon)) - H_f = 2011 \text{ mm}$   
 Height of wall from toe to front edge of top gabion  $H_{incl} = ((y_{g6} + h_6 / 2) \times \cos(\epsilon) - (x_{g6} - (w_6 / 2)) \times \sin(\epsilon)) = 1916 \text{ mm}$



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Active pressure using Coulomb theory

$$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))})^2) = \mathbf{0.247}$$

Active thrust due to soil

$$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = \mathbf{9.0 \text{ kN/m}}$$

Minimum surcharge (cl.4.6.3.2)

$$p_{o,min} = \min(H / H_{ref}, 1) \times q_{d,min} = \mathbf{6.7 \text{ kN/m}^2}$$

#### Horizontal forces

Retained soil

$$F_{soil,h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{11.4 \text{ kN/m}}$$

Surcharge

$$F_{surch,h} = \max((p_{o,G} \times \gamma_G + p_{o,Q} \times \gamma_Q), p_{o,min}) \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{13.3 \text{ kN/m}}$$

#### Vertical forces

Gabion weight

$$F_{gabion,v,f} = \gamma_{G,f} \times W_g = \mathbf{45.0 \text{ kN/m}}$$

Retained soil

$$F_{soil,v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{3.1 \text{ kN/m}}$$

Surcharge

$$F_{surch,v,f} = \max((p_{o,G} \times \gamma_{G,f} + p_{o,Q} \times \gamma_{Q,f}), p_{o,min}) \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{1.7 \text{ kN/m}}$$

#### Overtuning stability - take moments about the toe

Overtuning moment

$$M_o = F_{soil,h} \times d_{h,soil} + F_{surch,h} \times d_{h,surch} = \mathbf{14.0 \text{ kNm/m}}$$

Restoring moment

$$M_R = F_{gabion,v,f} \times X_g + F_{soil,v,f} \times b_{v,soil} + F_{surch,v,f} \times b_{v,surch} = \mathbf{48.2 \text{ kNm/m}}$$

Factor of safety

$$FoS_M = M_R / M_o = \mathbf{3.452}$$

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

$$T = F_{soil,h} + F_{surch,h} = \mathbf{24.7 \text{ kN/m}}$$

Total vertical force

$$N = F_{gabion,v,f} + F_{soil,v,f} + F_{surch,v,f} = \mathbf{49.8 \text{ kN/m}}$$

Sliding force

$$F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = \mathbf{14.8 \text{ kN/m}}$$

Sliding resistance

$$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = \mathbf{37.5 \text{ kN/m}}$$

Factor of safety

$$FoS_S = F_R / F_f = \mathbf{2.541}$$

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 5 and 6

##### Wall geometry

Horizontal distance to centre of gravity gabion 6

$$x_{g6} = w_6 / 2 = \mathbf{500 \text{ mm}}$$

Vertical distance to centre of gravity gabion 6

$$y_{g6} = h_6 / 2 = \mathbf{500 \text{ mm}}$$

Weight of gabion 6

$$W_{g6} = \gamma_d \times w_6 \times h_6 = \mathbf{18.0 \text{ kN/m}}$$

Weight of entire gabion

$$W_g = W_{g6} = \mathbf{18.0 \text{ kN/m}}$$

Horiz distance to centre of gravity entire gabion

$$x_g = ((W_{g6} \times x_{g6})) / W_g = \mathbf{500 \text{ mm}}$$

Vert distance to centre of gravity entire gabion

$$y_g = ((W_{g6} \times y_{g6})) / W_g = \mathbf{500 \text{ mm}}$$

Correcting for wall inclination horiz dist

$$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{586 \text{ mm}}$$

Vertical change in height due to wall inclination

$$H_f = y_{g6} + h_6/2 - ((y_{g6} + h_6/2) \times \cos(\epsilon) - (x_{g6} + w_6/2) \times \sin(\epsilon)) = \mathbf{209 \text{ mm}}$$

##### Design dimensions

Effective angle of rear plane of wall

$$\alpha = 90 \text{ deg} + \epsilon = \mathbf{101.0 \text{ deg}}$$

Effective face angle

$$\theta = 90 \text{ deg} - \epsilon = \mathbf{79.0 \text{ deg}}$$

Effective height of wall

$$H = (y_{g6} + h_6 / 2) + (w_6 \times \sin(\epsilon)) - H_f = \mathbf{982 \text{ mm}}$$



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Height of wall from toe to front edge of top gabion  $H_{incl} = ((y_{g6} + h_6 / 2) \times \cos(\epsilon) - (x_{g6} - (w_6 / 2)) \times \sin(\epsilon)) = 982\text{mm}$   
 Active pressure using Coulomb theory  $K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))})^2) = 0.202$   
 Active thrust due to soil  $P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = 1.8 \text{ kN/m}$   
 Minimum surcharge (cl.4.6.3.2)  $p_{o,min} = \min(H / H_{ref}, 1) \times q_{d,min} = 3.3 \text{ kN/m}^2$

#### Horizontal forces

Retained soil  $F_{soil,h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = 2.3 \text{ kN/m}$   
 Surcharge  $F_{surch,h} = \max((p_{o,G} \times \gamma_G + p_{o,Q} \times \gamma_Q), p_{o,min}) \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = 5.5 \text{ kN/m}$

#### Vertical forces

Gabion weight  $F_{gabion,v,f} = \gamma_{G,f} \times W_g = 18.0 \text{ kN/m}$   
 Retained soil  $F_{soil,v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = 0.4 \text{ kN/m}$   
 Surcharge  $F_{surch,v,f} = \max((p_{o,G} \times \gamma_{G,f} + p_{o,Q} \times \gamma_{Q,f}), p_{o,min}) \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = 0.4 \text{ kN/m}$

#### Overtuning stability - take moments about the toe

Overtuning moment  $M_o = F_{soil,h} \times d_{h,soil} + F_{surch,h} \times d_{h,surch} = 2.0 \text{ kNm/m}$   
 Restoring moment  $M_R = F_{gabion,v,f} \times X_g + F_{soil,v,f} \times b_{v,soil} + F_{surch,v,f} \times b_{v,surch} = 11.4 \text{ kNm/m}$   
 Factor of safety  $FoS_M = M_R / M_o = 5.810$   
 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  $T = F_{soil,h} + F_{surch,h} = 7.8 \text{ kN/m}$   
 Total vertical force  $N = F_{gabion,v,f} + F_{soil,v,f} + F_{surch,v,f} = 18.8 \text{ kN/m}$   
 Sliding force  $F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = 4.1 \text{ kN/m}$   
 Sliding resistance  $F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = 14.0 \text{ kN/m}$   
 Factor of safety  $FoS_S = F_R / F_f = 3.425$   
 Allowable factor of safety  $FoS_{S,allow} = 1.000$

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

#### Design approach 1

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

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

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

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

#### Design soil properties

Design effective shearing resistance angle  $\phi'_{r,d} = \text{Atan}(\tan(\phi'_{pk,k}) / \gamma_{\phi'}) = 26.6 \text{ deg}$   
 Design saturated density of retained soil  $\gamma_{s,d} = \gamma_{sr} / \gamma_{\gamma} = 18.0 \text{ kN/m}^3$   
 Design wall friction angle (cl.5.4.2.1)  $\delta_{r,d} = \min(\text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}), \phi'_{r,d} \times k_{\text{membrane}}) = 19.6 \text{ deg}$



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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

$$x_{g1} = w_1 / 2 = \mathbf{2000 \text{ mm}}$$

Vertical distance to centre of gravity gabion 1

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

Weight of gabion 1

$$W_{g1} = \gamma_d \times w_1 \times h_1 = \mathbf{72.0 \text{ kN/m}}$$

Horizontal distance to centre of gravity gabion 2

$$x_{g2} = w_2 / 2 + s_2 = \mathbf{2000 \text{ mm}}$$

Vertical distance to centre of gravity gabion 2

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

Weight of gabion 2

$$W_{g2} = \gamma_d \times w_2 \times h_2 = \mathbf{54.0 \text{ kN/m}}$$

Horizontal distance to centre of gravity gabion 3

$$x_{g3} = w_3 / 2 + s_2 + s_3 = \mathbf{2000 \text{ mm}}$$

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

$$W_{g3} = \gamma_d \times w_3 \times h_3 = \mathbf{45.0 \text{ kN/m}}$$

Horizontal distance to centre of gravity gabion 4

$$x_{g4} = w_4 / 2 + s_2 + s_3 + s_4 = \mathbf{2000 \text{ mm}}$$

Vertical distance to centre of gravity gabion 4

$$y_{g4} = h_4 / 2 + h_1 + h_2 + h_3 = \mathbf{3500 \text{ mm}}$$

Weight of gabion 4

$$W_{g4} = \gamma_d \times w_4 \times h_4 = \mathbf{36.0 \text{ kN/m}}$$

Horizontal distance to centre of gravity gabion 5

$$x_{g5} = w_5 / 2 + s_2 + s_3 + s_4 + s_5 = \mathbf{2000 \text{ mm}}$$

Vertical distance to centre of gravity gabion 5

$$y_{g5} = h_5 / 2 + h_1 + h_2 + h_3 + h_4 = \mathbf{4500 \text{ mm}}$$

Weight of gabion 5

$$W_{g5} = \gamma_d \times w_5 \times h_5 = \mathbf{27.0 \text{ kN/m}}$$

Horizontal distance to centre of gravity gabion 6

$$x_{g6} = w_6 / 2 + s_2 + s_3 + s_4 + s_5 + s_6 = \mathbf{2000 \text{ mm}}$$

Vertical distance to centre of gravity gabion 6

$$y_{g6} = h_6 / 2 + h_1 + h_2 + h_3 + h_4 + h_5 = \mathbf{5500 \text{ mm}}$$

Weight of gabion 6

$$W_{g6} = \gamma_d \times w_6 \times h_6 = \mathbf{18.0 \text{ kN/m}}$$

Weight of entire gabion

$$W_g = W_{g1} + W_{g2} + W_{g3} + W_{g4} + W_{g5} + W_{g6} = \mathbf{252.0 \text{ kN/m}}$$

Horiz distance to centre of gravity entire gabion

$$X_g = ((W_{g1} \times x_{g1}) + (W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4}) + (W_{g5} \times x_{g5}) + (W_{g6} \times x_{g6})) / W_g = \mathbf{2000 \text{ mm}}$$

Vert distance to centre of gravity entire gabion

$$Y_g = ((W_{g1} \times y_{g1}) + (W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4}) + (W_{g5} \times y_{g5}) + (W_{g6} \times y_{g6})) / W_g = \mathbf{2286 \text{ mm}}$$

Correcting for wall inclination horiz dist

$$X_g = X_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{2399 \text{ mm}}$$

Vertical change in height due to wall inclination

$$H_f = y_{g6} + h_6/2 - ((y_{g6} + h_6/2) \times \cos(\epsilon) - (x_{g6} + w_6/2) \times \sin(\epsilon)) = \mathbf{587 \text{ mm}}$$

### Design dimensions

Effective angle of rear plane of wall

$$\alpha = 90\text{deg} - \text{Atan}((w_1 - (x_{g6} + (w_6 / 2))) / (y_{g6} + h_6 / 2)) + \epsilon = \mathbf{87.0 \text{ deg}}$$

Effective face angle

$$\theta = \text{Atan}((y_{g6} + (h_6 / 2)) / ((x_{g6} - (w_6 / 2)))) - \epsilon = \mathbf{65.0 \text{ deg}}$$

Effective height of wall

$$H = (y_{g6} + h_6 / 2) + (w_1 \times \sin(\epsilon)) - H_f = \mathbf{6176 \text{ mm}}$$

Height of wall from toe to front edge of top gabion

$$H_{incl} = ((y_{g6} + h_6 / 2) \times \cos(\epsilon) - (x_{g6} - (w_6 / 2)) \times \sin(\epsilon)) = \mathbf{5604 \text{ mm}}$$

Active pressure using Coulomb theory

$$K_a = \frac{\sin(\alpha + \phi'_{r,d})^2}{(\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))))^2} = \mathbf{0.361}$$

Active thrust due to soil

$$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = \mathbf{123.8 \text{ kN/m}}$$

Minimum surcharge (cl.4.6.3.2)

$$p_{o,min} = \min(H / H_{ref}, 1) \times q_{d,min} = \mathbf{10.0 \text{ kN/m}^2}$$

### Horizontal forces

Retained soil

$$F_{soil,h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{114.2 \text{ kN/m}}$$

Surcharge

$$F_{surch,h} = \max((p_{o,G} \times \gamma_G + p_{o,Q} \times \gamma_Q), p_{o,min}) \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{47.3 \text{ kN/m}}$$



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### Vertical forces

Gabion weight	$F_{gabion\_v,f} = \gamma_{G,f} \times W_g = \mathbf{252.0 \text{ kN/m}}$
Retained soil	$F_{soil\_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{47.7 \text{ kN/m}}$
Surcharge	$F_{surch\_v,f} = \max((p_{o,G} \times \gamma_{G,f} + p_{o,Q} \times \gamma_{Q,f}), p_{o,min}) \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{8.6 \text{ kN/m}}$

### Overtuning stability - take moments about the toe

Overtuning moment	$M_o = F_{soil\_h} \times d_{h,soil} + F_{surch\_h} \times d_{h,surch} = \mathbf{257.9 \text{ kNm/m}}$
Restoring moment	$M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{surch\_v,f} \times b_{v,surch} = \mathbf{818.8 \text{ kNm/m}}$
Factor of safety	$FoSM = M_R / M_o = \mathbf{3.175}$
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	$T = F_{soil\_h} + F_{surch\_h} = \mathbf{161.5 \text{ kN/m}}$
Total vertical force	$N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{surch\_v,f} = \mathbf{308.2 \text{ kN/m}}$
Sliding force	$F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = \mathbf{99.7 \text{ kN/m}}$
Sliding resistance	$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bb,d}) = \mathbf{179.9 \text{ kN/m}}$
Factor of safety	$FoS_S = F_R / F_f = \mathbf{1.804}$
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	$x_{g2} = w_2 / 2 = \mathbf{1500 \text{ mm}}$
Vertical distance to centre of gravity gabion 2	$y_{g2} = h_2 / 2 = \mathbf{500 \text{ mm}}$
Weight of gabion 2	$W_{g2} = \gamma_d \times w_2 \times h_2 = \mathbf{54.0 \text{ kN/m}}$
Horizontal distance to centre of gravity gabion 3	$x_{g3} = w_3 / 2 + s_3 = \mathbf{1500 \text{ mm}}$
Vertical distance to centre of gravity gabion 3	$y_{g3} = h_3 / 2 + h_2 = \mathbf{1500 \text{ mm}}$
Weight of gabion 3	$W_{g3} = \gamma_d \times w_3 \times h_3 = \mathbf{45.0 \text{ kN/m}}$
Horizontal distance to centre of gravity gabion 4	$x_{g4} = w_4 / 2 + s_3 + s_4 = \mathbf{1500 \text{ mm}}$
Vertical distance to centre of gravity gabion 4	$y_{g4} = h_4 / 2 + h_2 + h_3 = \mathbf{2500 \text{ mm}}$
Weight of gabion 4	$W_{g4} = \gamma_d \times w_4 \times h_4 = \mathbf{36.0 \text{ kN/m}}$
Horizontal distance to centre of gravity gabion 5	$x_{g5} = w_5 / 2 + s_3 + s_4 + s_5 = \mathbf{1500 \text{ mm}}$
Vertical distance to centre of gravity gabion 5	$y_{g5} = h_5 / 2 + h_2 + h_3 + h_4 = \mathbf{3500 \text{ mm}}$
Weight of gabion 5	$W_{g5} = \gamma_d \times w_5 \times h_5 = \mathbf{27.0 \text{ kN/m}}$
Horizontal distance to centre of gravity gabion 6	$x_{g6} = w_6 / 2 + s_3 + s_4 + s_5 + s_6 = \mathbf{1500 \text{ mm}}$
Vertical distance to centre of gravity gabion 6	$y_{g6} = h_6 / 2 + h_2 + h_3 + h_4 + h_5 = \mathbf{4500 \text{ mm}}$
Weight of gabion 6	$W_{g6} = \gamma_d \times w_6 \times h_6 = \mathbf{18.0 \text{ kN/m}}$
Weight of entire gabion	$W_g = W_{g2} + W_{g3} + W_{g4} + W_{g5} + W_{g6} = \mathbf{180.0 \text{ kN/m}}$
Horiz distance to centre of gravity entire gabion	$X_g = ((W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4}) + (W_{g5} \times x_{g5}) + (W_{g6} \times x_{g6})) / W_g = \mathbf{1500 \text{ mm}}$
Vert distance to centre of gravity entire gabion	$Y_g = ((W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4}) + (W_{g5} \times y_{g5}) + (W_{g6} \times y_{g6})) / W_g = \mathbf{2000 \text{ mm}}$
Correcting for wall inclination horiz dist	$X_g = X_g \times \cos(\epsilon) + Y_g \times \sin(\epsilon) = \mathbf{1854 \text{ mm}}$
Vertical change in height due to wall inclination	$H_f = y_{g6} + h_6/2 - ((y_{g6} + h_6/2) \times \cos(\epsilon) - (X_{g6} + w_6/2) \times \sin(\epsilon)) = \mathbf{473 \text{ mm}}$



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### Design dimensions

Effective angle of rear plane of wall	$\alpha = 90\text{deg} - \text{Atan}((w_2 - (x_{g6} + (w_6 / 2))) / (y_{g6} + h_6 / 2)) + \varepsilon = 89.7 \text{ deg}$
Effective face angle	$\theta = \text{Atan}((y_{g6} + (h_6 / 2)) / ((x_{g6} - (w_6 / 2)))) - \varepsilon = 67.7 \text{ deg}$
Effective height of wall	$H = (y_{g6} + h_6 / 2) + (w_2 \times \sin(\varepsilon)) - H_f = 5099 \text{ mm}$
Height of wall from toe to front edge of top gabion	$H_{\text{incl}} = ((y_{g6} + h_6 / 2) \times \cos(\varepsilon) - (x_{g6} - (w_6 / 2)) \times \sin(\varepsilon)) = 4717\text{mm}$
Active pressure using Coulomb theory	$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))})^2) = 0.340$
Active thrust due to soil	$P_{a,\text{soil}} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = 79.6 \text{ kN/m}$
Minimum surcharge (cl.4.6.3.2)	$p_{o,\text{min}} = \min(H / H_{\text{ref}}, 1) \times q_{d,\text{min}} = 10.0 \text{ kN/m}^2$

### Horizontal forces

Retained soil	$F_{\text{soil}_h} = \gamma_G \times P_{a,\text{soil}} \times \cos(90 - \alpha + \delta_{r,d}) = 74.9 \text{ kN/m}$
Surcharge	$F_{\text{surch}_h} = \max((p_{o,G} \times \gamma_G + p_{o,Q} \times \gamma_Q), p_{o,\text{min}}) \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = 37.5 \text{ kN/m}$

### Vertical forces

Gabion weight	$F_{\text{gabion}_v,f} = \gamma_{G,f} \times W_g = 180.0 \text{ kN/m}$
Retained soil	$F_{\text{soil}_v,f} = \gamma_{G,f} \times P_{a,\text{soil}} \times \sin(90 - \alpha + \delta_{r,d}) = 27.1 \text{ kN/m}$
Surcharge	$F_{\text{surch}_v,f} = \max((p_{o,G} \times \gamma_{G,f} + p_{o,Q} \times \gamma_{Q,f}), p_{o,\text{min}}) \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = 5.9 \text{ kN/m}$

### Overtuning stability - take moments about the toe

Overtuning moment	$M_o = F_{\text{soil}_h} \times d_{h,\text{soil}} + F_{\text{surch}_h} \times d_{h,\text{surch}} = 158.6 \text{ kNm/m}$
Restoring moment	$M_R = F_{\text{gabion}_v,f} \times X_g + F_{\text{soil}_v,f} \times b_{v,\text{soil}} + F_{\text{surch}_v,f} \times b_{v,\text{surch}} = 430.7 \text{ kNm/m}$
Factor of safety	$FoS_M = M_R / M_o = 2.716$
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	$T = F_{\text{soil}_h} + F_{\text{surch}_h} = 112.4 \text{ kN/m}$
Total vertical force	$N = F_{\text{gabion}_v,f} + F_{\text{soil}_v,f} + F_{\text{surch}_v,f} = 213.0 \text{ kN/m}$
Sliding force	$F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon) = 69.7 \text{ kN/m}$
Sliding resistance	$F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bg,d}) = 129.2 \text{ kN/m}$
Factor of safety	$FoS_S = F_R / F_f = 1.854$
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 2 and 3

#### Wall geometry

Horizontal distance to centre of gravity gabion 3	$x_{g3} = w_3 / 2 = 1250 \text{ mm}$
Vertical distance to centre of gravity gabion 3	$y_{g3} = h_3 / 2 = 500 \text{ mm}$
Weight of gabion 3	$W_{g3} = \gamma_d \times w_3 \times h_3 = 45.0 \text{ kN/m}$
Horizontal distance to centre of gravity gabion 4	$x_{g4} = w_4 / 2 + s_4 = 1250 \text{ mm}$
Vertical distance to centre of gravity gabion 4	$y_{g4} = h_4 / 2 + h_3 = 1500 \text{ mm}$
Weight of gabion 4	$W_{g4} = \gamma_d \times w_4 \times h_4 = 36.0 \text{ kN/m}$
Horizontal distance to centre of gravity gabion 5	$x_{g5} = w_5 / 2 + s_4 + s_5 = 1250 \text{ mm}$
Vertical distance to centre of gravity gabion 5	$y_{g5} = h_5 / 2 + h_3 + h_4 = 2500 \text{ mm}$



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Weight of gabion 5	$W_{g5} = \gamma_d \times w_5 \times h_5 = \mathbf{27.0 \text{ kN/m}}$
Horizontal distance to centre of gravity gabion 6	$x_{g6} = w_6 / 2 + s_4 + s_5 + s_6 = \mathbf{1250 \text{ mm}}$
Vertical distance to centre of gravity gabion 6	$y_{g6} = h_6 / 2 + h_3 + h_4 + h_5 = \mathbf{3500 \text{ mm}}$
Weight of gabion 6	$W_{g6} = \gamma_d \times w_6 \times h_6 = \mathbf{18.0 \text{ kN/m}}$
Weight of entire gabion	$W_g = W_{g3} + W_{g4} + W_{g5} + W_{g6} = \mathbf{126.0 \text{ kN/m}}$
Horiz distance to centre of gravity entire gabion	$x_g = ((W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4}) + (W_{g5} \times x_{g5}) + (W_{g6} \times x_{g6})) / W_g = \mathbf{1250 \text{ mm}}$
Vert distance to centre of gravity entire gabion	$y_g = ((W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4}) + (W_{g5} \times y_{g5}) + (W_{g6} \times y_{g6})) / W_g = \mathbf{1643 \text{ mm}}$
Correcting for wall inclination horiz dist	$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{1541 \text{ mm}}$
Vertical change in height due to wall inclination	$H_f = y_{g6} + h_6/2 - ((y_{g6} + h_6/2) \times \cos(\epsilon) - (x_{g6} + w_6/2) \times \sin(\epsilon)) = \mathbf{407 \text{ mm}}$
<b>Design dimensions</b>	
Effective angle of rear plane of wall	$\alpha = 90\text{deg} - \text{Atan}((w_3 - (x_{g6} + (w_6 / 2))) / (y_{g6} + h_6 / 2)) + \epsilon = \mathbf{90.4 \text{ deg}}$
Effective face angle	$\theta = \text{Atan}((y_{g6} + (h_6 / 2)) / ((x_{g6} - (w_6 / 2)))) - \epsilon = \mathbf{68.4 \text{ deg}}$
Effective height of wall	$H = (y_{g6} + h_6 / 2) + (w_3 \times \sin(\epsilon)) - H_f = \mathbf{4070 \text{ mm}}$
Height of wall from toe to front edge of top gabion	$H_{incl} = ((y_{g6} + h_6 / 2) \times \cos(\epsilon) - (x_{g6} - (w_6 / 2)) \times \sin(\epsilon)) = \mathbf{3783 \text{ mm}}$
Active pressure using Coulomb theory	$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}))^2 = \mathbf{0.335}$
Active thrust due to soil	$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = \mathbf{50.0 \text{ kN/m}}$
Minimum surcharge (cl.4.6.3.2)	$p_{o,min} = \min(H / H_{ref}, 1) \times q_{d,min} = \mathbf{10.0 \text{ kN/m}^2}$
<b>Horizontal forces</b>	
Retained soil	$F_{soil,h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{47.2 \text{ kN/m}}$
Surcharge	$F_{surch,h} = \max((p_{o,G} \times \gamma_G + p_{o,Q} \times \gamma_Q), p_{o,min}) \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{29.6 \text{ kN/m}}$
<b>Vertical forces</b>	
Gabion weight	$F_{gabion,v,f} = \gamma_G \times W_g = \mathbf{126.0 \text{ kN/m}}$
Retained soil	$F_{soil,v,f} = \gamma_G \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{16.5 \text{ kN/m}}$
Surcharge	$F_{surch,v,f} = \max((p_{o,G} \times \gamma_G + p_{o,Q} \times \gamma_Q), p_{o,min}) \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{4.5 \text{ kN/m}}$
<b>Overturning stability - take moments about the toe</b>	
Overturning moment	$M_o = F_{soil,h} \times d_{h,soil} + F_{surch,h} \times d_{h,surch} = \mathbf{87.7 \text{ kNm/m}}$
Restoring moment	$M_R = F_{gabion,v,f} \times X_g + F_{soil,v,f} \times b_{v,soil} + F_{surch,v,f} \times b_{v,surch} = \mathbf{245.7 \text{ kNm/m}}$
Factor of safety	$FoS_M = M_R / M_o = \mathbf{2.803}$
Allowable factor of safety	$FoS_{M,allow} = \mathbf{1.000}$
<b>PASS - Design FOS for overturning exceeds min allowable FOS for overturning</b>	
<b>Sliding stability - ignore any passive pressure in front of the structure</b>	
Total horizontal force	$T = F_{soil,h} + F_{surch,h} = \mathbf{76.8 \text{ kN/m}}$
Total vertical force	$N = F_{gabion,v,f} + F_{soil,v,f} + F_{surch,v,f} = \mathbf{146.9 \text{ kN/m}}$
Sliding force	$F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = \mathbf{47.4 \text{ kN/m}}$
Sliding resistance	$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = \mathbf{89.0 \text{ kN/m}}$
Factor of safety	$FoS_S = F_R / F_f = \mathbf{1.879}$
Allowable factor of safety	$FoS_{S,allow} = \mathbf{1.000}$
<b>PASS - Design FOS for sliding exceeds min allowable FOS for sliding</b>	



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**Check overturning and sliding between courses 3 and 4**

**Wall geometry**

Horizontal distance to centre of gravity gabion 4	$x_{g4} = w_4 / 2 = 1000 \text{ mm}$
Vertical distance to centre of gravity gabion 4	$y_{g4} = h_4 / 2 = 500 \text{ mm}$
Weight of gabion 4	$W_{g4} = \gamma_d \times w_4 \times h_4 = 36.0 \text{ kN/m}$
Horizontal distance to centre of gravity gabion 5	$x_{g5} = w_5 / 2 + s_5 = 1000 \text{ mm}$
Vertical distance to centre of gravity gabion 5	$y_{g5} = h_5 / 2 + h_4 = 1500 \text{ mm}$
Weight of gabion 5	$W_{g5} = \gamma_d \times w_5 \times h_5 = 27.0 \text{ kN/m}$
Horizontal distance to centre of gravity gabion 6	$x_{g6} = w_6 / 2 + s_5 + s_6 = 1000 \text{ mm}$
Vertical distance to centre of gravity gabion 6	$y_{g6} = h_6 / 2 + h_4 + h_5 = 2500 \text{ mm}$
Weight of gabion 6	$W_{g6} = \gamma_d \times w_6 \times h_6 = 18.0 \text{ kN/m}$
Weight of entire gabion	$W_g = W_{g4} + W_{g5} + W_{g6} = 81.0 \text{ kN/m}$
Horiz distance to centre of gravity entire gabion	$X_g = ((W_{g4} \times x_{g4}) + (W_{g5} \times x_{g5}) + (W_{g6} \times x_{g6})) / W_g = 1000 \text{ mm}$
Vert distance to centre of gravity entire gabion	$y_g = ((W_{g4} \times y_{g4}) + (W_{g5} \times y_{g5}) + (W_{g6} \times y_{g6})) / W_g = 1278 \text{ mm}$
Correcting for wall inclination horiz dist	$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = 1225 \text{ mm}$
Vertical change in height due to wall inclination	$H_f = y_{g6} + h_6/2 - ((y_{g6} + h_6/2) \times \cos(\epsilon) - (x_{g6} + w_6/2) \times \sin(\epsilon)) = 341 \text{ mm}$

**Design dimensions**

Effective angle of rear plane of wall	$\alpha = 90\text{deg} - \text{Atan}((w_4 - (x_{g6} + (w_6 / 2))) / (y_{g6} + h_6 / 2)) + \epsilon = 91.5 \text{ deg}$
Effective face angle	$\theta = \text{Atan}((y_{g6} + (h_6 / 2)) / ((x_{g6} - (w_6 / 2)))) - \epsilon = 69.5 \text{ deg}$
Effective height of wall	$H = (y_{g6} + h_6 / 2) + (w_4 \times \sin(\epsilon)) - H_f = 3040 \text{ mm}$
Height of wall from toe to front edge of top gabion	$H_{incl} = ((y_{g6} + h_6 / 2) \times \cos(\epsilon) - (x_{g6} - (w_6 / 2)) \times \sin(\epsilon)) = 2849 \text{ mm}$
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	$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = 27.2 \text{ kN/m}$
Minimum surcharge (cl.4.6.3.2)	$p_{o,min} = \min(H / H_{ref}, 1) \times q_{d,min} = 10.0 \text{ kN/m}^2$

**Horizontal forces**

Retained soil	$F_{soil,h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = 25.9 \text{ kN/m}$
Surcharge	$F_{surch,h} = \max((p_{o,G} \times \gamma_G + p_{o,Q} \times \gamma_Q), p_{o,min}) \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = 21.7 \text{ kN/m}$

**Vertical forces**

Gabion weight	$F_{gabion,v,f} = \gamma_G \times W_g = 81.0 \text{ kN/m}$
Retained soil	$F_{soil,v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = 8.4 \text{ kN/m}$
Surcharge	$F_{surch,v,f} = \max((p_{o,G} \times \gamma_{G,f} + p_{o,Q} \times \gamma_{Q,f}), p_{o,min}) \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = 3.1 \text{ kN/m}$

**Overturning stability - take moments about the toe**

Overturning moment	$M_o = F_{soil,h} \times d_{h,soil} + F_{surch,h} \times d_{h,surch} = 41.1 \text{ kNm/m}$
Restoring moment	$M_R = F_{gabion,v,f} \times X_g + F_{soil,v,f} \times b_{v,soil} + F_{surch,v,f} \times b_{v,surch} = 122.2 \text{ kNm/m}$
Factor of safety	$FoSM = M_R / M_o = 2.974$
Allowable factor of safety	$FoSM_{allow} = 1.000$

**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	$T = F_{soil\_h} + F_{surch\_h} = 47.6$ kN/m
Total vertical force	$N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{surch\_v,f} = 92.5$ kN/m
Sliding force	$F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = 29.1$ kN/m
Sliding resistance	$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = 56.0$ kN/m
Factor of safety	$FoS_S = F_R / F_f = 1.924$
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 4 and 5

#### Wall geometry

Horizontal distance to centre of gravity gabion 5	$x_{g5} = w_5 / 2 = 750$ mm
Vertical distance to centre of gravity gabion 5	$y_{g5} = h_5 / 2 = 500$ mm
Weight of gabion 5	$W_{g5} = \gamma_d \times w_5 \times h_5 = 27.0$ kN/m
Horizontal distance to centre of gravity gabion 6	$x_{g6} = w_6 / 2 + s_6 = 750$ mm
Vertical distance to centre of gravity gabion 6	$y_{g6} = h_6 / 2 + h_5 = 1500$ mm
Weight of gabion 6	$W_{g6} = \gamma_d \times w_6 \times h_6 = 18.0$ kN/m
Weight of entire gabion	$W_g = W_{g5} + W_{g6} = 45.0$ kN/m
Horiz distance to centre of gravity entire gabion	$x_g = ((W_{g5} \times x_{g5}) + (W_{g6} \times x_{g6})) / W_g = 750$ mm
Vert distance to centre of gravity entire gabion	$y_g = ((W_{g5} \times y_{g5}) + (W_{g6} \times y_{g6})) / W_g = 900$ mm
Correcting for wall inclination horiz dist	$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = 908$ mm
Vertical change in height due to wall inclination	$H_f = y_{g6} + h_6/2 - ((y_{g6} + h_6/2) \times \cos(\epsilon) - (x_{g6} + w_6/2) \times \sin(\epsilon)) = 275$ mm

#### Design dimensions

Effective angle of rear plane of wall	$\alpha = 90\text{deg} - \text{Atan}((w_5 - (x_{g6} + (w_6 / 2))) / (y_{g6} + h_6 / 2)) + \epsilon = 93.9$ deg
Effective face angle	$\theta = \text{Atan}((y_{g6} + (h_6 / 2)) / ((x_{g6} - (w_6 / 2)))) - \epsilon = 71.9$ deg
Effective height of wall	$H = (y_{g6} + h_6 / 2) + (w_5 \times \sin(\epsilon)) - H_f = 2011$ mm
Height of wall from toe to front edge of top gabion	$H_{incl} = ((y_{g6} + h_6 / 2) \times \cos(\epsilon) - (x_{g6} - (w_6 / 2)) \times \sin(\epsilon)) = 1916$ mm
Active pressure using Coulomb theory	$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}))^2 = 0.311$
Active thrust due to soil	$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = 11.3$ kN/m
Minimum surcharge (cl.4.6.3.2)	$p_{o,min} = \min(H / H_{ref}, 1) \times q_{d,min} = 6.7$ kN/m <sup>2</sup>

#### Horizontal forces

Retained soil	$F_{soil\_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = 10.9$ kN/m
Surcharge	$F_{surch\_h} = \max((p_{o,G} \times \gamma_G + p_{o,Q} \times \gamma_Q), p_{o,min}) \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = 13.8$ kN/m

#### Vertical forces

Gabion weight	$F_{gabion\_v,f} = \gamma_{G,f} \times W_g = 45.0$ kN/m
Retained soil	$F_{soil\_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = 3.1$ kN/m
Surcharge	$F_{surch\_v,f} = \max((p_{o,G} \times \gamma_{G,f} + p_{o,Q} \times \gamma_{Q,f}), p_{o,min}) \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = 1.7$ kN/m

#### Overturning stability - take moments about the toe

Overturning moment	$M_o = F_{soil\_h} \times d_{h,soil} + F_{surch\_h} \times d_{h,surch} = 14.1$ kNm/m
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Restoring moment  $M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{surch\_v,f} \times b_{v,surch} = 48.1 \text{ kNm/m}$

Factor of safety  $FoS_M = M_R / M_o = 3.403$

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  $T = F_{soil\_h} + F_{surch\_h} = 24.7 \text{ kN/m}$

Total vertical force  $N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{surch\_v,f} = 49.8 \text{ kN/m}$

Sliding force  $F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = 14.8 \text{ kN/m}$

Sliding resistance  $F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = 30.0 \text{ kN/m}$

Factor of safety  $FoS_S = F_R / F_f = 2.029$

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 5 and 6

##### Wall geometry

Horizontal distance to centre of gravity gabion 6  $x_{g6} = w_6 / 2 = 500 \text{ mm}$

Vertical distance to centre of gravity gabion 6  $y_{g6} = h_6 / 2 = 500 \text{ mm}$

Weight of gabion 6  $W_{g6} = \gamma_d \times w_6 \times h_6 = 18.0 \text{ kN/m}$

Weight of entire gabion  $W_g = W_{g6} = 18.0 \text{ kN/m}$

Horiz distance to centre of gravity entire gabion  $x_g = ((W_{g6} \times x_{g6})) / W_g = 500 \text{ mm}$

Vert distance to centre of gravity entire gabion  $y_g = ((W_{g6} \times y_{g6})) / W_g = 500 \text{ mm}$

Correcting for wall inclination horiz dist  $X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = 586 \text{ mm}$

Vertical change in height due to wall inclination  $H_f = y_{g6} + h_6/2 - ((y_{g6} + h_6/2) \times \cos(\epsilon) - (x_{g6} + w_6/2) \times \sin(\epsilon)) = 209 \text{ mm}$

##### Design dimensions

Effective angle of rear plane of wall  $\alpha = 90 \text{ deg} + \epsilon = 101.0 \text{ deg}$

Effective face angle  $\theta = 90 \text{ deg} - \epsilon = 79.0 \text{ deg}$

Effective height of wall  $H = (y_{g6} + h_6 / 2) + (w_6 \times \sin(\epsilon)) - H_f = 982 \text{ mm}$

Height of wall from toe to front edge of top gabion  $H_{incl} = ((y_{g6} + h_6 / 2) \times \cos(\epsilon) - (x_{g6} - (w_6 / 2)) \times \sin(\epsilon)) = 982 \text{ mm}$

Active pressure using Coulomb theory  $K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))})^2) = 0.265$

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

Minimum surcharge (cl.4.6.3.2)  $p_{o,min} = \min(H / H_{ref}, 1) \times q_{d,min} = 3.3 \text{ kN/m}^2$

##### Horizontal forces

Retained soil  $F_{soil\_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = 2.3 \text{ kN/m}$

Surcharge  $F_{surch\_h} = \max((p_{o,G} \times \gamma_G + p_{o,Q} \times \gamma_Q), p_{o,min}) \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = 5.9 \text{ kN/m}$

##### Vertical forces

Gabion weight  $F_{gabion\_v,f} = \gamma_{G,f} \times W_g = 18.0 \text{ kN/m}$

Retained soil  $F_{soil\_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = 0.3 \text{ kN/m}$

Surcharge  $F_{surch\_v,f} = \max((p_{o,G} \times \gamma_{G,f} + p_{o,Q} \times \gamma_{Q,f}), p_{o,min}) \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = 0.4 \text{ kN/m}$



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**Overturning stability - take moments about the toe**

Overturning moment  $M_o = F_{soil\_h} \times d_{h,soil} + F_{surch\_h} \times d_{h,surch} = 2.1 \text{ kNm/m}$   
 Restoring moment  $M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{surch\_v,f} \times b_{v,surch} = 11.3 \text{ kNm/m}$   
 Factor of safety  $FoSM = M_R / M_o = 5.428$   
 Allowable factor of safety  $FoSM_{allow} = 1.000$

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

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

Total horizontal force  $T = F_{soil\_h} + F_{surch\_h} = 8.2 \text{ kN/m}$   
 Total vertical force  $N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{surch\_v,f} = 18.7 \text{ kN/m}$   
 Sliding force  $F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = 4.5 \text{ kN/m}$   
 Sliding resistance  $F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = 11.2 \text{ kN/m}$   
 Factor of safety  $FoSS = F_R / F_f = 2.498$   
 Allowable factor of safety  $FoSS_{allow} = 1.000$

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