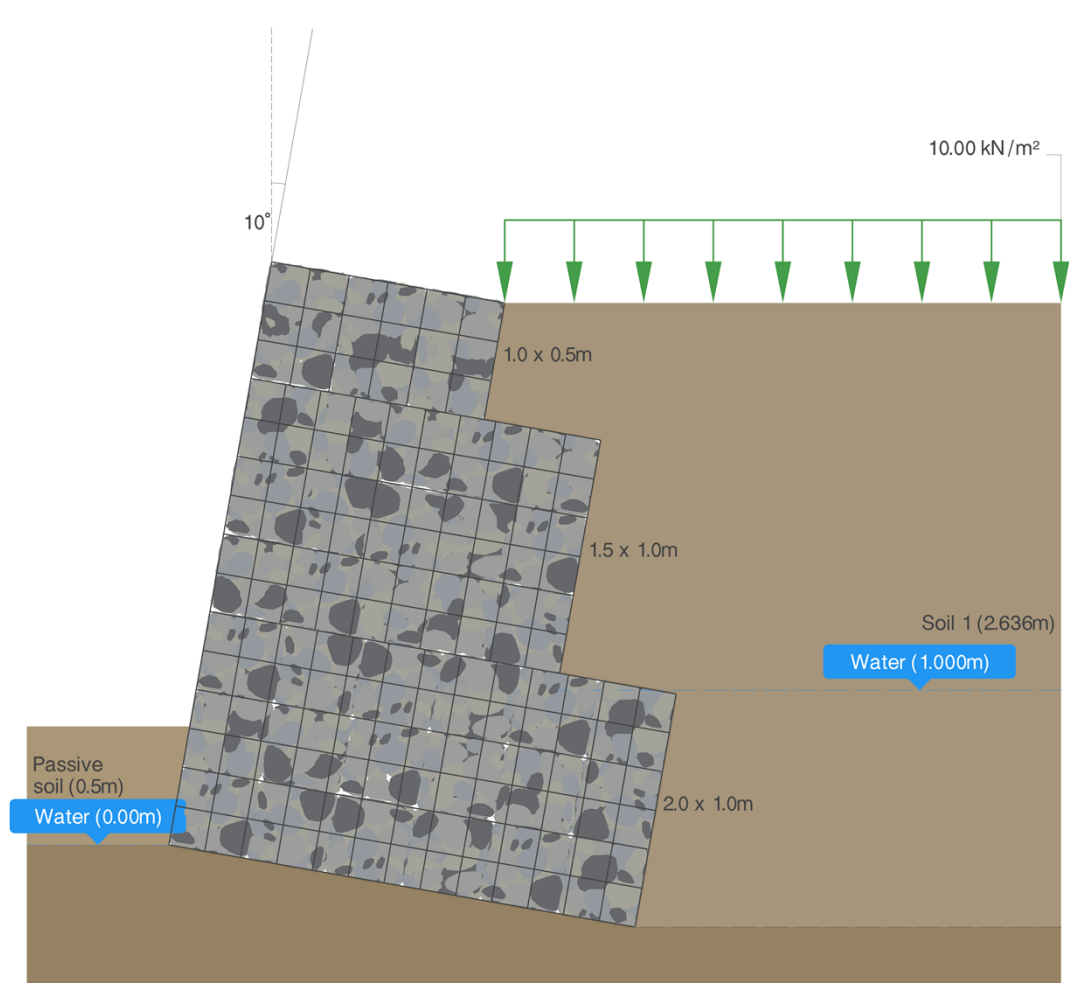


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## Gabion retaining wall

Design calculations guided by BS EN 1997-1:2004+A1:2013, the UK National Annex, BS 8002:2015 and other relevant publications.



### Gabion properties

| Description                                        | Value                    |
|----------------------------------------------------|--------------------------|
| Inclination of front face of wall, $\omega$        | 10.0 °                   |
| Infill material                                    | Slag                     |
| Design density, $\gamma_g$                         | 18.000 kN/m <sup>3</sup> |
| Internal friction between filled gabions, $\phi_g$ | 35.0 °                   |

### Structure details

| Gabion layer No | Width (m) | Height (m) | Offset (m) |
|-----------------|-----------|------------|------------|
| 3               | 1.0       | 0.5        | 0.0        |
| 2               | 1.5       | 1.0        | 0.0        |
| 1               | 2.0       | 1.0        | 0.0        |

|                                                                                                                                                          |            |  |             |                   |
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### Retained soil properties

| Layer | $\phi$ (°) | $\delta$ (°) | $\gamma_{\text{soil}}$ (kN/m <sup>3</sup> ) | $\gamma_{\text{sat}}$ (kN/m <sup>3</sup> ) | Height of layer $H_a$ (m) |
|-------|------------|--------------|---------------------------------------------|--------------------------------------------|---------------------------|
| 1     | 30.0       | 22.5         | 18.0                                        | 20.0                                       | 2.636                     |

### Passive soil properties

| Layer | $\phi$ (°) | $\delta$ (°) | $\gamma_{\text{soil}}$ (kN/m <sup>3</sup> ) | $\gamma_{\text{sat}}$ (kN/m <sup>3</sup> ) | Height of layer $H_p$ (m) |
|-------|------------|--------------|---------------------------------------------|--------------------------------------------|---------------------------|
| 1     | 30.0       | 22.5         | 18.0                                        | 20.0                                       | 0.5                       |

| Description               | Value |
|---------------------------|-------|
| Mobilisation factor (rpr) | 3.0   |

### Foundation soil properties

| Description                                              | Value                  |
|----------------------------------------------------------|------------------------|
| Soil condition                                           | Drained                |
| Angle of internal friction, $\phi'$                      | 35 °                   |
| Residual cohesion, $c'$                                  | 0 kN/m <sup>2</sup>    |
| Angle of surface friction, $\delta'$                     | 35 °                   |
| Bulk density, $\gamma_b$                                 | 18.0 kN/m <sup>3</sup> |
| Saturated density, $\gamma_s$                            | 20.0 kN/m <sup>3</sup> |
| User-defined allowable SLS bearing pressure, $q_a$       | 200 kN/m <sup>2</sup>  |
| SLS factor of safety against ultimate bearing resistance | 3                      |

### Water table properties

| Description                                        | Value                    |
|----------------------------------------------------|--------------------------|
| Depth of water from base on active side, $h_{wa}$  | 1.000 m                  |
| Depth of water from base on passive side, $h_{wp}$ | 0.000 m                  |
| Unit weight of water, $\gamma_w$                   | 10.000 kN/m <sup>3</sup> |

|                                                                                                                                                          |            |  |             |                   |
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## Loads

| Description  | Value                    |
|--------------|--------------------------|
| Surcharge, Q | 10.000 kN/m <sup>2</sup> |

## Design parameters

| Description                        | Value                                  |
|------------------------------------|----------------------------------------|
| Design Approach                    | Design Approach 1 - Combinations 1 & 2 |
| Pressure coefficient theory        | Eurocode 7 (Annex C.2)                 |
| Apply equation 6.5 of EN 1997-1    | No                                     |
| Apply no tension/middle third rule | Yes                                    |
| Presence of water table            | Yes                                    |

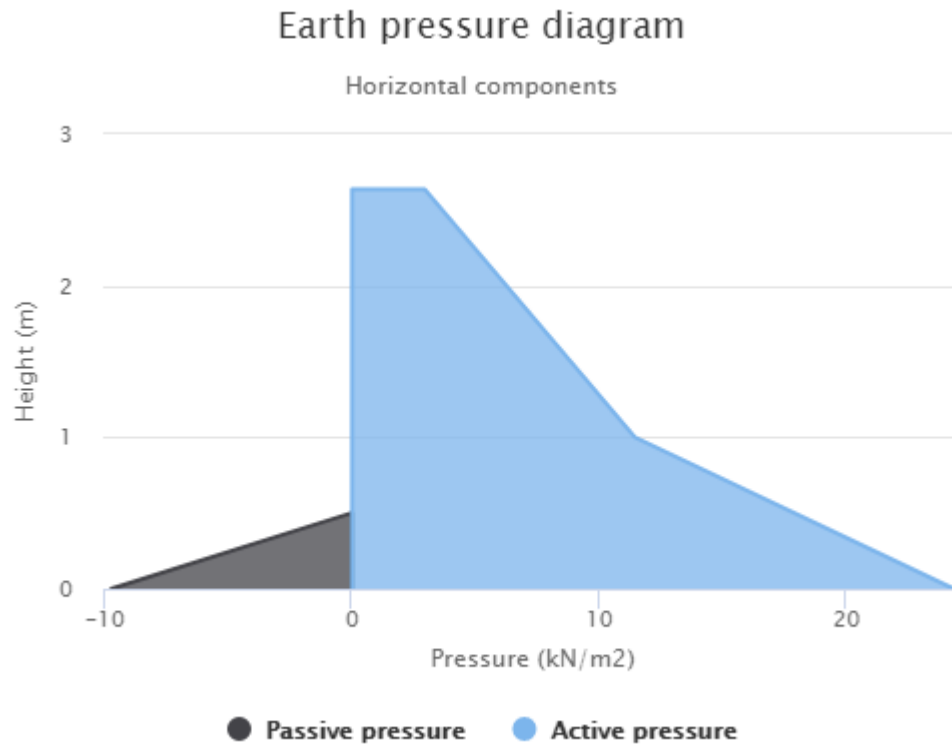
## Partial safety factors on actions

| Duration  | Action                   | Set  |     |     |
|-----------|--------------------------|------|-----|-----|
|           | Condition                | A1   | A2  | EQU |
| Permanent | Unfavourable $\gamma_G$  | 1.35 | 1.0 | 1.1 |
|           | Favourable $\gamma_{Gf}$ | 1.0  | 1.0 | 0.9 |
| Variable  | Unfavourable $\gamma_Q$  | 1.5  | 1.3 | 1.5 |
|           | Favourable $\gamma_{Qf}$ | 0.0  | 0.0 | 0.0 |

## Partial safety factors on soil parameters

| Material Property                                             | Set |      |     |
|---------------------------------------------------------------|-----|------|-----|
|                                                               | M1  | M2   | EQU |
| Angle of shearing resistance ( $\tan\phi'$ ) $\gamma_{\phi'}$ | 1.0 | 1.25 | 1.1 |
| Effective cohesion $\gamma_c$                                 | 1.0 | 1.25 | 1.1 |
| Undrained shear strength $\gamma_{cu}$                        | 1.0 | 1.4  | 1.2 |
| Weight density $\gamma_v$                                     | 1.0 | 1.0  | 1.0 |

|                                                                                                                                                            |            |  |             |                   |
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## Geotechnical analysis assumptions and limitations

Active and passive pressure/resistance co-efficients are based on EN 1997-1 Annex C2.

Active pressures are calculated on the inclined plane through the rear top edge of the top gabion to the rear bottom edge of the lowest gabion.

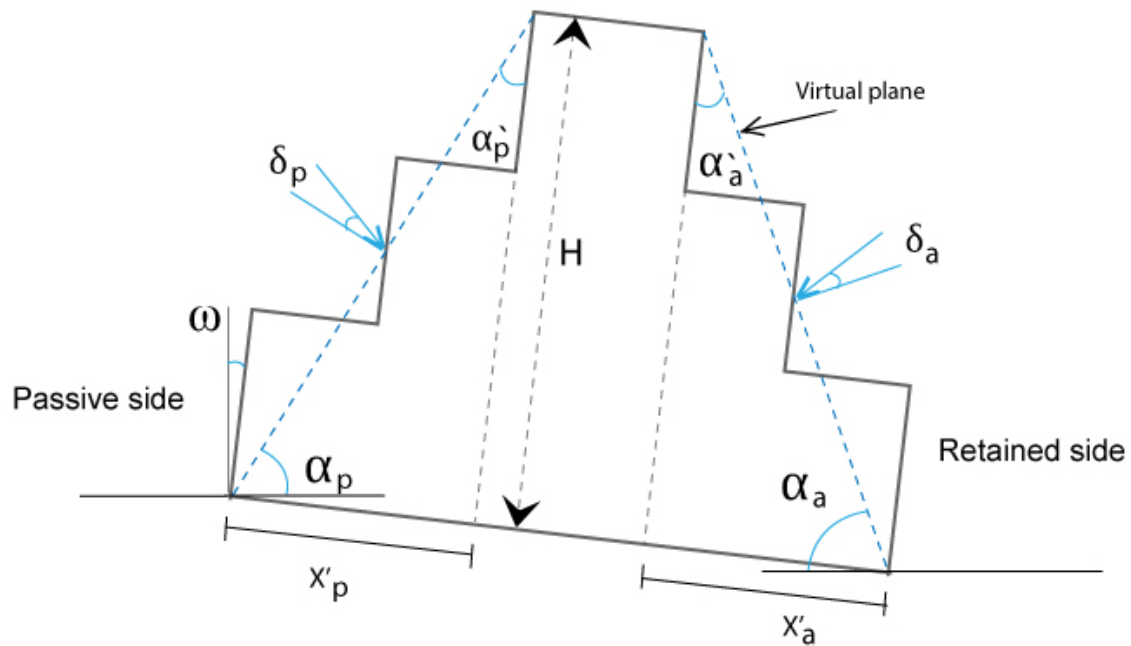
Active and passive co-efficients are calculated normal to the relevant virtual back. If the passive soil height is less than or equal to 1.25 times the vertical height of lowest gabion layer, the passive resistance coefficient is calculated normal to the gabion face itself.

The presence of water levels above the foundation level implies uplift water pressure on the base of the wall.

The overall base sliding is checked on the horizontal plane.

This software is intended to assist the design of retaining walls to resist local failure of the wall-soil system. It does not deal with the overall stability of any slope or land form into which the wall may be installed. If appropriate refer to slope stability software or specialist advice.

## Properties required to calculate pressure coefficients



|                                                                                          |                                                                                         |
|------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| Inclination of front face of wall                                                        | $\omega = 10.0^\circ$                                                                   |
| Total height of gabion wall                                                              | $H = 2.5$                                                                               |
| Total width of gabion                                                                    | $B = 2.00 \text{ m}$                                                                    |
| Offset from rear top edge of the top gabion to the rear bottom edge of the lowest gabion | $X'_a = 1.000 \text{ m}$                                                                |
| Offset from front top edge of the top gabion to front bottom edge of the lowest gabion   | $X'_p = 0.000 \text{ m}$                                                                |
| Effective angle between gabion face and the active virtual back                          | $\alpha'_a = \tan^{-1}\left(\frac{X'_a}{H}\right) = 21.8^\circ$                         |
| Inclination of virtual back to the horizontal                                            | $\alpha_a = 90 - \alpha'_a + \omega = 78.2^\circ$                                       |
| Effective angle between gabion face and the passive virtual back                         | $\alpha'_p = 0^\circ$                                                                   |
| Angle of passive virtual back of wall to horizontal                                      | $\alpha_p = 90 - \omega = 80.0^\circ$                                                   |
| Retained soil height                                                                     | $H_{\text{retained}} = \sqrt{X'^2_a + H^2} \cdot \sin \alpha_a = 2.636 \text{ m}$       |
| Height of wall from toe to front edge of top gabion                                      | $H_{\text{toe}} = \sqrt{X'^2_p + H^2} \cdot \cos(\omega + \alpha'_p) = 2.462 \text{ m}$ |

|                                                                                                                                                            |            |  |             |                   |
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Note: The coefficients and angle of resultant for soil layers are tabulated below.

Angle of pressure resultant to the horizontal - active ( $\delta_a - \omega + \alpha'_a$ ) °

| Layer | SLS    | EQU    | ULS SET1 | ULS SET2 |
|-------|--------|--------|----------|----------|
| 1     | 34.301 | 32.436 | 34.301   | 30.135   |

Angle of pressure resultant to the horizontal - passive ( $\delta_p + \omega + \alpha'_p$ ) °

| Layer | SLS  | EQU    | ULS SET1 | ULS SET2 |
|-------|------|--------|----------|----------|
| 1     | 32.5 | 30.634 | 32.5     | 28.334   |

#### Active pressure coefficients

Resultant pressure coefficients as applied to the virtual back

| Layer | SLS      |          | EQU      |          | ULS SET1 |          | ULS SET2 |          |
|-------|----------|----------|----------|----------|----------|----------|----------|----------|
|       | $k_{ya}$ | $k_{qa}$ | $k_{ya}$ | $k_{qa}$ | $k_{ya}$ | $k_{qa}$ | $k_{ya}$ | $k_{qa}$ |
| 1     | 0.349    | 0.357    | 0.378    | 0.386    | 0.349    | 0.357    | 0.417    | 0.426    |

$K_{ya}$  - Active earth pressure coefficient for soil weight.

$K_{qa}$  - Active earth pressure coefficient for surcharge.

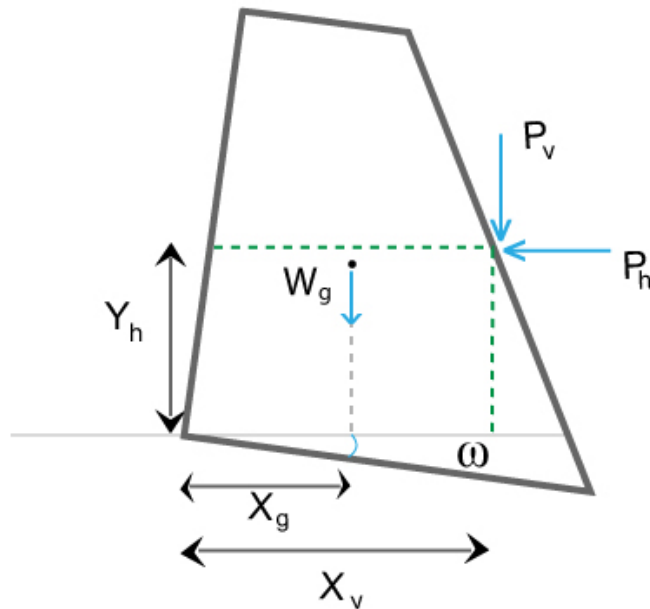
#### Passive pressure coefficients

Resultant pressure coefficients as applied to the face of lowest gabion

| Layer | SLS      | EQU      | ULS SET1 | ULS SET2 |
|-------|----------|----------|----------|----------|
|       | $k_{yp}$ | $k_{yp}$ | $k_{yp}$ | $k_{yp}$ |
| 1     | 3.845    | 3.432    | 3.845    | 2.978    |

|                                                                                                                                                            |            |  |             |                   |
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Forces on structure<sup>1</sup> (idealised and simplified)



| Description                                                  | Symbol   | SLS    | EQU    | ULS SET1 | ULS SET2 | Units |
|--------------------------------------------------------------|----------|--------|--------|----------|----------|-------|
| Total horizontal earth pressure                              | $P_h$    | 17.249 | 18.661 | 16.883   | 21.100   | kN    |
| Water pressure at base                                       | $P_w$    | 5.000  | 5.000  | 5.000    | 5.000    | kN    |
| <b>Total earth and water pressure above front edge</b>       |          |        |        |          |          |       |
| horizontal component                                         | $P_{hs}$ | 22.249 | 23.661 | 21.883   | 26.100   | kN/m  |
| vertical component                                           | $P_{vs}$ | 10.962 | 11.859 | 11.517   | 12.248   | kN/m  |
| centroid distance above front edge                           | $Y_{hs}$ | 0.438  | 0.445  | 0.435    | 0.457    | m     |
| centroid distance behind front edge                          | $X_{vs}$ | 1.806  | 1.804  | 1.806    | 1.802    | m     |
| <b>Total pressure due to surcharge above front edge</b>      |          |        |        |          |          |       |
| horizontal component                                         | $P_{hq}$ | 7.936  | 8.586  | 7.768    | 9.708    | kN/m  |
| vertical component                                           | $P_{vq}$ | 5.043  | 5.456  | 5.299    | 5.636    | kN/m  |
| centroid distance above front edge                           | $Y_{hq}$ | 0.971  | 0.971  | 0.971    | 0.971    | m     |
| centroid distance behind front edge                          | $X_{vq}$ | 1.694  | 1.694  | 1.694    | 1.694    | m     |
| <b>Total passive resistance above front edge<sup>2</sup></b> |          |        |        |          |          |       |
| horizontal component                                         | $P_{hp}$ | 2.432  | 2.215  | 2.432    | 1.966    | kN/m  |
| vertical component                                           | $P_{vp}$ | 1.549  | 1.312  | 1.549    | 1.060    | kN/m  |
| centroid distance above front edge                           | $Y_{hp}$ | 0.167  | 0.167  | 0.167    | 0.167    | m     |
| <b>Uplift water pressure on base</b>                         |          |        |        |          |          |       |
| uplift water force                                           | $P_{up}$ | 10.000 | 10.000 | 10.000   | 10.000   | kN/m  |
| centroid distance behind toe                                 | $T_{up}$ | 1.333  | 1.333  | 1.333    | 1.333    | m     |

|                                                                                                                                                          |            |  |             |                   |
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1: These loads and resistances incorporate partial safety factors for soil strength but not partial safety factors for loads

2: Passive resistances incorporate the input passive resistance mobilisation factor.

## Wall stability checks

### SLS bearing checks

BS EN 1997-1 cl. 6.6.2(16) and 200 kN/m<sup>2</sup> as user-defined safe bearing pressure.

### Overturning moments about front edge

|                                                                |                                                                                                                      |
|----------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|
| Overturning moment due to retained soil - horizontal component | $M_{hs} = \gamma_G \cdot P_{hs} \cdot Y_{hs} = 9.529 \text{ kNm/m}$                                                  |
| Overturning moment due to surcharge - horizontal component     | $M_{hq} = \gamma_Q \cdot P_{hq} \cdot Y_{hq} = 7.539 \text{ kNm/m}$                                                  |
| Overturning moment due to retained soil - vertical component   | $M_{vs} = -\gamma_G \cdot P_{vs} \cdot X_{vs} = -20.801 \text{ kNm/m}$                                               |
| Overturning moment due to surcharge - vertical component       | $M_{vq} = -\gamma_Q \cdot P_{vq} \cdot X_{vq} = -8.978 \text{ kNm}$                                                  |
| Overturning moment due to uplift of water                      | $M_{up} = \gamma_G \cdot P_{up} \cdot T_{up} = 13.333 \text{ kNm/m}$                                                 |
| Total overturning moment                                       | $M_o = M_{hs} + M_{hq} + M_{up} + M_{Fh,G} + M_{Fh,Q} + M_{vs} + M_{vq} + M_{Fv,G} + M_{Fv,Q} = 0.622 \text{ kNm/m}$ |

### Restoring moment

|                                            |                                                                |
|--------------------------------------------|----------------------------------------------------------------|
| Restoring moment due to self weight        | $M_{wg} = \gamma_G \cdot W_g \cdot X_g = 73.502 \text{ kNm/m}$ |
| Restoring moment due to passive resistance | $M_{hp} = P_{hp} \cdot Y_{hp} = 0.405 \text{ kNm/m}$           |
| Total restoring moment                     | $M_r = M_{wg} + M_{hp} = 73.907 \text{ kNm/m}$                 |

✓ Overturning moment 0.622 kNm is less than the restoring moment 73.907 kNm.

|                                       |                                                                                  |
|---------------------------------------|----------------------------------------------------------------------------------|
| Net vertical force on foundation soil | $V_d = W_g + P_{vs} + P_{vq} + P_{up} + F_{v,G} + F_{v,Q} = 78.816 \text{ kN/m}$ |
| Total Horizontal force                | $H_d = P_{hs} + P_{hq} + F_{h,Q} + F_{h,G} = 29.651 \text{ kN/m}$                |
| Eccentricity                          | $e = 0.5 \cdot B - \frac{\sum M_r - \sum M_o}{\sum W} = 0.070 \text{ m}$         |

✓ Eccentricity lies within the middle third ( $B/6 = 0.333 \text{ m}$ ), hence passes.

|                                           |                                                                                                      |
|-------------------------------------------|------------------------------------------------------------------------------------------------------|
| Pressure at toe based on linear behaviour | $\sigma_{toe} = \frac{\sum W}{B} \cdot \left(1 + \frac{6 \cdot e}{B}\right) = 47.704 \text{ kN/m}^2$ |
|-------------------------------------------|------------------------------------------------------------------------------------------------------|

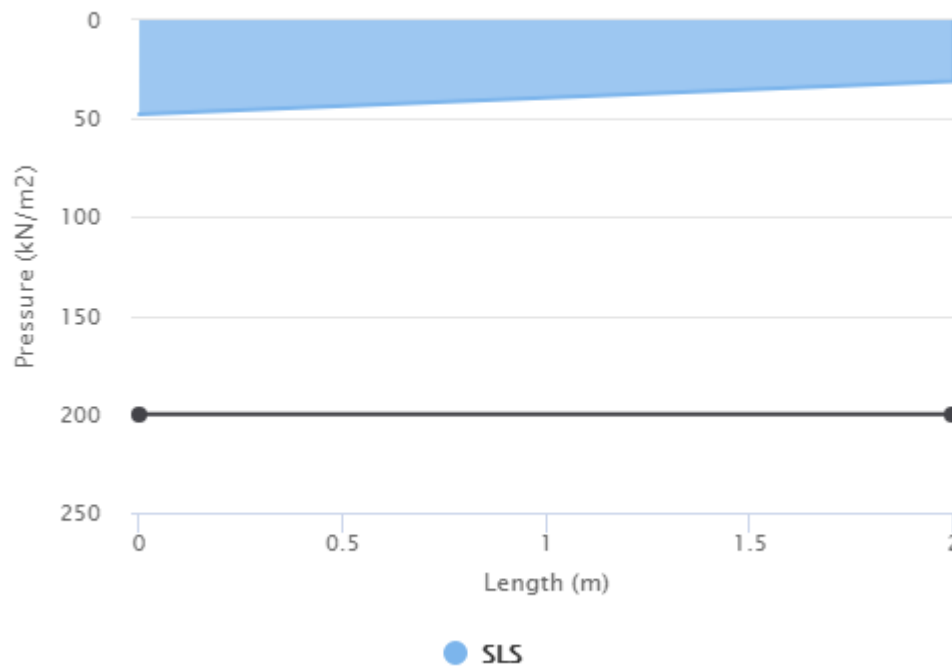


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Pressure at heel based on linear behaviour

$$\sigma_{\text{heel}} = \frac{\Sigma W}{B} \cdot \left(1 - \frac{6 \cdot e}{B}\right) = 31.112 \text{ kN/m}^2$$

### Bearing pressure diagram



✓ Bearing pressure 47.704 kN/m² is less than the allowable SLS bearing pressure 200 kN/m².

SLS Bearing capacity based on equivalent uniform pressure and resistance

Annex D of EC7

|                                          |                                                                                                                       |
|------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|
| Height of passive soil at toe            | $h_p = 0.500 \text{ m}$                                                                                               |
| Height of passive soil above water level | $h_{s,p} = h_p - h_{w,p1} = 0.500 \text{ m}$                                                                          |
| Vertical effective stress                | $q'_p = \Sigma \gamma_s \cdot h_{s,p} + \Sigma (\gamma_{\text{sat}} - \gamma_w) \cdot h_{w,p} = 9.000 \text{ kN/m}^2$ |
| Effective length                         | $l_{\text{eff}} = 1 \text{ m}$                                                                                        |
| Effective width                          | $b_{\text{eff}} = B - 2 \cdot e = 1.860 \text{ m}$                                                                    |
| Equivalent uniform pressure              | $\sigma_{\text{equ}} = \frac{V_d}{l_{\text{eff}} \cdot b_{\text{eff}}} = 42.382 \text{ kN/m}^2$                       |

Bearing capacity factors

$$N_q = e^{\pi \cdot \tan \phi'_d} \cdot \tan^2 \left( 45 + \frac{\phi'_d}{2} \right) = 33.296$$

$$N_c = (N_q - 1) \cdot \cot \phi'_d = 46.124$$

$$N_\gamma = 2 \cdot (N_q - 1) \cdot \tan \phi'_d = 45.228$$

|                                                                                                                                                          |            |  |             |                   |
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#### Load inclination factors

The retaining wall design assumes semi-infinite base length, thus the value of m is 2.

$$i_q = \left(1 - \frac{H}{V_d + A' \cdot C_d \cdot \cot \phi'_d}\right)^m = 0.389$$

$$i_v = \left(1 - \frac{H}{V_d + A' \cdot C_d \cdot \cot \phi'_d}\right)^{m+1} = 0.243$$

$$i_c = i_q - \frac{1 - i_q}{N_c \cdot \tan \phi'_d} = 0.370$$

#### Base inclination factors

$b_q, b_v, b_c$  are equal to 1 as the base is not inclined.

#### Base shape factors

$S_q, S_v, S_c$  are equal to 1 because the length is unlimited.

|                                                                  |                                                                                                                                  |
|------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| Unit weight of submerged soil                                    | $\gamma' = \gamma_{sat} - \gamma_w = 10.000 \text{ kN/m}^3$                                                                      |
| Cohesive component                                               | $q_c = C_d \cdot S_c \cdot i_c \cdot b_c \cdot N_c = 0.000 \text{ kN/m}^2$                                                       |
| Overburden component                                             | $q_o = q' \cdot N_q \cdot S_q \cdot i_q \cdot b_q = 89.848 \text{ kN/m}^2$                                                       |
| Density component                                                | $q_\gamma = 0.5 \cdot \gamma' \cdot b_{eff} \cdot S_\gamma \cdot i_\gamma \cdot b_\gamma \cdot N_\gamma = 77.930 \text{ kN/m}^2$ |
| Ultimate bearing capacity                                        | $q_{Rd} = q_c + q_o + q_\gamma = 167.778 \text{ kN/m}^2$                                                                         |
| FoS against bearing failure (Cl. 6.6.2(16) of BS EN 1997-1:2004) | $= \frac{q_{Rd}}{\sigma_{equ}} = 3.959$                                                                                          |

✓ Factor of safety against ultimate bearing failure 3.959 is greater than the required 3.

#### ULS combination - EQU

#### Overturning check about front edge

##### Overturning moment

|                                                                |                                                                        |
|----------------------------------------------------------------|------------------------------------------------------------------------|
| Overturning moment due to retained soil - horizontal component | $M_{hs} = \gamma_G \cdot P_{hs} \cdot Y_{hs} = 11.594 \text{ kNm/m}$   |
| Overturning moment due to surcharge - horizontal component     | $M_{hq} = \gamma_Q \cdot P_{hq} \cdot Y_{hq} = 12.500 \text{ kNm/m}$   |
| Overturning moment due to retained soil - vertical component   | $M_{vs} = -\gamma_G \cdot P_{vs} \cdot X_{vs} = -23.533 \text{ kNm/m}$ |
| Overturning moment due to surcharge - vertical component       | $M_{vq} = -\gamma_Q \cdot P_{vq} \cdot X_{vq} = -13.867 \text{ kNm}$   |

|                                                                                                                                                             |            |  |             |                   |
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Overturning moment due to uplift of water

$$M_{up} = \gamma_G \cdot P_{up} \cdot T_{up} = 14.667 \text{ kNm/m}$$

Total overturning moment

$$M_o = M_{hs} + M_{hq} + M_{up} + M_{Fh,G} + M_{Fh,Q} + M_{vs} + M_{vq} + M_{Fv,G} + M_{Fv,Q} = 1.360 \text{ kNm/m}$$

Restoring moment

Restoring moment due to self weight

$$M_{wg} = \gamma_{Gf} \cdot W_g \cdot X_g = 66.152 \text{ kNm/m}$$

Restoring moment due to passive resistance

$$M_{hp} = P_{hp} \cdot Y_{hp} = 0.369 \text{ kNm/m}$$

Total restoring moment

$$M_r = M_{wg} + M_{hp} = 66.521 \text{ kNm/m}$$

✓ Overturning moment 1.36 kNm is less than the restoring moment 66.521 kNm.

Sliding check

Sliding force

Horizontal component due to retained soil

$$P_{hs} = \gamma_G \cdot P_{hs} = 26.027 \text{ kN/m}$$

Horizontal component due to surcharge

$$P_{hq} = \gamma_Q \cdot P_{hq} = 12.879 \text{ kN/m}$$

Total Horizontal force

$$H_d = P_{hs} + P_{hq} + F_{h,Q} + F_{h,G} = 38.907 \text{ kN/m}$$

Sliding resistance on base plane

BS EN 1997-1 Eq. 6.2 - Cl. 6.5.3

Frictional factor

$$\mu = \frac{\tan \phi_b}{\gamma_{\phi}} = 0.637$$

Vertical component due to self weight

$$W_g = \gamma_{Gf} \cdot W_g = 64.800 \text{ kN/m}$$

Vertical component due to retained soil

$$P_{vs} = \gamma_G \cdot P_{vs} = 13.045 \text{ kN/m}$$

Vertical component due to surcharge

$$P_{vq} = \gamma_Q \cdot P_{vq} = 8.185 \text{ kN/m}$$

Water uplift force on base

$$P_{up} = -\gamma_{Gf} \cdot P_{up} = -9.000 \text{ kN/m}$$

Net Vertical force on foundation soil

$$V_d = W_g + P_{vs} + P_{vq} + P_{up} + F_{v,Q} + F_{v,G} = 77.030 \text{ kN/m}$$

Total sliding resistance

$$R_d = V_d \cdot \mu + P_t + P_{hp} = 51.248 \text{ kN/m}$$

✓ Sliding force 38.907 kN/m is less than the sliding resistance 51.248 kN/m.

Bearing pressure check

Net vertical force on foundation soil

$$V_d = W_g + P_{vs} + P_{vq} + P_{up} + F_{v,G} + F_{v,Q} = 89.430 \text{ kN/m}$$

|                                                                                                                                                             |            |  |             |                   |
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Eccentricity

$$e = 0.5 \cdot B - \frac{\Sigma Mr - \Sigma Mo}{\Sigma W} = 0.271 \text{ m}$$

✓ Eccentricity lies within the middle third ( $B/6 = 0.333 \text{ m}$ ), hence passes.

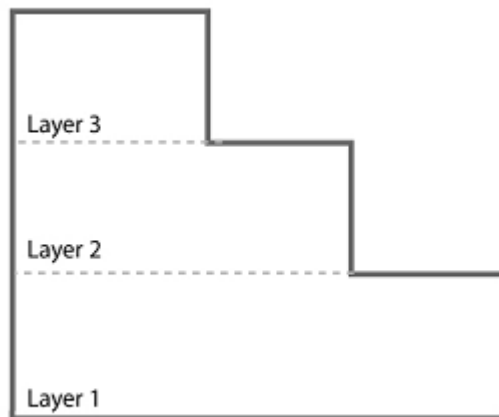
Pressure at toe based on linear behaviour

$$\sigma_{\text{toe}} = \frac{\Sigma W}{B} \cdot \left( 1 + \frac{6 \cdot e}{B} \right) = 81.118 \text{ kN/m}^2$$

Pressure at heel based on linear behaviour

$$\sigma_{\text{heel}} = \frac{\Sigma W}{B} \cdot \left( 1 - \frac{6 \cdot e}{B} \right) = 8.312 \text{ kN/m}^2$$

Stability checks at each gabion layer



Design friction between gabion layer

$$\mu_b = 0.637$$

Stability check below layer 2

Total width of gabion

$$B = 1.50 \text{ m}$$

Height of wall above front edge

$$H_{\text{toe}} = 1.477 \text{ m}$$

Overturning moment about front edge

Overturning moment due to retained soil - horizontal component

$$M_{hs} = \gamma_G \cdot P_{hs} \cdot Y_{hs} = 2.015 \text{ kNm/m}$$

Overturning moment due to surcharge - horizontal component

$$M_{hq} = \gamma_Q \cdot P_{hq} \cdot Y_{hq} = 3.986 \text{ kNm/m}$$

Overturning moment due to retained soil - vertical component

$$M_{vs} = -\gamma_G \cdot P_{vs} \cdot X_{vs} = -6.715 \text{ kNm/m}$$

|                                                                                                                                                            |            |  |             |            |
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Overturning moment  
due to surcharge -  
vertical component

$$M_{vq} = -\gamma_Q \cdot P_{vq} \cdot X_{vq} = -6.381 \text{ kNm}$$

Total overturning  
moment

$$M_o = M_{hs} + M_{hq} + M_{up} + M_{Fh,G} + M_{Fh,Q} + M_{vs} + M_{vq} + M_{Fv,G} + M_{Fv,Q} = -7.095 \text{ kNm/m}$$

Restoring moment

Restoring moment due to self  
weight

$$M_{wg} = \gamma_{Gf} \cdot W_g \cdot X_g = 25.805 \text{ kNm/m}$$

Total restoring moment

$$M_r = M_{wg} + M_{hp} = 25.805 \text{ kNm/m}$$

**i** There is no resultant overturning moment about the front edge, thus the factor of safety for overturning is infinite.

Sliding force

Parallel component due to  
retained soil

$$P_{hs} = \gamma_G \cdot P_{hs} \cdot \cos\omega = 7.605 \text{ kN/m}$$

Parallel component due to  
surcharge

$$P_{hq} = \gamma_Q \cdot P_{hq} \cdot \cos\omega = 7.527 \text{ kN/m}$$

Total Parallel force

$$H_d = P_{hs} + P_{hq} + F_{h,Q} + F_{h,G} = 15.132 \text{ kN/m}$$

Sliding resistance

Normal component due to self  
weight

$$W_g = \gamma_{Gf} \cdot W_g \cdot \cos\omega = 31.908 \text{ kN/m}$$

Normal component due to  
retained soil

$$P_{vs} = \gamma_G \cdot P_{vs} \cdot \cos\omega = 4.833 \text{ kN/m}$$

Normal component due to  
surcharge

$$P_{vq} = \gamma_Q \cdot P_{vq} \cdot \cos\omega = 4.783 \text{ kN/m}$$

Net Normal force on  
foundation soil

$$V_d = W_g + P_{vs} + P_{vq} + P_{up} + F_{v,Q} + F_{v,G} = 41.524 \text{ kN/m}$$

Total sliding resistance

$$R_d = V_d \cdot \mu + P_t + P_{hp} = 26.432 \text{ kN/m}$$

✓ Sliding force 15.132 kN/m is less than the sliding resistance 26.432 kN/m.

Eccentricity

$$e = 0.5 \cdot B - \frac{\sum M_r - \sum M_o}{\sum W} = -0.164 \text{ m}$$

✓ Eccentricity lies within the middle third ( $B/6 = 0.250 \text{ m}$ ), hence passes.

Stability check below layer 3

Total width of gabion

$$B = 1.00 \text{ m}$$

Height of wall above front edge

$$H_{toe} = 0.492 \text{ m}$$

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#### Overturning moment about front edge

|                                                                |                                                                                                                       |
|----------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|
| Overturning moment due to retained soil - horizontal component | $M_{hs} = \gamma_G \cdot P_{hs} \cdot Y_{hs} = -0.007 \text{ kNm/m}$                                                  |
| Overturning moment due to surcharge - horizontal component     | $M_{hq} = \gamma_Q \cdot P_{hq} \cdot Y_{hq} = 0.175 \text{ kNm/m}$                                                   |
| Overturning moment due to retained soil - vertical component   | $M_{vs} = -\gamma_G \cdot P_{vs} \cdot X_{vs} = -0.462 \text{ kNm/m}$                                                 |
| Overturning moment due to surcharge - vertical component       | $M_{vq} = -\gamma_Q \cdot P_{vq} \cdot X_{vq} = -1.427 \text{ kNm}$                                                   |
| Total overturning moment                                       | $M_o = M_{hs} + M_{hq} + M_{up} + M_{Fh,G} + M_{Fh,Q} + M_{vs} + M_{vq} + M_{Fv,G} + M_{Fv,Q} = -1.722 \text{ kNm/m}$ |

#### Restoring moment

|                                     |                                                                  |
|-------------------------------------|------------------------------------------------------------------|
| Restoring moment due to self weight | $M_{wg} = \gamma_{Gf} \cdot W_g \cdot X_g = 4.340 \text{ kNm/m}$ |
| Total restoring moment              | $M_r = M_{wg} + M_{hp} = 4.340 \text{ kNm/m}$                    |

**i** There is no resultant overturning moment about the front edge, thus the factor of safety for overturning is infinite.

#### Sliding force

|                                         |                                                                        |
|-----------------------------------------|------------------------------------------------------------------------|
| Parallel component due to retained soil | $P_{hs} = \gamma_G \cdot P_{hs} \cdot \cos\omega = 0.754 \text{ kN/m}$ |
| Parallel component due to surcharge     | $P_{hq} = \gamma_Q \cdot P_{hq} \cdot \cos\omega = 2.370 \text{ kN/m}$ |
| Total Parallel force                    | $H_d = P_{hs} + P_{hq} + F_{h,Q} + F_{h,G} = 3.123 \text{ kN/m}$       |

#### Sliding resistance

|                                       |                                                                                 |
|---------------------------------------|---------------------------------------------------------------------------------|
| Normal component due to self weight   | $W_g = \gamma_{Gf} \cdot W_g \cdot \cos\omega = 7.977 \text{ kN/m}$             |
| Normal component due to retained soil | $P_{vs} = \gamma_G \cdot P_{vs} \cdot \cos\omega = 0.479 \text{ kN/m}$          |
| Normal component due to surcharge     | $P_{vq} = \gamma_Q \cdot P_{vq} \cdot \cos\omega = 1.506 \text{ kN/m}$          |
| Net Normal force on foundation soil   | $V_d = W_g + P_{vs} + P_{vq} + P_{up} + F_{v,Q} + F_{v,G} = 9.962 \text{ kN/m}$ |
| Total sliding resistance              | $R_d = V_d \cdot \mu + P_t + P_{hp} = 6.341 \text{ kN/m}$                       |

✓ Sliding force 3.123 kN/m is less than the sliding resistance 6.341 kN/m.

|                                                                                                                                                          |            |  |             |                   |
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Eccentricity

$$e = 0.5 \cdot B - \frac{\Sigma M_r - \Sigma M_o}{\Sigma W} = -0.174 \text{ m}$$

✓ Eccentricity lies within the middle third ( $B/6 = 0.167 \text{ m}$ ), hence passes.

i No tension is allowed to develop beneath the base of the wall.

## Design Approach 1 - Combination 1 (A1 + M1 + R1)

### Overturning check

Overturning moments about front edge

|                                                                |                                                                                                                      |
|----------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|
| Overturning moment due to retained soil - horizontal component | $M_{hs} = \gamma_G \cdot P_{hs} \cdot Y_{hs} = 12.863 \text{ kNm/m}$                                                 |
| Overturning moment due to surcharge - horizontal component     | $M_{hq} = \gamma_Q \cdot P_{hq} \cdot Y_{hq} = 11.309 \text{ kNm/m}$                                                 |
| Overturning moment due to retained soil - vertical component   | $M_{vs} = -\gamma_G \cdot P_{vs} \cdot X_{vs} = -28.081 \text{ kNm/m}$                                               |
| Overturning moment due to surcharge - vertical component       | $M_{vq} = -\gamma_Q \cdot P_{vq} \cdot X_{vq} = -13.467 \text{ kNm}$                                                 |
| Overturning moment due to uplift of water                      | $M_{up} = \gamma_G \cdot P_{up} \cdot T_{up} = 18.000 \text{ kNm/m}$                                                 |
| Total overturning moment                                       | $M_o = M_{hs} + M_{hq} + M_{up} + M_{Fh,G} + M_{Fh,Q} + M_{vs} + M_{vq} + M_{Fv,G} + M_{Fv,Q} = 0.623 \text{ kNm/m}$ |

### Restoring moment

|                                            |                                                                   |
|--------------------------------------------|-------------------------------------------------------------------|
| Restoring moment due to self weight        | $M_{wg} = \gamma_{Gf} \cdot W_g \cdot X_g = 73.502 \text{ kNm/m}$ |
| Restoring moment due to passive resistance | $M_{hp} = P_{hp} \cdot Y_{hp} = 0.405 \text{ kNm/m}$              |
| Total restoring moment                     | $M_r = M_{wg} + M_{hp} = 73.907 \text{ kNm/m}$                    |

✓ Overturning moment 0.623 kNm is less than the restoring moment 73.907 kNm.

### Sliding check

Sliding force

|                                           |                                                                   |
|-------------------------------------------|-------------------------------------------------------------------|
| Horizontal component due to retained soil | $P_{hs} = \gamma_G \cdot P_{hs} = 29.542 \text{ kN/m}$            |
| Horizontal component due to surcharge     | $P_{hq} = \gamma_Q \cdot P_{hq} = 11.652 \text{ kN/m}$            |
| Total Horizontal force                    | $H_d = P_{hs} + P_{hq} + F_{h,Q} + F_{h,G} = 41.194 \text{ kN/m}$ |

|                                                                                                                                                          |            |  |             |            |
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Sliding resistance on base plane

BS EN 1997-1 Eq. 6.2 - Cl. 6.5.3

|                                         |                                                                                  |
|-----------------------------------------|----------------------------------------------------------------------------------|
| Frictional factor                       | $\mu = \frac{\tan \phi_b}{\gamma \phi'} = 0.700$                                 |
| Vertical component due to self weight   | $W_g = \gamma_{Gf} \cdot W_g = 72.000 \text{ kN/m}$                              |
| Vertical component due to retained soil | $P_{vs} = \gamma_G \cdot P_{vs} = 15.548 \text{ kN/m}$                           |
| Vertical component due to surcharge     | $P_{vq} = \gamma_Q \cdot P_{vq} = 7.949 \text{ kN/m}$                            |
| Water uplift force on base              | $P_{up} = -\gamma_{Gf} \cdot P_{up} = -10.000 \text{ kN/m}$                      |
| Net Vertical force on foundation soil   | $V_d = W_g + P_{vs} + P_{vq} + P_{up} + F_{v,Q} + F_{v,G} = 85.497 \text{ kN/m}$ |
| Total sliding resistance                | $R_d = V_d \cdot \mu + P_t + P_{hp} = 62.298 \text{ kN/m}$                       |

✓ Sliding force 41.194 kN/m is less than the sliding resistance 62.298 kN/m.

Bearing pressure check

|                                       |                                                                                   |
|---------------------------------------|-----------------------------------------------------------------------------------|
| Net vertical force on foundation soil | $V_d = W_g + P_{vs} + P_{vq} + P_{up} + F_{v,G} + F_{v,Q} = 107.197 \text{ kN/m}$ |
| Eccentricity                          | $e = 0.5 \cdot B - \frac{\sum M_r - \sum M_o}{\sum W} = 0.316 \text{ m}$          |

✓ Eccentricity lies within the middle third ( $B/6 = 0.333 \text{ m}$ ), hence passes.

Ultimate bearing capacity

Eq. 6.1 of cl. 6.5.2.1 (Annex D)

|                                          |                                                                                                            |
|------------------------------------------|------------------------------------------------------------------------------------------------------------|
| Height of passive soil at toe            | $h_p = 0.500 \text{ m}$                                                                                    |
| Height of passive soil above water level | $h_{s,p} = h_p - h_{w,p1} = 0.500 \text{ m}$                                                               |
| Vertical effective stress                | $q'_p = \sum \gamma_s \cdot h_{s,p} + \sum (\gamma_{sat} - \gamma_w) \cdot h_{w,p} = 9.000 \text{ kN/m}^2$ |
| Effective width                          | $b_{eff} = B - 2 \cdot e = 1.367 \text{ m}$                                                                |
| Equivalent uniform pressure              | $\sigma_{equ} = \frac{V_d}{l_{eff} \cdot b_{eff}} = 78.402 \text{ kN/m}^2$                                 |

Bearing capacity factors

$$N_q = e^{\pi \cdot \tan \phi'_d} \cdot \tan^2 \left( 45 + \frac{\phi'_d}{2} \right) = 33.296$$

$$N_c = (N_q - 1) \cdot \cot \phi'_d = 46.124$$

$$N_\gamma = 2 \cdot (N_q - 1) \cdot \tan \phi'_d = 45.228$$



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#### Load inclination factors

The retaining wall design assumes semi-infinite base length, thus the value of m is 2.

$$i_q = \left(1 - \frac{H}{V_d + A' \cdot C_d \cdot \cot \phi'_d}\right)^m = 0.379$$

$$i_\gamma = \left(1 - \frac{H}{V_d + A' \cdot C_d \cdot \cot \phi'_d}\right)^{m+1} = 0.233$$

$$i_c = i_q - \frac{1 - i_q}{N_c \cdot \tan \phi'_d} = 0.360$$

#### Base inclination factors

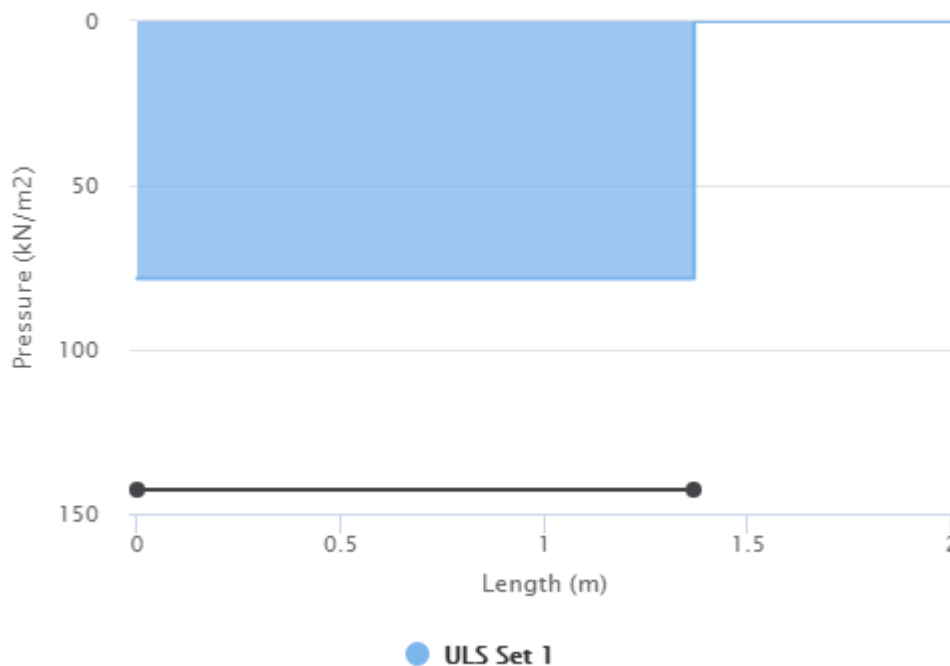
$b_q, b_\gamma, b_c$  are equal to 1 as the base is not inclined.

#### Base shape factors

$S_q, S_\gamma, S_c$  are equal to 1 because the length is unlimited.

|                               |                                                                                                                                         |
|-------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|
| Unit weight of submerged soil | $\gamma' = \gamma_{\text{sat}} - \gamma_w = 10.000 \text{ kN/m}^3$                                                                      |
| Cohesive component            | $q_c = C_d \cdot S_c \cdot i_c \cdot b_c \cdot N_c = 0.000 \text{ kN/m}^2$                                                              |
| Overburden component          | $q_o = q' \cdot N_q \cdot S_q \cdot i_q \cdot b_q = 87.536 \text{ kN/m}^2$                                                              |
| Density component             | $q_\gamma = 0.5 \cdot \gamma' \cdot b_{\text{eff}} \cdot S_\gamma \cdot i_\gamma \cdot b_\gamma \cdot N_\gamma = 55.099 \text{ kN/m}^2$ |
| Ultimate bearing capacity     | $q_{Rd} = q_c + q_o + q_\gamma = 142.634 \text{ kN/m}^2$                                                                                |

#### Bearing pressure diagram



✓ Bearing pressure 78.402 kN/m² is less than the ultimate bearing capacity 142.634 kN/m².

|                                                                                                                                                          |            |  |             |                   |
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#### Stability checks at each gabion layer

Design friction between gabion layer  $\mu_b = 0.7$

#### Stability check below layer 2

Total width of gabion  $B = 1.50 \text{ m}$   
Height of wall above front edge  $H_{toe} = 1.477 \text{ m}$

#### Overturning moment about front edge

|                                                                |                                                                                                                       |
|----------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|
| Overturning moment due to retained soil - horizontal component | $M_{hs} = \gamma_G \cdot P_{hs} \cdot Y_{hs} = 2.237 \text{ kNm/m}$                                                   |
| Overturning moment due to surcharge - horizontal component     | $M_{hq} = \gamma_Q \cdot P_{hq} \cdot Y_{hq} = 3.606 \text{ kNm/m}$                                                   |
| Overturning moment due to retained soil - vertical component   | $M_{vs} = -\gamma_G \cdot P_{vs} \cdot X_{vs} = -8.004 \text{ kNm/m}$                                                 |
| Overturning moment due to surcharge - vertical component       | $M_{vq} = -\gamma_Q \cdot P_{vq} \cdot X_{vq} = -6.197 \text{ kNm}$                                                   |
| Total overturning moment                                       | $M_o = M_{hs} + M_{hq} + M_{up} + M_{Fh,G} + M_{Fh,Q} + M_{vs} + M_{vq} + M_{Fv,G} + M_{Fv,Q} = -8.358 \text{ kNm/m}$ |

#### Restoring moment

|                                     |                                                                   |
|-------------------------------------|-------------------------------------------------------------------|
| Restoring moment due to self weight | $M_{wg} = \gamma_{Gf} \cdot W_g \cdot X_g = 28.672 \text{ kNm/m}$ |
| Total restoring moment              | $M_r = M_{wg} + M_{hp} = 28.672 \text{ kNm/m}$                    |

**i** There is no resultant overturning moment about the front edge, thus the factor of safety for overturning is infinite.

#### Sliding force

|                                         |                                                                        |
|-----------------------------------------|------------------------------------------------------------------------|
| Parallel component due to retained soil | $P_{hs} = \gamma_G \cdot P_{hs} \cdot \cos\omega = 8.444 \text{ kN/m}$ |
| Parallel component due to surcharge     | $P_{hq} = \gamma_Q \cdot P_{hq} \cdot \cos\omega = 6.809 \text{ kN/m}$ |
| Total Parallel force                    | $H_d = P_{hs} + P_{hq} + F_{h,Q} + F_{h,G} = 15.253 \text{ kN/m}$      |

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### Sliding resistance

|                                       |                                                                                  |
|---------------------------------------|----------------------------------------------------------------------------------|
| Normal component due to self weight   | $W_g = \gamma_{Gf} \cdot W_g \cdot \cos\omega = 35.453 \text{ kN/m}$             |
| Normal component due to retained soil | $P_{vs} = \gamma_G \cdot P_{vs} \cdot \cos\omega = 5.761 \text{ kN/m}$           |
| Normal component due to surcharge     | $P_{vq} = \gamma_Q \cdot P_{vq} \cdot \cos\omega = 4.645 \text{ kN/m}$           |
| Net Normal force on foundation soil   | $V_d = W_g + P_{vs} + P_{vq} + P_{up} + F_{v,Q} + F_{v,G} = 45.859 \text{ kN/m}$ |
| Total sliding resistance              | $R_d = V_d \cdot \mu + P_t + P_{hp} = 32.111 \text{ kN/m}$                       |

✓ Sliding force 15.253 kN/m is less than the sliding resistance 32.111 kN/m.

|              |                                                                           |
|--------------|---------------------------------------------------------------------------|
| Eccentricity | $e = 0.5 \cdot B - \frac{\sum M_r - \sum M_o}{\sum W} = -0.279 \text{ m}$ |
|--------------|---------------------------------------------------------------------------|

✓ Eccentricity lies within the middle third ( $B/6 = 0.250 \text{ m}$ ), hence passes.

i No tension is allowed to develop beneath the base of the wall.

### Stability check below layer 3

|                                 |                             |
|---------------------------------|-----------------------------|
| Total width of gabion           | $B = 1.00 \text{ m}$        |
| Height of wall above front edge | $H_{toe} = 0.492 \text{ m}$ |

### Overturning moment about front edge

|                                                                |                                                                                                                       |
|----------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|
| Overturning moment due to retained soil - horizontal component | $M_{hs} = \gamma_G \cdot P_{hs} \cdot Y_{hs} = -0.008 \text{ kNm/m}$                                                  |
| Overturning moment due to surcharge - horizontal component     | $M_{hq} = \gamma_Q \cdot P_{hq} \cdot Y_{hq} = 0.158 \text{ kNm/m}$                                                   |
| Overturning moment due to retained soil - vertical component   | $M_{vs} = -\gamma_G \cdot P_{vs} \cdot X_{vs} = -0.551 \text{ kNm/m}$                                                 |
| Overturning moment due to surcharge - vertical component       | $M_{vq} = -\gamma_Q \cdot P_{vq} \cdot X_{vq} = -1.386 \text{ kNm}$                                                   |
| Total overturning moment                                       | $M_o = M_{hs} + M_{hq} + M_{up} + M_{Fh,G} + M_{Fh,Q} + M_{vs} + M_{vq} + M_{Fv,G} + M_{Fv,Q} = -1.787 \text{ kNm/m}$ |

### Restoring moment

|                                     |                                                                  |
|-------------------------------------|------------------------------------------------------------------|
| Restoring moment due to self weight | $M_{wg} = \gamma_{Gf} \cdot W_g \cdot X_g = 4.822 \text{ kNm/m}$ |
| Total restoring moment              | $M_r = M_{wg} + M_{hp} = 4.822 \text{ kNm/m}$                    |

|                                                                                                                                                             |            |  |             |            |
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**i** There is no resultant overturning moment about the front edge, thus the factor of safety for overturning is infinite.

#### Sliding force

|                                         |                                                                        |
|-----------------------------------------|------------------------------------------------------------------------|
| Parallel component due to retained soil | $P_{hs} = \gamma_G \cdot P_{hs} \cdot \cos\omega = 0.837 \text{ kN/m}$ |
| Parallel component due to surcharge     | $P_{hq} = \gamma_Q \cdot P_{hq} \cdot \cos\omega = 2.144 \text{ kN/m}$ |
| Total Parallel force                    | $H_d = P_{hs} + P_{hq} + F_{h,Q} + F_{h,G} = 2.981 \text{ kN/m}$       |

#### Sliding resistance

|                                       |                                                                                  |
|---------------------------------------|----------------------------------------------------------------------------------|
| Normal component due to self weight   | $W_g = \gamma_{Gf} \cdot W_g \cdot \cos\omega = 8.863 \text{ kN/m}$              |
| Normal component due to retained soil | $P_{vs} = \gamma_G \cdot P_{vs} \cdot \cos\omega = 0.571 \text{ kN/m}$           |
| Normal component due to surcharge     | $P_{vq} = \gamma_Q \cdot P_{vq} \cdot \cos\omega = 1.462 \text{ kN/m}$           |
| Net Normal force on foundation soil   | $V_d = W_g + P_{vs} + P_{vq} + P_{up} + F_{v,Q} + F_{v,G} = 10.897 \text{ kN/m}$ |
| Total sliding resistance              | $R_d = V_d \cdot \mu + P_t + P_{hp} = 7.630 \text{ kN/m}$                        |

✓ Sliding force 2.981 kN/m is less than the sliding resistance 7.630 kN/m.

|              |                                                                           |
|--------------|---------------------------------------------------------------------------|
| Eccentricity | $e = 0.5 \cdot B - \frac{\sum M_r - \sum M_o}{\sum W} = -0.234 \text{ m}$ |
|--------------|---------------------------------------------------------------------------|

✓ Eccentricity lies within the middle third ( $B/6 = 0.167 \text{ m}$ ), hence passes.

**i** No tension is allowed to develop beneath the base of the wall.

### Design Approach 1 - Combination 2 (A2 + M2 + R1)

#### Overturning check

Overturning moments about front edge

|                                                                |                                                                        |
|----------------------------------------------------------------|------------------------------------------------------------------------|
| Overturning moment due to retained soil - horizontal component | $M_{hs} = \gamma_G \cdot P_{hs} \cdot Y_{hs} = 11.926 \text{ kNm/m}$   |
| Overturning moment due to surcharge - horizontal component     | $M_{hq} = \gamma_Q \cdot P_{hq} \cdot Y_{hq} = 12.249 \text{ kNm/m}$   |
| Overturning moment due to retained soil - vertical component   | $M_{vs} = -\gamma_G \cdot P_{vs} \cdot X_{vs} = -22.066 \text{ kNm/m}$ |

|                                                                                                                                                          |            |  |             |                   |
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|                                                          |                                                                                                                      |
|----------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|
| Overturning moment due to surcharge - vertical component | $M_{vq} = -\gamma_Q \cdot P_{vq} \cdot X_{vq} = -12.413 \text{ kNm}$                                                 |
| Overturning moment due to uplift of water                | $M_{up} = \gamma_G \cdot P_{up} \cdot T_{up} = 13.333 \text{ kNm/m}$                                                 |
| Total overturning moment                                 | $M_o = M_{hs} + M_{hq} + M_{up} + M_{Fh,G} + M_{Fh,Q} + M_{vs} + M_{vq} + M_{Fv,G} + M_{Fv,Q} = 3.029 \text{ kNm/m}$ |

#### Restoring moment

|                                            |                                                                   |
|--------------------------------------------|-------------------------------------------------------------------|
| Restoring moment due to self weight        | $M_{wg} = \gamma_{Gf} \cdot W_g \cdot X_g = 73.502 \text{ kNm/m}$ |
| Restoring moment due to passive resistance | $M_{hp} = P_{hp} \cdot Y_{hp} = 0.328 \text{ kNm/m}$              |
| Total restoring moment                     | $M_r = M_{wg} + M_{hp} = 73.830 \text{ kNm/m}$                    |

✓ Overturning moment 3.029 kNm is less than the restoring moment 73.83 kNm.

#### Sliding check

##### Sliding force

|                                           |                                                                   |
|-------------------------------------------|-------------------------------------------------------------------|
| Horizontal component due to retained soil | $P_{hs} = \gamma_G \cdot P_{hs} = 26.100 \text{ kN/m}$            |
| Horizontal component due to surcharge     | $P_{hq} = \gamma_Q \cdot P_{hq} = 12.621 \text{ kN/m}$            |
| Total Horizontal force                    | $H_d = P_{hs} + P_{hq} + F_{h,Q} + F_{h,G} = 38.720 \text{ kN/m}$ |

#### Sliding resistance on base plane

BS EN 1997-1 Eq. 6.2 - Cl. 6.5.3

|                                         |                                                                                  |
|-----------------------------------------|----------------------------------------------------------------------------------|
| Frictional factor                       | $\mu = \frac{\tan \phi_b}{\gamma_{\phi}} = 0.560$                                |
| Vertical component due to self weight   | $W_g = \gamma_{Gf} \cdot W_g = 72.000 \text{ kN/m}$                              |
| Vertical component due to retained soil | $P_{vs} = \gamma_G \cdot P_{vs} = 12.248 \text{ kN/m}$                           |
| Vertical component due to surcharge     | $P_{vq} = \gamma_Q \cdot P_{vq} = 7.326 \text{ kN/m}$                            |
| Water uplift force on base              | $P_{up} = -\gamma_{Gf} \cdot P_{up} = -10.000 \text{ kN/m}$                      |
| Net Vertical force on foundation soil   | $V_d = W_g + P_{vs} + P_{vq} + P_{up} + F_{v,Q} + F_{v,G} = 81.574 \text{ kN/m}$ |
| Total sliding resistance                | $R_d = V_d \cdot \mu + P_t + P_{hp} = 47.661 \text{ kN/m}$                       |

✓ Sliding force 38.720 kN/m is less than the sliding resistance 47.661 kN/m.

|                                                                                                                                                          |            |  |             |                   |
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### Bearing pressure check

Net vertical force on foundation soil

$$V_d = W_g + P_{vs} + P_{vq} + P_{up} + F_{v,G} + F_{v,Q} = 81.574 \text{ kN/m}$$

Eccentricity

$$e = 0.5 \cdot B - \frac{\sum M_r - \sum M_o}{\sum W} = 0.132 \text{ m}$$

✓ Eccentricity lies within the middle third ( $B/6 = 0.333 \text{ m}$ ), hence passes.

### Ultimate bearing capacity

Eq. 6.1 of cl. 6.5.2.1 (Annex D)

Height of passive soil at toe

$$h_p = 0.500 \text{ m}$$

Height of passive soil above water level

$$h_{s,p} = h_p - h_{w,p1} = 0.500 \text{ m}$$

Vertical effective stress

$$q'_p = \sum \gamma_s \cdot h_{s,p} + \sum (\gamma_{sat} - \gamma_w) \cdot h_{w,p} = 9.000 \text{ kN/m}^2$$

Effective width

$$b_{eff} = B - 2 \cdot e = 1.736 \text{ m}$$

Equivalent uniform pressure

$$\sigma_{equ} = \frac{V_d}{l_{eff} \cdot b_{eff}} = 46.994 \text{ kN/m}^2$$

### Bearing capacity factors

$$N_q = e^{\pi \cdot \tan \phi'_d} \cdot \tan^2 \left( 45 + \frac{\phi'_d}{2} \right) = 16.921$$

$$N_c = (N_q - 1) \cdot \cot \phi'_d = 28.422$$

$$N_\gamma = 2 \cdot (N_q - 1) \cdot \tan \phi'_d = 17.837$$

### Load inclination factors

The retaining wall design assumes semi-infinite base length, thus the value of m is 2.

$$i_q = \left( 1 - \frac{H}{V_d + A' \cdot C_d \cdot \cot \phi'_d} \right)^m = 0.276$$

$$i_\gamma = \left( 1 - \frac{H}{V_d + A' \cdot C_d \cdot \cot \phi'_d} \right)^{m+1} = 0.145$$

$$i_c = i_q - \frac{1 - i_q}{N_c \cdot \tan \phi'_d} = 0.231$$

### Base inclination factors

$b_q, b_\gamma, b_c$  are equal to 1 as the base is not inclined.

### Base shape factors

$S_q, S_\gamma, S_c$  are equal to 1 because the length is unlimited.

Unit weight of submerged soil

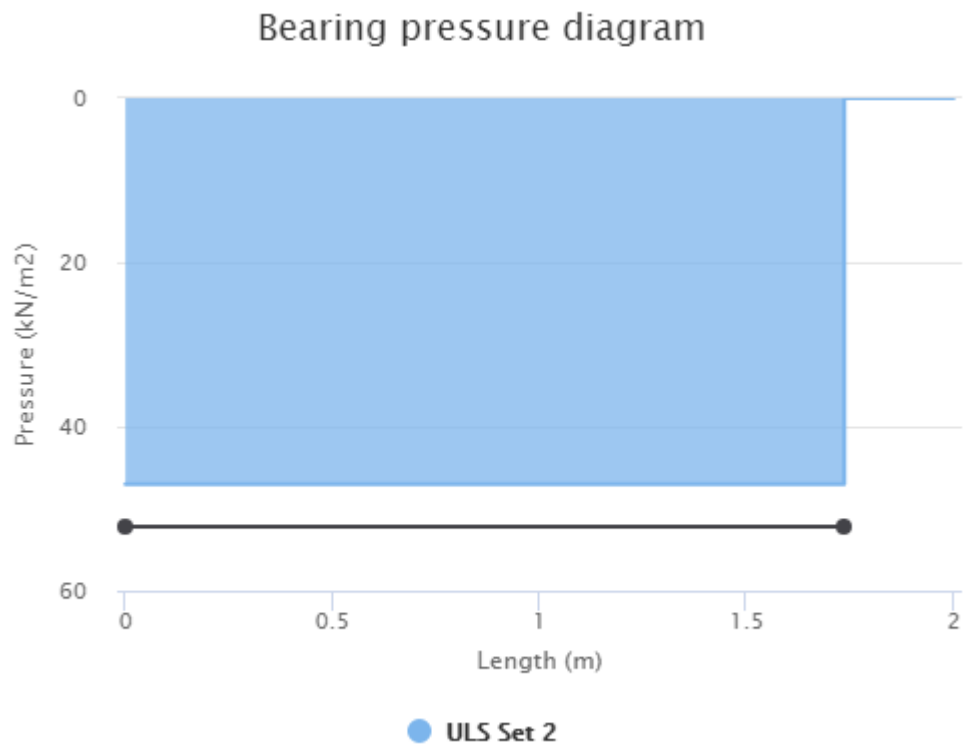
$$\gamma' = \gamma_{sat} - \gamma_w = 10.000 \text{ kN/m}^3$$

Cohesive component

$$q_c = C_d \cdot S_c \cdot i_c \cdot b_c \cdot N_c = 0.000 \text{ kN/m}^2$$

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|                           |                                                                                                         |
|---------------------------|---------------------------------------------------------------------------------------------------------|
| Overburden component      | $q_o = q' \cdot N_q \cdot S_q \cdot i_q \cdot b_q = 34.213 \text{ kN/m}^2$                              |
| Density component         | $q_v = 0.5 \cdot \gamma' \cdot b_{eff} \cdot S_v \cdot i_v \cdot b_v \cdot N_v = 18.009 \text{ kN/m}^2$ |
| Ultimate bearing capacity | $q_{Rd} = q_c + q_o + q_v = 52.221 \text{ kN/m}^2$                                                      |



✓ Bearing pressure 46.994 kN/m<sup>2</sup> is less than the ultimate bearing capacity 52.221 kN/m<sup>2</sup>.

#### Stability checks at each gabion layer

|                                      |                |
|--------------------------------------|----------------|
| Design friction between gabion layer | $\mu_b = 0.56$ |
|--------------------------------------|----------------|

#### Stability check below layer 2

|                                 |                             |
|---------------------------------|-----------------------------|
| Total width of gabion           | $B = 1.50 \text{ m}$        |
| Height of wall above front edge | $H_{toe} = 1.477 \text{ m}$ |

#### Overturning moment about front edge

|                                                                |                                                                     |
|----------------------------------------------------------------|---------------------------------------------------------------------|
| Overturning moment due to retained soil - horizontal component | $M_{hs} = \gamma_G \cdot P_{hs} \cdot Y_{hs} = 2.071 \text{ kNm/m}$ |
| Overturning moment due to surcharge - horizontal component     | $M_{hq} = \gamma_Q \cdot P_{hq} \cdot Y_{hq} = 3.906 \text{ kNm/m}$ |

|                                                                                                                                                            |            |  |             |            |
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Overtuning moment  
due to retained soil -  
vertical component

$$M_{vs} = -\gamma_G \cdot P_{vs} \cdot X_{vs} = -6.305 \text{ kNm/m}$$

Overtuning moment  
due to surcharge -  
vertical component

$$M_{vq} = -\gamma_Q \cdot P_{vq} \cdot X_{vq} = -5.712 \text{ kNm}$$

Total overturning  
moment

$$M_o = M_{hs} + M_{hq} + M_{up} + M_{Fh,G} + M_{Fh,Q} + M_{vs} + M_{vq} + M_{Fv,G} + M_{Fv,Q} = -6.040 \text{ kNm/m}$$

#### Restoring moment

Restoring moment due to self  
weight

$$M_{wg} = \gamma_{Gf} \cdot W_g \cdot X_g = 28.672 \text{ kNm/m}$$

Total restoring moment

$$M_r = M_{wg} + M_{hp} = 28.672 \text{ kNm/m}$$

**i** There is no resultant overturning moment about the front edge, thus the factor of safety for overturning is infinite.

#### Sliding force

Parallel component due to  
retained soil

$$P_{hs} = \gamma_G \cdot P_{hs} \cdot \cos\omega = 7.817 \text{ kN/m}$$

Parallel component due to  
surcharge

$$P_{hq} = \gamma_Q \cdot P_{hq} \cdot \cos\omega = 7.375 \text{ kN/m}$$

Total Parallel force

$$H_d = P_{hs} + P_{hq} + F_{h,Q} + F_{h,G} = 15.193 \text{ kN/m}$$

#### Sliding resistance

Normal component due to self  
weight

$$W_g = \gamma_{Gf} \cdot W_g \cdot \cos\omega = 35.453 \text{ kN/m}$$

Normal component due to  
retained soil

$$P_{vs} = \gamma_G \cdot P_{vs} \cdot \cos\omega = 4.538 \text{ kN/m}$$

Normal component due to  
surcharge

$$P_{vq} = \gamma_Q \cdot P_{vq} \cdot \cos\omega = 4.281 \text{ kN/m}$$

Net Normal force on  
foundation soil

$$V_d = W_g + P_{vs} + P_{vq} + P_{up} + F_{v,Q} + F_{v,G} = 44.272 \text{ kN/m}$$

Total sliding resistance

$$R_d = V_d \cdot \mu + P_t + P_{hp} = 24.800 \text{ kN/m}$$

✓ Sliding force 15.193 kN/m is less than the sliding resistance 24.800 kN/m.

Eccentricity

$$e = 0.5 \cdot B - \frac{\sum M_r - \sum M_o}{\sum W} = -0.214 \text{ m}$$

✓ Eccentricity lies within the middle third ( $B/6 = 0.250 \text{ m}$ ), hence passes.



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#### Stability check below layer 3

|                                 |                            |
|---------------------------------|----------------------------|
| Total width of gabion           | B = 1.00 m                 |
| Height of wall above front edge | H <sub>toe</sub> = 0.492 m |

#### Overturning moment about front edge

|                                                                |                                                                                                                       |
|----------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|
| Overturning moment due to retained soil - horizontal component | $M_{hs} = \gamma_G \cdot P_{hs} \cdot Y_{hs} = -0.007 \text{ kNm/m}$                                                  |
| Overturning moment due to surcharge - horizontal component     | $M_{hq} = \gamma_Q \cdot P_{hq} \cdot Y_{hq} = 0.171 \text{ kNm/m}$                                                   |
| Overturning moment due to retained soil - vertical component   | $M_{vs} = -\gamma_G \cdot P_{vs} \cdot X_{vs} = -0.434 \text{ kNm/m}$                                                 |
| Overturning moment due to surcharge - vertical component       | $M_{vq} = -\gamma_Q \cdot P_{vq} \cdot X_{vq} = -1.278 \text{ kNm}$                                                   |
| Total overturning moment                                       | $M_o = M_{hs} + M_{hq} + M_{up} + M_{Fh,G} + M_{Fh,Q} + M_{vs} + M_{vq} + M_{Fv,G} + M_{Fv,Q} = -1.548 \text{ kNm/m}$ |

#### Restoring moment

|                                     |                                                                  |
|-------------------------------------|------------------------------------------------------------------|
| Restoring moment due to self weight | $M_{wg} = \gamma_{Gf} \cdot W_g \cdot X_g = 4.822 \text{ kNm/m}$ |
| Total restoring moment              | $M_r = M_{wg} + M_{hp} = 4.822 \text{ kNm/m}$                    |

**i** There is no resultant overturning moment about the front edge, thus the factor of safety for overturning is infinite.

#### Sliding force

|                                         |                                                                        |
|-----------------------------------------|------------------------------------------------------------------------|
| Parallel component due to retained soil | $P_{hs} = \gamma_G \cdot P_{hs} \cdot \cos\omega = 0.775 \text{ kN/m}$ |
| Parallel component due to surcharge     | $P_{hq} = \gamma_Q \cdot P_{hq} \cdot \cos\omega = 2.322 \text{ kN/m}$ |
| Total Parallel force                    | $H_d = P_{hs} + P_{hq} + F_{h,Q} + F_{h,G} = 3.097 \text{ kN/m}$       |

#### Sliding resistance

|                                       |                                                                        |
|---------------------------------------|------------------------------------------------------------------------|
| Normal component due to self weight   | $W_g = \gamma_{Gf} \cdot W_g \cdot \cos\omega = 8.863 \text{ kN/m}$    |
| Normal component due to retained soil | $P_{vs} = \gamma_G \cdot P_{vs} \cdot \cos\omega = 0.450 \text{ kN/m}$ |
| Normal component due to surcharge     | $P_{vq} = \gamma_Q \cdot P_{vq} \cdot \cos\omega = 1.348 \text{ kN/m}$ |

|                                                                                                                                                            |            |  |             |            |
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Net Normal force on foundation soil

$$V_d = W_g + P_{vs} + P_{vq} + P_{up} + F_{v,Q} + F_{v,G} = 10.661 \text{ kN/m}$$

Total sliding resistance

$$R_d = V_d \cdot \mu + P_t + P_{hp} = 5.972 \text{ kN/m}$$

✓ Sliding force 3.097 kN/m is less than the sliding resistance 5.972 kN/m.

Eccentricity

$$e = 0.5 \cdot B - \frac{\Sigma M_r - \Sigma M_o}{\Sigma W} = -0.208 \text{ m}$$

✓ Eccentricity lies within the middle third ( $B/6 = 0.167 \text{ m}$ ), hence passes.

i No tension is allowed to develop beneath the base of the wall.

## Result summary

Overall stability checks at wall base

| Check                                                        | Calculated value | Limit value | Utilisation | Status |
|--------------------------------------------------------------|------------------|-------------|-------------|--------|
| <b>SLS load combination</b>                                  |                  |             |             |        |
| Overturning stability (kNm/m)                                | 0.622            | 73.907      | 0.008       | ✓ Pass |
| Base bearing eccentricity (m)                                | 0.070            | 0.333       | 0.211       | ✓ Pass |
| FOS - ultimate bearing failure                               | 3.959            | 3.0         | 0.758       | ✓ Pass |
| SLS allowable bearing check (kN/m <sup>2</sup> )             | 47.704           | 200.0       | 0.239       | ✓ Pass |
| <b>ULS load combination EQU</b>                              |                  |             |             |        |
| Sliding stability (kN/m)                                     | 38.907           | 51.248      | 0.759       | ✓ Pass |
| Overturning stability (kNm/m)                                | 1.36             | 66.521      | 0.020       | ✓ Pass |
| Base bearing eccentricity (m)                                | 0.271            | 0.333       | 0.814       | ✓ Pass |
| <b>ULS STR/GEO combination 1</b>                             |                  |             |             |        |
| Sliding stability (kN/m)                                     | 41.194           | 62.298      | 0.661       | ✓ Pass |
| Overturning stability (kNm/m)                                | 0.623            | 73.907      | 0.008       | ✓ Pass |
| Base bearing eccentricity (m)                                | 0.316            | 0.333       | 0.949       | ✓ Pass |
| ULS equivalent uniform bearing pressure (kN/m <sup>2</sup> ) | 78.402           | 142.634     | 0.55        | ✓ Pass |

|                                                                                                                                                             |            |  |             |                   |
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| Check                                                        | Calculated value | Limit value | Utilisation | Status    |
|--------------------------------------------------------------|------------------|-------------|-------------|-----------|
| <b>ULS STR/GEO combination 2</b>                             |                  |             |             |           |
| Sliding stability (kN/m)                                     | 38.720           | 47.661      | 0.812       | ✓<br>Pass |
| Overturning stability (kNm/m)                                | 3.029            | 73.83       | 0.041       | ✓<br>Pass |
| Base bearing eccentricity (m)                                | 0.132            | 0.333       | 0.396       | ✓<br>Pass |
| ULS equivalent uniform bearing pressure (kN/m <sup>2</sup> ) | 46.994           | 52.221      | 0.9         | ✓<br>Pass |

Stability checks at each gabion layer  
Sliding force and resistance (kN/m)

| Check                            | Calculated value | Limit value | Utilisation | Status    |
|----------------------------------|------------------|-------------|-------------|-----------|
| <b>ULS load combination EQU</b>  |                  |             |             |           |
| below gabion layer 2             | 15.132           | 26.432      | 0.572       | ✓<br>Pass |
| below gabion layer 3             | 3.123            | 6.341       | 0.493       | ✓<br>Pass |
| <b>ULS STR/GEO combination1</b>  |                  |             |             |           |
| below gabion layer 2             | 15.253           | 32.111      | 0.475       | ✓<br>Pass |
| below gabion layer 3             | 2.981            | 7.630       | 0.391       | ✓<br>Pass |
| <b>ULS STR/GEO combination 2</b> |                  |             |             |           |
| below gabion layer 2             | 15.193           | 24.800      | 0.613       | ✓<br>Pass |
| below gabion layer 3             | 3.097            | 5.972       | 0.519       | ✓<br>Pass |

Overturning moment and resistance (kNm/m)

| Check                            | Calculated value | Limit value | Utilisation | Status    |
|----------------------------------|------------------|-------------|-------------|-----------|
| <b>ULS load combination EQU</b>  |                  |             |             |           |
| below gabion layer 2             | -7.095           | 25.805      | 0           | ✓<br>Pass |
| below gabion layer 3             | -1.722           | 4.34        | 0           | ✓<br>Pass |
| <b>ULS STR/GEO combination 1</b> |                  |             |             |           |

|                                                                                   |            |  |             |                   |
|-----------------------------------------------------------------------------------|------------|--|-------------|-------------------|
|  | Project no |  | Date        | <b>21/11/2018</b> |
|                                                                                   | Name       |  | Prepared by |                   |
|                                                                                   | Item       |  | Checked by  |                   |
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| Check                            | Calculated value | Limit value | Utilisation | Status    |
|----------------------------------|------------------|-------------|-------------|-----------|
| below gabion layer 2             | -8.358           | 28.672      | 0           | ✓<br>Pass |
| below gabion layer 3             | -1.787           | 4.822       | 0           | ✓<br>Pass |
| <b>ULS STR/GEO combination 2</b> |                  |             |             |           |
| below gabion layer 2             | -6.04            | 28.672      | 0           | ✓<br>Pass |
| below gabion layer 3             | -1.548           | 4.822       | 0           | ✓<br>Pass |

Eccentricity calculated and middle third limit (m)

| Check                            | Calculated value | Limit value | Utilisation | Status    |
|----------------------------------|------------------|-------------|-------------|-----------|
| <b>ULS load combination EQU</b>  |                  |             |             |           |
| below gabion layer 2             | -0.164           | 0.25        | 0.656       | ✓<br>Pass |
| below gabion layer 3             | -0.174           | 0.167       | 1.042       | ✓<br>Pass |
| <b>ULS STR/GEO combination 1</b> |                  |             |             |           |
| below gabion layer 2             | -0.279           | 0.25        | 1.114       | ✓<br>Pass |
| below gabion layer 3             | -0.234           | 0.167       | 1.406       | ✓<br>Pass |
| <b>ULS STR/GEO combination 2</b> |                  |             |             |           |
| below gabion layer 2             | -0.214           | 0.25        | 0.857       | ✓<br>Pass |
| below gabion layer 3             | -0.208           | 0.167       | 1.247       | ✓<br>Pass |

✓ All stability checks have passed.