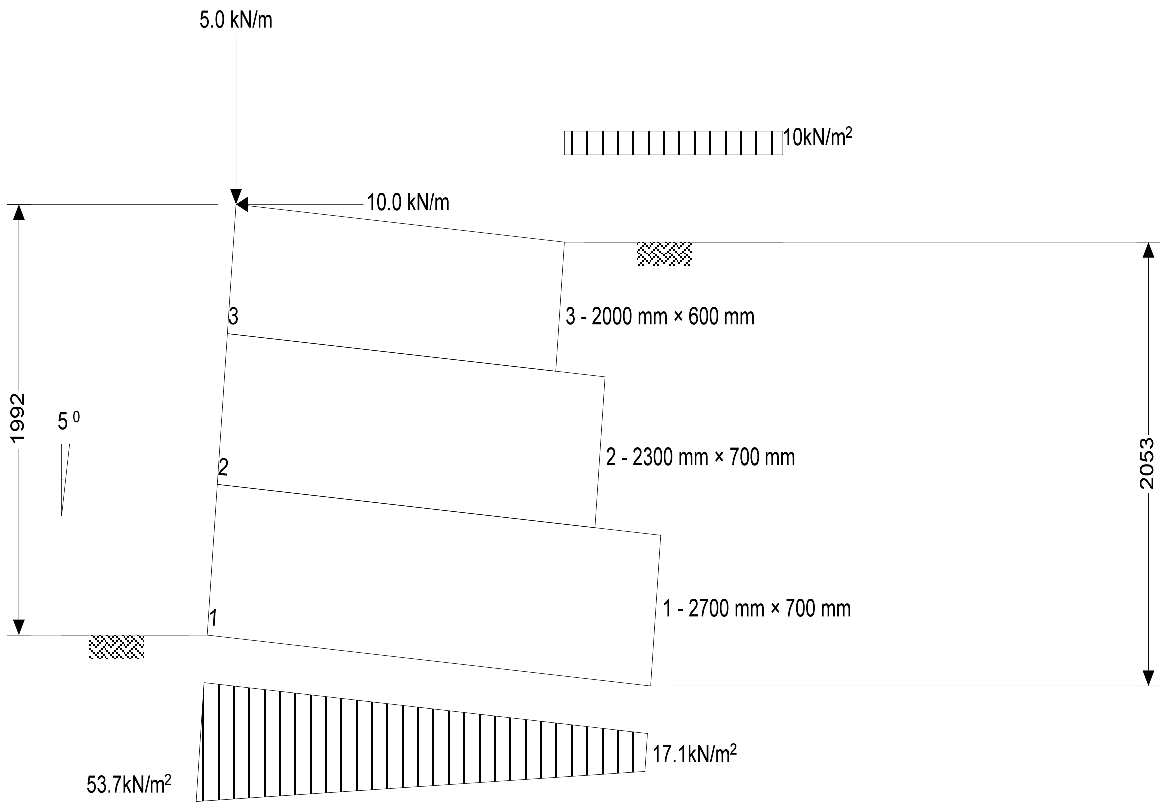
GABION RETAINING WALL ANALYSIS AND DESIGN (BS8002:1994)



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; ε = **5** deg

Wall fill

Gabion fill unit weight; γ_d = **15** kN/m^3

Centre of gravity

Horizontal distance to centre of gravity gabion 1; $x_{g1} = w_1 / 2$ = **1350** mm

Horizontal distance to centre of gravity gabion 2; $x_{g2} = w_2 / 2 + s_2$ = **1150** mm

Horizontal distance to centre of gravity gabion 3; $x_{g3} = w_3 / 2 + s_2 + s_3$ = **1000** mm

Vertical distance to centre of gravity gabion 1; $y_{g1} = h_1 / 2$ = **350** mm

Vertical distance to centre of gravity gabion 2; $y_{g2} = h_2 / 2 + h_1$ = **1050** mm

Vertical distance to centre of gravity gabion 3; $y_{g3} = h_3 / 2 + h_1 + h_2$ = **1700** mm

Weight of gabion 1; $W_{g1} = \gamma_d \times w_1 \times h_1$ = **28.4** kN/m

Weight of gabion 2; $W_{g2} = \gamma_d \times w_2 \times h_2$ = **24.2** kN/m

Weight of gabion 3; $W_{g3} = \gamma_d \times w_3 \times h_3$ = **18.0** kN/m

Weight of entire gabion; $W_g = W_{g1} + W_{g2} + W_{g3}$ = **70.5** kN/m

Horiz distance to centre of gravity entire gabion; $x_g = ((W_{g1} \times x_{g1}) + (W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3})) / W_g$ = **1192** mm

Vert distance to centre of gravity entire gabion; $y_g = ((W_{g1} \times y_{g1}) + (W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3})) / W_g$ = **934** mm

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

Calculate effective height of wall

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

Calculate the angle of rear plane of wall

Effective angle of rear plane of wall; α =Atan $[(y_{g3} + (h_3 / 2)) / (w_1 - (x_{g3} + (w_3/ 2)))] + \varepsilon$ = **75.7** deg

Calculate the effective face angle

Effective face angle; θ = 90 deg - ε = **85.0** deg

Soil parameters

Slope of retained soil; β = **0.0** deg

Mobilization factor; M = **1.0**

Internal angle of friction for retained soil; ϕ' = **38.0** deg

Saturated density of retained soil; γ_s = **23** kN/m^3

Coefficient for wall friction; K = **0.9**

Wall friction; $\delta = \phi' \times K$ = **34.2** deg

Design angle of base friction; δ_b = **30.0** deg

Bearing capacity of founding soil; q = **110** kN/m^2

Active Pressure using Coulomb Theory;

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

Loading

Surcharge; p_o = **10** kN/m^2

Horizontal line load; F_h = **10** kN/m

Vertical height of horizontal load from top gabion; H_{hl} = **0** mm

Dist of horiz. load from leading edge of top gabion; D_{hl} = **0** mm

Vertical height from toe; $d_{hl} = (H_{incl} + H_{hl} - D_{hl} \times \tan(\varepsilon))$ = **1992** mm

Horizontal distance of horiz. load from toe; $b_{hl} = (H_{incl} / \tan(\theta) + D_{hl})$ = **174** mm

Vertical line load; F_v = **5** kN/m

Dist of vert. load from leading edge of top gabion; D_{vl} = **0** mm

Horizontal distance of vert. load from toe; $b_{vl} = (H_{incl} / \tan(\theta) + D_{vl})$ = **174** mm

Surcharge loading as equiv height of soil; $h_s = p_o / \gamma_s$ = **435** mm

Active thrust due to soil; $P_{a,soil} = 0.5 \times K_a \times \gamma_s \times H^2$ = **17.1** kN/m

Active thrust due to surcharge; $P_{a,surch} = p_o \times K_a \times H$ = **7.2** kN/m

Total active thrust; $P_a = P_{a,soil} + P_{a,surch}$ = **24.3** kN/m

Total thrust resolved horizontally; $P_h = P_a \times \cos(90 - \alpha + \delta)$ = **16.1** kN/m

Total thrust resolved vertically; $P_v = P_a \times \sin(90 - \alpha + \delta)$ = **18.2** kN/m

Height above toe thrust acts if α is 0; $d_{h,soil} = H \times (H + 3 \times h_s) / (3 \times (H + 2 \times h_s))$ = **786** mm

Height above toe thrust acts; $d_h = d_{h,soil} - w_1 \times \sin(\varepsilon)$ = **551** mm

Horiz distance to where thrust acts; $b_v = w_1 \times \cos(\varepsilon) - (d_{h,soil} / \tan(\alpha))$ = **2489**mm

Overturning stability – take moments about the toe

Overturning moment; $M_o = (P_h \times d_h) + (F_h \times d_{hl})$ = **28.8** kNm/m

Restoring moment; $M_R = (P_v \times b_v) + (W_g \times X_g) + (F_v \times b_{vl})$ = **135.7** kNm/m

Factor of safety for overturning; $F_{o,M} = M_R / M_o$ = **4.71**

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; $N = W_g + P_v + F_v$ = **93.7** kN/m

Total horizontal force; $T = P_h + F_h$ = **26.1** kN/m

Sliding force; $F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon)$ = **17.8** kN/m

Resistance to sliding; $F_R = (N \times \cos(\varepsilon) + T \times \sin(\varepsilon)) \times \tan(\delta_b)$ = **55.2** kN/m

Factor of safety for sliding; $F_{o,S} = F_R / F_f$ = **3.09**

Min allowable factor of safety for sliding; $F_{o,S,min}$ = **1.50**

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

Pressure at base

Force normal to base; $N_s = (N \times \cos(\varepsilon) + T \times \sin(\varepsilon))$ = **95.6** kN/m

Eccentricity; $e = (w_1 / 2) - (M_R - M_o) / N_s$ = **232** mm

Reaction acts within middle third of base

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

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

PASS - Allowable bearing pressure exceeds max design pressure to base

<u>Check for sliding and overturning between courses 1 and 2</u>

Centre of gravity

Horizontal distance to centre of gravity gabion 2; $x_{g2} = w_2 / 2$ = **1150** mm

Horizontal distance to centre of gravity gabion 3; $x_{g3} = w_3 / 2 + s_3$ = **1000** mm

Vertical distance to centre of gravity gabion 2; $y_{g2} = h_2 / 2$ = **350** mm

Vertical distance to centre of gravity gabion 3; $y_{g3} = h_3 / 2 + h_2$ = **1000** mm

Weight of gabion 2; $W_{g2} = \gamma_d \times w_2 \times h_2$ = **24.2** kN/m

Weight of gabion 3; $W_{g3} = \gamma_d \times w_3 \times h_3$ = **18.0** kN/m

Weight of entire gabion; $W_g = W_{g2} + W_{g3}$ = **42.2** 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** mm

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

Correcting for wall inclination horiz dist; $X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon)$ = **1137** mm

Vertical change in height due to wall inclination; $H_f = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) \times \cos(\varepsilon) - (x_{g3} + w_3/2) \times \sin(\varepsilon))$ = **179** mm

Calculate effective height of wall

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

Height of wall from toe to front edge of top gabion; $H_{incl} = ((y_{g3} + h_3 / 2) \times \cos(\varepsilon) - (x_{g3} - (w_3/ 2)) \times \sin(\varepsilon))$ = **1295**mm

Calculate the angle of rear plane of wall

Effective angle of rear plane of wall; $\alpha = \text{Atan}[(y_{g3} + (h_3 / 2)) / (w_2 - (x_{g3} + (w_3/ 2)))] + \varepsilon$ = **82.0** deg

Calculate the effective face angle

Effective face angle; $\theta = 90 \text{ deg} - \varepsilon$ = **85.0** deg

Loading

Surcharge; p_o = **10** kN/m^2

Horizontal line load; F_h = **10** kN/m

Vertical height of horizontal load from top gabion; H_{hl} = **0** mm

Dist of horiz. load from leading edge of top gabion; D_{hl} = **0** mm

Vertical height from toe; $d_{hl} = (H_{incl} + H_{hl} - D_{hl} \times \tan(\varepsilon))$ = **1295** mm

Horizontal distance of horiz. load from toe; $b_{hl} = (H_{incl} / \tan(\theta) + D_{hl})$ = **113** mm

Vertical line load; F_v = **5** kN/m

Dist of vert. load from leading edge of top gabion; D_{vl} = **0** mm

Horizontal distance of vert. load from toe; $b_{vl} = (H_{incl} / \tan(\theta) + D_{vl}) = \mathbf{113}$ mm

Surcharge loading as equiv height of soil; $h_s = p_o / \gamma_s = \mathbf{435}$ mm

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

Active thrust due to surcharge; $P_{a,surch} = p_o \times K_a \times H = \mathbf{4.7}$ kN/m

Total active thrust; $P_a = P_{a,soil} + P_{a,surch} = \mathbf{11.7}$ kN/m

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

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

Height above toe thrust acts if α is 0; $d_{h,soil} = H \times (H + 3 \times h_s) / (3 \times (H + 2 \times h_s)) = \mathbf{528}$ mm

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

Horiz distance to where thrust acts; $b_v = w_2 \times \cos(\varepsilon) - (d_{h,soil} / \tan(\alpha)) = \mathbf{2217}$mm

Overturning stability – take moments about the toe

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

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

Factor of safety for overturning; $F_{o,M2} = M_{R2} / M_{o2} = \mathbf{4.17}$

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

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

Sliding stability – ignore any passive pressure infront of structure

Total vertical force; $N = W_g + P_v + F_v = \mathbf{55.0}$ kN/m

Total horizontal force; $T = P_h + F_h = \mathbf{18.7}$ kN/m

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

Resistance to sliding; $F_{R2} = (N \times \cos(\varepsilon) + T \times \sin(\varepsilon)) \times \tan(\delta_{bg}) = \mathbf{39.5}$ kN/m

Factor of safety for sliding; $F_{o,S2} = F_{R2} / F_{f2} = \mathbf{2.86}$

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

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

<u>Check for sliding and overturning between courses 2 and 3</u>

Centre of gravity

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

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

Weight of gabion 3; $W_{g3} = \gamma_d \times w_3 \times h_3 = \mathbf{18.0}$ kN/m

Weight of entire gabion; $W_g = W_{g3} = \mathbf{18.0}$ kN/m

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

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

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

Vertical change in height due to wall inclination; $H_f = y_{g3} + h_3/2 - ((y_{g3} + h_3/2) \times \cos(\varepsilon) - (x_{g3} + w_3/2) \times \sin(\varepsilon)) = \mathbf{177}$ mm

Calculate effective height of wall

Effective height of wall; $H = (y_{g3} + h_3 / 2) + (w_3 \times \sin(\varepsilon)) - H_f =$ **598** mm

Height of wall from toe to front edge of top gabion; $H_{incl} = ((y_{g3} + h_3 / 2) \times \cos(\varepsilon) - (x_{g3} - (w_3/ 2)) \times \sin(\varepsilon))$ = **598**mm

Calculate the angle of rear plane of wall

Effective angle of rear plane of wall; α =90 deg + ε = **95.0** deg

Calculate the effective face angle

Effective face angle; θ = 90 deg - ε = **85.0** deg

Loading

Surcharge; p_o = **10** kN/m^2

Horizontal line load; F_h = **10** kN/m

Vertical height of horizontal load from top gabion; H_{hl} = **0** mm

Dist of horiz. load from leading edge of top gabion; D_{hl} = **0** mm

Vertical height from toe; $d_{hl} = (H_{incl} + H_{hl} – D_{hl} \times \tan(\varepsilon))$ = **598** mm

Horizontal distance of horiz. load from toe; $b_{hl} = (H_{incl} / \tan(\theta) + D_{hl})$ = **52** mm

Vertical line load; F_v = **5** kN/m

Dist of vert. load from leading edge of top gabion; D_{vl} = **0** mm

Horizontal distance of vert. load from toe; $b_{vl} = (H_{incl} / \tan(\theta) + D_{vl})$ = **52** mm

Surcharge loading as equiv height of soil; $h_s = p_o / \gamma_s$ = **435** mm

Active thrust due to soil; $P_{a,soil} = 0.5 \times K_a \times \gamma_s \times H^2$ = **1.4** kN/m

Active thrust due to surcharge; $P_{a,surch} = p_o \times K_a \times H$ = **2.1** kN/m

Total active thrust; $P_a = P_{a,soil} + P_{a,surch}$ = **3.6** kN/m

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

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

Height above toe thrust acts if α is 0; $d_{h,soil} = H \times (H + 3 \times h_s) / (3 \times (H + 2 \times h_s))$ = **258** mm

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

Horiz distance to where thrust acts; $b_v = w_3 \times \cos(\varepsilon) – (d_{h,soil} / \tan(\alpha))$ = **2015**mm

Overturning stability – take moments about the toe

Overturning moment; $M_{o3} = (P_h \times d_h) + (F_h \times d_{hl})$ = **6.2** kNm/m

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

Factor of safety for overturning; $F_{o,M3} = M_{R3} / M_{o3}$ = **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** kN/m

Total horizontal force; $T = P_h + F_h$ = **13.1** kN/m

Sliding force; $F_{f3} = T \times \cos(\varepsilon) – N \times \sin(\varepsilon)$ = **10.9** kN/m

Resistance to sliding; $F_{R3} = (N \times \cos(\varepsilon) + T \times \sin(\varepsilon)) \times \tan(\delta_{bg})$ = **18.1** kN/m

Factor of safety for sliding; $F_{o,S3} = F_{R3} / F_{f3}$ = **1.66**

Min allowable factor of safety for sliding; $F_{o,S,min}$ = **1.50**

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