

Structural Analysis report in support of Gabion Retaining Wall

193 Graig Road, Godregraig



In accordance with EN 1997-1:2004

Preamble

This report has been prepared to analyse an existing structure in the form of Gabion baskets and mass concrete slab base to support/retain earth. The structure abuts the highway and is above 1.375m and is therefore required to supply and submit structural calculations to the local authority to evidence its integrity and satisfy all current codes.

Site Information

The gabion baskets front no. 193 Graig Road, Godregraig, providing a clear boundary line between the adopted highway and private land. To the rear of the gabion baskets, imported fill material followed by a reinforced concrete driveway. The survey of the land/topography was undertaken on 03.05.2020 on a dry and clear day.



Drawing

A survey drawing has been undertaken ref 100_8746.032, identifying three detailed cross sections in support of the calculations.

Calculations

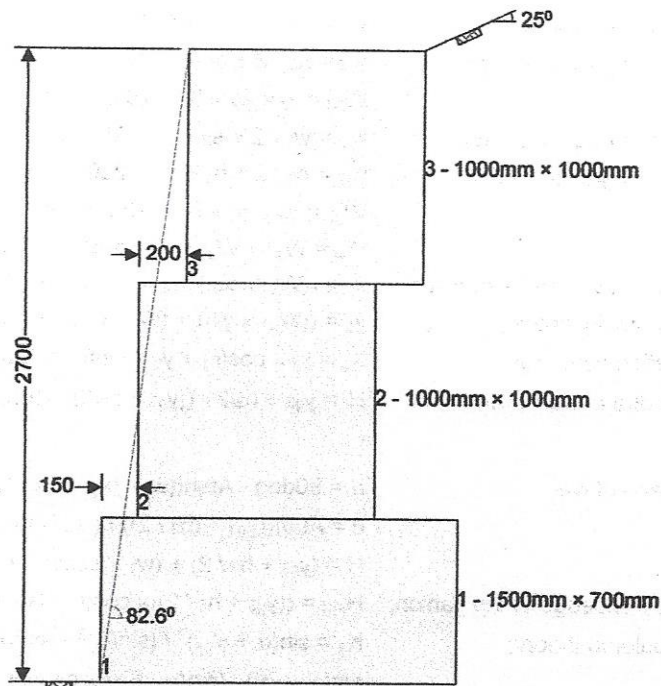
The following calculations were undertaken on Tedds software in accordance with EN 1997-1:2004 – code of practice for Geotechnical design and the UK National Annex. Tedds Calculation Version 2.0.02.

Note: Calculations were undertaken on worst case scenario section C – C as per drawing 100_8746.032.

GABION RETAINING WALL ANALYSIS & DESIGN

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

Tedds calculation version 2.0.02



Wall geometry

Width of gabion 1;

$w_1 = 1500 \text{ mm}$

Height of gabion 1;

$h_1 = 700 \text{ mm}$

Width of gabion 2;

$w_2 = 1000 \text{ mm}$

Height of gabion 2;

$h_2 = 1000 \text{ mm}$

Step to front face between courses 1 and 2;

$s_2 = 150 \text{ mm}$

Width of gabion 3;

$w_3 = 1000 \text{ mm}$

Height of gabion 3;

$h_3 = 1000 \text{ mm}$

Step to front face between courses 2 and 3;

$s_3 = 200 \text{ mm}$

Wall inclination;

$\varepsilon = 0 \text{ deg}$

Gabion properties

Unit weight of fill;

$\gamma_d = 20.0 \text{ kN/m}^3$

Friction between gabions;

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

Loading

Soil properties

Slope of retained soil;

$\beta = 25.0 \text{ deg}$

Characteristic effective shearing resistance angle;

$\phi'_{r,k} = 35.0 \text{ deg}$

Characteristic saturated density of retained soil;

$\gamma_{sr} = 21.0 \text{ kN/m}^3$

Coefficient for wall friction;

$k_{membrane} = 0.75$

Wall friction angle;

$\delta_{r,k} = 26.3 \text{ deg}$

Characteristic base friction angle;

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

Bearing capacity of founding soil;

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

Wall geometry

Horizontal distance to centre of gravity gabion 1;	$x_{g1} = w_1 / 2 = 750 \text{ mm}$
Vertical distance to centre of gravity gabion 1;	$y_{g1} = h_1 / 2 = 350 \text{ mm}$
Weight of gabion 1;	$W_{g1} = \gamma_d \times w_1 \times h_1 = 21.0 \text{ kN/m}$
Horizontal distance to centre of gravity gabion 2;	$x_{g2} = w_2 / 2 + s_2 = 650 \text{ mm}$
Vertical distance to centre of gravity gabion 2;	$y_{g2} = h_2 / 2 + h_1 = 1200 \text{ mm}$
Weight of gabion 2;	$W_{g2} = \gamma_d \times w_2 \times h_2 = 20.0 \text{ kN/m}$
Horizontal distance to centre of gravity gabion 3;	$x_{g3} = w_3 / 2 + s_2 + s_3 = 850 \text{ mm}$
Vertical distance to centre of gravity gabion 3;	$y_{g3} = h_3 / 2 + h_1 + h_2 = 2200 \text{ mm}$
Weight of gabion 3;	$W_{g3} = \gamma_d \times w_3 \times h_3 = 20.0 \text{ kN/m}$
Weight of entire gabion;	$W_g = W_{g1} + W_{g2} + W_{g3} = 61.0 \text{ kN/m}$
Horiz distance to centre of gravity entire gabion;	$x_g = ((W_{g1} \times x_{g1}) + (W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3})) / W_g = 750 \text{ mm}$
Vert distance to centre of gravity entire gabion;	$y_g = ((W_{g1} \times y_{g1}) + (W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3})) / W_g = 1235 \text{ mm}$
Correcting for wall inclination horiz dist;	$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = 750 \text{ mm}$
Vertical change in height due to wall inclination;	$H_f = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) \times \cos(\epsilon) - (x_{g3} + w_3/2) \times \sin(\epsilon)) = 0 \text{ mm}$

Design dimensions

Effective angle of rear plane of wall;	$\alpha = 90\text{deg} - \text{Atan}((w_1 - (x_{g3} + (w_3 / 2))) / (y_{g3} + h_3 / 2)) + \epsilon = 86.8 \text{ deg}$
Effective face angle;	$\theta = \text{Atan}((y_{g3} + (h_3 / 2)) / ((x_{g3} - (w_3 / 2)))) - \epsilon = 82.6 \text{ deg}$
Effective height of wall;	$H = (y_{g3} + h_3 / 2) + (w_1 \times \sin(\epsilon)) - H_f = 2700 \text{ mm}$
Height of wall from toe to front edge of top gabion;	$H_{ind} = ((y_{g3} + h_3 / 2) \times \cos(\epsilon) - (x_{g3} - (w_3 / 2)) \times \sin(\epsilon)) = 2700\text{mm}$
Active pressure using Coulomb theory;	$K_a = \sin(\alpha + \phi'_{r,k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,k}) \times (1 + \sqrt{(\sin(\phi'_{r,k} + \delta_{r,k}) \times \sin(\phi'_{r,k} - \beta) / (\sin(\alpha - \delta_{r,k}) \times \sin(\alpha + \beta))}))^2 = 0.404$
Active thrust due to soil;	$P_{a,soil} = 0.5 \times K_a \times \gamma_{sr} \times H^2 = 31.0 \text{ kN/m}$

Pressure at base

Horizontal forces

Retained soil;	$F_{soil,h,q} = P_{a,soil} \times \cos(90 - \alpha + \delta_{r,k}) = 27.0 \text{ kN/m}$
Height of soil thrust resolved vertically;	$d_{h,soil} = H / 3 - w_1 \times \sin(\epsilon) = 900 \text{ mm}$

Vertical forces

Gabion weight;	$F_{gabion,v,q} = W_g = 61.0 \text{ kN/m}$
Retained soil;	$F_{soil,v,q} = P_{a,soil} \times \sin(90 - \alpha + \delta_{r,k}) = 15.2 \text{ kN/m}$
Horizontal dist to where soil thrust acts;	$b_{v,soil} = w_1 \times \cos(\epsilon) - (H / 3) / \tan(\alpha) = 1450 \text{ mm}$
Total horizontal unfactored force;	$T_q = F_{soil,h,q} = 27.0 \text{ kN/m}$
Total vertical unfactored force;	$N_q = F_{gabion,v,q} + F_{soil,v,q} = 76.2 \text{ kN/m}$
Force normal to base;	$N_s = N_q \times \cos(\epsilon) + T_q \times \sin(\epsilon) = 76.2 \text{ kN/m}$
Total unfactored overturning force;	$M_{o,q} = F_{soil,h,q} \times d_{h,soil} = 24.3 \text{ kNm/m}$
Total unfactored restoring force;	$M_{R,q} = F_{gabion,v,q} \times X_g + F_{soil,v,q} \times b_{v,soil} = 67.8 \text{ kNm/m}$
Eccentricity;	$e = w_1 / 2 - (M_{R,q} - M_{o,q}) / N_s = 179 \text{ mm}$

Reaction acts within middle third of base

Pressure at toe;	$\sigma_{toe} = N_s / w_1 \times (1 + (6 \times e / w_1)) = 87.1 \text{ kN/m}^2$
Pressure at heel;	$\sigma_{heel} = N_s / w_1 \times (1 - (6 \times e / w_1)) = 14.5 \text{ kN/m}^2$
Factor of safety;	$FoS_q = q / \max(\sigma_{toe}, \sigma_{heel}) = 1.148$
Allowable factor of safety;	$FoS_{q,allow} = 1.000$

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;	$\gamma_\phi = 1.00$
Weight density;	$\gamma_\gamma = 1.00$

Design soil properties

Design effective shearing resistance angle;	$\phi'_{r,d} = \text{Atan}(\tan(\phi'_{r,k}) / \gamma_\phi) = 35.0 \text{ deg}$
Design saturated density of retained soil;	$\gamma_{s,d} = \gamma_{sr} / \gamma_\gamma = 21.0 \text{ kN/m}^3$
Design wall friction angle;	$\delta_{r,d} = \min(\text{atan}(\tan(\delta_{r,k}) / \gamma_\phi), \phi'_{r,d} \times k_{\text{membrane}}) = 26.3 \text{ deg}$
Design base friction angle;	$\delta_{bb,d} = \text{Atan}(\tan(\delta_{bb,k}) / \gamma_\phi) = 35.0 \text{ deg}$
Design friction between gabions;	$\delta_{bg,d} = \text{Atan}(\tan(\delta_{bg,k}) / \gamma_\phi) = 35.0 \text{ deg}$
Active pressure using Coulomb theory;	$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))))^2) = 0.404$
Active thrust due to soil;	$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = 31.0 \text{ kN/m}$

Horizontal forces

Retained soil;	$F_{soil,h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = 36.4 \text{ kN/m}$
----------------	---

Vertical forces

Gabion weight;	$F_{gabion,v,f} = \gamma_{G,f} \times W_g = 61.0 \text{ kN/m}$
Retained soil;	$F_{soil,v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = 15.2 \text{ kN/m}$

Overturning stability - take moments about the toe

Overturning moment;	$M_o = F_{soil,h} \times d_{h,soil} = 32.8 \text{ kNm/m}$
Restoring moment;	$M_R = F_{gabion,v,f} \times X_g + F_{soil,v,f} \times d_{v,soil} = 67.8 \text{ kNm/m}$
Factor of safety;	$FoSM = M_R / M_o = 2.070$
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;	$T = F_{soil,h} = 36.4 \text{ kN/m}$
Total vertical force;	$N = F_{gabion,v,f} + F_{soil,v,f} = 76.2 \text{ kN/m}$
Sliding force;	$F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = 36.4 \text{ kN/m}$
Sliding resistance;	$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bb,d}) = 53.4 \text{ kN/m}$
Factor of safety;	$FoSS = F_R / F_f = 1.466$
Allowable factor of safety;	$FoSS_{allow} = 1.000$

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

Check overturning and sliding between courses 1 and 2
Wall geometry

Horizontal distance to centre of gravity gabion 2;	$x_{g2} = w_2 / 2 = 500 \text{ mm}$
Vertical distance to centre of gravity gabion 2;	$y_{g2} = h_2 / 2 = 500 \text{ mm}$
Weight of gabion 2;	$W_{g2} = \gamma_d \times w_2 \times h_2 = 20.0 \text{ kN/m}$
Horizontal distance to centre of gravity gabion 3;	$x_{g3} = w_3 / 2 + s_3 = 700 \text{ mm}$
Vertical distance to centre of gravity gabion 3;	$y_{g3} = h_3 / 2 + h_2 = 1500 \text{ mm}$

Weight of gabion 3;

$$W_{g3} = \gamma_d \times w_3 \times h_3 = 20.0 \text{ kN/m}$$

Weight of entire gabion;

$$W_g = W_{g2} + W_{g3} = 40.0 \text{ kN/m}$$

Horiz distance to centre of gravity entire gabion;

$$x_g = ((W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3})) / W_g = 600 \text{ mm}$$

Vert distance to centre of gravity entire gabion;

$$y_g = ((W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3})) / W_g = 1000 \text{ mm}$$

Correcting for wall inclination horiz dist;

$$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = 600 \text{ mm}$$

Vertical change in height due to wall inclination;

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

Design dimensions

Effective angle of rear plane of wall;

$$\alpha = \text{Atan}((w_2 - (x_{g3} + (w_3 / 2))) / (y_{g3} + h_3 / 2)) + 90 \text{ deg} + \epsilon = 84.3 \text{ deg}$$

Effective face angle;

$$\theta = \text{Atan}((y_{g3} + (h_3 / 2)) / ((x_{g3} - (w_3 / 2)))) - \epsilon = 84.3 \text{ deg}$$

Effective height of wall;

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

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

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

Active pressure using Coulomb theory;

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

Active thrust due to soil;

$$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = 18.4 \text{ kN/m}$$

Horizontal forces

Retained soil;

$$F_{soil,h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = 21.1 \text{ kN/m}$$

Vertical forces

Gabion weight;

$$F_{gabion,v,f} = \gamma_{G,f} \times W_g = 40.0 \text{ kN/m}$$

Retained soil;

$$F_{soil,v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = 9.8 \text{ kN/m}$$

Overturning stability - take moments about the toe

Overturning moment;

$$M_o = F_{soil,h} \times d_{h,soil} = 14.1 \text{ kNm/m}$$

Restoring moment;

$$M_R = F_{gabion,v,f} \times X_g + F_{soil,v,f} \times b_{v,soil} = 33.1 \text{ kNm/m}$$

Factor of safety;

$$FoS_M = M_R / M_o = 2.351$$

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;

$$T = F_{soil,h} = 21.1 \text{ kN/m}$$

Total vertical force;

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

Sliding force;

$$F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = 21.1 \text{ kN/m}$$

Sliding resistance;

$$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = 34.8 \text{ kN/m}$$

Factor of safety;

$$FoS_S = F_R / F_f = 1.650$$

Allowable factor of safety;

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

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

Check overturning and sliding between courses 2 and 3

Wall geometry

Horizontal distance to centre of gravity gabion 3;

$$x_{g3} = w_3 / 2 = 500 \text{ mm}$$

Vertical distance to centre of gravity gabion 3;

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

Weight of gabion 3;

$$W_{g3} = \gamma_d \times w_3 \times h_3 = 20.0 \text{ kN/m}$$

Weight of entire gabion;

$$W_g = W_{g3} = 20.0 \text{ kN/m}$$

Horiz distance to centre of gravity entire gabion;

$$x_g = ((W_{g3} \times x_{g3})) / W_g = 500 \text{ mm}$$

Vert distance to centre of gravity entire gabion;

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

Correcting for wall inclination horiz dist;

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

Vertical change in height due to wall inclination;

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

Design dimensions

Effective angle of rear plane of wall;

$$\alpha = 90 \text{ deg} + \varepsilon = 90.0 \text{ deg}$$

Effective face angle;

$$\theta = 90 \text{ deg} - \varepsilon = 90.0 \text{ deg}$$

Effective height of wall;

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

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

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

Active pressure using Coulomb theory;

$$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}))^2 = 0.364$$

Active thrust due to soil;

$$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = 3.8 \text{ kN/m}$$

Horizontal forces

Retained soil;

$$F_{soil,h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = 4.6 \text{ kN/m}$$

Vertical forces

Gabion weight;

$$F_{gabion,v,f} = \gamma_{G,f} \times W_g = 20.0 \text{ kN/m}$$

Retained soil;

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

Overturning stability - take moments about the toe

Overturning moment;

$$M_o = F_{soil,h} \times d_{h,soil} = 1.5 \text{ kNm/m}$$

Restoring moment;

$$M_R = F_{gabion,v,f} \times X_g + F_{soil,v,f} \times b_{v,soil} = 11.7 \text{ kNm/m}$$

Factor of safety;

$$FoSM = M_R / M_o = 7.571$$

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;

$$T = F_{soil,h} = 4.6 \text{ kN/m}$$

Total vertical force;

$$N = F_{gabion,v,f} + F_{soil,v,f} = 21.7 \text{ kN/m}$$

Sliding force;

$$F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon) = 4.6 \text{ kN/m}$$

Sliding resistance;

$$F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bg,d}) = 15.2 \text{ kN/m}$$

Factor of safety;

$$FoSS = F_R / F_f = 3.278$$

Allowable factor of safety;

$$FoSS_{allow} = 1.000$$

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

Design approach 1

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

Permanent unfavourable action;

$$\gamma_G = 1.00$$

Permanent favourable action;

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

Variable unfavourable action;

$$\gamma_Q = 1.30$$

Variable favourable action;

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

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

Angle of shearing resistance;

$$\gamma_\psi = 1.25$$

Weight density;

$$\gamma_\gamma = 1.00$$

Design soil properties

Design effective shearing resistance angle;

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

Design saturated density of retained soil;

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

Design wall friction angle;

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

Design base friction angle;

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

Design friction between gabions;

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

Wall geometry

Horizontal distance to centre of gravity gabion 1;

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

Vertical distance to centre of gravity gabion 1;

$$y_{g1} = h_1 / 2 = 350 \text{ mm}$$

Weight of gabion 1;

$$W_{g1} = \gamma_d \times w_1 \times h_1 = 21.0 \text{ kN/m}$$

Horizontal distance to centre of gravity gabion 2;

$$x_{g2} = w_2 / 2 + s_2 = 650 \text{ mm}$$

Vertical distance to centre of gravity gabion 2;

$$y_{g2} = h_2 / 2 + h_1 = 1200 \text{ mm}$$

Weight of gabion 2;

$$W_{g2} = \gamma_d \times w_2 \times h_2 = 20.0 \text{ kN/m}$$

Horizontal distance to centre of gravity gabion 3;

$$x_{g3} = w_3 / 2 + s_2 + s_3 = 850 \text{ mm}$$

Vertical distance to centre of gravity gabion 3;

$$y_{g3} = h_3 / 2 + h_1 + h_2 = 2200 \text{ mm}$$

Weight of gabion 3;

$$W_{g3} = \gamma_d \times w_3 \times h_3 = 20.0 \text{ kN/m}$$

Weight of entire gabion;

$$W_g = W_{g1} + W_{g2} + W_{g3} = 61.0 \text{ kN/m}$$

Horiz distance to centre of gravity entire gabion;

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

Vert distance to centre of gravity entire gabion;

$$y_g = ((W_{g1} \times y_{g1}) + (W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3})) / W_g = 1235 \text{ mm}$$

Correcting for wall inclination horiz dist;

$$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = 750 \text{ mm}$$

Vertical change in height due to wall inclination;

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

Design dimensions

Effective angle of rear plane of wall;

$$\alpha = 90\text{deg} - \text{Atan}((w_1 - (x_{g3} + (w_3 / 2))) / (y_{g3} + h_3 / 2)) + \epsilon = 86.8 \text{ deg}$$

Effective face angle;

$$\theta = \text{Atan}((y_{g3} + (h_3 / 2)) / (x_{g3} - (w_3 / 2))) - \epsilon = 82.6 \text{ deg}$$

Effective height of wall;

$$H = (y_{g3} + h_3 / 2) + (w_1 \times \sin(\epsilon)) - H_f = 2700 \text{ mm}$$

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

$$H_{incl} = ((y_{g3} + h_3 / 2) \times \cos(\epsilon) - (x_{g3} - (w_3 / 2)) \times \sin(\epsilon)) = 2700 \text{ mm}$$

Active pressure using Coulomb theory;

$$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))})^2) = 0.560$$

Active thrust due to soil;

$$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = 42.9 \text{ kN/m}$$

Horizontal forces

Retained soil;

$$F_{soil,h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = 38.9 \text{ kN/m}$$

Vertical forces

Gabion weight;

$$F_{gabion,v,f} = \gamma_{G,f} \times W_g = 61.0 \text{ kN/m}$$

Retained soil;

$$F_{soil,v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = 17.9 \text{ kN/m}$$

Overturning stability - take moments about the toe

Overturning moment;

$$M_o = F_{soil,h} \times d_{h,soil} = 35.1 \text{ kNm/m}$$

Restoring moment;

$$M_R = F_{gabion,v,f} \times X_g + F_{soil,v,f} \times b_{v,soil} = 71.7 \text{ kNm/m}$$

Factor of safety;

$$FoSM = M_R / M_o = 2.046$$

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;

$$T = F_{soil,h} = 38.9 \text{ kN/m}$$

Total vertical force;

$$N = F_{gabion,v,f} + F_{soil,v,f} = 78.9 \text{ kN/m}$$

Sliding force;

$$F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = 38.9 \text{ kN/m}$$

Sliding resistance;

$$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bb,d}) = 44.2 \text{ kN/m}$$

Factor of safety;

$$FoSS = F_R / F_f = 1.135$$

Allowable factor of safety;

$$FoSS_{allow} = 1.000$$

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

Check overturning and sliding between courses 1 and 2

Wall geometry

Horizontal distance to centre of gravity gabion 2;

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

Vertical distance to centre of gravity gabion 2;

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

Weight of gabion 2;

$$W_{g2} = \gamma_d \times w_2 \times h_2 = 20.0 \text{ kN/m}$$

Horizontal distance to centre of gravity gabion 3;

$$x_{g3} = w_3 / 2 + s_3 = 700 \text{ mm}$$

Vertical distance to centre of gravity gabion 3;

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

Weight of gabion 3;

$$W_{g3} = \gamma_d \times w_3 \times h_3 = 20.0 \text{ kN/m}$$

Weight of entire gabion;

$$W_g = W_{g2} + W_{g3} = 40.0 \text{ kN/m}$$

Horiz distance to centre of gravity entire gabion;

$$x_g = ((W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3})) / W_g = 600 \text{ mm}$$

Vert distance to centre of gravity entire gabion;

$$y_g = ((W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3})) / W_g = 1000 \text{ mm}$$

Correcting for wall inclination horiz dist;

$$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = 600 \text{ mm}$$

Vertical change in height due to wall inclination;

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

Design dimensions

Effective angle of rear plane of wall;

$$\alpha = \text{Atan}((w_2 - (x_{g3} + (w_3 / 2))) / (y_{g3} + h_3 / 2)) + 90 \text{ deg} + \epsilon = 84.3 \text{ deg}$$

Effective face angle;

$$\theta = \text{Atan}((y_{g3} + (h_3 / 2)) / ((x_{g3} - (w_3 / 2)))) - \epsilon = 84.3 \text{ deg}$$

Effective height of wall;

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

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

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

Active pressure using Coulomb theory;

$$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}))^2 = 0.600$$

Active thrust due to soil;

$$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = 25.2 \text{ kN/m}$$

Horizontal forces

Retained soil;

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

Vertical forces

Gabion weight;

$$F_{gabion,v,f} = \gamma_{G,f} \times W_g = 40.0 \text{ kN/m}$$

Retained soil;

$$F_{soil,v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = 11.5 \text{ kN/m}$$

Overturning stability - take moments about the toe

Overturning moment;

$$M_o = F_{soil,h} \times d_{h,soil} = 14.9 \text{ kNm/m}$$

Restoring moment;

$$M_R = F_{gabion,v,f} \times X_g + F_{soil,v,f} \times b_{v,soil} = 34.8 \text{ kNm/m}$$

Factor of safety;

$$FoSM = M_R / M_o = 2.328$$

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;

$$T = F_{soil,h} = 22.4 \text{ kN/m}$$

Total vertical force;

$$N = F_{gabion,v,f} + F_{soil,v,f} = 51.5 \text{ kN/m}$$

Sliding force;

$$F_r = T \times \cos(\epsilon) - N \times \sin(\epsilon) = 22.4 \text{ kN/m}$$

Sliding resistance;

$$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = 28.9 \text{ kN/m}$$

Factor of safety;

$$FoSS = F_R / F_r = 1.289$$

Allowable factor of safety;

$$FoSS_{allow} = 1.000$$

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

Check overturning and sliding between courses 2 and 3

Wall geometry

Horizontal distance to centre of gravity gabion 3;

$$x_{g3} = w_3 / 2 = 500 \text{ mm}$$

Vertical distance to centre of gravity gabion 3;

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

Weight of gabion 3;

$$W_{g3} = \gamma_d \times w_3 \times h_3 = 20.0 \text{ kN/m}$$

Weight of entire gabion;

$$W_g = W_{g3} = 20.0 \text{ kN/m}$$

Horiz distance to centre of gravity entire gabion;

$$x_g = ((W_{g3} \times x_{g3})) / W_g = 500 \text{ mm}$$

Vert distance to centre of gravity entire gabion;

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

Correcting for wall inclination horiz dist;

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

Vertical change in height due to wall inclination;

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

Design dimensions

Effective angle of rear plane of wall;

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

Effective face angle;

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

Effective height of wall;

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

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

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

Active pressure using Coulomb theory;

$$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}))^2 = 0.514$$

Active thrust due to soil;

$$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = 5.4 \text{ kN/m}$$

Horizontal forces

Retained soil;

$$F_{soil,h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = 5.0 \text{ kN/m}$$

Vertical forces

Gabion weight;

$$F_{gabion,v,f} = \gamma_{G,f} \times W_g = 20.0 \text{ kN/m}$$

Retained soil;

$$F_{soil,v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = 2.0 \text{ kN/m}$$

Overturning stability - take moments about the toe

Overturning moment;

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

Restoring moment;

$$M_R = F_{gabion,v,f} \times X_g + F_{soil,v,f} \times b_{v,soil} = 12.0 \text{ kNm/m}$$

Factor of safety;

$$FoS_M = M_R / M_o = 7.154$$

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;

$$T = F_{soil,h} = 5.0 \text{ kN/m}$$

Total vertical force;

$$N = F_{gabion,v,f} + F_{soil,v,f} = 22.0 \text{ kN/m}$$

Sliding force;

$$F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = 5.0 \text{ kN/m}$$

Sliding resistance;

$$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = 12.3 \text{ kN/m}$$

Factor of safety;

$$FoS_s = F_R / F_f = 2.451$$

Allowable factor of safety;

$$FoS_{s,allow} = 1.000$$

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