



**Design Calculations for
Mr Wayne Rowles
Percy Road
Gabion Retaining Wall
250101-16-100-Rev A**

June 2025

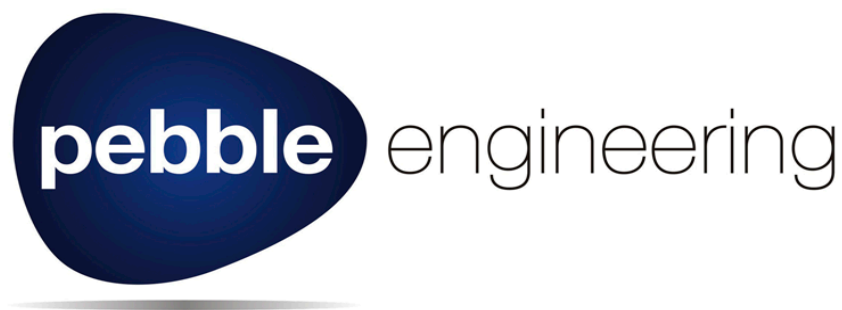
Design	Calculation no.	Project 250101	Phase Number 16	Set Number 100	Sheet 2	Rev. no. A
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REFERENCE

Client	Mr Wayne Rowles
Project Name	Percy Road
Structure	Gabion Retaining Wall
Subject of Calculation	Civil/Structural Calculations

REVISIONS OF CALCULATION SET

Rev.	Issue date	Description of calculation	Originator/ Date	Checker/ Date	Reviewer/ Date
A	27/06/2025	First Issue	KJR	AGD	DJO
			23/06/2025	26/06/2025	27/06/2025



KJ Rogers BSc(Hons) CEng MICE MStructE

Signed:

KJR

Date: 23/06/2025

A G Davies MEng(Hons) GMICE

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Date: 26/06/2025

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Date: 27/06/2025

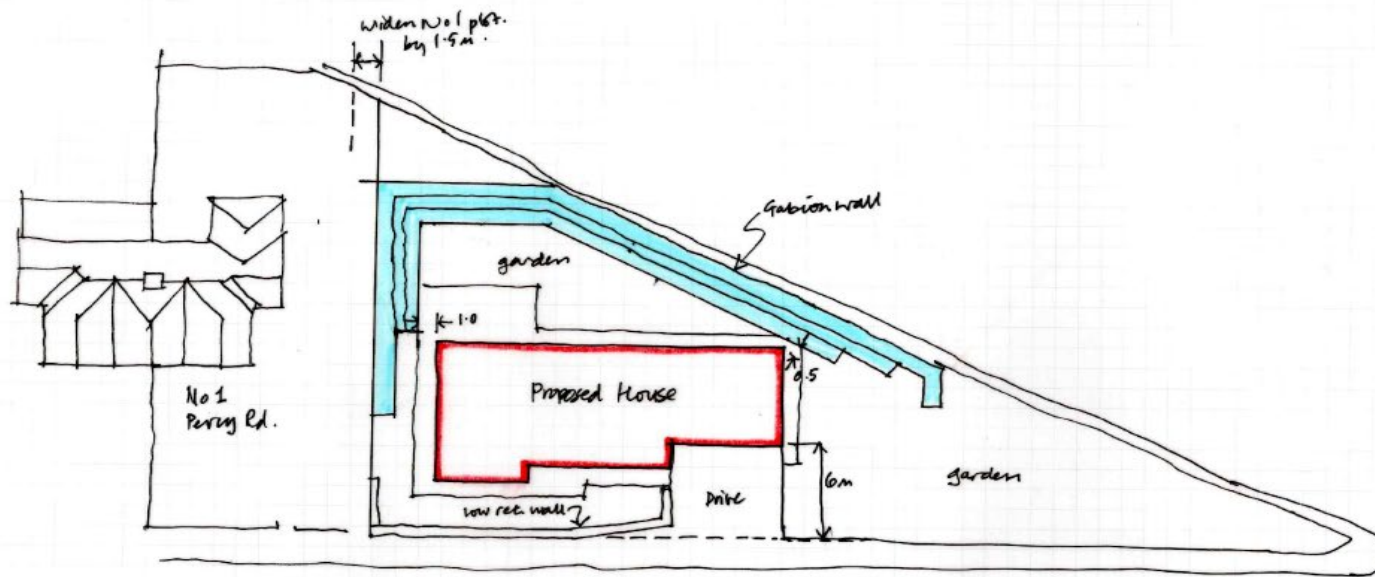
COMPANY

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CALCULATION DESIGN CRITERIA

Purpose of calculation	New Development for a domestic property requiring a retaining wall to the rear boundary. Proposed Gabion Basket retaining wall. Height of the retained earth varies from 3.8m down to 3.3m with backfill soil of 30 degrees to the boundary.
Method of calculation	Developed Excel Spreadsheet Hand Calculations SAND SCALE Structural Proforma
Source documents used (including codes, standards & drawings)	[1] BS EN 1990 - Basis of Structural Design [2] BS EN 1991 - Actions on Structures [3] BS EN 1992 - Design of Concrete Structures [4] BS EN 1997 - Geotechnical Design [5] BS8002 - Code of practise for earth retaining structures [6] Enviromesh - A reference guide of the designing of mass gravity gabion walls. [7] Foundation Design and Construction - Tomlinson 7th Edition
Calculation Criteria	Design undertaken to Eurocode partial factors for serviceability and ultimate limit state.
Health & Safety Risk Assessment	<u>Designers Risk Assessment</u> Soil instability during wall construction-resulting in serious injury. Existing ground to be inspected by competent person and TW measures to maintain soil stability during construction.
Key parameters used	Retained height to underside of base - 3.8m to 3.3m. Slope of backfill - 30 degrees max. Characteristic Internal friction angle of backfill - 35 degrees. Soil Density - 19kN/m ² and Surcharge - 10kN/m ² Allowable Bearing Pressure - 100 kN/m ² Kmembrane - 0.9 (stepped rear face of gabion) Base friction - $0.67 \cdot \Phi_k = 23.45$ degrees Gabion Wall inclination = 6 degrees. Concrete grade - C32/30, XC3 Nominal cover 50mm and 75mm for concrete cast against soil.
Other comments	
Output	See Design sketch 250101-16-SK01
Resulting drawings	None



Revised Plot 1(A) 1:250 @ A3. DATE 23 JUNE 2025
Proposed Site Plan.

PROJECT	PERCY ROAD.		PROJECT No	
TITLE			DATE	
BY	CHECKED BY	SHEET REF	REV	

Kevyn Davies Architect



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Calculation no. **250101**

Phase Number **16**

Set Number **100**

Sheet **6**

Rev. no. **A**

Geometry Table (no water) - Refer to following pages for calculations.

Course	Course Dimensions		Area	Mass kN	offset	Centre of gr abt toe		Area momts abt toe	
	Width	height				xx plane	yy plane	xx plane	yy plane
4.00	1.00	0.50	0.50	8.00	1.25	1.75	3.55	0.88	1.78
3.00	1.00	1.00	1.00	16.00	1.25	1.75	2.80	1.75	2.80
2.00	1.50	1.00	1.50	24.00	0.75	1.50	1.80	2.25	2.70
1.00	2.00	1.00	2.00	32.00	0.25	1.25	0.80	2.50	1.60
Concrete	2.50	0.30	0.75	18.00	0.00	1.25	0.15	0.94	0.11
Totals			5.75	98.00				7.38	8.88
Centre of gravity					Xg	Yg			
(assuming vertical)					1.28	1.54			
Correcting for wall inclination α					1.44				
Effective Wall Height									
co-ords of top wall (consider vertical)					2.25	3.80			
co-ords of btm wall (consider vertical)					2.50	0.00			
Inclination correction									
co-ords of top wall (adjusted)					2.65	3.56			
co-ords of btm wall (adjusted)					2.49	-0.26			
Effective slope angle β					-87.59	Degrees			

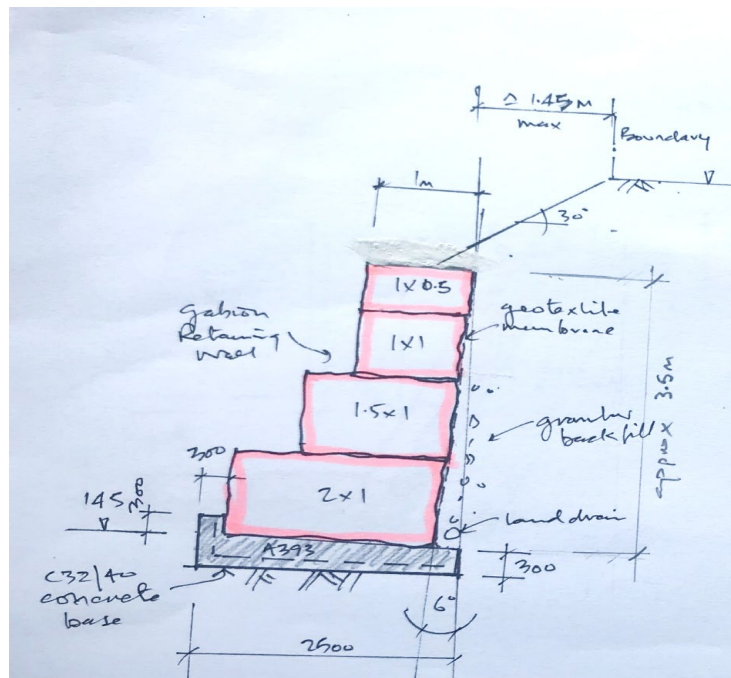
Or 92.41

Density of fill
height of gabion wall to underside of base
 α
Density of concrete

16 kN/m³
3.8 m
6 degrees
24 kN/m³

Limestone

Gabion Basket Calculation Sheet - Design Approach 1, Combination 1 to BS EN 1997
Global Stability



DA1 Comb 1

STR / GEO Partial Factors	
γ_G	1.35
$\gamma_{G,fav}$	1
γ_q	1.5
$\gamma_{q,fav}$	0
γ_ϕ	1

EQU Partial Factors	
γ_G	1.1
$\gamma_{G,fav}$	0.9
γ_q	1.5
$\gamma_{q,fav}$	0
γ_ϕ	1.1

Parameters

Height, h =	3.8 m
Slope of retained soil ϵ =	30 degrees
Internal Friction Angles ϕ_k =	35 degrees
Soil density γ_k =	19 kN/m ³
Surcharge $P_{0,k}$ =	10 kN/m ²
Surcharge $P_{0,d}$ =	15 kN/m ²
Allowable bearing pressure σ =	100 kN/m ²
Wall friction, δ	31.5 degrees
Base friction, ζ =	25.46 degrees
Wall inclination, α =	6 degrees
Effective plane at rear of wall, β =	92.4 degrees

0.9 used for K_{membrane}
Concrete cast on soil ϕ - 38

Active Pressure

Considering coulomb failure theory, active pressure on the wall is calculated by;

$$k_a = \frac{\sin^2(\beta + \varphi)}{\sin^2 \beta \sin(\beta - \varphi) \left[1 + \sqrt{\frac{\sin(\varphi + \delta) \sin(\varphi - \varepsilon)}{\sin(\beta - \delta) \sin(\beta + \varepsilon)}} \right]^2}$$

Therefore;

$$\begin{aligned} \sin^2(\beta + \varphi) &= 0.631 \\ \sin^2(\beta) &= 0.998 \\ \sin(\beta - \varphi) &= 0.843 \\ \sin(\varphi + \delta) &= 0.917 \\ \sin(\varphi - \varepsilon) &= 0.087 \\ \sin(\beta - \delta) &= 0.874 \\ \sin(\beta + \varepsilon) &= 0.844 \end{aligned}$$

$$k_a = 0.425 \quad \text{okay}$$

Calculation of active thrust (STR/GEO)

$$\begin{aligned} P_{a, \text{soil}} &= 0.5 * K_a * \gamma * h^2 &= 58.25 \text{ kN/m} &\text{SLS} \\ P_{a, \text{soil}, d} &= \gamma_G * 0.5 * K_a * \gamma * h^2 &= 78.64 \text{ kN/m} \\ P_{a, \text{surcharge}} &= P_0 * K_a * h &= 16.14 \text{ kN/m} &\text{SLS} \\ P_{a, \text{surcharge}, d} &= \gamma_q * P_0 * K_a * h &= 24.21 \text{ kN/m} \\ \text{STR/GEO } P_{a, d} &= \gamma_G P_{a, \text{soil}} + \gamma_q P_{a, \text{surcharge}} &= 102.85 \text{ kN/m} &\text{Max Loading} \\ \text{STR/GEO } P_{a, d} &= \gamma_G P_{a, \text{soil}} + \gamma_q P_{a, \text{surcharge}} &= 78.64 \text{ kN/m} &\text{No favourable} \end{aligned}$$

Calculation of active thrust (EQU)

$$\begin{aligned} \text{EQU } P_{a, d} &= \gamma_G P_{a, \text{soil}} + \gamma_q P_{a, \text{surcharge}} &= 88.28 \text{ kN/m} &\text{Max Loading} \\ \text{EQU } P_{a, d \text{ fav}} &= \gamma_{G, f} P_{a, \text{soil}} + \gamma_{q, f} P_{a, \text{surcharge}} &= 52.43 \text{ kN/m} &\text{No Favourable} \end{aligned}$$



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ACalculation of height of loads

$$dh_{\text{soil}} = h/3*((H+3*hs)/(H+2hs)) = 1.45 \text{ m above heel}$$

$$dh = dh_{\text{soil}} - b \sin(\alpha) = 1.40 \text{ m SLS}$$

$$bw = \text{width of base} = 1.19 \text{ m above toe}$$

$$hs,d = \text{surcharge loading as equivalent height of soil} = 1.14 \text{ m SLS}$$

$$= 2.5 \text{ m}$$

$$= 0.79 \text{ m ULS}$$

$$= 0.53 \text{ m SLS}$$

Calculation of horizontal and vertical components

STR/GEO	$Ph = P_{a,d} \cos(90-\beta+\delta)$	=	89.87 kN/m	Max.
STR/GEO	$Pv = P_{a,d} \sin(90-\beta+\delta)$	=	50.01 kN/m	Max.
STR/GEO	$Ph = P_{a,d} \cos(90-\beta+\delta)$	=	68.72 kN/m	Min.
STR/GEO	$Pv = P_{a,d} \sin(90-\beta+\delta)$	=	38.24 kN/m	Min.
EQU	$Pv = P_{a,d} \sin(90-\beta+\delta)$	=	42.93 kN/m	Max.
EQU	$Ph = P_{a,d} \cos(90-\beta+\delta)$	=	77.15 kN/m	Max.
EQU	$Pv = P_{a,d} \sin(90-\beta+\delta)$	=	25.49 kN/m	Min.
EQU	$Ph = P_{a,d} \cos(90-\beta+\delta)$	=	45.81 kN/m	Min.

Overturning Stability (EQU Verification)

$$M_{ed} = Ph \cdot dh = 91.90 \text{ kNm/m}$$

$$bv = bw \cos(\alpha) - dh_{\text{soil}} \tan(\beta) = 2.5474 \text{ m}$$

$$M_{Rd} = Pv \cdot bv + \gamma_{g,fav} Wg \cdot Xg = 191.7 \text{ kNm/m}$$

Sliding Stability (STR/GEO)

$$N = Wg + \sum Pv = 148.01 \text{ kN}$$

$$T = \sum Ph = 134.17 \text{ kN}$$

$$F_{ed} = T \cos(\alpha) - N \sin(\alpha) = 89.87 \text{ kN}$$

$$F_{Rd} = N \cos(\alpha) + T \sin(\alpha) \tan(\phi) = 73.9 \text{ kN/m}$$

$$= 74.6 \text{ kN}$$

Bearing Capacity Check (SLS)

$$M_{ed,\sigma} = (Pa_{\text{soil}} + Pa_{\text{surcharge}}) \cdot dh = 85.01 \text{ kNm/m}$$

$$bv = bw \cos(\alpha) - dh_{\text{soil}} \tan(\beta) = 2.5454 \text{ m}$$

$$Mr = Pv \cdot bv + \gamma_{g,fav} Wg \cdot Xg = 232.9 \text{ kNm/m}$$

$$e = bw/2 - (M_{Rd} - M_{ed,\sigma})/N = 0.148 \text{ Check } < bw/6 \quad 0.42 \quad \text{OK}$$

$$\sigma_{\text{toe}} = N/bw \cdot (1 + 6 \cdot e/bw) = 57.29 \text{ kN/m}^2$$

$$\sigma_{\text{heel}} = N/bw \cdot (1 - 6 \cdot e/bw) = 27.28 \text{ kN/m}^2$$



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Sliding Stability (Concrete base to gabion tier 1)

Height, h = 3.8 m

Calculation of active thrust (STR/GEO)

$$P_{a,soil} = 0.5 * K_a * \gamma * h^2 = 58.25 \text{ kN/m}$$

$$P_{a,soil,d} = Y_G * 0.5 * K_a * \gamma * h^2 = 78.64 \text{ kN/m}$$

$$P_{a,surcharge} = P_0 * K_a * h = 16.14 \text{ kN/m}$$

$$P_{a,surcharge,d} = Y_q * P_0 * K_a * h = 24.21 \text{ kN/m}$$

$$\text{STR/GEO } P_{a,d} = Y_G P_{a,soil} + Y_q P_{a,surcharge} = 102.85 \text{ kN/m}$$

Max Loading

Sliding Stability (STR/GEO)

Calculation of horizontal and vertical components

$$\text{STR/GEO } Ph = P_{a,d} * \cos(90 - \beta + \delta) = 89.87 \text{ kN/m}$$

$$\text{STR/GEO } Pv = P_{a,d} * \sin(90 - \beta + \delta) = 50.01 \text{ kN/m}$$

$$N = Wg + \sum Pv = 130.01 \text{ kN}$$

$$T = \sum Ph = 115.72 \text{ kN SLS}$$

$$F_{ed} = T \cos(\alpha) - N \sin(\alpha) = 89.87 \text{ kN}$$

$$F_{Rd} = N \cos(\alpha) + T \sin(\alpha) * \tan(\phi) \quad \#NAME? = 75.8 \text{ kN/m}$$

$$= 84.0 \text{ kN}$$

Sliding Stability (gabion tier 1 to gabion tier 2)

Height, h = 2.5 m

Calculation of active thrust (STR/GEO)

$$P_{a,soil} = 0.5 * K_a * \gamma * h^2 = 25.21 \text{ kN/m}$$

$$P_{a,soil,d} = Y_G * 0.5 * K_a * \gamma * h^2 = 34.04 \text{ kN/m}$$

$$P_{a,surcharge} = P_0 * K_a * h = 10.62 \text{ kN/m}$$

$$P_{a,surcharge,d} = Y_q * P_0 * K_a * h = 15.92 \text{ kN/m}$$

$$\text{STR/GEO } P_{a,d} = Y_G P_{a,soil} + Y_q P_{a,surcharge} = 49.96 \text{ kN/m}$$

Max Loading

Sliding Stability (STR/GEO)

Calculation of horizontal and vertical components

$$\text{STR/GEO } Ph = P_{a,d} * \cos(90 - \beta + \delta) = 43.66 \text{ kN/m}$$

$$\text{STR/GEO } Pv = P_{a,d} * \sin(90 - \beta + \delta) = 24.29 \text{ kN/m}$$

$$N = Wg + \sum Pv = 72.29 \text{ kN}$$

$$T = \sum Ph = 65.35 \text{ kN SLS}$$

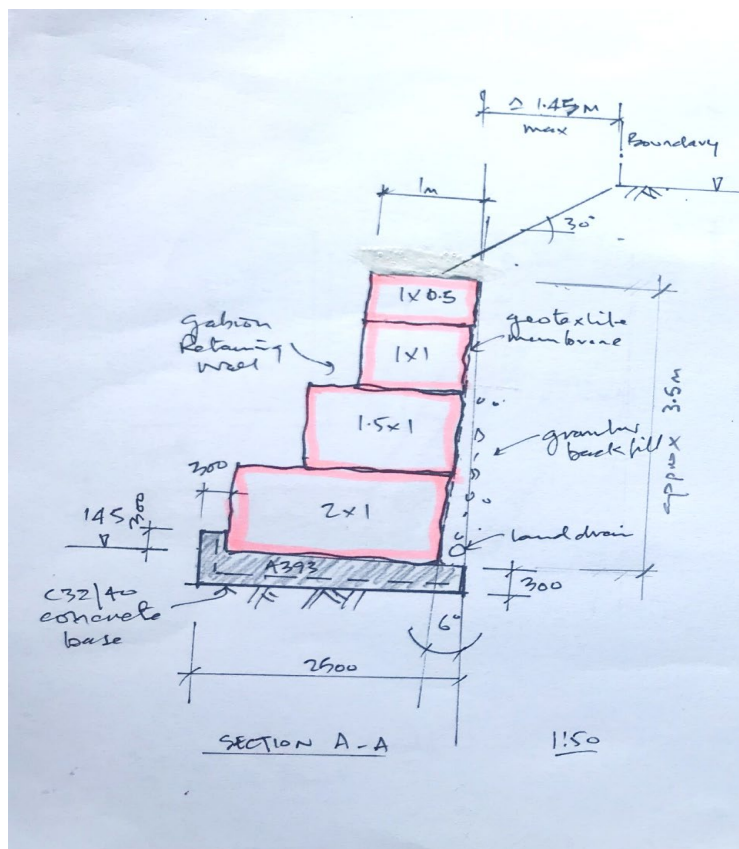
$$F_{ed} = T \cos(\alpha) - N \sin(\alpha) = 43.66 \text{ kN}$$

$$F_{Rd} = N \cos(\alpha) + T \sin(\alpha) * \tan(\phi) = 35.9 \text{ kN/m}$$

$$= 46.9 \text{ kN}$$

No further checks necessary on upper levels, sliding OK.

Gabion Basket Calculation Sheet - Design Approach 2, Combination 2 to BS EN 1997
Global Stability



DA1 Comb 2

STR / GEO Partial Factors	
γ_G	1
$\gamma_{G,fav}$	1
γ_q	1.3
$\gamma_{q,fav}$	0
γ_ϕ	1.25

Parameters

Height, h =	3.8 m	
Slope of retained soil ϵ =	30 degrees	
Internal Friction Angles ϕ_k =	35 degrees	
Internal Friction Angles ϕ_d =	28 degrees	
Soil density γ_k =	19 kN/m ³	
Surcharge $P_{0,k}$ =	10 kN/m ²	
Surcharge $P_{0,d}$ =	15 kN/m ²	
Allowable bearing pressure σ =	100 kN/m ²	
Wall friction, δ	31.5 degrees	0.9 used for K_{membrane}
Base friction, ζ =	20.368 degrees	Concrete cast on soil ϕ - 38
Wall inclination, α =	6 degrees	
Effective plane at rear of wall, β =	92.4 degrees	



Active Pressure

Considering coulomb failure theory, active pressure on the wall is calculated by;

$$k_a = \frac{\sin^2(\beta + \varphi)}{\sin^2 \beta \sin(\beta - \varphi) \left[1 + \frac{\sin(\varphi + \delta) \sin(\varphi - \varepsilon)}{\sin(\beta - \delta) \sin(\beta + \varepsilon)} \right]^2}$$

Therefore;

$\sin^2(\beta + \Phi)$	=	0.631
$\sin^2(\beta)$	=	0.998
$\sin(\beta - \Phi)$	=	0.843
$\sin(\Phi + \delta)$	=	0.917
$\sin(\Phi - \varepsilon)$	=	0.087
$\sin(\beta - \delta)$	=	0.874
$\sin(\beta + \varepsilon)$	=	0.844
k_a	=	0.425

Calculation of active thrust (STR/GEO)

$P_{a,soil} = 0.5 * K_a * \gamma * h^2$	=	58.25 kN/m	
$P_{a,soil,d} = Y_G * 0.5 * K_a * \gamma * h^2$	=	58.25 kN/m	
$P_{a,surcharge} = P_0 * K_a * h$	=	16.14 kN/m	
$P_{a,surcharge,d} = Y_q * P_0 * K_a * h$	=	20.98 kN/m	
STR/GEO $P_{a,d} = Y_G P_{a,soil} + Y_q P_{a,surcharge}$	=	79.23 kN/m	Max Loading
STR/GEO $P_{a,d} = Y_G P_{a,soil} + Y_q P_{a,surcharge}$	=	58.25 kN/m	No favourable



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ACalculation of height of loads

$$dh_{\text{soil}} = h/3 * ((H+3*hs)/(H+2hs)) = 1.45 \text{ m above heel}$$

$$dh = dh_{\text{soil}} - bw \sin(\alpha) = 1.40 \text{ m SLS}$$

$$dh = dh_{\text{soil}} - bw \sin(\alpha) = 1.19 \text{ m above toe}$$

$$bw = \text{width of base} = 1.14 \text{ m SLS}$$

$$hs, d = \text{surcharge loading as equivalent height of soil} = 2.5 \text{ m}$$

$$hs, d = \text{surcharge loading as equivalent height of soil} = 0.79 \text{ m ULS}$$

$$hs, d = \text{surcharge loading as equivalent height of soil} = 0.53 \text{ m SLS}$$

Calculation of horizontal and vertical components

$$\text{STR/GEO } Ph = P_{a,d} * \cos(90-\beta+\delta) = 69.24 \text{ kN/m} \quad \text{Max.}$$

$$\text{STR/GEO } Pv = P_{a,d} * \sin(90-\beta+\delta) = 38.52 \text{ kN/m} \quad \text{Max.}$$

$$\text{STR/GEO } Ph = P_{a,d} * \cos(90-\beta+\delta) = 50.90 \text{ kN/m} \quad \text{Min.}$$

$$\text{STR/GEO } Pv = P_{a,d} * \sin(90-\beta+\delta) = 28.32 \text{ kN/m} \quad \text{Min.}$$

Sliding Stability (STR/GEO)

$$N = Wg + \sum Pv = 136.52 \text{ kN}$$

$$N = Wg + \sum Pv = 134.17 \text{ kN SLS}$$

$$T = \sum Ph = 65.01 \text{ kN}$$

$$F_{ed} = T \cos(\alpha) - N \sin(\alpha) = 50.4 \text{ kN/m}$$

$$F_{Rd} = N \cos(\alpha) + T \sin(\alpha) * \tan(\phi) = 52.9 \text{ kN}$$

Bearing Capacity Check (SLS)

$$M_{ed,\sigma} = (Pa_{\text{soil}} + Pa_{\text{surcharge}}) * dh = 85.01 \text{ kNm/m}$$

$$bv = bw * \cos(\alpha) - dh_{\text{soil}} / \tan(\beta) = 2.5454 \text{ m}$$

$$Mr = Pv * bv + Wg * Xg = 238.9 \text{ kNm/m}$$

$$e = bw/2 - (M_{Rd} - M_{ed,\sigma}) / N = 0.103 \text{ Check } < bw/6 \quad 0.42 \quad \text{OK}$$

$$\sigma_{toe} = N/bw * (1 + 6 * e/bw) = 66.96 \text{ kN/m}^2$$

$$\sigma_{heel} = N/bw * (1 - 6 * e/bw) = 41.08 \text{ kN/m}^2$$



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ASliding Stability (Concrete base to gabion tier 1)

Height, h = 3.5 m

Calculation of active thrust (STR/GEO)

$$P_{a,soil} = 0.5 * K_a * \gamma * h^2 = 49.42 \text{ kN/m}$$

$$P_{a,soil,d} = Y_G * 0.5 * K_a * \gamma * h^2 = 49.42 \text{ kN/m}$$

$$P_{a,surcharge} = P_0 * K_a * h = 14.86 \text{ kN/m}$$

$$P_{a,surcharge,d} = Y_q P_0 * K_a * h = 19.32 \text{ kN/m}$$

$$\text{STR/GEO } P_{a,d} = Y_G P_{a,soil} + Y_q P_{a,surcharge} = 68.74 \text{ kN/m} \quad \text{Max Loading}$$

Sliding Stability (STR/GEO)Calculation of horizontal and vertical components

$$\text{STR/GEO } P_h = P_{a,d} * \cos(90 - \beta + \delta) = 60.07 \text{ kN/m} \quad \text{Max.}$$

$$\text{STR/GEO } P_v = P_{a,d} * \sin(90 - \beta + \delta) = 33.42 \text{ kN/m} \quad \text{Max.}$$

$$N = W_g + \sum P_v = 113.42 \text{ kN} \\ 103.87 \text{ kN SLS}$$

$$T = \sum P_h = 60.07 \text{ kN}$$

$$F_{ed} = T \cos(\alpha) - N \sin(\alpha) = 60.1 \text{ kN/m}$$

$$F_{Rd} = N \cos(\alpha) + T \sin(\alpha) * \tan(\phi) = 56.3 \text{ kN/m}$$

NOTE Add 300mm wide RC upstand to aid sliding resistance **Okay**

Sliding Stability (gabion tier 1 to gabion tier 2)

Height, h = 2.5 m

Calculation of active thrust (STR/GEO)

$$P_{a,soil} = 0.5 * K_a * \gamma * h^2 = 25.21 \text{ kN/m}$$

$$P_{a,soil,d} = Y_G * 0.5 * K_a * \gamma * h^2 = 25.21 \text{ kN/m}$$

$$P_{a,surcharge} = P_0 * K_a * h = 10.62 \text{ kN/m}$$

$$P_{a,surcharge,d} = Y_q P_0 * K_a * h = 13.80 \text{ kN/m}$$

$$\text{STR/GEO } P_{a,d} = Y_G P_{a,soil} + Y_q P_{a,surcharge} = 39.02 \text{ kN/m} \quad \text{Max Loading}$$

Sliding Stability (STR/GEO)Calculation of horizontal and vertical components

$$\text{STR/GEO } P_h = P_{a,d} * \cos(90 - \beta + \delta) = 34.09 \text{ kN/m} \quad \text{Max.}$$

$$\text{STR/GEO } P_v = P_{a,d} * \sin(90 - \beta + \delta) = 18.97 \text{ kN/m} \quad \text{Max.}$$

$$N = W_g + \sum P_v = 66.97 \text{ kN} \\ 61.55 \text{ kN SLS}$$

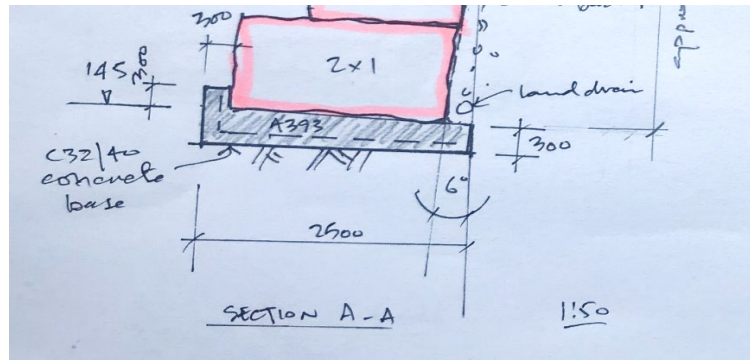
$$T = \sum P_h = 34.09 \text{ kN}$$

$$F_{ed} = T \cos(\alpha) - N \sin(\alpha) = 26.9 \text{ kN/m}$$

$$F_{Rd} = N \cos(\alpha) + T \sin(\alpha) * \tan(\phi) = 33.3 \text{ kN}$$

No further checks necessary on upper levels, sliding OK.

Wall A
Reinforced Concrete Base
Section Size



Slab acts as one way spanning parallel to wall length.

Design as section depth of 300mm.

Minimum steel

$$= (0.26 \times 2.9 \times 1000 \times (300 - 75 - 12/2)) / 500 = 330.252 \text{ mm}^2 \quad \text{C32/40 concrete}$$

Design to span simply supported over 1.0m void in ground (firm sub-soil)

w	(weight per metre run)	=	98.00 kN
L		=	1 m
M_{Ek}		$= 0 \times 0^2 / 8 =$	12.25 kNm
M_{Ed}		$= 1.35 \times 0 \times 0^2 / 8 =$	16.5 kNm
V_{Ek}		$= 0 / 2 =$	49 kN
V_{Ed}		$= 1.35 \times 0.167 =$	66.15 kN

Provide A393 to bottom of slab with 75mm cover



EC2 Ultimate Design - Singly Reinforced Section

MEd = 16.54 kNm (ULS)
VED = 66.15 kN (ULS)

Section Parameters:

Width, b = 1000 mm
Concrete cylinder strength, fck = 32 N/mm² (i.e.32N/mm² for C32/40)
Steel yield strength, fyk = 500 N/mm²
Height of section, H = 300 mm
Main Reinforcement dia = 10 mm
Transverse Reinforcement dia = 10 mm
Cover = 75 mm

Depth to tension reinforcement, d = 210 mm

$\gamma_{\text{concrete}} = 1.5$

Design compressive strength of concrete, fcd = $0.85 f_{ck} / \gamma_{\text{concrete}} = 18.13 \text{ N/mm}^2$

Maximum moment section can resist without comp steel = $0.167 \times f_{ck} \times b \times d^2 = 236 \text{ kNm}$

$k = MEd / (bd^2 f_{ck}) = 0.012$ but not > than 0.167
 $k = 0.01171875$

$z = d/2 \times (1 + \sqrt{1 - 3.53k}) = 208$ but not > 0.95d = 200
 $z = 200$

As Req'd = $MEd / (0.87 \times f_{yk} \times z) = 191 \text{ mm}^2$
Stress low, design based on minimum steel

As min = $0.26 \times f_{ctm} \times b \times d / f_{yk}$

Tensile cracking strength, fctm = $0.3 f_{ck}^{2/3} = 3.0 \text{ N/mm}^2$
As min = 330 mm²
As Req'd = 330 mm²

As max = $0.04 A_c = 12000 \text{ mm}^2$

As Prov = 393 mm²

H10's @ 150 =	523 mm ²
H12's @ 150 =	754 mm ²
H16's @ 150 =	1340 mm ²
H20's @ 150 =	2094 mm ²
H10's @ 200 =	393 mm ²
H10's @ 100 =	785 mm ²
H12's @ 200 =	565 mm ²
H16's @ 200 =	1005 mm ²

VED < VRdc

As/bd = 0.0019 < 0.02
As/bd = 0.0019

$k = 1 + (200/d)^{0.5} = 1.98$ < 2
 $k = 1.98$

$vRdc = (As/bd \times 100) \times f_{ck}^{1/3} = 1.82$

$VRdc = 0.12 \times k \times b \times d \times vRdc / 1000 = 90.42 \text{ kN}$

Min Stress, Vmin = $0.035 \times k \times 1.5 \times f_{ck}^{0.5} = 0.55 \text{ N/mm}^2$

$VRdm = Vmin \times b \times d / 1000 = 115.48 \text{ kN}$

Provide H10 @ 200 mesh in each base for minimum steel