



Vale Consultancy
CONSULTING CIVIL & STRUCTURAL ENGINEERS

Title: Structural Calculations

Project: Plot 1, Glannant Place, Cwmgwrach, Neath

Client: Andrew Johnson

Document No: 001
Project No: 14645
Prepared By: BR
Checked By: JM

Revision: -

Date: 25/02/2022

DESIGN STATEMENT

The design has been completed in accordance with British Standards BS6399, BS5628 (Masonry), BS5268 (Timber) & BS 5950 (Steel).

Information for this has been collated from information provided by the client.

The design is for 2 no. steels over rear bi-fold doors, 2 no. floor steels to support timber floor joists, timber floor joists & retaining wall.

The steel fabricator and contractor must check all site dimensions for the steel beams and posts prior to fabrication.

Contractor to check suitability of existing masonry for padstone and steel bearing.

Existing & proposed blockwork assumed to have minimum 7.3N/mm² compressive strength.

All dimensions, weights, member lengths, member tables, and any other relevant design information contained within this package is for analysis, and design purposes only, for submission to building control, and must not be used for pricing or fabrication purposes. Pricing and fabrication information is to be taken from provided SK sketch markups or Vale scheme drawings unless explicitly stated otherwise within this package. All queries are to be directed to the engineer prior to tendering, pricing or fabrication.

CDM Comments:

- All temporary propping/support is to correspond to contractor's specification and details.



PLOT 1, CLANNANT PLACE, NEATH.

LOADING : kN/m^2

ROOF - DEAD :

TILES	=	0.48
INS. FELT & DATTENS	=	0.10
RAFTERS	=	0.20
PLASTERBOARD & SKIM	=	<u>0.15</u>

$$0.93 / \cos(35) = \underline{\underline{1.14 \text{ kN/m}^2}}$$

ROOF - LIVE :

$$\text{SNOW} = \underline{\underline{0.60}}$$

FLOOR - DEAD

BOARDING	=	0.15
INSULATION	=	0.05
JOISTS	=	0.15
PLASTER & SKIM	=	<u>0.15</u>
		<u>0.50</u>

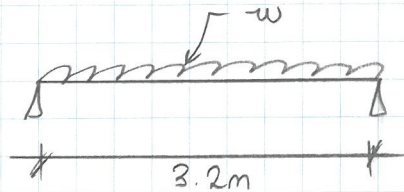
FLOOR - LIVE

$$\text{RESIDENTIAL} = \underline{\underline{1.50}}$$

WALLS

MASONRY (2 SKINS)	=	4.3
RENDER	=	0.15
PLASTER	=	<u>0.15</u>
		<u>4.60</u>

STEEL OVER REAR BI-FOLD DOORS



UNFACTORED
W =

$$\text{ROOF DEAD} = (1.15 \times 5\text{m}) = 5.75 \text{ kN/m}^2$$

$$\text{LIVE} = (0.6 \times 5\text{m}) = 3 \text{ kN/m}^2$$

$$\text{FLOOR DEAD} = (0.5 \times 2.0\text{m}) = 1.0 \text{ kN/m}$$

$$\text{LIVE} = (1.5 \times 2.0\text{m}) = 3.0 \text{ kN/m}$$

$$\text{WALLS} = (4.6 \times 2.5\text{m}) = 11.5 \text{ kN/m}$$

$$\begin{aligned} \text{TOTAL FACTORED} &= (18.25 \times 1.4) = 26 \text{ kN/m} \\ &= (6.0 \times 1.6) = \underline{\underline{10 \text{ kN/m}}} \end{aligned}$$

BENDING CHECK:

$$M_{\max} = \frac{WL^2}{8} = \frac{35 \times 3.8^2}{8} = \underline{\underline{65.0 \text{ kNm}}}$$

FROM MEMBER CAPACITY TABLE, TRY: 203 x 133 x 30 UB

$$M_{Cx} = 86.14 \text{ kNm} > 65.2 \text{ kNm} \therefore \text{BENDING OK.}$$

DEFLECTION CHECK:

$$\delta \text{ DEFLECTION MAX} = 3200 / 250 = 12.8 \text{ mm}$$

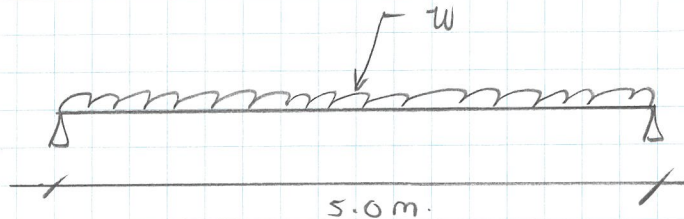
$$\delta \text{ DEFLECTION APPLIED} = \frac{5WL^4}{384EI} = \frac{5 \times 24.5 \times 3200^4}{384 \times 210 \times 10^3 \times 2100} = 7.58 \text{ mm}$$

$$\therefore 7.58 \times 12.8 \text{ mm} \therefore \text{OK.}$$

THEREFORE USE $\Rightarrow$ 1 No. 203 x 102 x 23 UB WITH AN 8MM BOTTOM PLATE.

STEEL SUPPORTING FIRST FLOOR JOISTS

DESIGN SPAN $\approx 5.0\text{m}$



LOADING: kN/m^2

UNFACTORED :

$$\text{FLOOR DEAD} = (0.5 \times 2.5\text{m}) = \underline{1.25\text{kN/m}^2}$$

$$\text{FLOOR LIVE} = (1.5 \times 2.5\text{m}) = \underline{3.75\text{kN/m}^2}$$

FACTORED :

$$\text{FLOOR DEAD} = (1.25 \times 1.4) = \underline{1.75\text{kN/m}^2}$$

$$\text{FLOOR LIVE} = (3.75 \times 1.6) = \underline{6.0\text{kN/m}^2}$$

BENDING CHECK:

$$\underline{7.75\text{kN/m}^2}$$

M_{MAX}

$$\frac{WL^2}{8} = \frac{7.75 \times 5^2}{8} = \underline{24.21\text{kNm}}$$

FROM MEMBER CAPACITY TABLE, TRY; 203 x 102 x 23 UB.

$M_{c,x}$

$$= 64.4\text{kNm} > 24.21\text{kNm} \therefore$$

BENDING OK.

DEFLECTION CHECK

δ DEFLECTION MAX

$$= 5000/250 = 20\text{mm}$$

δ DEFLECTION APPLIED

$$= \frac{5WL^4}{384EI} = \frac{5 \times 5 \times 5000^4}{384 \times 210 \times 10^3 \times 2100} = 9.2\text{mm}$$

$$\underline{9.2 < 20\text{mm} \therefore \text{OK.}}$$

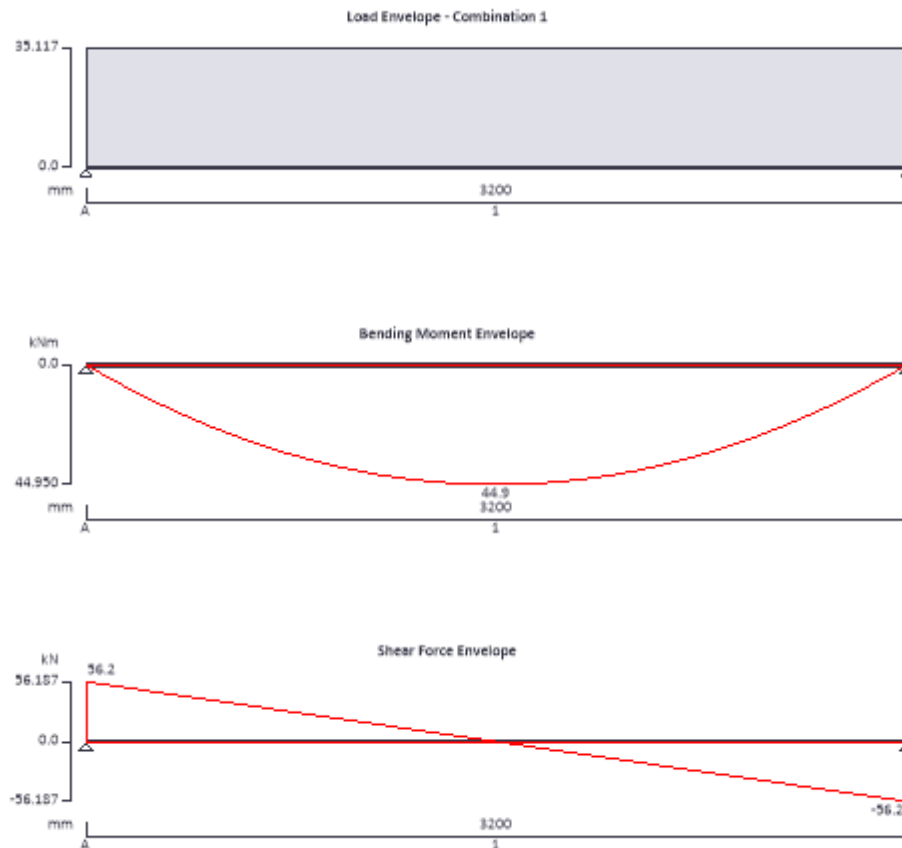
THEREFORE USE $\Rightarrow$ 1 No. 203 x 102 x 23 UB.

Project Plot 1, Glannant Place, Cwmgwrach				Job no. 14646	
Calcs for Steel over rear bi-fold doors				Start page no./Revision 1	
Calcs by BR	Calcs date 10/03/2022	Checked by JM	Checked date 25/02/2022	Approved by JM	Approved date 25/02/2022

STEEL BEAM ANALYSIS & DESIGN (BS5950)

In accordance with BS5950-1:2000 incorporating Corrigendum No.1

TEDDS calculation version 3.0.07



Support conditions

Support A

Vertically restrained
Rotationally free

Support B

Vertically restrained
Rotationally free

Applied loading

Beam loads

Dead self weight of beam $\times 1$
Masonry - Dead full UDL 11.5 kN/m
Roof Dead - Dead full UDL 5.5 kN/m
Roof Live - Imposed full UDL 3 kN/m
Floor Dead - Dead full UDL 1 kN/m
Floor Live - Imposed full UDL 3 kN/m

Load combinations

Load combination 1

Support A

Dead $\times 1.40$
Imposed $\times 1.60$
Dead $\times 1.40$
Imposed $\times 1.60$

Support B

Dead $\times 1.40$

Imposed $\times 1.60$

Analysis results

Maximum moment

 $M_{max} = 44.9 \text{ kNm}$
 $M_{min} = 0 \text{ kNm}$

Maximum shear

 $V_{max} = 56.2 \text{ kN}$
 $V_{min} = -56.2 \text{ kN}$

Deflection

 $\delta_{max} = 7.7 \text{ mm}$
 $\delta_{min} = 0 \text{ mm}$

Maximum reaction at support A

 $R_{A_{max}} = 56.2 \text{ kN}$
 $R_{A_{min}} = 56.2 \text{ kN}$

Unfactored dead load reaction at support A

 $R_{A_{Dead}} = 29.2 \text{ kN}$

Unfactored imposed load reaction at support A

 $R_{A_{Imposed}} = 9.6 \text{ kN}$

Maximum reaction at support B

 $R_{B_{max}} = 56.2 \text{ kN}$
 $R_{B_{min}} = 56.2 \text{ kN}$

Unfactored dead load reaction at support B

 $R_{B_{Dead}} = 29.2 \text{ kN}$

Unfactored imposed load reaction at support B

 $R_{B_{Imposed}} = 9.6 \text{ kN}$

Section details

Section type

UKB 203x102x23 (Tata Steel Advance)

Steel grade

S275
From table 9: Design strength p_y

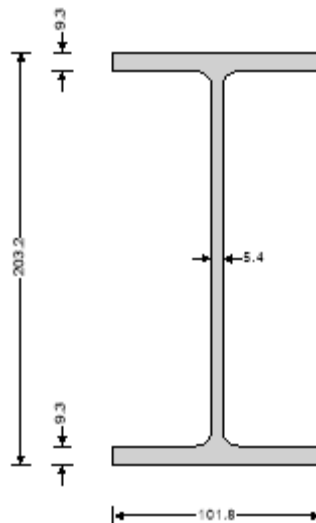
Thickness of element

 $\max(T, t) = 9.3 \text{ mm}$

Design strength

 $p_y = 275 \text{ N/mm}^2$

Modulus of elasticity

 $E = 205000 \text{ N/mm}^2$


Lateral restraint

Span 1 has full lateral restraint

Effective length factors

Effective length factor in major axis

 $K_x = 1.00$

Effective length factor in minor axis

 $K_y = 1.00$

Effective length factor for lateral-torsional buckling

 $K_{LT.A} = 1.00$
 $K_{LT.B} = 1.00$

Classification of cross sections - Section 3.5

 $\epsilon = \sqrt{[275 \text{ N/mm}^2 / p_y]} = 1.00$

Internal compression parts - Table 11

Depth of section

 $d = 169.4 \text{ mm}$
 $d / t = 31.4 \times \epsilon \leq 80 \times \epsilon$

Class 1 plastic

Outstand flanges - Table 11

Width of section

$$b = B / 2 = 50.9 \text{ mm}$$

$$b / T = 5.5 \times \epsilon \leq 9 \times \epsilon$$

Class 1 plastic

Section is class 1 plastic

Shear capacity - Section 4.2.3

Design shear force

$$F_v = \max(\text{abs}(V_{\max}), \text{abs}(V_{\min})) = 56.2 \text{ kN}$$

$$d / t < 70 \times \epsilon$$

Web does not need to be checked for shear buckling

Shear area

$$A_v = t \times D = 1097 \text{ mm}^2$$

Design shear resistance

$$P_v = 0.6 \times p_y \times A_v = 181.1 \text{ kN}$$

PASS - Design shear resistance exceeds design shear force

Moment capacity - Section 4.2.5

Design bending moment

$$M = \max(\text{abs}(M_{s1_max}), \text{abs}(M_{s1_min})) = 44.9 \text{ kNm}$$

Moment capacity low shear - cl.4.2.5.2

$$M_c = \min(p_y \times S_{xx}, 1.2 \times p_y \times Z_{xx}) = 64.4 \text{ kNm}$$

PASS - Moment capacity exceeds design bending moment

Check vertical deflection - Section 2.5.2

Consider deflection due to dead and imposed loads

Limiting deflection

$$\delta_{lim} = L_{s1} / 250 = 12.8 \text{ mm}$$

Maximum deflection span 1

$$\delta = \max(\text{abs}(\delta_{\max}), \text{abs}(\delta_{\min})) = 7.666 \text{ mm}$$

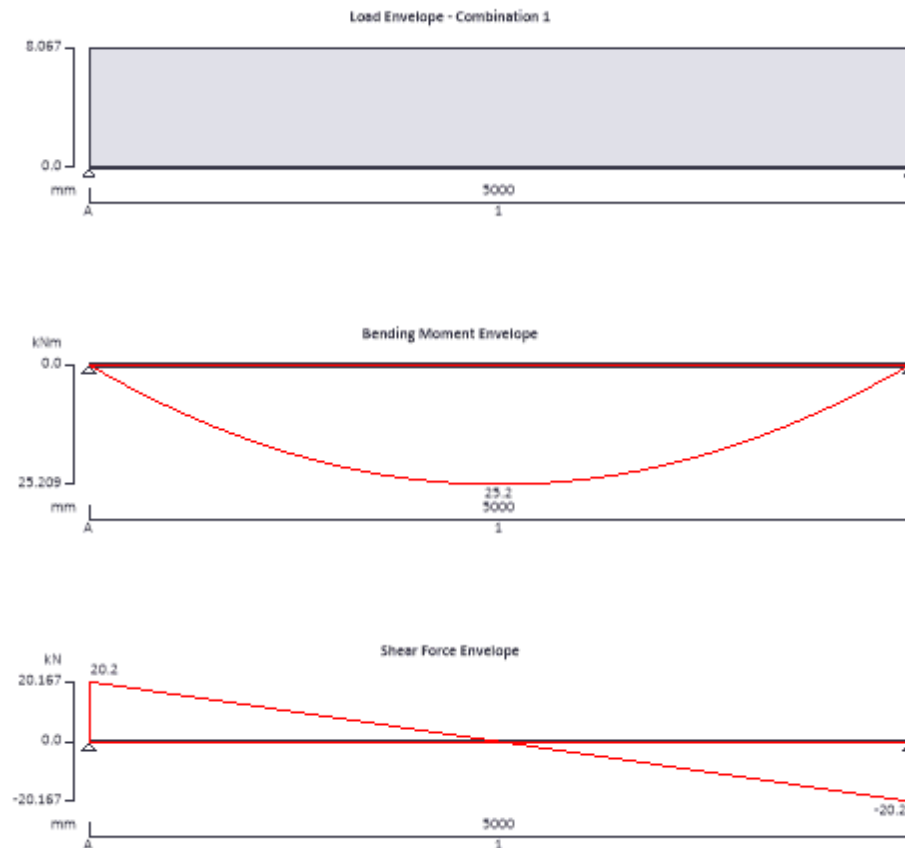
PASS - Maximum deflection does not exceed deflection limit

Project Plot 1, Glannant Place, Cwmgwrach				Job no. 14646	
Calcs for First floor steel				Start page no./Revision 4	
Calcs by BR	Calcs date 25/02/2022	Checked by JM	Checked date 25/02/2022	Approved by JM	Approved date 25/02/2022

STEEL BEAM ANALYSIS & DESIGN (BS5950)

In accordance with BS5950-1:2000 incorporating Corrigendum No.1

TEDDS calculation version 3.0.07



Support conditions

Support A	Vertically restrained Rotationally free
Support B	Vertically restrained Rotationally free

Applied loading

Beam loads	Dead self weight of beam $\times 1$ Floor Dead - Dead full UDL 1.25 kN/m Floor Live - Imposed full UDL 3.75 kN/m
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Load combinations

Load combination 1	Support A	Dead $\times 1.40$
		Imposed $\times 1.60$
		Dead $\times 1.40$
		Imposed $\times 1.60$
	Support B	Dead $\times 1.40$
		Imposed $\times 1.60$

Project Plot 1, Glannant Place, Cwmgwrach				Job no. 14646	
Calcs for First floor steel				Start page no./Revision 5	
Calcs by BR	Calcs date 25/02/2022	Checked by JM	Checked date 25/02/2022	Approved by JM	Approved date 25/02/2022

Analysis results

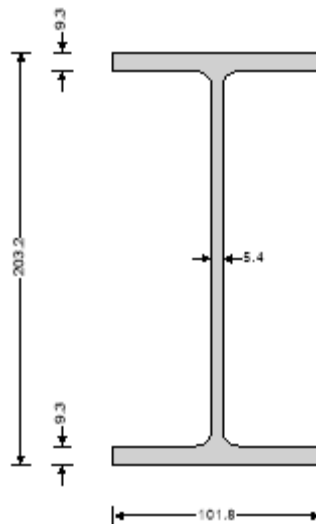
Maximum moment	$M_{max} = 25.2 \text{ kNm}$	$M_{min} = 0 \text{ kNm}$
Maximum shear	$V_{max} = 20.2 \text{ kN}$	$V_{min} = -20.2 \text{ kN}$
Deflection	$\delta_{max} = 9.9 \text{ mm}$	$\delta_{min} = 0 \text{ mm}$
Maximum reaction at support A	$R_{A_max} = 20.2 \text{ kN}$	$R_{A_min} = 20.2 \text{ kN}$
Unfactored dead load reaction at support A	$R_{A_Dead} = 3.7 \text{ kN}$	
Unfactored imposed load reaction at support A	$R_{A_Imposed} = 9.4 \text{ kN}$	
Maximum reaction at support B	$R_{B_max} = 20.2 \text{ kN}$	$R_{B_min} = 20.2 \text{ kN}$
Unfactored dead load reaction at support B	$R_{B_Dead} = 3.7 \text{ kN}$	
Unfactored imposed load reaction at support B	$R_{B_Imposed} = 9.4 \text{ kN}$	

Section details

Section type	UKB 203x102x23 (Tata Steel Advance)
Steel grade	S275

From table 9: Design strength p_y

Thickness of element	$\max(T, t) = 9.3 \text{ mm}$
Design strength	$p_y = 275 \text{ N/mm}^2$
Modulus of elasticity	$E = 205000 \text{ N/mm}^2$



Lateral restraint

Span 1 has full lateral restraint

Effective length factors

Effective length factor in major axis	$K_x = 1.00$
Effective length factor in minor axis	$K_y = 1.00$
Effective length factor for lateral-torsional buckling	$K_{LT,A} = 1.00$
	$K_{LT,B} = 1.00$

Classification of cross sections - Section 3.5

$$\varepsilon = \sqrt{[275 \text{ N/mm}^2 / p_y]} = 1.00$$

Internal compression parts - Table 11

Depth of section	$d = 169.4 \text{ mm}$	
	$d / t = 31.4 \times \varepsilon \leq 80 \times \varepsilon$	Class 1 plastic

Outstand flanges - Table 11

Width of section

$$b = B / 2 = 50.9 \text{ mm}$$

$$b / T = 5.5 \times \epsilon \leq 9 \times \epsilon$$

Class 1 plastic

Section is class 1 plastic

Shear capacity - Section 4.2.3

Design shear force

$$F_v = \max(\text{abs}(V_{\max}), \text{abs}(V_{\min})) = 20.2 \text{ kN}$$

$$d / t < 70 \times \epsilon$$

Web does not need to be checked for shear buckling

Shear area

$$A_v = t \times D = 1097 \text{ mm}^2$$

Design shear resistance

$$P_v = 0.6 \times p_y \times A_v = 181.1 \text{ kN}$$

PASS - Design shear resistance exceeds design shear force

Moment capacity - Section 4.2.5

Design bending moment

$$M = \max(\text{abs}(M_{s1_max}), \text{abs}(M_{s1_min})) = 25.2 \text{ kNm}$$

Moment capacity low shear - cl.4.2.5.2

$$M_c = \min(p_y \times S_{xx}, 1.2 \times p_y \times Z_{xx}) = 64.4 \text{ kNm}$$

PASS - Moment capacity exceeds design bending moment

Check vertical deflection - Section 2.5.2

Consider deflection due to dead and imposed loads

Limiting deflection

$$\delta_{lim} = L_{s1} / 250 = 20 \text{ mm}$$

Maximum deflection span 1

$$\delta = \max(\text{abs}(\delta_{\max}), \text{abs}(\delta_{\min})) = 9.857 \text{ mm}$$

PASS - Maximum deflection does not exceed deflection limit

Project Plot 1, Glannant Place, Cwmgwrach				Job no. 14645	
Calcs for Timber floor joists				Start page no./Revision 7	
Calcs by BR	Calcs date 02/03/2022	Checked by JM	Checked date 25/02/2022	Approved by JM	Approved date 25/02/2022

TIMBER JOIST DESIGN (BS5268-2:2002)

Tedds calculation version 1.1.04

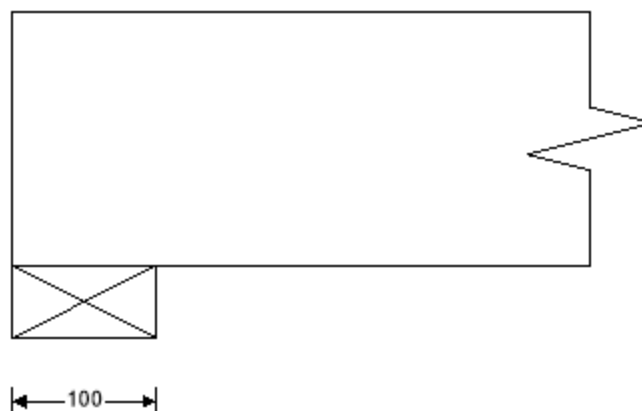
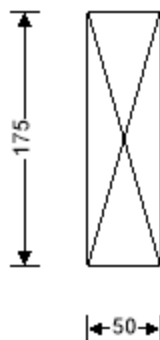
Joist details

Joist breadth	b = 50 mm
Joist depth	h = 175 mm
Joist spacing	s = 400 mm
Timber strength class	C24
Service class of timber	1



Span details

Number of spans	N_{span} = 1
Length of bearing	L_b = 100 mm
Effective length of span	L_{s1} = 3000 mm



Section properties

Second moment of area	$I = b \times h^3 / 12 = 22330729 \text{ mm}^4$
Section modulus	$Z = b \times h^2 / 6 = 255208 \text{ mm}^3$

Loading details

Joist self weight	$F_{swt} = b \times h \times \rho_{char} \times g_{acc} = 0.03 \text{ kN/m}$
Dead load	$F_{d_udl} = 0.75 \text{ kN/m}^2$
Imposed UDL(Long term)	$F_{i_udl} = 1.50 \text{ kN/m}^2$
Imposed point load (Medium term)	$F_{i_pt} = 1.40 \text{ kN}$

Modification factors

Service class for bending parallel to grain	K_{2m} = 1.00
Service class for compression	K_{2c} = 1.00
Service class for shear parallel to grain	K_{2s} = 1.00
Service class for modulus of elasticity	K_{2e} = 1.00

Section depth factor

$K_7 = 1.06$

Load sharing factor

$K_8 = 1.10$

Consider long term loads

Load duration factor

$K_3 = 1.00$

Maximum bending moment

$M = 1.046 \text{ kNm}$

Maximum shear force

$V = 1.395 \text{ kN}$

Maximum support reaction

$R = 1.395 \text{ kN}$

Maximum deflection

$\delta = 4.280 \text{ mm}$

Check bending stress

Bending stress

$\sigma_m = 7.500 \text{ N/mm}^2$

Permissible bending stress

$\sigma_{m_adm} = \sigma_m \times K_{2m} \times K_3 \times K_7 \times K_8 = 8.754 \text{ N/mm}^2$

Applied bending stress

$\sigma_{m_max} = M / Z = 4.100 \text{ N/mm}^2$

PASS - Applied bending stress within permissible limits

Check shear stress

Shear stress

$\tau = 0.710 \text{ N/mm}^2$

Permissible shear stress

$\tau_{adm} = \tau \times K_{2s} \times K_3 \times K_8 = 0.781 \text{ N/mm}^2$

Applied shear stress

$\tau_{max} = 3 \times V / (2 \times b \times h) = 0.239 \text{ N/mm}^2$

PASS - Applied shear stress within permissible limits

Check bearing stress

Compression perpendicular to grain (no wane)

$\sigma_{cp1} = 2.400 \text{ N/mm}^2$

Permissible bearing stress

$\sigma_{c_adm} = \sigma_{cp1} \times K_{2c} \times K_3 \times K_8 = 2.640 \text{ N/mm}^2$

Applied bearing stress

$\sigma_{c_max} = R / (b \times L_b) = 0.279 \text{ N/mm}^2$

PASS - Applied bearing stress within permissible limits

Check deflection

Permissible deflection

$\delta_{adm} = \min(L_{s1} \times 0.003, 14 \text{ mm}) = 9.000 \text{ mm}$

Bending deflection (based on E_{mean})

$\delta_{bending} = 4.067 \text{ mm}$

Shear deflection

$\delta_{shear} = 0.213 \text{ mm}$

Total deflection

$\delta = \delta_{bending} + \delta_{shear} = 4.280 \text{ mm}$

PASS - Actual deflection within permissible limits

Consider medium term loads

Load duration factor

$K_3 = 1.25$

Maximum bending moment

$M = 1.421 \text{ kNm}$

Maximum shear force

$V = 1.895 \text{ kN}$

Maximum support reaction

$R = 1.895 \text{ kN}$

Maximum deflection

$\delta = 4.997 \text{ mm}$

Check bending stress

Bending stress

$\sigma_m = 7.500 \text{ N/mm}^2$

Permissible bending stress

$\sigma_{m_adm} = \sigma_m \times K_{2m} \times K_3 \times K_7 \times K_8 = 10.942 \text{ N/mm}^2$

Applied bending stress

$\sigma_{m_max} = M / Z = 5.569 \text{ N/mm}^2$

PASS - Applied bending stress within permissible limits

Check shear stress

Shear stress

$\tau = 0.710 \text{ N/mm}^2$

Permissible shear stress

$\tau_{adm} = \tau \times K_{2s} \times K_3 \times K_8 = 0.976 \text{ N/mm}^2$

Applied shear stress

$\tau_{max} = 3 \times V / (2 \times b \times h) = 0.325 \text{ N/mm}^2$

Project Plot 1, Glannant Place, Cwmgwrach				Job no. 14645	
Calcs for Timber floor joists				Start page no./Revision 9	
Calcs by BR	Calcs date 02/03/2022	Checked by JM	Checked date 25/02/2022	Approved by JM	Approved date 25/02/2022

PASS - Applied shear stress within permissible limits

Check bearing stress

Compression perpendicular to grain (no wane)

$$\sigma_{cp1} = \mathbf{2.400 \text{ N/mm}^2}$$

Permissible bearing stress

$$\sigma_{c_adm} = \sigma_{cp1} \times K_{2c} \times K_3 \times K_8 = \mathbf{3.300 \text{ N/mm}^2}$$

Applied bearing stress

$$\sigma_{c_max} = R / (b \times L_b) = \mathbf{0.379 \text{ N/mm}^2}$$

PASS - Applied bearing stress within permissible limits

Check deflection

Permissible deflection

$$\delta_{adm} = \min(L_{s1} \times 0.003, 14 \text{ mm}) = \mathbf{9.000 \text{ mm}}$$

Bending deflection (based on E_{mean})

$$\delta_{bending} = \mathbf{4.709 \text{ mm}}$$

Shear deflection

$$\delta_{shear} = \mathbf{0.289 \text{ mm}}$$

Total deflection

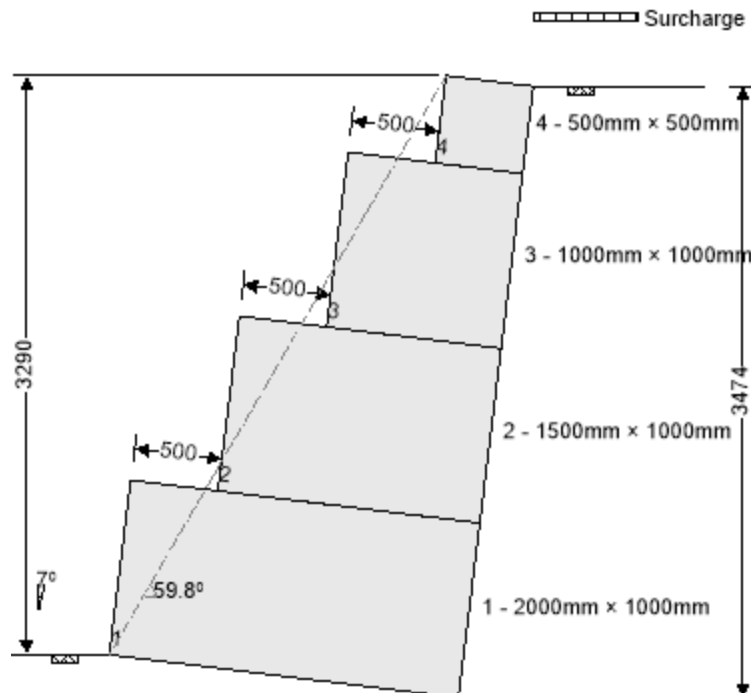
$$\delta = \delta_{bending} + \delta_{shear} = \mathbf{4.997 \text{ mm}}$$

PASS - Actual deflection within permissible limits

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



Wall geometry

Width of gabion 1	$w_1 = 2000$ mm
Height of gabion 1	$h_1 = 1000$ mm
Width of gabion 2	$w_2 = 1500$ 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	$w_3 = 1000$ mm
Height of gabion 3	$h_3 = 1000$ mm
Step to front face between courses 2 and 3	$s_3 = 500$ mm
Width of gabion 4	$w_4 = 500$ mm
Height of gabion 4	$h_4 = 500$ mm
Step to front face between courses 3 and 4	$s_4 = 500$ mm
Wall inclination	$\varepsilon = 7$ deg

Gabion properties

Unit weight of fill	$\gamma_d = 16.0$ kN/m ³
Friction between gabions	$\delta_{bg,k} = 35.0$ deg

Loading

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

Slope of retained soil	$\beta = 0.0$ deg
Characteristic peak shearing resistance angle	$\phi'_{pk,k} = 30.0$ deg
Characteristic saturated density of retained soil	$\gamma_{sr} = 21.0$ kN/m ³
Coefficient for wall friction	$k_{membrane} = 0.75$

Wall friction angle

$$\delta_{r,k} = \mathbf{22.5 \text{ deg}}$$

Characteristic base friction angle

$$\delta_{bb,k} = \mathbf{30.0 \text{ deg}}$$

Bearing capacity of founding soil

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

Wall geometry

Horizontal distance to centre of gravity gabion 1

$$x_{g1} = w_1 / 2 = \mathbf{1000 \text{ mm}}$$

Vertical distance to centre of gravity gabion 1

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

Weight of gabion 1

$$W_{g1} = \gamma_d \times w_1 \times h_1 = \mathbf{32.0 \text{ kN/m}}$$

Horizontal distance to centre of gravity gabion 2

$$x_{g2} = w_2 / 2 + s_2 = \mathbf{1250 \text{ mm}}$$

Vertical distance to centre of gravity gabion 2

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

Weight of gabion 2

$$W_{g2} = \gamma_d \times w_2 \times h_2 = \mathbf{24.0 \text{ kN/m}}$$

Horizontal distance to centre of gravity gabion 3

$$x_{g3} = w_3 / 2 + s_2 + s_3 = \mathbf{1500 \text{ mm}}$$

Vertical distance to centre of gravity gabion 3

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

Weight of gabion 3

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

Horizontal distance to centre of gravity gabion 4

$$x_{g4} = w_4 / 2 + s_2 + s_3 + s_4 = \mathbf{1750 \text{ mm}}$$

Vertical distance to centre of gravity gabion 4

$$y_{g4} = h_4 / 2 + h_1 + h_2 + h_3 = \mathbf{3250 \text{ mm}}$$

Weight of gabion 4

$$W_{g4} = \gamma_d \times w_4 \times h_4 = \mathbf{4.0 \text{ kN/m}}$$

Weight of entire gabion

$$W_g = W_{g1} + W_{g2} + W_{g3} + W_{g4} = \mathbf{76.0 \text{ kN/m}}$$

Horiz distance to centre of gravity entire gabion

$$x_g = ((W_{g1} \times x_{g1}) + (W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4})) / W_g = \mathbf{1224 \text{ mm}}$$

Vert distance to centre of gravity entire gabion

$$y_g = ((W_{g1} \times y_{g1}) + (W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4})) / W_g = \mathbf{1382 \text{ mm}}$$

Correcting for wall inclination horiz dist

$$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{1383 \text{ mm}}$$

Vertical change in height due to wall inclination

$$H_r = y_{g4} + h_4/2 - ((y_{g4} + h_4/2) \times \cos(\epsilon) - (x_{g4} + w_4/2) \times \sin(\epsilon)) = \mathbf{270 \text{ mm}}$$

Design dimensions

Effective angle of rear plane of wall

$$\alpha = 90 \text{ deg} + \epsilon = \mathbf{97.0 \text{ deg}}$$

Effective face angle

$$\theta = \text{Atan}((y_{g4} + (h_4 / 2)) / ((x_{g4} - (w_4 / 2)))) - \epsilon = \mathbf{59.8 \text{ deg}}$$

Effective height of wall

$$H = (y_{g4} + h_4 / 2) + (w_1 \times \sin(\epsilon)) - H_r = \mathbf{3474 \text{ mm}}$$

Height of wall from toe to front edge of top gabion

$$H_{incl} = ((y_{g4} + h_4 / 2) \times \cos(\epsilon) - (x_{g4} - (w_4 / 2)) \times \sin(\epsilon)) = \mathbf{3291 \text{ mm}}$$

Active pressure using Coulomb theory

$$K_a = \sin(\alpha + \phi'_{r,k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,k}) \times (1 + \sqrt{(\sin(\phi'_{r,k} + \delta_{r,k}) \times \sin(\phi'_{r,k} - \beta) / (\sin(\alpha - \delta_{r,k}) \times \sin(\alpha + \beta))}))^2) = \mathbf{0.249}$$

Active thrust due to soil

$$P_{a,soil} = 0.5 \times K_a \times \gamma_{sr} \times H^2 = \mathbf{31.5 \text{ kN/m}}$$

Minimum surcharge (cl.4.6.3.2)

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

Pressure at base

Horizontal forces

Retained soil

$$F_{soil,h,q} = P_{a,soil} \times \cos(90 - \alpha + \delta_{r,k}) = \mathbf{30.4 \text{ kN/m}}$$

Height of soil thrust resolved vertically

$$d_{h,soil} = H / 3 - w_1 \times \sin(\epsilon) = \mathbf{914 \text{ mm}}$$

Surcharge

$$F_{surch,h,q} = \max(p_{o,Q}, p_{o,min}) \times K_a \times H \times \cos(90 - \alpha + \delta_{r,k}) = \mathbf{8.3 \text{ kN/m}}$$

Height of surcharge thrust resolved vertically

$$d_{h,surch} = H / 2 - w_1 \times \sin(\epsilon) = \mathbf{1493 \text{ mm}}$$

Vertical forces

Gabion weight

$$F_{gabion,v,q} = W_g = \mathbf{76.0 \text{ kN/m}}$$

Retained soil

$$F_{soil,v,q} = P_{a,soil} \times \sin(90 - \alpha + \delta_{r,k}) = \mathbf{8.4 \text{ kN/m}}$$

Horizontal dist to where soil thrust acts

$$b_{v,soil} = w_1 \times \cos(\epsilon) - (H / 3) / \tan(\alpha) = \mathbf{2127 \text{ mm}}$$

Surcharge

$$F_{surch,v,q} = \max(p_{o,Q}, p_{o,min}) \times K_a \times H \times \sin(90 - \alpha + \delta_{r,k}) = \mathbf{2.3 \text{ kN/m}}$$

Horizontal dist to where surcharge thrust acts

$$b_{v,surch} = w_1 \times \cos(\epsilon) - (H / 2) / \tan(\alpha) = \mathbf{2198 \text{ mm}}$$

Total horizontal unfactored force

$$T_q = F_{soil_h,q} + F_{surch_h,q} = \mathbf{38.7 \text{ kN/m}}$$

Total vertical unfactored force

$$N_q = F_{gabion_v,q} + F_{soil_v,q} + F_{surch_v,q} = \mathbf{86.7 \text{ kN/m}}$$

Force normal to base

$$N_s = N_q \times \cos(\epsilon) + T_q \times \sin(\epsilon) = \mathbf{90.8 \text{ kN/m}}$$

Total unfactored overturning force

$$M_{o,q} = F_{soil_h,q} \times d_{h,soil} + F_{surch_h,q} \times d_{h,surch} = \mathbf{40.2 \text{ kNm/m}}$$

Total unfactored restoring force

$$M_{R,q} = F_{gabion_v,q} \times X_g + F_{soil_v,q} \times b_{v,soil} + F_{surch_v,q} \times b_{v,surch} = \mathbf{128.1 \text{ kNm/m}}$$

Eccentricity

$$e = w_1 / 2 - (M_{R,q} - M_{o,q}) / N_s = \mathbf{32 \text{ mm}}$$

Reaction acts within middle third of base

Pressure at toe

$$\sigma_{toe} = N_s / w_1 \times (1 + (6 \times e / w_1)) = \mathbf{49.7 \text{ kN/m}^2}$$

Pressure at heel

$$\sigma_{heel} = N_s / w_1 \times (1 - (6 \times e / w_1)) = \mathbf{41.1 \text{ kN/m}^2}$$

Factor of safety

$$FoS_Q = q / \max(\sigma_{toe}, \sigma_{heel}) = \mathbf{2.011}$$

Allowable factor of safety

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

PASS - Design FoS for allowable bearing pressure exceeds min allowable pressure to base

Design approach 1

Partial factors on actions - Section A.3.1 - Combination 1

Permanent unfavourable action

$$\gamma_G = \mathbf{1.35}$$

Permanent favourable action

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

Variable unfavourable action

$$\gamma_Q = \mathbf{1.50}$$

Variable favourable action

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

Partial factors for soil parameters - Section A.3.2 - Combination 1

Angle of shearing resistance

$$\gamma_{\phi'} = \mathbf{1.00}$$

Weight density

$$\gamma_r = \mathbf{1.00}$$

Design soil properties

Design effective shearing resistance angle

$$\phi'_{r,d} = \text{Atan}(\tan(\phi'_{pk,k}) / \gamma_{\phi'}) = \mathbf{30.0 \text{ deg}}$$

Design saturated density of retained soil

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

Design wall friction angle (cl.5.4.2.1)

$$\delta_{r,d} = \min(\text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}), \phi'_{r,d} \times k_{\text{membrane}}) = \mathbf{22.5 \text{ deg}}$$

Design base friction angle

$$\delta_{bb,d} = \text{Atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = \mathbf{30.0 \text{ deg}}$$

Design friction between gabions

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

Active pressure using Coulomb theory

$$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta)))^2}) = \mathbf{0.249}$$

Active thrust due to soil

$$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = \mathbf{31.5 \text{ kN/m}}$$

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

$$F_{soil_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{41.0 \text{ kN/m}}$$

Surcharge

$$F_{surch_h} = \max(p_{o,Q} \times \gamma_Q, p_{o,min}) \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{12.5 \text{ kN/m}}$$

Vertical forces

Gabion weight

$$F_{gabion_v,f} = \gamma_{G,f} \times W_g = \mathbf{76.0 \text{ kN/m}}$$

Retained soil

$$F_{soil_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{8.4 \text{ kN/m}}$$

Surcharge

$$F_{surch_v,f} = \max(p_{o,Q} \times \gamma_{Q,f}, p_{o,min}) \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{2.3 \text{ kN/m}}$$

Overturning stability - take moments about the toe

Overturning moment

$$M_o = F_{soil_h} \times d_{h,soil} + F_{surch_h} \times d_{h,surch} = \mathbf{56.1 \text{ kNm/m}}$$

Restoring moment

$$M_R = F_{gabion_v,f} \times X_g + F_{soil_v,f} \times b_{v,soil} + F_{surch_v,f} \times b_{v,surch} = \mathbf{128.1 \text{ kNm/m}}$$

Factor of safety

$$FoS_M = M_R / M_o = \mathbf{2.283}$$

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	$T = F_{soil_h} + F_{surch_h} = \mathbf{53.5 \text{ kN/m}}$
Total vertical force	$N = F_{gabion_v,f} + F_{soil_v,f} + F_{surch_v,f} = \mathbf{86.7 \text{ kN/m}}$
Sliding force	$F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = \mathbf{42.5 \text{ kN/m}}$
Sliding resistance	$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bb,d}) = \mathbf{53.5 \text{ kN/m}}$
Factor of safety	$FoS_S = F_R / F_f = \mathbf{1.258}$
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	$x_{g2} = w_2 / 2 = \mathbf{750 \text{ mm}}$
Vertical distance to centre of gravity gabion 2	$y_{g2} = h_2 / 2 = \mathbf{500 \text{ mm}}$
Weight of gabion 2	$W_{g2} = \gamma_d \times w_2 \times h_2 = \mathbf{24.0 \text{ kN/m}}$
Horizontal distance to centre of gravity gabion 3	$x_{g3} = w_3 / 2 + s_3 = \mathbf{1000 \text{ mm}}$
Vertical distance to centre of gravity gabion 3	$y_{g3} = h_3 / 2 + h_2 = \mathbf{1500 \text{ mm}}$
Weight of gabion 3	$W_{g3} = \gamma_d \times w_3 \times h_3 = \mathbf{16.0 \text{ kN/m}}$
Horizontal distance to centre of gravity gabion 4	$x_{g4} = w_4 / 2 + s_3 + s_4 = \mathbf{1250 \text{ mm}}$
Vertical distance to centre of gravity gabion 4	$y_{g4} = h_4 / 2 + h_2 + h_3 = \mathbf{2250 \text{ mm}}$
Weight of gabion 4	$W_{g4} = \gamma_d \times w_4 \times h_4 = \mathbf{4.0 \text{ kN/m}}$
Weight of entire gabion	$W_g = W_{g2} + W_{g3} + W_{g4} = \mathbf{44.0 \text{ kN/m}}$
Horiz distance to centre of gravity entire gabion	$x_g = ((W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4})) / W_g = \mathbf{886 \text{ mm}}$
Vert distance to centre of gravity entire gabion	$y_g = ((W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4})) / W_g = \mathbf{1023 \text{ mm}}$
Correcting for wall inclination horiz dist	$x_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{1004 \text{ mm}}$
Vertical change in height due to wall inclination	$H_f = y_{g4} + h_4/2 - ((y_{g4} + h_4/2) \times \cos(\epsilon) - (x_{g4} + w_4/2) \times \sin(\epsilon)) = \mathbf{201 \text{ mm}}$

Design dimensions

Effective angle of rear plane of wall	$\alpha = 90 \text{ deg} + \epsilon = \mathbf{97.0 \text{ deg}}$
Effective face angle	$\theta = \text{Atan}((y_{g4} + (h_4 / 2)) / ((x_{g4} - (w_4 / 2)))) - \epsilon = \mathbf{61.2 \text{ deg}}$
Effective height of wall	$H = (y_{g4} + h_4 / 2) + (w_2 \times \sin(\epsilon)) - H_f = \mathbf{2481 \text{ mm}}$
Height of wall from toe to front edge of top gabion	$H_{incl} = ((y_{g4} + h_4 / 2) \times \cos(\epsilon) - (x_{g4} - (w_4 / 2)) \times \sin(\epsilon)) = \mathbf{2359 \text{ mm}}$
Active pressure using Coulomb theory	$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}))^2 = \mathbf{0.249}$
Active thrust due to soil	$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = \mathbf{16.1 \text{ kN/m}}$
Minimum surcharge (cl.4.6.3.2)	$p_{o,min} = \min(H / H_{ref}, 1) \times q_{d,min} = \mathbf{8.3 \text{ kN/m}^2}$

Horizontal forces

Retained soil	$F_{soil_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{20.9 \text{ kN/m}}$
Surcharge	$F_{surch_h} = \max(p_{o,Q} \times \gamma_Q, p_{o,min}) \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{8.9 \text{ kN/m}}$

Vertical forces

Gabion weight	$F_{gabion_v,f} = \gamma_G \times W_g = \mathbf{44.0 \text{ kN/m}}$
Retained soil	$F_{soil_v,f} = \gamma_G \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{4.3 \text{ kN/m}}$
Surcharge	$F_{surch_v,f} = \max(p_{o,Q} \times \gamma_Q, p_{o,min}) \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{1.4 \text{ kN/m}}$

Overturning stability - take moments about the toe

Overturning moment	$M_o = F_{soil_h} \times d_{h,soil} + F_{surch_h} \times d_{h,surch} = \mathbf{22.9 \text{ kNm/m}}$
Restoring moment	$M_R = F_{gabion_v,f} \times x_g + F_{soil_v,f} \times b_{v,soil} + F_{surch_v,f} \times b_{v,surch} = \mathbf{53.3 \text{ kNm/m}}$
Factor of safety	$FoS_M = M_R / M_o = \mathbf{2.326}$

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Calcs for Gabion Retaining Wall				Start page no./Revision 14	
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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

$$T = F_{soil_h} + F_{surch_h} = 29.8 \text{ kN/m}$$

Total vertical force

$$N = F_{gabion_v,f} + F_{soil_v,f} + F_{surch_v,f} = 49.7 \text{ kN/m}$$

Sliding force

$$F_r = T \times \cos(\epsilon) - N \times \sin(\epsilon) = 23.5 \text{ kN/m}$$

Sliding resistance

$$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = 37.1 \text{ kN/m}$$

Factor of safety

$$FoS_S = F_R / F_r = 1.574$$

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

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

Horizontal distance to centre of gravity gabion 4

$$x_{g4} = w_4 / 2 + s_4 = 750 \text{ mm}$$

Vertical distance to centre of gravity gabion 4

$$y_{g4} = h_4 / 2 + h_3 = 1250 \text{ mm}$$

Weight of gabion 4

$$W_{g4} = \gamma_d \times w_4 \times h_4 = 4.0 \text{ kN/m}$$

Weight of entire gabion

$$W_g = W_{g3} + W_{g4} = 20.0 \text{ kN/m}$$

Horiz distance to centre of gravity entire gabion

$$x_g = ((W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4})) / W_g = 550 \text{ mm}$$

Vert distance to centre of gravity entire gabion

$$y_g = ((W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4})) / W_g = 650 \text{ mm}$$

Correcting for wall inclination horiz dist

$$x_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = 625 \text{ mm}$$

Vertical change in height due to wall inclination

$$H_r = y_{g4} + h_4/2 - ((y_{g4} + h_4/2) \times \cos(\epsilon) - (x_{g4} + w_4/2) \times \sin(\epsilon)) = 133 \text{ mm}$$

Design dimensions

Effective angle of rear plane of wall

$$\alpha = 90 \text{ deg} + \epsilon = 97.0 \text{ deg}$$

Effective face angle

$$\theta = \text{Atan}((y_{g4} + (h_4 / 2)) / ((x_{g4} - (w_4 / 2)))) - \epsilon = 64.6 \text{ deg}$$

Effective height of wall

$$H = (y_{g4} + h_4 / 2) + (w_3 \times \sin(\epsilon)) - H_r = 1489 \text{ mm}$$

Height of wall from toe to front edge of top gabion

$$H_{incl} = ((y_{g4} + h_4 / 2) \times \cos(\epsilon) - (x_{g4} - (w_4 / 2)) \times \sin(\epsilon)) = 1428 \text{ mm}$$

Active pressure using Coulomb theory

$$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}))^2 = 0.249$$

Active thrust due to soil

$$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = 5.8 \text{ kN/m}$$

Minimum surcharge (cl.4.6.3.2)

$$p_{o,min} = \min(H / H_{ref}, 1) \times q_{d,min} = 5.0 \text{ kN/m}^2$$

Horizontal forces

Retained soil

$$F_{soil_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = 7.5 \text{ kN/m}$$

Surcharge

$$F_{surch_h} = \max(p_{o,Q} \times \gamma_Q, p_{o,min}) \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = 5.3 \text{ kN/m}$$

Vertical forces

Gabion weight

$$F_{gabion_v,f} = \gamma_G \times W_g = 20.0 \text{ kN/m}$$

Retained soil

$$F_{soil_v,f} = \gamma_G \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = 1.5 \text{ kN/m}$$

Surcharge

$$F_{surch_v,f} = \max(p_{o,Q} \times \gamma_{Q,f}, p_{o,min}) \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = 0.5 \text{ kN/m}$$

Overturning stability - take moments about the toe

Overturning moment

$$M_o = F_{soil_h} \times d_{h,soil} + F_{surch_h} \times d_{h,surch} = 6.1 \text{ kNm/m}$$

Restoring moment

$$M_R = F_{gabion_v,f} \times x_g + F_{soil_v,f} \times b_{v,soil} + F_{surch_v,f} \times b_{v,surch} = 14.7 \text{ kNm/m}$$

Factor of safety

$$FoS_M = M_R / M_o = 2.385$$

Allowable factor of safety

$$FoS_{M_allow} = 1.000$$

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Calcs for Gabion Retaining Wall				Start page no./Revision 15	
Calcs by BR	Calcs date 02/03/2022	Checked by MJ	Checked date 02/03/2022	Approved by MJ	Approved date 02/03/2022

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	$T = F_{soil_h} + F_{surch_h} = 12.9$ kN/m
Total vertical force	$N = F_{gabion_v,f} + F_{soil_v,f} + F_{surch_v,f} = 22.0$ kN/m
Sliding force	$F_t = T \times \cos(\epsilon) - N \times \sin(\epsilon) = 10.1$ kN/m
Sliding resistance	$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = 16.4$ kN/m
Factor of safety	$FoS_S = F_R / F_t = 1.626$
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	$x_{g4} = W_4 / 2 = 250$ mm
Vertical distance to centre of gravity gabion 4	$y_{g4} = h_4 / 2 = 250$ mm
Weight of gabion 4	$W_{g4} = \gamma_d \times W_4 \times h_4 = 4.0$ kN/m
Weight of entire gabion	$W_g = W_{g4} = 4.0$ kN/m
Horiz distance to centre of gravity entire gabion	$x_g = ((W_{g4} \times x_{g4})) / W_g = 250$ mm
Vert distance to centre of gravity entire gabion	$y_g = ((W_{g4} \times y_{g4})) / W_g = 250$ mm
Correcting for wall inclination horiz dist	$x_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = 279$ mm
Vertical change in height due to wall inclination	$H_r = y_{g4} + h_4/2 - ((y_{g4} + h_4/2) \times \cos(\epsilon) - (x_{g4} + W_4/2) \times \sin(\epsilon)) = 65$ mm

Design dimensions

Effective angle of rear plane of wall	$\alpha = 90 \text{ deg} + \epsilon = 97.0$ deg
Effective face angle	$\theta = 90 \text{ deg} - \epsilon = 83.0$ deg
Effective height of wall	$H = (y_{g4} + h_4 / 2) + (W_4 \times \sin(\epsilon)) - H_r = 496$ mm
Height of wall from toe to front edge of top gabion	$H_{incl} = ((y_{g4} + h_4 / 2) \times \cos(\epsilon) - (x_{g4} - (W_4 / 2)) \times \sin(\epsilon)) = 496$ mm
Active pressure using Coulomb theory	$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}))^2 = 0.249$
Active thrust due to soil	$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = 0.6$ kN/m
Minimum surcharge (cl.4.6.3.2)	$p_{o,min} = \min(H / H_{ref}, 1) \times q_{d,min} = 1.7$ kN/m ²

Horizontal forces

Retained soil	$F_{soil_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = 0.8$ kN/m
Surcharge	$F_{surch_h} = \max(p_{o,Q} \times \gamma_Q, p_{o,min}) \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = 1.8$ kN/m

Vertical forces

Gabion weight	$F_{gabion_v,f} = \gamma_{G,f} \times W_g = 4.0$ kN/m
Retained soil	$F_{soil_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = 0.2$ kN/m
Surcharge	$F_{surch_v,f} = \max(p_{o,Q} \times \gamma_{Q,f}, p_{o,min}) \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = 0.1$ kN/m

Overturning stability - take moments about the toe

Overturning moment	$M_o = F_{soil_h} \times d_{h,soil} + F_{surch_h} \times d_{h,surch} = 0.4$ kNm/m
Restoring moment	$M_R = F_{gabion_v,f} \times x_g + F_{soil_v,f} \times b_{v,soil} + F_{surch_v,f} \times b_{v,surch} = 1.2$ kNm/m
Factor of safety	$FoS_M = M_R / M_o = 2.925$
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	$T = F_{soil_h} + F_{surch_h} = 2.6$ kN/m
Total vertical force	$N = F_{gabion_v,f} + F_{soil_v,f} + F_{surch_v,f} = 4.2$ kN/m

Project Plot 1, Glannant Place, Cwmgwrach, Neath, SA11 5TE				Job no. 14645	
Calcs for Gabion Retaining Wall				Start page no./Revision 16	
Calcs by BR	Calcs date 02/03/2022	Checked by MJ	Checked date 02/03/2022	Approved by MJ	Approved date 02/03/2022

Sliding force $F_I = T \times \cos(\epsilon) - N \times \sin(\epsilon) = \mathbf{2.1 \text{ kN/m}}$
Sliding resistance $F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = \mathbf{3.2 \text{ kN/m}}$
Factor of safety $FoS_S = F_R / F_I = \mathbf{1.516}$
Allowable factor of safety $FoS_{S_allow} = \mathbf{1.000}$
PASS - Design FOS for sliding exceeds min allowable FOS for sliding

Design approach 1

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

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

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

Angle of shearing resistance $\gamma_\psi = \mathbf{1.25}$
Weight density $\gamma_\gamma = \mathbf{1.00}$

Design soil properties

Design effective shearing resistance angle $\phi'_{r,d} = \text{Atan}(\tan(\phi'_{pk,k}) / \gamma_\psi) = \mathbf{24.8 \text{ deg}}$
Design saturated density of retained soil $\gamma_{s,d} = \gamma_{sr} / \gamma_\gamma = \mathbf{21.0 \text{ kN/m}^3}$
Design wall friction angle (cl.5.4.2.1) $\delta_{r,d} = \min(\text{atan}(\tan(\delta_{r,k}) / \gamma_\psi), \phi'_{r,d} \times k_{\text{membrane}}) = \mathbf{18.3 \text{ deg}}$
Design base friction angle $\delta_{bb,d} = \text{Atan}(\tan(\delta_{bb,k}) / \gamma_\psi) = \mathbf{24.8 \text{ deg}}$
Design friction between gabions $\delta_{bg,d} = \text{Atan}(\tan(\delta_{bg,k}) / \gamma_\psi) = \mathbf{29.3 \text{ deg}}$

Wall geometry

Horizontal distance to centre of gravity gabion 1 $x_{g1} = w_1 / 2 = \mathbf{1000 \text{ mm}}$
Vertical distance to centre of gravity gabion 1 $y_{g1} = h_1 / 2 = \mathbf{500 \text{ mm}}$
Weight of gabion 1 $W_{g1} = \gamma_d \times w_1 \times h_1 = \mathbf{32.0 \text{ kN/m}}$
Horizontal distance to centre of gravity gabion 2 $x_{g2} = w_2 / 2 + s_2 = \mathbf{1250 \text{ mm}}$
Vertical distance to centre of gravity gabion 2 $y_{g2} = h_2 / 2 + h_1 = \mathbf{1500 \text{ mm}}$
Weight of gabion 2 $W_{g2} = \gamma_d \times w_2 \times h_2 = \mathbf{24.0 \text{ kN/m}}$
Horizontal distance to centre of gravity gabion 3 $x_{g3} = w_3 / 2 + s_2 + s_3 = \mathbf{1500 \text{ mm}}$
Vertical distance to centre of gravity gabion 3 $y_{g3} = h_3 / 2 + h_1 + h_2 = \mathbf{2500 \text{ mm}}$
Weight of gabion 3 $W_{g3} = \gamma_d \times w_3 \times h_3 = \mathbf{16.0 \text{ kN/m}}$
Horizontal distance to centre of gravity gabion 4 $x_{g4} = w_4 / 2 + s_2 + s_3 + s_4 = \mathbf{1750 \text{ mm}}$
Vertical distance to centre of gravity gabion 4 $y_{g4} = h_4 / 2 + h_1 + h_2 + h_3 = \mathbf{3250 \text{ mm}}$
Weight of gabion 4 $W_{g4} = \gamma_d \times w_4 \times h_4 = \mathbf{4.0 \text{ kN/m}}$
Weight of entire gabion $W_g = W_{g1} + W_{g2} + W_{g3} + W_{g4} = \mathbf{76.0 \text{ kN/m}}$
Horiz distance to centre of gravity entire gabion $x_g = ((W_{g1} \times x_{g1}) + (W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4})) / W_g = \mathbf{1224 \text{ mm}}$
Vert distance to centre of gravity entire gabion $y_g = ((W_{g1} \times y_{g1}) + (W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4})) / W_g = \mathbf{1382 \text{ mm}}$
Correcting for wall inclination horiz dist $x_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{1383 \text{ mm}}$
Vertical change in height due to wall inclination $H_r = y_{g4} + h_4/2 - ((y_{g4} + h_4/2) \times \cos(\epsilon) - (x_{g4} + w_4/2) \times \sin(\epsilon)) = \mathbf{270 \text{ mm}}$

Design dimensions

Effective angle of rear plane of wall $\alpha = 90 \text{ deg} + \epsilon = \mathbf{97.0 \text{ deg}}$
Effective face angle $\theta = \text{Atan}((y_{g4} + (h_4 / 2)) / ((x_{g4} - (w_4 / 2)))) - \epsilon = \mathbf{59.8 \text{ deg}}$
Effective height of wall $H = (y_{g4} + h_4 / 2) + (w_1 \times \sin(\epsilon)) - H_r = \mathbf{3474 \text{ mm}}$

Height of wall from toe to front edge of top gabion $H_{incl} = ((y_{g4} + h_4 / 2) \times \cos(\epsilon) - (x_{g4} - (w_4 / 2)) \times \sin(\epsilon)) = \mathbf{3291mm}$

Active pressure using Coulomb theory $K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta)))})^2) = \mathbf{0.314}$

Active thrust due to soil $P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = \mathbf{39.8 kN/m}$

Minimum surcharge (cl.4.6.3.2) $p_{o,min} = \min(H / H_{ref}, 1) \times q_{d,min} = \mathbf{10.0 kN/m^2}$

Horizontal forces

Retained soil $F_{soil,h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{39.0 kN/m}$

Surcharge $F_{surch,h} = \max(p_{o,Q} \times \gamma_Q, p_{o,min}) \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{13.9 kN/m}$

Vertical forces

Gabion weight $F_{gabion,v,f} = \gamma_{G,f} \times W_g = \mathbf{76.0 kN/m}$

Retained soil $F_{soil,v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{7.8 kN/m}$

Surcharge $F_{surch,v,f} = \max(p_{o,Q} \times \gamma_{Q,f}, p_{o,min}) \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{2.1 kN/m}$

Overturning stability - take moments about the toe

Overturning moment $M_o = F_{soil,h} \times d_{h,soil} + F_{surch,h} \times d_{h,surch} = \mathbf{56.5 kNm/m}$

Restoring moment $M_R = F_{gabion,v,f} \times X_g + F_{soil,v,f} \times b_{v,soil} + F_{surch,v,f} \times b_{v,surch} = \mathbf{126.5 kNm/m}$

Factor of safety $FoS_M = M_R / M_o = \mathbf{2.239}$

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 $T = F_{soil,h} + F_{surch,h} = \mathbf{53.0 kN/m}$

Total vertical force $N = F_{gabion,v,f} + F_{soil,v,f} + F_{surch,v,f} = \mathbf{86.0 kN/m}$

Sliding force $F_t = T \times \cos(\epsilon) - N \times \sin(\epsilon) = \mathbf{42.1 kN/m}$

Sliding resistance $F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bb,d}) = \mathbf{42.4 kN/m}$

Factor of safety $FoS_S = F_R / F_t = \mathbf{1.007}$

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 $x_{g2} = w_2 / 2 = \mathbf{750 mm}$

Vertical distance to centre of gravity gabion 2 $y_{g2} = h_2 / 2 = \mathbf{500 mm}$

Weight of gabion 2 $W_{g2} = \gamma_d \times w_2 \times h_2 = \mathbf{24.0 kN/m}$

Horizontal distance to centre of gravity gabion 3 $x_{g3} = w_3 / 2 + S_3 = \mathbf{1000 mm}$

Vertical distance to centre of gravity gabion 3 $y_{g3} = h_3 / 2 + h_2 = \mathbf{1500 mm}$

Weight of gabion 3 $W_{g3} = \gamma_d \times w_3 \times h_3 = \mathbf{16.0 kN/m}$

Horizontal distance to centre of gravity gabion 4 $x_{g4} = w_4 / 2 + S_3 + S_4 = \mathbf{1250 mm}$

Vertical distance to centre of gravity gabion 4 $y_{g4} = h_4 / 2 + h_2 + h_3 = \mathbf{2250 mm}$

Weight of gabion 4 $W_{g4} = \gamma_d \times w_4 \times h_4 = \mathbf{4.0 kN/m}$

Weight of entire gabion $W_g = W_{g2} + W_{g3} + W_{g4} = \mathbf{44.0 kN/m}$

Horiz distance to centre of gravity entire gabion $X_g = ((W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4})) / W_g = \mathbf{886 mm}$

Vert distance to centre of gravity entire gabion $y_g = ((W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4})) / W_g = \mathbf{1023 mm}$

Correcting for wall inclination horiz dist $X_g = X_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{1004 mm}$

Vertical change in height due to wall inclination $H_f = y_{g4} + h_4/2 - ((y_{g4} + h_4/2) \times \cos(\epsilon) - (x_{g4} + w_4/2) \times \sin(\epsilon)) = \mathbf{201 mm}$

Design dimensions

Effective angle of rear plane of wall $\alpha = 90 \text{ deg} + \epsilon = \mathbf{97.0 \text{ deg}}$

Effective face angle	$\theta = \text{Atan}((y_{g4} + (h_4 / 2)) / ((x_{g4} - (w_4 / 2)))) - \varepsilon = \mathbf{61.2 \text{ deg}}$
Effective height of wall	$H = (y_{g4} + h_4 / 2) + (w_2 \times \sin(\varepsilon)) - H_f = \mathbf{2481 \text{ mm}}$
Height of wall from toe to front edge of top gabion	$H_{incl} = ((y_{g4} + h_4 / 2) \times \cos(\varepsilon) - (x_{g4} - (w_4 / 2)) \times \sin(\varepsilon)) = \mathbf{2359 \text{ mm}}$
Active pressure using Coulomb theory	$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}))^2 = \mathbf{0.314}$
Active thrust due to soil	$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = \mathbf{20.3 \text{ kN/m}}$
Minimum surcharge (cl.4.6.3.2)	$p_{o,min} = \min(H / H_{ref}, 1) \times q_{d,min} = \mathbf{8.3 \text{ kN/m}^2}$
Horizontal forces	
Retained soil	$F_{soil,h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{19.9 \text{ kN/m}}$
Surcharge	$F_{surch,h} = \max(p_{o,Q} \times \gamma_Q, p_{o,min}) \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{9.9 \text{ kN/m}}$
Vertical forces	
Gabion weight	$F_{gabion,v,f} = \gamma_{G,f} \times W_g = \mathbf{44.0 \text{ kN/m}}$
Retained soil	$F_{soil,v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{4.0 \text{ kN/m}}$
Surcharge	$F_{surch,v,f} = \max(p_{o,Q} \times \gamma_{Q,f}, p_{o,min}) \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{1.3 \text{ kN/m}}$
Overturning stability - take moments about the toe	
Overturning moment	$M_o = F_{soil,h} \times d_{h,soil} + F_{surch,h} \times d_{h,surch} = \mathbf{23.4 \text{ kNm/m}}$
Restoring moment	$M_R = F_{gabion,v,f} \times X_g + F_{soil,v,f} \times b_{v,soil} + F_{surch,v,f} \times b_{v,surch} = \mathbf{52.6 \text{ kNm/m}}$
Factor of safety	$FoS_M = M_R / M_o = \mathbf{2.254}$
Allowable factor of safety	$FoS_{M,allow} = \mathbf{1.000}$
<i>PASS - Design FOS for overturning exceeds min allowable FOS for overturning</i>	
Sliding stability - ignore any passive pressure in front of the structure	
Total horizontal force	$T = F_{soil,h} + F_{surch,h} = \mathbf{29.9 \text{ kN/m}}$
Total vertical force	$N = F_{gabion,v,f} + F_{soil,v,f} + F_{surch,v,f} = \mathbf{49.3 \text{ kN/m}}$
Sliding force	$F_t = T \times \cos(\varepsilon) - N \times \sin(\varepsilon) = \mathbf{23.6 \text{ kN/m}}$
Sliding resistance	$F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bg,d}) = \mathbf{29.4 \text{ kN/m}}$
Factor of safety	$FoS_S = F_R / F_t = \mathbf{1.245}$
Allowable factor of safety	$FoS_{S,allow} = \mathbf{1.000}$
<i>PASS - Design FOS for sliding exceeds min allowable FOS for sliding</i>	
Check overturning and sliding between courses 2 and 3	
Wall geometry	
Horizontal distance to centre of gravity gabion 3	$x_{g3} = w_3 / 2 = \mathbf{500 \text{ mm}}$
Vertical distance to centre of gravity gabion 3	$y_{g3} = h_3 / 2 = \mathbf{500 \text{ mm}}$
Weight of gabion 3	$W_{g3} = \gamma_d \times w_3 \times h_3 = \mathbf{16.0 \text{ kN/m}}$
Horizontal distance to centre of gravity gabion 4	$x_{g4} = w_4 / 2 + s_4 = \mathbf{750 \text{ mm}}$
Vertical distance to centre of gravity gabion 4	$y_{g4} = h_4 / 2 + h_3 = \mathbf{1250 \text{ mm}}$
Weight of gabion 4	$W_{g4} = \gamma_d \times w_4 \times h_4 = \mathbf{4.0 \text{ kN/m}}$
Weight of entire gabion	$W_g = W_{g3} + W_{g4} = \mathbf{20.0 \text{ kN/m}}$
Horiz distance to centre of gravity entire gabion	$X_g = ((W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4})) / W_g = \mathbf{550 \text{ mm}}$
Vert distance to centre of gravity entire gabion	$y_g = ((W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4})) / W_g = \mathbf{650 \text{ mm}}$
Correcting for wall inclination horiz dist	$X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon) = \mathbf{625 \text{ mm}}$
Vertical change in height due to wall inclination	$H_f = y_{g4} + h_4/2 - ((y_{g4} + h_4/2) \times \cos(\varepsilon) - (x_{g4} + w_4/2) \times \sin(\varepsilon)) = \mathbf{133 \text{ mm}}$
Design dimensions	
Effective angle of rear plane of wall	$\alpha = 90 \text{ deg} + \varepsilon = \mathbf{97.0 \text{ deg}}$
Effective face angle	$\theta = \text{Atan}((y_{g4} + (h_4 / 2)) / ((x_{g4} - (w_4 / 2)))) - \varepsilon = \mathbf{64.6 \text{ deg}}$

Effective height of wall	$H = (y_{g4} + h_4 / 2) + (w_3 \times \sin(\epsilon)) - H_f = \mathbf{1489 \text{ mm}}$
Height of wall from toe to front edge of top gabion	$H_{incl} = ((y_{g4} + h_4 / 2) \times \cos(\epsilon) - (x_{g4} - (w_4 / 2)) \times \sin(\epsilon)) = \mathbf{1428 \text{ mm}}$
Active pressure using Coulomb theory	$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}))^2 = \mathbf{0.314}$
Active thrust due to soil	$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = \mathbf{7.3 \text{ kN/m}}$
Minimum surcharge (cl.4.6.3.2)	$p_{o,min} = \min(H / H_{ref}, 1) \times q_{d,min} = \mathbf{5.0 \text{ kN/m}^2}$
Horizontal forces	
Retained soil	$F_{soil,h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{7.2 \text{ kN/m}}$
Surcharge	$F_{surch,h} = \max(p_{o,Q} \times \gamma_Q, p_{o,min}) \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{6.0 \text{ kN/m}}$
Vertical forces	
Gabion weight	$F_{gabion,v,f} = \gamma_{G,f} \times W_g = \mathbf{20.0 \text{ kN/m}}$
Retained soil	$F_{soil,v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{1.4 \text{ kN/m}}$
Surcharge	$F_{surch,v,f} = \max(p_{o,Q} \times \gamma_{Q,f}, p_{o,min}) \times K_a \times H \times \sin(90 - \alpha + \delta_{r,d}) = \mathbf{0.5 \text{ kN/m}}$
Overtuning stability - take moments about the toe	
Overtuning moment	$M_o = F_{soil,h} \times d_{h,soil} + F_{surch,h} \times d_{h,surch} = \mathbf{6.4 \text{ kNm/m}}$
Restoring moment	$M_R = F_{gabion,v,f} \times X_g + F_{soil,v,f} \times b_{v,soil} + F_{surch,v,f} \times b_{v,surch} = \mathbf{14.5 \text{ kNm/m}}$
Factor of safety	$FoSM = M_R / M_o = \mathbf{2.268}$
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	$T = F_{soil,h} + F_{surch,h} = \mathbf{13.1 \text{ kN/m}}$
Total vertical force	$N = F_{gabion,v,f} + F_{soil,v,f} + F_{surch,v,f} = \mathbf{21.9 \text{ kN/m}}$
Sliding force	$F_t = T \times \cos(\epsilon) - N \times \sin(\epsilon) = \mathbf{10.4 \text{ kN/m}}$
Sliding resistance	$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = \mathbf{13.1 \text{ kN/m}}$
Factor of safety	$FoS_S = F_R / F_t = \mathbf{1.260}$
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 3 and 4

Wall geometry

Horizontal distance to centre of gravity gabion 4	$x_{g4} = w_4 / 2 = \mathbf{250 \text{ mm}}$
Vertical distance to centre of gravity gabion 4	$y_{g4} = h_4 / 2 = \mathbf{250 \text{ mm}}$
Weight of gabion 4	$W_{g4} = \gamma_d \times w_4 \times h_4 = \mathbf{4.0 \text{ kN/m}}$
Weight of entire gabion	$W_g = W_{g4} = \mathbf{4.0 \text{ kN/m}}$
Horiz distance to centre of gravity entire gabion	$x_g = ((W_{g4} \times x_{g4})) / W_g = \mathbf{250 \text{ mm}}$
Vert distance to centre of gravity entire gabion	$y_g = ((W_{g4} \times y_{g4})) / W_g = \mathbf{250 \text{ mm}}$
Correcting for wall inclination horiz dist	$X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = \mathbf{279 \text{ mm}}$
Vertical change in height due to wall inclination	$H_f = y_{g4} + h_4/2 - ((y_{g4} + h_4/2) \times \cos(\epsilon) - (x_{g4} + w_4/2) \times \sin(\epsilon)) = \mathbf{65 \text{ mm}}$

Design dimensions

Effective angle of rear plane of wall	$\alpha = 90 \text{ deg} + \epsilon = \mathbf{97.0 \text{ deg}}$
Effective face angle	$\theta = 90 \text{ deg} - \epsilon = \mathbf{83.0 \text{ deg}}$
Effective height of wall	$H = (y_{g4} + h_4 / 2) + (w_4 \times \sin(\epsilon)) - H_f = \mathbf{496 \text{ mm}}$
Height of wall from toe to front edge of top gabion	$H_{incl} = ((y_{g4} + h_4 / 2) \times \cos(\epsilon) - (x_{g4} - (w_4 / 2)) \times \sin(\epsilon)) = \mathbf{496 \text{ mm}}$
Active pressure using Coulomb theory	$K_a = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times (1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}))^2 = \mathbf{0.314}$

Active thrust due to soil

$$P_{a,soil} = 0.5 \times K_a \times \gamma_{s,d} \times H^2 = \mathbf{0.8 \text{ kN/m}}$$

Minimum surcharge (cl.4.6.3.2)

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

Horizontal forces

Retained soil

$$F_{soil,h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{0.8 \text{ kN/m}}$$

Surcharge

$$F_{surch,h} = \max(p_{o,Q} \times \gamma_Q, p_{o,min}) \times K_a \times H \times \cos(90 - \alpha + \delta_{r,d}) = \mathbf{2.0 \text{ kN/m}}$$

Vertical forces

Gabion weight

$$F_{gabion,v,f} = \gamma_{G,f} \times W_g = \mathbf{4.0 \text{ kN/m}}$$

Retained soil

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

Surcharge

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

Overtuning stability - take moments about the toe

Overturning moment

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

Restoring moment

$$M_R = F_{gabion,v,f} \times X_g + F_{soil,v,f} \times b_{v,soil} + F_{surch,v,f} \times b_{v,surch} = \mathbf{1.2 \text{ kNm/m}}$$

Factor of safety

$$FoS_M = M_R / M_o = \mathbf{2.687}$$

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

$$T = F_{soil,h} + F_{surch,h} = \mathbf{2.8 \text{ kN/m}}$$

Total vertical force

$$N = F_{gabion,v,f} + F_{soil,v,f} + F_{surch,v,f} = \mathbf{4.2 \text{ kN/m}}$$

Sliding force

$$F_f = T \times \cos(\epsilon) - N \times \sin(\epsilon) = \mathbf{2.3 \text{ kN/m}}$$

Sliding resistance

$$F_R = (T \times \sin(\epsilon) + N \times \cos(\epsilon)) \times \tan(\delta_{bg,d}) = \mathbf{2.5 \text{ kN/m}}$$

Factor of safety

$$FoS_S = F_R / F_f = \mathbf{1.124}$$

Allowable factor of safety

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

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