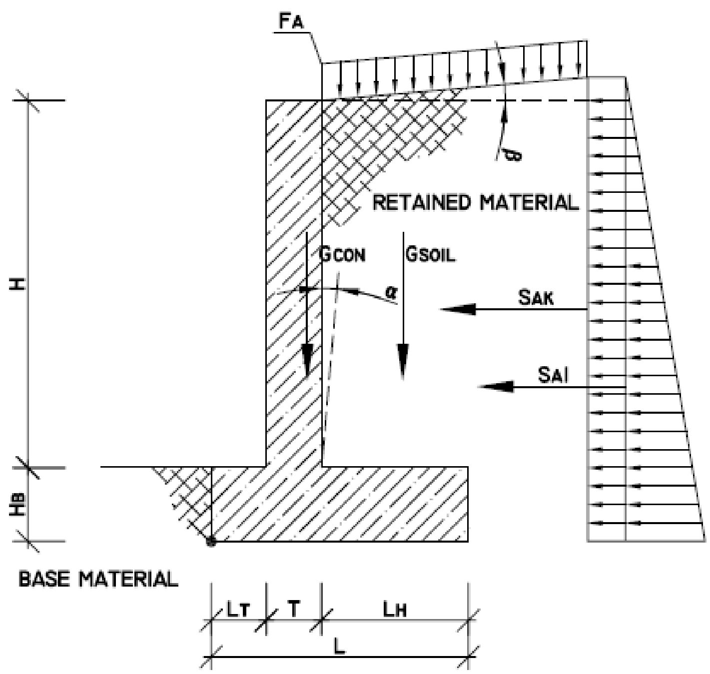
SOFTWARE ANALYSIS OF RETAINING WALLS



Project: S**oftware analysis of retaining walls**

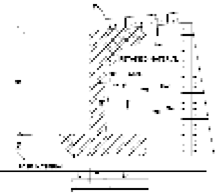
Project description: **Analysis of retaining walls of certain height made of elastoplastic concrete**

Project number: **2012014**

Prepared by: **Josef Novak (email: novakjsf@yahoo.com , Ph.:0466 672 466)**

Prepared for: **Elastoplastic concrete (EPC)**

Date: **October 2012**



1. CONTENT

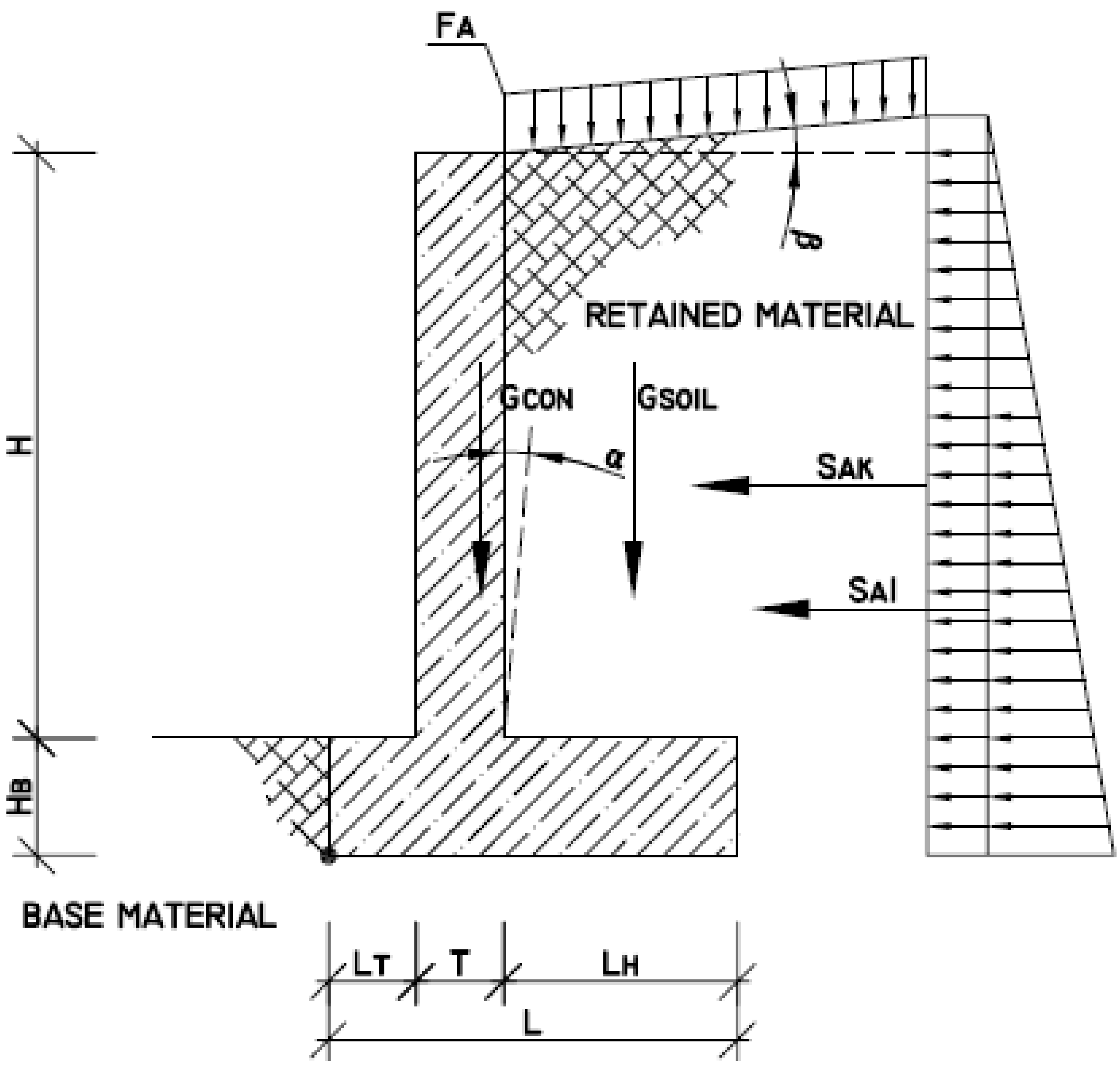
2. PRELUDE

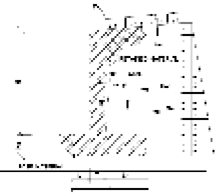
The report is written to show a possible use of elastoplastic concrete for retaining walls. The data included in the report such as the elastoplastic concrete properties have been already described in the previous reports.

This report shows the possible use for a cantilevered retaining wall of the certain height. The designed retaining walls are analysed for the all states in accordance to the Australian Standard: Earth-retaining structures – AS4678-2002: stability limit state – overturning, stability limit state – sliding, soil bearing capacity and ultimate limit state of a retaining wall.

The load used for the analysis in the report is the active earth pressure from the retained material and the passive earth pressure from the base material positively acting on an elastoplastic concrete retaining wall (no surcharge on plan and no load from water pressure). The retained material properties used for the analysis in the report is considered like one of the worst soil for this purpose. That means the analysis result is on a positive side. The base material properties used for the analysis is considered like soil with the better properties. The analysis is based on Coulomb theory which is commonly used for this sort of analyses.

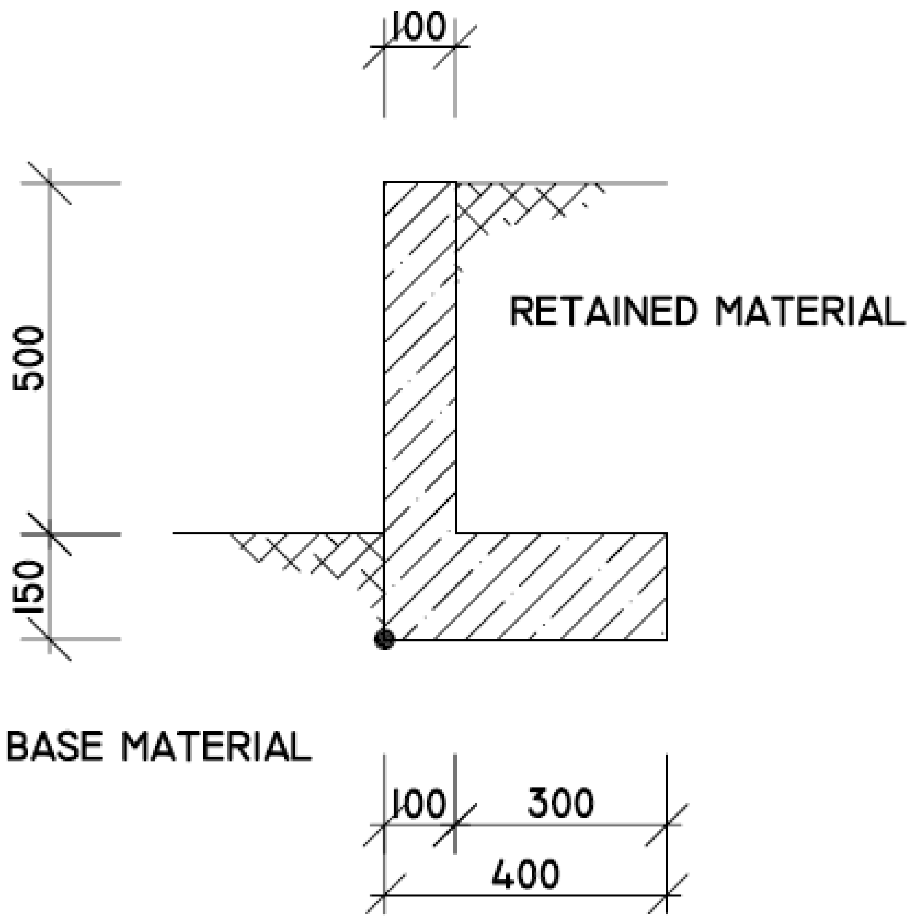
3. STATIC MODEL FOR ANALYSES





4. RETAINING WALL ANALYSIS (0mm - 500mm HIGH)

4.1 Retaining wall model



4.2 Retaining wall analysis

<u>RETAINING WAL PROPERTIES</u>

Retaining wall dimensions

» $H =$ 0,500 m *Heigth of retaining wall stem*

» $H_b =$ 0,150 m *Heigth of retaining wall base*

» $h_{soil} =$ 0,150 m *Heigth of soil in front of the retaining wall*

» $l_t =$ 0,000 m *Lenght of toe*

» $t =$ 0,100 m *Retaining wall thickness*

» $l_h =$ 0,300 m *Length of heel*

» $\alpha =$ 0 ° *Angle of rear face of wall*

Extra load acting on the ground surface

» $f_a =$ 0,00 kN/m^2 *Surcharge load on plan*

$H_{eqv} = f_a / \gamma_{soil} =$ 0,000 m *Equivalent heigth of soil*

Retained soil material

» $\gamma_{soil} =$ 21,00 kN/m^3 *Density of soil*

» $\varphi_{ef} =$ 18,00 ° *Effective internal friction angle*

» $\phi_{\varphi} =$ 0,85 [-] *Material strength uncertainty factor*

$\varphi' =$ 15,44 ° *Design internal friction angle*

» $\sigma_{Rd} =$ 100 kPa *Allowable ultimate bearing pressure*

» $\beta =$ 0 ° *Angle of soil surface behind wall*

$\delta =$ 10 ° *Angle of base friction*

The typical soil of this properties is claysoil.

Base soil material

» $\gamma_{soil} =$ 19,00 kN/m^3 *Density of soil*

» $\varphi_{ef} =$ 35,00 ° *Effective internal friction angle*

» $\phi_{\varphi} =$ 0,85 [-] *Material strength uncertainty factor*

$\varphi' =$ 30,76 ° *Design internal friction angle*

» σ_{Rd} = 150 kPa *Allowable ultimate bearing pressure*

δ = 21 ° *Angle of base friction*

The typical soil of this properties is gravelsoil and sand soil.

Concrete

» Concrete: C25/30

f_{ck} = 25,00 MPa *Characteristic compressive cylinder strength of plain concrete*

$f_{ct,f}$ = 3,000 MPa *Characteristic flexural tensile strength of plain concrete*

» γ_{con} = 25,00 kN/m^3 *Density of concrete*

Earth pressure factors

$K_a = \cos^2 (\varphi' - \alpha) / [\cos^2 (\alpha) \,.\, \cos (\alpha + \delta) \,.\, (1 + (\sin (\varphi' + \delta) \,.\, \sin (\varphi' - \beta) /$

$/ (\cos (\alpha + \delta) \,.\, \cos (\alpha - \beta)))^{0,5}]^2$

K_a = 0,52 [-] *Active earth pressure factor*

$K_p = [\sin (90 - \varphi')]^2 / \{\sin (90 - \delta) \,.\, [1 - ((\sin (\varphi' + \delta) \,.\, \sin (\varphi') / \sin (90 + \delta))^{0,5}]^2\}$

K_p = 6,53 [-] *Passive earth pressure factor*

A/ STABILITY ANALYSIS - OVERTURNING

$S_{ak} = f_a \,.\, K_a \,.\, (H_b + H)$ = 0,000 kN *Effective value of horizontal surcharge force*

$h_{ak} = (H_b + H) / 2$ = 0,325 m *Force arm of extra surcharge on plan*

γ_{ak} = 1,50 [-] *Stability load factor for overturning live load*

$S_{a1} = (H_b + H)^2 \,.\, \gamma_{soil} \,.\, K_a / 2$ = 2,32 kN *Effective value of horizontal active earth press*

$h_{a1} = (H_b + H) / 3$ = 0,217 m *Force arm of active earth pressure*

γ_{a1} = 1,25 [-] *Stability load factor for overturning dead load*

$G_{con} = [(l_t + t + l_h) \,.\, H_b + H \,.\, t] \,.\, \gamma_{con}$ = 2,75 kN *Effective vertical force of concrete R*

$h_{con} = [(l_t + t + l_h)^2 \,.\, H_b / 2 + H \,.\, t \,.\, (l_t + t / 2)] / [(l_t + t + l_h) \,.\, H_b + H \,.\, t]$ = 0,132 m *F*

γ_{con} = 0,90 [-] *Stability load factor for restoring dead load*

$G_{soil} = l_h \,.\, H \,.\, \gamma_{soil}$ = 3,15 kN *Effective vertical force of backfill*

$h_{soil} = l_t + t + l_h / 3$ = 0,200 m *Force arm of backfill*

γ_{soil} = 0,90 [-] *Stability load factor for restoring dead load*

$M_{over} = S_a \,.\, h_a \,.\, \gamma_{ak} + S_{a1} \,.\, h_{a1} \,.\, \gamma_{a1} =$ 0,629 kNm ***Overturning moment***

$M_{rest} = G_{con} \,.\, h_{con} \,.\, \gamma_{con} + G_{soil} \,.\, h_{soil} \,.\, \gamma_{soil}) =$ 0,89 kNm ***Restoring moment***

$M_{rest} =$ 0,89 kNm > $M_{over} =$ 0,629 kNm OK

B/ ANALYSIS OF STABILITY AGAINTS SLIDING

$S_{ak} = f_a \,.\, K_a \,.\, (H_b + H) =$ 0,000 kN *Effective value of horizontal surcharge force*

$\gamma_{ak} =$ 1,50 [-] *Stability load factor for overturning live load*

$S_{a1} = (H_b + H)^2 \,.\, \gamma_{soil} \,.\, K_a / 2 =$ 2,32 kN *Effective value of horizontal active earth press*

$\gamma_{a1} =$ 1,25 [-] *Stability load factor for overturning dead load*

$S_{a2} = H_{soil}^{\;2} \,.\, \gamma_{soil} \,.\, K_p / 2 =$ 1,54 kN *Effective value of horizontal passive earth pressur*

$\gamma_{a2} =$ 0,90 [-] *Stability load factor for restoring dead load*

$G_{con} = [(l_t + t + l_h) \,.\, H_b + H \,.\, t] \,.\, \gamma_{con} =$ 2,75 kN *Effective vertical force of concrete R*

$\gamma_{con} =$ 0,90 [-] *Stability load factor for restoring dead load*

$G_{soil} = l_h \,.\, H \,.\, \gamma_{soil} =$ 3,15 kN *Effective vertical force of backfill*

$\gamma_{soil} =$ 0,90 [-] *Stability load factor for restoring dead load*

$F_{slid} = S_{ak} \,.\, \gamma_{ak} + S_{a1} \,.\, \gamma_{a1} =$ 2,904 kN ***Sliding force***

$F_{rest} = \gamma_{a2} \,.\, S_{a2} + (G_{con} \,.\, \gamma_{con} + G_{soil} \,.\, \gamma_{soil}) \,.\, tg\, \delta =$ 3,375 kN ***Resistance force***

$F_{rest} =$ 3,38 kN > $F_{slid} =$ 2,90 kN OK

C/ SOIL BEARING CAPACITY ANALYSIS

$M_{over} = S_a \,.\, h_a \,.\, \gamma_{ak} + S_{a1} \,.\, h_{a1} \,.\, \gamma_{a1} =$ 0,629 kNm *Overturning moment*

$G_{con} = [(l_t + t + l_h) \,.\, H_b + H \,.\, t] \,.\, \gamma_{con} =$ 2,75 kN *Effective vertical force of concrete R*

$\gamma_{con} =$ 1,25 [-] *Stability load factor for restoring dead load*

$G_{soil} = l_h \,.\, H \,.\, \gamma_{soil} =$ 3,15 kN *Effective vertical force of backfill*

$\gamma_{soil} =$ 1,25 [-] *Stability load factor for restoring dead load*

$e = M_{over} / (\gamma_{con} \,.\, G_{con} + \gamma_{soil} \,.\, G_{soil}) =$ 0,085 m *Total force eccentricity*

$e' = (l_t + t + l_h) / 2 - (G_{con} \,.\, h_{con} + G_{soil} \,.\, h_{soil}) / (G_{con} + G_{soil}) =$ 0,032 m

$b_{eff} = [l_t + t + l_h - 2 \cdot (e + e')] =$ 0,166 m *Load effective width*

$\sigma = (1{,}25 \cdot G_{con} + 1{,}25 \cdot G_{soil}) / b_{eff} =$ 44,49 kPa *Maximum stress in soil*

σ_{Rd} = 150,00 kPa > σ = 44,49 kPa OK

D/ ULTIMATE LIMIT STATE OF RETAINING WALL

Internal force analysis

$S_{ah} = f_a \cdot K_a \cdot H =$ 0,000 kN *Effective value of horizontal surcharge force*

$h_{ah} = H / 2 =$ 0,250 m *Force arm of horizontal surcharge force*

$\gamma_{ah} =$ 1,50 [-] *Load factor for live load (ultimate limit state)*

$S_{a1} = H^2 \cdot \gamma_{soil} \cdot K_a / 2 =$ 1,375 kN *Horizontal force from active earth pressure*

$h_{a1} = H / 3 =$ 0,167 m *Force arm of active earth pressure*

$\gamma_{a1} =$ 1,25 [-] *Load factor for dead load (ultimate limit state)*

$M_{Sd} = \gamma_{ah} \cdot S_{ah} \cdot h_{ah} + \gamma_{a1} \cdot S_{a1} \cdot h_{a1}) =$ 0,29 kNm *Design bending moment*

Fiber concrete structure analysis

$b =$ 1,000 m *Width of a cross-section*

$h =$ 0,100 m *Height of a cross-section*

$f_{ck} =$ 25,00 MPa *Characteristic compressive cylinder strength of plain concrete*

$f_{ct,f} =$ 3,000 MPa *Characteristic flexural tensile strength of plain concrete*

$\phi =$ 0,60 *Capacity reduction factor*

Elastoplastic concrete properties

$m_f =$ 2,50 kg/m^3 *Dosage of plastic fibres per m^3 (max. 7,5 kg)*

$f_{fct,f} =$ 3,356 MPa *Characteristic flexural tensile strength of fiberconcrete*

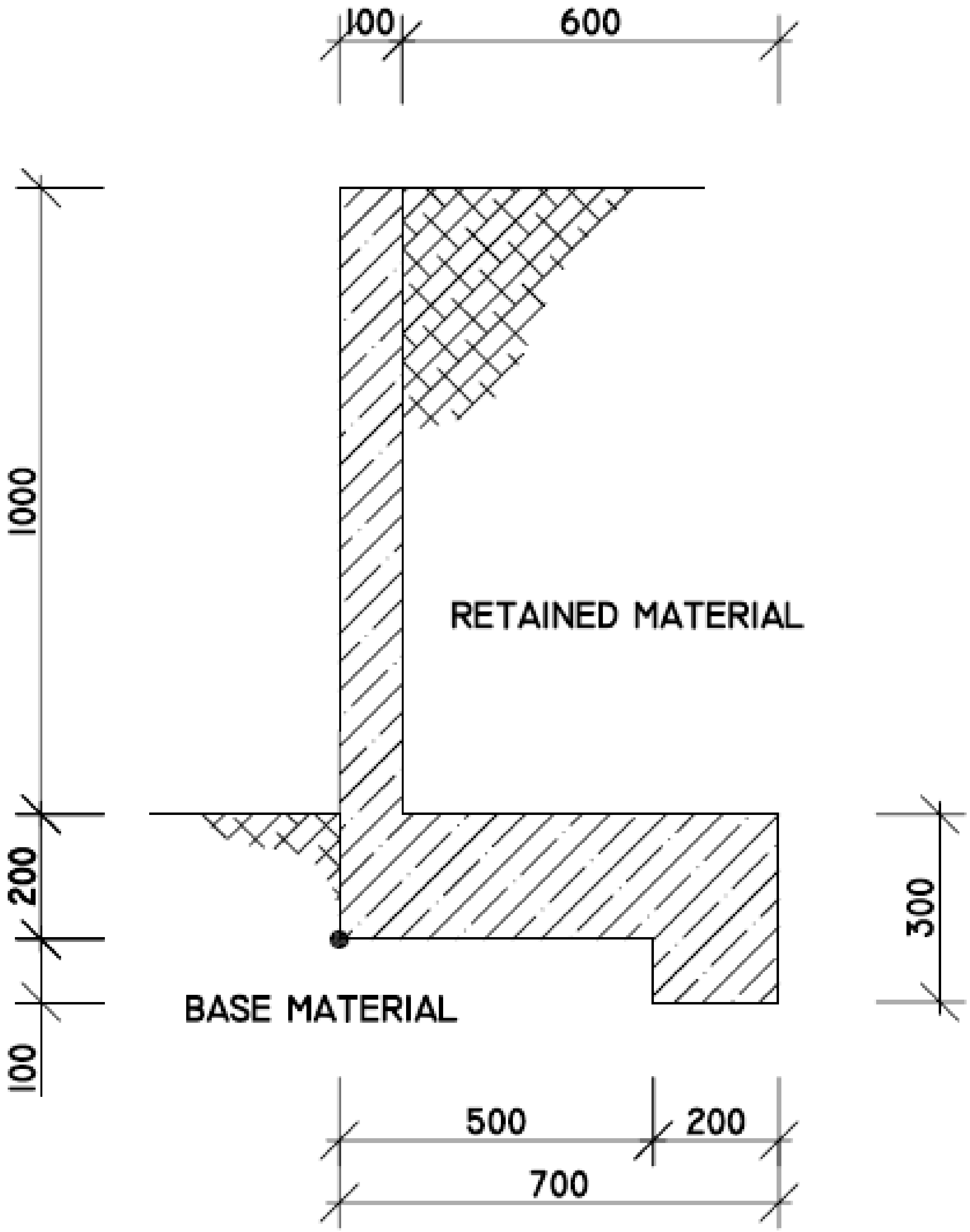
$I_y = b \cdot h^3 / 12 =$ 8,33E-05 m^4 *Second moment of area of the cross-section*

$M_{uo} = 1{,}2 \cdot f_{fct,f} \cdot I_y / (h / 2) \cdot \Phi =$ 4,028 kNm *Design strength in bending*

M_{uo} = 4,028 kNm > M_{Sd} = 0,286 kNm OK

5. RETAINING WALL ANALYSIS (0mm - 1000mm HIGH)

5.1 Retaining wall model



5.2 Retaining wall analysis

<u>RETAINING WAL PROPERTIES</u>

Retaining wall dimensions

» $H =$ 1,000 m *Heigth of retaining wall stem*

» $H_b =$ 0,200 m *Heigth of retaining wall base*

» $h_{soil} =$ 0,300 m *Heigth of soil in front of the retaining wall*

» $l_t =$ 0,000 m *Lenght of toe*

» $t =$ 0,100 m *Retaining wall thickness*

» $l_h =$ 0,600 m *Length of heel*

» $\alpha =$ 0 ° *Angle of rear face of wall*

Extra load acting on the ground surface

» $f_a =$ 0,00 kN/m^2 *Surcharge load on plan*

$H_{eqv} = f_a / \gamma_{soil} =$ 0,000 m *Equivalent heigth of soil*

Retained soil material

» $\gamma_{soil} =$ 21,00 kN/m^3 *Density of soil*

» $\varphi_{ef} =$ 18,00 ° *Effective internal friction angle*

» $\phi_\varphi =$ 0,85 [-] *Material strength uncertainty factor*

$\varphi' =$ 15,44 ° *Design internal friction angle*

» $\sigma_{Rd} =$ 100 kPa *Allowable ultimate bearing pressure*

» $\beta =$ 0 ° *Angle of soil surface behind wall*

$\delta =$ 10 ° *Angle of base friction*

The typical soil of this properties is claysoil.

Base soil material

» $\gamma_{soil} =$ 19,00 kN/m^3 *Density of soil*

» $\varphi_{ef} =$ 35,00 ° *Effective internal friction angle*

» $\phi_\varphi =$ 0,85 [-] *Material strength uncertainty factor*

$\varphi' =$ 30,76 ° *Design internal friction angle*

» σ_{Rd} = 150 kPa *Allowable ultimate bearing pressure*

δ = 21 ° *Angle of base friction*

The typical soil of this properties is gravelsoil and sand soil.

Concrete

» Concrete: C25/30

f_{ck} = 25,00 MPa *Characteristic compressive cylinder strength of plain concrete*

$f_{ct,f}$ = 3,000 MPa *Characteristic flexural tensile strength of plain concrete*

» γ_{con} = 25,00 kN/m^3 *Density of concrete*

Earth pressure factors

$K_a = \cos^2 (\varphi' - \alpha) / [\cos^2 (\alpha) \, . \, \cos (\alpha + \delta) \, . \, (1 + (\sin (\varphi' + \delta) \, . \, \sin (\varphi' - \beta) /$
$/ (\cos (\alpha + \delta) \, . \, \cos (\alpha - \beta)))^{0,5}]^2$

K_a = 0,52 [-] *Active earth pressure factor*

$K_p = [\sin (90 - \varphi')]^2 / \{\sin (90 - \delta) \, . \, [1 - ((\sin (\varphi' + \delta) \, . \, \sin (\varphi') / \sin (90 + \delta))^{0,5}]^2\}$

K_p = 6,53 [-] *Passive earth pressure factor*

A/ STABILITY ANALYSIS

$S_{ak} = f_a \, . \, K_a \, . \, (H_b + H)$ = 0,000 kN *Effective value of horizontal surcharge force*

$h_{ak} = (H_b + H) / 2$ = 0,600 m *Force arm of extra surcharge on plan*

γ_{ak} = 1,50 [-] *Stability load factor for overturning live load*

$S_{a1} = (H_b + H)^2 \, . \, \gamma_{soil} \, . \, K_a / 2$ = 7,92 kN *Effective value of horizontal active earth press*

$h_{a1} = (H_b + H) / 3$ = 0,400 m *Force arm of active earth pressure*

γ_{a1} = 1,25 [-] *Stability load factor for overturning dead load*

$G_{con} = [(l_t + t + l_h) \, . \, H_b + H \, . \, t] \, . \, \gamma_{con}$ = 6,00 kN *Effective vertical force of concrete R*

$h_{con} = [(l_t + t + l_h)^2 \, . \, H_b / 2 + H \, . \, t \, . \, (l_t + t / 2)] / [(l_t + t + l_h) \, . \, H_b + H \, . \, t]$ = 0,225 m *F*

γ_{con} = 0,90 [-] *Stability load factor for restoring dead load*

$G_{soil} = l_h \, . \, H \, . \, \gamma_{soil}$ = 12,60 kN *Effective vertical force of backfill*

$h_{soil} = l_t + t + l_h / 3$ = 0,300 m *Force arm of backfill*

γ_{soil} = 0,90 [-] *Stability load factor for restoring dead load*

$M_{over} = S_a \cdot h_a \cdot \gamma_{ak} + S_{a1} \cdot h_{a1} \cdot \gamma_{a1} =$ 3,960 kNm ***Overturning moment***

$M_{rest} = G_{con} \cdot h_{con} \cdot \gamma_{con} + G_{soil} \cdot h_{soil} \cdot \gamma_{soil}) =$ 4,62 kNm ***Restoring moment***

$M_{rest} =$ 4,62 kNm > $M_{over} =$ 3,960 kNm OK

B/ ANALYSIS OF STABILITY AGAINTS SLIDING

$S_{ak} = f_a \cdot K_a \cdot (H_b + H) =$ 0,000 kN *Effective value of horizontal surcharge force*

$\gamma_{ak} =$ 1,50 [-] *Stability load factor for overturning live load*

$S_{a1} = (H_b + H)^2 \cdot \gamma_{soil} \cdot K_a / 2 =$ 7,92 kN *Effective value of horizontal active earth press*

$\gamma_{a1} =$ 1,25 [-] *Stability load factor for overturning dead load*

$S_{a2} = H_{soil}^2 \cdot \gamma_{soil} \cdot K_p / 2 =$ 6,18 kN *Effective value of horizontal passive earth pressur*

$\gamma_{a2} =$ 0,90 [-] *Stability load factor for restoring dead load*

$G_{con} = [(l_t + t + l_h) \cdot H_b + H \cdot t] \cdot \gamma_{con} =$ 6,00 kN *Effective vertical force of concrete R*

$\gamma_{con} =$ 0,90 [-] *Stability load factor for restoring dead load*

$G_{soil} = l_h \cdot H \cdot \gamma_{soil} =$ 12,60 kN *Effective vertical force of backfill*

$\gamma_{soil} =$ 0,90 [-] *Stability load factor for restoring dead load*

$F_{slid} = S_{ak} \cdot \gamma_{ak} + S_{a1} \cdot \gamma_{a1} =$ 9,899 kN ***Sliding force***

$F_{rest} = \gamma_{a2} \cdot S_{a2} + (G_{con} \cdot \gamma_{con} + G_{soil} \cdot \gamma_{soil}) \cdot \mathrm{tg}\,\delta =$ 11,82 kN ***Resistance force***

$F_{rest} =$ 11,82 kN > $F_{slid} =$ 9,90 kN OK

C/ SOIL BEARING CAPACITY ANALYSIS

$M_{over} = S_a \cdot h_a \cdot \gamma_{ak} + S_{a1} \cdot h_{a1} \cdot \gamma_{a1} =$ 3,960 kNm *Overturning moment*

$G_{con} = [(l_t + t + l_h) \cdot H_b + H \cdot t] \cdot \gamma_{con} =$ 6,00 kN *Effective vertical force of concrete R*

$\gamma_{con} =$ 1,25 [-] *Stability load factor for restoring dead load*

$G_{soil} = l_h \cdot H \cdot \gamma_{soil} =$ 12,60 kN *Effective vertical force of backfill*

$\gamma_{soil} =$ 1,25 [-] *Stability load factor for restoring dead load*

$e = M_{over} / (\gamma_{con} \cdot G_{con} + \gamma_{soil} \cdot G_{soil}) =$ 0,170 m *Total force eccentricity*

$e' = (l_t + t + l_h) / 2 - (G_{con} \cdot h_{con} + G_{soil} \cdot h_{soil}) / (G_{con} + G_{soil}) =$ 0,074 m

$b_{eff} = [l_t + t + l_h - 2 \,.\, (e + e')] =$ 0,211 m *Load effective width*

$\sigma = (1{,}25 \,.\, G_{con} + 1{,}25 \,.\, G_{soil}) / b_{eff} =$ 110,19 kPa *Maximum stress in soil*

σ_{Rd} = 150,00 kPa > σ = 110,19 kPa OK

D/ ULTIMATE LIMIT STATE OF RETAINING WALL

Internal force analysis

$S_{ah} = f_a \,.\, K_a \,.\, H =$ 0,000 kN *Effective value of horizontal surcharge force*

$h_{ah} = H / 2 =$ 0,500 m *Force arm of horizontal surcharge force*

$\gamma_{ah} =$ 1,50 [-] *Load factor for live load (ultimate limit state)*

$S_{a1} = H^2 \,.\, \gamma_{soil} \,.\, K_a / 2 =$ 5,500 kN *Horizontal force from active earth pressure*

$h_{a1} = H / 3 =$ 0,333 m *Force arm of active earth pressure*

$\gamma_{a1} =$ 1,25 [-] *Load factor for dead load (ultimate limit state)*

$M_{Sd} = \gamma_{ah} \,.\, S_{ah} \,.\, h_{ah} + \gamma_{a1} \,.\, S_{a1} \,.\, h_{a1}) =$ 2,29 kNm ***Design bending moment***

Fiber concrete structure analysis

$b =$ 1,000 m *Width of a cross-section*

$h =$ 0,100 m *Height of a cross-section*

$f_{ck} =$ 25,00 MPa *Characteristic compressive cylinder strength of plain concrete*

$f_{ct,f} =$ 3,000 MPa *Characteristic flexural tensile strength of plain concrete*

$\phi =$ 0,60 *Capacity reduction factor*

Elastoplastic concrete properties

m_f = 2,50 kg/m^3 ***Dosage of plastic fibres per m^3 (max. 7,5 kg)***

$f_{fct,f} =$ 3,356 MPa *Characteristic flexural tensile strength of fiberconcrete*

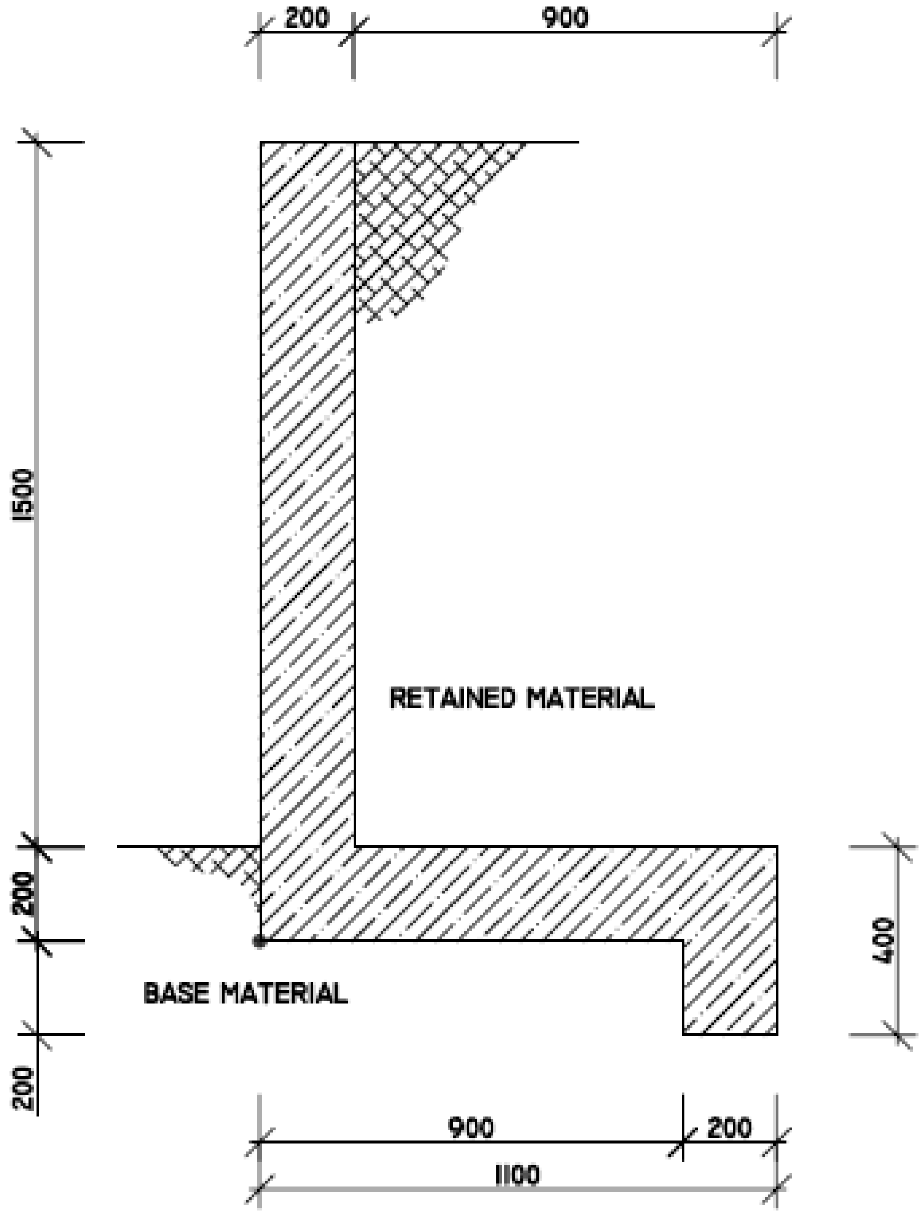
$I_y = b \,.\, h^3 / 12 =$ 8,33E-05 m^4 *Second moment of area of the cross-section*

$M_{uo} = 1{,}2 \,.\, f_{fct,f} \,.\, I_y / (h / 2) \,.\, \Phi =$ 4,028 kNm *Design strength in bending*

M_{uo} = 4,028 kNm > M_{Sd} = 2,291 kNm OK

6. RETAINING WALL ANALYSIS (0mm - 1500mm HIGH)

6.1 Retaining wall model



6.2 Retaining wall model

RETAINING WAL PROPERTIES

Retaining wall dimensions

» $H =$ 1,500 m *Heigth of retaining wall stem*

» $H_b =$ 0,200 m *Heigth of retaining wall base*

» $h_{soil} =$ 0,400 m *Heigth of soil in front of the retaining wall*

» $l_t =$ 0,000 m *Lenght of toe*

» $t =$ 0,200 m *Retaining wall thickness*

» $l_h =$ 0,900 m *Length of heel*

» $\alpha =$ 0 ° *Angle of rear face of wall*

Extra load acting on the ground surface

» $f_a =$ 0,00 kN/m^2 *Surcharge load on plan*

$H_{eqv} = f_a / \gamma_{soil} =$ 0,000 m *Equivalent heigth of soil*

Retained soil material

» $\gamma_{soil} =$ 21,00 kN/m^3 *Density of soil*

» $\varphi_{ef} =$ 18,00 ° *Effective internal friction angle*

» $\phi_{\varphi} =$ 0,85 [-] *Material strength uncertainty factor*

$\varphi' =$ 15,44 ° *Design internal friction angle*

» $\sigma_{Rd} =$ 100 kPa *Allowable ultimate bearing pressure*

» $\beta =$ 0 ° *Angle of soil surface behind wall*

$\delta =$ 10 ° *Angle of base friction*

The typical soil of this properties is claysoil.

Base soil material

» $\gamma_{soil} =$ 19,00 kN/m^3 *Density of soil*

» $\varphi_{ef} =$ 35,00 ° *Effective internal friction angle*

» $\phi_{\varphi} =$ 0,85 [-] *Material strength uncertainty factor*

$\varphi' =$ 30,76 ° *Design internal friction angle*

» $\sigma_{Rd} =$ 150 kPa *Allowable ultimate bearing pressure*

$\delta =$ 21 ° *Angle of base friction*

The typical soil of this properties is gravelsoil and sand soil.

Concrete

» Concrete: C25/30

f_{ck} = 25,00 MPa *Characteristic compressive cylinder strength of plain concrete*

$f_{ct,f}$ = 3,000 MPa *Characteristic flexural tensile strength of plain concrete*

» γ_{con} = 25,00 kN/m^3 *Density of concrete*

Earth pressure factors

$K_a = \cos^2(\varphi' - \alpha) / [\cos^2(\alpha) \cdot \cos(\alpha + \delta) \cdot (1 + (\sin(\varphi' + \delta) \cdot \sin(\varphi' - \beta) /$
$/ (\cos(\alpha + \delta) \cdot \cos(\alpha - \beta)))^{0,5}]^2$

K_a = 0,52 [-] *Active earth pressure factor*

$K_p = [\sin(90 - \varphi')]^2 / \{\sin(90 - \delta) \cdot [1 - ((\sin(\varphi' + \delta) \cdot \sin(\varphi') / \sin(90 + \delta))^{0,5}]^2\}$

K_p = 6,53 [-] *Passive earth pressure factor*

A/ STABILITY ANALYSIS - OVERTURNING

$S_{ak} = f_a \cdot K_a \cdot (H_b + H)$ = 0,000 kN *Effective value of horizontal surcharge force*

$h_{ak} = (H_b + H) / 2$ = 0,850 m *Force arm of extra surcharge on plan*

γ_{ak} = 1,50 [-] *Stability load factor for overturning live load*

$S_{a1} = (H_b + H)^2 \cdot \gamma_{soil} \cdot K_a / 2$ = 15,9 kN *Effective value of horizontal active earth press*

$h_{a1} = (H_b + H) / 3$ = 0,567 m *Force arm of active earth pressure*

γ_{a1} = 1,25 [-] *Stability load factor for overturning dead load*

$G_{con} = [(l_t + t + l_h) \cdot H_b + H \cdot t] \cdot \gamma_{con}$ = 13,00 kN *Effective vertical force of concrete R*

$h_{con} = [(l_t + t + l_h)^2 \cdot H_b / 2 + H \cdot t \cdot (l_t + t / 2)] / [(l_t + t + l_h) \cdot H_b + H \cdot t]$ = 0,290 m *F*

γ_{con} = 0,90 [-] *Stability load factor for restoring dead load*

$G_{soil} = l_h \cdot H \cdot \gamma_{soil}$ = 28,35 kN *Effective vertical force of backfill*

$h_{soil} = l_t + t + l_h / 3$ = 0,500 m *Force arm of backfill*

γ_{soil} = 0,90 [-] *Stability load factor for restoring dead load*

$M_{over} = S_a \cdot h_a \cdot \gamma_{ak} + S_{a1} \cdot h_{a1} \cdot \gamma_{a1}$ = 11,26 kNm ***Overturning moment***

$M_{rest} = G_{con} \cdot h_{con} \cdot \gamma_{con} + G_{soil} \cdot h_{soil} \cdot \gamma_{soil})$ = 16,16 kNm ***Restoring moment***

M_{rest} = 16,16 kNm > M_{over} = 11,26 kNm OK

B/ ANALYSIS OF STABILITY AGAINTS SLIDING

$S_{ak} = f_a \,.\, K_a \,.\, (H_b + H) =$ 0,000 kN *Effective value of horizontal surcharge force*

$\gamma_{ak} =$ 1,50 [-] *Stability load factor for overturning live load*

$S_{a1} = (H_b + H)^2 \,.\, \gamma_{soil} \,.\, K_a / 2 =$ 15,9 kN *Effective value of horizontal active earth press*

$\gamma_{a1} =$ 1,25 [-] *Stability load factor for overturning dead load*

$S_{a2} = H_{soil}^2 \,.\, \gamma_{soil} \,.\, K_p / 2 =$ 11,0 kN *Effective value of horizontal passive earth pressur*

$\gamma_{a2} =$ 0,90 [-] *Stability load factor for restoring dead load*

$G_{con} = [(l_t + t + l_h) \,.\, H_b + H \,.\, t] \,.\, \gamma_{con} =$ 13,00 kN *Effective vertical force of concrete R*

$\gamma_{con} =$ 0,90 [-] *Stability load factor for restoring dead load*

$G_{soil} = l_h \,.\, H \,.\, \gamma_{soil} =$ 28,35 kN *Effective vertical force of backfill*

$\gamma_{soil} =$ 0,90 [-] *Stability load factor for restoring dead load*

$F_{slid} = S_{ak} \,.\, \gamma_{ak} + S_{a1} \,.\, \gamma_{a1} =$ 19,87 kN ***Sliding force***

$F_{rest} = \gamma_{a2} \,.\, S_{a2} + (G_{con} \,.\, \gamma_{con} + G_{soil} \,.\, \gamma_{soil}) \,.\, tg\, \delta =$ 23,80 kN ***Resistance force***

$F_{rest} =$ 23,80 kN > $F_{slid} =$ 19,87 kN OK

C/ SOIL BEARING CAPACITY ANALYSIS

$M_{over} = S_a \,.\, h_a \,.\, \gamma_{ak} + S_{a1} \,.\, h_{a1} \,.\, \gamma_{a1} =$ 11,26 kNm *Overturning moment*

$G_{con} = [(l_t + t + l_h) \,.\, H_b + H \,.\, t] \,.\, \gamma_{con} =$ 13,00 kN *Effective vertical force of concrete R*

$\gamma_{con} =$ 1,25 [-] *Stability load factor for restoring dead load*

$G_{soil} = l_h \,.\, H \,.\, \gamma_{soil} =$ 28,35 kN *Effective vertical force of backfill*

$\gamma_{soil} =$ 1,25 [-] *Stability load factor for restoring dead load*

$e = M_{over} / (\gamma_{con} \,.\, G_{con} + \gamma_{soil} \,.\, G_{soil}) =$ 0,218 m *Total force eccentricity*

$e' = (l_t + t + l_h) / 2 - (G_{con} \,.\, h_{con} + G_{soil} \,.\, h_{soil}) / (G_{con} + G_{soil}) =$ 0,116 m

$b_{eff} = [l_t + t + l_h - 2 \,.\, (e + e')] =$ 0,433 m *Load effective width*

$\sigma = (1{,}25 \,.\, G_{con} + 1{,}25 \,.\, G_{soil}) / b_{eff} =$ 119,49 kPa *Maximum stress in soil*

$\sigma_{Rd} =$ 150,00 kPa > $\sigma =$ 119,49 kPa OK

D/ ULTIMATE LIMIT STATE OF RETAINING WALL

Internal force analysis

$S_{ah} = f_a \, . \, K_a \, . \, H =$ 0,000 kN *Effective value of horizontal surcharge force*

$h_{ah} = H / 2 =$ 0,750 m *Force arm of horizontal surcharge force*

$\gamma_{ah} =$ 1,50 [-] *Load factor for live load (ultimate limit state)*

$S_{a1} = H^2 \, . \, \gamma_{soil} \, . \, K_a / 2 =$ 12,37 kN *Horizontal force from active earth pressure*

$h_{a1} = H / 3 =$ 0,500 m *Force arm of active earth pressure*

$\gamma_{a1} =$ 1,25 [-] *Load factor for dead load (ultimate limit state)*

$M_{Sd} = \gamma_{ah} \, . \, S_{ah} \, . \, h_{ah} + \gamma_{a1} \, . \, S_{a1} \, . \, h_{a1}) =$ 7,73 kNm ***Design bending moment***

Fiber concrete structure analysis

$b =$ 1,000 m *Width of a cross-section*

$h =$ 0,200 m *Height of a cross-section*

$f_{ck} =$ 25,00 MPa *Characteristic compressive cylinder strength of plain concrete*

$f_{ct,f} =$ 3,000 MPa *Characteristic flexural tensile strength of plain concrete*

$\phi =$ 0,60 *Capacity reduction factor*

Elastoplastic concrete properties

$m_f =$ 2,50 kg/m^3 ***Dosage of plastic fibres per m^3 (max. 7,5 kg)***

$f_{fct,f} =$ 3,356 MPa *Characteristic flexural tensile strength of fiberconcrete*

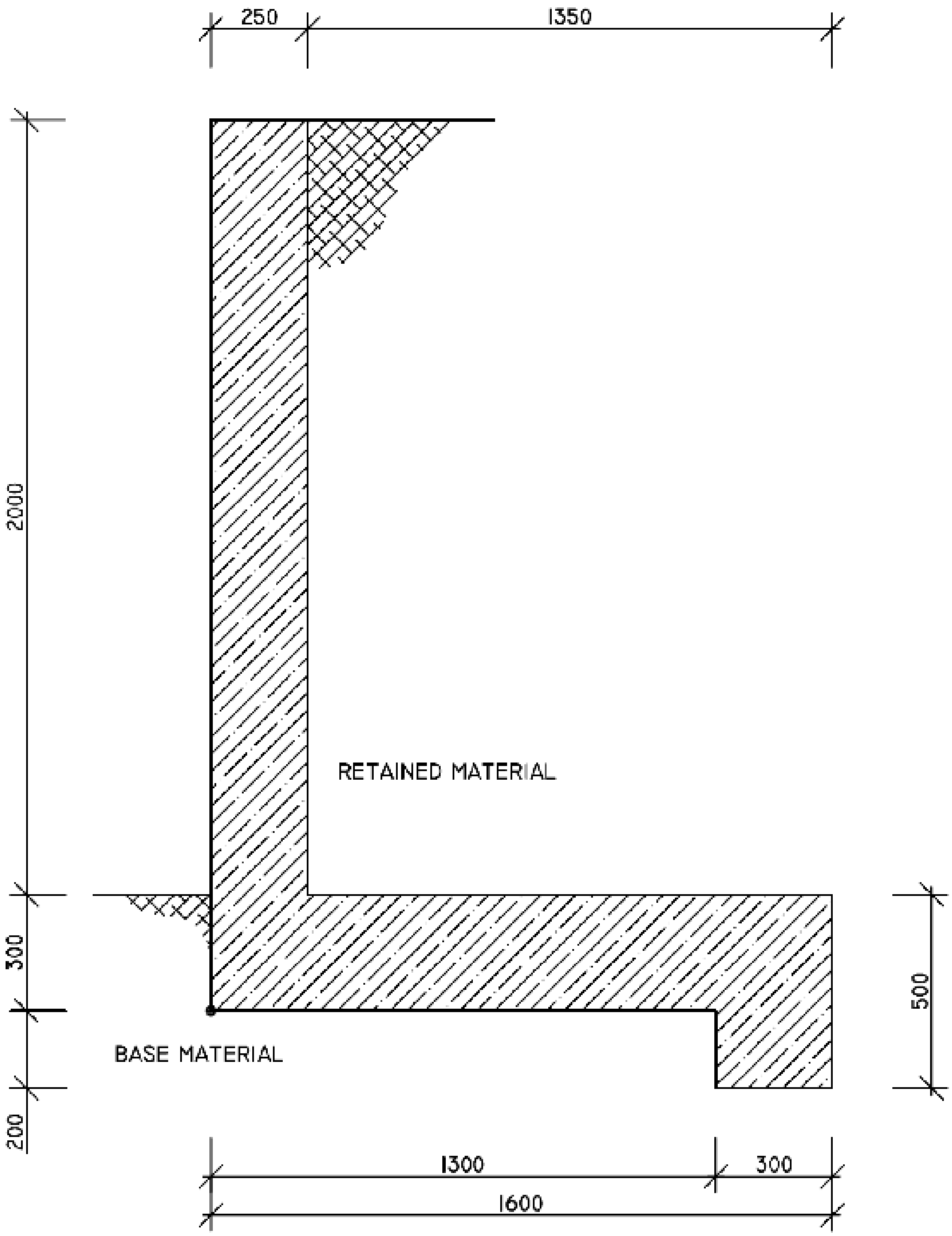
$I_y = b \, . \, h^3 / 12 =$ 0,000667 m^4 *Second moment of area of the cross-section*

$M_{uo} = 1{,}2 \, . \, f_{fct,f} \, . \, I_y / (h / 2) \, . \, \Phi =$ 16,110 kNm *Design strength in bending*

$M_{uo} =$ 16,11 kNm > $M_{Sd} =$ 7,734 kNm OK

7. RETAINING WALL ANALYSIS (0mm - 2000mm HIGH)

7.1 Retaining wall model



7.2 Retaining wall model

<u>RETAINING WAL PROPERTIES</u>

Retaining wall dimensions

» $H =$ 2,000 m *Heigth of retaining wall stem*

» $H_b =$ 0,300 m *Heigth of retaining wall base*

» $h_{soil} =$ 0,500 m *Heigth of soil in front of the retaining wall*

» $l_t =$ 0,000 m *Lenght of toe*

» $t =$ 0,250 m *Retaining wall thickness*

» $l_h =$ 1,350 m *Length of heel*

» $\alpha =$ 0 ° *Angle of rear face of wall*

Extra load acting on the ground surface

» $f_a =$ 0,00 kN/m^2 *Surcharge load on plan*

$H_{eqv} = f_a / \gamma_{soil} =$ 0,000 m *Equivalent heigth of soil*

Retained soil material

» $\gamma_{soil} =$ 21,00 kN/m^3 *Density of soil*

» $\varphi_{ef} =$ 18,00 ° *Effective internal friction angle*

» $\phi_{\varphi} =$ 0,85 [-] *Material strength uncertainty factor*

$\varphi' =$ 15,44 ° *Design internal friction angle*

» $\sigma_{Rd} =$ 100 kPa *Allowable ultimate bearing pressure*

» $\beta =$ 0 ° *Angle of soil surface behind wall*

$\delta =$ 10 ° *Angle of base friction*

The typical soil of this properties is claysoil.

Base soil material

» $\gamma_{soil} =$ 19,00 kN/m^3 *Density of soil*

» $\varphi_{ef} =$ 35,00 ° *Effective internal friction angle*

» $\phi_{\varphi} =$ 0,85 [-] *Material strength uncertainty factor*

$\varphi' =$ 30,76 ° *Design internal friction angle*

» $\sigma_{Rd} =$ 150 kPa *Allowable ultimate bearing pressure*

$\delta =$ 21 ° *Angle of base friction*

The typical soil of this properties is gravelsoil and sand soil.

Concrete

» Concrete: C25/30

f_{ck} = 25,00 MPa *Characteristic compressive cylinder strength of plain concrete*

$f_{ct,f}$ = 3,000 MPa *Characteristic flexural tensile strength of plain concrete*

» γ_{con} = 25,00 kN/m^3 *Density of concrete*

Earth pressure factors

$K_a = \cos^2(\varphi' - \alpha) / [\cos^2(\alpha) \,.\, \cos(\alpha + \delta) \,.\, (1 + (\sin(\varphi' + \delta) \,.\, \sin(\varphi' - \beta) /$
$/ (\cos(\alpha + \delta) \,.\, \cos(\alpha - \beta)))^{0,5}]^2$

K_a = 0,52 [-] *Active earth pressure factor*

$K_p = [\sin(90 - \varphi')]^2 / \{\sin(90 - \delta) \,.\, [1 - ((\sin(\varphi' + \delta) \,.\, \sin(\varphi') / \sin(90 + \delta))^{0,5}]^2\}$

K_p = 6,53 [-] *Passive earth pressure factor*

A/ STABILITY ANALYSIS - OVERTURNING

$S_{ak} = f_a \,.\, K_a \,.\, (H_b + H)$ = 0,000 kN *Effective value of horizontal surcharge force*

$h_{ak} = (H_b + H) / 2$ = 1,150 m *Force arm of extra surcharge on plan*

γ_{ak} = 1,50 [-] *Stability load factor for overturning live load*

$S_{a1} = (H_b + H)^2 \,.\, \gamma_{soil} \,.\, K_a / 2$ = 29,1 kN *Effective value of horizontal active earth press*

$h_{a1} = (H_b + H) / 3$ = 0,767 m *Force arm of active earth pressure*

γ_{a1} = 1,25 [-] *Stability load factor for overturning dead load*

$G_{con} = [(l_t + t + l_h) \,.\, H_b + H \,.\, t] \,.\, \gamma_{con}$ = 24,50 kN *Effective vertical force of concrete R*

$h_{con} = [(l_t + t + l_h)^2 \,.\, H_b / 2 + H \,.\, t \,.\, (l_t + t / 2)] / [(l_t + t + l_h) \,.\, H_b + H \,.\, t]$ = 0,456 m *F*

γ_{con} = 0,90 [-] *Stability load factor for restoring dead load*

$G_{soil} = l_h \,.\, H \,.\, \gamma_{soil}$ = 56,70 kN *Effective vertical force of backfill*

$h_{soil} = l_t + t + l_h / 3$ = 0,700 m *Force arm of backfill*

γ_{soil} = 0,90 [-] *Stability load factor for restoring dead load*

$M_{over} = S_a \,.\, h_a \,.\, \gamma_{ak} + S_{a1} \,.\, h_{a1} \,.\, \gamma_{a1}$ = 27,88 kNm ***Overturning moment***

$M_{rest} = G_{con} \,.\, h_{con} \,.\, \gamma_{con} + G_{soil} \,.\, h_{soil} \,.\, \gamma_{soil})$ = 45,77 kNm ***Restoring moment***

M_{rest} = 45,77 kNm > M_{over} = 27,88 kNm OK

B/ ANALYSIS OF STABILITY AGAINTS SLIDING

$S_{ak} = f_a \,.\, K_a \,.\, (H_b + H) =$ 0,000 kN *Effective value of horizontal surcharge force*

$\gamma_{ak} =$ 1,50 [-] *Stability load factor for overturning live load*

$S_{a1} = (H_b + H)^2 \,.\, \gamma_{soil} \,.\, K_a / 2 =$ 29,1 kN *Effective value of horizontal active earth press*

$\gamma_{a1} =$ 1,25 [-] *Stability load factor for overturning dead load*

$S_{a2} = H_{soil}^2 \,.\, \gamma_{soil} \,.\, K_p / 2 =$ 17,2 kN *Effective value of horizontal passive earth pressur*

$\gamma_{a2} =$ 0,90 [-] *Stability load factor for restoring dead load*

$G_{con} = [(l_t + t + l_h) \,.\, H_b + H \,.\, t] \,.\, \gamma_{con} =$ 24,50 kN *Effective vertical force of concrete R*

$\gamma_{con} =$ 0,90 [-] *Stability load factor for restoring dead load*

$G_{soil} = l_h \,.\, H \,.\, \gamma_{soil} =$ 56,70 kN *Effective vertical force of backfill*

$\gamma_{soil} =$ 0,90 [-] *Stability load factor for restoring dead load*

$F_{slid} = S_{ak} \,.\, \gamma_{ak} + S_{a1} \,.\, \gamma_{a1} =$ 36,37 kN ***Sliding force***

$F_{rest} = \gamma_{a2} \,.\, S_{a2} + (G_{con} \,.\, \gamma_{con} + G_{soil} \,.\, \gamma_{soil}) \,.\, tg\, \delta =$ 42,77 kN ***Resistance force***

$F_{rest} =$ 42,77 kN > $F_{slid} =$ 36,37 kN OK

C/ SOIL BEARING CAPACITY ANALYSIS

$M_{over} = S_a \,.\, h_a \,.\, \gamma_{ak} + S_{a1} \,.\, h_{a1} \,.\, \gamma_{a1} =$ 27,88 kNm *Overturning moment*

$G_{con} = [(l_t + t + l_h) \,.\, H_b + H \,.\, t] \,.\, \gamma_{con} =$ 24,50 kN *Effective vertical force of concrete R*

$\gamma_{con} =$ 1,25 [-] *Stability load factor for restoring dead load*

$G_{soil} = l_h \,.\, H \,.\, \gamma_{soil} =$ 56,70 kN *Effective vertical force of backfill*

$\gamma_{soil} =$ 1,25 [-] *Stability load factor for restoring dead load*

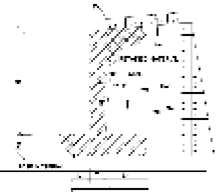
$e = M_{over} / (\gamma_{con} \,.\, G_{con} + \gamma_{soil} \,.\, G_{soil}) =$ 0,275 m *Total force eccentricity*

$e' = (l_t + t + l_h) / 2 - (G_{con} \,.\, h_{con} + G_{soil} \,.\, h_{soil}) / (G_{con} + G_{soil}) =$ 0,174 m

$b_{eff} = [l_t + t + l_h - 2 \,.\, (e + e')] =$ 0,703 m *Load effective width*

$\sigma = (1{,}25 \,.\, G_{con} + 1{,}25 \,.\, G_{soil}) / b_{eff} =$ 144,35 kPa *Maximum stress in soil*

$\sigma_{Rd} =$ 150,00 kPa > $\sigma =$ 144,35 kPa OK



D/ ULTIMATE LIMIT STATE OF RETAINING WALL

Internal force analysis

$S_{ah} = f_a \,.\, K_a \,.\, H =$ 0,000 kN *Effective value of horizontal surcharge force*

$h_{ah} = H / 2 =$ 1,000 m *Force arm of horizontal surcharge force*

$\gamma_{ah} =$ 1,50 [-] *Load factor for live load (ultimate limit state)*

$S_{a1} = H^2 \,.\, \gamma_{soil} \,.\, K_a / 2 =$ 22,00 kN *Horizontal force from active earth pressure*

$h_{a1} = H / 3 =$ 0,667 m *Force arm of active earth pressure*

$\gamma_{a1} =$ 1,25 [-] *Load factor for dead load (ultimate limit state)*

$M_{Sd} = \gamma_{ah} \,.\, S_{ah} \,.\, h_{ah} + \gamma_{a1} \,.\, S_{a1} \,.\, h_{a1}) =$ 18,33 kNm ***Design bending moment***

Fiber concrete structure analysis

$b =$ 1,000 m *Width of a cross-section*

$h =$ 0,250 m *Height of a cross-section*

$f_{ck} =$ 25,00 MPa *Characteristic compressive cylinder strength of plain concrete*

$f_{ct,f} =$ 3,000 MPa *Characteristic flexural tensile strength of plain concrete*

$\phi =$ 0,60 *Capacity reduction factor*

Elastoplastic concrete properties

$m_f =$ 2,50 kg/m^3 ***Dosage of plastic fibres per m^3 (max. 7,5 kg)***

$f_{fct,f} =$ 3,356 MPa *Characteristic flexural tensile strength of fiberconcrete*

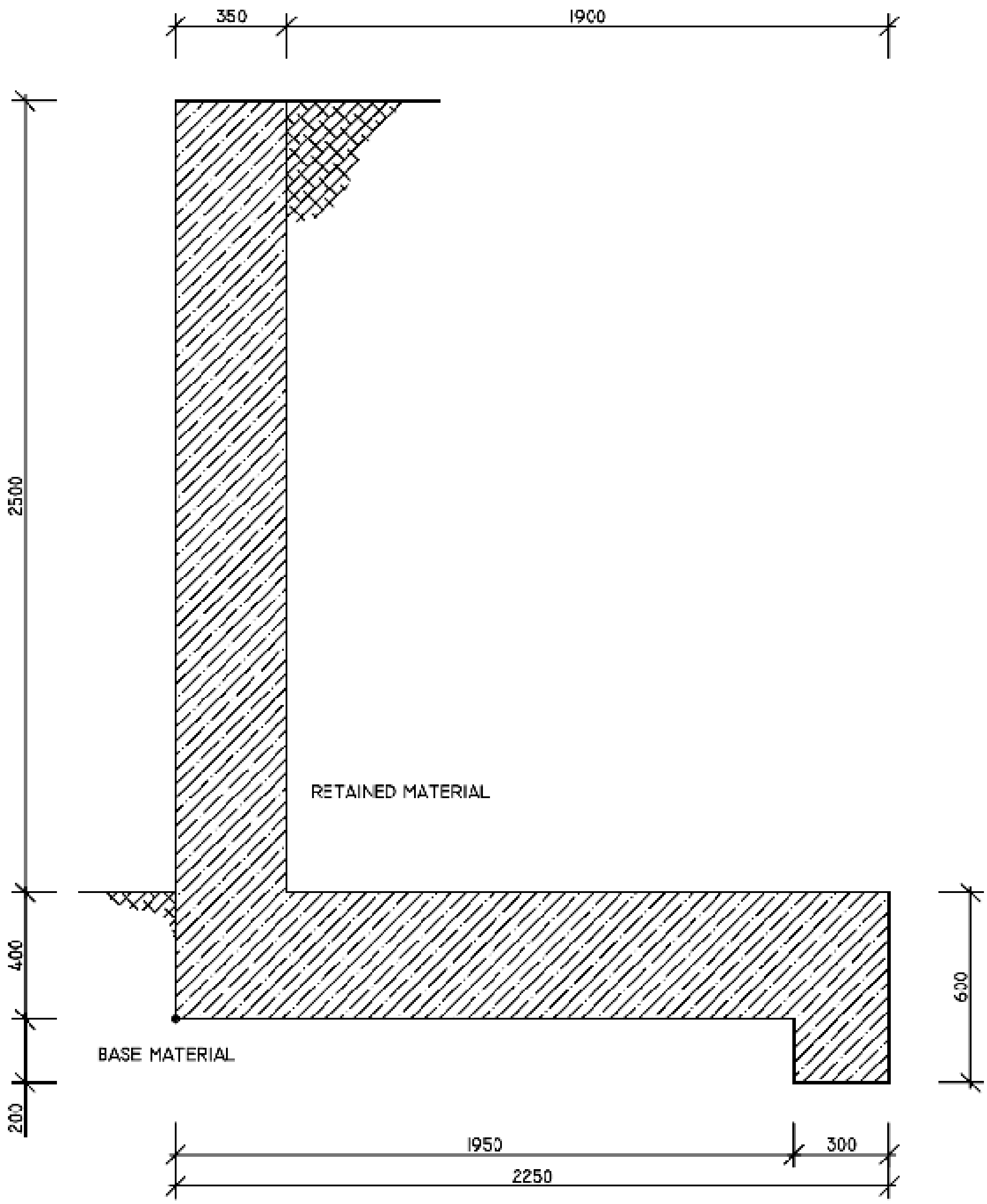
$I_y = b \,.\, h^3 / 12 =$ 0,001302 m^4 *Second moment of area of the cross-section*

$M_{uo} = 1{,}2 \,.\, f_{fct,f} \,.\, I_y / (h / 2) \,.\, \Phi =$ 25,172 kNm *Design strength in bending*

$M_{uo} =$ 25,17 kNm > $M_{Sd} =$ 18,33 kNm OK

8. RETAINING WALL ANALYSIS (0mm - 2500mm HIGH)

8.1 Retaining wall model



8.2 Retaining wall model

RETAINING WAL PROPERTIES

Retaining wall dimensions

» $H =$ 2,500 m *Heigth of retaining wall stem*

» $H_b =$ 0,400 m *Heigth of retaining wall base*

» $h_{soil} =$ 0,600 m *Heigth of soil in front of the retaining wall*

» $l_t =$ 0,000 m *Lenght of toe*

» $t =$ 0,350 m *Retaining wall thickness*

» $l_h =$ 1,900 m *Length of heel*

» $\alpha =$ 0 ° *Angle of rear face of wall*

Extra load acting on the ground surface

» $f_a =$ 0,00 kN/m^2 *Surcharge load on plan*

$H_{eqv} = f_a / \gamma_{soil} =$ 0,000 m *Equivalent heigth of soil*

Retained soil material

» $\gamma_{soil} =$ 21,00 kN/m^3 *Density of soil*

» $\varphi_{ef} =$ 18,00 ° *Effective internal friction angle*

» $\phi_{\varphi} =$ 0,85 [-] *Material strength uncertainty factor*

$\varphi' =$ 15,44 ° *Design internal friction angle*

» $\sigma_{Rd} =$ 100 kPa *Allowable ultimate bearing pressure*

» $\beta =$ 0 ° *Angle of soil surface behind wall*

$\delta =$ 10 ° *Angle of base friction*

The typical soil of this properties is claysoil.

Base soil material

» $\gamma_{soil} =$ 19,00 kN/m^3 *Density of soil*

» $\varphi_{ef} =$ 35,00 ° *Effective internal friction angle*

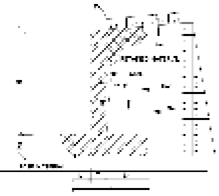
» $\phi_{\varphi} =$ 0,85 [-] *Material strength uncertainty factor*

$\varphi' =$ 30,76 ° *Design internal friction angle*

» $\sigma_{Rd} =$ 200 kPa *Allowable ultimate bearing pressure*

$\delta =$ 21 ° *Angle of base friction*

The typical soil of this properties is gravelsoil and sand soil.



Concrete

» Concrete: C25/30

f_{ck} = 25,00 MPa *Characteristic compressive cylinder strength of plain concrete*

$f_{ct,f}$ = 3,000 MPa *Characteristic flexural tensile strength of plain concrete*

» γ_{con} = 25,00 kN/m^3 *Density of concrete*

Earth pressure factors

$K_a = \cos^2(\varphi' - \alpha) / [\cos^2(\alpha) \,.\, \cos(\alpha + \delta) \,.\, (1 + (\sin(\varphi' + \delta) \,.\, \sin(\varphi' - \beta) /$

$/ (\cos(\alpha + \delta) \,.\, \cos(\alpha - \beta)))^{0,5}]^2$

K_a = 0,52 [-] *Active earth pressure factor*

$K_p = [\sin(90 - \varphi')]^2 / \{\sin(90 - \delta) \,.\, [1 - ((\sin(\varphi' + \delta) \,.\, \sin(\varphi') / \sin(90 + \delta))^{0,5}]^2\}$

K_p = 6,53 [-] *Passive earth pressure factor*

<u>A/ STABILITY ANALYSIS - OVERTURNING</u>

$S_{ak} = f_a \,.\, K_a \,.\, (H_b + H)$ = 0,000 kN *Effective value of horizontal surcharge force*

$h_{ak} = (H_b + H) / 2$ = 1,450 m *Force arm of extra surcharge on plan*

γ_{ak} = 1,50 [-] *Stability load factor for overturning live load*

$S_{a1} = (H_b + H)^2 \,.\, \gamma_{soil} \,.\, K_a / 2$ = 46,3 kN *Effective value of horizontal active earth press*

$h_{a1} = (H_b + H) / 3$ = 0,967 m *Force arm of active earth pressure*

γ_{a1} = 1,25 [-] *Stability load factor for overturning dead load*

$G_{con} = [(l_t + t + l_h) \,.\, H_b + H \,.\, t] \,.\, \gamma_{con}$ = 44,38 kN *Effective vertical force of concrete R*

$h_{con} = [(l_t + t + l_h)^2 \,.\, H_b / 2 + H \,.\, t \,.\, (l_t + t / 2)] / [(l_t + t + l_h) \,.\, H_b + H \,.\, t]$ = 0,657 m *F*

γ_{con} = 0,90 [-] *Stability load factor for restoring dead load*

$G_{soil} = l_h \,.\, H \,.\, \gamma_{soil}$ = 99,75 kN *Effective vertical force of backfill*

$h_{soil} = l_t + t + l_h / 3$ = 0,983 m *Force arm of backfill*

γ_{soil} = 0,90 [-] *Stability load factor for restoring dead load*

$\mathbf{M_{over} = S_a \,.\, h_a \,.\, \gamma_{ak} + S_{a1} \,.\, h_{a1} \,.\, \gamma_{a1}}$ **= 55,89 kNm** ***Overturning moment***

$\mathbf{M_{rest} = G_{con} \,.\, h_{con} \,.\, \gamma_{con} + G_{soil} \,.\, h_{soil} \,.\, \gamma_{soil})}$ **= 114,5 kNm** ***Restoring moment***

<u>$\mathbf{M_{rest}}$ = 114,5 kNm > $\mathbf{M_{over}}$ = 55,89 kNm OK</u>

B/ ANALYSIS OF STABILITY AGAINTS SLIDING

$S_{ak} = f_a \cdot K_a \cdot (H_b + H) =$ 0,000 kN *Effective value of horizontal surcharge force*

$\gamma_{ak} =$ 1,50 [-] *Stability load factor for overturning live load*

$S_{a1} = (H_b + H)^2 \cdot \gamma_{soil} \cdot K_a / 2 =$ 46,3 kN *Effective value of horizontal active earth press*

$\gamma_{a1} =$ 1,25 [-] *Stability load factor for overturning dead load*

$S_{a2} = H_{soil}^2 \cdot \gamma_{soil} \cdot K_p / 2 =$ 24,7 kN *Effective value of horizontal passive earth pressure*

$\gamma_{a2} =$ 0,90 [-] *Stability load factor for restoring dead load*

$G_{con} = [(l_t + t + l_h) \cdot H_b + H \cdot t] \cdot \gamma_{con} =$ 44,38 kN *Effective vertical force of concrete R*

$\gamma_{con} =$ 0,90 [-] *Stability load factor for restoring dead load*

$G_{soil} = l_h \cdot H \cdot \gamma_{soil} =$ 99,75 kN *Effective vertical force of backfill*

$\gamma_{soil} =$ 0,90 [-] *Stability load factor for restoring dead load*

$F_{slid} = S_{ak} \cdot \gamma_{ak} + S_{a1} \cdot \gamma_{a1} =$ 57,81 kN ***Sliding force***

$F_{rest} = \gamma_{a2} \cdot S_{a2} + (G_{con} \cdot \gamma_{con} + G_{soil} \cdot \gamma_{soil}) \cdot tg\ \delta =$ 70,75 kN ***Resistance force***

$F_{rest} =$ 70,75 kN > $F_{slid} =$ 57,81 kN OK

C/ SOIL BEARING CAPACITY ANALYSIS

$M_{over} = S_a \cdot h_a \cdot \gamma_{ak} + S_{a1} \cdot h_{a1} \cdot \gamma_{a1} =$ 55,89 kNm *Overturning moment*

$G_{con} = [(l_t + t + l_h) \cdot H_b + H \cdot t] \cdot \gamma_{con} =$ 44,38 kN *Effective vertical force of concrete R*

$\gamma_{con} =$ 1,25 [-] *Stability load factor for restoring dead load*

$G_{soil} = l_h \cdot H \cdot \gamma_{soil} =$ 99,75 kN *Effective vertical force of backfill*

$\gamma_{soil} =$ 1,25 [-] *Stability load factor for restoring dead load*

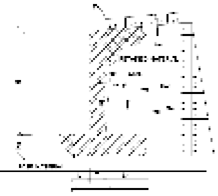
$e = M_{over} / (\gamma_{con} \cdot G_{con} + \gamma_{soil} \cdot G_{soil}) =$ 0,310 m *Total force eccentricity*

$e' = (l_t + t + l_h) / 2 - (G_{con} \cdot h_{con} + G_{soil} \cdot h_{soil}) / (G_{con} + G_{soil}) =$ 0,242 m

$b_{eff} = [l_t + t + l_h - 2 \cdot (e + e')] =$ 1,145 m *Load effective width*

$\sigma = (1{,}25 \cdot G_{con} + 1{,}25 \cdot G_{soil}) / b_{eff} =$ 157,33 kPa *Maximum stress in soil*

$\sigma_{Rd} =$ 200,00 kPa > $\sigma =$ 157,33 kPa OK



D/ ULTIMATE LIMIT STATE OF RETAINING WALL

Internal force analysis

$S_{ah} = f_a \,.\, K_a \,.\, H =$ 0,000 kN *Effective value of horizontal surcharge force*

$h_{ah} = H / 2 =$ 1,250 m *Force arm of horizontal surcharge force*

$\gamma_{ah} =$ 1,50 [-] *Load factor for live load (ultimate limit state)*

$S_{a1} = H^2 \,.\, \gamma_{soil} \,.\, K_a / 2 =$ 34,37 kN *Horizontal force from active earth pressure*

$h_{a1} = H / 3 =$ 0,833 m *Force arm of active earth pressure*

$\gamma_{a1} =$ 1,25 [-] *Load factor for dead load (ultimate limit state)*

$\mathbf{M_{Sd} = \gamma_{ah} \,.\, S_{ah} \,.\, h_{ah} + \gamma_{a1} \,.\, S_{a1} \,.\, h_{a1}) = 35{,}80}$ **kNm** ***Design bending moment***

Fiber concrete structure analysis

$b =$ 1,000 m *Width of a cross-section*

$h =$ 0,350 m *Height of a cross-section*

$f_{ck} =$ 25,00 MPa *Characteristic compressive cylinder strength of plain concrete*

$f_{ct,f} =$ 3,000 MPa *Characteristic flexural tensile strength of plain concrete*

$\phi =$ 0,60 *Capacity reduction factor*

Elastoplastic concrete properties

$\mathbf{m_f =}$ **2,50 kg/m^3** ***Dosage of plastic fibres per m^3 (max. 7,5 kg)***

$f_{fct,f} =$ 3,356 MPa *Characteristic flexural tensile strength of fiberconcrete*

$I_y = b \,.\, h^3 / 12 =$ 0,003573 m^4 *Second moment of area of the cross-section*

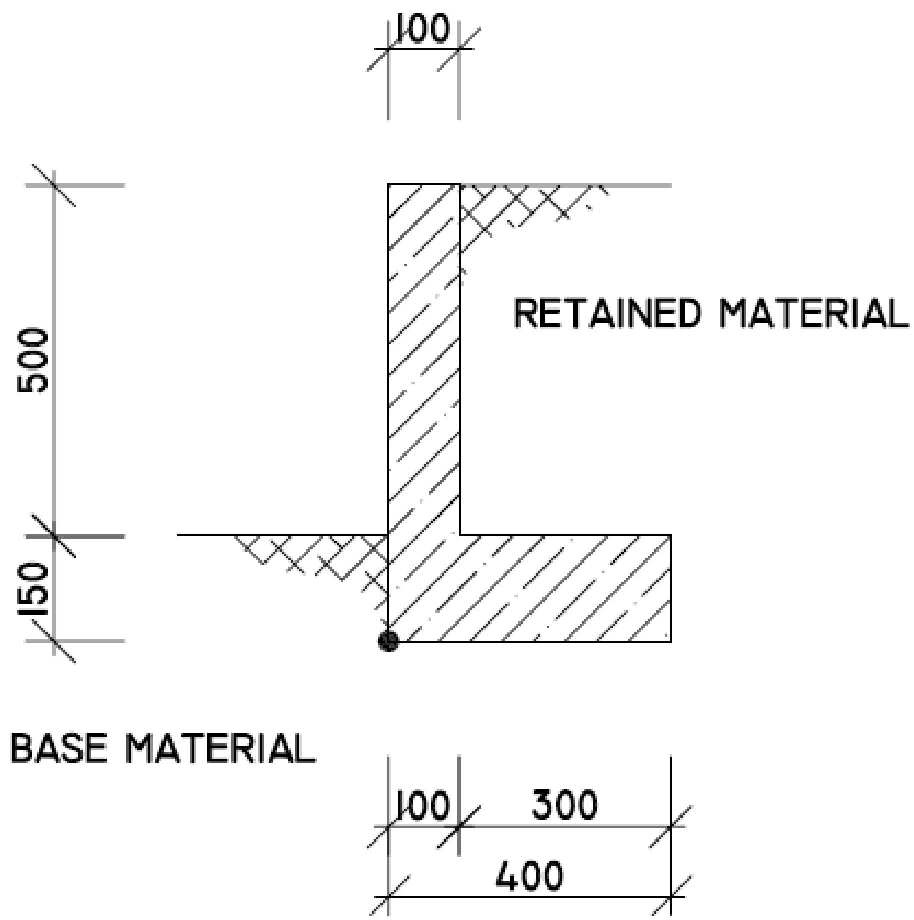
$\mathbf{M_{uo} = 1{,}2 \,.\, f_{fct,f} \,.\, I_y / (h / 2) \,.\, \Phi =}$ **49,337 kNm** *Design strength in bending*

$\mathbf{M_{uo} =}$ **49,34 kNm > $\mathbf{M_{Sd} =}$ 35,80 kNm OK**

9. RESULT SUMMARY

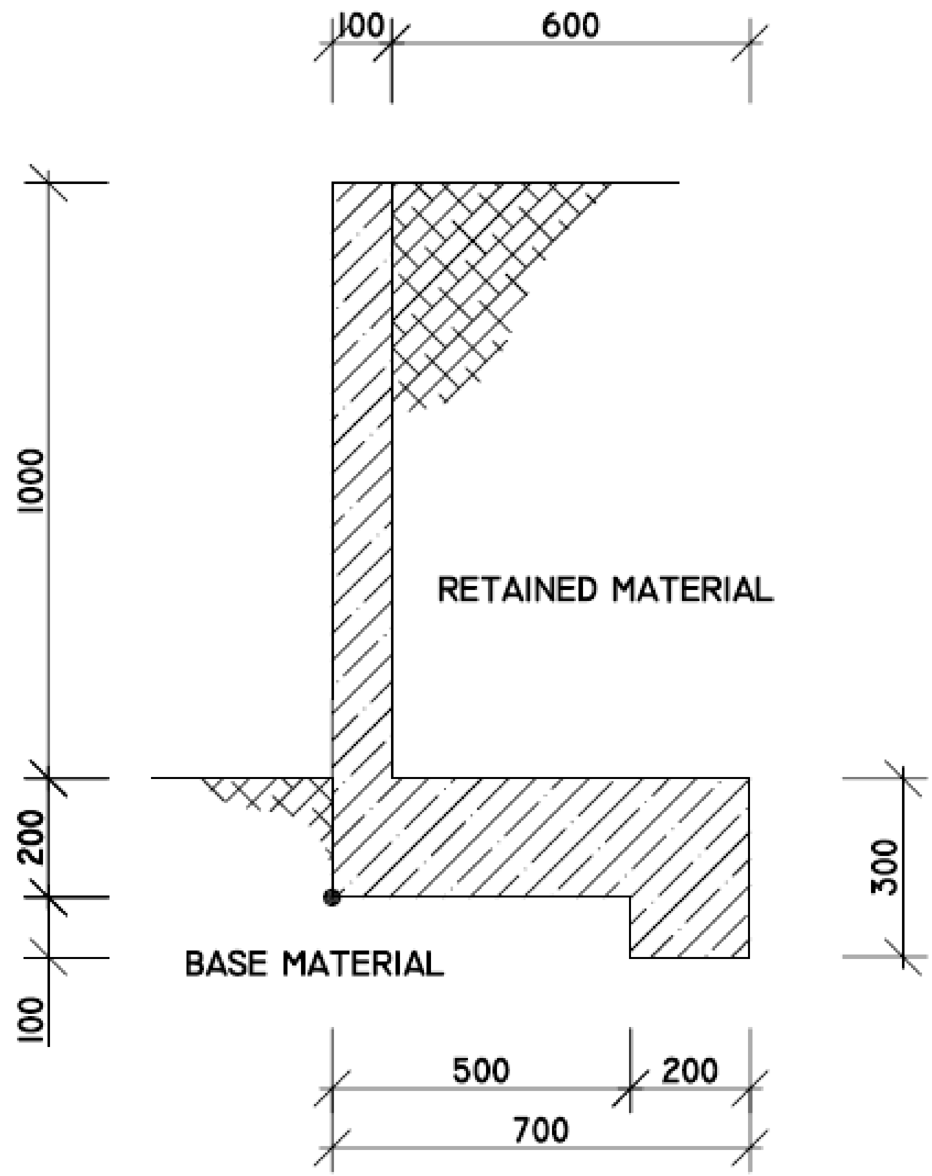
9.1 Retaining wall (0mm - 500mm high)

Parameter	Allowable value	Internal force
Stabality analysis - overturning	**0,89 kNm**	**0,63 kNm**
Stabality analysis - sliding	**3,38 kN**	**2,90 kN**
Soil bearing capacity	**150,00 kPa**	**44,49 kPa**
Ultimate limit state of retaining wall	**4,03 kNm**	**0,29 kNm**



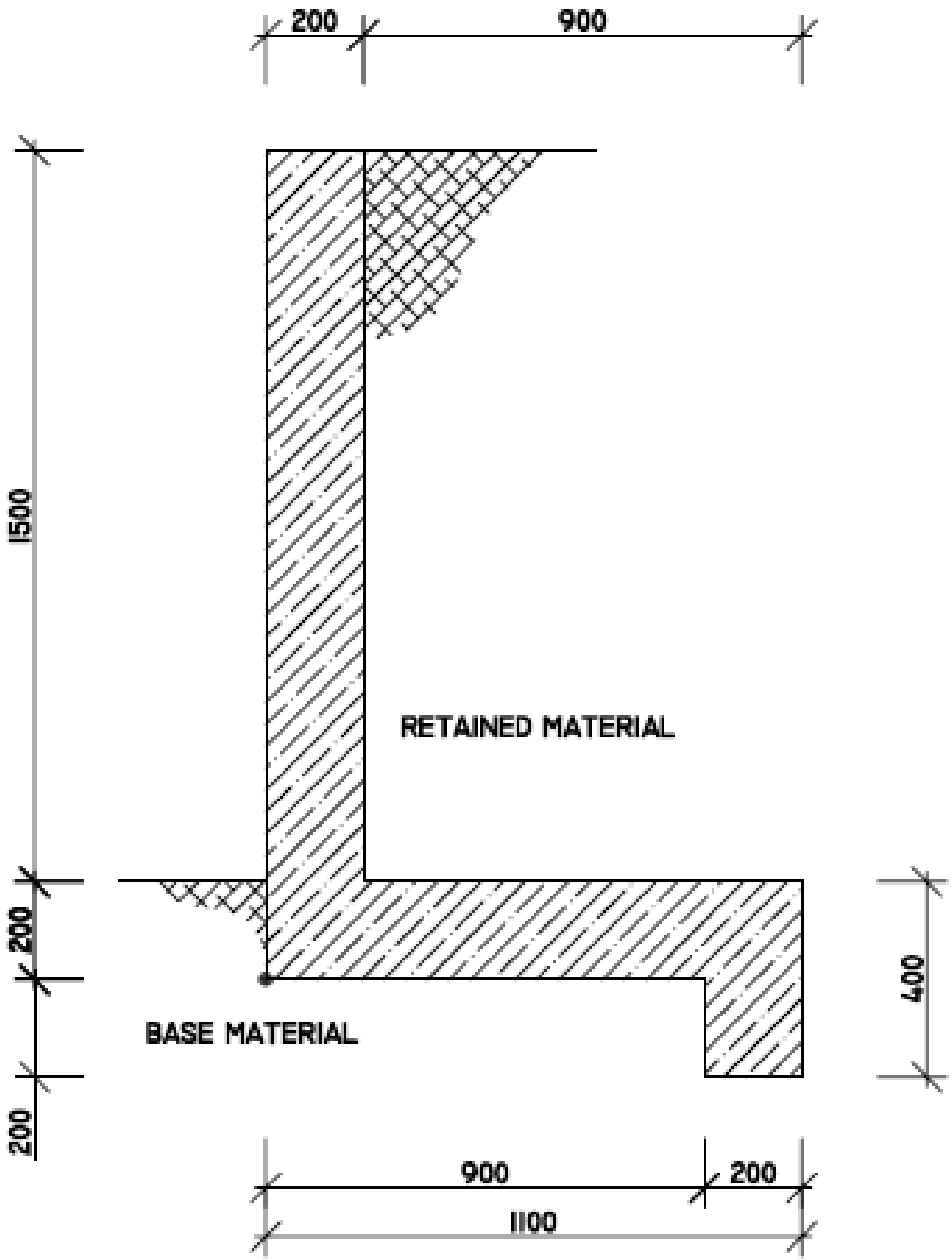
9.2 Retaining wall (0mm - 1000mm high)

Parameter	Allowable value	Internal force
Stabality analysis - overturning	**4,62 kNm**	**3,96 kNm**
Stabality analysis - sliding	**11,82 kN**	**9,90 kN**
Soil bearing capacity	**150,00 kPa**	**110,19 kPa**
Ultimate limit state of retaining wall	**4,03 kNm**	**2,29 kNm**



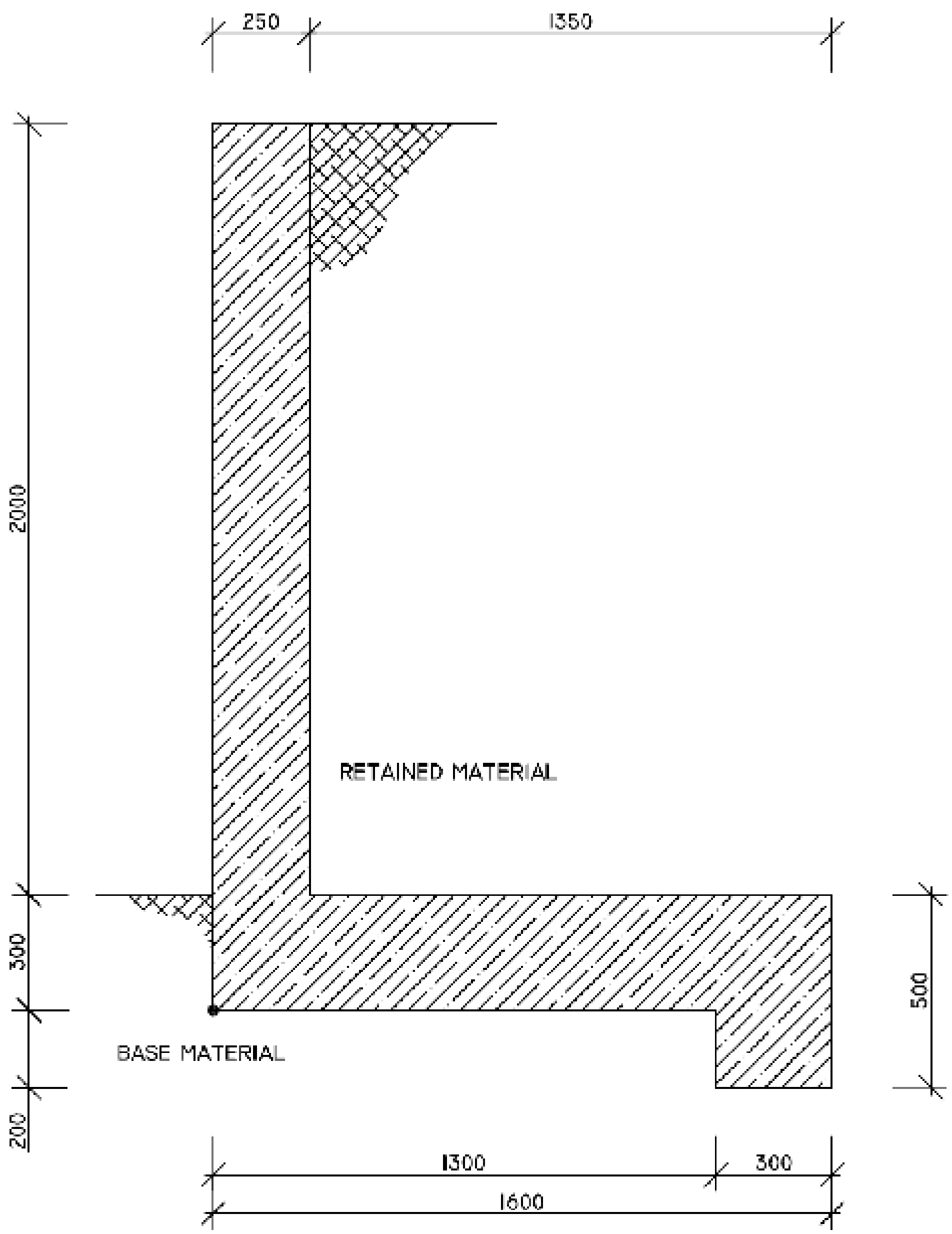
9.3 Retaining wall (0mm - 1500mm high)

Parameter	Allowable value	Internal force
Stabality analysis - overturning	**16,16 kNm**	**11,26 kNm**
Stabality analysis - sliding	**23,80 kN**	**19,87 kN**
Soil bearing capacity	**150,00 kPa**	**119,49 kPa**
Ultimate limit state of retaining wall	**16,11 kNm**	**7,73 kNm**



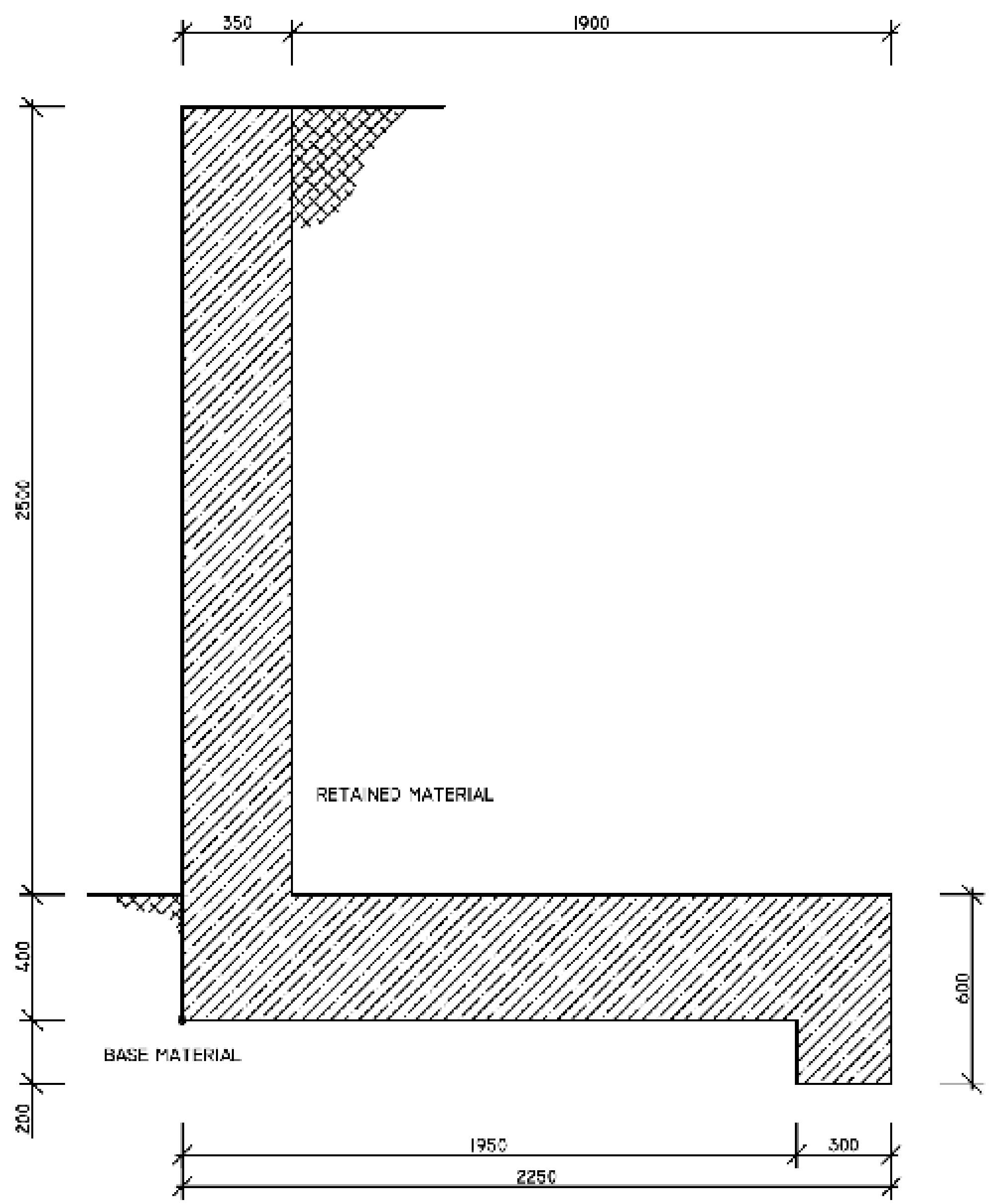
9.4 Retaining wall (0mm - 2000mm high)

Parameter	Allowable value	Internal force
Stabality analysis - overturning	**45,77 kNm**	**27,88 kNm**
Stabality analysis - sliding	**42,77 kN**	**36,37 kN**
Soil bearing capacity	**150,00 kPa**	**144,35 kPa**
Ultimate limit state of retaining wall	**25,17 kNm**	**18,33 kNm**



9.5 Retaining wall (0mm - 2500mm high)

Parameter	Allowable value	Internal force
Stabality analysis - overturning	**114,51 kNm**	**55,89 kNm**
Stabality analysis - sliding	**70,75 kN**	**57,81 kN**
Soil bearing capacity	**200,00 kPa**	**157,33 kPa**
Ultimate limit state of retaining wall	**49,34 kNm**	**35,80 kNm**



10. CONCLUSION

The analysis in the report shows a possible use of elastoplastic concrete for retaining walls of the certain dimensions. The major issues of the 0 - 2,5m high retaining walls are a stability of a structure. The structure stability depends on a shape of a retaining wall, load and material properties of retained and base material. Load used for the analysis is only the load from soil with no surcharge load on plan or water pressure load.

However the internal forces such as a bending moment does not reach big values. Regarding to that fact elastaoplastic concrete can be efficiently used for the retaining walls described in the report. The location with the maximum bending moment is between a retaining wall steam and a retaining wall base. Based on a practical process of a retaining wall build-up it is still recommended to use starter bars to transfer all the internal forces between these two parts of a retaining wall unless the whole retaining wall is being concreted at one go. That means if a retaining wall could be concreted at one go (without a construction joint), there is no extra reinforcement required. **According to the retaining wall analysis I recommend to use elastoplastic concrete (min concrete C25/30, fiber BarChip48, min. dosage 4 kg/m^3) for the retaining walls described in the report.**

Retaining walls from elastoplastic concrete with different input conditions (different shape, high, load water pressure, surcharge load on plan, material of retained and base material) might satisfied the requirements in accordance with Australian Standards. However, firstly an analyses of that retaining walls with different input conditions are required.