GABION RETAINING WALL ANALYSIS AND DESIGN (BS8002:1994)

Wall geometry
Width of gabion 1; \( w_1 = 2700 \) mm
Height of gabion 1; \( h_1 = 700 \) mm
Width of gabion 2; \( w_2 = 2300 \) mm
Height of gabion 2; \( h_2 = 700 \) mm
Step to front face between 1 and 2; \( s_2 = 0 \) mm
Width of gabion 3; \( w_3 = 2000 \) mm
Height of gabion 3; \( h_3 = 600 \) mm
Step to front face between 2 and 3; \( s_3 = 0 \) mm
Wall inclination; \( \varepsilon = 5 \) deg

Wall fill

Gabion fill unit weight; \( \gamma_d = 15 \text{ kN/m}^3 \)

Centre of gravity

| Horizontal distance to centre of gravity gabion 1; \( x_{g1} = w_1 / 2 = 1350 \text{ mm} \) |
| Horizontal distance to centre of gravity gabion 2; \( x_{g2} = w_2 / 2 + s_2 = 1150 \text{ mm} \) |
| Horizontal distance to centre of gravity gabion 3; \( x_{g3} = w_3 / 2 + s_2 + s_3 = 1000 \text{ mm} \) |
| Vertical distance to centre of gravity gabion 1; \( y_{g1} = h_1 / 2 = 350 \text{ mm} \) |
| Vertical distance to centre of gravity gabion 2; \( y_{g2} = h_2 / 2 + h_1 = 1050 \text{ mm} \) |
| Vertical distance to centre of gravity gabion 3; \( y_{g3} = h_3 / 2 + h_1 + h_2 = 1700 \text{ mm} \) |
| Weight of gabion 1; \( W_{g1} = \gamma_d \times w_1 \times h_1 = 28.4 \text{ kN/m} \) |
| Weight of gabion 2; \( W_{g2} = \gamma_d \times w_2 \times h_2 = 24.2 \text{ kN/m} \) |
| Weight of gabion 3; \( W_{g3} = \gamma_d \times w_3 \times h_3 = 18.0 \text{ kN/m} \) |
| Weight of entire gabion; \( W_g = W_{g1} + W_{g2} + W_{g3} = 70.5 \text{ kN/m} \) |
| Horiz distance to centre of gravity entire gabion; \( x_g = \frac{(W_{g1} \times x_{g1}) + (W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3})}{W_g} = 1192 \text{ mm} \) |
| Vert distance to centre of gravity entire gabion; \( y_g = \frac{(W_{g1} \times y_{g1}) + (W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3})}{W_g} = 934 \text{ mm} \) |

Correcting for wall inclination horiz dist; \( X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon) = 1269 \text{ mm} \)

Vertical change in height due to wall inclination; \( H_f = y_{g3} + h_3 / 2 - ((y_{g3} + h_3 / 2) \times \cos(\varepsilon) - (x_{g3} + w_3 / 2) \times \sin(\varepsilon)) = 182 \text{ mm} \)

Calculate effective height of wall

Effective height of wall; \( H = (y_{g3} + h_3 / 2) + (w_1 \times \sin(\varepsilon)) - H_f = 2053 \text{ mm} \)

Height of wall from toe to front edge of top gabion; \( H_{incl} = (y_{g3} + h_3 / 2) \times \cos(\varepsilon) - (x_{g3} + w_3 / 2) \times \sin(\varepsilon) = 1992 \text{ mm} \)

Calculate the angle of rear plane of wall

Effective angle of rear plane of wall; \( \alpha = \arctan \left[ (y_{g3} + (h_3 / 2)) / (w_1 - (x_{g3} + (w_3 / 2))) \right] \pm \varepsilon = 75.7 \text{ deg} \)

Calculate the effective face angle

Effective face angle; \( \theta = 90 \text{ deg} - \varepsilon = 85.0 \text{ deg} \)

Soil parameters

| Slope of retained soil; \( \beta = 0.0 \text{ deg} \) |
| Mobilization factor; \( M = 1.0 \) |
| Internal angle of friction for retained soil; \( \phi' = 38.0 \text{ deg} \) |
| Saturated density of retained soil; \( \gamma_s = 23 \text{ kN/m}^3 \) |
| Coefficient for wall friction; \( K = 0.9 \) |
| Wall friction; \( \delta = \phi' \times K = 34.2 \text{ deg} \) |
| Design angle of base friction; \( \delta_b = 30.0 \text{ deg} \) |
| Bearing capacity of founding soil; \( q = 110 \text{ kN/m}^2 \) |
Active Pressure using Coulomb Theory:

\[
K_a = \frac{\sin(\alpha + \phi')}{\left[\sin(\alpha)\right]^2 \times \sin(\alpha - \delta) \times (1 + \sqrt{\left[\sin(\phi' + \delta) \times \sin(\phi' - \beta)\right] / \left(\sin(\alpha - \delta) \times \sin(\alpha + \beta)\right)}}^2 = 0.352
\]

Loading

Surcharge;

\[
p_o = 10 \text{ kN/m}^2
\]

Horizontal line load;

\[
F_h = 10 \text{ kN/m}
\]

Vertical height of horizontal load from top gabion;

\[
H_{hl} = 0 \text{ mm}
\]

Dist of horiz. load from leading edge of top gabion;

\[
D_{hl} = 0 \text{ mm}
\]

Vertical height from toe;

\[
d_t = (H_{incl} + H_{hl} - D_{hl} \times \tan(\epsilon)) = 1992 \text{ mm}
\]

Horizontal distance of horiz. load from toe;

\[
b_{hl} = (H_{incl} / \tan(\theta)) + D_{hl} = 174 \text{ mm}
\]

Vertical load line;

\[
F_v = 5 \text{ kN/m}
\]

Dist of vert. load from leading edge of top gabion;

\[
D_{vl} = 0 \text{ mm}
\]

Horizontal distance of vert. load from toe;

\[
b_{vl} = (H_{incl} / \tan(\theta)) + D_{vl} = 174 \text{ mm}
\]

Surcharge loading as equiv height of soil;

\[
h_s = p_o / \gamma_s = 435 \text{ mm}
\]

Active thrust due to soil;

\[
P_{a,soil} = 0.5 \times K_a \times \gamma_s \times H^2 = 17.1 \text{ kN/m}
\]

Active thrust due to surcharge;

\[
P_{a,sur} = p_o \times K_a \times H = 24.3 \text{ kN/m}
\]

Total active thrust;

\[
P_a = P_{a,soil} + P_{a,sur} = 24.3 \text{ kN/m}
\]

Total thrust resolved horizontally;

\[
P_h = P_a \times \cos(90 - \alpha + \delta) = 16.1 \text{ kN/m}
\]

Total thrust resolved vertically;

\[
P_v = P_a \times \sin(90 - \alpha + \delta) = 18.2 \text{ kN/m}
\]

Height above toe thrust acts if \( \alpha \) is 0;

\[
d_h = (H_{incl} / \tan(\theta)) = 786 \text{ mm}
\]

Height above toe thrust acts;

\[
d_h = d_{h,soil} - w_1 \times \sin(\epsilon) = 551 \text{ mm}
\]

Horiz distance to where thrust acts;

\[
b_v = w_1 \times \cos(\epsilon) - (d_{h,soil} / \tan(\alpha)) = 2489 \text{ mm}
\]

Overturning stability – take moments about the toe

Overturning moment;

\[
M_o = (P_h \times d_h) + (F_h \times d_{hl}) = 28.8 \text{ kNm/m}
\]

Restoring moment;

\[
M_R = (P_v \times b_v) + (W_g \times X_g) + (F_v \times b_{vl}) = 135.7 \text{ kNm/m}
\]

\[
F_{o,M} = M_R / M_o = 4.71
\]

\[
F_{o,M,min} = 2.00
\]

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

Sliding stability – ignore any passive pressure infront of structure

Total vertical force;

\[
N = W_g + P_v + F_v = 93.7 \text{ kN/m}
\]

Total horizontal force;

\[
T = P_h + F_h = 26.1 \text{ kN/m}
\]

Sliding force;

\[
F_s = T \times \cos(c) - N \times \sin(c) = 17.8 \text{ kN/m}
\]

Resistance to sliding;

\[
F_R = (N \times \cos(c) + T \times \sin(c)) \times \tan(\delta_0) = 55.2 \text{ kN/m}
\]

\[
F_{o,S} = F_R / F_s = 3.09
\]

\[
F_{o,S,min} = 1.50
\]

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

**Pressure at base**

Force normal to base; \( N_s = (N \times \cos (\phi) + T \times \sin (\phi)) = 95.6 \text{ kN/m} \)

Eccentricity; \( e = (w_1 / 2) - (M_R - M_N) / N_s = 232 \text{ mm} \)

**Reaction acts within middle third of base**

Pressure at toe; \( \sigma_{\text{toe}} = (N_N / w_1) \times (1 + (6 \times e / w_1)) = 53.7 \text{ kN/m}^2 \)

Pressure at heel; \( \sigma_{\text{heel}} = (N_N / w_1) \times (1 - (6 \times e / w_1)) = 17.1 \text{ kN/m}^2 \)

**PASS - Allowable bearing pressure exceeds max design pressure to base**

Check for sliding and overturning between courses 1 and 2

**Centre of gravity**

Horizontal distance to centre of gravity gabion 2; \( x_{g2} = w_2 / 2 = 1150 \text{ mm} \)

Horizontal distance to centre of gravity gabion 3; \( x_{g3} = w_3 / 2 + s_3 = 1000 \text{ mm} \)

Vertical distance to centre of gravity gabion 2; \( y_{g2} = h_2 / 2 = 350 \text{ mm} \)

Vertical distance to centre of gravity gabion 3; \( y_{g3} = h_3 / 2 + h_2 = 1000 \text{ mm} \)

Weight of gabion 2; \( W_{g2} = \gamma_d \times w_2 \times h_2 = 24.2 \text{ kN/m} \)

Weight of gabion 3; \( W_{g3} = \gamma_d \times w_3 \times h_3 = 18.0 \text{ kN/m} \)

Weight of entire gabion; \( W_g = W_{g2} + W_{g3} = 42.2 \text{ kN/m} \)

Horiz distance to centre of gravity entire gabion; \( x_g = ((W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3})) / W_g = 1086 \text{ mm} \)

Vert distance to centre of gravity entire gabion; \( y_g = ((W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3})) / W_g = 628 \text{ mm} \)

Correcting for wall inclination horiz dist; \( H_f = y_{g3} + h_3 / 2 - ((y_{g3} + h_3 / 2) \times \cos (\phi) - (x_{g3} + w_3 / 2) \times \sin (\phi)) = 179 \text{ mm} \)

**Calculate effective height of wall**

Effective height of wall; \( H = (y_{g3} + h_3 / 2) + (w_2 \times \sin (\phi)) - H_f = 1321 \text{ mm} \)

Height of wall from toe to front edge of top gabion; \( H_{\text{foe}} = ((y_{g3} + h_3 / 2) / (w_2 - (x_{g3} + w_3 / 2) \times \sin (\phi)) + \phi = 82.0 \text{ deg} \)

**Calculate the effect of rear plane of wall**

Effective face angle; \( \theta = 90 \text{ deg} - \phi = 85.0 \text{ deg} \)

**Loading**

Surcharge; \( p_o = 10 \text{ kN/m}^2 \)

Horizontal line load; \( F_h = 10 \text{ kN/m} \)

Vertical height of horizontal load from top gabion; \( H_{hl} = 0 \text{ mm} \)

Dist of horiz. load from leading edge of top gabion; \( D_{hl} = 0 \text{ mm} \)

Vertical height from toe; \( H_{hl} = (H_{hl} + H_{hl} - D_{hl} \times \tan (\phi)) = 1295 \text{ mm} \)

Horizontal distance from horiz. load from toe; \( D_{hl} = (H_{hl} / \tan (\phi)) + D_{hl} = 113 \text{ mm} \)

Vertical line load; \( F_v = 5 \text{ kN/m} \)

Dist of vert. load from leading edge of top gabion; \( D_{hl} = 0 \text{ mm} \)
Horizontal distance of vert. load from toe; \( b_v = \frac{H_{incl}}{\tan(\theta)} + D_v = 113 \text{ mm} \)

Surcharge loading as equiv height of soil; \( h_s = \frac{p_o}{\gamma_s} = 435 \text{ mm} \)

Active thrust due to soil; \( P_{a,soil} = 0.5 \times K_a \times \gamma_s \times H^2 = 7.1 \text{ kN/m} \)

Active thrust due to surcharge; \( P_{a,surch} = P_o \times K_a \times H = 4.7 \text{ kN/m} \)

Total active thrust; \( P_a = P_{a,soil} + P_{a,surch} = 11.7 \text{ kN/m} \)

Total thrust resolved horizontally; \( P_h = P_a \times \cos(90 - \alpha + \delta) = 8.7 \text{ kN/m} \)

Total thrust resolved vertically; \( P_v = P_a \times \sin(90 - \alpha + \delta) = 7.9 \text{ kN/m} \)

Height above toe thrust acts if \( \alpha \) is 0; \( d_{h,soil} = H \times \frac{(H + 3 \times h_s)}{(3 \times (H + 2 \times h_s))} = 528 \text{ mm} \)

Height above toe thrust acts; \( d_h = d_{h,soil} - w_2 \times \sin(\epsilon) = 327 \text{ mm} \)

Horiz distance to where thrust acts; \( b_v = w_2 \times \cos(\epsilon) - \frac{d_{h,soil}}{\tan(\alpha)} = 2217 \text{ mm} \)

Overturning stability – take moments about the toe

Overturning moment; \( M_{o2} = (P_h \times d_h) + (F_h \times d_h) = 15.8 \text{ kNm/m} \)

Restoring moment; \( M_{R2} = (P_v \times b_v) + (W_g \times X_g) + (F_v \times b_v) = 65.9 \text{ kNm/m} \)

Factor of safety for overturning; \( F_{o,M2} = \frac{M_{R2}}{M_{o2}} = 4.17 \)

Min allowable factor of safety for overturning; \( F_{o,M,min} = 2.00 \)

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

Sliding stability – ignore any passive pressure infront of structure

Total vertical force; \( N = W_g + P_v + F_v = 55.0 \text{ kN/m} \)

Total horizontal force; \( T = P_h + F_h = 18.7 \text{ kN/m} \)

Sliding force; \( F_{f2} = T \times \cos(\epsilon) - N \times \sin(\epsilon) = 13.8 \text{ kN/m} \)

Resistance to sliding; \( F_{R2} = (N \times \cos(\epsilon) + T \times \sin(\epsilon)) \times \tan(\delta_bg) = 39.5 \text{ kN/m} \)

Factor of safety for sliding; \( F_{o,S2} = \frac{F_{R2}}{F_{f2}} = 2.86 \)

Min allowable factor of safety for sliding; \( F_{o,S,min} = 1.50 \)

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

Check for sliding and overturning between courses 2 and 3

Centre of gravity

Horizontal distance to centre of gravity gabion 3; \( x_{g3} = w_3 / 2 = 1000 \text{ mm} \)

Vertical distance to centre of gravity gabion 3; \( y_{g3} = h_3 / 2 = 300 \text{ mm} \)

Weight of entire gabion; \( W_g = W_{g3} = 18.0 \text{ kN/m} \)

Horiz distance to centre of gravity entire gabion; \( x_g = ((W_{g3} \times x_{g3}) / W_g = 1000 \text{ mm} \)

Vert distance to centre of gravity entire gabion; \( y_g = ((W_{g3} \times y_{g3}) / W_g = 300 \text{ mm} \)

Correcting for wall inclination horiz dist; \( X_g = x_g \times \cos(\epsilon) + y_g \times \sin(\epsilon) = 1022 \text{ mm} \)

Vertical change in height due to wall inclination; \( H_f = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) \times \cos(\epsilon) - (x_{g3} + w_3/2) \times \sin(\epsilon)) = 177 \text{ mm} \)
Calculate effective height of wall

Effective height of wall;
\[ H = \left( y_g + \frac{h}{2}\right) + \left( w_3 \times \sin(\varepsilon) \right) - H_f = 598 \text{ mm} \]

Calculate the angle of rear plane of wall

Effective angle of rear plane of wall; \( \alpha = 90 \text{ deg} + \varepsilon = 95.0 \text{ deg} \)

Calculate the effective face angle

Effective face angle; \( \theta = 90 \text{ deg} - \varepsilon = 85.0 \text{ deg} \)

Loading

Surcharge; \( p_0 = 10 \text{ kN/m}^2 \)

Horizontal line load; \( F_h = 10 \text{ kN/m} \)

Vertical height of horizontal load from top gabion; \( h_{h0} = 0 \text{ mm} \)

Dist of horiz. load from leading edge of top gabion; \( d_{h0} = 0 \text{ mm} \)

Vertical height from toe; \( h_{b0} = (H_{b0} = \tan(\theta) + d_{h0}) = 52 \text{ mm} \)

Vertical line load; \( F_v = 5 \text{ kN/m} \)

Dist of vert. load from leading edge of top gabion; \( d_{v0} = 0 \text{ mm} \)

Horizontal distance of vert. load from toe; \( b_{v0} = (H_{b0} = \tan(\theta) + d_{v0}) = 52 \text{ mm} \)

Surcharge loading as equiv height of soil; \( h_s = \frac{p_0}{\gamma_s} = 435 \text{ mm} \)

Active thrust due to soil; \( P_a,soil = 0.5 \times K_a \times \gamma_s \times H^2 = 1.4 \text{ kN/m} \)

Active thrust due to surcharge; \( P_a,surch = p_0 \times K_a \times H = 2.1 \text{ kN/m} \)

Total active thrust; \( P_a = P_a,soil + P_a,surch = 3.6 \text{ kN/m} \)

Total thrust resolved horizontally; \( P_h = P_a \times \cos(90 - \alpha + \delta) = 3.1 \text{ kN/m} \)

Total thrust resolved vertically; \( P_v = P_a \times \sin(90 - \alpha + \delta) = 1.7 \text{ kN/m} \)

Height above toe thrust acts if \( \alpha = 0 \); \( d_{h,soil} = H \times (H + 3 \times h_0) / (3 \times (H + 2 \times h_0)) = 258 \text{ mm} \)

Height above toe thrust acts; \( d_h = d_{h,soil} - w_3 \times \sin(\varepsilon) = 84 \text{ mm} \)

Horizon distance to where thrust acts; \( b_v = w_3 \times \cos(\varepsilon) - (d_{h,soil} / \tan(\alpha)) = 2015 \text{ mm} \)

Overturning stability – take moments about the toe

Overturning moment; \( M_{b3} = (P_h \times d_h) + (F_h \times d_{v0}) = 6.2 \text{ kNm/m} \)

Restoring moment; \( M_{R3} = (P_v \times b_v) + (W_g \times X_g) + (F_v \times b_{v0}) = 22.2 \text{ kNm/m} \)

Factor of safety for overturning; \( F_{o,M3} = M_{R3} / M_{b3} = 3.55 \)

Min allowable factor of safety for overturning; \( F_{o,M,min} = 2.00 \)

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

Sliding stability – ignore any passive pressure infront of structure

Total vertical force; \( N = W_g + P_v + F_v = 24.7 \text{ kN/m} \)

Total horizontal force; \( T = P_h + F_h = 13.1 \text{ kN/m} \)

Sliding force; \( F_{R3} = T \times \cos(\varepsilon) - N \times \sin(\varepsilon) = 10.9 \text{ kN/m} \)
Resistance to sliding;
\[ F_R3 = (N \times \cos(\alpha) + T \times \sin(\alpha)) \times \tan(\delta_{bg}) = 18.1 \text{kN/m} \]

Factor of safety for sliding;
\[ F_{o,93} = F_R3 / F_{f3} = 1.66 \]

Min allowable factor of safety for sliding;
\[ F_{o,93,\text{min}} = 1.50 \]

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