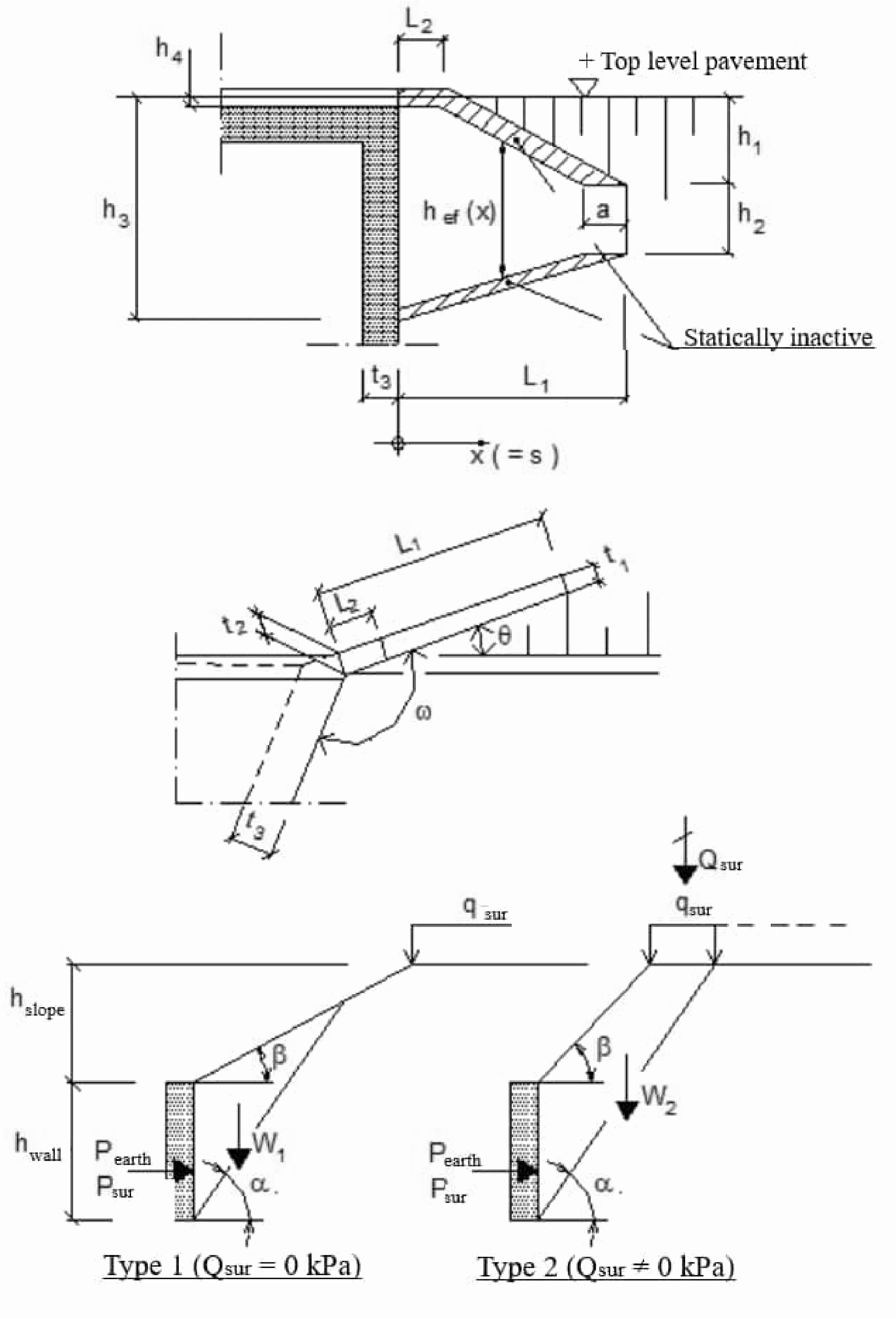
Object : L = 4.0 m

PRINCIPLE SKETCH



Earth pressure method of Culman

Date: 11-19-2025

File : PROG K2_002.mcdx

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 : $q_{över} := 20 \cdot kPa$

Load coefficients :

Earth pressure

$\psi\gamma_{ULS.1} := 1.49$ $\psi\gamma_{SLS.1} := 1.34$

Surcharge

$\psi\gamma_{ULS.2} := 1.71$ $\psi\gamma_{SLS.2} := 0$

CALCULATION

Earth pressure according method of Culman:

Nivå överkant vingmur : $mur_{ök} = \mathrm{linterp}\left[(0m\ \ L_2\ \ L_1),(h_3\ \ h_3\ \ h_3 - h_1),s\right]$

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

Vingmurens höjd : $h_{mur} = mur_{ök} - mur_{uk}$

Släntens höjd : $h_{slänt} = \mathrm{linterp}\left[(0m\ \ L_2\ \ L_1),(0m\ \ 0m\ \ h_1),s\right]$

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, sålunda inget tillskott av överlast) :

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

Vertikallaster för brottfigur typ 2 (= brottlinje hamnar ovanför slänt vilket ger ett bidrag från överlast) :

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

$$Q_{över}(q) = q\cdot\left[(h_{mur} + h_{slänt})\cdot\tan\left(\frac{\pi}{2} - \alpha\right) - \frac{h_{slänt}(s)}{\tan(\beta)}\right]$$

Vilojordtrycksresultant enligt Culmann under inverkan av jordlast + överlast :

$$p_o(q) = \begin{vmatrix} W_{jord} \leftarrow W_1 \text{ if } (h_{mur} + h_{slänt}) \cdot \tan(90° - \alpha) < \dfrac{h_{slänt}}{\tan(\beta)} \\ W_{jord} \leftarrow W_2 + Q_{över}(q) \text{ otherwise} \\ p_{aktiv} \leftarrow W_{jord} \cdot \tan(\alpha - \varphi) \\ p_{aktiv} \cdot \dfrac{K_o}{K_a} \end{vmatrix}$$

Utvärdera största last av jordtryck och överlast genom att kontrollera antal vinklar mellan φ och 90°. Överlastens lasteffekt fås som skillnaden mellan jordtrycksresultant med och utan överlast

$$p_{jord}(s) = \begin{vmatrix} N_\alpha \leftarrow 20st \\ \Delta\alpha \leftarrow \dfrac{90° - \varphi}{N_\alpha - 1} \\ \alpha \leftarrow \varphi \\ p_{max} \leftarrow p_o(0kPa) \\ \text{for } i \in 2..N_\alpha \\ \quad \begin{vmatrix} \alpha \leftarrow \alpha + \Delta\alpha \\ p_{vilo} \leftarrow p_o(0kPa) \\ \text{if } p_{vilo} > p_{max} \\ \quad \begin{vmatrix} p_{max} \leftarrow p_{vilo} \\ \alpha_{max} \leftarrow \alpha \end{vmatrix} \end{vmatrix} \end{vmatrix}$$

$$p_{över}(s) = \begin{vmatrix} N_\alpha \leftarrow 20st \\ \Delta\alpha \leftarrow \dfrac{90° - \varphi}{N_\alpha - 1} \\ \alpha \leftarrow \varphi \\ p_{max} \leftarrow p_o(q_{över}) - p_o(0kPa) \\ \text{for } i \in 2..N_\alpha \\ \quad \begin{vmatrix} \alpha \leftarrow \alpha + \Delta\alpha \\ p_{över} \leftarrow p_o(q_{över}) - p_o(0kPa) \\ \text{if } p_{över} > p_{max} \\ \quad \begin{vmatrix} p_{max} \leftarrow p_{över} \\ \alpha_{max} \leftarrow \alpha \end{vmatrix} \end{vmatrix} \end{vmatrix}$$

Forces earth pressure & surcharge :

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

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

Lastkombinering - Lk ULS och Lk SLS :

Snittkraft i frontmur för inspänningssnitt :

$$N'_{ULS.front} = \left(\psi\gamma_{ULS.1} \cdot H'_{jord}(0 \cdot m) + \psi\gamma_{ULS.2} \cdot H'_{över}(0 \cdot m)\right) \cdot \sin(\alpha)$$

$$M'_{ULS.front} = \psi\gamma_{ULS.1} \cdot M'_{jord}(0 \cdot m) + \psi\gamma_{ULS.2} \cdot M'_{över}(0 \cdot m) + N'_{ULS.front} \cdot \frac{t_3}{2}$$

$$N'_{SLS.front} = \left(\psi\gamma_{SLS.1} \cdot H'_{jord}(0 \cdot m) + \psi\gamma_{SLS.2} \cdot H'_{över}(0 \cdot m)\right) \cdot \sin(\alpha)$$

$$M'_{SLS.front} = \psi\gamma_{SLS.1} \cdot M'_{jord}(0 \cdot m) + \psi\gamma_{SLS.2} \cdot M'_{över}(0 \cdot m) + N'_{SLS.front} \cdot \frac{t_3}{2}$$

Snittkrafter i vingmur :

$$Q'_{ULS}(s) = \psi\gamma_{ULS.1} \cdot H'_{jord}(s) + \psi\gamma_{ULS.2} \cdot H'_{över}(s)$$

$$M'_{ULS}(s) = \psi\gamma_{ULS.1} \cdot M'_{jord}(s) + \psi\gamma_{ULS.2} \cdot M'_{över}(s)$$

$$M'_{SLS}(s) = \psi\gamma_{SLS.1} \cdot M'_{jord}(s) + \psi\gamma_{SLS.2} \cdot M'_{över}(s)$$

Beräkning av effektiv höjd :

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

$$\Delta h = 1.099\ m$$

Nivå överkant effektiv vingmur :

$$Nivå_{ök} = \text{linterp}\left[\begin{pmatrix} 0m & L_2 & L_1 - a & L_1 \end{pmatrix}^T, \begin{pmatrix} h_3 - h_4 & h_3 - h_4 & h_3 - h_1 & h_3 - h_1 \end{pmatrix}^T, s\right]$$

Nivå underkant effektiv vingmur :

$$Nivå_{uk} = \text{linterp}\left[\begin{pmatrix} 0m & L_1 - L_2 & L_1 \end{pmatrix}^T, \begin{pmatrix} \frac{a}{L} \cdot \Delta h & \Delta h & \Delta h \end{pmatrix}^T, s\right]$$

Effektiv höjd vingmur :

$$h_{ef}(s) = Nivå_{ök} - Nivå_{uk}$$

Design forces (Lc ULS & Lc SLS) distributes 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 :

$$Q_{ULS.ving} = \frac{Q'_{ULS}(s)}{h_{ef}(s)}$$

$$M_{ULS.ving} = \frac{M'_{ULS}(s)}{h_{ef}(s)}$$

$$M_{SLS.ving} = \frac{M'_{SLS}(s)}{h_{ef}(s)}$$

Dead weight wingwall :

$$t = t_2 - \frac{t_2 - t_1}{L_1} \cdot s$$

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

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

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

RESULTS

Partial results

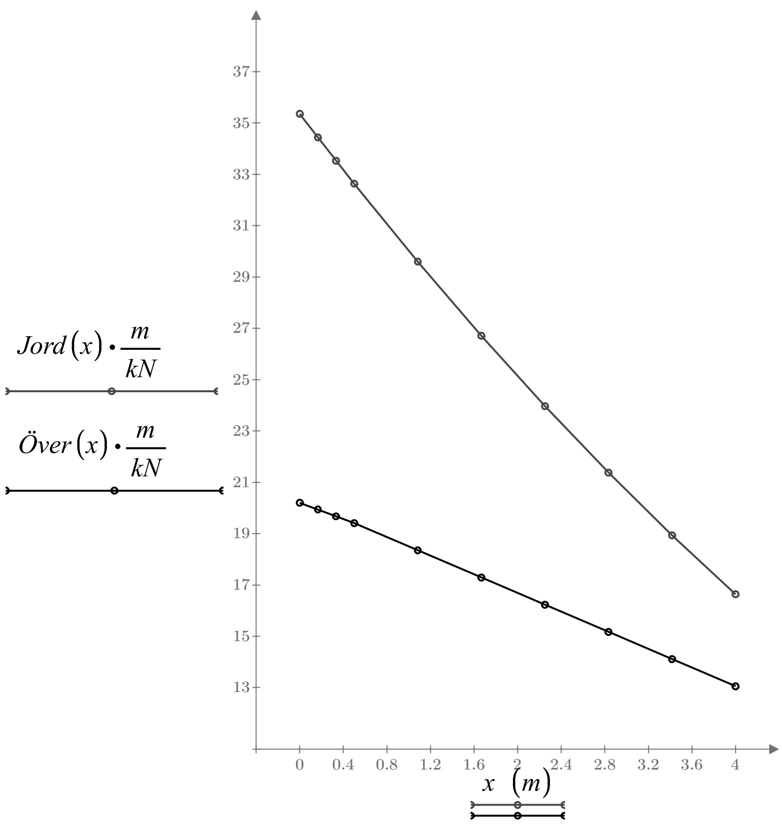
$\varphi = 45\ °$: design friction angle associated to K_o

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

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

x	p_{jord}	α_{tillh}	$p_{över}$	α_{tillh}
0	35,4	66	20,2	66
0,167	34,4	66	19,9	66
0,333	33,5	66	19,7	66
0,500	32,6	66	19,4	66
1,08	29,6	66	18,3	66
1,67	26,7	66	17,3	66
2,25	24,0	66	16,2	66
2,83	21,4	66	15,2	66
3,42	18,9	66	14,1	66
4,00	16,6	66	13,0	66
m	kN/m	grader	kN/m	grader

Evaluation earth pressure & surcharge in diagram format :



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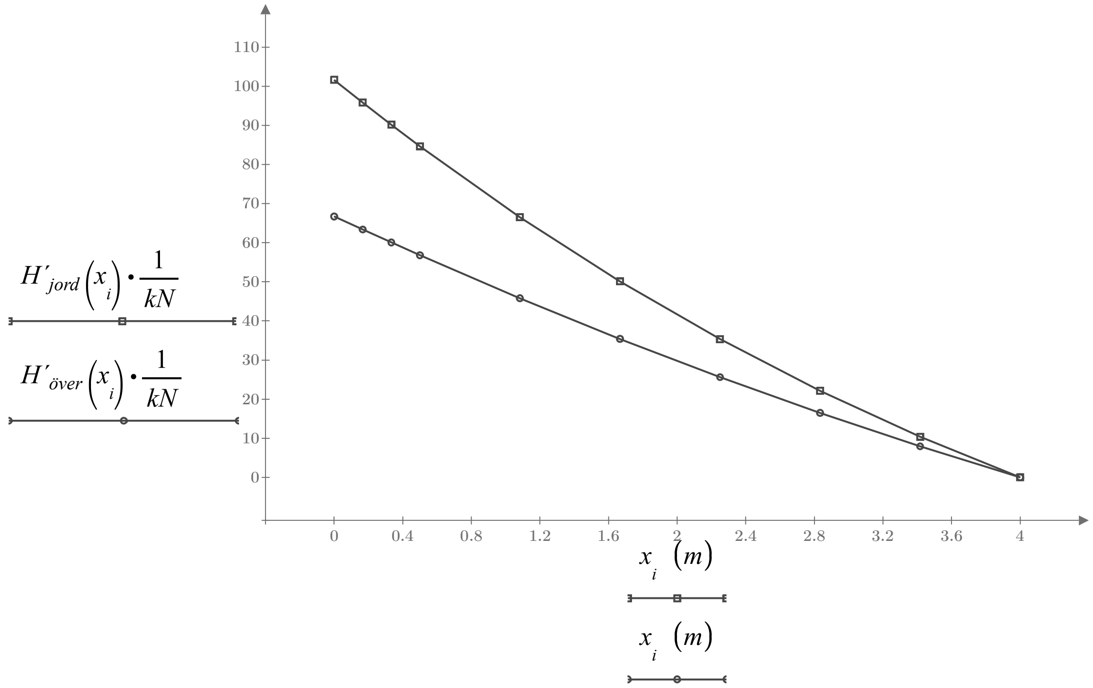
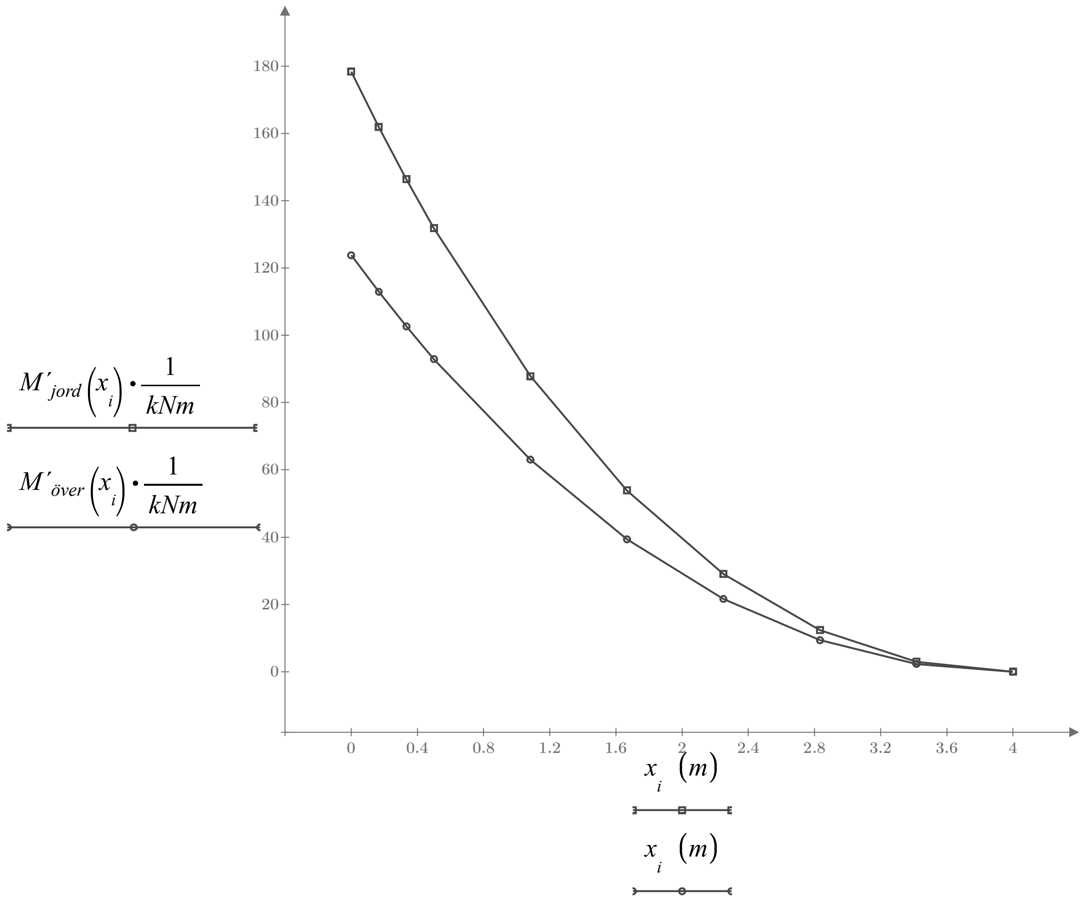
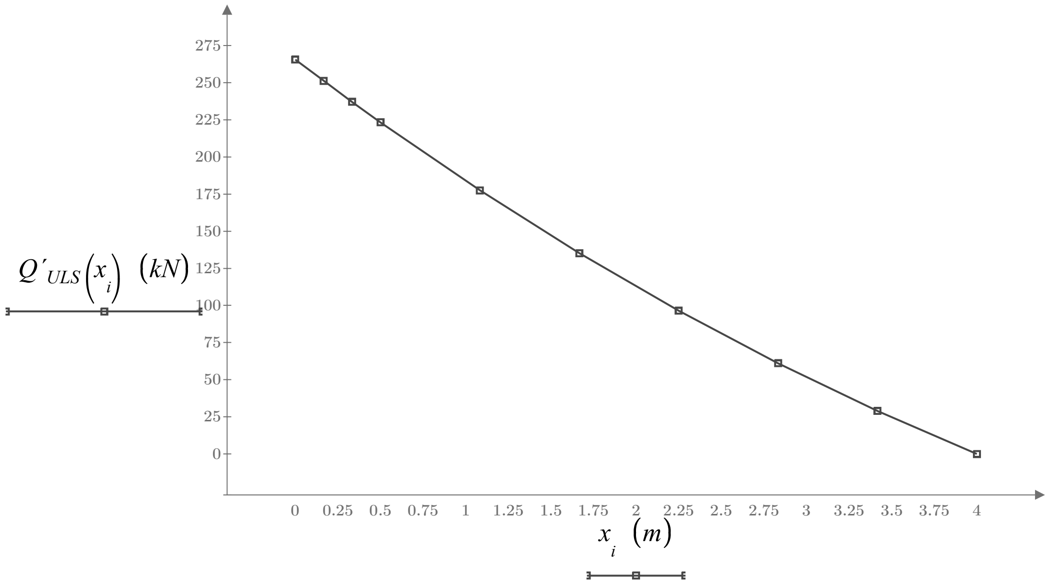
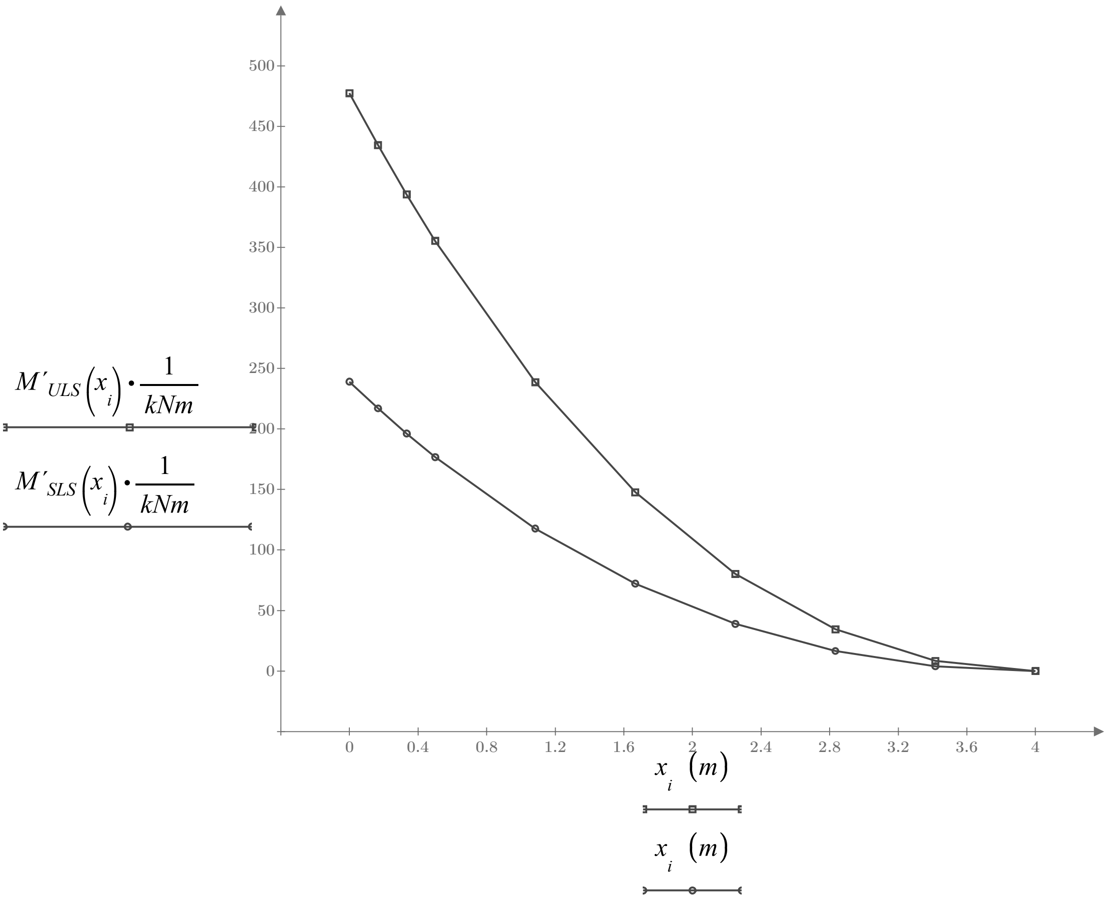
Evaluation forces associated to earth pressure & surcharge :



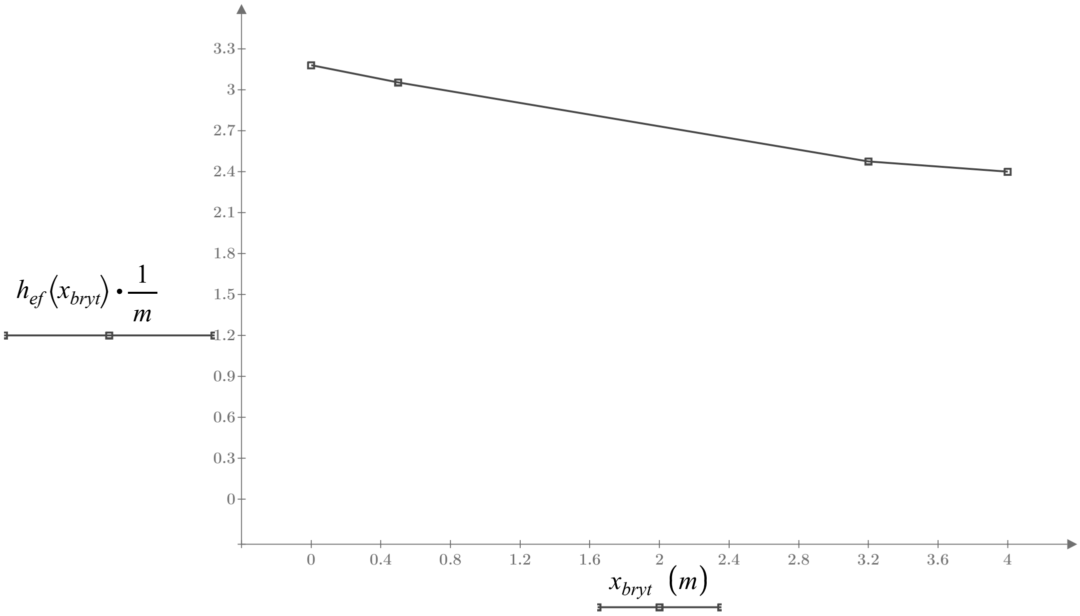


Evaluation design forces associated to LC ULS & LC SLS :





Evaluation of effective height :



Detailed results

Design forces in section where wingwall is clamped to abutment:

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

$N_{ULS.front}$	$M_{ULS.front}$	$N_{SLS.front}$	$M_{SLS.front}$
83	175	43	88
kN/m	kNm/m	kN/m	kNm/m

Design forces in wingwall:

x	$Q_{ULS.ving}$	$M_{ULS.ving}$	$M_{SLS.ving}$	t (x)
0	84	150	75	0,400
0,167	80	138	69	0,400
0,333	77	127	63	0,400
0,500	73	116	58	0,400
1,08	61	81	40	0,400
1,67	48	53	26	0,400
2,25	36	30	15	0,400
2,83	24	13	6	0,400
3,42	12	3	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.

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

$p_{jord.1} = 1\ \frac{kN}{m}$

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

$p_{över.1} = 0\ \frac{kN}{m}$