Object : L = 4.0 m

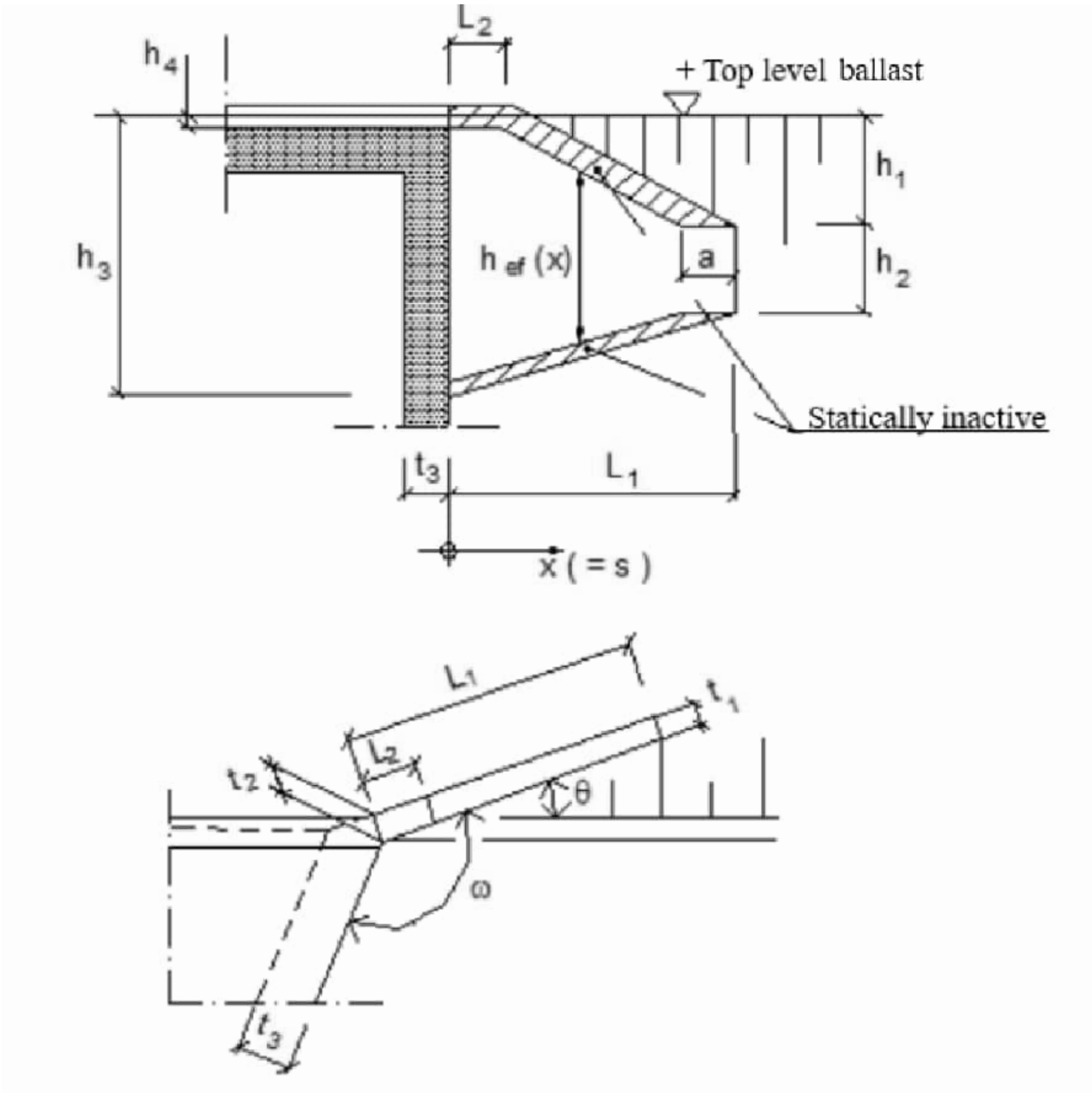
THEORY

When determining the design earth pressure on a wing wall, Culmann's method is applied to determine the pressure from the backfill. This is used when Rankine's method does not work in a battered slope.

When determining the contribution from live load, however, Rankine's method is applied. In the check, load spreading (1:N) through the fill is applied. Typically N = 1 is governing for low wing walls but should be verified.

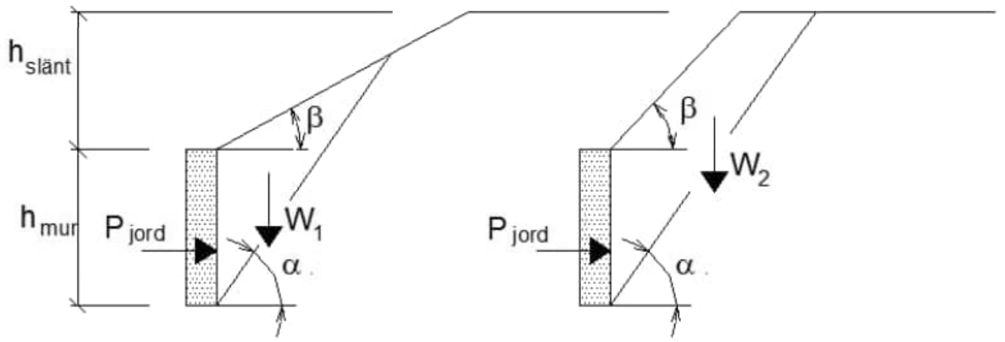
The pressure effects from backfill and live load are added even though the failure angle (α) may differ between them. This simplification is nevertheless considered conservative.

PRINCIPLE SKETCH



Date: 11-19-2025

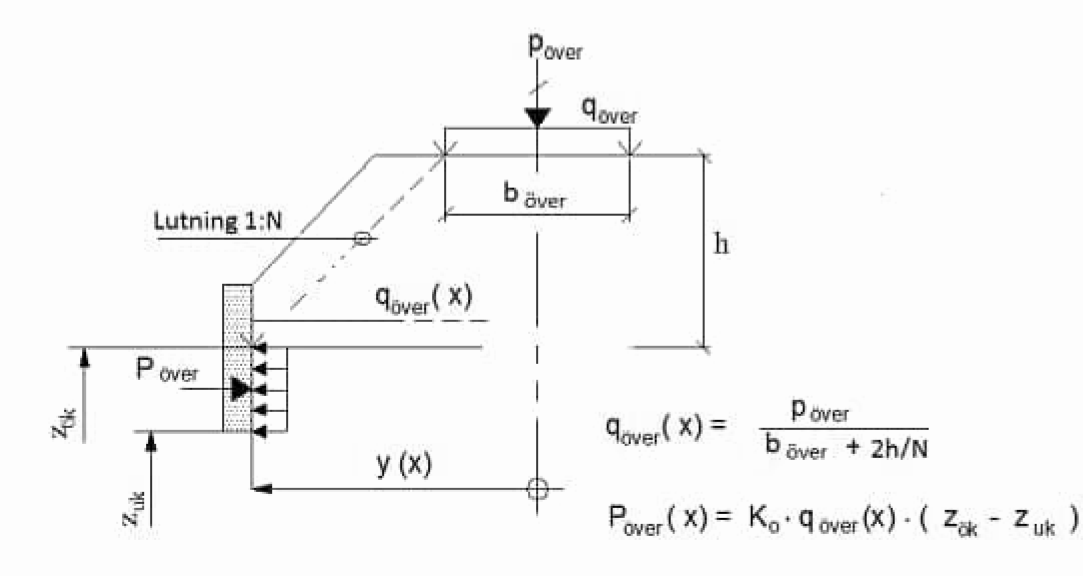
File : PROG K2_003.mcdx



Typ 1
($Q_{över} = 0$)

Typ 2
($Q_{över} \neq 0$)

Earth pressure according Culman
(Applied for determination of earth pressure)



Surcharge in frictional material according to Rankine
(Applied for determination of surcharge)

INPUT

Geometry :

$L_1 := 4.00 \cdot m$ $L_2 := 0.50 \cdot m$

$h_1 := 1 \cdot mm$ $h_2 := 2.40 \cdot m$ $h_3 := 3.50 \cdot m$ $h_4 := 0.10 \cdot m$

$t_1 := 0.40 \cdot m$ $t_2 := 0.40 \cdot m$ $t_3 := 0.60 \cdot m$

Angle wingwall-abutment: $\omega := 91 \cdot °$

Angle wingwall-road : $\theta := 1 \cdot °$

Distance from break point for effective height : $a := 0.80 \cdot m$

Material :

Soil material : $\gamma_{jord} := 20 \cdot \frac{kN}{m^3}$ $K_o := 0.29$ $K_a := 0.17$

Concrete : $\gamma_{btg} := 25 \cdot \frac{kN}{m^3}$

Loads :

Surcharge :

$p_{över} := 200 \cdot \frac{kN}{m}$

$b_{över} := 2.25 \cdot m$ $y_{start} := 2.0 \cdot m$ $N := 1$

Load coefficients :

Earth pressure

$\psi\gamma_{jord.ULS} := 1.49$ $\psi\gamma_{jord.SLS} := 1.34$

Surcharge

$\psi\gamma_{över.ULS} := 1.5$ $\psi\gamma_{över.SLS} := 0.3$

CALCULATION

Earth pressure according method of Culman:

Nivå överkant vingmur : $mur_{\ddot{o}k}(x) = \mathrm{linterp}\left[\begin{pmatrix} 0 \\ L_2 \\ L_1 \end{pmatrix}, \begin{pmatrix} h_3 \\ h_3 \\ h_3 - h_1 \end{pmatrix}, x\right]$

Nivå underkant vingmur : $mur_{uk}(x) = \mathrm{linterp}\left[\begin{pmatrix} 0 \\ L_1 \end{pmatrix}, \begin{pmatrix} 0 \\ h_3 - h_1 - h_2 \end{pmatrix}, x\right]$

Vingmurens höjd : $h_{mur}(x) = mur_{\ddot{o}k}(x) - mur_{uk}(x)$

Släntens höjd : $h_{slänt}(x) = \mathrm{linterp}\left[\begin{pmatrix} 0 \\ L_2 \\ L_1 \end{pmatrix}, \begin{pmatrix} 0 \\ 0 \\ h_1 \end{pmatrix}, x\right]$

Friktionsvinkel: $\varphi = \mathrm{asin}(1 - K_o)$

Lutning hos slänten ned till överkant vingmur mätt vinkelrätt mot vingen :

$$\beta = \mathrm{atan}\left[\frac{h_1}{(L_1 - L_2)\tan(\theta)}\right]$$

Vertikallast för brottfigur typ 1 (= brottlinje i slänt) :

$$W_1 = h_{mur}(x)\cdot\sin\left(\frac{\pi}{2} - \alpha\right)\cdot\left(h_{mur}(x)\cdot\cos\left(\frac{\pi}{2} - \alpha\right) + \frac{h_{mur}(x)\cdot\sin\left(\frac{\pi}{2} - \alpha\right)}{\tan(\alpha - \beta)}\right)\cdot\frac{\gamma_{jord}}{2}$$

Vertikallaster för brottfigur typ 2 (= brottlinje hamnar ovanför slänt) :

$$W_2 = \left[\left(h_{mur}(x) + h_{slänt}(x)\right)^2\cdot\tan\left(\frac{\pi}{2} - \alpha\right) - \frac{h_{slänt}(x)^2}{\tan(\beta)}\right]\cdot\frac{\gamma_{jord}}{2}$$

Resultant of earth pressure according to Culman under the action of soil load:

$$P_o = \left| \begin{array}{l} W_{jord} \leftarrow W_1 \;\; \text{if} \;\; (h_{mur}(x) + h_{slänt}(x)) \cdot \tan(90° - \alpha) < \dfrac{h_{slänt}(x)}{\tan(\beta)} \\ W_{jord} \leftarrow W_2 \;\; \text{otherwise} \\ P_{aktiv} \leftarrow W_{jord} \cdot \tan(\alpha - \varphi) \\ P_{vilo} \leftarrow P_{aktiv} \cdot \dfrac{K_o}{K_a} \\ P_{vilo} \end{array} \right.$$

Evaluate the maximum earth pressure by checking N_α for angles between φ and 90°:

$$P_{jord} = \left| \begin{array}{l} N_\alpha \leftarrow 20st \\ \Delta\alpha \leftarrow \dfrac{90° - \varphi}{N_\alpha - 1} \\ \alpha \leftarrow \varphi \\ P_{max} \leftarrow P_o(s, \alpha) \\ \text{for} \;\; i \in 2..N_\alpha \\ \quad \left| \begin{array}{l} \alpha \leftarrow \alpha + \Delta\alpha \\ P_{vilo} \leftarrow P_o \\ \text{if} \;\; P_{vilo} > P_{max} \\ \quad \left| \begin{array}{l} P_{max} \leftarrow P_{vilo} \\ \alpha_{max} \leftarrow \alpha \end{array} \right. \end{array} \right. \end{array} \right.$$

Sections where forces are determined (total 10 sections):

$$\Delta_x = \frac{L_1 - L_2}{6}$$

$$x = \left(0 \;\; \frac{1}{3}L_2 \;\; \frac{2}{3}L_2 \;\; L_2 \;\; L_2 + \Delta_x \;\; L_2 + 2 \cdot \Delta_x \;\; L_2 + 3 \cdot \Delta_x \;\; L_2 + 4 \cdot \Delta_x \;\; L_2 + 5\Delta_x \;\; L_1 \right)$$

Create function for earth pressure using result from 10 sections:

$$P_{vilo}(x) = \text{lspline}(P_{jord}, x)$$

Load intensity of surcharge in frictional material according to Rankine:

Level of top of load height relative to wing wall:

$$y_{slut} = y_{start} + L_1 \cdot \sin(\theta)$$

$$y_{mitt} = \frac{y_{start} + y_{slut}}{2}$$

$$z_{start} = h_3 - N \cdot (y_{start} - 0.5 b_{över})$$

$$z_{slut} = h_3 - N \cdot (y_{slut} - 0.5 b_{över})$$

$$z_{ök}(x) = \text{linterp}\left[\begin{pmatrix} 0 \\ L_1 \end{pmatrix}, \begin{pmatrix} z_{start} \\ z_{slut} \end{pmatrix}, x\right]$$

Nivå underkant vingmur :

$$z_{uk}(x) = \text{linterp}\left[\begin{pmatrix} 0 \\ L_1 \end{pmatrix}, \begin{pmatrix} 0 \\ h_3 - h_1 - h_2 \end{pmatrix}, x\right]$$

Effektiv bealstningshöjd mot vingmur : $h_{över}(x) = z_{ök}(x) - z_{uk}(x)$

Skärningspunkt mellan $z_{ök}(x)$ och $z_{uk}(x)$:

$$x_{skär} = 0.5 L_1$$

Given

$$z_{ök}(x_{skär}) = z_{uk}(x_{skär})$$

$$x_{skär} = \text{Find}(x_{skär})$$

Belastninglängd mot vingmur :

$$L_{över} = \text{if}(x_{skär} > L_1, L_1, x_{skär})$$

$x_{start} = 0m$ $\qquad x_{mitt} = \frac{L_{över}}{2}$ $\qquad x_{slut} = L_{över}$

Vertikal lastintensitet på nivå där lastspridning 1:1 belastar vingmur :

$$q_{över}(s) = \begin{cases} 0kPa & \text{if } s > L_{över} \\ \dfrac{P_{över}}{2 \cdot \left[y_{start} + (y_{slut} - y_{start}) \cdot \dfrac{x}{L_1}\right]} & \text{otherwise} \end{cases}$$

Lastintensitet mot vingmur :

$$P_{över} = K_o \cdot q_{över}(x) \cdot h_{över}(x)$$

Forces earth pressure & surcharge:

$$H'_{jord} = \int_{x}^{L_1} p_{vilo}(s)\,ds \qquad M'_{jord} = \int_{x}^{L_1} (s-x)\cdot p_{vilo}(s)\,ds$$

$$H'_{över} = \begin{cases} 0kN & \text{if } x > L_{över} \\ \int_{x}^{L_{över}} p_{över}\,ds & \end{cases} \qquad M'_{över} = \begin{cases} 0kNm & \text{if } x > L_{över} \\ \int_{x}^{L_{över}} (s-x)\cdot p_{över}\,ds & \text{otherwise} \end{cases}$$

Load combinations ULS & SLS :

Forces in abutment where wingwall is clamped :

$$N'_{ULS.front} = \left(\gamma\psi_{jord.ULS}\cdot H'_{jord}(x=0m) + \gamma\psi_{över.ULS}\cdot H'_{över}(x=0m)\right)\cdot \sin(\omega)$$

$$M'_{ULS.front} = \gamma\psi_{jord.ULS}\cdot M'_{jord}(x=0m) + \gamma\psi_{över.ULS}\cdot M'_{över}(x=0m) + N'_{ULS.front}\cdot\frac{t_3}{2}$$

$$N'_{SLS.front} = \left(\gamma\psi_{jord.SLS}\cdot H'_{jord}(x=0m) + \gamma\psi_{över.SLS}\cdot H'_{över}(x=0m)\right)\cdot \sin(\omega)$$

$$M'_{SLS.front} = \gamma\psi_{jord.SLS}\cdot M'_{jord}(x=0m) + \gamma\psi_{över.SLS}\cdot M'_{över}(x=0m) + N'_{SLS.front}\cdot\frac{t_3}{2}$$

Forces in wingwall :

$$Q'_{ULS} = \gamma\psi_{jord.ULS}\cdot H'_{jord} + \gamma\psi_{över.ULS}\cdot H'_{över}$$

$$M'_{ULS} = \gamma\psi_{jord.ULS}\cdot M'_{jord} + \gamma\psi_{över.ULS}\cdot M'_{över}$$

$$M'_{SLS} = \gamma\psi_{jord.SLS}\cdot M'_{jord} + \gamma\psi_{över.ULS}\cdot M'_{över}$$

Calculation effective height :

$$\Delta h = h_3 - h_2 - h_1$$

Nivå överkant effektiv vingmur :

$$\text{Nivå}_{ök}(x) = \text{linterp}\left[\begin{pmatrix} 0m \\ L_2 \\ L_1 - a \\ L_1 \end{pmatrix}, \begin{pmatrix} h_3 - h_4 \\ h_3 - h_4 \\ h_3 - h_1 \\ h_3 - h_1 \end{pmatrix}, x\right]$$

Nivå underkant effektiv vingmur :

$$\text{Nivå}_{uk}(x) = \text{linterp}\left[\begin{pmatrix} 0 \\ L_1 - L_2 \\ L_1 \end{pmatrix}, \begin{pmatrix} \frac{a}{L_1} \cdot \Delta h \\ \Delta h \\ \Delta h \end{pmatrix}, x\right]$$

Effektiv höjd vingmur : $h_{ef}(x) = \text{Nivå}_{ök}(x) - \text{Nivå}_{uk}(x)$

Design forces (load combinations ULS & SLS) distributed over effective height:

Snittkraft i frontmur för inspänningssnitt :

$$H_{ef} = h_{ef}(0m)$$

$$N_{ULS.front} = \frac{N'_{ULS.front}}{H_{ef}}$$

$$M_{ULS.front} = \frac{M'_{ULS.front}}{H_{ef}}$$

$$N_{SLS.front} = \frac{N'_{SLS.front}}{H_{ef}}$$

$$M_{SLS.front} = \frac{M'_{SLS.front}}{H_{ef}}$$

Snittkrafter i vingmur :

$$Q_{ULS}(x) = \frac{Q'_{ULS}}{h_{ef}(x)} \qquad M_{ULS}(x) = \frac{M'_{ULS}}{h_{ef}(x)} \qquad M_{SLS}(s) = \frac{M'_{SLS}}{h_{ef}(x)}$$

Dead weight wingwall :

$$t(x) = t_2 - \frac{t_2 - t_1}{L_1} \cdot x$$

$$A(x) = h_{mur}(x) \cdot t(x)$$

$$V_{egen} = \gamma_{btg} \int_0^{L_1} A(x)\, dx$$

$$M_{egen} = \gamma_{btg} \int_0^{L_1} A(x) \cdot s\, dx$$

RESULTS

Partial results

Design friction angle associated to K_0 : $\varphi = 45\ °$

Angle from top of road and to top of wing wall measured perpendicular to wingwall : $\beta = 1\ °$

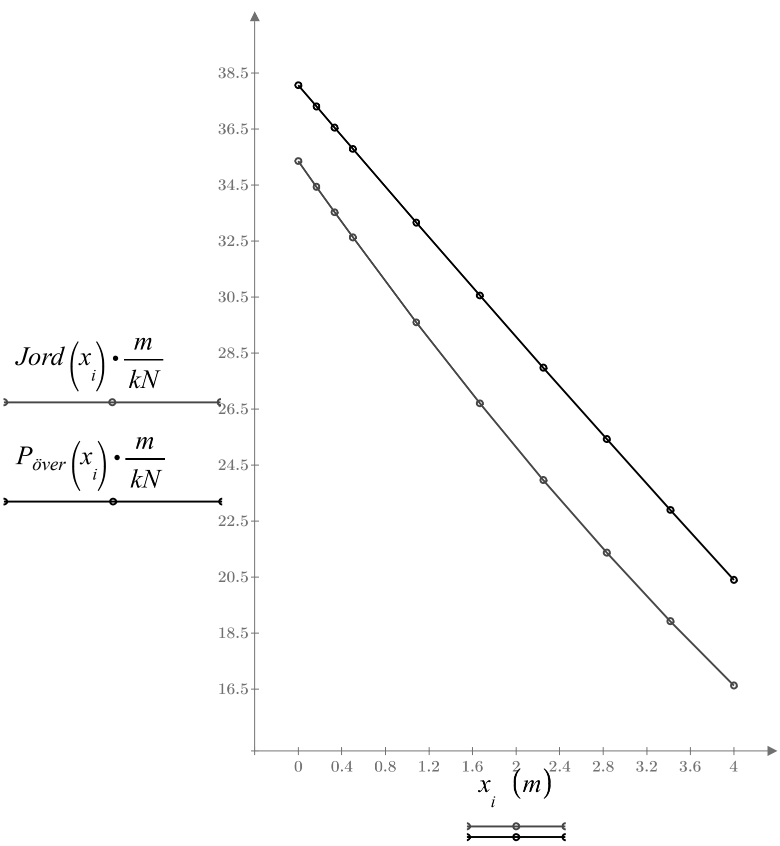
Load area surcharge :

x	$z_{\ddot{a}k}(x)$	$z_{uk}(x)$	y (x)	Snitt
0	2,625	0	2,000	Vingrot
2,000	2,590	0,550	2,035	$0.5L_{över}$

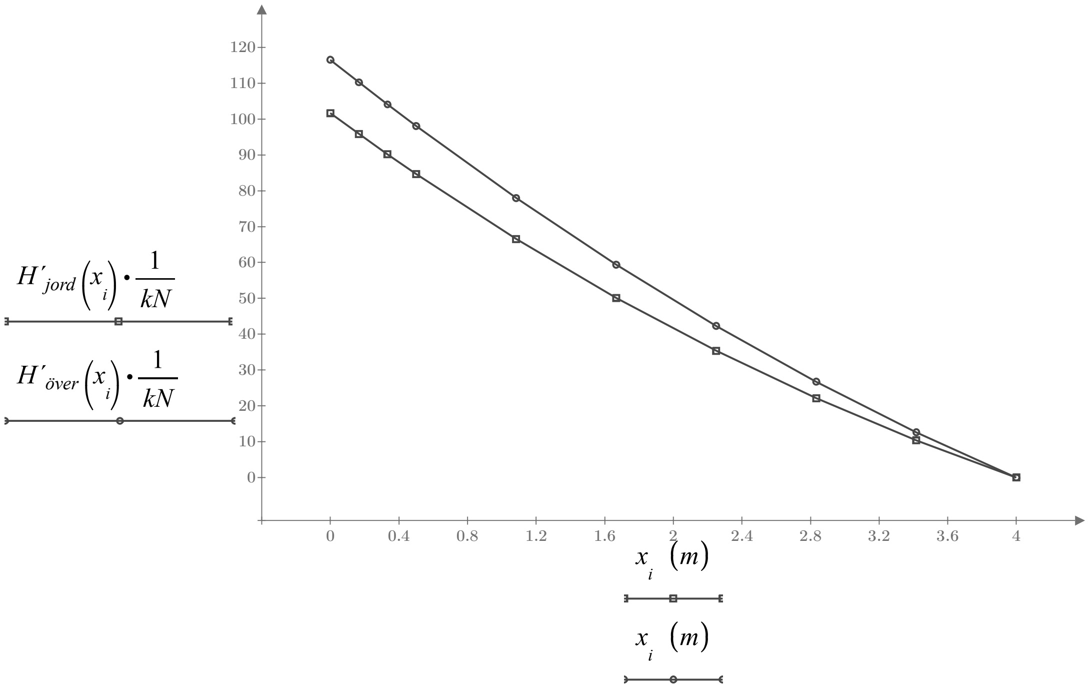
Evaluation earth pressure, surcharge & associated critical rupture angle in table

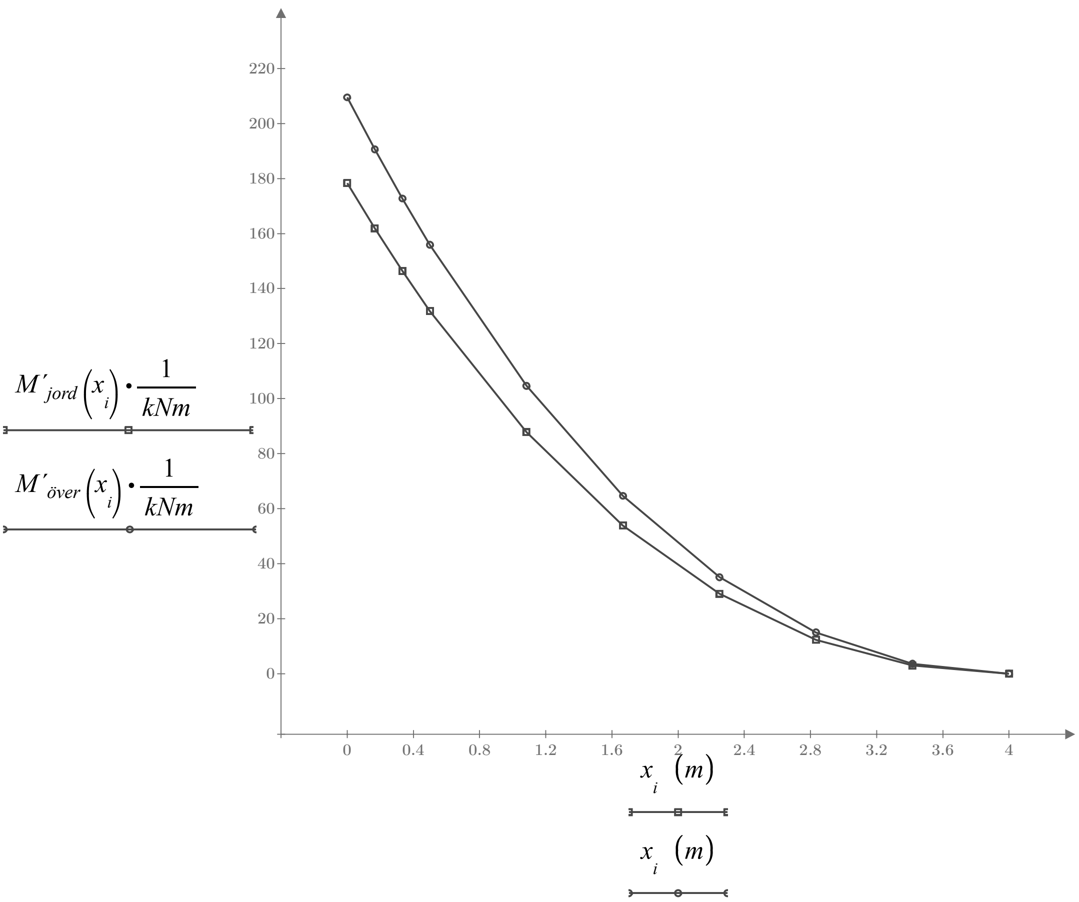
x	P_{jord}	α_{tillh}	$P_{över}$
0	35	66	38
0,17	34	66	37
0,33	34	66	37
0,50	33	66	36
1,08	30	66	33
1,67	27	66	31
2,25	24	66	28
2,83	21	66	25
3,42	19	66	23
4,00	17	66	20
m	kN/m	grader	kN/m

Evaluation earth pressure & surcharge in diagram format :

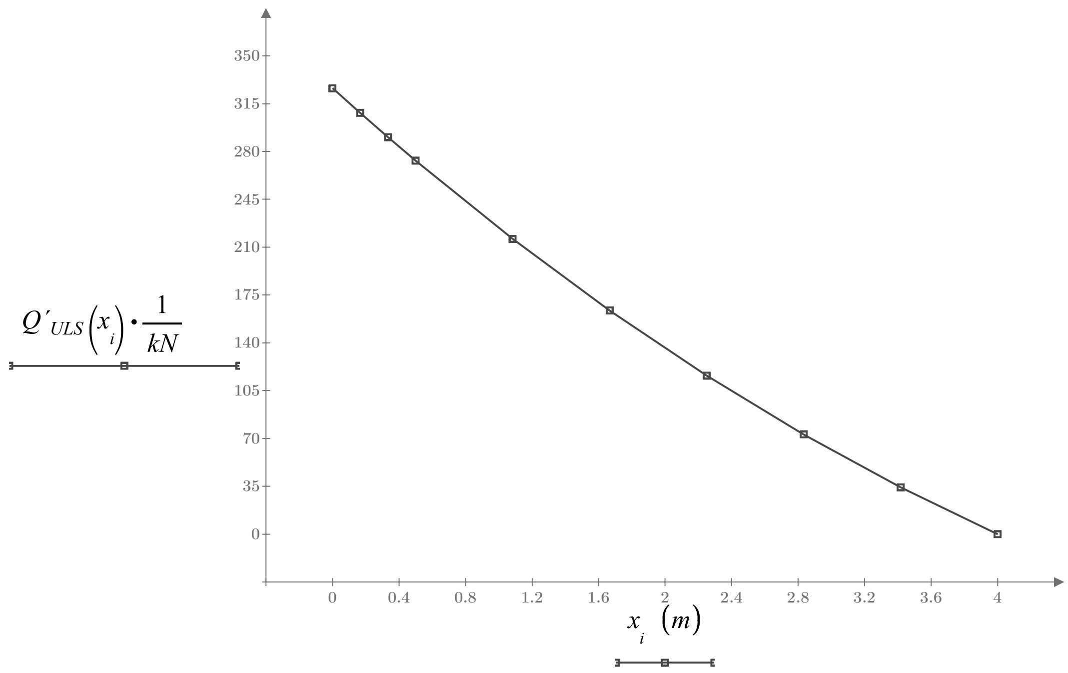


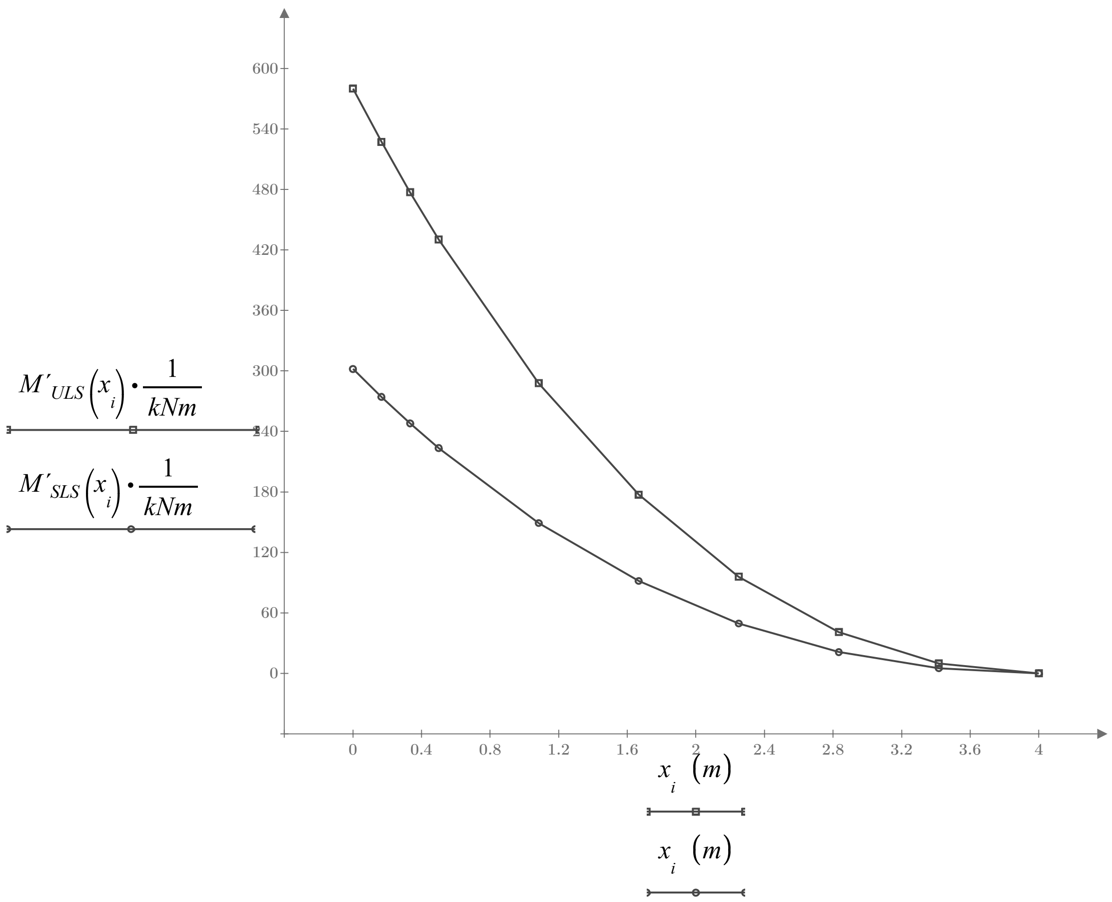
Evaluation forces associated to earth pressure & surcharge :



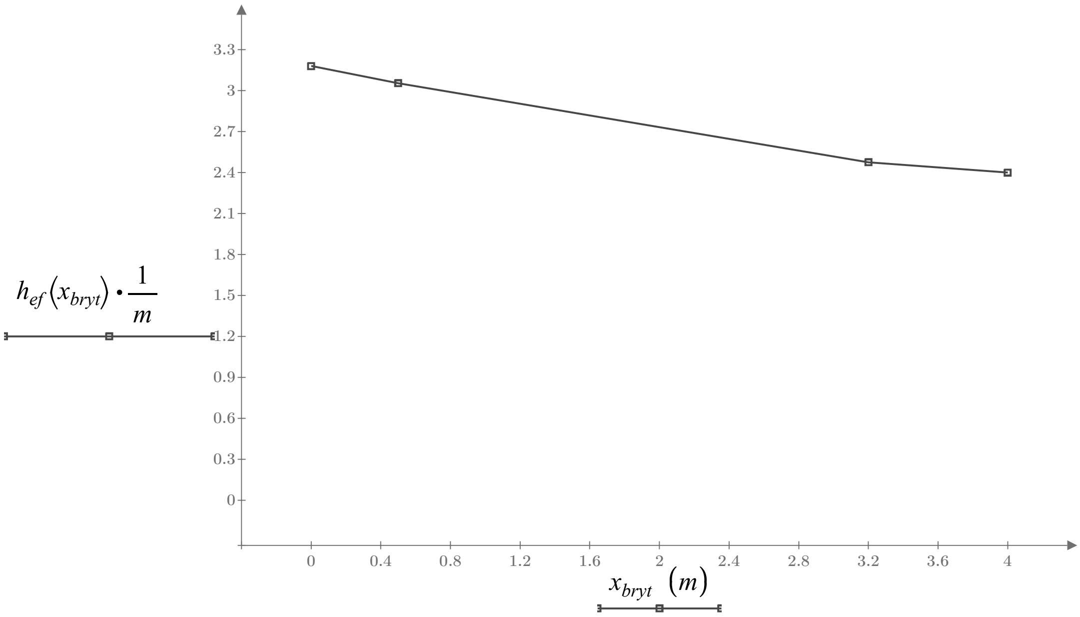


Evaluation design forces associated to LC ULS & LC SLS :





Evaluation of effective height :



Detailed results

Design forces in section where wingwall is clamped to abutment:

Effective height in clamped section: $H_{ef} = 3.2\ m$

N_{ULS}	M_{ULS}	N_{SLS}	M_{SLS}
103	213	54	111
kN/m	kNm/m	kN/m	kNm/m

Design forces in wingwall:

x	Q_{ULS}	M_{ULS}	M_{SLS}	t (x)
0	103	182	95	0,400
0,17	98	168	87	0,400
0,33	94	154	80	0,400
0,50	89	141	73	0,400
1,08	74	98	51	0,400
1,67	58	63	33	0,400
2,25	43	36	18	0,400
2,83	29	16	8	0,400
3,42	14	4	2	0,400
4,00	0	0	0	0,400
m	kN/m	kNm/m	kNm/m	m

Load on abutment from dead weight of wingwall :

$V_{egen} = 118\ kN$ $M_{egen} = 221\ kNm$

$x_{tp} := \frac{M_{egen}}{V_{egen}}$ $x_{tp} = 1.88\ m$

The associated perpendicular to abutment load is a triangular line load with peak intensity given below.

$p_{egen} := M_{egen} \cdot \frac{6}{H_{ef}^{2}} \cdot \sin(\omega)$ $p_{egen} = 131\ \frac{kN}{m}$

Load on abutment from earth pressure & surcharge on wingwall :

The associated perpendicular to abutment load is a rectangular angular line load with intensity given below.

$p_{jord.1} := -\frac{H'_{jord}(0 \cdot m)}{H_{ef}} \cdot \cos(\omega)$ $p_{jord.1} = 1\ \frac{kN}{m}$

$p_{över.1} := -\frac{H'_{över}(0 \cdot m)}{H_{ef}} \cdot \cos(\omega)$ $p_{över.1} = 1\ \frac{kN}{m}$