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1 Laurel Cottages, Garth, Glyn Ceiriog

Retaining Wall

STRUCTURAL CALCULATIONS

September 2024

Job No. 2024/207

SCHEME

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	Initials	**Date**
Prepared by	AH	09/24
Checked by		

1 Laurel Cottages, Garth, Glyn Ceiriog

Preamble to Calculations

Scope of Calculations

These calculations have been prepared at the request of the owner of the above property. The calculations cover the structural design of retaining wall to support elevated ground levels above a proposed parking area at the property.

No warranty is given by the issue of the calculations to the structural integrity of any other part of the proposed building for which calculations or structural advice has not been specifically requested or given

Building Regulations Approval

The owners of the property are advised that the approval of the Local Planning and/or Building Control should be obtained prior to any ordering of materials or fabrication. No responsibility is accepted for any changes that may be required as a result of work having proceeded before such approvals have been obtained.

Measurements and Dimensions

Dimensions and details for the purpose of the calculations have been taken from pdf drawings provided by the Architect for the scheme. Where necessary, the drawings have been scaled.

The person responsible for carrying out the Works should ensure that all assumptions and dimensions used in the calculations are checked on site before ordering of materials or fabrication. Any discrepancies or dimensions found to be significantly different from that assumed should be brought to the attention of the undersigned, so that such discrepancy can be checked, and if necessary, the calculations amended.

Design References

Structural design has been based on any or all of the following:

- Building Regulations – Approved Document A
- EN1990 – Basis of Structural Design.
- EN1991 – Actions on Structures.
- EN1992 – Design of Concrete Structures.
- EN1993 – Design of Steel Structures.
- EN1994 – Design of Composite Steel and Concrete Structures.
- EN1995 – Design of Timber Structures.
- EN1996 – Design of Masonry Structures.
- EN1997 – Geotechnical Design

Liability

Nothing in the Contract confers nor purports to confer on any third party any benefit nor any right to enforce any terms of this Contract pursuant to the Contracts (Rights of Third Parties) Act 1999.

Copyright

The design report including any calculations, sketches, drawings and schedules are the copyright of Andrew Hannett Limited who will retain ownership until the account has been settled in full. The information contained herein shall not be shared with or issued to third parties for construction, approvals or any other purposes until the account has been settled in full. Andrew Hannett Limited reserve the right to withdraw the design report at any point until the account has been settled in full.

CONSTRUCTION (DESIGN & MANAGEMENT) REGULATIONS CDM2015

The design reflected in this design report has been developed for Building Regulations and Construction purposes. Our appointment as Principal Designer stops after issue of this design package.

The Domestic Client duties under CDM2015 must be undertaken by the Contractor, or where there is more than one contractor, the Principal Contractor. Contractors in Domestic Projects must be aware of their Client duties under the Construction (Design and Management) Regulations 2015. Should this not be the case, then further guidance must be sought. Additional guidance in relation to the duties of the various parties is available on the HSE website.

In accordance with the Construction (Design & Management) Regulations 2015 it is our policy to 'Design Out' as many identifiable risks as possible for the construction, maintenance and demolition of the project. A Competent Contractor should be aware of 'normal' risks involved with the construction process. Unusual and/or significant residual risks that cannot be eliminated as part of the design process are listed below:

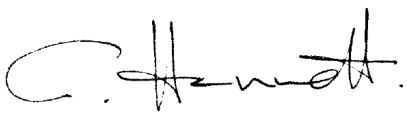
1. None Identified.

Safe methods and systems of work remain the responsibility of the Principal Contractor and must be identified in the Construction Phase Plan. A Construction Phase Plan must be drawn up for every project by the Contractor or Principal Contractor.

If any party using this design package considers or identifies any 'Abnormal' or 'Unusual' risks that have not been identified above they should share this with the project team immediately.

Health and Safety File – when our appointment as Principal Designer ends we will pass the Health and Safety File to the Principal Contractor. The Principal Contractor will be responsible for developing this and handing it to the Client on completion. The CITB has developed an app for iOS and Android platforms to aid in the compilation of Health and Safety Files.

Calculation Pages, Sketches and Drawings contained herein:
Calculation pages 1 to 12 inclusive.
Sketches SK01 – 03 including notes.

Signed:  *Date:* 06 Sept. 24

Andrew Hannett. B.Eng(Hons), C.Eng, MICE

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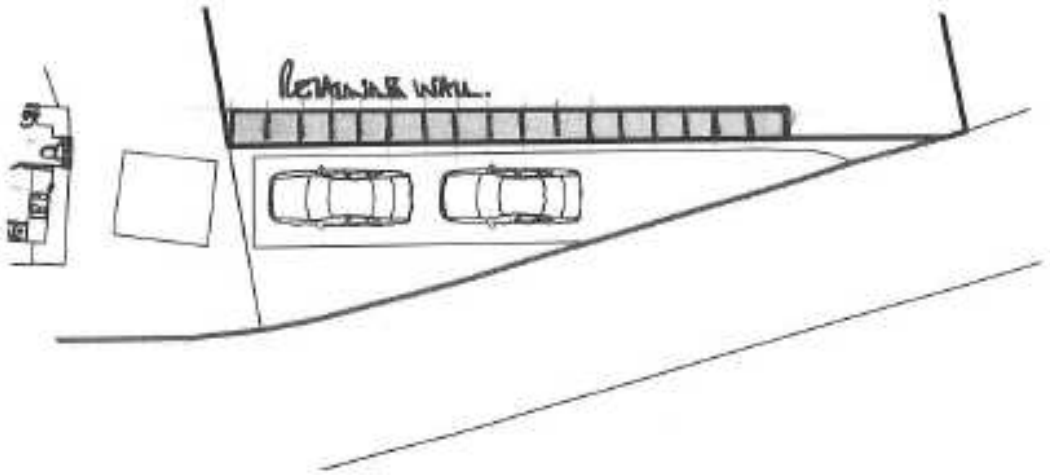
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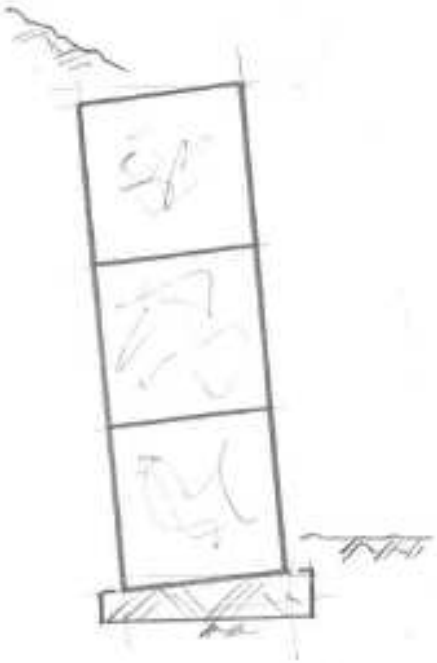
Retaining Wall

RETAINING WALL

Provide calculations in support of structural design of retaining wall to support elevated ground levels above a proposed parking area at the property.

Retaining wall will support heavily wooded slope to the rear of the property. Bedrock is known to be at shallow depth in the area. However, for the purposes of design backfill will be assumed to comprise compacted granular material.





RETAINING WALL

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 2.0.04

Design summary

Combination 1

Action	Resistance	Force	FoS	Allowable FoS	Status
Overturning, sliding and bearing at base level					
Overturning (kNm/m)	46.4	29.2	1.586	1.000	PASS
Sliding (kN/m)	43.3	27.1	1.598	1.000	PASS
Bearing (kN/m^2)	100.0	96.1	1.041	1.000	PASS
Eccentricity (mm)	Reaction acts within the middle third of base				PASS
Overturning and sliding between courses 1 and 2					
Overturning (kNm/m)	25.1	8.1	3.099	1.000	PASS
Sliding (kN/m)	26.4	10.9	2.436	1.000	PASS
Overturning and sliding between courses 2 and 3					
Overturning (kNm/m)	9.6	0.8	11.895	1.000	PASS
Sliding (kN/m)	12.0	1.8	6.608	1.000	PASS

Combination 2

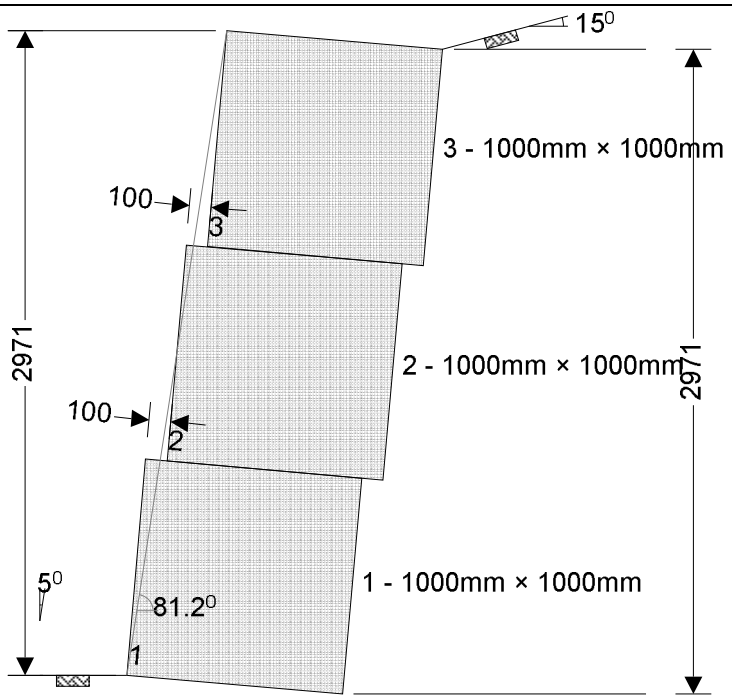
Action	Resistance	Force	FoS	Allowable FoS	Status
Overturning, sliding and bearing at base level					
Overturning (kNm/m)	47.2	29.2	1.615	1.000	PASS
Sliding (kN/m)	35.1	27.0	1.300	1.000	PASS
Bearing (kN/m^2)	100.0	96.1	1.041	1.000	PASS
Eccentricity (mm)	Reaction acts within the middle third of base				PASS
Overturning and sliding between courses 1 and 2					
Overturning (kNm/m)	25.4	8.1	3.129	1.000	PASS
Sliding (kN/m)	21.3	10.9	1.963	1.000	PASS
Overturning and sliding between courses 2 and 3					
Overturning (kNm/m)	9.7	0.8	11.762	1.000	PASS
Sliding (kN/m)	9.6	1.9	5.161	1.000	PASS

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Retaining Wall



Wall geometry

Width of gabion 1	w_1 = **1000** mm
Height of gabion 1	h_1 = **1000** mm
Width of gabion 2	w_2 = **1000** mm
Height of gabion 2	h_2 = **1000** mm
Step to front face between courses 1 and 2	s_2 = **100** mm
Width of gabion 3	w_3 = **1000** mm
Height of gabion 3	h_3 = **1000** mm
Step to front face between courses 2 and 3	s_3 = **100** mm
Wall inclination	ε = **5** deg

Gabion properties

Unit weight of fill	γ_d = **16.0** kN/m^3
Friction between gabions	$\delta_{bg.k}$ = **35.0** deg

Loading

Soil properties

Slope of retained soil	β = **15.0** deg
Characteristic effective shearing resistance angle	$\phi'_{r.k}$ = **35.0** deg
Characteristic saturated density of retained soil	γ_{sr} = **21.0** kN/m^3
Coefficient for wall friction	$k_{membrane}$ = **0.75**
Wall friction angle	$\delta_{r.k}$ = **26.3** deg
Characteristic base friction angle	$\delta_{bb.k}$ = **35.0** deg
Bearing capacity of founding soil	q = **100** kN/m^2

Wall geometry

Horizontal distance to centre of gravity gabion 1	$x_{g1} = w_1 / 2$ = **500** mm
Vertical distance to centre of gravity gabion 1	$y_{g1} = h_1 / 2$ = **500** mm
Weight of gabion 1	$W_{g1} = \gamma_d \times w_1 \times h_1$ = **16.0** kN/m

Horizontal distance to centre of gravity gabion 2	$x_{g2} = w_2 / 2 + s_2 =$ **600** mm
Vertical distance to centre of gravity gabion 2	$y_{g2} = h_2 / 2 + h_1 =$ **1500** mm
Weight of gabion 2	$W_{g2} = \gamma_d \times w_2 \times h_2 =$ **16.0** kN/m
Horizontal distance to centre of gravity gabion 3	$x_{g3} = w_3 / 2 + s_2 + s_3 =$ **700** mm
Vertical distance to centre of gravity gabion 3	$y_{g3} = h_3 / 2 + h_1 + h_2 =$ **2500** mm
Weight of gabion 3	$W_{g3} = \gamma_d \times w_3 \times h_3 =$ **16.0** kN/m
Weight of entire gabion	$W_g = W_{g1} + W_{g2} + W_{g3} =$ **48.0** kN/m
Horiz distance to centre of gravity entire gabion	$x_g = ((W_{g1} \times x_{g1}) + (W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3})) / W_g =$ **600** mm
Vert distance to centre of gravity entire gabion	$y_g = ((W_{g1} \times y_{g1}) + (W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3})) / W_g =$ **1500** mm
Correcting for wall inclination horiz dist	$X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon) =$ **728** mm
Vertical change in height due to wall inclination	$H_f = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) \times \cos(\varepsilon) - (x_{g3} + w_3/2) \times \sin(\varepsilon)) =$ **116** mm
Design dimensions	
Effective angle of rear plane of wall	$\alpha = \text{Atan}((w_1 - (x_{g3} + (w_3 / 2))) / (y_{g3} + h_3 / 2)) + 90 \text{ deg} + \varepsilon =$ **91.2** deg
Effective face angle	$\theta = \text{Atan}((y_{g3} + (h_3 / 2)) / ((x_{g3} - (w_3 / 2)))) - \varepsilon =$ **81.2** deg
Effective height of wall	$H = (y_{g3} + h_3 / 2) + (w_1 \times \sin(\varepsilon)) - H_f =$ **2971** mm
Height of wall from toe to front edge of top gabion	$H_{incl} = ((y_{g3} + h_3 / 2) \times \cos(\varepsilon) - (x_{g3} - (w_3 / 2)) \times \sin(\varepsilon)) =$ **2971**mm
Active pressure using Coulomb theory	$K_a = \sin(\alpha + \phi'_{r.k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.k}) \times (1 + \sqrt{(\sin(\phi'_{r.k} + \delta_{r.k}) \times \sin(\phi'_{r.k} - \beta) / (\sin(\alpha - \delta_{r.k}) \times \sin(\alpha + \beta))))^2}) =$ **0.286**
Active thrust due to soil	$P_{a,soil} = 0.5 \times K_a \times \gamma_{sr} \times H^2 =$ **26.5** kN/m
Pressure at base	
Horizontal forces	
Retained soil	$F_{soil_h,q} = P_{a,soil} \times \cos(90 - \alpha + \delta_{r.k}) =$ **24.0** kN/m
Height of soil thrust resolved vertically	$d_{h,soil} = H / 3 - w_1 \times \sin(\varepsilon) =$ **903** mm
Vertical forces	
Gabion weight	$F_{gabion_v,q} = W_g =$ **48.0** kN/m
Retained soil	$F_{soil_v,q} = P_{a,soil} \times \sin(90 - \alpha + \delta_{r.k}) =$ **11.2** kN/m
Horizontal dist to where soil thrust acts	$b_{v,soil} = w_1 \times \cos(\varepsilon) - (H / 3) / \tan(\alpha) =$ **1017** mm
Total horizontal unfactored force	$T_q = F_{soil_h,q} =$ **24.0** kN/m
Total vertical unfactored force	$N_q = F_{gabion_v,q} + F_{soil_v,q} =$ **59.2** kN/m
Force normal to base	$N_s = N_q \times \cos(\varepsilon) + T_q \times \sin(\varepsilon) =$ **61.1** kN/m
Total unfactored overturning force	$M_{o,q} = F_{soil_h,q} \times d_{h,soil} =$ **21.7** kNm/m
Total unfactored restoring force	$M_{R,q} = F_{gabion_v,q} \times X_g + F_{soil_v,q} \times b_{v,soil} =$ **46.4** kNm/m
Eccentricity	$e = w_1 / 2 - (M_{R,q} - M_{o,q}) / N_s =$ **95** mm
	Reaction acts within middle third of base
Pressure at toe	$\sigma_{toe} = N_s / w_1 \times (1 + (6 \times e / w_1)) =$ **96.1** kN/m^2
Pressure at heel	$\sigma_{heel} = N_s / w_1 \times (1 - (6 \times e / w_1)) =$ **26.1** kN/m^2
Factor of safety	$FoS_Q = q / \max(\sigma_{toe}, \sigma_{heel}) =$ **1.041**
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	γ_{γ} = **1.00**
Design soil properties	
Design effective shearing resistance angle	$\phi'_{r.d} = \text{Atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'})$ = **35.0** deg
Design saturated density of retained soil	$\gamma_{s.d} = \gamma_{sr} / \gamma_{\gamma}$ = **21.0** kN/m^3
Design wall friction angle	$\delta_{r.d} = \min(\text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'}), \phi'_{r.d} \times k_{membrane})$ = **26.3** deg
Design base friction angle	$\delta_{bb.d} = \text{Atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'})$ = **35.0** deg
Design friction between gabions	$\delta_{bg.d} = \text{Atan}(\tan(\delta_{bg.k}) / \gamma_{\phi'})$ = **35.0** deg
Active pressure using Coulomb theory	$K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times (1 + \sqrt{(\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))))^2})$ = **0.286**
Active thrust due to soil	$P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2$ = **26.5** kN/m
Horizontal forces	
Retained soil	$F_{soil_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d})$ = **32.4** kN/m
Vertical forces	
Gabion weight	$F_{gabion_v,f} = \gamma_{G,f} \times W_g$ = **48.0** kN/m
Retained soil	$F_{soil_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d})$ = **11.2** kN/m
Overturning stability - take moments about the toe	
Overturning moment	$M_o = F_{soil_h} \times d_{h,soil}$ = **29.2** kNm/m
Restoring moment	$M_R = F_{gabion_v,f} \times X_g + F_{soil_v,f} \times b_{v,soil}$ = **46.4** kNm/m
Factor of safety	$FoS_M = M_R / M_o$ = **1.586**
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	$T = F_{soil_h}$ = **32.4** kN/m
Total vertical force	$N = F_{gabion_v,f} + F_{soil_v,f}$ = **59.2** kN/m
Sliding force	$F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon)$ = **27.1** kN/m
Sliding resistance	$F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bb.d})$ = **43.3** kN/m
Factor of safety	$FoS_S = F_R / F_f$ = **1.598**
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 1 and 2

Wall geometry	
Horizontal distance to centre of gravity gabion 2	$x_{g2} = w_2 / 2$ = **500** mm
Vertical distance to centre of gravity gabion 2	$y_{g2} = h_2 / 2$ = **500** mm
Weight of gabion 2	$W_{g2} = \gamma_d \times w_2 \times h_2$ = **16.0** kN/m
Horizontal distance to centre of gravity gabion 3	$x_{g3} = w_3 / 2 + s_3$ = **600** mm
Vertical distance to centre of gravity gabion 3	$y_{g3} = h_3 / 2 + h_2$ = **1500** mm
Weight of gabion 3	$W_{g3} = \gamma_d \times w_3 \times h_3$ = **16.0** kN/m
Weight of entire gabion	$W_g = W_{g2} + W_{g3}$ = **32.0** kN/m
Horiz distance to centre of gravity entire gabion	$x_g = ((W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3})) / W_g$ = **550** mm
Vert distance to centre of gravity entire gabion	$y_g = ((W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3})) / W_g$ = **1000** mm

Correcting for wall inclination horiz dist	$X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon)$ = **635** mm
Vertical change in height due to wall inclination	$H_f = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) \times \cos(\varepsilon) - (x_{g3} + w_3/2) \times \sin(\varepsilon))$ = **103** mm
Design dimensions	
Effective angle of rear plane of wall	α = Atan((w$_2$ - (x$_{g3}$ + (w$_3$ / 2))) / (y$_{g3}$ + h$_3$ / 2)) + 90 deg + ε = **92.1** deg
Effective face angle	θ = Atan((y$_{g3}$ + (h$_3$ / 2)) / ((x$_{g3}$ - (w$_3$ / 2)))) - ε = **82.1** deg
Effective height of wall	$H = (y_{g3} + h_3 / 2) + (w_2 \times \sin(\varepsilon)) - H_f$ = **1984** mm
Height of wall from toe to front edge of top gabion	$H_{incl} = ((y_{g3} + h_3 / 2) \times \cos(\varepsilon) - (x_{g3} - (w_3 / 2)) \times \sin(\varepsilon))$ = **1984**mm
Active pressure using Coulomb theory	$K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times (1 + \sqrt{(\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))))^2})$ = **0.277**
Active thrust due to soil	$P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2$ = **11.4** kN/m
Horizontal forces	
Retained soil	$F_{soil_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d})$ = **14.1** kN/m
Vertical forces	
Gabion weight	$F_{gabion_v,f} = \gamma_{G,f} \times W_g$ = **32.0** kN/m
Retained soil	$F_{soil_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d})$ = **4.7** kN/m
Overturning stability - take moments about the toe	
Overturning moment	$M_o = F_{soil_h} \times d_{h,soil}$ = **8.1** kNm/m
Restoring moment	$M_R = F_{gabion_v,f} \times X_g + F_{soil_v,f} \times b_{v,soil}$ = **25.1** kNm/m
Factor of safety	$FoS_M = M_R / M_o$ = **3.099**
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	$T = F_{soil_h}$ = **14.1** kN/m
Total vertical force	$N = F_{gabion_v,f} + F_{soil_v,f}$ = **36.7** kN/m
Sliding force	$F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon)$ = **10.9** kN/m
Sliding resistance	$F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bg.d})$ = **26.4** kN/m
Factor of safety	$FoS_S = F_R / F_f$ = **2.436**
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** mm
Vertical distance to centre of gravity gabion 3	$y_{g3} = h_3 / 2$ = **500** mm
Weight of gabion 3	$W_{g3} = \gamma_d \times w_3 \times h_3$ = **16.0** kN/m
Weight of entire gabion	$W_g = W_{g3}$ = **16.0** kN/m
Horiz distance to centre of gravity entire gabion	$x_g = ((W_{g3} \times x_{g3})) / W_g$ = **500** mm
Vert distance to centre of gravity entire gabion	$y_g = ((W_{g3} \times y_{g3})) / W_g$ = **500** mm
Correcting for wall inclination horiz dist	$X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon)$ = **542** mm
Vertical change in height due to wall inclination	$H_f = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) \times \cos(\varepsilon) - (x_{g3} + w_3/2) \times \sin(\varepsilon))$ = **91** mm
Design dimensions	
Effective angle of rear plane of wall	α = 90 deg + ε = **95.0** deg
Effective face angle	θ = 90deg - ε = **85.0** deg
Effective height of wall	$H = (y_{g3} + h_3 / 2) + (w_3 \times \sin(\varepsilon)) - H_f$ = **996** mm

Height of wall from toe to front edge of top gabion	$H_{incl} = ((y_{g3} + h_3 / 2) \times \cos(\varepsilon) - (x_{g3} - (w_3 / 2)) \times \sin(\varepsilon))$ = **996**mm
Active pressure using Coulomb theory	$K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times (1 + \sqrt{(\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))))^2})$ = **0.253**
Active thrust due to soil	$P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2$ = **2.6** kN/m
Horizontal forces	
Retained soil	$F_{soil_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d})$ = **3.3** kN/m
Vertical forces	
Gabion weight	$F_{gabion_v,f} = \gamma_{G,f} \times W_g$ = **16.0** kN/m
Retained soil	$F_{soil_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d})$ = **1.0** kN/m
Overturning stability - take moments about the toe	
Overturning moment	$M_o = F_{soil_h} \times d_{h,soil}$ = **0.8** kNm/m
Restoring moment	$M_R = F_{gabion_v,f} \times X_g + F_{soil_v,f} \times b_{v,soil}$ = **9.6** kNm/m
Factor of safety	$FoS_M = M_R / M_o$ = **11.895**
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	$T = F_{soil_h}$ = **3.3** kN/m
Total vertical force	$N = F_{gabion_v,f} + F_{soil_v,f}$ = **17.0** kN/m
Sliding force	$F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon)$ = **1.8** kN/m
Sliding resistance	$F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bg.d})$ = **12.0** kN/m
Factor of safety	$FoS_S = F_R / F_f$ = **6.608**
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	γ_G = **1.00**
Permanent favourable action	$\gamma_{G,f}$ = **1.00**
Variable unfavourable action	γ_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	γ_γ = **1.00**
Design soil properties	
Design effective shearing resistance angle	$\phi'_{r.d} = \text{Atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'})$ = **29.3** deg
Design saturated density of retained soil	$\gamma_{s.d} = \gamma_{sr} / \gamma_\gamma$ = **21.0** kN/m^3
Design wall friction angle	$\delta_{r.d} = \min(\text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'}), \phi'_{r.d} \times k_{membrane})$ = **21.5** deg
Design base friction angle	$\delta_{bb.d} = \text{Atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'})$ = **29.3** deg
Design friction between gabions	$\delta_{bg.d} = \text{Atan}(\tan(\delta_{bg.k}) / \gamma_{\phi'})$ = **29.3** deg
Wall geometry	
Horizontal distance to centre of gravity gabion 1	$x_{g1} = w_1 / 2$ = **500** mm
Vertical distance to centre of gravity gabion 1	$y_{g1} = h_1 / 2$ = **500** mm
Weight of gabion 1	$W_{g1} = \gamma_d \times w_1 \times h_1$ = **16.0** kN/m
Horizontal distance to centre of gravity gabion 2	$x_{g2} = w_2 / 2 + s_2$ = **600** mm

Vertical distance to centre of gravity gabion 2	$y_{g2} = h_2 / 2 + h_1 =$ **1500** mm
Weight of gabion 2	$W_{g2} = \gamma_d \times w_2 \times h_2 =$ **16.0** kN/m
Horizontal distance to centre of gravity gabion 3	$x_{g3} = w_3 / 2 + s_2 + s_3 =$ **700** mm
Vertical distance to centre of gravity gabion 3	$y_{g3} = h_3 / 2 + h_1 + h_2 =$ **2500** mm
Weight of gabion 3	$W_{g3} = \gamma_d \times w_3 \times h_3 =$ **16.0** kN/m
Weight of entire gabion	$W_g = W_{g1} + W_{g2} + W_{g3} =$ **48.0** kN/m
Horiz distance to centre of gravity entire gabion	$x_g = ((W_{g1} \times x_{g1}) + (W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3})) / W_g =$ **600** mm
Vert distance to centre of gravity entire gabion	$y_g = ((W_{g1} \times y_{g1}) + (W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3})) / W_g =$ **1500** mm
Correcting for wall inclination horiz dist	$X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon) =$ **728** mm
Vertical change in height due to wall inclination	$H_f = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) \times \cos(\varepsilon) - (x_{g3} + w_3/2) \times \sin(\varepsilon)) =$ **116** mm
Design dimensions	
Effective angle of rear plane of wall	$\alpha = \text{Atan}((w_1 - (x_{g3} + (w_3 / 2))) / (y_{g3} + h_3 / 2)) + 90 \text{ deg} + \varepsilon =$ **91.2** deg
Effective face angle	$\theta = \text{Atan}((y_{g3} + (h_3 / 2)) / ((x_{g3} - (w_3 / 2)))) - \varepsilon =$ **81.2** deg
Effective height of wall	$H = (y_{g3} + h_3 / 2) + (w_1 \times \sin(\varepsilon)) - H_f =$ **2971** mm
Height of wall from toe to front edge of top gabion	$H_{incl} = ((y_{g3} + h_3 / 2) \times \cos(\varepsilon) - (x_{g3} - (w_3 / 2)) \times \sin(\varepsilon)) =$ **2971**mm
Active pressure using Coulomb theory	$K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times (1 + \sqrt{(\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))))^2}) =$ **0.372**
Active thrust due to soil	$P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2 =$ **34.5** kN/m
Horizontal forces	
Retained soil	$F_{soil_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d}) =$ **32.3** kN/m
Vertical forces	
Gabion weight	$F_{gabion_v,f} = \gamma_{G,f} \times W_g =$ **48.0** kN/m
Retained soil	$F_{soil_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d}) =$ **12.0** kN/m
Overturning stability - take moments about the toe	
Overturning moment	$M_o = F_{soil_h} \times d_{h,soil} =$ **29.2** kNm/m
Restoring moment	$M_R = F_{gabion_v,f} \times X_g + F_{soil_v,f} \times b_{v,soil} =$ **47.2** kNm/m
Factor of safety	$FoS_M = M_R / M_o =$ **1.615**
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	$T = F_{soil_h} =$ **32.3** kN/m
Total vertical force	$N = F_{gabion_v,f} + F_{soil_v,f} =$ **60.0** kN/m
Sliding force	$F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon) =$ **27.0** kN/m
Sliding resistance	$F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bb.d}) =$ **35.1** kN/m
Factor of safety	$FoS_S = F_R / F_f =$ **1.300**
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 1 and 2	
Wall geometry	
Horizontal distance to centre of gravity gabion 2	$x_{g2} = w_2 / 2 =$ **500** mm
Vertical distance to centre of gravity gabion 2	$y_{g2} = h_2 / 2 =$ **500** mm
Weight of gabion 2	$W_{g2} = \gamma_d \times w_2 \times h_2 =$ **16.0** kN/m
Horizontal distance to centre of gravity gabion 3	$x_{g3} = w_3 / 2 + s_3 =$ **600** mm
Vertical distance to centre of gravity gabion 3	$y_{g3} = h_3 / 2 + h_2 =$ **1500** mm

Weight of gabion 3	$W_{g3} = \gamma_d \times w_3 \times h_3$ = **16.0** kN/m
Weight of entire gabion	$W_g = W_{g2} + W_{g3}$ = **32.0** kN/m
Horiz distance to centre of gravity entire gabion	$x_g = ((W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3})) / W_g$ = **550** mm
Vert distance to centre of gravity entire gabion	$y_g = ((W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3})) / W_g$ = **1000** mm
Correcting for wall inclination horiz dist	$X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon)$ = **635** mm
Vertical change in height due to wall inclination	$H_f = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) \times \cos(\varepsilon) - (x_{g3} + w_3/2) \times \sin(\varepsilon))$ = **103** mm
Design dimensions	
Effective angle of rear plane of wall	α = Atan((w2 - (x_{g3} + (w_3 / 2))) / (y_{g3} + h_3 / 2)) + 90 deg + ε = **92.1** deg
Effective face angle	θ = Atan((y_{g3} + (h_3 / 2)) / ((x_{g3} - (w_3 / 2)))) - ε = **82.1** deg
Effective height of wall	$H = (y_{g3} + h_3 / 2) + (w_2 \times \sin(\varepsilon)) - H_f$ = **1984** mm
Height of wall from toe to front edge of top gabion	$H_{incl} = ((y_{g3} + h_3 / 2) \times \cos(\varepsilon) - (x_{g3} - (w_3 / 2)) \times \sin(\varepsilon))$ = **1984**mm
Active pressure using Coulomb theory	$K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times (1 + \sqrt{(\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))))^2})$ = **0.363**
Active thrust due to soil	$P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2$ = **15.0** kN/m
Horizontal forces	
Retained soil	$F_{soil_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d})$ = **14.1** kN/m
Vertical forces	
Gabion weight	$F_{gabion_v,f} = \gamma_{G,f} \times W_g$ = **32.0** kN/m
Retained soil	$F_{soil_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d})$ = **5.0** kN/m
Overturning stability - take moments about the toe	
Overturning moment	$M_o = F_{soil_h} \times d_{h,soil}$ = **8.1** kNm/m
Restoring moment	$M_R = F_{gabion_v,f} \times X_g + F_{soil_v,f} \times b_{v,soil}$ = **25.4** kNm/m
Factor of safety	$FoS_M = M_R / M_o$ = **3.129**
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	$T = F_{soil_h}$ = **14.1** kN/m
Total vertical force	$N = F_{gabion_v,f} + F_{soil_v,f}$ = **37.0** kN/m
Sliding force	$F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon)$ = **10.9** kN/m
Sliding resistance	$F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bg.d})$ = **21.3** kN/m
Factor of safety	$FoS_S = F_R / F_f$ = **1.963**
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** mm
Vertical distance to centre of gravity gabion 3	$y_{g3} = h_3 / 2$ = **500** mm
Weight of gabion 3	$W_{g3} = \gamma_d \times w_3 \times h_3$ = **16.0** kN/m
Weight of entire gabion	$W_g = W_{g3}$ = **16.0** kN/m
Horiz distance to centre of gravity entire gabion	$x_g = ((W_{g3} \times x_{g3})) / W_g$ = **500** mm
Vert distance to centre of gravity entire gabion	$y_g = ((W_{g3} \times y_{g3})) / W_g$ = **500** mm
Correcting for wall inclination horiz dist	$X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon)$ = **542** mm
Vertical change in height due to wall inclination	$H_f = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) \times \cos(\varepsilon) - (x_{g3} + w_3/2) \times \sin(\varepsilon))$ = **91** mm

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Retaining Wall

Design dimensions

Effective angle of rear plane of wall	α = 90 deg + ε = **95.0** deg
Effective face angle	θ = 90deg - ε = **85.0** deg
Effective height of wall	$H = (y_{g3} + h_3 / 2) + (w_3 \times \sin(\varepsilon)) - H_f$ = **996** mm
Height of wall from toe to front edge of top gabion	$H_{incl} = ((y_{g3} + h_3 / 2) \times \cos(\varepsilon) - (x_{g3} - (w_3 / 2)) \times \sin(\varepsilon))$ = **996**mm
Active pressure using Coulomb theory	$K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times (1 + \sqrt{(\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))))^2})$ = **0.337**
Active thrust due to soil	$P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2$ = **3.5** kN/m

Horizontal forces

Retained soil	$F_{soil_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d})$ = **3.4** kN/m

Vertical forces

Gabion weight	$F_{gabion_v,f} = \gamma_{G,f} \times W_g$ = **16.0** kN/m
Retained soil	$F_{soil_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d})$ = **1.0** kN/m

Overturning stability - take moments about the toe

Overturning moment	$M_o = F_{soil_h} \times d_{h,soil}$ = **0.8** kNm/m
Restoring moment	$M_R = F_{gabion_v,f} \times X_g + F_{soil_v,f} \times b_{v,soil}$ = **9.7** kNm/m
Factor of safety	$FoS_M = M_R / M_o$ = **11.762**
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	$T = F_{soil_h}$ = **3.4** kN/m
Total vertical force	$N = F_{gabion_v,f} + F_{soil_v,f}$ = **17.0** kN/m
Sliding force	$F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon)$ = **1.9** kN/m
Sliding resistance	$F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bg.d})$ = **9.6** kN/m
Factor of safety	$FoS_S = F_R / F_f$ = **5.161**
Allowable factor of safety	FoS_{S_allow} = **1.000**

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